Keywords: digital potentiometer, low pass filter, filter, low-pass filter, lowpass filte, anti aliasing, sampled data system, folded, Nyquist, data converters, spectrum, harmonics, FFT, ADC, convolution, DAC, op amps, RC, LC, Butterworth

TUTORIAL 4993

Reduce the Chances of Human Error: Part 2, Super Amps and Filters for Analog Interface

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Abstract: A common view holds that digital circuits just work naturally, but analog circuits are hard to implement. There is truth to that old belief—analog interface is an expert subject that requires training. It is, moreover, always better to avoid an issue than to try to solve it later. This is precisely why we should take advantage of some basic concepts that experienced analog engineers perform as a reflex. This application note provides some basic reminders and concepts about amplifiers and filters for you to consider during a design.

Introduction

As children we learned to share and in that process we learned about portions. Many parents taught this to children by having one child cut the pie or cake and then letting another child pick the piece first. We can be sure that great care was used to make the pieces all the same size.

We are reminded of a good lesson in life, "It's the ratio that counts." We use ratios in everyday life when we compare distances between different routes or the taste of two foods. (Yes, mom's cooking was better, or maybe we were too young to know any difference?).

Moving from children, pies, and cakes to analog engineering design, we realize that ratios—the relative amount, proportion, percentage, share, part, and fraction—are all important measurements in analog design. When we ignore these ratios and relationships, we introduce human error into what must be a precise process. This application note shares some analog concepts about amplifiers and filters that will help reduce the chances of "human" error and improve the analog design.

Considerations for Signal to Noise (SNR)

Crosstalk and signal to noise (SNR) are expressed as ratios, a proportion of good to bad. How does one improve the SNR of a signal? If a particular circuit contributes considerable noise, we have two basic options: first, reduce the noise somehow, or second, increase the amplitude of the good signal before it goes through the stage. **Figure 1** illustrates the concept.

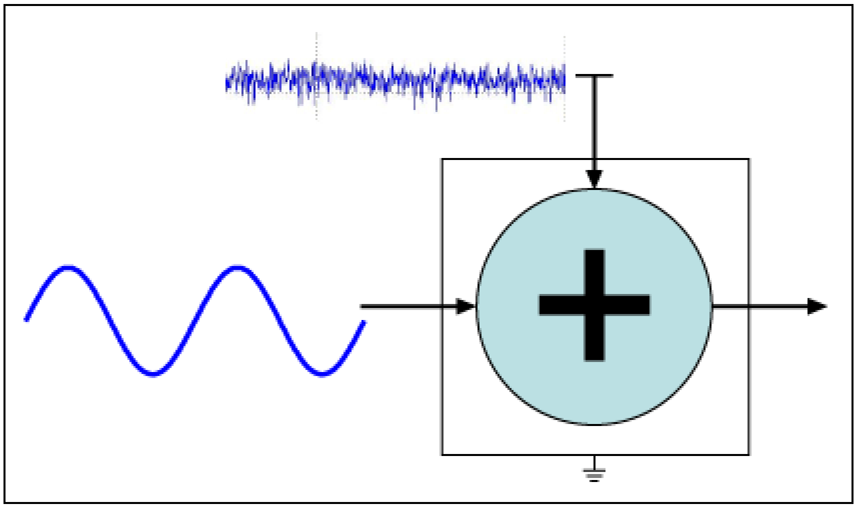

Figure 1. Power-supply noise is added to the signal.

In application note 4992, "Reduce the Chances of Human Error: Part 1, Power and Ground," we concentrated on power noise, ground, and layout. In this companion article we examine how to control noise in the signal path. We discuss the characteristics of the signal and noise as we proceed through the various circuit stages.

Is the major noise source harmonics of a switching power supply? If the power-supply noise is 50kHz and higher and if our wanted signal is 1kHz, then filtering may be feasible. If we will be going into an ADC next, the anti-aliasing filter may help.

Reducing Noise

What possibilities does an experienced circuit designer evaluate? The simplest fix is to amplify the signal before the noise is added. Yes, straightforward enough, but unfortunately this solution most often cannot be used because the incoming signal already has noise present. So now we get creative and consider how to separate the signal from noise? Can we use highpass, lowpass, or bandpass filters? Can we discriminate on the basis of amplitude, limiting, noise blanking, or coring? Can we use preemphasis before the noise is introduced and deemphasis after to increase SNR? Can we discriminate on the basis of time, i.e., sample at a minimum noise level or interference time? Can we time average, or if the signal is repetitive, can we sum cycles or average in two, three, or more dimensions?

Turning from component functions, think about the system as a whole. What are the system goals? How will the system be used? How will the human senses interact with the information provided by the system? In short, consider all the information that we can muster.

The above set of questions reflects considerable design experience and knowledge. This is precisely why smart companies hire experienced engineers and mentor the new engineers to build a solid design team.

We can use an example to illustrate the thinking and development process. The first observation finds that the system has a high-gain operational amplifier at its input. The op amp feeds an analog-to-digital converter (ADC). Occasionally a large noise pulse appears on the signal and this causes the op amp to saturate. The op amp recovery time might be as long as milliseconds or seconds. How will we approach the issue? Since every case will be different, we will just ask questions and point out possible solutions.

First, gather data to try to understand what is happening. Can we fix the source? No. So we decide that the noise spike is unavoidable. What do we know about its risetime amplitude and duration? If the spike is very fast and narrow and our wanted signal is relatively slow, can we separate them by filtering? Can we detect the spike and open a series switch to blank out the spike from the main path? Could we add a pair of diodes like an electrostatic discharge (ESD) structure to clip any signal that goes above V_{CC} or below ground? Can we learn from application note 4344, "Rail Splitter, from Abraham Lincoln to Virtual Ground?" In **Figure 2** of that application note we create a voltage between V_{CC} and ground at the average signal level of the wanted signal. If the series resistor was replaced with a pair of back-to-back diodes (Figure 2), the signal spike would be limited to the voltage ±0.6V for silicon diodes (red dashed lines) and ~±0.3V for Schottky diodes (green dashed lines). The reverse recovery time for silicon diodes can be between one hundreds and several hundreds of nanoseconds. Schottky diodes have a switching time of ~100ps for the small signal diodes but, because of their operating physics, do not have a reverse recovery time. The diodes can also be placed in the op amp feedback loop to reduce gain during the spike. **Figure 3** shows the effect of limiting.

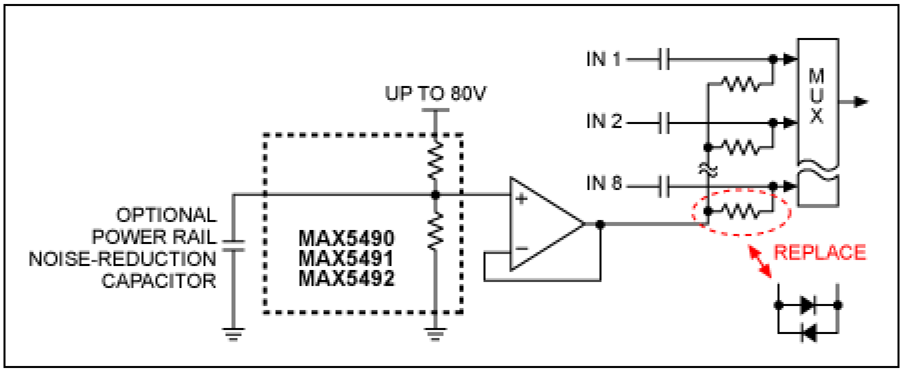

Figure 2. Replacing a series resistor with a pair of back-to-back diodes.

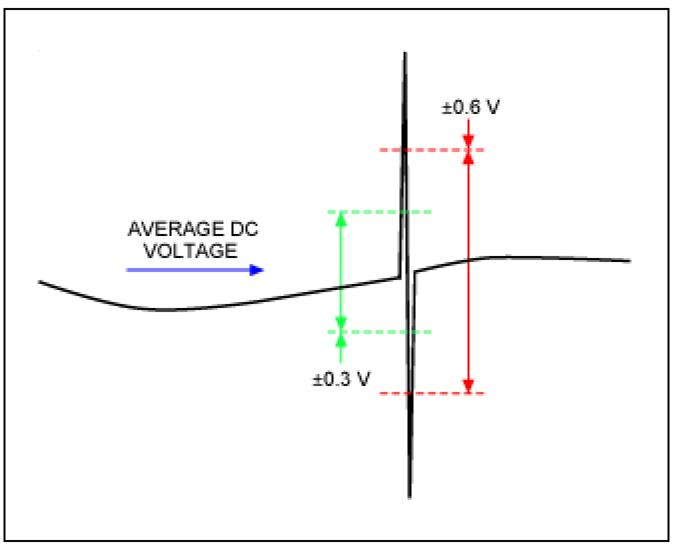

Figure 3. Diode limiter effect, ±0.3V Schottky, ±0.6V silicon.

Figure 3 may help relieve op amp saturation and recovery time, but is it enough? We could add circuits to blank out the noise pulse as in **Figure 4**.

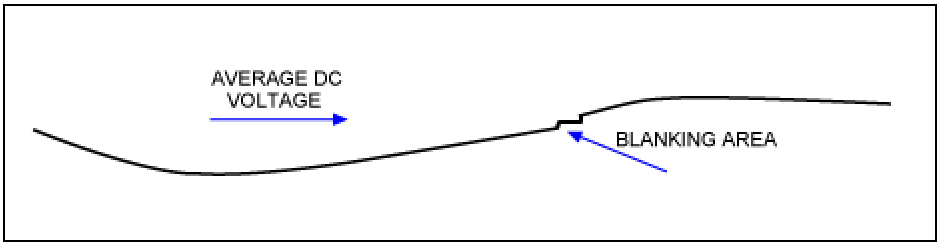

Figure 4. Noise pulse blanking.

The block diagram of the blanking circuit is **Figure 5**.

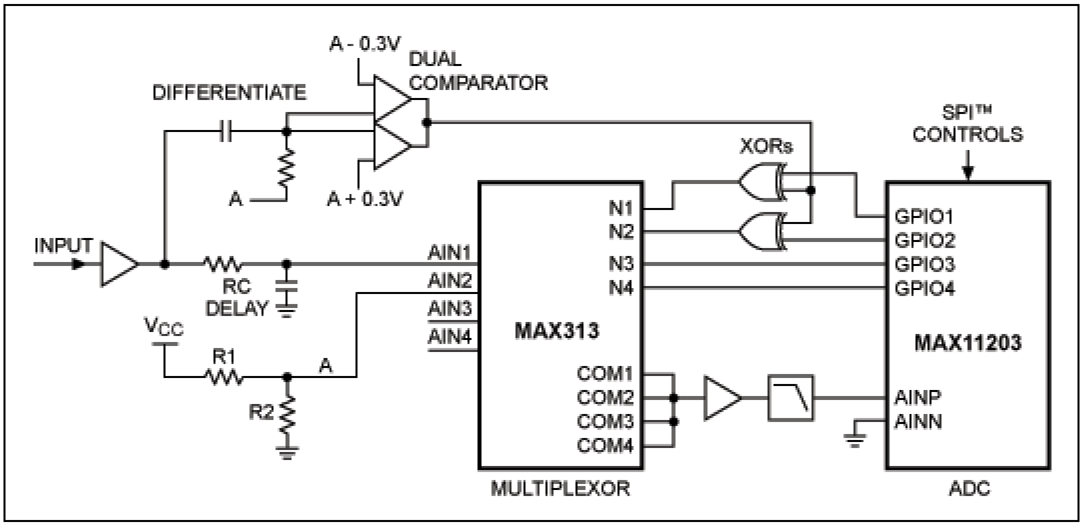

Figure 5. Noise-blanking block diagram.

From the basic concept of blanking in Figure 5, more elegance can be added. The input buffer may not be needed if the source is low impedance. R1 and R2 set a DC value as shown in application note 4344, "Rail Splitter, from Abraham Lincoln to Virtual Ground," mentioned above. Alternatively, the input signal could be AC coupled to this same voltage or the input signal could be averaged over the long term to produce this voltage. The main signal path is from the input buffer through a RC delay, the mux, buffer, and lowpass filter to the ADC. The MAX11203 ADC has four general-purpose input or output (GPIO) ports controlled by the SPI interface. The GPIO is set so that the AIN1of the MAX313 multiplexor is on and AIN2 is off. We highpass or differentiate the noise pulse. The dual or window comparator output will be active while the noise pulse exceeds 0.3V in either the positive or negative direction. The XOR gated inverts the logic to the mux, thereby turning off the main path and switching on the DC voltage. The RC delay also delays the main path long enough for the comparator path to change state. If the RC delay degrades the signal bandwidth too much, an LC delay line can be substituted.

The input buffer of Figure 5 could use a MAX4209 instrument amplifier which has incredibly low offset drift despite its high gain. Application note 4179, "Autozero Noise Filtering Improves Instrumentation Amplifier Output," explains why.

The filter just before the ADC in Figure 5 can control signal bandwidth to meet Nyquist anti-aliasing, reduce noise, or soften the residual blanking glitch. The following application notes will provide advice and ideas:

- 3077, "A Digitally Controllable Lowpass Filter Using a Digital Potentiometer"
- 928, "Filter Basics: Anti-Aliasing"

- 3716, "Folded-Frequency Calculator"
- 3494, "The Basics of Anti-Aliasing: Using Switched-Capacitor Filters"
- 733, "A Filter Primer"
- 1795, "Analog Filter Design Demystified"
- 724, "Generating Switched-Capacitor-Filter Clocks"

Application note 4617, "ADC Input Translator," uses resistor-dividers to scale the differential inputs and a stable voltage reference to offset the inputs. This circuit design enables an ADC with a 0V to 5V input range (e.g., the MAX1402) to accept inputs in the range +10.5V to -10.5V.

Calibration ideas using digital-to-analog converters (DACs) and potentiometers are covered in application notes 4494, "Methods for Calibrating Gain Error in Data-Converter Systems," and 818, "Digital Adjustment of DC-DC Converter Output Voltage in Portable Applications." The digital-output voltage-adjustment methods are performed with DAC, a trim pot (digital potentiometer), and PWM output of a microprocessor. Application note 4704, "Introduction to Electronic Calibration and Methods for Correcting Manufacturing Tolerances in Industrial Equipment Designs," includes a discussion of the DS4303 infinite sample-and-hold to capture a DC Voltage. Other application notes about digital pots include:

- 4101, "Differentiating Digital Potentiometer Features"
- 593, "Dallas Semiconductor Digital Potentiometers: Frequently Asked Questions"
- 4025, "DACs vs. Digital Potentiometers: Which Is Right for My Application?"

Analog I/O, interface circuits and digital-port signal protection ideas are discussed in the following application notes:

- Sensor signal conditioners
- 651, "ESD Protection for I/O Ports"
- 1167, "Practical Aspects of EMI Protection"
- 3950, "A Measurement Technique for Determining RF Immunity"
- RS-232, RS-485, smartcard interface, USB, LVDS
- 2023, "LVDS Serializer-Deserializer Performance over Twisted Pair Cable"

Maxim has watchdog circuits which ensure that microprocessor-controlled devices react in a known manner if the processor loses control. The following application notes offer ideas for using watchdogs: 4558, "Simple Latching Watchdog Timer," and 4229, "Comparison of Internal and External Watchdog Timers."

Microprocessor-controlled system clocks typically are of two types: system clocks controlling computing functions in orderly ways, and real time clocks (RTCs) or clocks that relate to human time concepts. Computer clocks operate like soldiers marching in cadence. This can result in interference products that may not meet regulatory requirements. Clock-generator spread-spectrum techniques to reduce this interference are discussed in these notes: 2863, "The Effects of Adjusting the DS1086L's Dither Span and Dither Frequency on EMC Measurements," and 3512, "Automotive Applications for Silicon Spread-Spectrum Oscillators." RTC ideas are found at www.maximintegrated.com/appnotes10.cfm/ac_pk/21.

Conclusion

Noise and interference control is different in every circuit and system. Thankfully, the laws of physics prevail and engineers must work hard to silence noise. This discussion has tried to help designers anticipate noise and interference issues before the design starts and during the design. After the product is in production, the options for correction are severely limited.

Related Parts

DS1085	EconOscillator Frequency Synthesizer	Free Samples
DS1086	Spread-Spectrum EconOscillator	Free Samples
DS1086	Spread-Spectrum EconOscillator	Free Samples
DS1086L	3.3V Spread-Spectrum EconOscillator	Free Samples
DS1086L	3.3V Spread-Spectrum EconOscillator	Free Samples
DS1087L	3.3V Spread-Spectrum EconOscillator	Free Samples
DS1087L	3.3V Spread-Spectrum EconOscillator	Free Samples
DS1089L	3.3V Center Spread-Spectrum EconOscillator™	Free Samples
DS1090	Low-Frequency, Spread-Spectrum EconOscillator	Free Samples
DS1094L	Multiphase Spread-Spectrum EconOscillator	Free Samples
DS1267	±5V Dual Digital Potentiometer Chip	Free Samples
DS1804	Nonvolatile Trimmer Potentiometer	Free Samples
DS1847	Dual Temperature-Controlled NV Variable Resistor	Free Samples
DS1848	Dual Temperature-Controlled NV Variable Resistor & Memory	Free Samples
DS1851	Dual Temperature-Controlled NV Digital-to-Analog Converters	Free Samples
DS3502	High-Voltage NV I²C Potentiometer	Free Samples
DS3903	Triple 128-Position Nonvolatile Digital Potentiometer	Free Samples
DS3904	Triple, 128-Position, Nonvolatile, Variable, Digital Resistor/Switch	Free Samples
DS3906	Triple NV Low Step Size Variable Resistor Plus Memory	Free Samples
DS3930	Hex Nonvolatile Potentiometer with I/O and Memory	Free Samples
DS4303	Electronically Programmable Voltage Reference	Free Samples
DS4303	Electronically Programmable Voltage Reference	Free Samples
MAX1067	Multichannel, 14-Bit, 200ksps Analog-to-Digital Converters	Free Samples
MAX1213	1.8V, 12-Bit, 170Msps ADC for Broadband Applications	Free Samples
MAX1214	1.8V, 12-Bit, 210Msps ADC for Broadband Applications	Free Samples
MAX1215	1.8V, 12-Bit, 250Msps ADC for Broadband Applications	
MAX12527	Dual, 65Msps, 12-Bit, IF/Baseband ADC	Free Samples
MAX12528	Dual, 80Msps, 12-Bit, IF/Baseband ADC	Free Samples

MAX12553	14-Bit, 65Msps, 3.3V ADC	Free Samples
MAX12555	14-Bit, 95Msps, 3.3V ADC	
MAX12557	Dual, 65Msps, 14-Bit, IF/Baseband ADC	Free Samples
MAX12558	Dual, 80Msps, 14-Bit, IF/Baseband ADC	Free Samples
MAX1402	+5V, 18-Bit, Low-Power, Multichannel, Oversampling (Sigma-Delta) ADC	Free Samples
MAX1480E	±15kV ESD-Protected, Isolated RS-485/RS-422 Data Interfaces	Free Samples
MAX1488E	±15kV ESD-Protected, Quad, Low-Power RS-232 Line Driver	Free Samples
MAX1490E	±15kV ESD-Protected, Isolated RS-485/RS-422 Data Interfaces	Free Samples
MAX1553	High-Efficiency, 40V Step-Up Converters for 2 to 10 White LEDs	Free Samples
MAX19586	High-Dynamic-Range, 16-Bit, 80Msps ADC with -82dBFS Noise Floor	Free Samples
MAX253	1W Primary-Side Transformer H-Bridge Driver for Isolated Supplies	Free Samples
MAX274	4th- and 8th-Order, Continuous-Time Active Filters	Free Samples
MAX275	4th- and 8th-Order, Continuous-Time Active Filters	Free Samples
MAX3080	Fail-Safe, High-Speed (10Mbps), Slew-Rate-Limited RS-485/RS-422 Transceivers	Free Samples
MAX3083	Fail-Safe, High-Speed (10Mbps), Slew-Rate-Limited RS-485/RS-422 Transceivers	Free Samples
MAX3088	Fail-Safe, High-Speed (10Mbps), Slew-Rate-Limited RS-485/RS-422 Transceivers	Free Samples
MAX3188	1Mbps, 1µA RS-232 Transmitters in SOT23-6	
MAX3190E	±15kV ESD-Protected, 460kbps, RS-232 Transmitters in SOT23-6	Free Samples
MAX321	Precision, Dual Supply, SPST, Analog CMOS Switches	Free Samples
MAX3223E	±15kV ESD-Protected, 1µA, 3.0V to 5.5V, 250kbps, RS-232 Transceivers with AutoShutdown	Free Samples
MAX3225E	±15kV ESD-Protected, 1µA, 1Mbps, 3.0V to 5.5V, RS-232 Transceivers with AutoShutdown Plus	Free Samples
MAX3226	1µA Supply Current, 1Mbps, 3.0V to 5.5V, RS-232 Transceivers with AutoShutdown Plus	Free Samples
MAX3228	+2.5V to +5.5V RS-232 Tranceivers in UCSP	

MAX3244E	±15kV ESD-Protected, 1µA, 1Mbps, 3.0V to 5.5V, RS-232 Transceivers with AutoShutdown Plus	Free Samples
MAX3245E	±15kV ESD-Protected, 1µA, 1Mbps, 3.0V to 5.5V, RS-232 Transceivers with AutoShutdown Plus	Free Samples
MAX3311E	±15kV ESD-Protected, 460kbps, 1µA, RS-232-Compatible Transceivers in µMAX	Free Samples
MAX3313E	±15kV ESD-Protected, 460kbps, 1µA, RS-232-Compatible Transceivers in µMAX	Free Samples
MAX3387E	3V, ±15kV ESD-Protected, AutoShutdown Plus RS-232 Transceiver for PDAs and Cell Phones	Free Samples
MAX3388E	2.5V, ±15kV ESD-Protected RS-232 Transceivers for PDAs and Cell Phones	Free Samples
MAX3443E	±15kV ESD-Protected, ±60V Fault-Protected, 10Mbps, Fail-Safe RS-485/J1708 Transceivers	Free Samples
MAX3483E	3.3V Powered, ±15kV ESD-Protected, 12Mbps, Slew-Rate-Limited True RS-485/RS-422 Transceivers	Free Samples
MAX3485	3.3V Powered, 10Mbps and Slew-Rate Limited, True RS-485/RS-422 Transceivers	Free Samples
MAX3490	3.3V Powered, 10Mbps and Slew-Rate Limited, True RS-485/RS-422 Transceivers	Free Samples
MAX4167	High-Output-Drive, Precision, Low-Power, Single-Supply, Rail-to-Rail I/O Op Amps with Shutdown	Free Samples
MAX4209	Ultra-Low Offset/Drift, Precision Instrumentation Amplifiers with REF Buffer	Free Samples
MAX4232	High-Output-Drive, 10MHz, 10V/µs, Rail-to-Rail I/O Op Amps with Shutdown in SC70	Free Samples
MAX4238	Ultra-Low Offset/Drift, Low-Noise, Precision SOT23 Amplifiers	Free Samples
MAX4506	Fault-Protected, High-Voltage Signal-Line Protectors	Free Samples
MAX4551	±15kV ESD-Protected, Quad, Low-Voltage, SPST Analog Switches	Free Samples
MAX4558	±15kV ESD-Protected, Low-Voltage, CMOS Analog Multiplexers Switches	Free Samples
MAX4568	±15kV ESD-Protected, Low-Voltage, SPDT/SPST, CMOS Analog Switches	Free Samples
MAX4575	±15kV ESD-Protected, Low-Voltage, Dual, SPST, CMOS Analog Switches	Free Samples
MAX4630	±15kV ESD-Protected, Low-Voltage, Quad, SPST, CMOS Analog Switches	Free Samples

MAX4640	±15kV ESD-Protected, Low-Voltage, Quad, SPST, CMOS Analog Switches	Free Samples
MAX483E	±15kV ESD-Protected, Slew-Rate-Limited, Low-Power, RS-485/RS-422 Transceivers	Free Samples
MAX485E	±15kV ESD-Protected, Slew-Rate-Limited, Low-Power, RS-485/RS-422 Transceivers	Free Samples
MAX487E	±15kV ESD-Protected, Slew-Rate-Limited, Low-Power, RS-485/RS-422 Transceivers	Free Samples
MAX488	Low-Power, Slew-Rate-Limited RS-485/RS-422 Transceivers	Free Samples
MAX491E	±15kV ESD-Protected, Slew-Rate-Limited, Low-Power, RS-485/RS-422 Transceivers	Free Samples
MAX5105	Nonvolatile, Quad, 8-Bit DACs	Free Samples
MAX5106	Nonvolatile, Quad, 8-Bit DACs	Free Samples
MAX5109	Nonvolatile, Dual, 8-Bit DACs with 2-Wire Serial Interface	Free Samples
MAX5115	Nonvolatile, Quad, 8-Bit DACs with 2-Wire Serial Interface	Free Samples
MAX5116	Nonvolatile, Quad, 8-Bit DACs with 2-Wire Serial Interface	Free Samples
MAX516	Quad, DAC-Programmed, CMOS Comparator	Free Samples
MAX5160	Low-Power Digital Potentiometers	Free Samples
MAX5355	10-Bit Voltage-Output DACs in 8-Pin µMAX	Free Samples
MAX5361	Low-Cost, Low-Power 6-Bit DACs with 2-Wire Serial Interface in SOT23 Package	Free Samples
MAX5361	Low-Cost, Low-Power 6-Bit DACs with 2-Wire Serial Interface in SOT23 Package	Free Samples
MAX5363	Low-Cost, Low-Power, 6-Bit DACs with 3-Wire Serial Interface in SOT23	Free Samples
MAX5364	Low-Cost, Low-Power, 6-Bit DACs with 3-Wire Serial Interface in SOT23	Free Samples
MAX5380	Low-Cost, Low-Power, 8-Bit DACs with 2-Wire Serial Interface in SOT23	Free Samples
MAX5381	Low-Cost, Low-Power, 8-Bit DACs with 2-Wire Serial Interface in SOT23	Free Samples
MAX5383	Low-Cost, Low-Power, 8-Bit DACs with 3-Wire Serial Interface in SOT23	Free Samples
MAX5384	Low-Cost, Low-Power, 8-Bit DACs with 3-Wire Serial	Free Samples

	Interface in SOT23	
MAX5400	256-Tap SOT-PoT, Low-Drift Digital Potentiometers in SOT23	Free Samples
MAX5401	256-Tap SOT-PoT, Low-Drift Digital Potentiometers in SOT23	Free Samples
MAX5402	256-Tap, µPoT Low-Drift, Digital Potentiometer	Free Samples
MAX5422	256-Tap, Nonvolatile, SPI-Interface, Digital Potentiometers	Free Samples
MAX5427	32-Tap, One-Time Programmable, Linear-Taper Digital Potentiometers	Free Samples
MAX5427	32-Tap, One-Time Programmable, Linear-Taper Digital Potentiometers	Free Samples
MAX5428	32-Tap, One-Time Programmable, Linear-Taper Digital Potentiometers	Free Samples
MAX5429	32-Tap, One-Time Programmable, Linear-Taper Digital Potentiometers	Free Samples
MAX5437	±15V, 128-Tap, Low-Drift Digital Potentiometers	Free Samples
MAX5439	±15V, 128-Tap, Low-Drift Digital Potentiometers	Free Samples
MAX5456	Stereo Audio Taper Potentiometers with Pushbutton Interface	Free Samples
MAX5457	Stereo Audio Taper Potentiometers with Pushbutton Interface	Free Samples
MAX5460	32-Tap FleaPoT™, 2-Wire Digital Potentiometers	Free Samples
MAX5463	32-Tap FleaPoT™, 2-Wire Digital Potentiometers	Free Samples
MAX5466	32-Tap FleaPoT™, 2-Wire Digital Potentiometers	Free Samples
MAX5477	Dual, 256-Tap, Nonvolatile, I^2C-Interface, Digital Potentiometers	Free Samples
MAX5481	10-Bit, Nonvolatile, Linear-Taper Digital Potentiometers	Free Samples
MAX5490	100kΩ Precision-Matched Resistor-Divider in SOT23	Free Samples
MAX5491	Precision-Matched Resistor-Divider in SOT23	Free Samples
MAX5491	Precision-Matched Resistor-Divider in SOT23	Free Samples
MAX5492	10kΩ Precision-Matched Resistor-Divider in SOT23	Free Samples
MAX5547	Dual, 10-Bit, Current-Sink Output DAC	Free Samples
MAX5550	Dual, 10-Bit, Programmable, 30mA High-Output-Current DAC	Free Samples
MAX5774	32-Channel, 14-Bit, Voltage-Output DACs with Serial	Free Samples

	Interface	
MAX5873	12-Bit, 200Msps, High-Dynamic-Performance, Dual DAC with CMOS Inputs	Free Samples
MAX5874	14-Bit, 200Msps, High-Dynamic-Performance, Dual DAC with CMOS Inputs	Free Samples
MAX5875	16-Bit, 200Msps, High-Dynamic-Performance, Dual DAC with CMOS Inputs	Free Samples
MAX5876	12-Bit, 250Msps, High-Dynamic-Performance, Dual DAC with LVDS Inputs	Free Samples
MAX5877	14-Bit, 250Msps, High-Dynamic-Performance, Dual DAC with LVDS Inputs	Free Samples
MAX5878	16-Bit, 250Msps, High-Dynamic-Performance, Dual DAC with LVDS Inputs	Free Samples
MAX5893	12-Bit, 500Msps Interpolating and Modulating Dual DAC with CMOS Inputs	Free Samples
MAX5894	14-Bit, 500Msps, Interpolating and Modulating Dual DAC with CMOS Inputs	Free Samples
MAX5895	16-Bit, 500Msps Interpolating and Modulating Dual DAC with CMOS Inputs	Free Samples
MAX5898	16-Bit, 500Msps, Interpolating and Modulating Dual DAC with Interleaved LVDS Inputs	Free Samples
MAX6037	Low-Power, Fixed and Adjustable Reference with Shutdown in SOT23	Free Samples
MAX6143	High-Precision Voltage Reference with Temperature Sensor	Free Samples
MAX6143	High-Precision Voltage Reference with Temperature Sensor	Free Samples
MAX6160	SOT23, Low-Cost, Low-Dropout, 3-Terminal Voltage References	Free Samples
MAX6160	SOT23, Low-Cost, Low-Dropout, 3-Terminal Voltage References	Free Samples
MAX6173	High-Precision Voltage References with Temperature Sensor	Free Samples
MAX6173	High-Precision Voltage References with Temperature Sensor	Free Samples
MAX6174	High-Precision Voltage References with Temperature Sensor	Free Samples
MAX6175	High-Precision Voltage References with Temperature Sensor	Free Samples

MAX6176	High-Precision Voltage References with Temperature Sensor	Free Samples
MAX6177	High-Precision Voltage References with Temperature Sensor	Free Samples
MAX6220	Low-Noise, Precision, +2.5V/+4.096V/+5V Voltage Reference	Free Samples
MAX6220	Low-Noise, Precision, +2.5V/+4.096V/+5V Voltage Reference	Free Samples
MAX6225	Low-Noise, Precision, +2.5V/+4.096V/+5V Voltage References	Free Samples
MAX6225	Low-Noise, Precision, +2.5V/+4.096V/+5V Voltage References	Free Samples
MAX6241	Low-Noise, Precision, +2.5V/+4.096V/+5V Voltage References	Free Samples
MAX6250	Low-Noise, Precision, +2.5V/+4.096V/+5V Voltage References	Free Samples
MAX6325	1ppm/°C, Low-Noise, +2.5V/+4.096V/+5V Voltage References	Free Samples
MAX6341	1ppm/°C, Low-Noise, +2.5V/+4.096V/+5V Voltage References	Free Samples
MAX6350	1ppm/°C, Low-Noise, +2.5V/+4.096V/+5V Voltage References	Free Samples
MAX674	+10V Precision Voltage Reference	Free Samples
MAX6749	µP Reset Circuits with Capacitor-Adjustable Reset/Watchdog Timeout Delay	Free Samples
MAX675	Precision, 5V Voltage Reference, Replaced MAX673	Free Samples
MAX6752	µP Reset Circuits with Capacitor-Adjustable Reset/Watchdog Timeout Delay	Free Samples
MAX7375	3-Pin Silicon Oscillator	Free Samples
MAX7400	8th-Order, Lowpass, Elliptic, Switched-Capacitor Filters	Free Samples
MAX7401	8th-Order, Lowpass, Bessel, Switched-Capacitor Filters	Free Samples
MAX7403	8th-Order, Lowpass, Elliptic, Switched-Capacitor Filters	Free Samples
MAX7404	8th-Order, Lowpass, Elliptic, Switched-Capacitor Filters	Free Samples
MAX7405	8th-Order, Lowpass, Bessel, Switched-Capacitor Filters	Free Samples
MAX7407	8th-Order, Lowpass, Elliptic, Switched-Capacitor Filters	Free Samples
MAX7408	5th Order, Lowpass, Elliptic, Switched-Capacitor Filters	Free Samples

MAX7410	5th-Order, Lowpass, Switched-Capacitor Filters	Free Samples
MAX7411	5th Order, Lowpass, Elliptic, Switched-Capacitor Filters	Free Samples
MAX7412	5th Order, Lowpass, Elliptic, Switched-Capacitor Filters	Free Samples
MAX7413	5th-Order, Lowpass, Switched-Capacitor Filters	Free Samples
MAX7414	5th-Order, Lowpass, Switched-Capacitor Filters	Free Samples
MAX7415	5th Order, Lowpass, Elliptic, Switched-Capacitor Filters	Free Samples
MAX7418	5th-Order, Lowpass, Switched-Capacitor Filters	Free Samples
MAX7418	5th-Order, Lowpass, Switched-Capacitor Filters	Free Samples
MAX7419	5th-Order, Lowpass, Switched-Capacitor Filters	Free Samples
MAX7419	5th-Order, Lowpass, Switched-Capacitor Filters	Free Samples
MAX7420	5th-Order, Lowpass, Switched-Capacitor Filters	Free Samples
MAX7421	5th-Order, Lowpass, Switched-Capacitor Filters	Free Samples
MAX7490	Dual Universal Switched-Capacitor Filters	Free Samples
MAX7490	Dual Universal Switched-Capacitor Filters	Free Samples
MAX7491	Dual Universal Switched-Capacitor Filters	Free Samples
MAX9205	10-Bit Bus LVDS Serializers	Free Samples
MAX9206	10-Bit Bus LVDS Deserializers	Free Samples
MAX9207	10-Bit Bus LVDS Serializers	Free Samples
MAX9208	10-Bit Bus LVDS Deserializers	Free Samples
REF01	+5V, +10V Precision Voltage References	Free Samples
REF02	+5V, +10V Precision Voltage References	Free Samples

More Information
For Technical Support: http://www.maximintegrated.com/support
For Samples: http://www.maximintegrated.com/samples
Other Questions and Comments: http://www.maximintegrated.com/contact

Application Note 4993: http://www.maximintegrated.com/an4993
TUTORIAL 4993, AN4993, AN 4993, APP4993, Appnote4993, Appnote 4993