FREQUENCY DEVICES™

848/878 Series

Digitally Programmable 8-Pole Active Filters

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General Description

The 848 and 878 Series are digitally-programmable lowpass and highpass active filters that are tunable over a 256:1 frequency range. These units contain 8 bits CMOS clocked "D" latches which can be digitally configured to operate in any of three modes:

a.) Transfer frequency control input data into the latches on the STROBE (or CLOCK) rising edge.

b.) As above, but on the STROBE falling edge.

c.) Continuously follow the frequency tuning input data, in a non-latching transparent mode.

Each unit is available with any single factory-set tuning range listed below:
- 1 Versions: 0.1 Hz to 25.6 Hz
- 2 Versions: 1.0 Hz to 256 Hz
- 3 Versions: 10 Hz to 2560 Hz
- 4 Versions: 100 Hz to 25.6 kHz
- 5 Versions: 200 Hz to 51.2 kHz

All 848/878 Series models are fully finished filters which require no external components or adjustments, and operate from non-critical ±12 to ±18V power supplies. A 20 kΩ input impedance and a 10 Ω (max.) output impedance make these compact (2.0"W x 4.0"L footprint, by 0.75"H or 1.0"H) encapsulated plug-in modules convenient and easy to use.

Features

8 Pole:
Lowpass Butterworth - 848P8B
Lowpass Bessel - 848P8L
Lowpass Linear Phase - 848DOW
Lowpass Elliptic - 848P8E
Highpass Butterworth - 878P8B
Highpass Elliptic - 878P8E

- Digitally Programmable Corner Frequency via CMOS Interface Logic
- Internally Latched Data Lines to Store Frequency Selection Data
- Most Widely Used Transfer Characteristics for Broadest Application Scope
- Plug-in Ready-to-use Fully Finished Filter Component

Applications

- Programmable Automatic Test Equipment (A.T.E.) Systems
- Data Acquisition Systems
- Anti-Alias Prefiltering
- Real and Compressed Time Data Analysis
- Production Test Systems
- Industrial Process Control

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General Analog Specifications

Stability	±0.01%/°C
Analog Input Characteristics[1]	
Impedance	20 kΩ
Voltage Range	± 10 V
Maximum Safe Voltage	± V_S
Analog Output Characteristics[1]	
Resistance	10 Ω max.
Linear Operating Range	± 10 V
Maximum Current[2]	± 2 mA
Offset Voltage	2 mV typ., 20 mV max.
Offset vs. Temperature	See discussion, next page.
Power Supply (+/-V_S)	
Rated Voltage	±15 Vdc
Operating Range	±12 to ± 18 Vdc
Maximum Safe Voltage	±18 Vdc
Quiescent Current	40 mA max.
Temperature	
Operating	0°C to +70°C
Storage	-25°C to +85°C

Deviations from theoretical responses

Characteristic Response	At dc for Lowpass At 100 kHz for H.P. - A -	At fc, the - 3dB Corner Freq. - B -	At f_{70dB}, Freq. for - 70dB Gain - C -
Lowpass	± 0.2 dB	± 0.5 dB	± 2 dB
Highpass	± 0.5 dB	± 0.5 dB	± 2 dB

The above table defines lowpass responses having a dc (100 kHz for Highpass) gain of 0 dB ±A (the value in column A), a gain of - 3 dB ±B at corner frequency f_C, or at the 0.01dB ripple frequency fr of the elliptic models and a gain of - 70 dB ± C at $f_{70\ dB}$.

In general, filters programmed at frequencies below 20 kHz fall well within the above deviation boundries. These error bounds on the filter transfer characteristics are approached only as the programmed frequencies reach 20 kHz and above

Notes:

1. Input and output signal voltages are referenced to supply common.
2. Output is short circuit protected to common. DO NOT CONNECT TO ±V_S.

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General Analog Specifications (cont'd)

-3dB Corner Frequency	±2%
Passband Ripple (theoretical)	
Butterworth	0.0 dB
Bessel	0.0 dB
Linear Phase	0.015 dB (60 dB model)
	0.15 dB (80 dB model)
Elliptic	0.035 dB
Typical Noise (Butterworth, Bessel, Linear Phase)	
Narrow Band	(5 Hz to 50 kHz) 50 μV_{rms}
Wide Band	(5 Hz to 2 MHz) 200 μV_{rms}
Typical Noise (Elliptic)	
Narrow Band	(5 Hz to 50 kHz) 75 μV_{rms}
Wide Band	(5Hz to 2 MHz) 250 μV_{rms}
Phase Match (All models)[2]	
@ fc (fr)	Typical ± 1.0°, Maximum ± 2.0°
Passband	Typical ± 0.5°, Maximum ±1.0°
Gain Match (All models)[2]	
@fc (fr)	Typical ± 0.1 dB, Maximum ± 0.2 dB
Passband	Typical ± 0.05 dB, Maximum ± 0.1 dB
Distortion[1] (For range -1, -2,-3,-4, all lowpass models)	
Typical	0.002% (-94 dB)
Maximum	0.004% (-88 dB)
Distortion[1] (For range -5 - all lowpass models)	
Typical	0.004% (-88 dB)
Maximum	0.025% (-72 dB)

Note

1. For input signals ≤ 3 V_{rms} the total harmonic distortion is ≤ 0.01% (-80 dB) for all five ranges.
2. Unit to unit match for the same transfer function set to the same frequency.

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848/878 Series DC Offset, Grounding and Control Characteristics

C Offset vs. Temperature

The DC offset voltage of 848/878 Series filters originates at two internal sources that cause it to vary with temperature and selected frequency. Slight mismatches between operational amplifier (op amp) semi-conductor junctions create the first source of DC offset. Switching element leakage currents flowing through switch-selected tuning resistors predominate as the second source of dc offset. Though small at 25°C, the switch leakage currents increase exponentially with absolute temperature to become significantly large at higher temperatures. This becomes a problem when the filter is tuned to low frequencies, which require high-value tuning resistors.

Figure A illustrates the worst case temperature behavior of the offset voltage; this improves with higher frequency codes. The maximum DC offset voltage will generally occur at the highest temperature and the lowest corner frequency (all "0" input code).

User Notes

Grounding: To achieve specified precision, all analog and digital grounds are connected internal to the filter. Should this cause a problem, all digital inputs (C, P, and D_0 - D_7) can be optically isolated.

Settling Time: When tuned to a different frequency, a filter requires sufficient transient settling time corresponding to several cycles of the new frequency. PLEASE NOTE: DO NOT use these filters in frequency scanning applications without considering settling time.

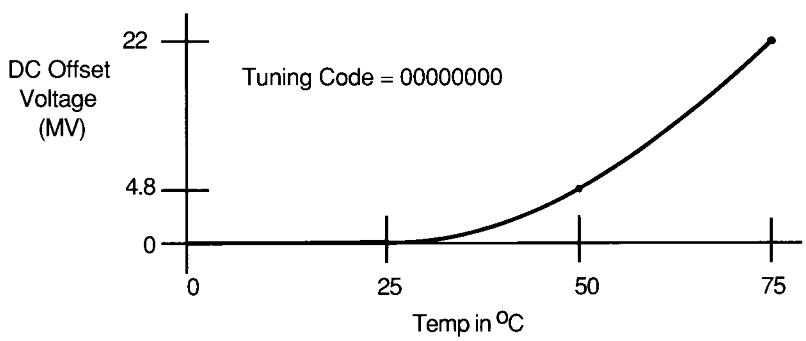

Figure A. The DC offset voltage drift varies with tuning code. Turning on the LSB would halve the Maximum DC offset. See Discussion.

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848/878 Series Data Control Characteristics

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 -->1	frequency latched on rising edge
Mode 2	P = 1; C = 1	frequency follows input codes
	P = 1; C = 1 -->0	frequency latched on falling edge
Input Data Levels (CMOS Logic)		
Input Voltage (Vs = 15V)	**Min.**	**Max. Acceptable**
Low Level In	0 Volts	4 Volts
High Level In	11 Volts	15 Volts
Input Current	**Typ.**	**Max.**
High Level In	$-10^{-5}\,\mu A$	$-1\,\mu A$
Low Level In	$+10^{-5}\,\mu A$	$+1\,\mu A$
Input Capacitance	5 pF	7.5 pF
Latch Response		
Data Set Up Time[1]	25 ns	---
Data Hold Time[2]	50 ns	---
Strobe Min Pulse Width	80 ns	---

Notes:

1. The time data must be present before occurence of strobe edge.
2. The time data must be present after occurence of strobe edge.

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848/878 Series Digital Tuning Characteristics

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:

$$fc = (fmax/256)\,[\,1 + D_7 * 2^7 + D_6 * 2^6 + D_5 * 2^5 + D_4 * 2^4 + D_3 * 2^3 + D_2 * 2^2 + D_1 * 2^1 + D_0 * 2^0]$$

where D_0 - D_7 = "0" or "1", and

fmax = Maximum tunable frequency

fc = corner frequency

Minimum tunable frequency = fmax/256 (D_0 - > D_7 = 0)

Minimum frequency step (Resolution)= fmax/256

Input Data Format

Frequency Select Bits

Positive Logic — Logic "1" = +Vs, Logic "0" = Gnd — Logic threshold typ. = 0.45 Vs

Bit Weighting (Binary-Coded) — D0 = least significant bit (LSB), D7 = most significant bit (MSB)

Frequency Range — 256:1, Binary Weighted

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	Corner Frequency (fc)
0	0	0	0	0	0	0	0	fmax/256
0	0	0	0	0	0	0	1	fmax/128
0	0	0	0	0	0	1	1	fmax/64
0	0	0	0	0	1	1	1	fmax/32
0	0	0	0	1	1	1	1	fmax/16
0	0	0	1	1	1	1	1	fmax/8
0	0	1	1	1	1	1	1	fmax/2
0	1	1	1	1	1	1	1	fmax/4
1	1	1	1	1	1	1	1	fmax

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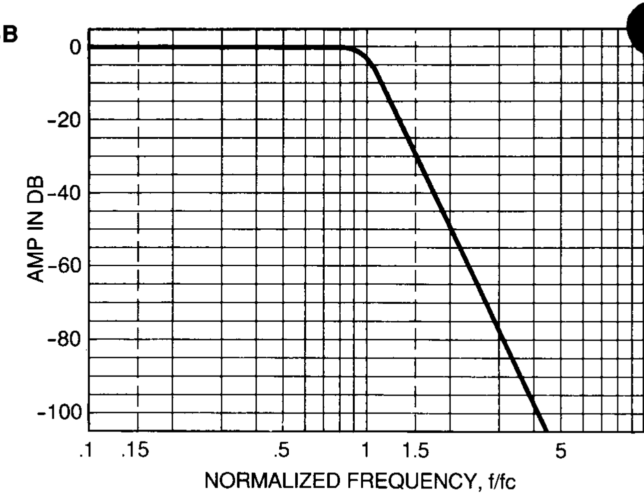
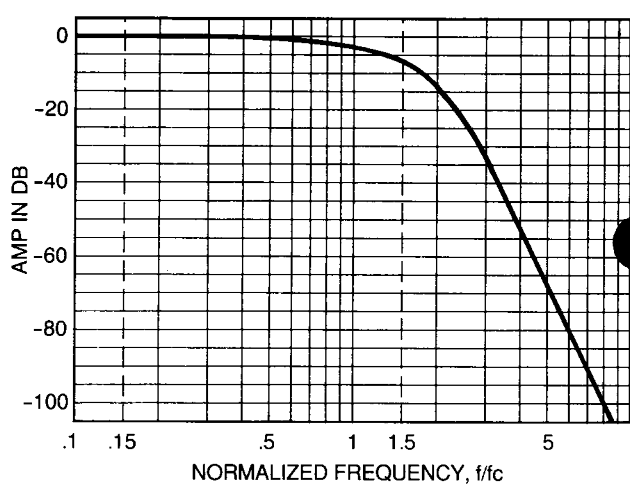
Lowpass Theoretical Frequency Response Curves

Butterworth 848P8B



Bessel 848P8L



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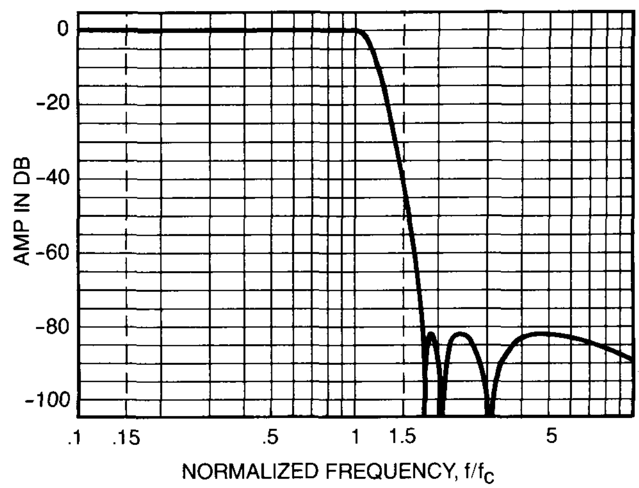
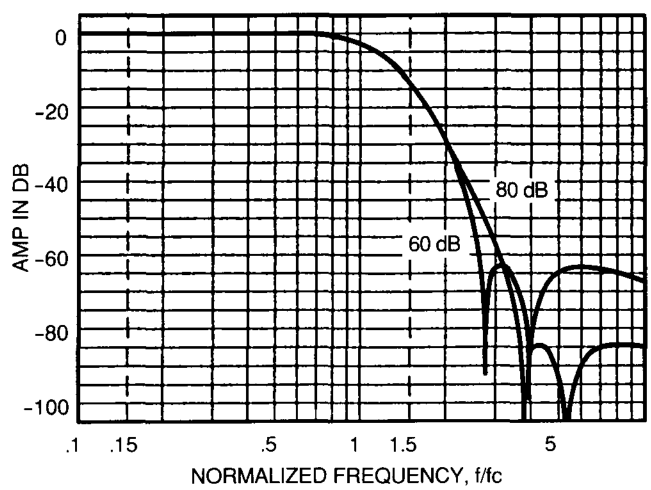
Lowpass Theoretical Frequency Response Curves

Elliptic 848PE8O



Linear Phase 848DOW60 848DOW80



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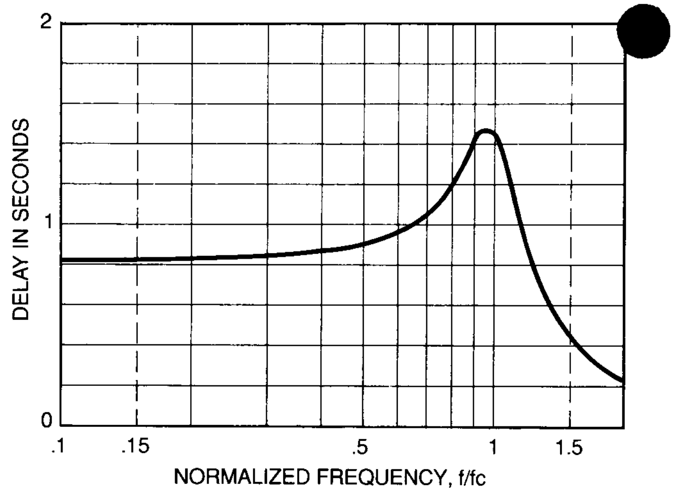
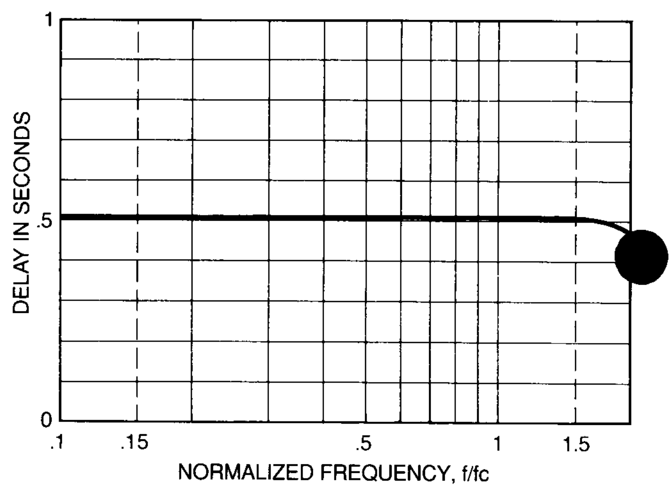
Lowpass Theoretical Delay Curves

Butterworth 848P8B



Bessel 848P8L



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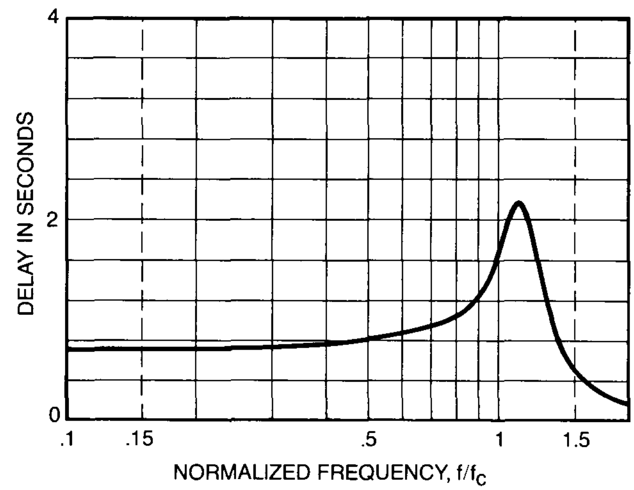
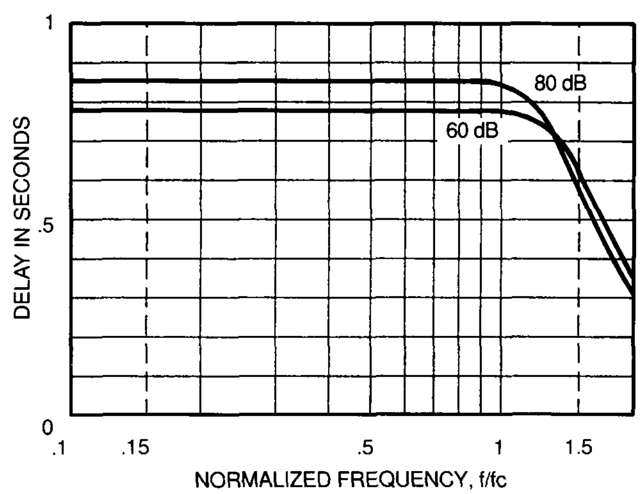
Lowpass Theoretical Delay Curves

Elliptic 848P8E8O



Linear Phase
848DOW60
848DOW80



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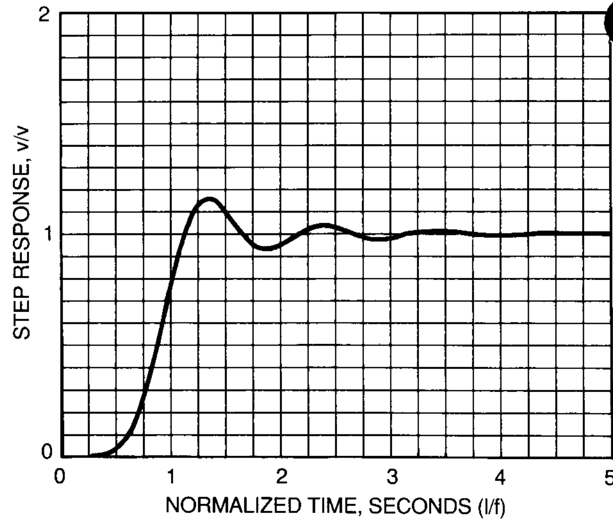
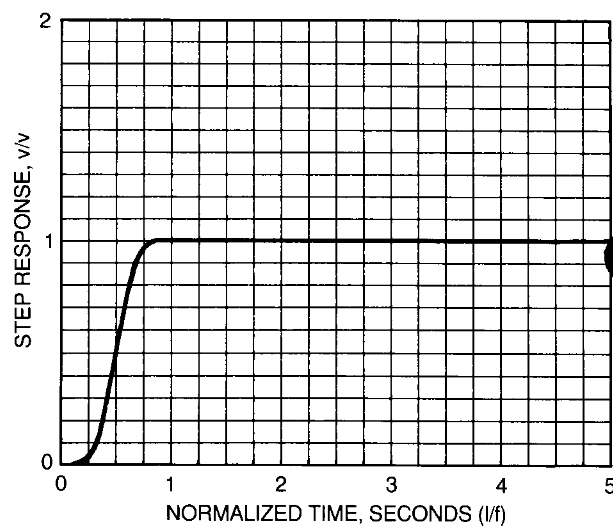
Lowpass Theoretical Step Response Curves

Butterworth 848P8B



Bessel 848P8L



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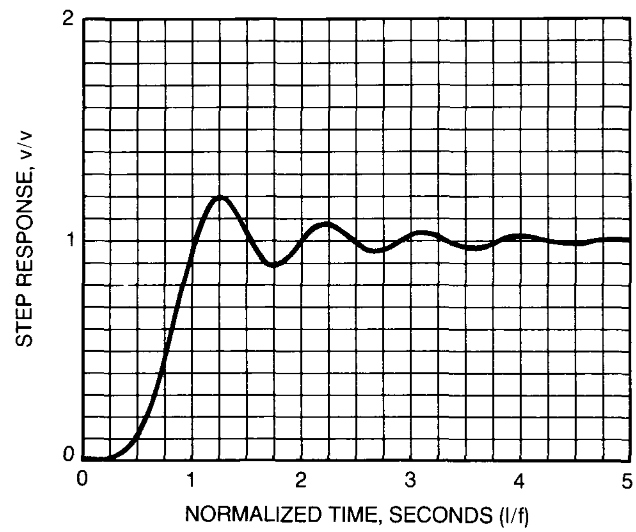
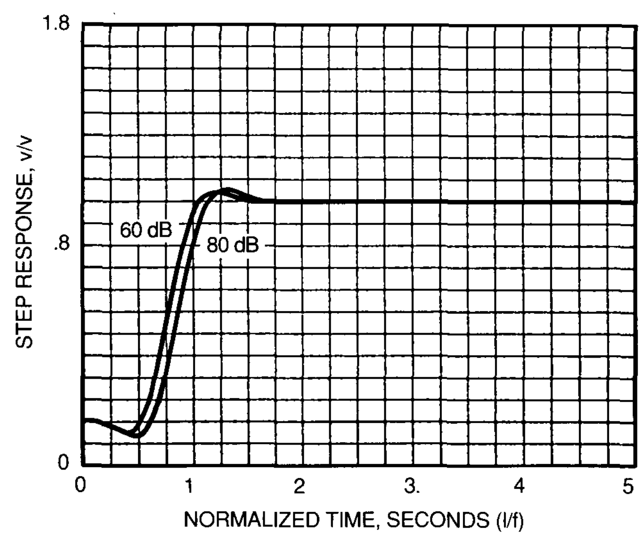
Lowpass Theoretical Step Response Curves

Elliptic 848P8E8O



Linear Phase
848DOW60
848DOW80



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848P8B Butterworth (8-Pole)Lowpass Theoretical Response Data

f/fc	Amp (dB)	Phase (deg)	Delay (sec)
0.00	0.000	0.00	0.816
0.10	0.000	-29.4	0.819
0.20	0.000	-59.0	0.828
0.30	0.000	-89.1	0.843
0.40	0.000	-120	0.868
0.50	0.000	-152	0.902
0.60	0.000	-185	0.956
0.70	-0.014	-221	1.04
0.80	-0.121	-261	1.19
0.90	-0.738	-307	1.40
1.00	-3.01	-360	1.46
1.20	-12.9	-445	0.873
1.50	-28.2	-511	0.448
2.00	-48.2	-563	0.226
2.50	-63.7	-600	0.139
3.00	-76.3	-621	0.094
4.00	-96.3	-646	0.052
5.00	-111.8	-661	0.033
6.00	-124.5	-671	0.023
7.00	-132.2	-678	0.017
8.00	-144.5	-683	0.013
9.00	-152.7	-687	0.010
10.0	-160.0	-691	0.008

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848P8L Bessel (8-Pole) Lowpass Theoretical Response Data

f/fc	Amp (dB)	Phase (deg)	Delay (sec)
0.00	0.000	0.00	0.506
0.10	-0.029	-18.2	0.506
0.20	-0.117	-36.4	0.506
0.30	-0.264	-54.7	0.506
0.40	-0.470	-72.9	0.506
0.50	-0.747	-91.1	0.506
0.60	-1.06	-109.3	0.506
0.70	-1.45	-127.5	0.506
0.80	-1.91	-145.7	0.506
0.90	-2.42	-164.0	0.506
1.00	-3.01	-184.2	0.506
1.20	-4.40	-218.6	0.506
1.50	-7.08	-273.2	0.504
2.00	-13.7	-361.9	0.468
2.50	-23.1	-436.4	0.352
3.00	-33.4	-489.2	0.241
4.00	-51.8	-551.8	0.126
5.00	-66.8	-587.3	0.077
6.00	-79.2	-610.2	0.052
7.00	-89.8	-626.3	0.038
8.00	-99.0	-683.2	0.029
9.00	-107.1	-647.4	0.023
10.0	-114.4	-654.3	0.018

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848P8E80 Elliptic (8-Pole) Lowpass Theoretical Response Data

Amplitude and Time Response Data

f/f_c	Amp (dB)	Phase (deg)	Delay (sec)
0.00	0.00	0.00	0.713
0.10	-.004	-25.7	0.716
0.20	-.014	-51.6	0.724
0.30	-.024	-77.9	0.740
0.40	-.020	-105	0.767
0.50	.007	-133	0.811
0.60	.033	-163	0.872
0.70	.014	-196	0.946
0.80	-.041	-232	1.04
0.90	-.016	-272	1.23
1.00	-.035	-323	1.65
1.20	-8.28	-467	1.86
1.40	-29.3	-558	0.753
1.60	-51.5	-594	0.381
1.70	-65.2	-606	0.296
1.80	-113	-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
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

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848DOW Linear Phase (8-Pole) Lowpass Theoretical Response Data

●plitude and Time Response

	-60 dB Attenuation Floor			-80 dB Attenuation Floor		
f/f_c	Amp (dB)	Phase (deg)	Delay (sec)	Amp (dB)	Phase (deg)	Delay (sec)
0.00	0.000	-0.00	0.776	0.000	0.00	0.852
0.10	0.005	-27.9	0.776	0.017	-30.7	0.852
0.20	0.012	-55.9	0.776	0.058	-61.4	0.852
0.30	0.005	-83.9	0.776	0.099	-92.0	0.852
0.40	-0.042	-112	0.776	0.105	-123	0.852
0.50	-0.160	-140	0.776	0.034	-153	0.852
0.60	-0.384	-168	0.776	-0.157	-184	0.852
0.70	-0.745	-196	0.776	-0.510	-215	0.852
0.80	-1.28	-224	0.776	-1.07	-245	0.851
0.90	-2.02	-252	0.776	-1.89	-276	0.849
1.00	-3.01	-279	0.773	-3.01	-306	0.841
1.50	-13.0	-409	0.620	-14.1	-440	0.582
2.00	-29.4	-495	0.351	-29.1	-517	0.312
2.50	-50.5	-544	0.212	-43.4	-561	0.189
3.00	-63.7	-395	0.142	-57.6	-589	0.126
10.0	-67.3	-318	0.012	-84.9	-321	0.011

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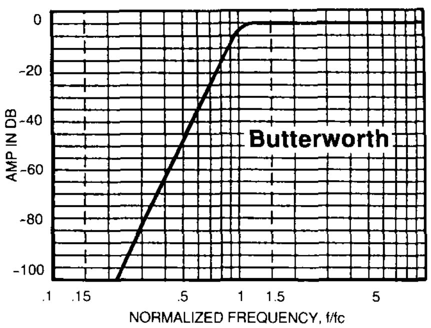
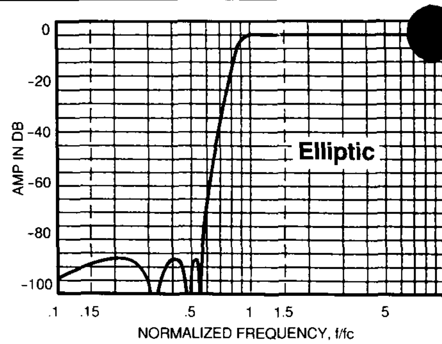
878 Series Theoretical Highpass Butterworth and Elliptic Response Data





Normalized Theoretical Data Tables

	Butterworth Response			Elliptic Response		
f/fc	**Amp (dB)**	**Phase (deg)**	**Delay (sec)**	**Amp (dB)**	**Phase (deg)**	**Delay (sec)**
0.10	-160	690.6	0.819	-89.3	164.3	0.440
0.20	-112	661.0	0.828	-82.1	140.1	0.459
0.30	-83.7	630.9	0.843	-90.6	131.0	0.495
0.40	-63.7	600.2	0.867	-82.4	292.2	0.559
0.50	-48.2	568.3	0.903	-87.8	450.2	0.671
0.55	-41.5	551.9	0.927	-90.0	437.4	0.761
0.60	-35.5	534.9	0.956	-60.1	602.6	0.890
0.70	-24.8	499.1	1.04	-32.4	563.1	1.37
0.80	-15.6	459.2	1.19	13.1	497.5	2.35
0.90	-8.1	412.6	1.40	-2.2	401.0	2.66
1.00	-3.0	360.0	1.46	-0.04	323.5	1.65
1.20	-0.2	275.5	0.873	-0.05	244.8	0.757
1.50	-0.01	208.6	0.448	-0.03	185.1	0.409
2.00	0.0	151.7	0.226	-0.01	133.4	0.203
2.50	0.0	119.8	0.139	-0.02	105.0	0.123
3.00	0.0	99.2	0.095	-0.03	86.9	0.083
4.00	0.0	74.0	0.052	-0.02	64.7	0.046
5.00	0.0	59.0	0.033	-0.01	51.6	0.029
6.00	0.0	49.1	0.023	-0.01	42.9	0.020
7.00	0.0	42.1	0.017	-0.01	36.8	0.015
8.00	0.0	36.8	0.018	-0.01	32.1	0.011
9.00	0.0	32.7	0.010	-0.01	28.6	0.009
10.0	0.0	29.4	0.008	0.0	25.7	0.007

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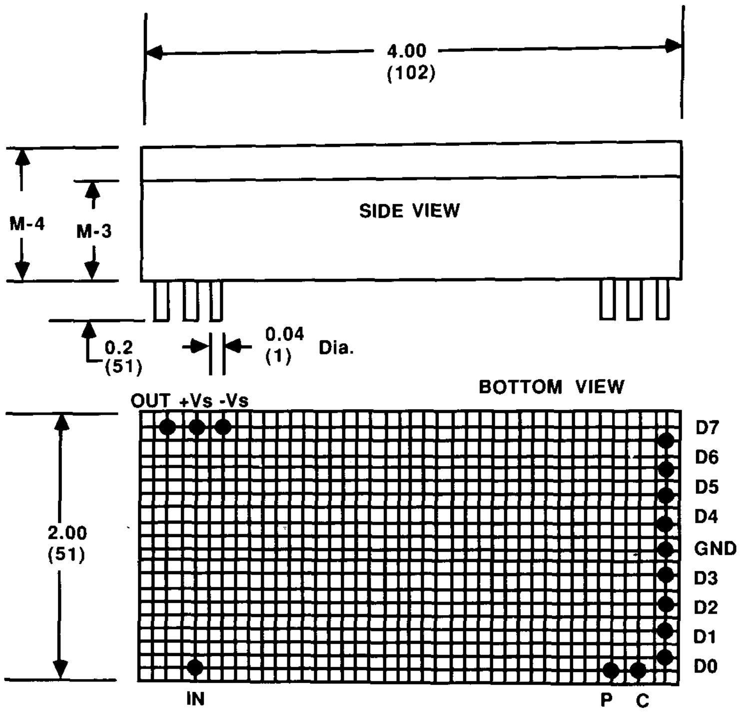
848/878 Series Package *and* Pin-out Data

FREQUENCY DEVICES™



Package and Pin-out Data - Dimensions in Inches (mm)

Case Dimensions. All 848/878 Series Models

Case	Dimensions in inches and (mm)
M-3	2.0"W x 4.0"L x 0.75"H (51 x 102 x 25 mm)
M-4	2.0"W x 4.0"L x 1.0"H (51 x 102 x 25 mm)

Terminal Key

In	Analog Input Signal	D_0 Tuning Bit 0 (LSB)
Out	Analog Output Signal	D_1 Tuning Bit 1
GND	Power and Signal Return	D_2 Tuning Bit 2
"P"	Transition Polarity Bit	D_3 Tuning Bit 3
"C"	Tuning Strobe Bit	D_4 Tuning Bit 4
+Vs	Supply Voltage, Positive	D_5 Tuning Bit 5
-Vs	Supply Voltage, Negative	D_6 Tuning Bit 6
		D_7 Tuning Bit 7 (MSB)

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Ordering Information
848 Series
Bessel, Butterworth and Elliptic Models

Butterworth Versions

Model Number	No. Poles	Tuning (Hz) Range	Min. Step	Case
848P8B-1	8	0.1 to 25.6	0.1	M-4
848P8B-2	8	1.0 to 256	1.0	M-3
848P8B-3	8	10 to 2560	10	M-3
848P8B-4	8	100 to 25.6k	100	M-3
848P8B-5	8	200 to 51.2k	200	M-3

Bessel Version

Model Number	No. Poles	Tuning (Hz) Range	Min. Step	Case
848P8L-1	8	0.1 to 25.6	0.1	M-4
848P8L-2	8	1.0 to 256	1.0	M-3
848P8L-3	8	10 to 2560	10	M-3
848P8L-4	8	100 to 25.6k	100	M-3
848P8L-5	8	200 to 51.2k	200	M-3

EllipticVersions

Model Number	No. Poles	Tuning (Hz) Range	Min. Step	Case
848P8P8E80-1	8	0.1 to 25.6	0.1	M-4
848P8P8E80-2	8	1.0 to 256	1.0	M-3
848P8P8E80-3	8	10 to 2560	10	M-3
848P8P8E80-4	8	100 to 25.6k	100	M-3
848P8P8E80-5	8	200 to 51.2k	200	M-3

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Ordering Infomation
848DOW
Linear Phase
Lowpass Models

-60 dB Attenuation Floor

Model Number	No. Poles	Tuning (Hz) Range	Min. Step	Case
848P8DOW60-1	8	0.1 to 25.6	0.1	M-4
848P8DOW60-2	8	1.0 to 256	1.0	M-3
848P8DOW60-3	8	10 to 2560	10	M-3
848P8DOW60-4	8	100 to 25.6k	100	M-3
848P8DOW60-5	8	200 to 51.2k	200	M-3

-80 dB Attenuation Floor

Model Number	No. Poles	Tuning (Hz) Range	Min. Step	Case
848P8DOW80-1	8	0.1 to 25.6	0.1	M-4
848P8DOW80-2	8	1.0 to 256	1.0	M-3
848P8DOW80-3	8	10 to 2560	10	M-3
848P8DOW80-4	8	100 to 25.6k	100	M-3
848P8DOW80-5	8	200 to 51.2k	200	M-3

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Ordering Information
878 Series
Highpass Models

Butterworth Versions

Model Number	No. Poles	Tuning (Hz) Range	Min. Step	Case
878P8B-1	8	0.1 to 25.6	0.1	M-4
878P8B-2	8	1.0 to 256	1.0	M-3
878P8B-3	8	10 to 2560	10	M-3
878P8B-4	8	100 to 25.6k	100	M-3
878P8B-5	8	200 to 51.2k	200	M-3

Elliptic Versions

Model Number	No. Poles	Tuning (Hz) Range	Min. Step	Case
878P8E-1	8	0.1 to 25.6	0.1	M-4
878P8E-2	8	1.0 to 256	1.0	M-3
878P8E-3	8	10 to 2560	10	M-3
878P8E-4	8	100 to 25.6k	100	M-3
878P8E-5	8	200 to 51.2k	200	M-3

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