High Frequency Resistor Programmable Universal Active Filter
Data Sheet

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

<table>
<thead>
<tr>
<th>Part Number</th>
<th>Package</th>
<th>Operating Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>MSU1HF1P</td>
<td>8 Pin Dip</td>
<td>0 - 70°C</td>
</tr>
<tr>
<td>MSU1HF1S</td>
<td>8 Pin SOIC</td>
<td>0 - 70°C</td>
</tr>
<tr>
<td>MSU1HF2P</td>
<td>8 Pin Dip</td>
<td>0 - 70°C</td>
</tr>
<tr>
<td>MSU1HF2S</td>
<td>8 Pin SOIC</td>
<td>0 - 70°C</td>
</tr>
<tr>
<td>MSU1HF3P</td>
<td>8 Pin Dip</td>
<td>0 - 70°C</td>
</tr>
<tr>
<td>MSU1HF3S</td>
<td>8 Pin SOIC</td>
<td>0 - 70°C</td>
</tr>
<tr>
<td>MSU1HF4P</td>
<td>8 Pin Dip</td>
<td>0 - 70°C</td>
</tr>
<tr>
<td>MSU1HF4S</td>
<td>8 Pin SOIC</td>
<td>0 - 70°C</td>
</tr>
<tr>
<td>MSU2HF1P</td>
<td>16 Pin Dip</td>
<td>0 - 70°C</td>
</tr>
<tr>
<td>MSU2HF1S</td>
<td>16 Pin SOIC</td>
<td>0 - 70°C</td>
</tr>
</tbody>
</table>

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**Electrical Characteristics**

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

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

<table>
<thead>
<tr>
<th>Pin</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PWR</td>
</tr>
<tr>
<td>2</td>
<td>VSS</td>
</tr>
<tr>
<td>3</td>
<td>OUT1</td>
</tr>
<tr>
<td>4</td>
<td>GND</td>
</tr>
<tr>
<td>5</td>
<td>LP1</td>
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<tr>
<td>6</td>
<td>BPN1</td>
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<tr>
<td>7</td>
<td>BPP1</td>
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<td>8</td>
<td>HP1</td>
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<tr>
<td>9</td>
<td>HP2</td>
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<td>10</td>
<td>BPP2</td>
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<td>BPN2</td>
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<td>12</td>
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<td>13</td>
<td>CLK</td>
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<td>14</td>
<td>OUT2</td>
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<tr>
<td>15</td>
<td>FO</td>
</tr>
<tr>
<td>16</td>
<td>VDD</td>
</tr>
</tbody>
</table>

**16 Pin Configuration**

<table>
<thead>
<tr>
<th>8 PIN</th>
<th>16 PIN</th>
</tr>
</thead>
<tbody>
<tr>
<td>OUT</td>
<td>VDD</td>
</tr>
<tr>
<td>LP</td>
<td>VSS</td>
</tr>
<tr>
<td>BP</td>
<td>GND</td>
</tr>
<tr>
<td>HP</td>
<td>CLK</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**16 Pin**

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

**Pin Configurations**

- **8 PIN**
  - OUT
  - LP
  - BP
  - HP
- **16 PIN**
  - VDDA
  - FO
  - OUT2
  - CLK
  - LP2
  - BPN2
  - BPP2

---

# High Frequency Resistor Programmable Universal Active Filter

**Data Sheet**

## Filter Types Available

<table>
<thead>
<tr>
<th>Filter Type</th>
<th>MSU2HF1</th>
<th>MSU1HF1/4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lowpass</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Bandpass</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Highpass</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Lowpass elliptical</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Highpass elliptical</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Notch</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Oscillator</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Allpass</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>Biquad</td>
<td>yes</td>
<td>no</td>
</tr>
</tbody>
</table>

## Transfer Functions

### Lowpass

\[ H(s) = \frac{-\omega_0^2}{s^2 + \left(\frac{\omega_0}{Q}\right)s + \omega_0^2} \]

### Bandpass

\[ H(s) = \frac{-\left(\frac{\omega_0}{Q}\right)s}{s^2 + \left(\frac{\omega_0}{Q}\right)s + \omega_0^2} \]

### Highpass

\[ H(s) = \frac{s^2}{s^2 + \left(\frac{\omega_0}{Q}\right)s + \omega_0^2} \]

### Lowpass Elliptic

\[ H(s) = \frac{\left(\frac{\omega_0}{\omega_z}\right)^2 s^2 + \omega_0^2}{s^2 + \left(\frac{\omega_0}{Q}\right)s + \omega_0^2} \]

### Highpass Elliptic

\[ H(s) = \frac{s^2 + \left(\frac{\omega_0}{\omega_z}\right)^2 \omega_0^2}{s^2 + \left(\frac{\omega_0}{Q}\right)s + \omega_0^2} \]

### Notch

\[ H(s) = \frac{s^2 + \omega_0^2}{s^2 + \left(\frac{\omega_0}{Q}\right)s + \omega_0^2} \]

### Allpass

\[ H(s) = \frac{s^2 - \left(\frac{\omega_0}{Q}\right)s + \omega_0^2}{s^2 + \left(\frac{\omega_0}{Q}\right)s + \omega_0^2} \]
NOTE: \( f_c > 36 \) \( f_o \)

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 \( f_c/f_o \) 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

\[
\begin{align*}
K_1 &= \frac{R_3}{R_1 + 2R_3} \\
K_2 &= \frac{R_6}{R_4 + R_6} \\
Q &= \frac{4K_1 K_2}{K_2 R_4 + R_6} \\
f_0 &= 4K_1 \cdot f_c \left( \frac{K_1}{\alpha} \right) \\
\end{align*}
\]

(1) If a gain other than unity is desired then

\[
\text{gain} = \frac{R_1}{R_2} \quad \text{and} \quad K_1 \text{ from the biquad equations should be substituted for } K_1
\]

(2) where \( \alpha \) is 6.25 or 12.5.

Gain (1) = 1

\[
\begin{align*}
K_1 &= \frac{R_3}{R_1 + R_3} \\
K_2 &= \frac{R_6}{R_4 + R_6} \\
Q &= \frac{3K_1}{K_2} \cdot \frac{K_1}{\alpha(2)} \\
f_0 &= 3K_1 \cdot f_c \left( \frac{K_1}{\alpha(2)} \right) \\
\end{align*}
\]

(1) Gain may be adjusted independent of \( Q \) using the resistor divider described by \( K_5 \) from the biquad equations. Use the \( K_6 \) equation in place of \( K_2 \) for the gain equation only.

(2) where \( \alpha \) is 6.25 or 12.5.

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

\[
\begin{align*}
K_1 &= \frac{R_3}{R_1 + R_3} \\
K_2 &= \frac{R_6}{R_4 + 2R_6} \\
Q &= \frac{4K_1 K_2}{K_2 R_4 + 2R_6} \\
f_0 &= 4K_1 \cdot f_c \left( \frac{K_1}{\alpha(2)} \right) \\
\end{align*}
\]

(1) For gains not equal to unity, gain = \( R_2/R_5 \) and \( K_2 \) should be replaced with \( K_2 \) from the biquad equations.

(2) where \( \alpha \) is 6.25 or 12.5.
DC Gain (1) = Unity; \( R_1 = R_2 \)

\[
\begin{align*}
\begin{align*}
\frac{f_0}{f_c} &= 3K_1 \
K_1 &= \frac{R_3}{\alpha R_1 + 2R_3}
\end{align*}
\end{align*}
\]

\[
\begin{align*}
K_2 &= \frac{R_6}{R_4 + R_6} \\
Q &= 3K_1 \frac{K_2}{R_1 R_2 + R_1 R_3 + R_2 R_3}
\end{align*}
\]

\[
\begin{align*}
f_z &= \sqrt{\frac{R_3}{R_1 + R_3}} \frac{f_0}{f_c} \\
K_3 &= \frac{R_{10}}{R_9 + R_{10}}
\end{align*}
\]

(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 \( \frac{3}{\alpha} \) term should also be multiplied by the gain.

(2) where \( \alpha \) is 6.25 or 12.5.

Gain = Unity

\[
\begin{align*}
\begin{align*}
\frac{f_0}{f_c} &= 3K_1 \
K_1 &= \frac{R_3}{\alpha R_1 + 2R_3}
\end{align*}
\end{align*}
\]

\[
\begin{align*}
K_2 &= \frac{R_6}{R_4 + R_6} \\
Q &= 3K_1 \frac{K_2}{R_1 R_2 + R_1 R_3 + R_2 R_3}
\end{align*}
\]

\[
\begin{align*}
f_z &= \sqrt{\frac{R_3}{R_1 + R_3}} \frac{f_0}{f_c} \\
K_3 &= \frac{R_{10}}{R_9 + R_{10}}
\end{align*}
\]

(1) where \( \alpha \) is 6.25 or 12.5.

Gain = Unity; \( R_1 = R_2; R_3 = R_4; R_6 = R_9 \)

\[
\begin{align*}
\begin{align*}
\frac{f_0}{f_c} &= 3K_1 \
K_1 &= \frac{R_3}{\alpha R_1 + 2R_3}
\end{align*}
\end{align*}
\]

\[
\begin{align*}
K_2 &= \frac{R_6}{R_4 + R_6} \\
Q &= 3K_1 \frac{K_2}{R_1 R_2 + R_1 R_3 + R_2 R_3}
\end{align*}
\]

\[
\begin{align*}
f_z &= \sqrt{\frac{R_3}{R_1 + R_3}} \frac{f_0}{f_c} \\
K_3 &= \frac{R_{10}}{R_9 + R_{10}}
\end{align*}
\]

(1) where \( \alpha \) is 6.25 or 12.5.
The biquad is the most general purpose filter type. By adjusting the values of $K_1$ through $K_6$, 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.

\[
V_{OUT} = V_{IN} \left[-K_3S_2 - K_4S f_c + K_5S_2 f_c - K_6 f_c^2 \right]
\]

\[
S_2 = \frac{K_2 S f_c + K_1 f_c^2}{4} \quad \frac{16}{4}
\]

\[
K_1 = \frac{R_3}{R_2R_3 + R_1R_3 + R_2R_3}
\]

\[
K_2 = \frac{R_4}{R_4R_5 + R_4R_6 + R_5R_6}
\]

\[
K_3 = \frac{R_9}{R_9 + R_10}
\]

\[
K_4 = \frac{R_3R_6}{R_3R_6 + R_4R_6 + R_5R_6}
\]

\[
K_5 = \frac{R_9}{R_7 + R_8}
\]

\[
K_6 = \frac{R_3R_3}{R_1R_2 + R_1R_3 + R_2R_3}
\]

(1) where $\alpha$ is 6.25 or 12.5.