FREQUENCY DEVICES

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864 SERIES DIGITALLY PROGRAMMABLE BANDPASS ACTIVE FILTERS

FEATURES

2 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

T-64-05

- Programmable Automatic Test Equipment (A.T.E.) Systems
- Production Test Systems
- Industrial Process Control
- Programmable Comb Filtering
- Frequency Spectrum Analysis
- Vibration Analysis

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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 ±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 0.4"H or 0.6"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	
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, GROUNDING AND CONTROL CHARACTERISTICS

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.

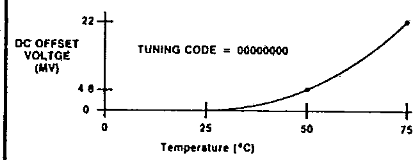

Figure A. The DC offset voltage drift varies with tuning code. Turning on the LSB would halve the maximum DC offset See discussion.

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_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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**864 SERIES
DIGITAL TUNING
CHARACTERISTICS**

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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).

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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 = center frequency
Minimum tunable frequency = fmax/256 ($D_0 \rightarrow D_7 = 0$)
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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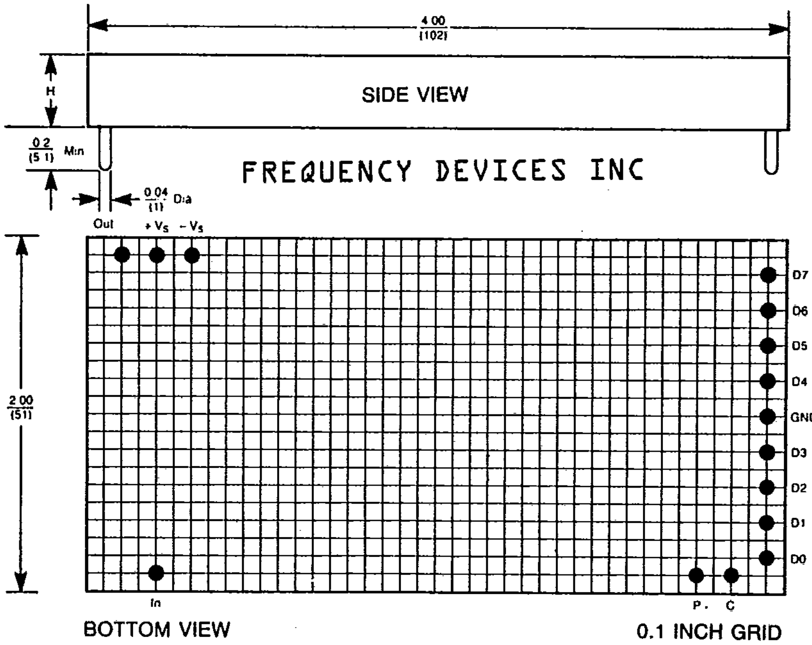
PACKAGE AND PIN-OUT DATA DIMENSIONS IN INCHES (MM)



CASE DIMENSIONS, ALL 864 SERIES MODELS

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

TERMINAL KEY

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

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864 SERIES THEORETICAL BANDPASS AMPLITUDE RESPONSE

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AMPLITUDE RESPONSE CURVES..

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TWO DECADES ABOUT fo

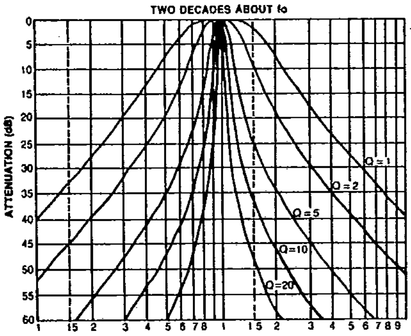

FIGURE 1 NORMALIZED FREQUENCY (f/fo)

IN THE VICINITY OF fo

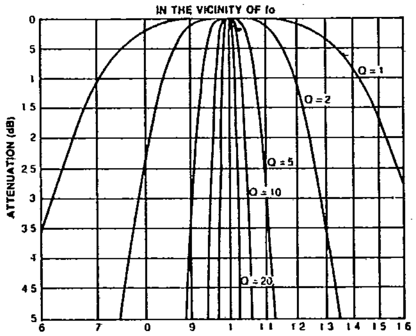

FIGURE 2 NORMALIZED FREQUENCY (f/fo)

NORMALIZED THEORETICAL AMPLITUDE DATA

Q ->	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	
AMP. (dB)	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

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PHASE RESPONSE CURVES.. T-64-05

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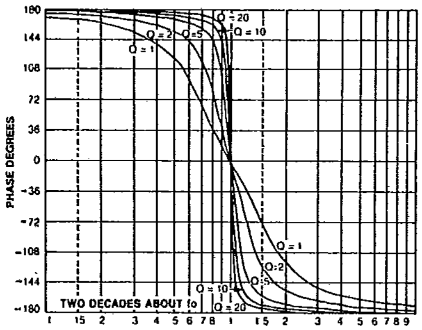

FIGURE 3 NORMALIZED FREQUENCY (f/fo)

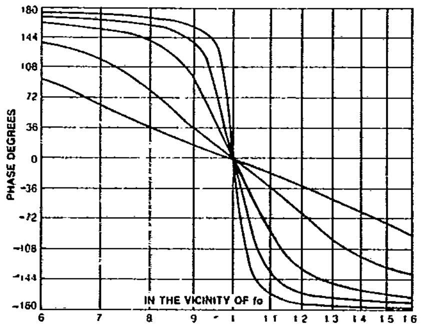

FIGURE 4 NORMALIZED FREQUENCY (f/fo)

NORMALIZED THEORETICAL PHASE RESPONSE DATA

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	oo	0	oo	0	oo	0	oo	0	oo

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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 178, 179.

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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