**Micro Linear**

November 1995
PRELIMINARY

# ML6420

## Triple Phase-Equalized, Low-Pass Video Filter

## GENERAL DESCRIPTION

The ML6420 monolithic BiCMOS 6th-order filter provides fixed frequency low pass filtering for video applications. This triple phase-equalized filter is designed for input anti-aliasing filtering.

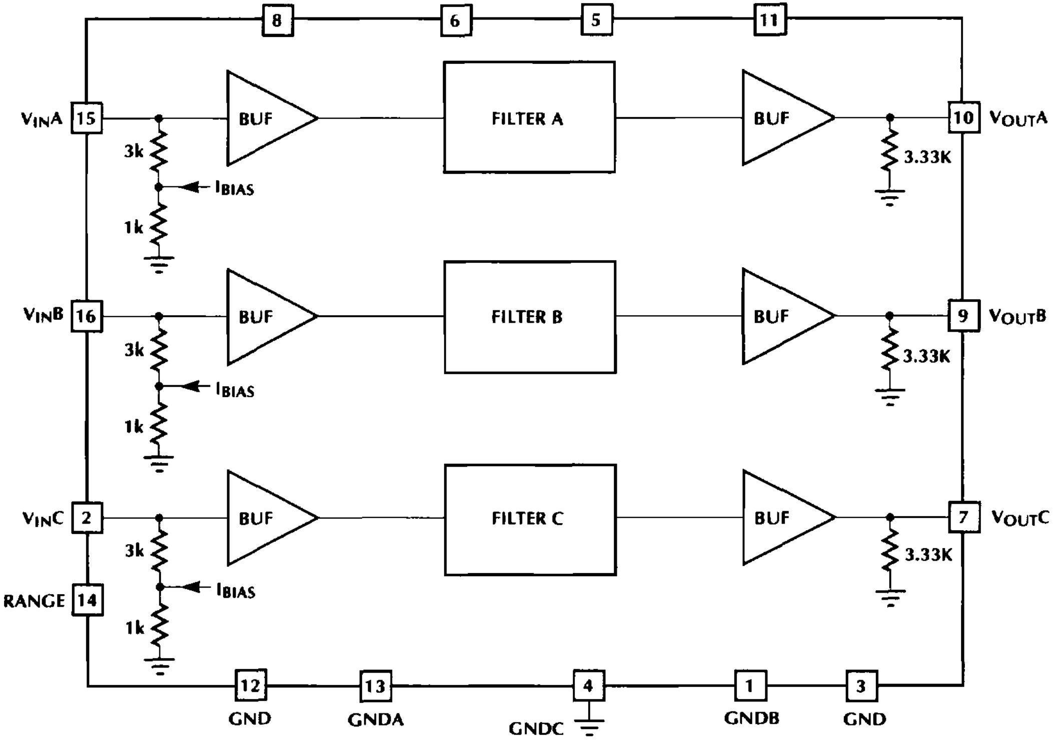
Cut-off frequencies are either 5.50, 9.34, 3.34 or 1.67MHz. Each channel incorporates a 6th-order lowpass filter, a first order all-pass filter, and a 75Ω coax cable driver. A control pin (Range) is provided to allow the inputs to swing from 0 to 1V, or 0 to 2V, by providing a 0.5V offset to the input.

The filters are powered from a single 5V supply, and can drive $1V_{P-P}$ over 75Ω (0.5V to 1.5V), or $2V_{P-P}$ over 150Ω (0.5V to 2.5V). The output swing of 0.5V to 2.5V allows direct interface to ML6400's A/D converters for video digitization.

## FEATURES

- 5.5, 9.34, 3.34, or 1.67MHz bandwidth
- 6th-order filter with equalizer
- >45dB stopband rejection
- No external components or clocks
- ±10% frequency accuracy over supply and temperature (max.)
- <2% Differential Gain
- <2° Differential Phase
- <20ns group delay variation
- Drives $1V_{P-P}$ into 75Ω, or $2V_{P-P}$ into 150Ω
- 5V ±10% operation
- 16-pin SOIC package

## BLOCK DIAGRAM

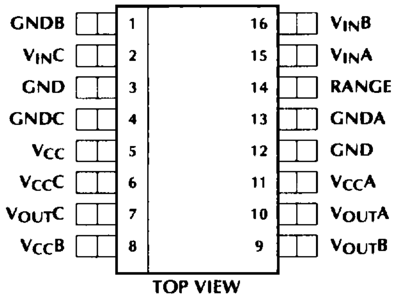


| | ML6420-1 | ML6420-2 | ML6420-3 | ML6420-4 |
|---|---|---|---|---|
| **Filter A** | 5.50 MHz | 5.50 MHz | 9.34 MHz | 9.34 MHz |
| **Filter B** | 5.50 MHz | 1.67 MHz | 9.34 MHz | 3.34 MHz |
| **Filter C** | 5.50 MHz | 1.67 MHz | 9.34 MHz | 3.34 MHz |

Triple Input/Anti-aliasing Video Filter

## PIN CONFIGURATION

**ML6420**
**16-Pin SOIC (S16W)**



## PIN DESCRIPTION

| PIN# | NAME | FUNCTION |
|---|---|---|
| 1 | GNDB | Ground pin for filter B. |
| 2 | $V_{IN}C$ | Signal input to filter C. ($V_{IN}$ = 0.5V to 2.5V when Range is low, $V_{IN}$ = 0V to 2V when Range is high). Input impedance is 4KΩ. |
| 3 | GND | Power and logic ground. |
| 4 | GNDC | Ground pin for filter C. |
| 5 | $V_{CC}$ | Positive supply for bias circuit: 4.5V to 5.5VDC. |
| 6 | $V_{CC}C$ | Power supply voltage for filter C: 4.5V to 5.5V. |
| 7 | $V_{OUT}C$ | Output of filter C. Drive is $1V_{P-P}$ into 75Ω (0.5V to 1.5V) or $2V_{P-P}$ into 150Ω (0.5V to 2.5V). |
| 8 | $V_{CC}B$ | Power supply voltage for filter B: 4.5V to 5.5V. |
| 9 | $V_{OUT}B$ | Output of filter B. Drive is $1V_{P-P}$ into 75Ω (0.5V to 1.5V) or $2V_{P-P}$ into 150Ω (0.5V to 2.5V). |
| 10 | $V_{OUT}A$ | Output of filter A. Drive is $1V_{P-P}$ into 75Ω (0.5V to 1.5V) or $2V_{P-P}$ into 150Ω (0.5V to 2.5V). |
| 11 | $V_{CC}A$ | Power supply voltage for filter A: 4.5V to 5.5V. |
| 12 | GND | Power and logic ground. |
| 13 | GNDA | Ground pin for filter A. |
| 14 | RANGE | Input signal range select. When Range is low (0), the input signal range is 0.5V to 2.5V, with an output range of 0.5V to 2.5V. When Range is high (1) the input signal range is 0V to 2V, while the output range is 0.5V to 2.5V. |
| 15 | $V_{IN}A$ | Signal input to filter A. ($V_{IN}$ = 0.5V to 2.5V when Range is Low, $V_{IN}$ = 0V to 2V when Range is High). Input impedance is 4kΩ. |
| 16 | $V_{IN}B$ | Signal input to filter B. ($V_{in}$ = 0.5V to 2.5V when Range is Low, $V_{in}$ = 0V to 2V when Range is High). Input impedance is 4kΩ. |

## ABSOLUTE MAXIMUM RATINGS

Absolute maximum ratings are those values beyond which the device could be permanently damaged. Absolute maximum ratings are stress ratings only and functional device operation is not implied.

Supply Voltage ($V_{CC}$) .................................... –0.3 to +7V
GND .................................................. –0.3 to $V_{CC}$ +0.3V
Logic Inputs ........................................ –0.3 to $V_{CC}$ +0.3V
Input Current per Pin ............................................ ±25mA
Storage Temperature .................................. –65° to 150°C
Package Dissipation at $T_A$ = 25°C ............................. 1W
Lead Temperature (Soldering 10 sec) ...................... 150°C
Thermal Resistance ($\theta_{JA}$) ...................................... 90°C/W

## OPERATING CONDITIONS

Supply Voltage ................................................. 5V ± 10%
Temperature Range ................................. 0°C < to < 70°C

## ELECTRICAL CHARACTERISTICS

Unless otherwise specified $V_{CC}$ = 5V ± 10% and $T_A = T_{MIN}$ to $T_{MAX}$, $R_L$ =75Ω or 150Ω, $V_{OUT} = 2V_{P-P}$ for 150Ω Load and $V_{OUT} = 1V_{P-P}$ for 75Ω Load (Note 1)

| PARAMETER | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|
| **General** | | | | | |
| Input Impedance ($R_{IN}$) | | 3 | 4 | 5 | kΩ |
| Input R Matching ($\Delta R/R_{IN}$) | | | | ±2 | % |
| Input Current ($I_{BIAS}$) | $V_{IN}$ = 0.5V, range = low | | –80 | | µA |
| | $V_{IN}$ = 0.0V, range = high | | –125 | | µA |
| Small Signal Gain | $V_{IN} = 4mV_{P-P}$ at 100kHz | –0.5 | 0 | +0.5 | dB |
| Differential Gain | $V_{IN}$ = 1.8V ± 0.7V at 3.58 & 4.43 MHz | | 1 | 2 | % |
| Differential Phase | $V_{IN}$ = 1.8V ± 0.7V at 3.58 & 4.43 MHz | | 1 | 2 | deg |
| Input Range ($V_{IN}$) | Range = 0 | 0.5 | | 2.5 | V |
| | Range = 1 | 0.0 | | 2.0 | V |
| Peak Overshoot | 2T, $0.7V_{P-P}$ pulse | | 2.0 | | % |
| Crosstalk | $f_{IN}$ = 3.58, $f_{IN}$ = 4.43MHz | 50 | | | dB |
| Channel to Channel Group Delay Matching ($f_C$ = 5.5MHz) | $f_{IN}$ = 100KHz | | | ±20 | ns |
| Channel to Channel Gain Matching | $f_{IN}$ = 100KHz | | | ±3 | % |
| Output Current | $R_L$ = 0 (short circuit) | | 75 | | mA |
| Load Capacitance ($C_L$) | | | | 35 | pF |
| Composite Chroma/Luma delay | $f_C$ = 5.5MHz | | | ±20 | ns |
| | $f_C$ = 9.34MHz | | 10 | TBD | ns |
| **5.50MHz Filter** | | | | | |
| Bandwidth (monotonic passband) | –3dB | 4.95 | 5.50 | 6.05 | MHz |
| Stopband Attenuation | $f_{IN}$ = 10MHz | 18 | 20 | | dB |
| | $f_{IN}$ = 50MHz | 30 | 35 | | dB |
| Output Noise | BW = 30MHz | | | 700 | $\mu V_{RMS}$ |

## ELECTRICAL CHARACTERISTICS (Continued)

| PARAMETER | CONDITIONS | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|
| **9.34MHz Filter** | | | | | |
| Bandwidth (monotonic passband) | –3dB | 8.41 | 9.34 | 10.27 | MHz |
| Stopband Attenuation | $f_{IN}$ = 17MHz | 18 | 20 | | dB |
| | $f_{IN}$ = 85MHz | 30 | 35 | | |
| Output Noise | BW = 30MHz | | | 700 | $\mu V_{RMS}$ |
| **3.34MHz Filter** | | | | | |
| Bandwidth (monotonic passband) | –3dB | 3.00 | 3.34 | 3.67 | MHz |
| Stopband Attenuation | $f_{IN}$ = 9.82MHz | 30 | 33 | | dB |
| | $f_{IN}$ = 60MHz | 45 | 50 | | dB |
| Output Noise | BW = 30MHz | | | 490 | $\mu V_{RMS}$ |
| **1.67MHz Filter** | | | | | |
| Bandwidth (monotonic passband) | –3dB | 1.50 | 1.67 | 1.84 | MHz |
| Stopband Attenuation | $f_{IN}$ = 4.91MHz | 30 | 33 | | dB |
| | $f_{IN}$ = 30MHz | 45 | 50 | | dB |
| Output Noise | BW = 30MHz | | | 490 | $\mu V_{RMS}$ |
| **Digital and DC** | | | | | |
| Logic Input Low ($V_{IL}$) | Range | | | 0.8 | V |
| Logic Input High ($V_{IH}$) | Range | $V_{CC}$ – 0.8 | | | V |
| Logic Input Low ($I_{IL}$) | $V_{IN}$ = GND | –1 | | | µA |
| Logic Input High ($I_{IL}$) | $V_{IN}$ = $V_{CC}$ | | | 1 | µA |
| Supply Current ($I_{CC}$) $R_L$ = 75Ω | $V_{IN}$ = 0.5V | | 110 | 135 | mA |
| | $V_{IN}$ = 1.5V | | 140 | 175 | mA |

Note 1: Limits are guaranteed by 100% testing, sampling or correlation with worst case test conditions.
Note 2: Maximum resistance on the outputs is 500Ω in order to improve step response.
Note 3: Connect all ground pins to the ground plane via the shortest path.

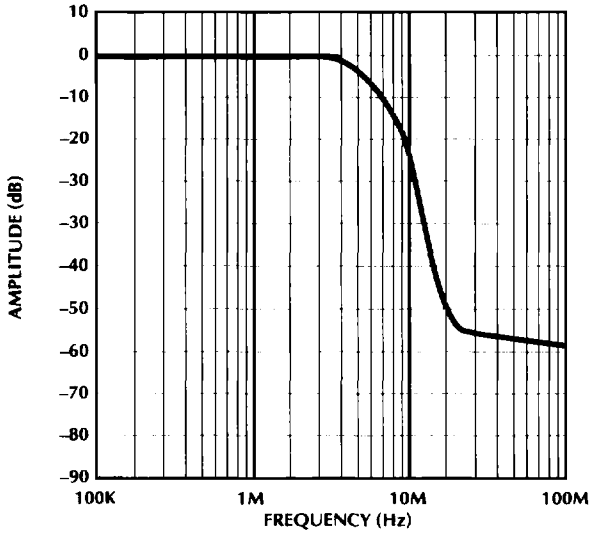


**Figure 1. Stop-Band Amplitude vs Frequency ($f_C$ = 5.5MHz).**

**Note:** Figures 1, 2 and 3, data was measured using the test circuit in Figure 6.

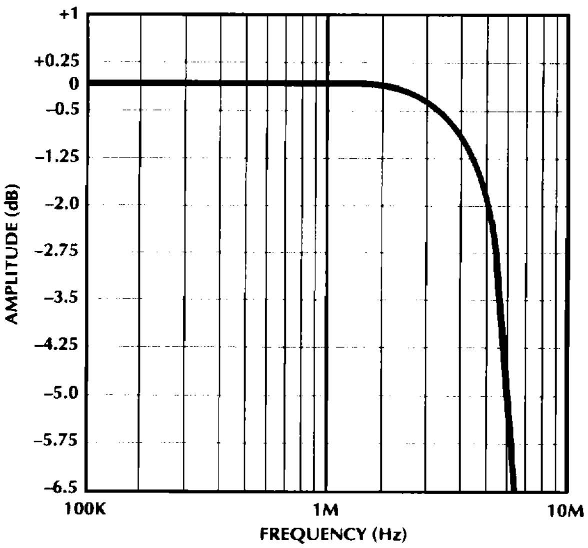


Figure 2. Pass-Band Amplitude vs Frequency ($f_C$ = 5.5MHz).

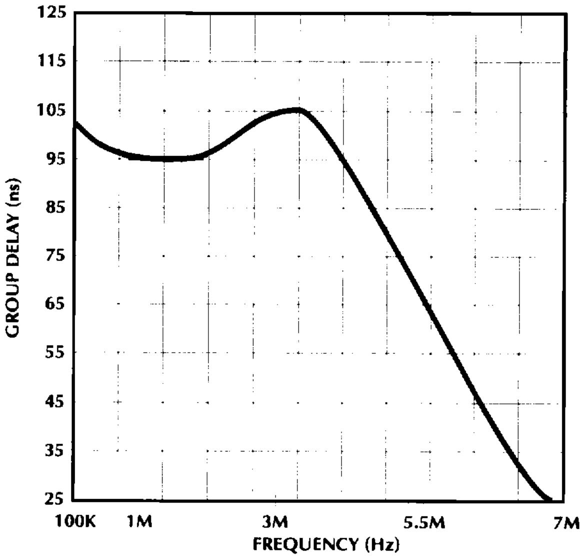


Figure 3. Group Delay vs Frequency ($f_C$ = 5.5MHz).

**Note:** Figures 1, 2 and 3, data was measured using the test circuit in Figure 6.

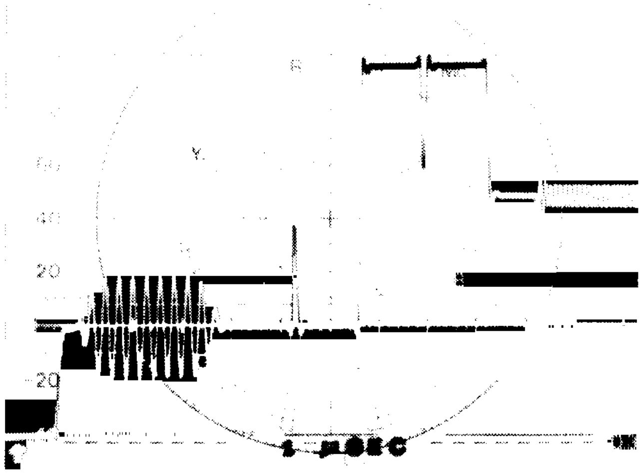


Figure 4. Burst with 100ns pulse and fast transition at ML6420 output showing symetrical pulse response.

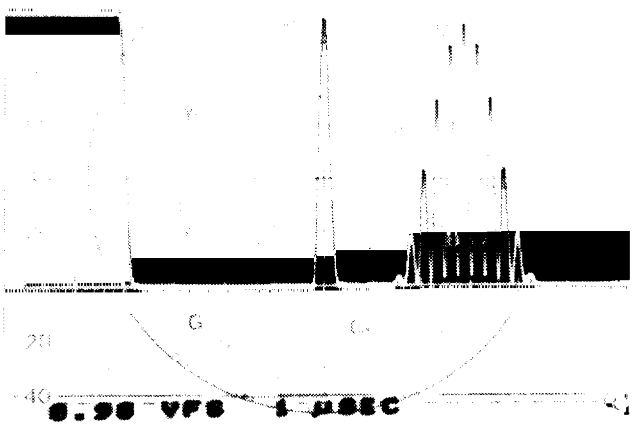


Figure 5. Step with 2T and 12T response at ML6420 output showing accurate pulse response without overshoot or ringing.

**Note:** Figures 4 and 5, data was measured using the test circuit in Figure 7.

## FUNCTIONAL DESCRIPTION

The ML6420 single-chip Triple Video Filter IC is intended for low cost consumer and professional video applications. Each of the three channels incorporates an input buffer amplifier, a sixth order lowpass filter, a first order allpass equalizer, and an output amplifier capable of driving 75Ω to ground.

The ML6420 is a low cost solution, trading off power dissipation and cost with video performance. When Range is low the input and output signal range is 0.5V to 2.5V. When the input signal includes 0V, Range should be tied high. In this case, an offset is added to the input so that the output swing is kept between 0.5V to 2.5V. The output amplifier is capable of driving up to 24mA of peak current; therefore the output voltage should not exceed 1.8V when driving 75Ω to ground.

## APPLICATION GUIDELINES

### OUTPUT CONSIDERATIONS

The triple filters have unity gain. The circuit has unity gain (0dB) when connected to a 150Ω load, and a –6dB gain when driving a 75Ω load via a 75Ω series output resistor. The output may be either AC or DC coupled. For AC coupling (Figure 6), the –3dB point should be 5Hz or less. There must also be a DC path of ≤500Ω to ground for biasing.

### INPUT CONSIDERATIONS

The input resistance is 4kΩ. The input may be either DC or AC coupled. (Note that each input sources 80 to 125μA of bias current).

### LAYOUT CONSIDERATIONS

In order to obtain full performance from these triple filters, layout is very important. Good high frequency decoupling is required between each power supply and ground. Otherwise, oscillations and/or excessive crosstalk may occur. A ground plane is recommended.

Each filter has its own supply and ground pins. In the test circuit, 0.1μF capacitors are connected in parallel with 0.001μF capacitors on pins 5, 6, 8 and 11 for maximum noise rejection (Figure 6).

Further noise reduction is achieved by using series ferrite beads. In typical applications, this degree of bypassing may not be necessary.

Since there are three filters in one 16-pin SOIC package, space the signal leads away from each other as much as possible.

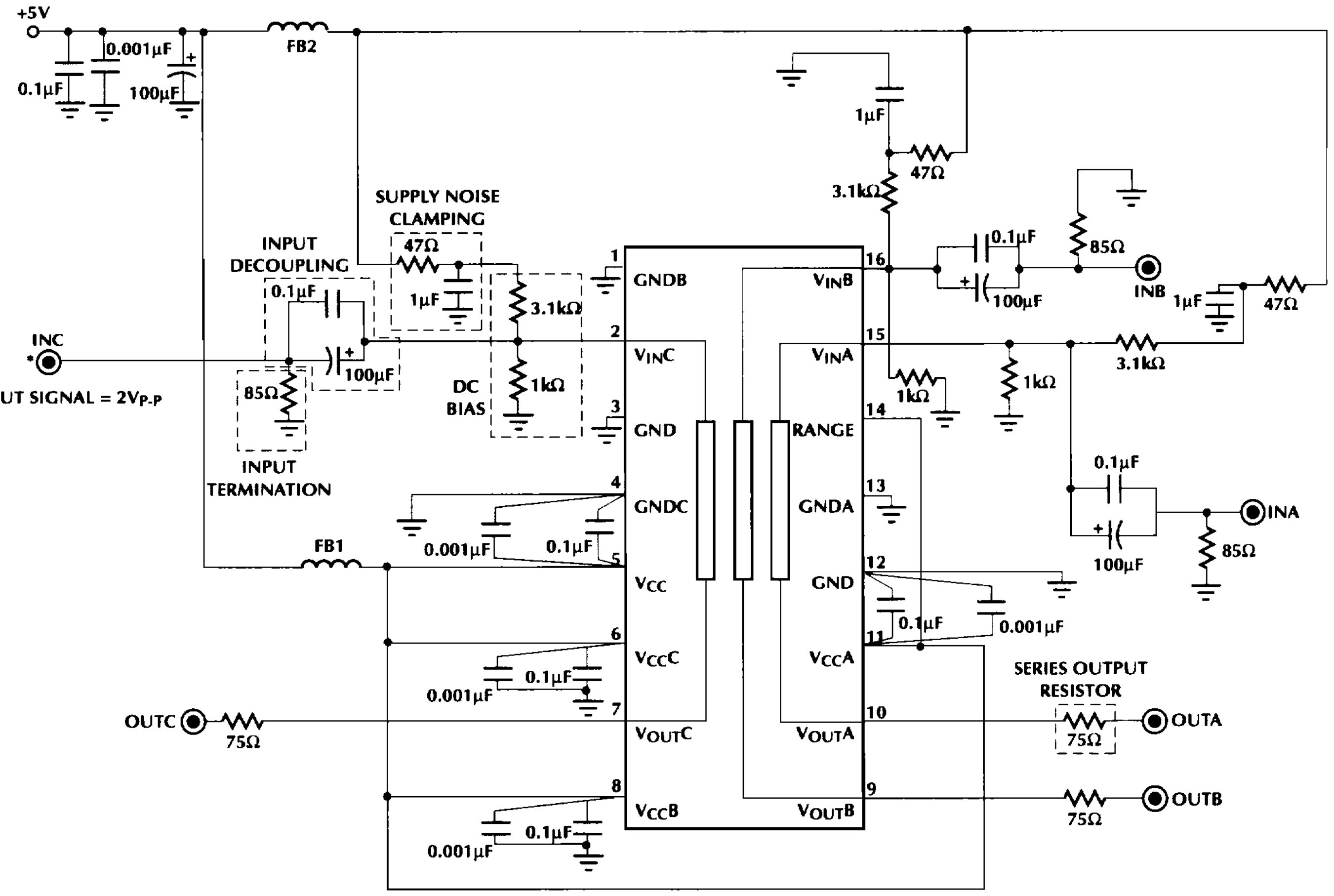


Figure 6. ML6420 AC Coupled DC Bias Test Circuit

## ML6420 VIDEO LOW PASS FILTER

**Filter Selection:** The ML6420 provides several choices in filter cut-off frequencies depending on the application.

**RGB:** When the BW of each signal is the same, then the ML6420-1 (5.5MHz) or ML6420-3 (9.34MHz) are appropriate depending on the sampling rate.

**YUV:** When the Luminance bandwidth is different from the color bandwidth, then the ML6420-2 5.50MHz filter with two 1.67MHz filters on the ML6420-4 with the 9.34, 3.34 and 3.3MHz filters are most appropriate. The 1.67MHz filter provides a narrower BW for optimal data compression, and has a time delay of 3.5 clock clycles at 13.5MHz for simple delay precompensation

**S-Video:** For Y/C (S-video) and Y/C + CV (Composite Video) systems the 5.5MHz or 9.34MHz filters are appropriate. In NTSC the C signal occupies the bandwidth from about 2.6MHz to about 4.6MHz, while in PAL the C signal occupies the bandwidth from about 3.4MHz to about 5.4MHz. In both cases, a 5.5MHz low pass filter provides adequate rejection for both sampling and reconstruction. In addition, using the same filter for both Y/C and CV maintains identical signal timing without adjustments.

**Composite:** When one or more composite signals need to be filtered, then the 5.50MHz and 9.34MHz filters permit filtering of one, two or three composite signals.

**4X Over sampling:** While the ML6420 filters can eliminate the need for over sampling combined with digital filtering, there are times when over sampling is used. For these situations, 9.34MHz is used in place of 5.5MHz, and 3.34MHz is used in place of 1.67MHz.

**NTSC/PAL:** A 5.50MHz cut-off frequency provides good filtering for 4.2MHz, 5.0MHz and 5.5MHz signals without the need to change filters on a production basis.

**Sinx/x:** For digital video system with output D/A converters, there is a fall-off in response with frequency due to discrete sampling. The fall-off follows a sinx/x response. The ML6421 filters have a complementary boost to provide a flatter overall response. The boost is designed for 13.5MHz Y/C and CV sampling and 6.75MHz U/V sampling. The ML6421 has the same pin-out as the ML6420.

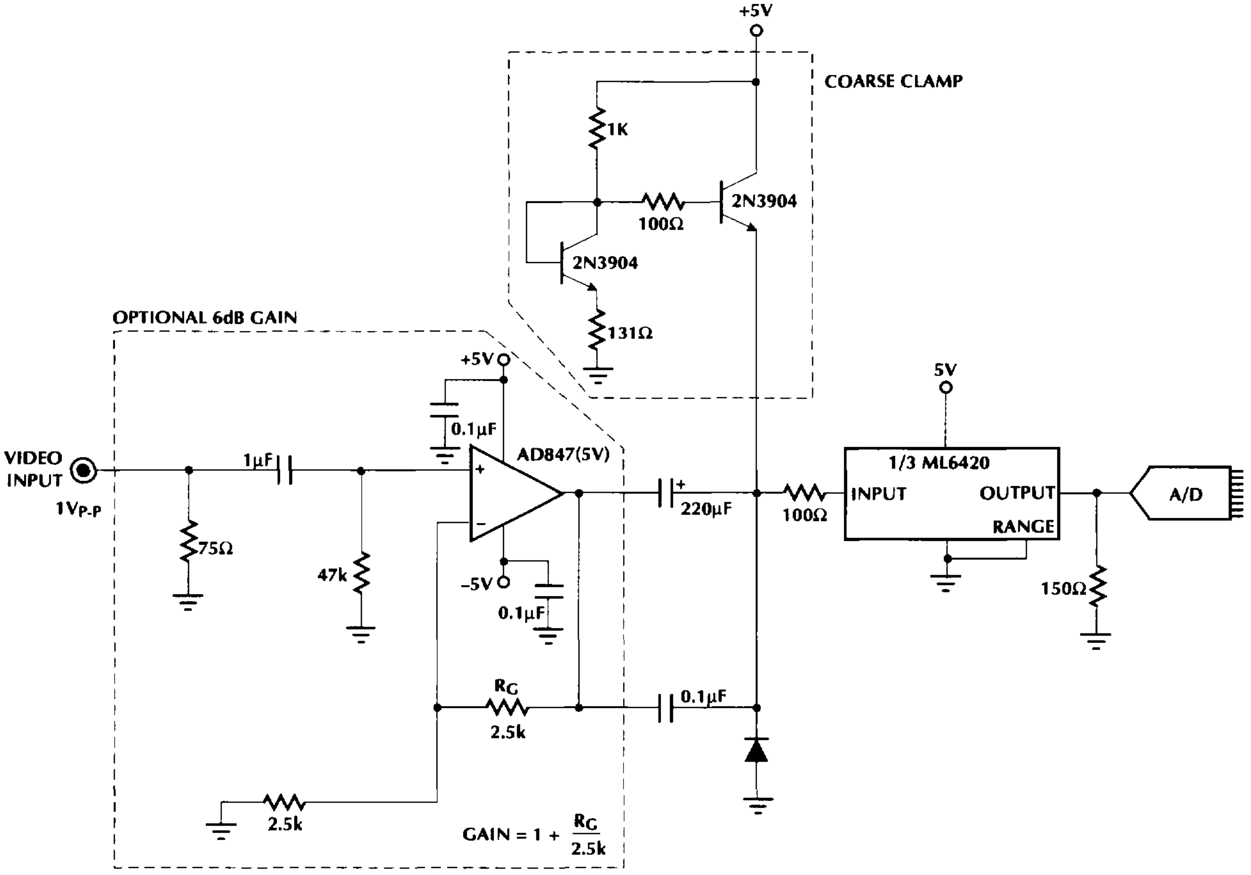


Figure 7. ML6420 Video Clamp Prior to A/D Conversion

## TYPICAL CLAMPING SCHEMES

Figures 8 and 9 show two typical applications of the ML6420 for anti-aliasing prior to A-to-D conversion. In Figure 8, a single precision digital feedback clamp circuit includes both the ADC and the ML6420. This establishes the proper DC operating point for the ML6420 (with Range input = 0, $0.5V \le V_{IN} \le 2.5V$; with Range input = 5V, $0.0 \le V_{IN} \le 2.0V$.) and the ADC. Figure 8 is typically used with ADC's that require external clamp circuitry. Figure 9 shows AC coupled application for ADC's with built-in clamps. In this case, the clamp is internal to the ADC and the ML6420 uses a simple coarse clamp at its input to establish proper operating point.

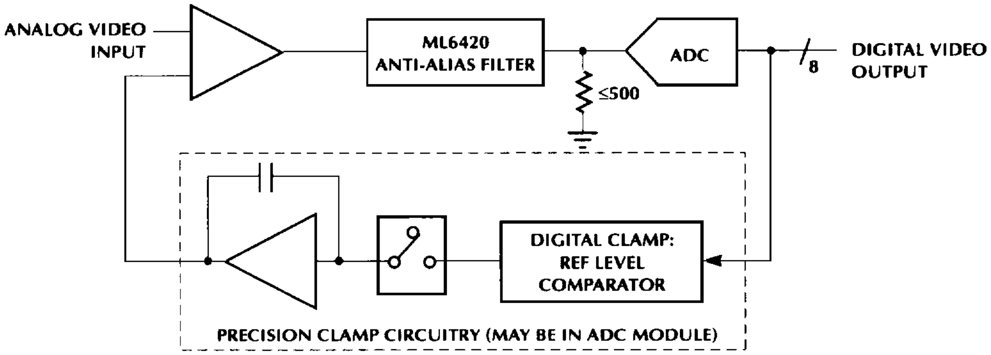


Figure 8. ML6420 in DC Coupled Video Digitizer for $2V_{P-P}$ Video Signals

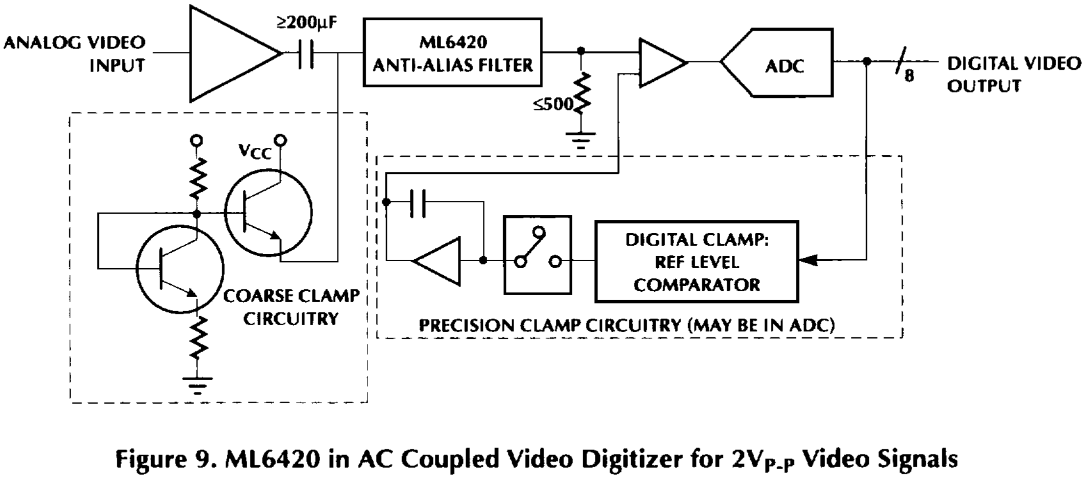


Figure 9. ML6420 in AC Coupled Video Digitizer for $2V_{P-P}$ Video Signals

## USING VIDEO FILTERS

The ML6420 is a monolithic, triple lowpass filter intended for input anti-aliasing prior to analog to digital conversion in video systems.

### ALIASING: THE PROBLEM

Aliasing is a signal distorting process that occurs when an analog signal is sampled. If the analog signal contains frequencies greater than half of the sampling rate, those frequencies will be altered and "folded back" in the frequency domain. These frequencies represent a distortion of the original signal as represented in the sampled domain, and cannot be corrected after sampling.

### THE RESULT OF ALIASING IN A TV PICTURE

Aliasing causes several disturbing distortions to a picture. Since the folded spectrum adds to the original spectrum, it will sometimes be in phase, and sometimes out of phase causing ripples in response that depend on the position of the picture element relative to the clock. The net effect is that picture elements, edges, highlights, and details will "wink" in amplitude as they move across a picture if they have high frequency content above Nyquist frequency of the sampler.

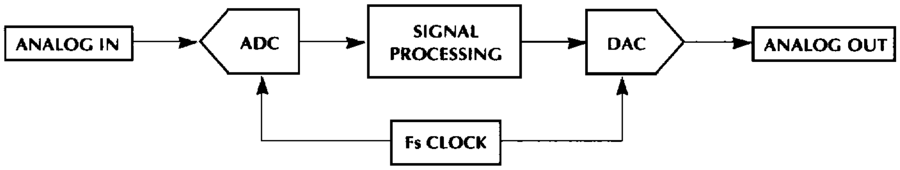


Figure 10. Simplified Digital Video Processing System

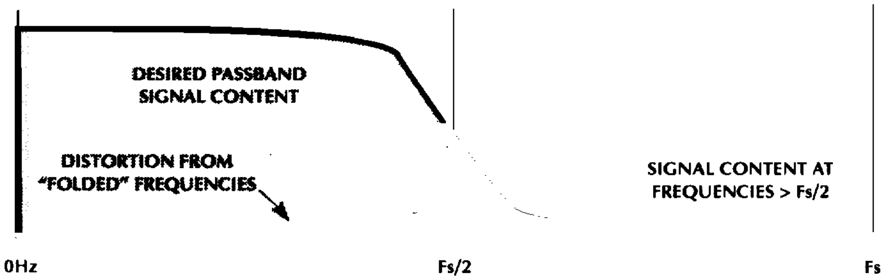


Figure 11. Aliasing in the Frequency Domain

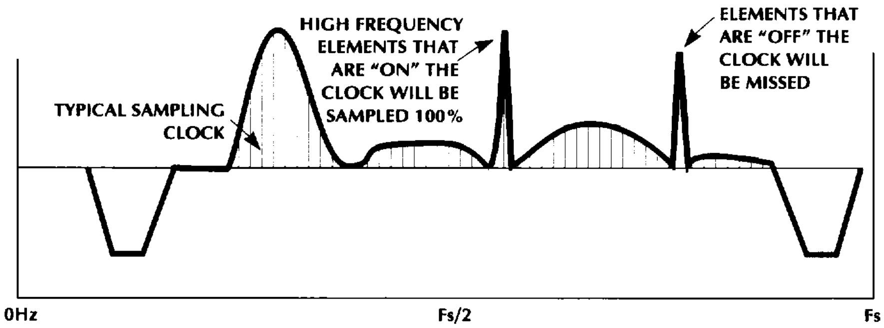


Figure 12. Aliasing in the Time Domain

### ANTI-ALIASING

Anti-aliasing reduces the bandwidth of the signal to a value appropriate for the sample processing system. Some detail information is lost, but only the information that cannot be unambiguously displayed is removed. Assuming that the passband contains the "real" picture information, the only distortion that occurs is due to amplitude and phase variations of the anti-aliasing filter in the passband. The following section shows approaches using digital and analog filters in an oversampled system, and a monolithic analog filter as a lower cost alternative.

### OVERSAMPLING

Aliasing cannot be removed once it occurs, it must be prevented at the signal sampler. Many current systems are choosing to prevent aliasing by increasing the clock rate of the sampler. This is known as "oversampling". Doubling the clock rate greatly reduces the burden on the analog anti-alias filter, but the increased data rate greatly increases the size, complexity and cost of the Digital Signal Processing (DSP) circuitry. Since the higher clock rate generates more samples than are necessary to represent the desired passband content, a digital filter may be used to decimate the signal back to a lower sample rate, saving size, complexity and power in the downstream circuitry. But since this digital filter itself is a complex digital block, this method cannot be considered the lowest cost approach to solving the anti-alias problem.

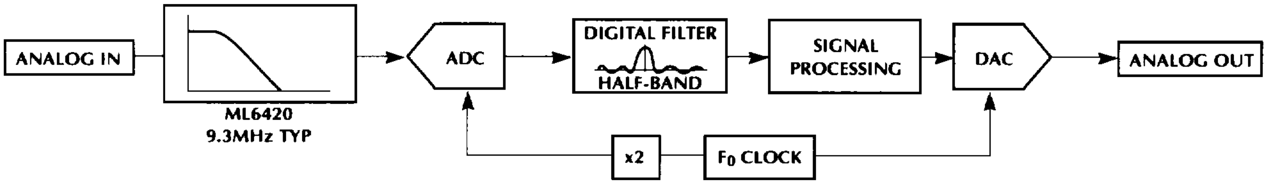


Figure 13. Oversampled Video Processing System with Analog LPF & Half-Band Digital Filter

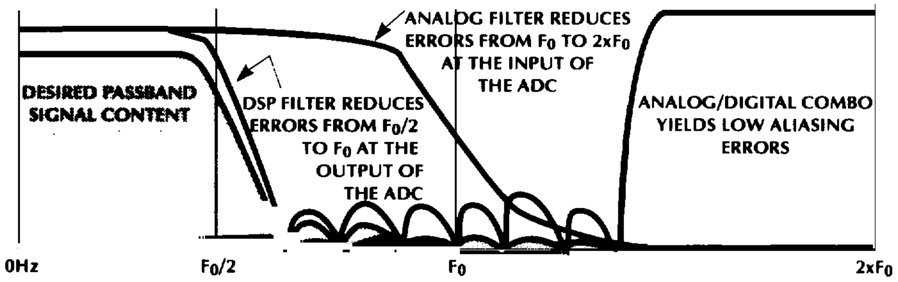


Figure 14. Digital Filtering in the Frequency Domain

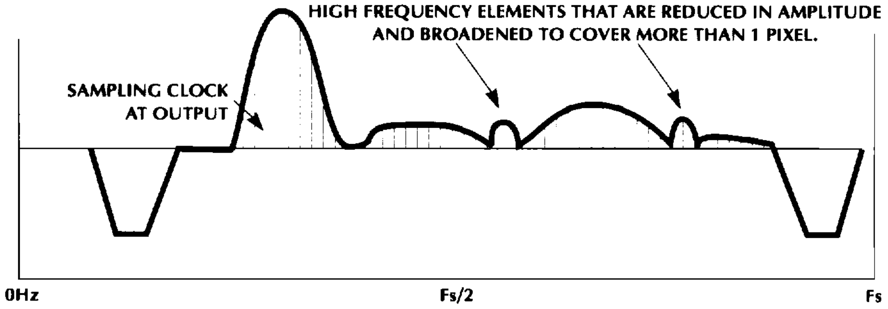


Figure 15. Digital Filtering in the Time Domain

## NYQUIST SAMPLING

In traditional systems, before the advent of higher speed ADCs, anti-aliasing filters were designed in the analog domain. The movement toward higher sampling rates was an attempt to circumvent the difficult challenge of designing a sharp roll-off, linear phase, non-distorting analog filter. The ML6420 series of filters solve this problem where it is best solved, in the analog domain. Since they are monolithic, their application is simple. Since they have flat amplitude and linear phase, they are low distortion. And since the aliasing is removed at the analog input to the ADC, the clock rates are minimized, the DSP half band filter (a very expensive chip at current market prices) is eliminated, and significant power is conserved.

### Oversampling vs Nyquist sampling

Clearly the purely analog monolithic solution versus the analog/digital solution using DSP filtering are different ways of solving the same problem. Other than costs (purely analog is many times less expensive) there are no real differences in performance for applications that require flatness specs of ±0.5db to 4.5MHz for consumer and pro-sumer video applications. The ML6420 is also phase corrected for flat group delay, a feature not found in typical low cost analog filters, and a characteristic often associated with digital filters alone. The following section highlights the importance of linear phase response in video applications.

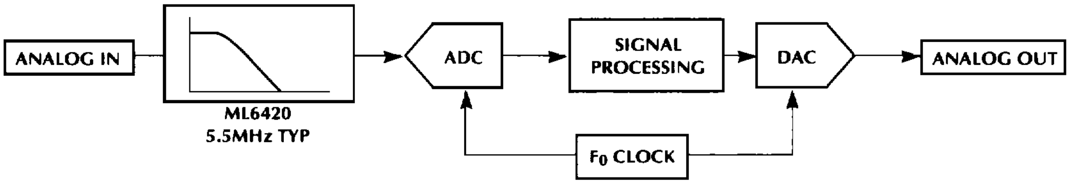


Figure 16. Video Processing System with Monolithic Analog Anti-Alias Filter

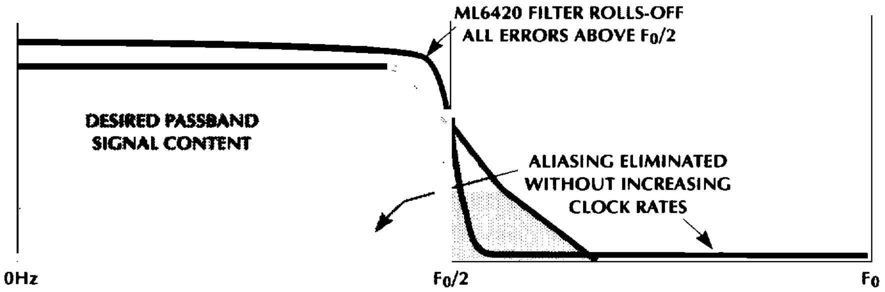


Figure 17. Analog Filtering in the Frequency Domain

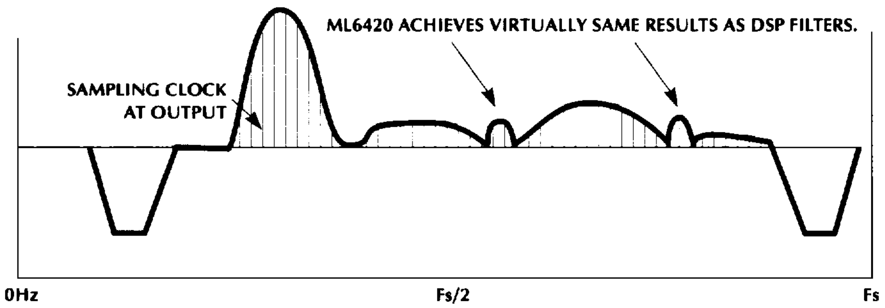


Figure 18. Analog Filtering in the Time Domain

## TIME DOMAIN RESPONSE: TRANSIENTS AND RINGING

The phase response of filters is often ignored in applications where time domain waveforms are not relevant. But in video applications the time domain waveform is the signal that is finally presented on the screen to the viewer, and so time domain characteristics such as pulse response symmetry, pre-shoot, over-shoot and ringing are very important. Video applications are very demanding in that they require both sharp cutoff characteristics and linear phase. The interest and application of DSP to the problem (as shown above) is based on the linear phase characteristic of a particular class of digital filters known as symmetrical FIR filters. Use of these filters guarantees the best possible time domain characteristics for a given amplitude characteristic. In the analog domain phase linearity is not automatic (except for special phase linear filters such as Bessel or Equi-Ripple filters, both of which have inadequate amplitude characteristics for most video anti-alias applications) and it is often assumed that linear phase is unachievable. This is not true. Similarly, in the digital domain it is often assumed that sharp cutoff amplitude characteristics can be achieved without overshoot and ringing. This is also not true. Phase linear filters whether digital or analog have symmetrical response to symmetrical inputs. High roll-off rate filters (whether analog or digital) have ringing and overshoot. In the example below, the traditional 2T test pulse is applied to a traditional, non-phase linear analog filter, the ML6420 pure analog anti-alias filter (5.5MHz) and the combined analog/digital filters (9.3MHz analog filter and half-band digital filter.)

As seen in Figure 19c, the ML6420 filter provides a time domain response that is comparable to more complex and expensive digital filters.

### Typical Passive Filter

The output waveform is not symmetric. All ringing occurs after the main pulse. Result is visual smearing and fine ghosting to the right of every edge in the picture.

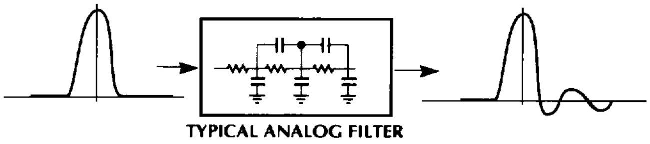


Figure 19a.

### Phase Corrected Analog Filter

Output waveform is substantially symmetric. Ringing is greatly reduced. Result is increase in apparent resolution. No smearing or ghosting.

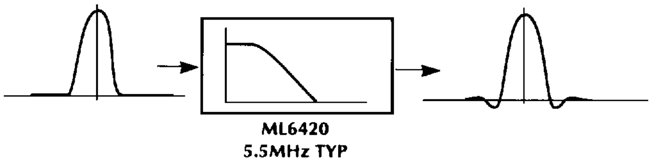


Figure 19b.

### Analog Filtering in the Time Domain

Output waveform is symmetric. Ringing is about the same as ML6420 alone. Difference between purely analog and analog/digital approach is subtle and will only have a material effect on multi-pass video processing.

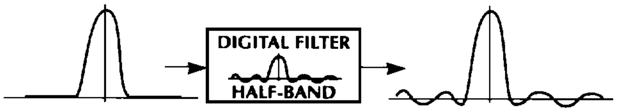
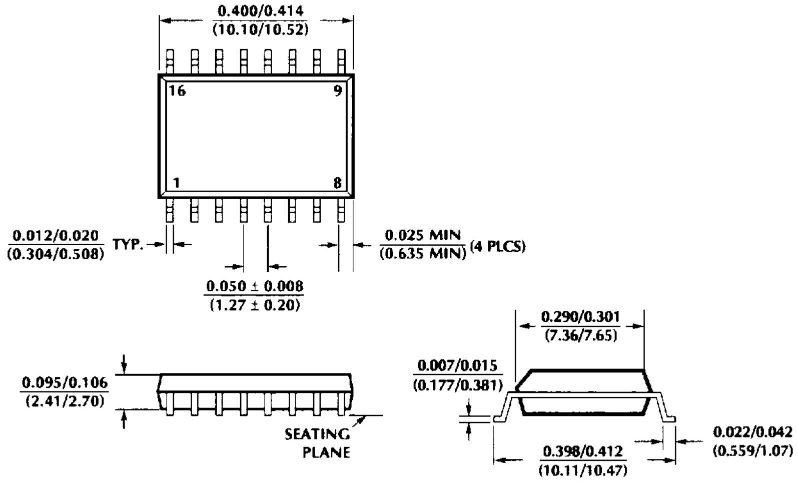


Figure 19c.

# PHYSICAL DIMENSIONS inches (millimeters)

**Package: S16W**
**16-pin SOIC**



## ORDERING INFORMATION

| PART NUMBER | BW (MHZ) | TEMPERATURE RANGE | PACKAGE |
|---|---|---|---|
| ML6420-1CS | 5.50/5.50/5.50 | 0°C to 70°C | 16-pin SOIC wide (S16W) |
| ML6420-2CS | 5.50/1.67/1.67 | 0°C to 70°C | 16-pin SOIC wide (S16W) |
| ML6420-3CS | 9.34/9.34/9.34 | 0°C to 70°C | 16-pin SOIC wide (S16W) |
| ML6420-4CS | 9.34/3.34/3.34 | 0°C to 70°C | 16-pin SOIC wide (S16W) |

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Micro Linear

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