5/98

High Frequency Resistor Programmable Universal Active Filter

Preliminary Data Sheet

MSU1HF1/4,MSU2HF1

Description

The high frequency resistor programmable universal active filter is a CMOS chip that can be configured for Lowpass, Bandpass, Highpass, Elliptic, Notch or Allpass filters using external resistors. The filters come in one (8 pin) or two (16 pin) section versions. The device is a switched-capacitor filter using a topology that requires fewer pins, less power consumption and provides higher frequency performance than other switched-capacitor universal active filters. The clock to corner ratio as well as the Q are set by external resistors.

Depending on the filter type and response, from zero to nine external resistors are needed for each section. The sections may be cascaded to realize higher order filters.

The devices have a selectable nominal sample to corner ratio of either 6.25 to 1 or 12.5 to 1 and come in either a low power version (fo‹100 kHz)or a higher power version (fo‹500kHz). The devices are double sampled to reduce the clock frequency by a factor of two.

Features

Low Power Consumption	
High Frequency Operation	
Low Cost	
Small Package Size	8 or 16 pin DIP or SOIC
Wide Q Range	0.5 to over 20
Wide Clock to Center/Corner Frequency Range	6.25:1 to over 50:1
Accurate Switched-Capacitor Technology	

Applications

- General Purpose Filtering
- Portable Equipment
- Instrumentation

Absolute Maximum Ratings

Power Supply Voltage	+6v
Storage Temperature	-60 to +150°C
Operating Temperature	0 to 70°C

Ordering Information

Part Number	Package	Operating Temperature
MSU1HF1P	8 Pin Dip	0 - 70°C
MSU1HF1S	8 Pin SOIC	0 - 70°C
MSU1HF2P	8 Pin Dip	0 - 70°C
MSU1HF2S	8 Pin SOIC	0 - 70°C
MSU1HF3P	8 Pin Dip	0 - 70°C
MSU1HF3S	8 Pin SOIC	0 - 70°C
MSU1HF4P	8 Pin Dip	0 - 70°C
MSU1HF4S	8 Pin SOIC	0 - 70°C
MSU2HF1P	16 Pin Dip	0 - 70°C
MSU2HF1S	16 Pin SOIC	0 - 70°C

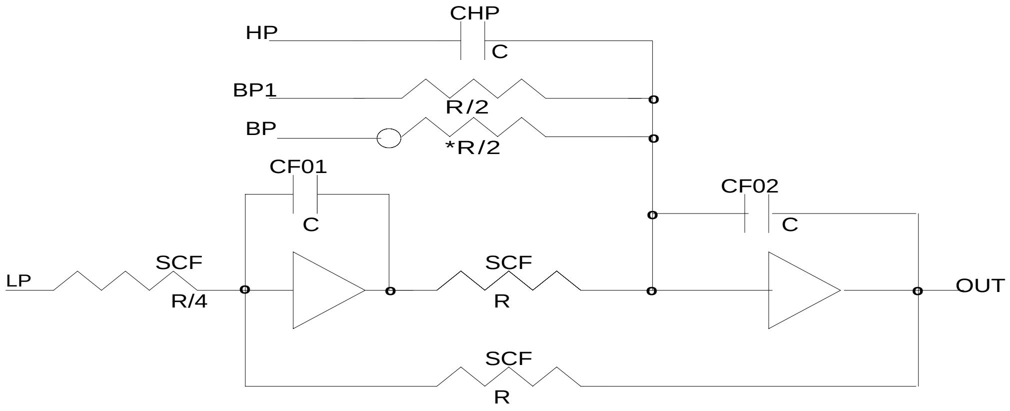
High Frequency Resistor Programmable Universal Active Filter Preliminary Data Sheet

Electrical Characteristics

PARAMETERS	SYMBOL	CONDITIONS	MIN TYP MAX	UNITS
DC Specifications				
Operating Voltage	VDD		4.5 5.0 5.5	V
Supply Current	IDD	MSU2HF1 PWR = 1	8	mA
		MSU2HF1 PWR = 0	25	mA
		MSU1HF1/3	6	mA
		MSU1HF2/4	15	mA
Output Impedance			700	ohm
Output Offset			20	mV
AC Specifications				
Output Swing			4.0 4.5	Vp-p
Input Impedance	Zin		1	Mohm
Nominal Sample to corner	Fo	MSU2HF1 FO = 1	6.25	
		FO = 0	12.5	
		MSU1HF1/2	6.25	
		MSU1HF3/4	12.5	
Center/Corner Range note(1)		MSU2HF1 PWR = 1	100	KHz
		PWR = 0	500	KHz
		MSU1HF1/3	100	KHz
		MSU1HF2/4	500	KHz
Clock Input Voltage	CKin		0.1note(2) 5	Vp-p

note(1): the clock to corner ratio is one-half the sample to corner ratio
note(2): 100mV sine wave clock requires capacitive coupling

Block Diagram



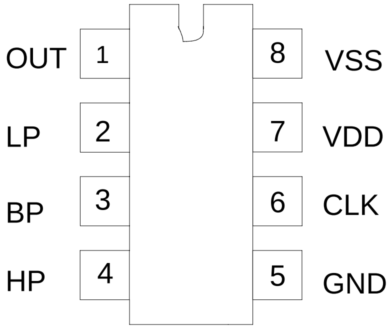
*BPP input is noninverting

Pin Description

16 Pin	8 Pin		
1		PWR	Power Select Pin 0 = High 1 = Low
2	8	VSS	Negative Supply, Typically 0V for single supply, - 2.5 V for dual supply
3	1	OUT1	Section One Output
4	5	GND	Ground Reference, Typically 2.5V for single supply, 0V for dual supply
5	2	LP1	Section One Lowpass Input
6	3	BPN1	Section One Negative Bandpass Input
7		BPP1	Section One Positive Bandpass Input
8	4	HP1	Section One High Pass Input
9		HP2	Section Two High Pass Input
10		BPP2	Section Two Positive Bandpass Input
11		BPN2	Section Two Negative Bandpass Input
12		LP2	Section Two Lowpass Input
13	6	CLK	Input Clock, Typically 200mV for AC coupled sine wave, 5V for CMOS input
14		OUT2	Section Two Output
15		FO	Clock to Center/Corner, Select Pin, Low = 6.25 to 1 High = 3.125 (sample rate is 2x)
16	7	VDD	Positive Supply, Typically 5V for single supply, 2.5V for dual supply

Pin Configuration

8 PIN



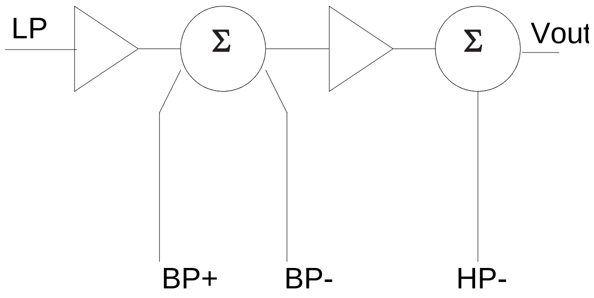
16 PIN

High Frequency Resistor Programmable Universal Active Filter
Preliminary Data Sheet

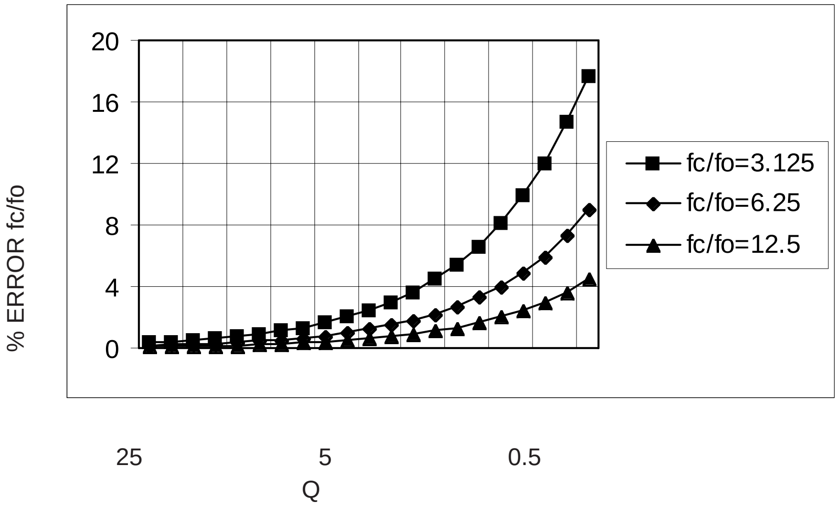
Filter Types Available

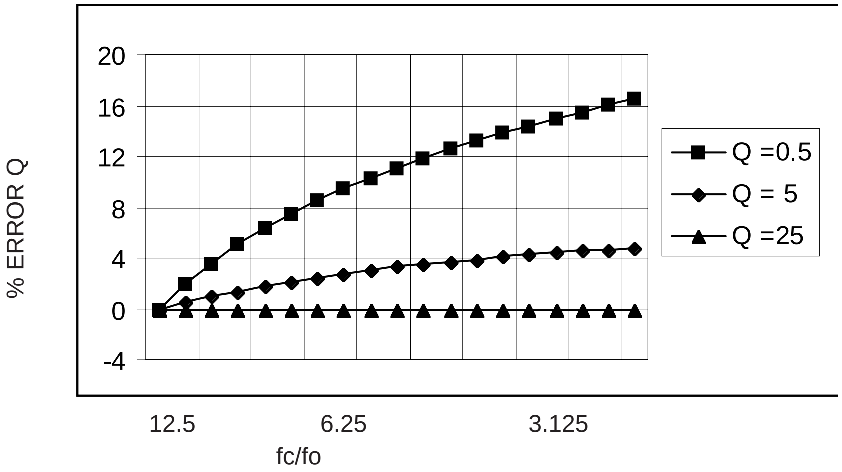
	MSU2HF1	**MSU1HF1/4**
Lowpass	yes	yes
Bandpass	yes	yes
Highpass	yes	yes
Lowpass elliptical	yes	yes
Highpass elliptical	yes	yes
Notch	yes	yes
Oscillator	yes	no
Allpass	yes	no
Biquad	yes	no

Block Diagram



Programming Non-Linearities





Transfer Functions

Lowpass

$$H(s) = -\frac{\omega_0^2}{S^2 + (\omega_0/Q)S + \omega_0^2}$$

Bandpass

$$H(s) = \frac{-(\omega_0/Q)S}{S^2 + (\omega_0/Q)S + \omega_0^2}$$

Highpass

$$H(s) = \frac{S^2}{S^2 + (\omega_0/Q)S + \omega_0^2}$$

Lowpass Elliptic

$$H(s) = \frac{(\omega_0/\omega_z)^2 S^2 + \omega_0^2}{S^2 + (\omega_0/Q)S + \omega_0^2}$$

Highpass Elliptic

$$H(s) = \frac{S^2 + (\omega_z/\omega_0)^2\omega_0^2}{S^2 + (\omega_0/Q)S + \omega_0^2}$$

Notch

$$H(s) = \frac{S^2 + \omega_0^2}{S^2 + (\omega_0/Q)S + \omega_0^2}$$

Allpass

$$H(s) = \frac{S^2 - (\omega_0/Q)S + \omega_0^2}{S^2 + (\omega_0/Q)S + \omega_0^2}$$

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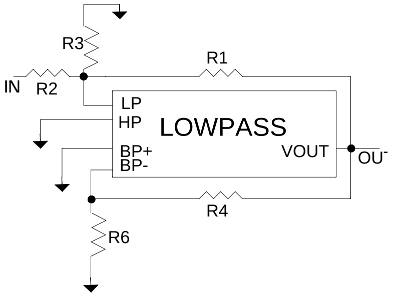
Preliminary Data Sheet

NOTE: $\frac{f_c}{f_o} > 36$

For lowpass, lowpass elliptical, highpass elliptical, allpass and notch filters. This limitation due to the particular ratio of R_1 and R_2 and allows realizable values of R_3. Other minimum values of fc/fo can be obtained by using other values of R_1 and R_2 in the basic biquad equations.



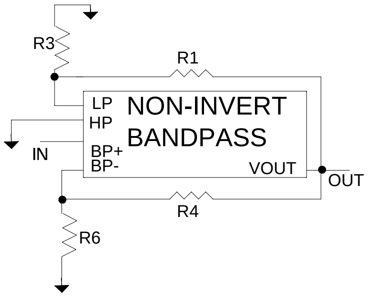
Assumption (1) $R_1 = R_2$; DC Gain = Unity

$$f_0 = \sqrt{K_1} \cdot \frac{fc}{\alpha\,(2)} \qquad K_1 = \frac{R_3}{R_1 + 2R_3}$$

$$Q = \sqrt{\frac{K_1}{K_2}} \qquad K_2 = \frac{R_6}{R_4 + R_6}$$

(1) If a gain other than unity is desired then gain = R_1/R_2 and K_1 from the biquad equations should be substituted for K_1

(2) where α is 6.25 or 12.5.



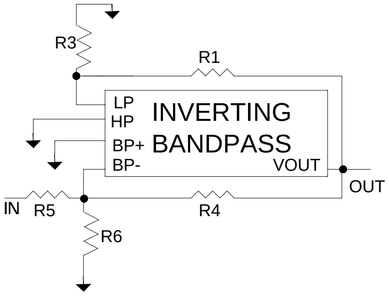
Gain (1) = $\frac{1}{K_2}$

$$f_0 = \sqrt{K_1} \cdot \frac{fc}{\alpha(2)} \qquad K_1 = \frac{R_3}{R_1 + R_3}$$

$$Q = \sqrt{\frac{K_1}{K_2}} \qquad K_2 = \frac{R_6}{R_4 + R_6}$$

(1) Gain may be adjusted independent of Q using the resistor divider described by K_5 from the biquad equations. Use the K_5 equation in place of K_2 for the gain equation only.

(2) where α is 6.25 or 12.5.



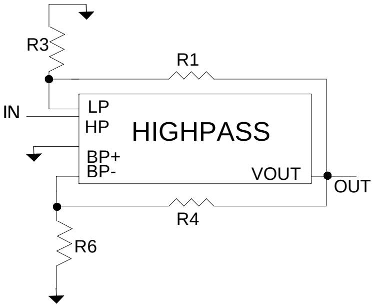
Assumption(1) $R_4 = R_5$; Gain = Unity

$$f_0 = \sqrt{K_1} \cdot \frac{fc}{\alpha(2)} \qquad K_1 = \frac{R_3}{R_1 + R_3}$$

$$Q = \sqrt{\frac{K_1}{K_2}} \qquad K_2 = \frac{R_6}{R_4 + 2R_6}$$

(1) For gains not equal to unity, gain = R_4/R_5 and K_2 should be replaced with K_2 from the biquad equations.

(2) where α is 6.25 or 12.5.

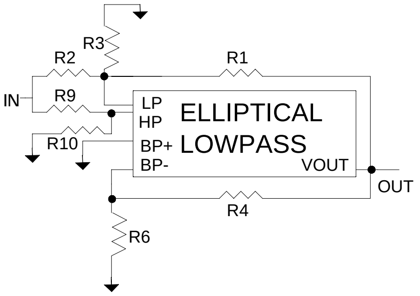


Gain = Unity

$$f_0 = \sqrt{K_1} \cdot \frac{fc}{\alpha(1)} \qquad K_1 = \frac{R_3}{R_1 + R_3}$$

$$Q = \sqrt{\frac{K_1}{K_2}} \qquad K_2 = \frac{R_6}{R_4 + R_6}$$

High Frequency Resistor Programmable Universal Active Filter Preliminary Data Sheet



DC Gain (1) = Unity; R_1 = R2

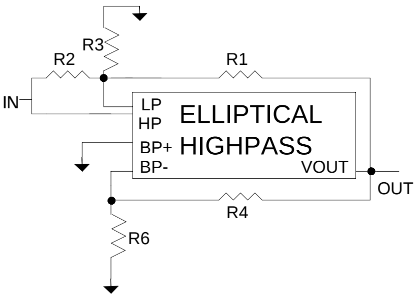
$f_0 = \sqrt{K_1} \cdot \frac{fc}{\alpha}$ $\quad K_1 = \frac{R_3}{R_1 + 2R_3}$

$Q = \frac{\sqrt{K_1}}{K_2}$ $\quad K_2 = \frac{R_6}{R_4 + R_6}$

$f_z = \sqrt{\frac{1}{K_3}} \cdot f_0$ $\quad K_3 = \frac{R_{10}}{R_9 + R_{10}}$

(1) For gain other than unity, gain = R_1/R_2 and K_1 from the bequad equation should be substituted for K_1. The $\sqrt{1/K_3}$ term should also be multiplied by the gain.

(2) where α is 6.25 or 12.5.



Gain = Unity

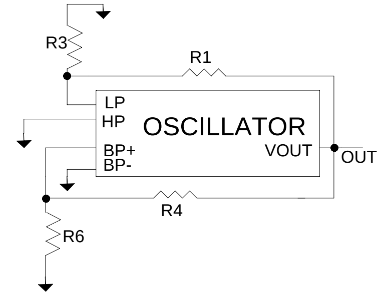
(1) $f_0 = \sqrt{K_1} \cdot \frac{fc}{\alpha}$

$Q = \frac{\sqrt{K_1}}{K_2}$ $\quad K_1 = \frac{R_2R_3}{R_1R_2 + R_1R_3 + R_2R_3}$

$f_z = \sqrt{\frac{R1}{R_2}} \cdot f_0$ $\quad K_2 = \frac{R_6}{R_4 + R_6}$

(1) For this case only, the resistor value R_1 and R_2 should be determined for f_z before the resistor values for f_0 (R_3) are calculated

(2) where α is 6.25 or 12.5.

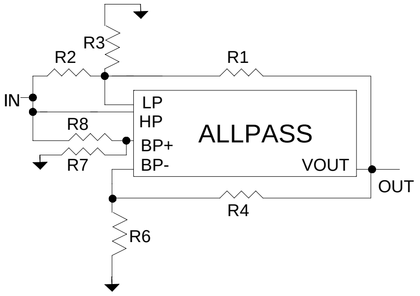


(1) $f_0 = \sqrt{\frac{R_3}{R_1 + R_3}} \cdot \frac{fc}{\alpha}$ $\quad$ (2) $\frac{R_4}{R_6} \cong 20$

(1) f_0 is also a function of the feedback coefficient defined by R_4 and R_6 and can vary considerably from the calculated value. For a fixed feedback coefficient, f_0 will not vary by more than plus or minus 1%.

(2) The distortion of the sine wave can be adjusted by varying this ratio.

(3) where α is 6.25 or 12.5.

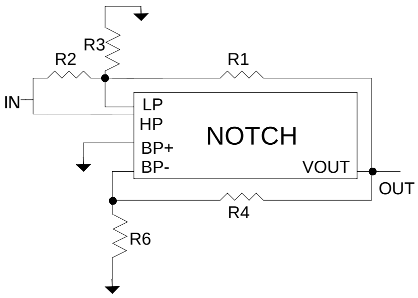


Gain = Unity; $R_1 = R_2$; $R_7 = R_4$; $R_8 = R_6$

$f_0 = \sqrt{K_1} \cdot \frac{fc}{\alpha}$ $\quad K_1 = \frac{R_3}{R_1 + 2R_3}$

$Q = \frac{\sqrt{K_1}}{K_2}$ $\quad K_2 = \frac{R_6}{R_4 + R_6}$

(1) where α is 6.25 or 12.5.



Gain = Unity; $R_1 = R_2$

$$f_0 = \sqrt{K_1} \cdot \frac{fc}{\alpha} \qquad K_1 = \frac{R_3}{R_1 + 2R_3}$$

$$Q = \frac{\sqrt{K_1}}{K_2} \qquad K_2 = \frac{R_6}{R_4 + R_6}$$

(1) where α is 6.25 or 12.5.

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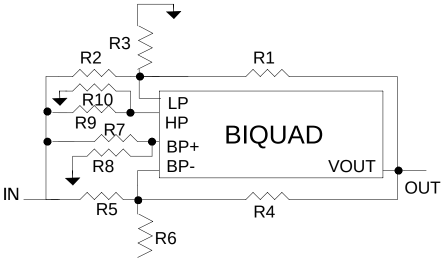

The biquad is the most general purpose filter type. By adjusting the values of K1 through K6, virtually any second order transfer function can be achieved. In some cases, it may be necessary to use an inverting op amp to achieve the correct polarity on these constants.

$$VOUT = VIN \frac{\left[-K_3S_2 - K_4S \frac{fc}{4} + K_5S \frac{fc}{4} - K_6 \frac{fc^2}{16} \right]}{S_2 \quad K_2S \frac{fc}{4} + K_1 \frac{Fc^2}{16}}$$

$$K_1 = \frac{R_2R_3}{R_1R_2 + R_1R_3 + R_2R_3} \qquad K_4 = \frac{R_4R_6}{R_4R_5 + R_4R_6 + R_5R_6}$$

$$K_2 = \frac{R_5R_6}{R_4R_5 + R_4R_6 + R_5R_6} \qquad K_5 = \frac{R_8}{R_7 + R_8}$$

$$K_3 = \frac{R_{10}}{R_9 + R_{10}} \qquad K_6 = \frac{R_1R_3}{R_1R_2 + R_1R_3 + R_2R_3}$$