FREQUENCY DEVICES™, INC.

90PF Slot Card

Introduction

Dual Channel Programmable Filter/Amplifier Card

Description

Each 90PF slot card provides two channels of precision, low noise and distortion (-100 dB typical) programmable filters with up to 60 dB of pre and 20 dB of post adjustable gain.

Filter modules are programmable from 0.1 Hz to 300 kHz utilizing 4, 11-bit tuning ranges. When assembled with a high-pass filter in channel one (1) and a low-pass filter in channel two (2), 90PF slot cards can be configured on the fly to operate as a low-pass, high-pass, band-pass, or band-reject (notch) filter. Customers can select any combination of two available filter modules per slot card to meet their application specific signal conditioning needs.

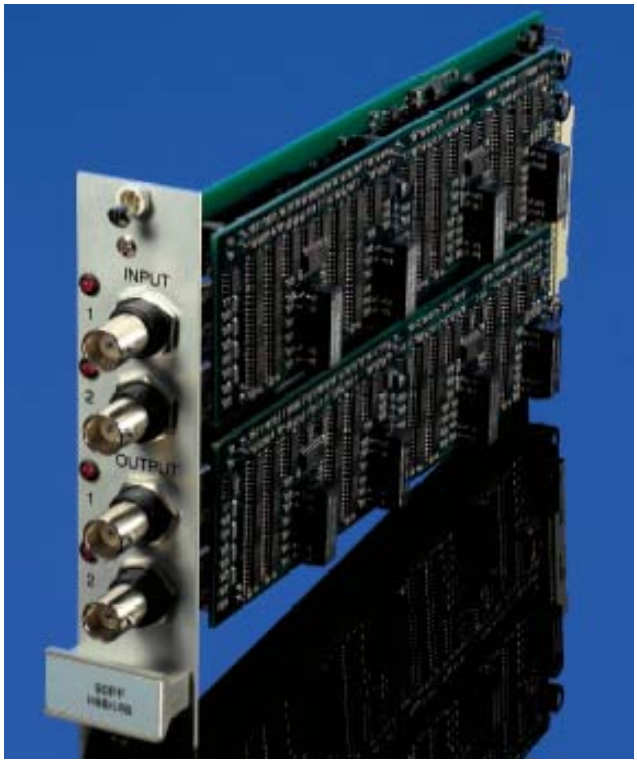
Front panel mounted BNC's provide easy access for connection of signal input and output. Other features include differential or single-ended input, AC or DC-coupled input, single ended output, LED clipping indicators and fine adjustment of DC offset. Operating the 90PF in filter BYPASS mode allows the design engineer to use each channel as a precision instrumentation grade programmable amplifier.

Features

- 0.1 Hz to 300 kHz Tuning Range
- Selectable single-ended or differential input
- Gain/phase matched channels
- LED clipping indicators
- Memory storage for up to 9 set-ups/slot card
- <-100 dB signal-to-noise ratio to 100 kHz BW
- Programmable gain, 60 dB pre and 20 dB post

Applications

- Anti-Aliasing
- Sound Measurement
- Noise Testing
- Audio Communications
- Medical Research
- Industrial Process Control
- Seismic Analysis
- Vibration Analysis



Available 90PF Low Pass Filters

Part #	dB	# Poles	Filter Type
L8B	-100	8	Butterworth
L8L	-100	8	Bessel
L8E	-88	8, 6-zero	Elliptic, 1.77
L8EX	-80≤100kHz -60>100kHz	8, 6-zero	Elliptic, 1.56
L8EY	-100	8, 6-zero	Elliptic, 2.00
L8D80	-80	8, 6-zero	Constant Delay
L8D10	-100	8, 6-zero	Constant Delay

Available 90PF High Pass Filters

Part #	dB	# Poles	Filter Type
H8B	-100	8	Butterworth
H8E	-88	8, 6-zero	Elliptic, 1.77
H8EX	-80≤100kHz -60>100kHz	8, 6-zero	Elliptic, 1.56
H8EY	-100	8, 6-zero	Elliptic, 2.00

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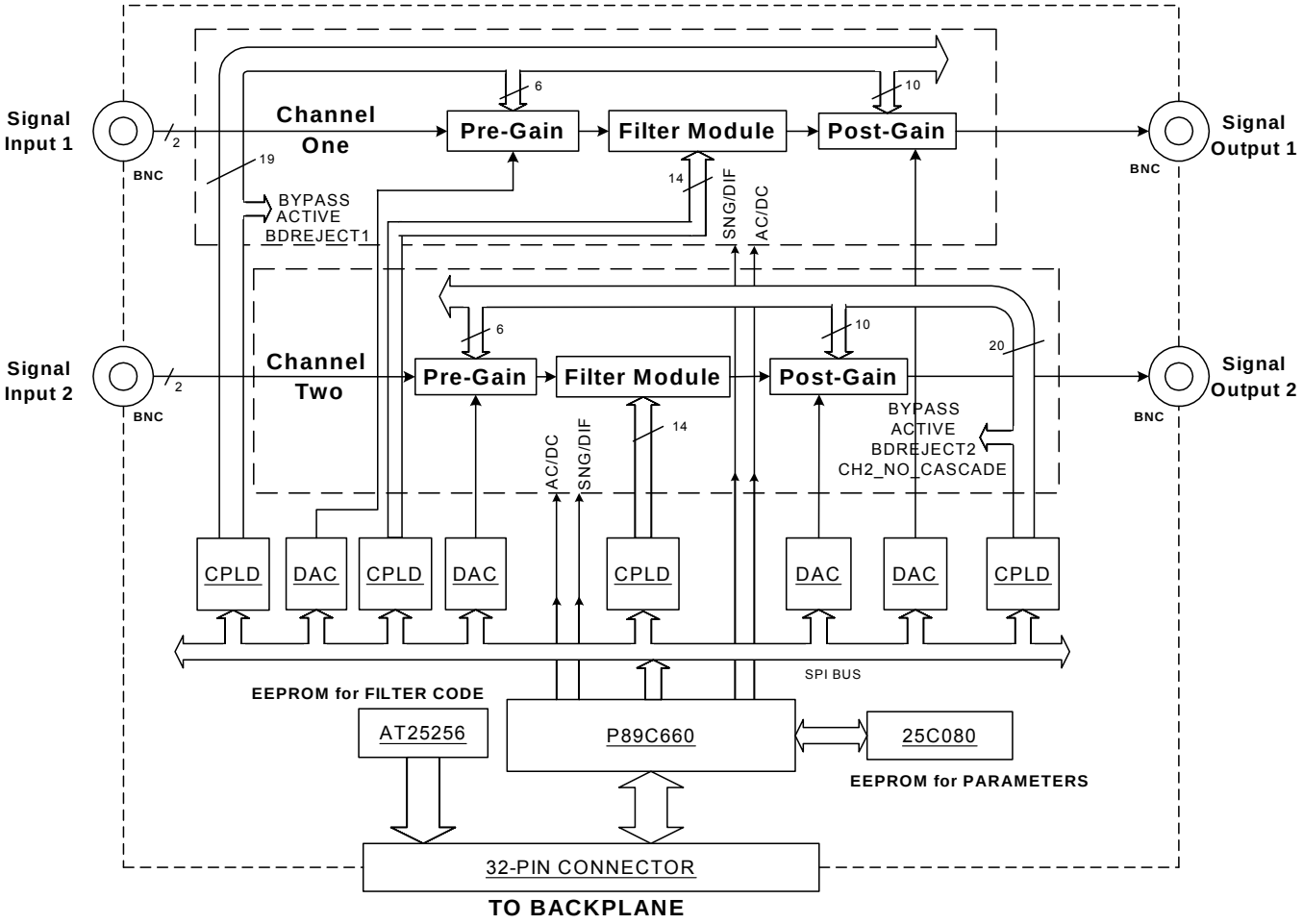

Figure 1 – Signal Path

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Specifications

Product Model	90PF - L8B	90PF - L8L	90PF - L8E	90PF - L8EX
Transfer Function	8-Pole Butterworth	8-Pole Bessel	8-Pole, 6-Zero elliptic – 1.77	8-Pole, 6-Zero elliptic – 1.56
Tuning Range	0.1 Hz to 300 kHz	0.1 Hz to 300 kHz	0.1 Hz to 300 kHz	0.1 Hz to 300 kHz
Theoretical Transfer Characteristics	Appendix A Page 9	Appendix A Page 4	Appendix A Page 24	Appendix A Page 23
Passband Ripple (theoretical)	0.0 dB	0.0 dB	±0.035 dB	±0.05 dB
Pass Band Gain (non-inverting)	0 ± 0.2 dB	0 ± 0.2 dB	0 ± 0.2 dB	0 ± 0.2 dB to 100 kHz 0 ± 0.4 dB >100 kHz
Stop Band	**Attenuation Rate** 48 dB/octave	**Attenuation Rate** 48 dB/octave	**Attenuation** 80 dB	**Attenuation** 80 dB <100kHz> 60dB
Corner Frequency Accuracy	f_c ±2% max.	f_c ± 2% max.	f_r ± 2% max.	f_r ± 2% max. ± 3% > 100 kHz
Amplitude	-3 dB	-3 dB	-0.035 dB	-0.05 dB
Phase	-360°	-182°	-323°	-414°
Phase Match[1]	0 - f_c ±2° max. ±1° typ.	0 - f_c ±2° max. ±1° typ.	0 – 0.8f_r ±2° max. ±1° typ. 0.8f_r - f_r ±4° max. ±2° typ.	0 – 0.8f_r ±3°max ±4°>100kHz 0.8f_r - f_r ±4° max. ±5°>100kHz
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	0.5 dB 1.00 f_r 3.01 dB 1.05 f_r 60.0 dB 1.45 f_r 80.0 dB 1.56 f_r
Amplitude Accuracy[1] **0.1 to 100 kHz (theoretical)**	**0 - 0.8 f_c** ±0.2 dB max. ±0.1 dB typ. **0.8 f_c - f_c** ±0.3 dB max. ±0.15 dB typ.	**0 - 0.8 f_c** ±0.2 dB max. ±0.1 dB typ. **0.8 f_c - f_c** ±0.3 dB max. ±0.15 dB typ.	**0 - 0.8 f_r** ±0.2 dB max. ±0.1 dB typ. **0.8 f_r - f_r** ±0.4 dB max. ±0.2 dB typ.	**0 - 0.8 f_r** ±0.2 dB max. ±0.1 dB typ. **0.8 f_r - f_r** ±0.7 dB max. ±0.35 dB typ.
Total Harmonic Distortion @ 1 kHz	<-100dB typ.@3V_{rms}	<-100dB typ.@3V_{rms}	<-100dB typ.@3V_{rms}	<-100dB typ.@3V_{rms}
Broad Band Noise (5 Hz to 2MHz)	200μV_{rms} typ.	200μV_{rms} typ.	200μV_{rms} typ.	200μV_{rms} typ.
Narrow Band Noise	<100nV/$\sqrt{Hz}$ typ.	<100nV/$\sqrt{Hz}$ typ.	<100nV/$\sqrt{Hz}$ typ.	<100nV/$\sqrt{Hz}$ typ.

Note 1: Channel to channel match for the same transfer function set to the same frequency and operating configuration.

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Product Model	90PF - L8EY	90PF - L8D80	90PF - L8D10
Transfer Function	8-Pole, 6-Zero elliptic – 2.00	8-Pole, 6-Zero constant delay	8-Pole, 6-Zero constant delay
Tuning Range	0.1 Hz to 300 kHz	0.1 Hz to 300 kHz	0.1 Hz to 300 kHz
Theoretical Transfer Characteristics	Appendix A Page 25	Appendix A Page 21	Appendix A Page 22
Passband Ripple (theoretical)	0.05 dB	0.10 dB	0.15 dB
Pass Band Gain (non-inverting)	0 ± 0.2 dB	0 ± 0.2 dB	0 ± 0.2 dB
Stop Band	**Attenuation Rate** 100 dB	**Attenuation Rate** 80 dB	**Attenuation Rate** 100 dB
Corner Frequency Accuracy **Amplitude** **Phase**	f_r ± 2% max. -0.05 dB -419°	f_c ± 2% max. -3 dB -306°	f_c ±2% max. -3 dB -311°
Phase Match[1]	0 – 0.8f_r ±3° max. ±1.5° typ. 0.8f_r - f_r ±4° max. ±2° typ.	0 – 0.8f_c ±2° max. ±1° typ. 0.8f_c – f_c ±4° max. ±2° typ.	0 – 0.8f_c ±2° max. ±1° typ. 0.8f_c – f_c ±4° max. ±2° typ.
Filter Attenuation (theoretical)	0.5 dB 1.00 f_r 3.01 dB 1.06 f_r 80.0 dB 1.83 f_r 100.0 dB 2.00 f_r	3.01 dB 1.00 f_c 60.0 dB 3.08 f_c 80.0 dB 3.57 f_c	3.01 dB 1.00 f_c 80.0 dB 4.45 f_c 100 dB 5.20 f_c
Amplitude Accuracy[1] **0.1 to 100 kHz (theoretical)**	**0 - 0.8 f_r** ±0.2 dB max. ±0.1 dB typ. **0.8 f_r - f_r** ±0.5 dB max. ±0.25 dB typ.	**0 - 0.8 f_c** ±0.2 dB max. ±0.1 dB typ. **0.8 f_c - f_c** ±0.4 dB max. ±0.2 dB typ.	**0 - 0.8 f_c** ±0.2 dB max. ±0.1 dB typ. **0.8 f_c - f_c** ±0.5 dB max. ±0.25 dB typ.
Total Harmonic Distortion @ 1 kHz	<-100dB typ.@3V_{rms}	<-100dB typ.@3V_{rms}	<-100dB typ.@3V_{rms}
Broad Band Noise (5 Hz to 2MHz)	200μV_{rms} typ.	200μV_{rms} typ.	200μV_{rms} typ.
Narrow Band Noise	<100nV/$\sqrt{Hz}$ typ.	<100nV/$\sqrt{Hz}$ typ.	<100nV/$\sqrt{Hz}$ typ.

Note 1: Channel to channel match for the same transfer function set to the same frequency and operating configuration.

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Specifications

	90PF - H8B	90PF - H8E
Transfer Function	8-Pole Butterworth	8-Pole, 6-Zero elliptic – 1.77
Tuning Range	0.1 Hz to 300 kHz	0.1 Hz to 300 kHz
Theoretical Transfer Characteristics	Appendix A Page 29	Appendix A Page 37
Passband Ripple (theoretical)	0.0 dB	±0.035 dB
Pass Band Gain (non-inverting)	0 ± 0.2dB to 100kHz 0 ± 0.5dB to 400kHz	0 ± 0.2dB to 100kHz 0 ± 0.5dB to 400kHz
Power Bandwidth	500 kHz	500 kHz
Small Signal Bandwidth	(-6 dB) 1 MHz	(-6 dB) 1 MHz
Stop Band	**Attenuation Rate** 48 dB/octave	**Attenuation** 80 dB
Corner Frequency		
Accuracy	f_c ± 2% max.	f_r ± 2% max.
Amplitude	-3 dB	-0.035 dB
Phase	-360°	-323.5°
Phase Match[1]	**f_c to 100 kHz** ±3° max. ±1.5° typ.	**f_r – 1.25 f_r** ±4° max. ±2° typ. **1.25f_r to 100 kHz** ±2° max. ±1° typ.
Filter Attenuation (theoretical)	-83 dB 0.30 f_c -48 dB 0.50 f_c -3.01 dB 1.00 f_c -0.01 dB 1.50 f_c	-80.0 dB 0.56 f_r -60.0 dB 0.60 f_r -0.03 dB 1.00 f_r 0.00 dB 2.00 f_r
Amplitude Accuracy[1] **0.1 Hz to 100 kHz (theoretical)**	**f_c – 1.25 f_c** ±0.3 dB max. ±0.15 dB typ. **1.25 f_c – 400 kHz** ±0.5 dB max.	**f_r – 1.25 f_r** ±0.4 dB max. ±0.2 dB typ. **1.25 f_r – 400 kHz** ±0.5 dB max.
Total Harmonic Distortion @ 1 kHz	<-100dB typ. @ $3V_{rms}$	<-100dB typ. @ $3V_{rms}$
Broad Band Noise (5 Hz – 2 MHz)	$400\mu V_{rms}$ typ.	$400\mu V_{rms}$ typ.
Narrow Band Noise	<100nV/$\sqrt{Hz}$ typ.	<100nV/$\sqrt{Hz}$ typ

Note 1: Channel to channel match for the same transfer function set to the same frequency and operating configuration.

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Specifications

	90PF - H8EX	90PF - H8EY
Transfer Function	8-Pole, 6-Zero elliptic – 1.56	8-Pole, 6-Zero elliptic – 2.00
Tuning Range	0.1 Hz to 300 kHz	0.1 Hz to 300 kHz
Theoretical Transfer Characteristics	Appendix A Page 36	Appendix A Page 38
Passband Ripple (theoretical)	±0.05 dB	±0.05 dB
Pass Band Gain (non-inverting)	0 ± 0.3dB to 100kHz 0 ± 2.0dB to 400kHz	0 ± 0.2dB to 100kHz 0 ± 2.0dB to 400kHz
Power Bandwidth	500 kHz	500 kHz
Small Signal Bandwidth	(-6 dB) 1 MHz	(-6 dB) 1 MHz
Stop Band	**Attenuation** 80 dB <100kHz> 60dB	**Attenuation** 100 dB
Corner Frequency Accuracy	f_r ± 2% max. ± 4% > 100 kHz	f_r ± 2% max.
Amplitude	-0.05 dB	-0.05 dB
Phase	-414°	-419°
Phase Match[1]	**f_r – 1.25 f_r** ±4° max. ±5° > 100 kHz. **1.25f_r to 100 kHz** ±3° max. ±4° > 100 kHz.	**f_r – 1.25 f_r** ±4° max. ±2° typ. **1.25f_r to 100 kHz** ±3° max. ±1.5° typ.
Filter Attenuation (theoretical)	-80.0 dB 0.64 f_r -60.0 dB 0.69 f_r -3.01 dB 0.95 f_r -0.03 dB 1.00 f_r 0.00 dB 2.00 f_r	100 dB 0.05 f_r -80.0 dB 0.55 f_r -3.01 dB 0.94 f_r -0.03 dB 1.00 f_r 0.00 dB 2.00 f_r
Amplitude Accuracy[1] **0.1 Hz to 100 kHz (theoretical)**	**f_r – 1.25 f_r** ±0.5 dB max. ±0.25 dB typ. **1.25 f_r – 400 kHz** ±0.7 dB max.	**f_r – 1.25 f_r** ±0.5 dB max. ±0.25 dB typ. **1.25 f_r – 400 kHz** ±0.5 dB max.
Total Harmonic Distortion @ 1 kHz	<-100dB typ. @ $3V_{rms}$	<-100dB typ. @ $3V_{rms}$
Broad Band Noise (5 Hz – 2 MHz)	$400\mu V_{rms}$ typ.	$400\mu V_{rms}$ typ.
Narrow Band Noise	<100nV/$\sqrt{Hz}$ typ	<100nV/$\sqrt{Hz}$ typ

Note 1: Channel to channel match for the same transfer function set to the same frequency and operating configuration.

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Bypass Mode Specifications @ 25ºC

Dual Channel Programmable Filter/Amplifier Card

Input Characteristics

Input Impedance:	
Differential	2 MΩ shunted by 47pF
Single Ended	1 MΩ shunted by 47pF
Coupling	AC or DC
Maximum Input Signal	±10V pk @0 dB
Input Voltage:	
Linear Differential	20V p-p (Gain Set at 0 dB)
Max. Safe Differential	Any Continuous value between ±40V
Max Safe Common Mode	Any Continuous value between ±40V
Bias Current	1 nA typ., 2 nA max.
Common Mode Rejection Ratio with 2kΩ source unbalance and 0 dB gain	>60 dB, dc to 50kHz

Output Characteristics

Full Power Bandwidth	dc to 1.0 MHz
Small Signal Bandwidth (1V pk-pk)	1.0 MHz @ -6dB
Related Output	10V p-p for R_L = 50Ω 20V p-p for R_L = 2kΩ
Output Protection	short circuit to Ground only
Output Impedance	50Ω
Offset Voltage	Adjustable to zero, In 1 mV steps. (Range ±100mV dc)

General

Cross Talk between Channels	<-100 dB @ 1 kHz
Operating Temperature	0ºC to 50ºC
Offset Temperature Coeff.	10µV/ºC RTI
Humidity	0 to 95%, non-condensing
Slot Card Dimensions	100 x 220 mm (3U)
Weight	0.60 Lbs., (0.3 Kg.)

Amplifier Characteristics

Distortion @ 1 kHz	<-100 dB typ. @ 3.0 Vrms
Noise Density	14 nV/$\sqrt{Hz}$

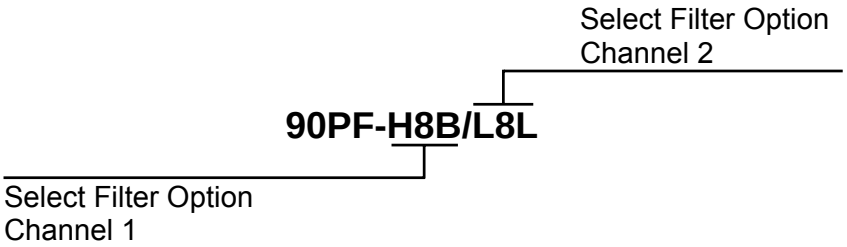
Pre Filter Gain (No Filter)

Gain Settings	0 to 60 dB in 5 dB steps ±0.1 dB tolerance
Signal Bandwidth	-6.0 dB @ 1.0 MHz@ +60 dB
Amplitude Match	±0.1 dB @ DC
Gain Accuracy@ DC	±0.1 dB

Post Filter Gain (No Filter)

Gain Settings	0 to 20 dB in 1 dB steps ±0.1 dB tolerance
Signal Bandwidth	-6.0 dB @ 1.0 MHz
Amplitude Match	±0.1 dB @ DC
Gain Accuracy@ DC	±0.1 dB

Ordering Information



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FREQUENCY DEVICES™, INC.

8-Pole

Bessel

Low-Pass

Appendix A

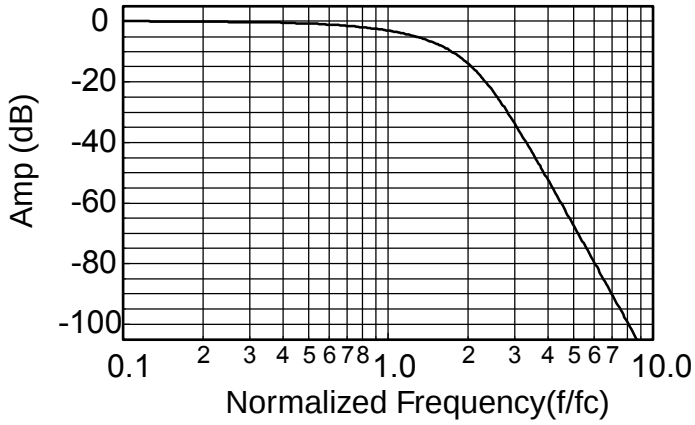
Theoretical Transfer Characteristics

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

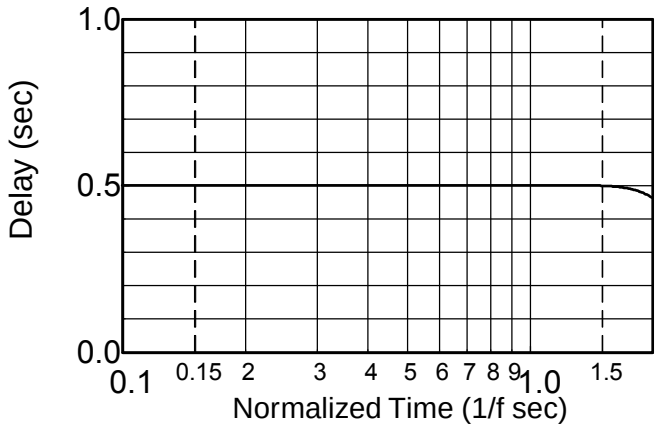
1. **Normalized Group Delay:**
The above delay data is normalized to a corner frequency of 1.0Hz.The actual delay is the normalized delay divided by the actual corner frequency (fc).

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

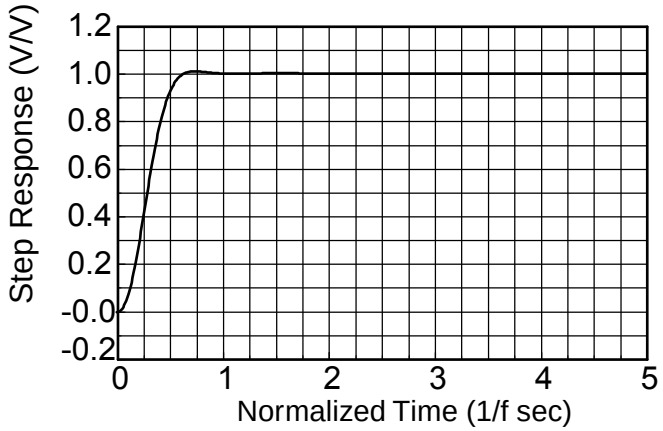
Frequency Response



Delay (Normalized)



Step Response



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FREQUENCY DEVICES™, INC.

Low-Pass

8-Pole

Butterworth

Appendix A

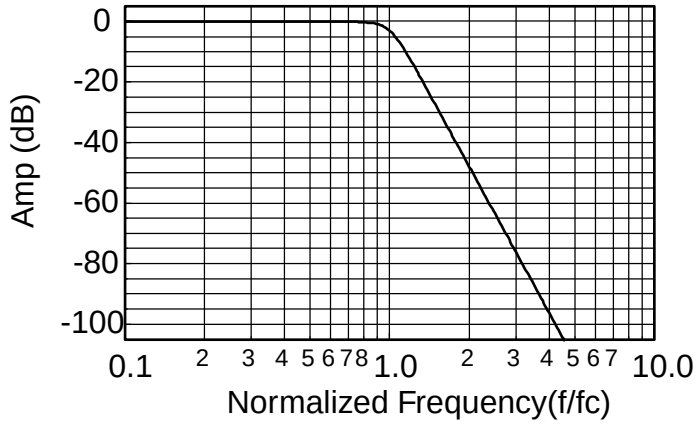
Theoretical Transfer Characteristics

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

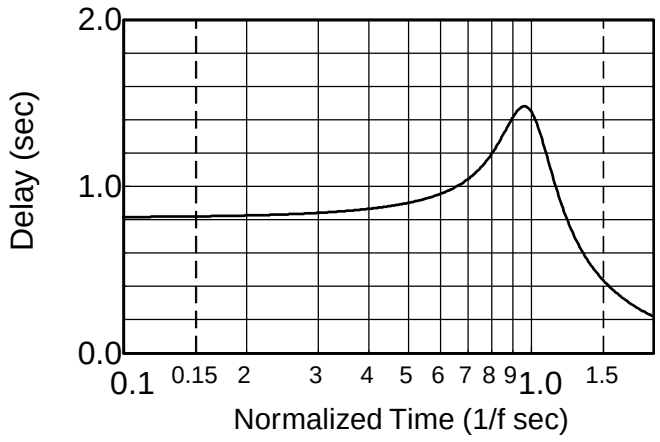
1.**Normalized Group Delay:**
The above delay data is normalized to a corner frequency of 1.0Hz.The actual delay is the normalized delay divided by the actual corner frequency (fc).

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

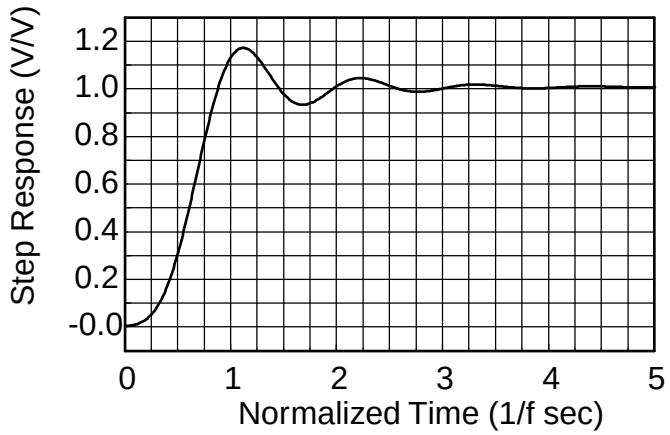
Frequency Response



Delay (Normalized)



Step Response



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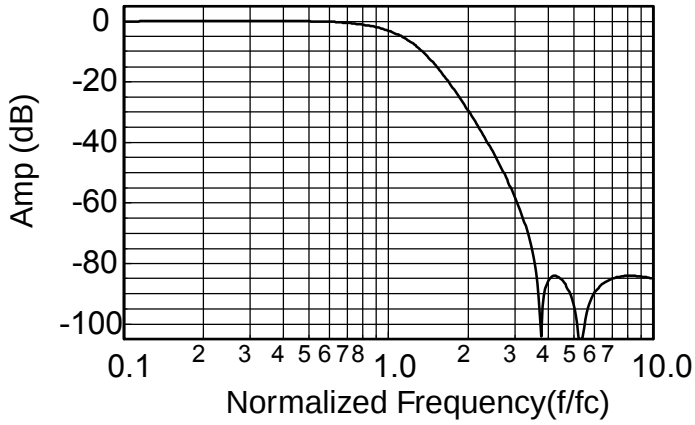
Theoretical Transfer Characteristics

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

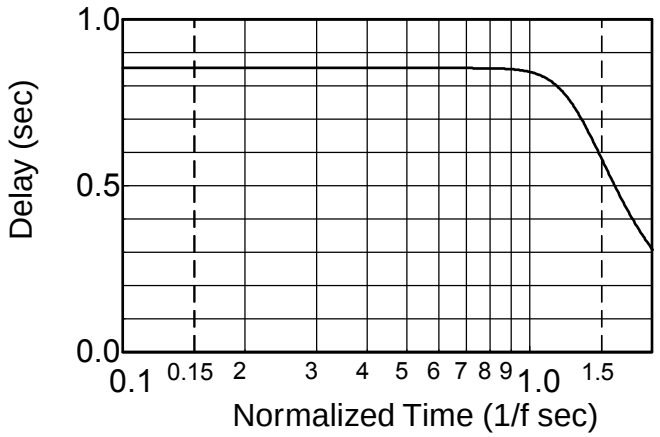
1. **Normalized Group Delay:**
The above delay data is normalized to a corner frequency of 1.0Hz.The actual delay is the normalized delay divided by the actual corner frequency (fc).

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

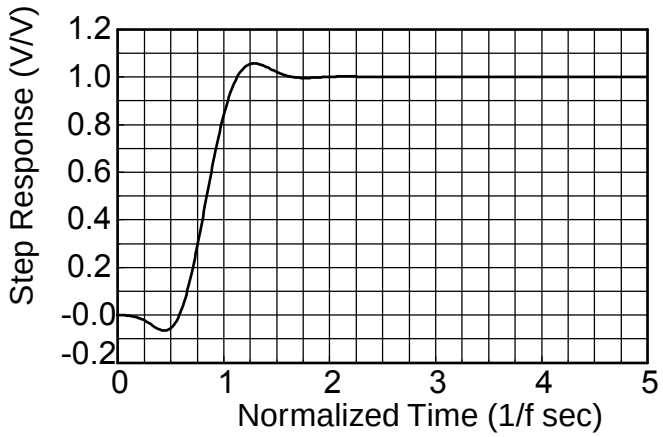
Frequency Response



Delay (Normalized)



Step Response



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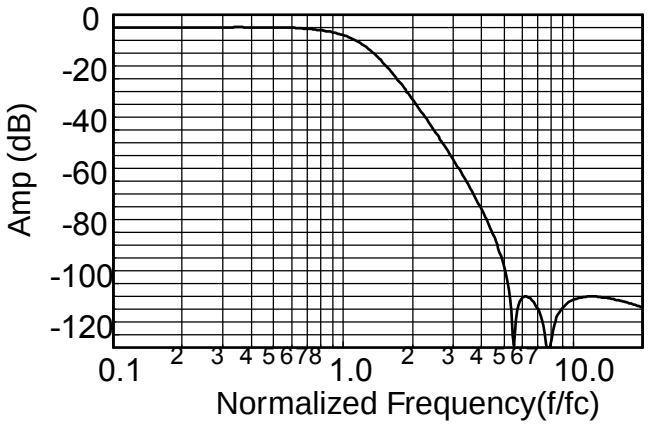
Theoretical Transfer Characteristics

f/fc (Hz)	Amp (dB)	Phase (deg)	Delay[1] (sec)
0.00	0.00	0.00	.865
0.10	0.015	-31.1	.865
0.20	0.051	-62.3	.865
0.30	0.085	-93.4	.865
0.40	0.085	-125	.865
0.50	0.010	-156	.865
0.60	-0.182	-187	.865
0.70	-0.532	-218	.865
0.80	-1.09	-249	.864
0.85	-1.45	-265	.863
0.90	-1.89	-280	.861
0.95	-2.41	-296	.857
1.00	-3.01	-311	.851
1.10	-4.50	-341	.828
1.20	-6.38	-370	.785
1.40	-11.2	-422	.650
1.60	-16.8	-464	.504
1.80	-22.5	-496	.389
2.00	-28.0	-520	.306
2.25	-34.5	-544	.235
2.50	-40.5	-563	.186
2.75	-46.1	-578	.151
3.00	-51.4	-591	.125
3.50	-61.5	-610	.090
4.00	-71.2	-624	.068
4.50	-81.3	-635	.054
5.00	-93.4	-643	.043
5.50	-142	-651	.036
6.00	-105	-476	.030
6.20	-105	-478	.028
6.50	-106	-481	.025
7.00	-110	-486	.022
8.00	-122	-312	.017
9.00	-109	-318	.013
10.0	-106	-322	.011
12.0	-105	-328	.007
14.0	-106	-333	.005
16.0	-107	-336	.004
18.0	-108	-339	.003
20.0	-109	-341	.003

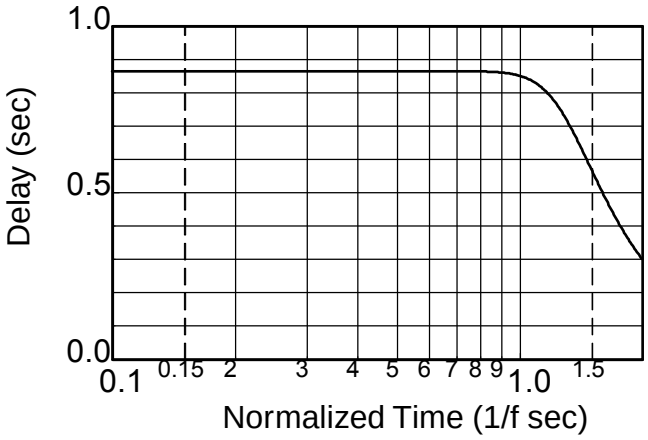
1.**Normalized Group Delay:**
The above delay data is normalized to a corner frequency of 1.0Hz.The actual delay is the normalized delay divided by the actual corner frequency (fc).

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

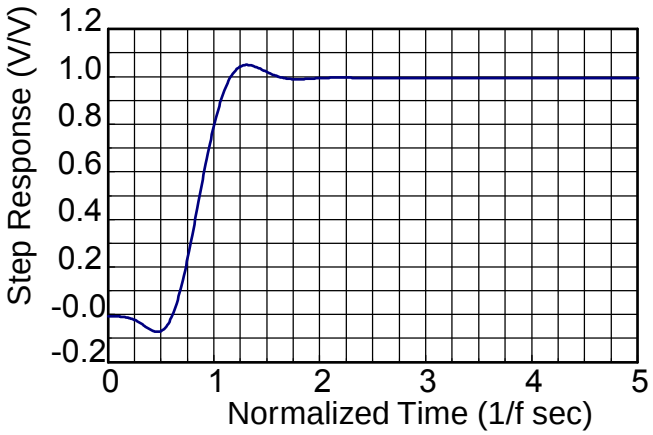
Frequency Response



Delay (Normalized)



Step Response



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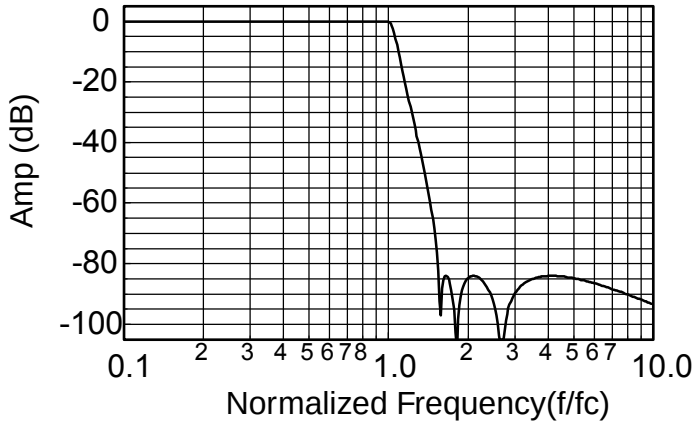
Theoretical Transfer Characteristics

f/fc (Hz)	Amp (dB)	Phase (deg)	Delay[1] (sec)
0.00	0.00	0.00	0.823
0.10	-0.001	-29.7	0.829
0.20	-0.013	-59.8	0.844
0.30	-0.040	-90.5	0.865
0.40	-0.049	-122	0.904
0.50	-0.018	-156	0.972
0.55	-0.003	-174	1.016
0.60	-0.002	-192	1.064
0.65	-0.019	-212	1.116
0.70	-0.042	-233	1.178
0.75	-0.049	-255	1.264
0.80	-0.026	-279	1.388
0.85	-0.001	-305	1.557
0.90	-0.024	-335	1.767
0.95	-0.045	-369	2.111
1.00	-0.050	-414	3.062
1.10	-10.48	-531	2.043
1.20	-25.96	-576	0.814
1.30	-39.45	-598	0.493
1.40	-52.87	-614	0.348
1.50	-69.11	-624	0.265
1.60	-89.09	-453	0.211
1.70	-85.32	-459	0.174
1.75	-89.95	-463	0.156
1.80	-103.5	-465	0.147
1.85	-95.94	-288	0.158
1.90	-89.31	-290	0.126
1.95	-86.44	-292	0.117
2.00	-84.96	-295	0.110
2.20	-84.54	-302	0.087
2.40	-88.65	-307	0.069
2.60	-99.78	-311	0.057
2.80	-99.97	-135	0.048
3.00	-90.20	-139	0.041
3.50	-85.09	-145	0.029
4.00	-84.04	-150	0.022
5.00	-84.76	-156	0.014
6.00	-86.45	-160	0.009
7.00	-88.31	-163	0.007
8.00	-90.11	-165	0.005
9.00	-91.82	-167	0.004
10.0	-93.41	-168	0.003

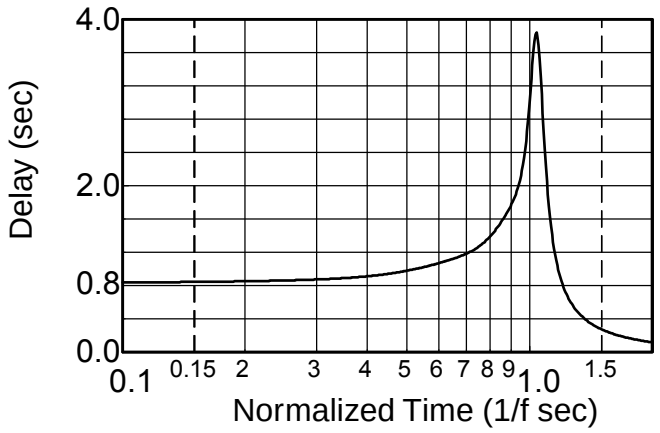
1. **Normalized Group Delay:**
The above delay data is normalized to a corner frequency of 1.0Hz.The actual delay is the normalized delay divided by the actual corner frequency (fc).

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

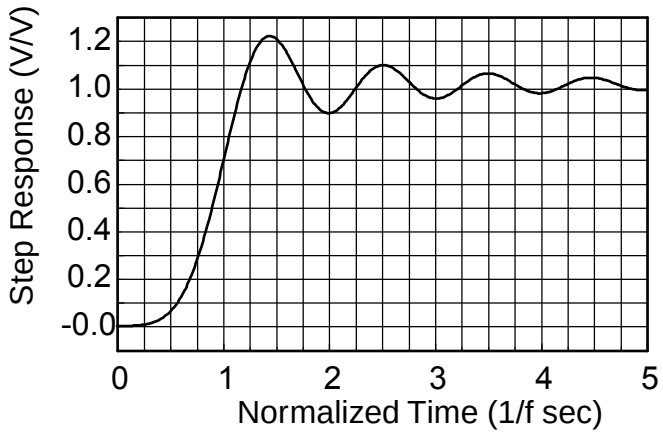
Frequency Response



Delay (Normalized)



Step Response



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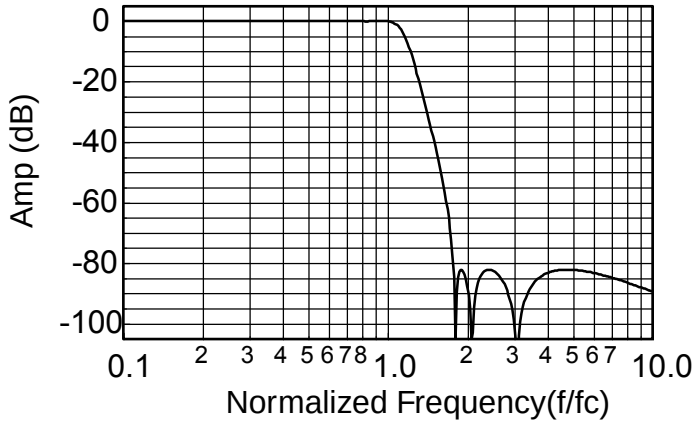
Theoretical Transfer Characteristics

f/fc (Hz)	Amp (dB)	Phase (deg)	Delay[1] (sec)
0.00	0.00	0.00	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

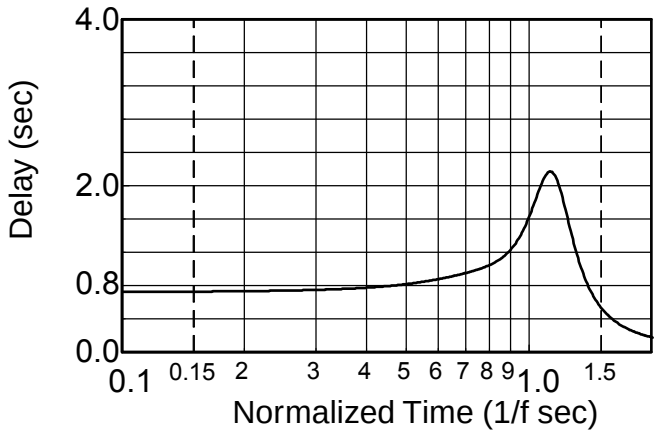
1. **Normalized Group Delay:**
The above delay data is normalized to a corner frequency of 1.0Hz.The actual delay is the normalized delay divided by the actual corner frequency (fc).

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

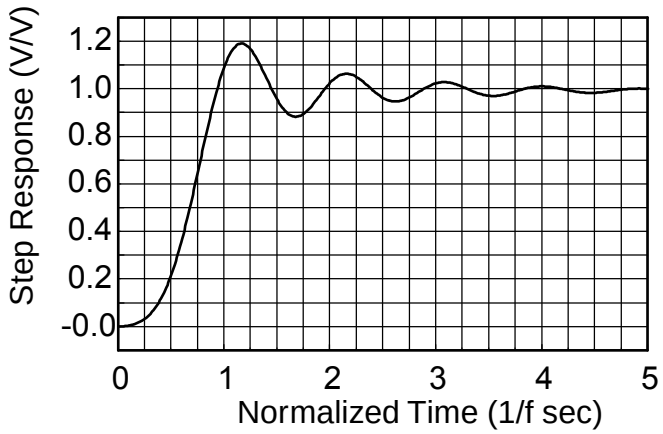
Frequency Response



Delay (Normalized)



Step Response



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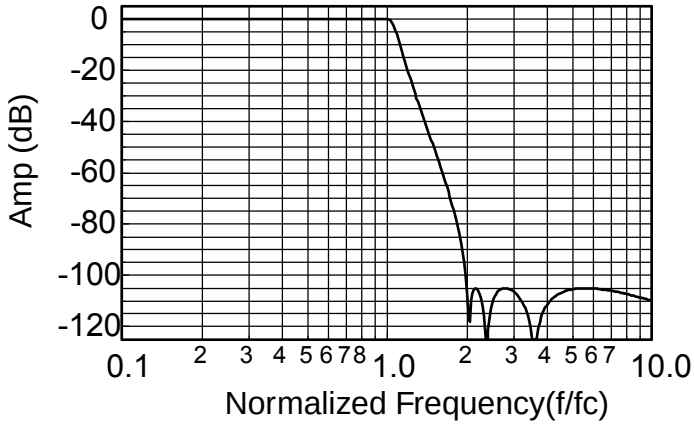
Theoretical Transfer Characteristics

f/fc (Hz)	Amp (dB)	Phase (deg)	Delay[1] (sec)
0.00	0.00	0.00	0.885
0.10	-0.001	-31.9	0.891
0.20	-0.015	-64.2	0.903
0.30	-0.040	-97.0	0.922
0.40	-0.042	-131	0.958
0.50	-0.001	-166	1.020
0.55	0.000	-185	1.057
0.60	-0.007	-204	1.099
0.65	-0.027	-225	1.140
0.70	-0.045	-245	1.193
0.75	-0.040	-268	1.269
0.80	-0.014	-291	1.377
0.85	-0.001	-317	1.513
0.90	-0.031	-346	1.677
0.95	-0.036	-378	1.960
1.00	-0.046	-419	2.681
1.10	-7.910	-525	2.127
1.20	-21.06	-573	0.856
1.30	-31.96	-597	0.509
1.40	-41.51	-612	0.357
1.50	-50.35	-623	0.271
1.60	-58.90	-632	0.216
1.70	-67.54	-639	0.177
1.75	-72.04	-642	0.162
1.80	-76.79	-645	0.149
1.85	-81.93	-647	0.138
1.90	-87.78	-650	0.128
1.95	-95.04	-652	0.119
2.00	-106.6	-654	0.111
2.20	-106.0	-481	0.087
2.40	-121.3	-307	0.070
2.60	-106.5	-311	0.058
2.80	-105.0	-315	0.049
3.00	-106.4	-318	0.042
3.50	-123.6	-325	0.030
4.00	-111.5	-149	0.022
5.00	-105.4	-156	0.014
6.00	-105.1	-160	0.010
7.00	-106.0	-163	0.007
8.00	-107.3	-165	0.005
9.00	-108.6	-167	0.004
10.0	-110.0	-168	0.003

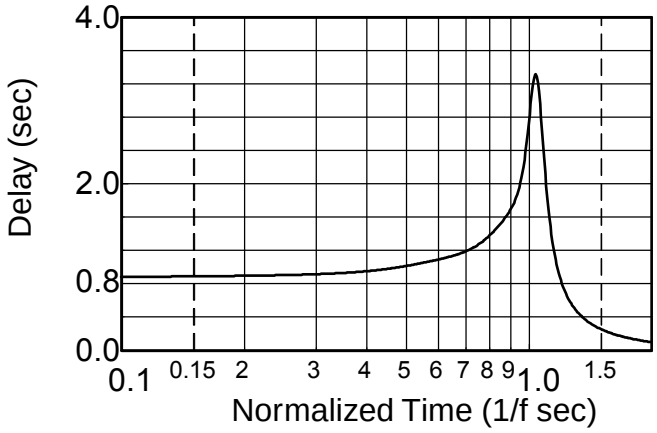
1. **Normalized Group Delay:**
The above delay data is normalized to a corner frequency of 1.0Hz.The actual delay is the normalized delay divided by the actual corner frequency (fc).

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

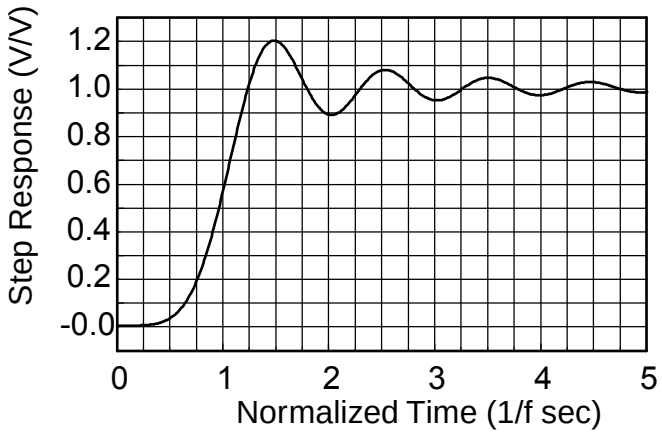
Frequency Response



Delay (Normalized)



Step Response



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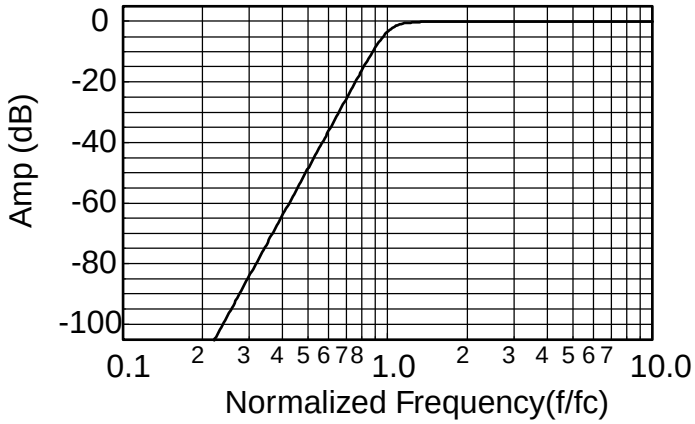
Theoretical Transfer Characteristics

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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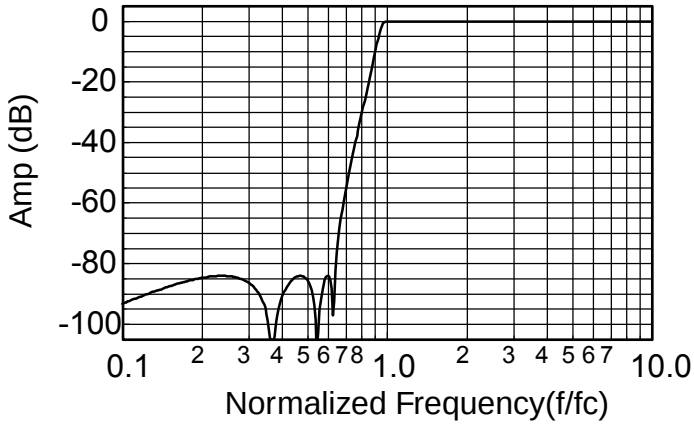
Theoretical Transfer Characteristics

f/fc (Hz)	Amp (dB)	Phase (deg)	Delay[1] (sec)
0.10	-93.4	168	0.334
0.20	-84.8	156	0.344
0.30	-86.0	143	0.363
0.40	-92.6	310	0.392
0.50	-85.0	295	0.439
0.55	-114	287	0.472
0.60	-84.1	458	0.515
0.70	-57.0	617	0.652
0.80	-32.8	589	0.962
0.85	-22.6	569	1.325
0.90	-12.3	538	2.198
0.95	-3.08	483	3.993
1.00	-0.05	414	3.062
1.10	-0.03	341	1.498
1.20	-0.01	296	1.039
1.30	-0.04	264	0.773
1.40	-0.05	239	0.612
1.50	-0.03	219	0.505
1.60	-0.01	202	0.426
1.70	0.00	188	0.364
1.80	0.00	176	0.315
1.90	-0.01	165	0.275
2.00	-0.02	156	0.243
2.50	-0.05	122	0.145
3.00	-0.05	101	0.097
4.00	-0.03	75.1	0.053
5.00	-0.01	59.8	0.034
6.00	-0.01	49.7	0.023
7.00	0.00	42.5	0.017
8.00	0.00	37.2	0.013
9.00	0.00	33.0	0.010
10.0	0.00	29.7	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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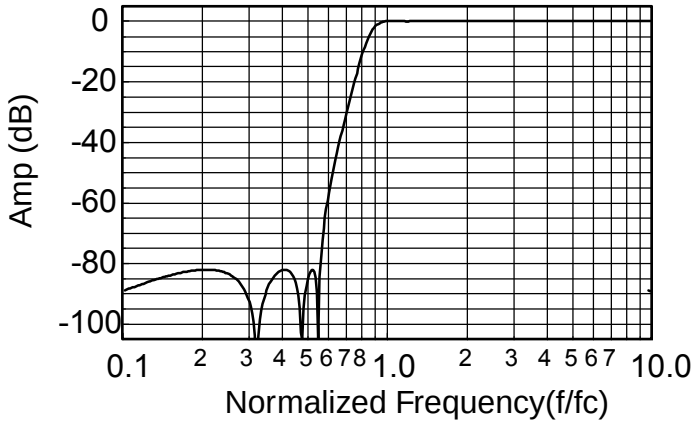
Theoretical Transfer Characteristics

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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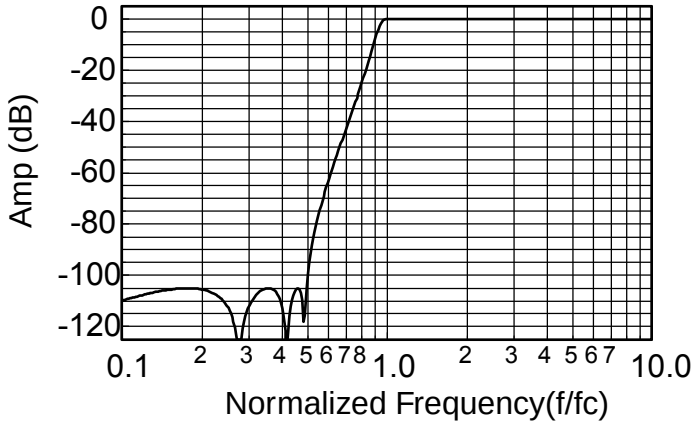
Theoretical Transfer Characteristics

f/fc (Hz)	Amp (dB)	Phase (deg)	Delay[1] (sec)
0.10	-110	168	0.338
0.20	-105	156	0.348
0.30	-114	323	0.367
0.40	-110	309	0.397
0.50	-107	654	0.445
0.55	-78.6	646	0.480
0.60	-64.6	637	0.524
0.70	-44.1	615	0.669
0.80	-26.7	586	1.001
0.85	-18.2	565	1.401
0.90	-9.46	533	2.315
0.95	-2.16	478	3.604
1.00	-0.046	419	2.681
1.10	-0.038	352	1.416
1.20	-0.001	308	1.018
1.30	-0.032	277	0.773
1.40	-0.046	252	0.618
1.50	-0.034	231	0.514
1.60	-0.016	214	0.436
1.70	-0.004	200	0.376
1.80	0.000	187	0.328
1.90	-0.003	176	0.288
2.00	-0.010	166	0.255
2.50	-0.042	131	0.153
3.00	-0.045	108	0.103
4.00	-0.028	80.6	0.057
5.00	-0.015	64.2	0.036
6.00	-0.008	53.4	0.025
7.00	-0.005	45.7	0.018
8.00	-0.003	40.0	0.014
9.00	-0.002	35.5	0.011
10.0	-0.001	31.9	0.009

Frequency Response



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