FREQUENCY DEVICES

FREQUENCY DEVICES INC

848 SERIES DIGITALLY PROGRAMMABLE LOWPASS ACTIVE FILTERS

T-64-05

FEATURES

8-Pole Lowpass Butterworth, and Bessel Models featuring:

- **Digitally Programmable Corner Frequency via CMOS Interface Logic**
- **Internally Latched Control 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**

GENERAL DESCRIPTION

The **848 Series** are digitally-programmable lowpass active filters that are tunc1able over a 256:1 frequency range. These units contain 8-bit 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.

Ten models offer a choice of 8-pole Butterworth and Bessel transfer characteristics. Each is available with any single factory-set tuning range listed below:

- –1 Versions: 0.1Hz to 25.6Hz
- –2 Versions: 1.0Hz to 256Hz
- –3 Versions: 10Hz to 2560Hz
- –4 Versions: 100Hz to 25.6kHz
- –5 Versions: 200Hz to 51.2kHz

All **848 Series** models are fully finished filters which require no external components or adjustments, and operate from non-critical ±12 to ±18V power supplies. A 20KΩ input impedance and a 10Ω (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.

CONDENSED FREQUENCY SELECTION TABLE

MSB	---	---	---	---	---	---	LSB	<– **Bit Weight**
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	**Corner Frequency (fc)**
D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	
0	0	0	0	0	0	0	0	fmax/256
0	0	0	0	0	0	1	1	fmax/64
0	0	0	0	1	1	1	1	fmax/16
0	1	1	1	1	1	1	1	fmax/2
1	1	1	1	1	1	1	1	fmax

Five of the possible 256 frequency selection codes.

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ANALOG SPECIFICATIONS (Typical @ 25°C & ±15Vdc unless otherwise noted)

RESPONSE CHARACTERISTICS	
DC Gain (Non-inverting)	See Table A.
Gain Tolerance	
@ DC (Zero Frequency)	See Table A.
@ −3dB Corner Freq. f_c	See Table A.
@ −70dB Frequency f_{70dB}	See Table A.
Tuning Characteristics	
Programming Range	Fmax/256 to Fmax
Step Size (Resolution)	Fmax/256
Stability	±0.01%/°C
ATTENUATION CHARACTERISTICS	
Gain vs. Frequency Plot	See Figures 1 and 2
Gain, Phase and Delay Data	See Tables 1 and 2
ANALOG INPUT CHARACTERISTICS	
Impedance	20KΩ
Voltage Range	±10V
Maximum Safe Voltage	±Vs
ANALOG OUTPUT CHARACTERISTICS	
Resistance	10Ω max.
Linear Operating Range	±10V
Maximum Current	±2mA
Offset Voltage	2mV typ., 20mV max.
Offset vs. Temperature	See discussion, next page.
Noise	50μV RMS
POWER SUPPLY (±Vs)	
Rated Voltage	±15Vdc
Operating Range	±12 to ±18Vdc
Maximum Safe Voltage	±18Vdc
Quiescent Current	40mA max.
TEMPERATURE	
Operating	0°C to +70°C
Storage	−25°C to +85°C

Notes:
1. Input and output signal voltages are referenced to supply common.
2. Output is short circuit protected to common. DO NOT CONNECT TO ±Vs.
3. Measured in a 5Hz to 50kHz bandwidth.

Table A. Deviations from theoretical responses

Characteristic Response	At DC or Zero Frequency -A-	At fc, the −3dB Corner Frequency -B-	At f_{70dB}, Frequency for −70dB Gain -C-
Butterworth	±0.2dB	±0.5dB	±2dB
Bessel	±0.2dB	±0.5dB	±3dB

The above table defines lowpass responses having a DC gain of 0dB ±A (the value in column A), a gain of −3dB ±B at corner frequency f_c, and a gain of −70dB ±C at f_{70dB}, the frequency for a theoretical gain of −70dB.

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

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848 SERIES
DC OFFSET, GROUNDING AND CONTROL CHARACTERISTICS

DC OFFSET vs. TEMPERATURE

The DC offset voltage of **848 Series** filters originates at two internal sources that cause it to vary with temperature and selected frequency. Slight mismatches between operational amplifier (op amp) semiconductor 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). This recommends the user to select the model with the LOWEST CORNER FREQUENCY possible.

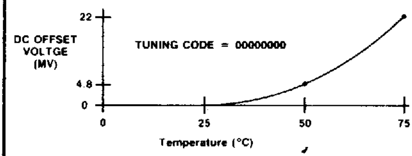

Figure A. The DC offset voltage drift varies with tuning code. Turning on the LSB would halve the maximum DC offset. See discussion.

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.

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} μA	– 1μA
Low Level In	$+10^{-5}$μA	+ 1μA
Input Capacitance	5pF	7.5pf
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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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 $D_0 - D_7$ = Logic "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. = 0.45Vs
Bit Weighting (Binary-Coded)	D_0 = least significant bit (LSB) D_7 = most significant bit (MSB)	
Frequency Range	256:1, Binary Weighted	

DIGITAL FREQUENCY SELECTION

Nine of the 256 possible frequency selection codes

MSB	---	---	---	---	---	---	LSB	<– **Bit Weight**
2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0	**Corner Frequency (fc)**
D_7	D_6	D_5	D_4	D_3	D_2	D_1	D_0	
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/4
0	1	1	1	1	1	1	1	fmax/2
1	1	1	1	1	1	1	1	fmax

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848 SERIES PACKAGE AND PIN-OUT DATA

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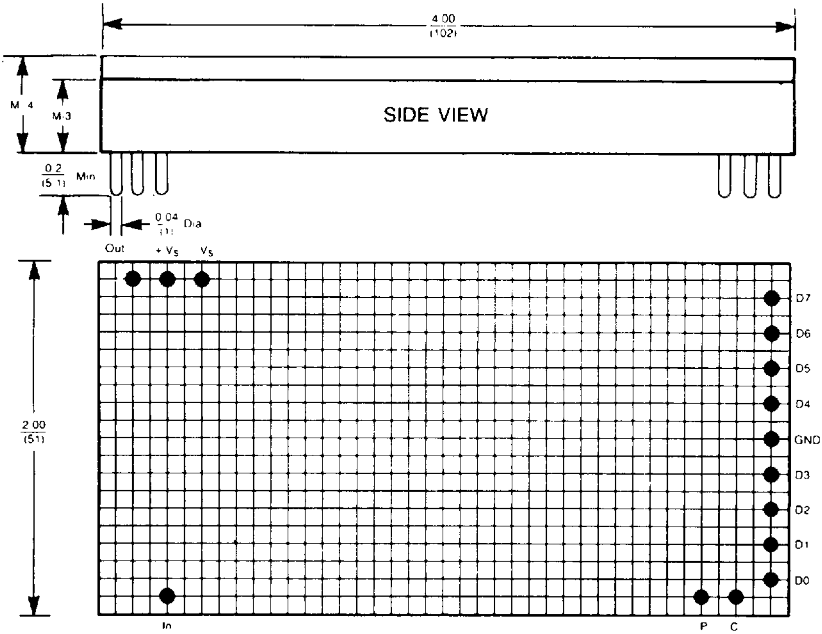

BOTTOM VIEW

PACKAGE AND PIN-OUT DATA
DIMENSIONS
IN INCHES (MM)
0.1 INCH GRID

CASE DIMENSIONS. ALL 848 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 19 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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848 SERIES THEORETICAL LOWPASS, BUTTERWORTH AND BESSEL RESPONSES

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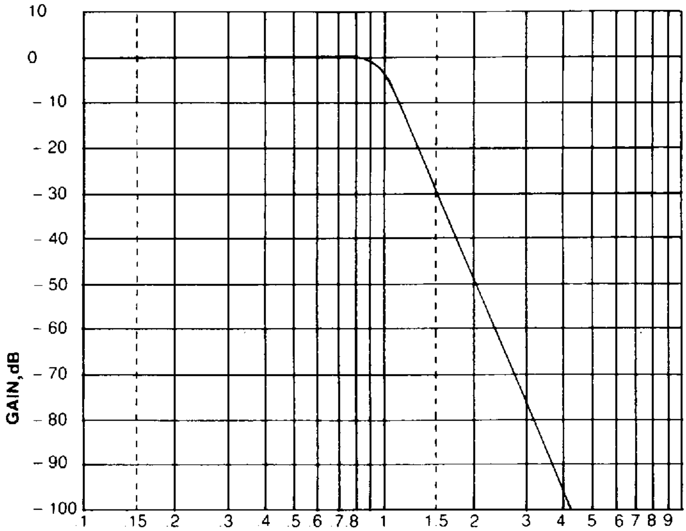

FIGURE 1 NORMALIZED FREQUENCY f/f_c

Table 1. 8-POLE BUTTERWORTH

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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848 SERIES THEORETICAL LOWPASS BESSEL RESPONSE

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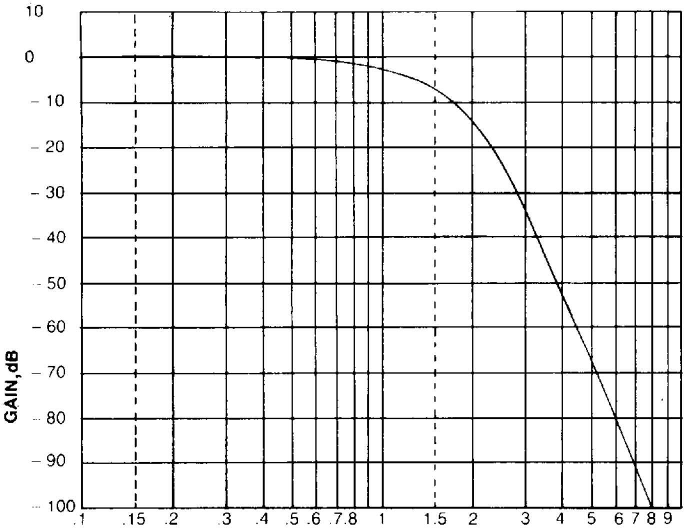

FIGURE 2 NORMALIZED FREQUENCY f/f_c

NORMALIZED THEORETICAL DATA TABLE

Table 2. 8-POLE BESSEL

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	-182.2	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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AVAILABLE 848 LOWPASS MODELS

Butterworth Versions

BUTTERWORTH	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
Figure 1 and Table 1	← TRANSFER CHARACTERISTICS			

Bessel Versions

BESSEL	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
Figure 2 and Table 2	← TRANSFER CHARACTERISTICS			

HOW TO ORDER

The above tables list the fifteen **848 Series** models and the sets of transfer characteristics, frequency range and tuning resolution that distinguish between models. Selection is the simple matter of choosing the filter model with the frequency response, range and resolution required by the application. NOTE: SELECT THE LOWEST FREQUENCY MODEL THAT SPANS THE FREQUENCY RANGE OF INTEREST FOR LOWEST DC OFFSET AND BEST FILTER PERFORMANCE.

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Highpass Filter Selection Guide

SERIES	DESCRIPTION	f RANGE	POLES	TYPES*	PAGE
701	Fixed Frequency	0.01Hz - 0.1Hz	2	B,T	91
708	Fixed Frequency	0.1Hz - 1Hz	2	B,T	91
709	Fixed Frequency	0.1Hz - 1Hz	4	B,T	91
710	Fixed Frequency	1Hz - 10Hz	2	B,T	91
711	Fixed Frequency	1Hz - 10Hz	4	B,T	91
712	Fixed Frequency	10Hz - 20kHz	2	B,T	91
713	Fixed Frequency	10Hz - 20kHz	4	B,T	91
723	Fixed Frequency	1Hz - 100Hz	6	B	91
724	Fixed Frequency	100Hz - 20kHz	6	B	91
751	Fixed Frequency	0.001Hz - 0.01Hz	2	B,T	91
753	Fixed Frequency	0.001Hz - 0.1Hz	4	B,T	91
770	Resistive Tuneable	0.02Hz - 20kHz	2,4	B	103
874	Digitally Programmable	0.1Hz - 51.2kHz	4	B,T	115

*B = Butterworth, T = Tschebeyschev

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