Programmable Gain Amplifiers (PGAs), Operational Amplifiers and Comparators Design Guide

High Performance Devices for a Variety of Precision and Embedded Systems Applications

Design ideas in this guide use the following devices. A complete device list and corresponding data sheets for these products can be found at www.microchip.com.

**Programmable Gain Amplifiers:**
- MCP6S21/2/6/8
- MCP6S91/2/3

**Operational Amplifiers:**
- MCP601
- MCP616
- MCP6021
- MCP6281
- MCP6041
- TC1029
- TC1030
- TC1034

- MCP606
- MCP6001
- MCP6231
- MCP6241
- MCP6271
- MCP6291
- MCP6141
- TC913

**Comparators:**
- MCP6541
- TC1027
- TC1039
- TC1034

- MCP6546
- TC1037
- TC1041
- TC913
It is vital for designers of embedded control products to select the most suitable controller and companion devices. Embedded control products are found in all market segments: consumer, PC peripherals, telecommunications, automotive and industrial. Most embedded control products must meet special requirements: cost effectiveness, low-power, small-footprint and a high level of system integration.

Microchip has established itself as a leading supplier of embedded control solutions. The combination of high performance mixed-signal and linear analog products provide the basis for this leadership. Microchip’s extensive family of Programmable Gain Amplifiers (PGAs), Operational Amplifiers and Comparators are an example of the innovation and improvement in design that Microchip is committed to deliver to our customers.

**PROGRAMMABLE GAIN AMPLIFIERS**

The **MCP6S21/2/6/8** and **MCP6S91/2/3** precision Programmable Gain Amplifiers (PGAs) are programmable over an SPI™ bus and thus add gain control and input channel selection to the embedded control system. These PGAs are optimized for high speed, low offset voltage and single-supply operation with rail-to-rail input and output capability.

**OPERATIONAL AMPLIFIERS**

Microchip’s family of operational amplifiers are suitable for low power, precision and general purpose applications.

Microchip’s **MCP601**, **MCP6001** and **MCP6241**, are low-cost op amps suitable for general purpose applications such as signal amplification, sensor buffer or driving an analog-to-digital converters.

The **MCP6041** and **MCP6141** are 600 nA, rail-to-rail input and output op amps that are ideal for battery powered applications.

The **MCP606** and **MCP616** families also consume very low current and provide wide Gain Bandwidth Product. These op amps are targeted for low power precision applications with very low offset voltage.

**COMPARATORS**

Several comparators are offered with low supply voltage (1.8) and low supply current (1μA). Examples include the **MCP6541**, **TC1039**, **TC1038** and the **MCP6546** family of push-pull and open-drain comparators, which are designed for very low power single-supply applications.

The **MCP6021** family of op amps has a Total Harmonic Distortion plus Noise ratio of 0.00064% with 600Ω load at a gain of +1V/V. This device is ideal for single-supply audio applications.

The **MCP6271**, **MCP6281** and **MCP6291** families are also targeted for low-cost precision applications. These devices are characterized with a Extended Temperature range of -40°C to +125°C, which are ideal for automotive applications.

The **MCP6541**, **TC1039** and **TC1038** families of comparators have a push-pull output that interfaces with CMOS/TTL logic. The output limits supply current surges and dynamic power consumption while switching.

The **MCP6546** family of comparators has an open-drain output that can be pulled up to 10V supply.

The linear building blocks such as **TC1027**, **TC1039** and **TC1041**, have integrated reference voltage and shutdown which makes them ideal for low power portable applications.
Microchip’s industry first precision Programmable Gain Amplifiers (PGAs), the MCP6S21/2/6/8 and MCP6S91/2/3 come with Serial Peripheral Interface (SPI) and up to eight multiplexed input channels. These PGAs are configured in a non-inverting configuration with gains of 1, 2, 4, 5, 8, 10, 16 or 32V/V that can be digitally selected using a microcontroller. The input channels are also selected using the digital interface. These devices come with an internal register that allow the user to select gains, channels and shutdown the device.

These amplifiers were designed with the embedded control system in mind. The typical complexity of multiple sensor systems is reduced to one amplifier that the microcontroller can control. This reduces the demand on the microcontroller I/O and allows control over the level gain. One superior amplifier can be used to perform the functions of multiple amplifiers at a lower cost.

Programmable Gain Amplifiers Key Features:
- Multiplexed Inputs:
  - MCP6S21/2/6/8: 1, 2, 6 or 8 channels
  - MCP6S91/2/3: 1 or 2 channels
- 8 gain selections: +1, +2, +4, +5, +8, +10, +16 or +32V/V
- Serial Peripheral Interface (SPI)
- Rail-to-Rail Input and Output
- Low Gain Error: ±1% (max.)
- Low Offset (MCP6S21/2/6/8): ±275 μV (max.)
- High Bandwidth: 2 to 12 MHz (typ)
- Low Noise: 10 nV/√Hz at 10 kHz (typ)
- Low Supply Current: 1.0 mA (typ)
- Single Supply: 2.5V to 5.5V

Programmable Gain Amplifiers Applications:
- A/D Converter Driver
- Multiplexed Analog Applications
- Data Acquisition
- Industrial Instrumentation

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### MCP6S28 Circuit

Product Specifications: Programmable Gain Amplifiers

<table>
<thead>
<tr>
<th>Device</th>
<th>Switching Channels</th>
<th>-3 dB Bandwidth (MHz)</th>
<th>Gain Steps (V/V)</th>
<th>Supply Current (mA Typ.)</th>
<th>Supply Voltage (V)</th>
<th>Vos (±μV) Max.</th>
<th>Noise (nV/√Hz Typ.)</th>
<th>Packages</th>
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<tr>
<td>MCP6S21</td>
<td>1</td>
<td>2 to 12</td>
<td>1, 2, 4, 5, 8, 10, 16, 32</td>
<td>1.0</td>
<td>2.5 to 5.5</td>
<td>275</td>
<td>10</td>
<td>8PDIP, 8SOIC, 8MSOP</td>
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<tr>
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<td>2 to 12</td>
<td>1, 2, 4, 5, 8, 10, 16, 32</td>
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<td>2.5 to 5.5</td>
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<td>10</td>
<td>8PDIP, 8SOIC, 8MSOP</td>
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<td>6</td>
<td>2 to 12</td>
<td>1, 2, 4, 5, 8, 10, 16, 32</td>
<td>1.0</td>
<td>2.5 to 5.5</td>
<td>275</td>
<td>10</td>
<td>14PDIP, 14SOIC, 14TSSOP</td>
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<tr>
<td>MCP6S28</td>
<td>8</td>
<td>2 to 12</td>
<td>1, 2, 4, 5, 8, 10, 16, 32</td>
<td>1.0</td>
<td>2.5 to 5.5</td>
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<td>16PDIP, 16SOIC</td>
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<td>MCP6S91</td>
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<td>2.5 to 5.5</td>
<td>4,000</td>
<td>10</td>
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<td>1, 2, 4, 5, 8, 10, 16, 32</td>
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<td>MCP6S93</td>
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<td>1, 2, 4, 5, 8, 10, 16, 32</td>
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<td>2.5 to 5.5</td>
<td>4,000</td>
<td>10</td>
<td>10MSOP</td>
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</table>
Microchip offers wide bandwidth rail-to-rail input and output op amps for precision applications. The MCP6021 family of op amps has a Total Harmonic Distortion (THD) plus Noise ratio of 0.00064% with 600Ω load at a gain of +1V/V. This device is ideal for single-supply audio applications. The MCP6291 and MCP6281 families are also targeted for low cost precision applications. These devices are characterized with the Extended Temperature range of -40°C to +125°C, which are ideal for automotive applications.

**MCP6021 Operational Amplifier Key Features:**
- Rail-to-Rail Input/Output
  - MCP1
- Gain Bandwidth Product: 10 MHz (typ.)
- Low Noise: 8.7 nV/Hz (typ.), at 10 kHz
- Low Offset Voltage:
  - Industrial Temperature: ±500 μV (max.)
  - Extended Temperature: ±250 μV (max.)
- Mid-Supply Reference Voltage (VREF)
- Low Supply Current: 1 mA (typ.)
- Total Harmonic Distortion: 0.00053% (typ. G = 1)
- Power Supply Range: 2.5V to 5.5V
- Temperature Range:
  - Industrial: -40°C to +85°C
  - Extended: -40°C to +125°C

**Operational Amplifiers Applications:**
- Automotive
- Driving A/D Converters
- Multi-Pole Active Filters
- Barcode Scanners
- Audio Processing
- Communications
- DAC Buffer
- Test Equipment
- Medical Instrumentation
- Portable Equipment
- Photodiode Pre-amps
- Analog Filters
- Notebooks and PDAs
- Battery-powered Systems

**Product Specifications: Operational Amplifiers**

<table>
<thead>
<tr>
<th>Device</th>
<th>Op Amp</th>
<th>Bandwidth (MHz Typ.)</th>
<th>Slew Rate (V/μs Typ.)</th>
<th>Current (mA Typ.)</th>
<th>Supply Voltage (V)</th>
<th>Offset Voltage (± μV max.)</th>
<th>Temp. Range (°C)</th>
<th>Packages</th>
</tr>
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<tbody>
<tr>
<td>MCP6021</td>
<td>Single, Dual, Single w/ Chip Select, Quad</td>
<td>10</td>
<td>7</td>
<td>1</td>
<td>2.5 to 5.5</td>
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<td>-40 to +85</td>
<td>PDIP, SOIC, MSOP, TSSOP</td>
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<tr>
<td>MCP6291</td>
<td>Single, Dual, Single w/ Chip Select, Quad</td>
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<td>7</td>
<td>1</td>
<td>2.4 to 5.5</td>
<td>3000</td>
<td>-40 to +125</td>
<td>PDIP, SOIC, MSOP, TSSOP</td>
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<td>MCP6281</td>
<td>Single, Dual, Single w/ Chip Select, Quad</td>
<td>5</td>
<td>2.5</td>
<td>0.45</td>
<td>2.2V to 5.5V</td>
<td>3000</td>
<td>-40 to +125</td>
<td>PDIP, SOIC, MSOP, TSSOP</td>
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</tbody>
</table>
Microchip offers a number of low-cost op amps that are suitable for general purpose applications such as signal amplification, sensor buffer or driving an analog-to-digital converter. These op amps provide competitive bandwidth per given quiescent current. For example, the **MCP6001** device has a high phase margin which makes it ideal for capacitive load applications. The low supply voltage, low quiescent current and wide bandwidth makes the MCP6001 ideal for battery-powered applications.

This device is offered in a **SOT-23-5** package with three different pin outs. It’s also available in a **SC-70-5** package which is 50% smaller then SOT-23-5 package.

**MCP6001 Key Features:**
- Gain Bandwidth Product: 1 MHz (typ.)
- Rail-to-Rail Input/Output
- Supply Voltage: 1.8V to 5.5V
- Supply Current: IQ = 100 μA (typ.)
- Phase Margin: 90° (typ.)
- Temperature Range:
  - Industrial: -40°C to +85°C
  - Extended: -40°C to +125°C
- Available in Single, Dual and Quad
- Available in SC-23-5 and SOT-70-5 packages

**MCP6001 Applications:**
- Automotive
- Portable Equipment
- Photodiode Pre-amps
- Analog Filters
- Notebooks and PDAs
- Battery-powered Systems

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**Product Specifications: Operational Amplifiers**

<table>
<thead>
<tr>
<th>Device</th>
<th>Op Amp</th>
<th>Bandwidth (kHz Typ.)</th>
<th>Slew Rate (V/μs Typ.)</th>
<th>Current (μA Typ.)</th>
<th>Supply Voltage (V)</th>
<th>Offset Voltage (±mV max.)</th>
<th>Temp. Range (°C)</th>
<th>Packages</th>
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<td>-40 to +125</td>
<td>PDIP SOIC, TSSOP SOT-23-5</td>
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<td>MCP6001</td>
<td>Single, Dual, Quad</td>
<td>1000</td>
<td>0.6</td>
<td>100</td>
<td>1.8V to 5.5V</td>
<td>7</td>
<td>-40 to +125</td>
<td>PDIP SOIC, MSOP SC-70-5, SOT-23-5</td>
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<td>MCP6271</td>
<td>Single, Dual, Single w/ Chip Select, Quad</td>
<td>2000</td>
<td>0.9</td>
<td>170</td>
<td>2.0V to 5.5V</td>
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<td>-40 to +125</td>
<td>PDIP SOIC, MSOP</td>
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<td>MCP6241</td>
<td>Single</td>
<td>650</td>
<td>0.3</td>
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<td>1.8V to 5.5V</td>
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<td>-40 to +125</td>
<td>PDIP SOIC, SC-70-5, SOT-23-5</td>
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</table>
High Performance Devices for a Variety of Precision and Embedded Systems Applications

LOW POWER OPERATIONAL AMPLIFIERS

Microchip’s MCP6041 and MCP6141 rail-to-rail input and output op amps draw a maximum of 1 μA quiescent current. These devices provide 14 kHz and 100 kHz of Gain Bandwidth Product, respectively, with a 1.4V to 5.5V supply voltage. The MCP6141 has a minimum stable gain of 10. Both op amps are ideal for battery powered applications such as battery current sensing and wearable devices.

The MCP606 and MCP616 devices also draw very low current and provide wide bandwidth. These op amps are targeted for low power, precision applications with very low offset voltage.

The MCP6231 and MCP6241 are rail-to-rail input and output op amps that provide high performance while drawing only 20 μA and 50 μA quiescent current, respectively. They provide wider bandwidth (300 kHz and 550 kHz) than the other op amps in this category. They work well in low power applications that cannot compromise on bandwidth.

MCP6041 and MCP6141 Key Features:
- Low Quiescent Current: 600 nA Amplifier (typ.)
- Rail-to-Rail Input: -0.3V to VDD +0.3V (max.)
- Rail-to-Rail Output: – VSS +10 mV to VDD -10 mV (max.)
- Gain Bandwidth Product: 14 kHz (typ), MCP6041
  Gain Bandwidth Product: 100 kHz (typ), MCP6141 (G ≥ 10)
- Wide Supply Voltage Range: 1.4V to 5.5V (max.)
- Available in Single, Dual and Quad
- Chip Select (CS) with MCP6043 and MCP6143
- SOT-23-5 package (MCP6041 only)

MCP6041 and MCP6141 Applications:
- Booth Tags
- Wearable Products
- Temperature Measurement
- Battery-powered Systems

Product Specifications: Operational Amplifiers

<table>
<thead>
<tr>
<th>Device</th>
<th>Op Amp</th>
<th>Bandwidth (kHz Typ.)</th>
<th>Slew Rate (V/μs Typ.)</th>
<th>Current (μA Typ.)</th>
<th>Supply Voltage (V)</th>
<th>Offset Voltage (±mV max.)</th>
<th>Temp. Range (°C)</th>
<th>Packages</th>
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<td>Single, Dual, Single w/ Chip Select, Quad</td>
<td>155</td>
<td>80</td>
<td>19</td>
<td>2.5 to 5.5</td>
<td>250</td>
<td>-40 to +85</td>
<td>PDIP, SOIC, TSSOP, SOT-23-5</td>
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<tr>
<td>MCP616</td>
<td>Single, Dual, Single w/ Chip Select, Quad</td>
<td>190</td>
<td>80</td>
<td>19</td>
<td>2.3 to 5.5</td>
<td>150</td>
<td>-40 to +85</td>
<td>PDIP, SOIC, MSOP</td>
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<td>MCP6041</td>
<td>Single, Dual, Single w/ Chip Select, Quad</td>
<td>14</td>
<td>3</td>
<td>0.6</td>
<td>1.4 to 5.5</td>
<td>3000</td>
<td>-40 to +85</td>
<td>PDIP, SOIC, MSOP, TSSOP, SOT-23-5</td>
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<td>MCP6141</td>
<td>Single, Dual, Single w/ Chip Select, Quad</td>
<td>100</td>
<td>24</td>
<td>0.6</td>
<td>1.4 to 5.5</td>
<td>3000</td>
<td>-40 to +85</td>
<td>PDIP, SOIC, MSOP, TSSOP</td>
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<tr>
<td>MCP6231</td>
<td>Single, Dual, Quad</td>
<td>300</td>
<td>150</td>
<td>20</td>
<td>1.8 to 5.5</td>
<td>5000</td>
<td>-40 to +125</td>
<td>PDIP, SOIC, TSSOP, SOT-23-5, SC-70-5</td>
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<td>MCP6241</td>
<td>Single, Dual, Quad</td>
<td>550</td>
<td>300</td>
<td>50</td>
<td>1.8 to 5.5</td>
<td>5000</td>
<td>-40 to +125</td>
<td>PDIP, SOIC, TSSOP, SOT-23-5, SC-70-5</td>
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</table>
Microchip has three new and innovative cascaded dual op amp families: MCP6275 (2 MHz), MCP6285 (5 MHz) and MCP6295 (10 MHz).

**MCP62X5 Key Features:**
- Chip Select (CS) Pin for Both Amplifiers
- Small 8-pin Packages (PDIP-8, SOIC-8, MSOP-8)
- Pinout Similar to the Industry Standard for Duals

The two op amps are connected so that they will support many application circuits.

The output of op amp A is connected internally to the non-inverting input of op amp B (see Pinout Configuration). Combining these into one pin (VOUTA/VINB+ = pin # 1) makes it possible to add a CS input (pin # 5) to an 8-pin package. Both op amps function as normal op amps.

The CS input helps conserve power in many popular dual op amp applications. This pinout makes it relatively easy to modify many existing designs for these parts.

**MCP62X5 Applications:**
The most common application circuit supported by these parts is cascaded amplifiers (see Cascaded Amplifiers). These parts allow for easy layout in this common application. Usually, most of the gain is produced by the first stage.

There are several interesting variations of the circuit in the Cascaded Amplifiers illustration that are supported by these parts. For instance, the input op amp (op amp A) can be configured as an inverting amplifier, as an inverting (Miller) integrator, or as a difference amplifier. The output amplifier can be set up as a unity gain buffer to isolate the load from op amp A. This results in an overall performance improvement when driving heavy loads (e.g., 1 kΩ).

### Product Specifications: Cascaded Dual Operational Amplifiers

<table>
<thead>
<tr>
<th>Device</th>
<th>Op Amp</th>
<th>Bandwidth (MHz Typ.)</th>
<th>Slew Rate (V/μs Typ.)</th>
<th>Current (mA Typ.)</th>
<th>Supply Voltage (V)</th>
<th>Offset Voltage (±mV max.)</th>
<th>Temp. Range (°C)</th>
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<td>2.5</td>
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<tr>
<td>MCP6295</td>
<td>Single, Dual, Single w/ Chip Select, Quad</td>
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<td>7</td>
<td>1</td>
<td>2.4 to 5.5</td>
<td>3</td>
<td>-40 to +125</td>
<td>PDIP, SOIC, MSOP, TSSOP</td>
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</table>
FilterLab® 2.0 is an innovative software tool that simplifies active (op amp) filter design. Available at no cost from Microchip's web site (www.microchip.com), the FilterLab 2.0 active filter software design tool provides full schematic diagrams of the filter circuit with component values and displays the frequency response.

FilterLab 2.0 allows the design of low-pass filters up to an 8th order filter with Chebychev, Bessel or Butterworth responses from frequencies of 0.1 Hz to 10 MHz. FilterLab 2.0 also can be used to design band-pass and high-pass filters with Chebychev and Butterworth responses. The circuit topologies supported by FilterLab 2.0 are the Sallen Key and Multiple Feedback (MFB). The low-pass filters can use either the Sallen Key or MFB, the band-pass is available with the MFB and the high-pass uses the Sallen Key.

Users can select a flat passband or sharp transition from passband to stopband. Options, such as minimum ripple factor, sharp transition and linear phase delay are available. Once the filter response has been identified, FilterLab 2.0 generates the frequency response and the circuit. For maximum design flexibility, changes in capacitor values can be implemented to fit the demands of the application. FilterLab 2.0 will recalculate all values to meet the desired response, allowing real-world values to be substituted or changed as part of the design process.

FilterLab also generates a SPICE model of the designed filter. Extraction of this model will allow time domain analysis in SPICE simulations, streamlining the design process.

Further consideration is given to designs used in conjunction with an analog-to-digital converter (ADC). A suggested filter can be generated by simply inputting the bit resolution and sample rate via the Anti-Aliasing Wizard. This eliminates erroneous signals folded back into the digital data due to the aliasing effect.

FilterLab 2.0 Key Features:
- A Variety of Active Filter Types
  - Low-pass, Band-pass or High-pass
  - Bessel, Butterworth or Chebychev
  - Sallen Key and Multiple Feedback Topologies
- A Wide Range of Selectable Parameters
  - Gain: 1 and 10 V/V
  - Order: 1 to 8
  - Passband Ripple: 0.01 dB to 3.0 dB
  - Stopband Attenuation: 10 dB to 100 dB
  - Cut-off Frequency: 0.1 Hz to 1 MHz
  - Stop-band Frequency: 0.1 Hz to 1 MHz
  - Bandpass Q: 0.5 to 5.0
  - Bandpass Fractional Bandwidth: 20% to 200%

FilterLab 2.0 Key Features (Continued):
- Easy-to-Use Design Windows for Filter
  - Frequency Response
  - Circuit Diagram
  - SPICE Listing
- Design Aids
  - Toolbar
  - Filter Design Wizard
  - Filter Selection Wizard
  - Anti-Aliasing Wizard (for ADCs)
- Component Value Generation
  - Automatic Calculation of Components
  - Either Exact or 1% Resistor Values
  - Can Manually Input Capacitors
- User’s Guide (Help Menu)
  - How to Use Chapters
  - Technical Background Appendices (SPICE Interface, Filter Templates, Group Delay, Bessel Filter Response, Op Amp Selection and Selected References)
Microchip’s family of push-pull and open-drain comparators, the MCP6541 and the MCP6546, are designed for very low power single supply applications. These devices fully operate with a supply voltage as low as 1.6V, while drawing 600 nA (typ.) current. The typical propagation delays of these low power comparator families is 4 μs.

The open-drain output of the MCP6546 family can be used as a level-shifter for up to 10V using a pull-up resistor. It can also be used as a wired-OR logic. The internal input hysteresis eliminates output switching due to internal noise voltage, reducing current draw.

### MCP654X Key Features:

- Low Quiescent Current: 600 nA/Comparator (typ.)
- Rail-to-Rail Input: Vss -0.3V to Vdd +0.3V
- CMOS/TTL-Compatible Output
- Push-pull and Open-drain Output
- Propagation Delay: 4 μs (typ.)
- Wide Supply Voltage Range: 1.6V to 5.5V
- Available in Single, Dual and Quad
- Chip Select (CS) with MCP6543 and MCP6548
- Low Switching Current
- Internal Hysteresis: 3.3 mV (typ.)

### MCP6541 and MCP6546 Applications:

- Laptop Computers
- Mobile Phones
- Metering Systems
- Hand-held Electronics
- RC Timers
- Alarm and Monitoring Circuits
- Windowed Comparators
- Multi-vibrators

### Product Specifications: Comparators

<table>
<thead>
<tr>
<th>Device</th>
<th>Comparator Type</th>
<th>Current (μA Typ.)</th>
<th>Supply Voltage (V)</th>
<th>Offset Voltage (±mV max.)</th>
<th>Temperature Range (°C)</th>
<th>Package</th>
<th>Output</th>
</tr>
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<tr>
<td>MCP6541</td>
<td>Single, Dual, Single w/Chip Select, Quad</td>
<td>0.6</td>
<td>1.6 to 5.5</td>
<td>7</td>
<td>-40 to +85</td>
<td>PDIP SOIC, MSOP TSSOP SOT-23-5, SC-70-5</td>
<td>Push-Pull</td>
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<td>MCP6546</td>
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<td>0.6</td>
<td>1.6 to 5.5</td>
<td>7</td>
<td>-40 to +85</td>
<td>PDIP SOIC, MSOP TSSOP SOT-23-5, SC-70-5</td>
<td>Open-Drain</td>
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<tr>
<td>TC1027</td>
<td>Quad</td>
<td>18</td>
<td>1.8 to 5.5</td>
<td>5</td>
<td>-40 to +85</td>
<td>PDIP SOIC, MSOP SOT-23</td>
<td>Push-Pull</td>
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<td>TC1037</td>
<td>Single</td>
<td>4</td>
<td>1.8 to 5.5</td>
<td>5</td>
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<td>SOT-23</td>
<td>Push-Pull</td>
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<tr>
<td>TC1038</td>
<td>Single</td>
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<td>SOT-23</td>
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<tr>
<td>TC1041</td>
<td>Dual</td>
<td>10</td>
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<td>5</td>
<td>-40 to +85</td>
<td>SOIC, MSOP</td>
<td>Push-Pull</td>
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</table>
The following literature is available on the Microchip web site: www.microchip.com.

**Application Notes**

**AN248: Interfacing MCP6S2X PGAs to PICmicro® Microcontroller**

The MCP6S21/2/6/8 family of one, two, six or eight channel Programmable Gain Amplifiers (PGAs) communicate using a standard 3-wire Serial Peripheral Interface (SPI™) protocol. This application note shows how to program the six channel MCP6S26 PGA gains, channels and shutdown registers using the PIC16C505 microcontroller.

**AN251: Bridge-Sensing with the MCP6S2X PGAs**

Resistive sensors configured as Wheatstone bridges are primarily used to sense pressure, temperature or loads. An external A/D converter (ADC) and a digitally Programmable Gain Amplifier (PGA) can easily be used to convert the difference in voltage from these resistor bridge sensors to usable digital words for manipulation by the microcontroller.

**AN865: “Sensing Light with a Programmable Gain Amplifier”**

Photo sensors bridge the gap between light and electronics. Microchip’s Programmable Gain Amplifiers (PGAs) are not well suited for precision applications (such as CT scanners), but they can be effectively used in position photo sensing applications minus the headaches of amplifier stability.

**AN867: Designing Operational Amplifier Oscillator Circuits for Sensor Applications**

Operational amplifier (op amp) oscillators can be used to accurately measure resistive and capacitive sensors. Oscillator design can be simplified by using the procedure discussed in this application note. The derivation of the design equations provides a method to select the passive components and determine the influence of each component on the frequency of oscillation. The procedure will be demonstrated by analyzing two state-variable RC op amp oscillator circuits.

**AN866: Temperature Sensing with a Programmable Gain Amplifier**

Although it is simple to measure temperature in a stand-alone system without the help of Microchip’s Programmable Gain Amplifiers, a variety of problems can be eliminated by implementing temperature sensing capability in multiplexed applications with a PGA.

**Technical Briefs**

**TB023:** “Serialized Quick Turn Programming® (SQTP®)

**TB065:** “Linear Circuit Devices for Applications in Battery Powered Wireless Systems”

**Design Tools**

SPICE Macro Model

FilterLab® Analog Filtering Design Software