



DS-00864-00

**FEATURES**

- Pole-Pair Bandpass Models with Butterworth Transfer Characteristics, 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
- Production Test Systems
- Industrial Process Control
- Programmable Comb Filtering
- Frequency Spectrum Analysis
- Vibration Analysis

**GENERAL DESCRIPTION**

The **864 Series** are digitally-programmable bandpass active filters that are tunable 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) Follow the tuning input data, in a non-latching transparent mode.

Twenty two models offer a selection of 2 pole-pair bandpass responses with Butterworth transfer characteristics. The choices

include a Q of 1, 2, 5, 10 or 20, plus any single tuning 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 **864 Series** models are fully finished filters which require no external components or adjustments, and operate from non-critical  $\pm 12$  to  $\pm 18V$  power supplies. A 20K $\Omega$  input impedance and a 10 $\Omega$  (max.) output impedance make these compact (2.0"W x 4.0"L footprint, by 0.4"H or 0.6"H) encapsulated plug-in modules convenient and easy to use.

**CONDENSED FREQUENCY SELECTION TABLE**

MSB	---	---	---	---	---	---	LSB	<-- Bit Weight
2 <sup>7</sup>	2 <sup>6</sup>	2 <sup>5</sup>	2 <sup>4</sup>	2 <sup>3</sup>	2 <sup>2</sup>	2 <sup>1</sup>	2 <sup>0</sup>	Corner Frequency (fc)
D <sub>7</sub>	D <sub>6</sub>	D <sub>5</sub>	D <sub>4</sub>	D <sub>3</sub>	D <sub>2</sub>	D <sub>1</sub>	D <sub>0</sub>	
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.



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

**RESPONSE CHARACTERISTICS**

Gain @ $f_0$ (Non-inverting)	0 ± 0.2dB
Gain @ Specific Frequencies	
@ $f_1$ (-3dB), $f_h$ (-3dB)	-3 ± 0.5dB
@ $f_1$ (-40dB), $f_h$ (-40dB)	-40 ± 2dB
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, 2, 3, 4
Gain, Phase and Delay Data	See Tables 1, 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	20mA 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.

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**DC OFFSET vs. TEMPERATURE**

The DC offset voltage of **864 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.

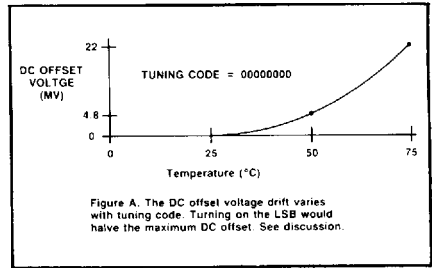


Figure A. The DC offset voltage drift varies with tuning code. Turning on the LSB would halve the maximum DC offset. See discussion.

**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<sub>0</sub> - D<sub>7</sub>) 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**

<b>Data Control Lines</b>		
Functions	Latch Strobe (C) Transition Polarity (P)	
<b>Data Control Modes</b>		
Mode 1	P = 0; C = 0 P = 0; C = 0 -> 1	frequency follows input codes frequency latched on rising edge
Mode 2	P = 1; C = 1 P = 1; C = 1 -> 0	frequency follows input codes frequency latched on falling edge
<b>INPUT DATA LEVELS</b> (CMOS Logic)		
<b>Input Voltage</b> (V <sub>s</sub> = 15V)	<b>Min.</b>	<b>Max. Acceptable</b>
Low Level In	0 Volts	4 Volts
High Level In	11 Volts	15 Volts
<b>Input Current</b>	<b>Typ.</b>	<b>Max.</b>
High Level In	- 10 <sup>-5</sup> μA	- 1 μA
Low Level In	+ 10 <sup>-5</sup> μA	+ 1 μA
<b>Input Capacitance</b>	5pF	7.5pf
<b>Latch Response</b>		
Data Set Up Time <sup>1</sup>	25 ns	—
Data Hold Time <sup>2</sup>	50 ns	—
Strobe		
Min Pulse Width	80 ns	—

- Notes:** 1. The time data must be present before occurrence of strobe edge.  
2. The time data must be present after occurrence of strobe edge.

3731130 0002649 539



**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<sub>0</sub> - D<sub>7</sub>), a latch strobe bit (C), and a transition polarity bit (P).

Filter tuning follows the tuning equation given below:

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

where D<sub>0</sub> - D<sub>7</sub> = Logic "0" or "1", and

f<sub>max</sub> = maximum tunable frequency

f<sub>c</sub> = center frequency

Minimum tunable frequency = f<sub>max</sub>/256 (D<sub>0</sub> → D<sub>7</sub> = 0)

Minimum frequency step (Resolution) = f<sub>max</sub>/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<sub>0</sub> = least significant bit (LSB)

D<sub>7</sub> = most significant bit (MSB)

Frequency Range

256:1, Binary Weighted

**DIGITAL FREQUENCY SELECTION**

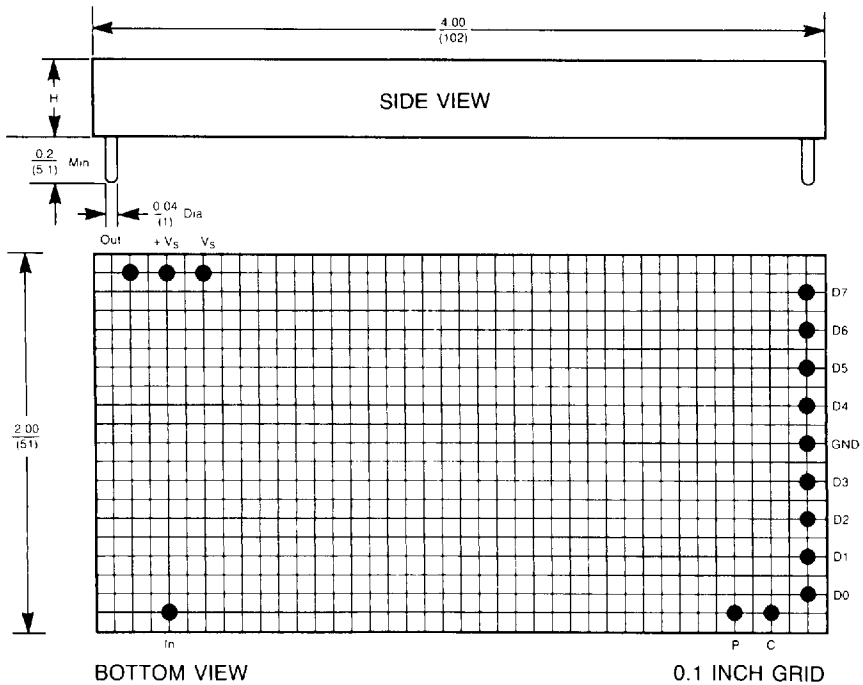
Nine of the 256 possible frequency selection codes

MSB	---	---	---	---	---	---	LSB	< - Bit Weight
27	26	25	24	23	22	21	20	Corner Frequency (f <sub>c</sub> )
D <sub>7</sub>	D <sub>6</sub>	D <sub>5</sub>	D <sub>4</sub>	D <sub>3</sub>	D <sub>2</sub>	D <sub>1</sub>	D <sub>0</sub>	
0	0	0	0	0	0	0	0	f <sub>max</sub> /256
0	0	0	0	0	0	0	1	f <sub>max</sub> /128
0	0	0	0	0	0	1	1	f <sub>max</sub> /64
0	0	0	0	0	1	1	1	f <sub>max</sub> /32
0	0	0	0	1	1	1	1	f <sub>max</sub> /16
0	0	0	1	1	1	1	1	f <sub>max</sub> /8
0	0	1	1	1	1	1	1	f <sub>max</sub> /4
0	1	1	1	1	1	1	1	f <sub>max</sub> /2
1	1	1	1	1	1	1	1	f <sub>max</sub>

4 ■ 3731130 0002650 250 ■



**PACKAGE AND PIN-OUT DATA  
DIMENSIONS  
IN INCHES (MM)**



**CASE DIMENSIONS. ALL 864 SERIES MODELS**

CASE	DIMENSIONS IN INCHES AND (MM)
M-1	2.0"W x 4.0"L x 0.6"H (51 x 102 x 15 mm)
M-2	2.0"W x 4.0"L x 0.4"H (51 x 102 x 10 mm)

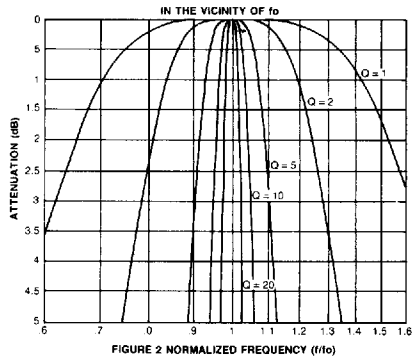
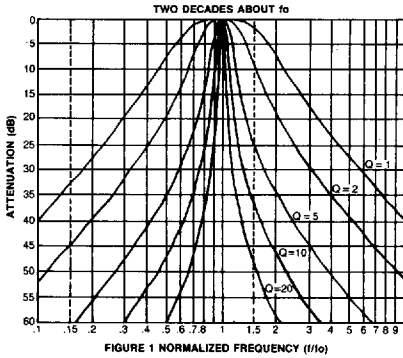
**TERMINAL KEY**

- |      |                          |                |                    |
|------|--------------------------|----------------|--------------------|
| In   | Analog Input Signal      | D <sub>0</sub> | Tuning Bit 0 (LSB) |
| Out  | Analog Output Signal     | D <sub>1</sub> | Tuning Bit 1       |
| GND  | Power and Signal Return  | D <sub>2</sub> | Tuning Bit 2       |
| "P"  | Transition Polarity Bit  | D <sub>3</sub> | Tuning Bit 3       |
| "C"  | Tuning Strobe Bit        | D <sub>4</sub> | Tuning Bit 4       |
| + Vs | Supply Voltage, Positive | D <sub>5</sub> | Tuning Bit 5       |
| - Vs | Supply Voltage, Negative | D <sub>6</sub> | Tuning Bit 6       |
|      |                          | D <sub>7</sub> | Tuning Bit 7 (MSB) |

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**AMPLITUDE RESPONSE CURVES..**



**NORMALIZED THEORETICAL  
AMPLITUDE DATA**

Table 1.

Q →	Q = 1		Q = 2		Q = 5		Q = 10		Q = 20	
AMP. (dB)	f < fo < f		f < fo < f		f < fo < f		f < fo < f		f < fo < f	
	f/fo	fo/f	f/fo	fo/f	f/fo	fo/f	f/fo	fo/f	f/fo	fo/f
0.5	0.75	1.34	0.86	1.16	0.94	1.06	0.97	1.03	0.99	1.02
1.0	0.71	1.42	0.84	1.19	0.93	1.07	0.97	1.04	0.98	1.02
1.5	0.67	1.48	0.82	1.22	0.92	1.08	0.96	1.04	0.98	1.02
2.0	0.65	1.53	0.81	1.24	0.92	1.09	0.96	1.05	0.98	1.02
2.5	0.64	1.57	0.79	1.26	0.91	1.10	0.95	1.05	0.98	1.02
3.0	0.62	1.62	0.78	1.28	0.91	1.10	0.95	1.05	0.98	1.03
5.0	0.56	1.78	0.74	1.35	0.89	1.13	0.94	1.06	0.97	1.03
10.0	0.46	2.19	0.66	1.52	0.84	1.19	0.92	1.09	0.96	1.04
15.0	0.37	2.72	0.57	1.75	0.79	1.26	0.89	1.13	0.94	1.06
20.0	0.29	3.45	0.49	2.06	0.73	1.36	0.89	1.17	0.92	1.08
25.0	0.23	4.44	0.40	2.51	0.66	1.51	0.81	1.23	0.90	1.11
30.0	0.17	5.80	0.32	3.13	0.59	1.71	0.76	1.32	0.87	1.15
35.0	0.13	7.63	0.25	4.00	0.50	2.00	0.69	1.44	0.83	1.21
40.0	0.10	10.1	0.19	5.19	0.41	2.41	0.62	1.62	0.78	1.28
45.0	0.08	13.4	0.15	6.13	0.33	3.00	0.54	1.87	0.72	1.39
50.0	0.06	17.3	0.11	9.00	0.26	3.82	0.45	2.23	0.65	1.54



**PHASE RESPONSE CURVES..**

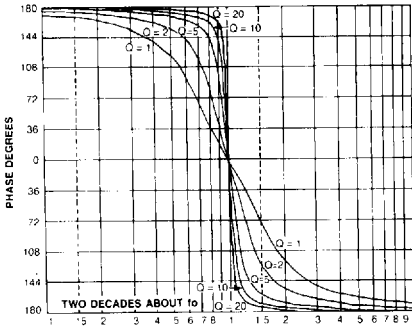


FIGURE 3 NORMALIZED FREQUENCY (f/fo)

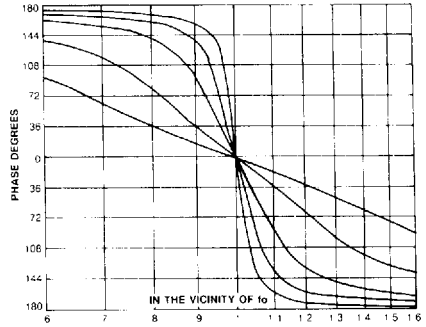


FIGURE 4 NORMALIZED FREQUENCY (f/fo)

**NORMALIZED THEORETICAL  
PHASE RESPONSE DATA**

Table 2.

PHASE ANGLE (deg)	Q = 1		Q = 2		Q = 5		Q = 10		Q = 20	
	f < fo < f		f < fo < f		f < fo < f		f < fo < f		f < fo < f	
POL-<	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)	(-)	(+)
MAG.	f/fo	fo/f	f/fo	fo/f	f/fo	fo/f	f/fo	fo/f	f/fo	fo/f
5	0.97	1.03	0.99	1.02	0.99	1.01	0.10	1.00	1.00	1.00
10	0.94	1.06	0.97	1.03	0.99	1.01	0.99	1.01	1.00	1.00
15	0.91	1.10	0.96	1.05	0.98	1.02	0.99	1.01	1.00	1.01
30	0.84	1.19	0.92	1.09	0.97	1.04	0.98	1.02	0.99	1.01
45	0.77	1.29	0.89	1.14	0.95	1.05	0.97	1.03	0.99	1.01
60	0.72	1.39	0.85	1.18	0.94	1.07	0.97	1.03	0.98	1.02
75	0.67	1.50	0.81	1.23	0.92	1.09	0.96	1.04	0.98	1.02
90	0.62	1.62	0.78	1.28	0.91	1.11	0.95	1.05	0.98	1.03
105	0.56	1.77	0.74	1.35	0.89	1.13	0.94	1.06	0.97	1.03
120	0.50	1.99	0.70	1.44	0.86	1.16	0.93	1.08	0.96	1.04
135	0.42	2.36	0.63	1.59	0.83	1.21	0.91	1.10	0.95	1.05
150	0.32	3.13	0.52	1.92	0.76	1.39	0.89	1.15	0.93	1.07
165	0.18	5.64	0.33	3.06	0.59	1.69	0.76	1.31	0.87	1.15
180	0	∞	0	∞	0	∞	0	∞	0	∞

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**AVAILABLE 864 SERIES BANDPASS MODELS**

FREQ	TUNING RANGE				
	0.1Hz to 25.6Hz	1.0Hz to 256Hz	10Hz to 2.56kHz	100Hz to 25.6kHz	200Hz to 51.2kHz
	MINIMUM TUNABLE STEP (RESOLUTION)				
	0.1Hz	1.0Hz	10Hz	100Hz	200Hz
CASE	M-1	M-2	M-2	M-2	M-2
"Q"	MODELS				
Q = 1	864P8BQ1-1	864P8BQ1-2	864P8BQ1-3	864P8BQ1-4	864P8BQ1-5
Q = 2	864P8BQ2-1	864P8BQ2-2	864P8BQ2-3	864P8BQ2-4	864P8BQ2-5
Q = 5	864P8BQ5-1	864P8BQ5-2	864P8BQ5-3	864P8BQ5-4	864P8BQ5-5
Q = 10	864P8BQ10-1	864P8BQ10-2	864P8BQ10-3	864P8BQ10-4	---
Q = 20	864P8BQ20-1	864P8BQ20-2	864P8BQ20-3	---	---

TRANSFER CHARACTERISTICS APPEAR IN TABLES ON PAGES 6 & 7.

**HOW TO ORDER**

The AVAILABLE MODELS table above lists the twenty two **864 Series** models and the features that distinguish each model from the other. Selection is the simple matter of choosing the filter model with the frequency response, range and resolution required by the application. NOTE: FOR LOWEST DC OFFSET AND BEST FILTER PERFORMANCE, SELECT THE LOWEST FREQUENCY MODEL THAT SPANS THE BANDWIDTH OF INTEREST.

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