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APPLICATION NOTE 4490

How Signal Chains and PLCs Impact Our Lives

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Abstract: It is incredible how many programmable logic controls (PLCs) around us make our modern life possible and pleasant. Machines in our homes heat and cool our air and water, as well as preserve and cook our food. This tutorial explains the importance of PLCs, and describes how to choose component parts using the parametric tools on the Maxim's website.

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Introduction

Automation by closed-loop signal-chain control is everywhere. It makes our homes more pleasant. It gives automobiles the ever-widening range of functions that goes beyond the freedom to travel. It is, in fact, quite astounding to look around and realize that so many of the today's products are manufactured with the help a closed-loop signal chain. It is also important to note that in industrial plants and factories, a more complex form of a signal chain is called a programmable logic controller (PLC). In this tutorial, we will see that signal-chain and PLC applications are limited only by our imaginations.

Signal Chains All Around You

Signal chains surround us. They make our modern life possible and pleasant. In fact, an application with a signal chain appears anytime one needs a control loop to monitor, manage, handle, regulate, limit, or organize something.

Machines using signal chains heat and cool air and water in our homes. They chill and cook our food. In industry almost everything that we buy is manufactured utilizing signal chains. Think of your automobile. (Yes, most of us jump into our cars without thinking. We drive our automobiles to work and some people drive using the "bang-bang" approach. This is not the bang-bang servo that we discuss in the Appendix, but actually hitting things.) Automotive antilock brakes, cruise controls, automatic transmissions, and traction controls are examples of signal-chain uses.

A Basic Signal Chain Controls with Feedback

How simple can a signal chain or process control be? Consider a common household oven and an electronic control unit (ECU) in an automobile.

The oven's components are enclosed inside one container, so no long-distance communication is necessary. When the user sets the thermostat to the desired temperature, the oven maintains the internal temperature at the set point (**Figure 1**).

The smell of cookies in the oven brings back pleasant memories.

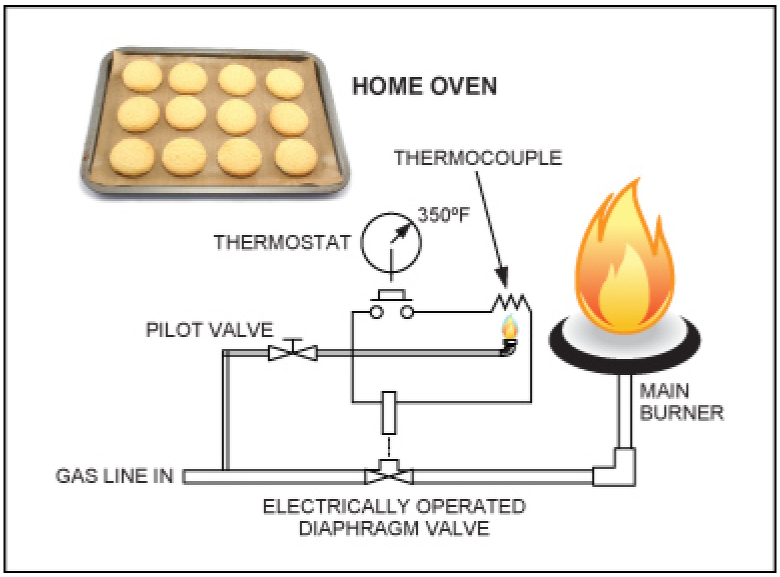

Figure 1. A household oven is a simple example of a signal chain or process feedback control.

When the thermostat setting senses that the oven temperature is low, the switch is closed, thus completing the circuit to open the gas valve to the main burner. Once the thermostat detects that the oven has reached the set point, the switch opens, the gas valve closes, and the main burner shuts off. The cycle repeats as needed. The pilot light provides a fail-safe function, while also providing an ignition source for the main burner. If the pilot light were to go out, no voltage would be created by the thermocouple so the main valve would not open.

Modern high-end cars can have up to 80 ECUs. They control engines, antilock brakes, cruise controls, automatic transmissions, and traction. Most ECUs are examples of signal chains because they sense one or more physical parameters, apply a logic or intelligence, and produce an action to benefit the consumer. (See the block diagram of signal-chain feedback in **Figure 2**). **Table 1** outlines the signal-chain functions for various automotive applications.

Table 1. Signal-Chain Applications in an Automobile

Application	Parameters Sensed	Logic or Intelligence	Actions	Benefits
Engine control	Temperature, air mass; fuel volume; engine speed and rotation angle; throttle position; engine load	Optimizes multiple sensor inputs for conditions and maximum benefits	Controls air/fuel ratio, ignition timing, idle speed, variable-valve timing	Better fuel economy; reduced engine emissions; longer engine life; best power when needed
Antilock brakes	Vehicle speed; wheel speed; brake pressure	Compares wheel speeds during breaking to identify skidding	Controls valves and pumps	Increases driver control; decreases stopping distance under most adverse conditions
Cruise control	Vehicle speed; engine speed; brake switch	Sets and maintains vehicle speed through changing conditions	Adjusts throttle position	Better fuel economy; driver comfort
Automatic transmissions	Throttle position; engine load; kick-down switch; vehicle speed, wheel speed; torque convertor slip	Optimizes multiple sensor inputs for conditions	Controls shifting; fast under power to minimize band and clutch wear; slow for passenger comfort under lower power loading	Better fuel economy; increased transmission life; better vehicle handling; faster shift speed
		Compares	Reduces engine	

Traction control	Throttle position; engine load; vehicle speed; wheel speed	throttle vehicle and wheel for varying road-surface conditions	power by removing fuel or spark from cylinder(s) or changing throttle position; applies brakes on one or more wheels	Reduces traction loss on acceleration, enhancing driver control

Signal chains are also used for other automotive safety and convenience systems: infotainment; parking assist; airbags; seat belts; door locks; electric windows; running, courtesy, head, and tail lights; power steering; heating; air conditioning; seat control; and telephone...to name a few.

The Difference Between a Signal Chain and a PLC

A signal chain system that goes beyond what is needed for such a small, simple system like a household oven is called a PLC. Recalling that "signal chains are all around you," think next of an industrial factory. What controls and configurations are necessary in a factory? In a fully automated bakery, for example, many subsystems are needed such as weigh scales, valves, flow gauges, mixers, yeast-rising warming chambers, ovens, conveyer belts, fans, and packaging equipment. To be fully automated, the bakery needs a process-control system to manage and coordinate all of the time-critical events among these subsystems. To ensure successful coordination and operation for all these operations, each of these subsystems would include one or more PLCs. Even more complex communications are required when the controllers and the controlled elements are separated by a significant distance. In a complex control environment like a factory with operations spread among several buildings or sites, a PLC spends significant time communicating signals and process events to components throughout the system.

This leads us to the most important difference between a PLC and a signal chain: a PLC makes process change easy. We can illustrate this with a short digression into the history of automation in an automotive factory. An automotive company's strategy to manage change resulted in a PLC.

The Invention of a PLC

Factory automation took hold in the automotive industry when Henry Ford[1] expanded mass-production techniques early in the Twentieth Century. He used fixed assembly stations with the cars moving between positions. The employees learned just a few assembly tasks and performed those tasks for days on end. After many years the changeover for a new car model became very costly and time consuming. The production process was controlled by thousands of hard-wired relays, switches, cam and drum timers, and dedicated closed-loop controllers. To retool for the next model required electricians to mechanically rewire all of the thousands of relays. And then the troubleshooting began to ensure that the safety interlocks, control, and sequencing were all correct.

It was this need to manage the seemingly constant change that resulted in the invention of the PLC. In 1968 Dick Morely and his company were designing a new invention, a programmable controller. Meanwhile General Motors®, (GM®) the automobile company, "wanted a solid-state controller as an electronic replacement for hard-wired relay systems."[2] GM asked Morley for a quotation to solve their issue. Mr. Morely responded. He is now regarded as the father of the PLC and holds a patent on it.[3]

GM first used a PLC to assemble automobile automatic transmissions. An assembly plant is made of hundreds of machines that need to be coordinated to function smoothly. The PLC allowed the production line to be repurposed easily. Now a reprogrammed basic machine could be reused to produce a new part.

We can illustrate the pivotal importance of this evolution by focusing on one machine, a numerically controlled (NC) milling machine, and by comparing the old control system with a PLC. First, a human loaded a bare piece of metal on the cutting table and locked it down. Several switches verified that the metal was in the proper position. The operator then indicated that his body was out of danger by pushing two widely spaced buttons, one with each hand. A mechanical guard extended to protect the operator from flying metal shavings. Finally, multiple cutters sculpted the metal in a precise sequence. When the part was complete the mill retracted the tools, stopped all movements, and opened the guard so the human could remove the part and replace it with a new metal blank. Before the PLC, each of these small steps in the operation was hard wired with relays, timers, limit and position switches. It worked reliably...until one needed to make even a small change. The worst possible situation was when a new step needed to be added in the middle of the sequence. Someone might need to unwire all the steps after the new step, add the new step (a hardware relay or timer), and rewire everything that followed.

Enter the PLC. With a PLC that same milling machine becomes a general tool that is controlled and quickly changed a software or logic change. Changing a tool and giving it new instructions now allowed the basic mill to make many different parts. By extending this to the many machines in a factory, an automotive assembly line or other factory quickly adapted to change.

Today you find PLCs used in a modern factories, including an automotive assembly line. Similarly, a chemical, food, or cosmetic company may have to mix many different formulas to make their products. Without the PLC and its easy-to-reconfigure logic, manufacturing changes would still be cumbersome and costly. Many of the items that are common in our lives would be unaffordable.

We use PLCs in our daily lives more than each of us realizes. For other family-oriented examples, see the Appendix.

Factory Automation, Control, and Monitoring

There are areas in a factory that are too dangerous for humans. Fortunately, we have the brains and ability to use machines, and we let a PLC (Figure 2) control those machines.

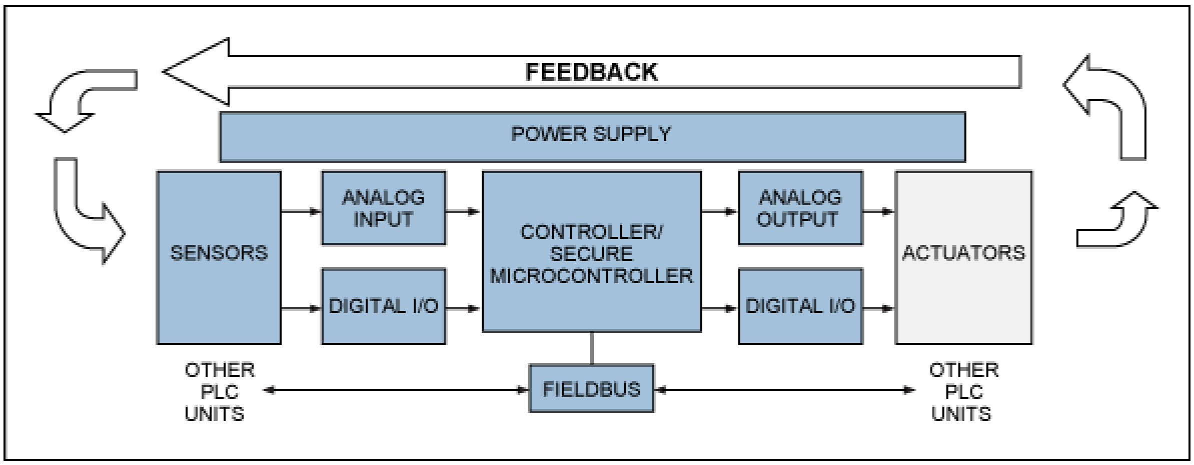

Figure 2. Diagram of a simple, common signal-chain and PLC loop used in many product disciplines.

Table 2 summarizes how PLC and signal-chain basics begin once we sense something, usually a physical parameter. Then PLC and signal-chain applications become so numerous and commonplace that we take many of their functions for granted.

Table 2. Measured Parameters that Provide PLC Inputs

Dimensions	Pitch	Position
Intensity	Energy	Pressure
Impedance	Temperature	Humidity
Density	Speed	Frequency
Viscosity	Time of flight	Phase
Velocity	Distance	Time
Acceleration	Pressure	Salinity
Water purity	Torque	Volume
Weight	State of charge	Gasses
Mass	Conductivity	Ph
Resistance	Dissolved oxygen	Voltage
Capacitance	Ion concentration	Current
Inductance	Chemicals	Level
Rotation	Charge (electrons)	Color

On the output side of a signal chain or PLC, we monitor a system or we operate or move something. **Table 3** shows things monitored or controlled by a PLC.

Table 3. Things Monitored/Controlled by a PLC Output

Valve	Pressure	Switch
Motor	Humidity	Solenoid
Pressure	Force feedback	Lights
Velocity	Room entry	Weight
Flow	Sequence	Speed
Volume	Authorization	Meters
Torque	Attenuation	Display
Frequency	Equalization	Calibration
Voltage	Communication	Time
Current	Gain offset	Tool
Distance	Flux density	Pitch

Position	Temperature	Filter
Power	Galvanometers	Acceleration
Brightness	Air-fuel ration	Contrast

Maxim's portfolio is second to none, especially for portable and green energy devices where low-power consumption is critical. Small size is also necessary in such battery-operated devices. Find more information and recommended parts using Maxim's PLC solutions. With new parts appearing on the website daily, the parametric search tool helps engineers select exactly the right part based on electrical criteria.

For example, on the Data Converters Product Page you see a selection of resolutions. Choosing a 12-bit DAC causes the parameter table to be displayed for over 250 parts with 20 parameters (10 less-used parameters are hidden on the left). To use the tables, first click on the "Hidden Columns;" select ICC (mA); click "Hidden Columns;" select ICC (mA); click "Smallest Available Package (mm²)." Now move the slider under ICC (mA) to < 1mA and move the slider under Smallest Available Package (mm²). This shortens the list to over 70 parts. Continue selecting the number of channels, power-on reset (POR) state, output type, and interface to reduce the selection to a manageable numbers of parts and data sheets.

There is another example of the easy-to-use web functions for parts selection. Return to the home page (click the Maxim logo at the upper left of most pages). Mouse over "Power Management" in the left column and select "Voltage References." Now you can select a voltage, or "low power" or "small package" to see featured products.

Need more help? We have field support with Maxim and distribution sales and field application engineers worldwide.

Conclusion

Control-loop signal chains or PLCs, in relatively simple or complex applications, are found all around us. They heat and cool, and keep a temperature constant in any structure, regardless of size. Signal chains monitor and control antilock brakes, cruise controls, automatic transmissions, and traction controls in automobiles. Many household appliances today contain a signal chain. We spoke about an oven, but the list is seemingly endless: the microwave; washers and dryers; and even the lawn sprinkler that can sense ground moisture and regulate water use. Finally, it is important to remember that all these goods are produced in a factory where a PLC monitors and controls most every electronic system that operates or moves.

References

1. For more information on Henry Ford and factory automation of automobiles, you can start here (http://en.wikipedia.org/wiki/Assembly_line).
2. Dunn, Allison, "The father of invention: Dick Morley looks back on the 40th anniversary of the PLC," Manufacturing Automation Magazine, September 12, 2008, www.automationmag.com/features/the-father-of-invention-dick-morley-looks-back-on-the-40th-anniversary-of-the-plc.html.
3. Dick Morley is known as the "father" of the PLC. His US Patent 3,761,893 is the basis of many PLCs today. http://patft.uspto.gov/netahtml/PTO/srchnum.htm.

Appendix: More PLCs in the Home

In a home, my home, we use a PLC in the crudest possible way. We have a "bang-bang servo," which is basically an old-fashioned human intervention for our heating, ventilating, and air-conditioning (HVAC) system. Bang-bang servos work because the system has a bandwidth so incredibly low that things change over minutes and hours. The thermal inertia of the walls, floor, and ceiling in our homes is very high, so a simple on/off thermostat controls heating and the air conditioning. Meanwhile, ventilation uses the most expensive and complex servo loop possible: a whole house fan pulls in air through open doors and windows and then exhausts it through the attic. The servo is very complex because it operates on human intervention. During the day we choose to use the fan instead of air conditioning to save energy. A timer turns the fan off at which time we have to shut the doors and windows.

Operation of the heating and air-conditioning control system is, theoretically, simpler than the bang-bang method above, but humans can complicate anything. The system is controlled by a bimetallic thermostat; the heater runs until the set point is exceeded. The heater turns off until the bimetallic strip cools and then the heater goes back on and repeats the cycle. The opposite happens for cooling. Depending on the weather, the heat loss or gain in the house changes the duty cycle of the on- and off-times. It is simple and reliable.

So much for theory of operation...humans have a propensity to complicate even the simplest systems with unexpected and often comical consequences. We replaced the old natural gas-fired forced-air heater with a modern high-efficiency furnace. This did two great things: it got me a lot of points with my wife because the new furnace fits entirely in the attic crawl space; and we have the prospect of saving money over time. The old furnace used a metal pipe to exhaust the very hot combustion products. The new one is a condensing furnace with the exhaust through a plastic pipe, and the air is just warm to the touch. At the same time we installed a more efficient air conditioner and a new thermostat. The new thermostat works well, but it is our human sensibilities that are skewed. First, it is digital, has a microprocessor and a real-time clock (RTC). It has many modes, more than we ever use. Now I have to learn how to program it. (My wife does not program it because she put it on my task list.) Second, placebos have powerful effects on humans. The old thermostat had hysteresis. It might have been as large as three or four degrees but we did not know and did not care. Now we both peek at the display as we walk past and get a silly, knowing smile.

Related Parts		
MAX1391	1.5V to 3.6V, 416ksps, 1-Channel True-Differential/2-Channel Single-Ended, 8-Bit, SAR ADCs	Free Samples
MAX1393	1.5V to 3.6V, 312.5ksps, 1-Channel True-Differential/2-Channel Single-Ended, 12-Bit, SAR ADCs	Free Samples
MAX501	Voltage-Output, 12-Bit Multiplying DACs	Free Samples
MAX502	Voltage-Output, 12-Bit Multiplying DACs	Free Samples
MAX507	Voltage-Output, 12-Bit DAC with Internal Reference and	Free Samples

	12-Bit Interface	
MAX508	Voltage-Output, 12-Bit DAC with Internal Reference and 12-Bit Interface	Free Samples
MAX5104	Low-Power, Dual, Voltage-Output, 12-Bit DAC with Serial Interface	Free Samples
MAX5120	+3V/+5V, 12-Bit, Serial, Voltage-Output DACs with Internal Reference	Free Samples
MAX5121	+3V/+5V, 12-Bit, Serial, Voltage-Output DACs with Internal Reference	Free Samples
MAX5122	+5V/+3V, 12-Bit, Serial, Force/Sense DACs with 10ppm/°C Internal Reference	Free Samples
MAX5123	+5V/+3V, 12-Bit, Serial, Force/Sense DACs with 10ppm/°C Internal Reference	Free Samples
MAX5123	+5V/+3V, 12-Bit, Serial, Force/Sense DACs with 10ppm/°C Internal Reference	Free Samples
MAX5130	+3V/+5V, 13-Bit, Serial, Voltage-Output DACs with Internal Reference	Free Samples
MAX5131	+3V/+5V, 13-Bit, Serial, Voltage-Output DACs with Internal Reference	Free Samples
MAX5132	+5V/+3V, 13-Bit, Serial, Force/Sense DACs with 10ppm/°C Internal Reference	Free Samples
MAX5133	+5V/+3V, 13-Bit, Serial, Force/Sense DACs with 10ppm/°C Internal Reference	Free Samples
MAX5134	Pin-/Software-Compatible, 16-/12-Bit, Voltage-Output DACs	Free Samples
MAX5134A	Pin-/Software-Compatible, 16-/12-Bit, Voltage-Output DACs	Free Samples
MAX5135	Pin-/Software-Compatible, 16-/12-Bit, Voltage-Output DACs	Free Samples
MAX5136	Pin-/Software-Compatible, 16-/12-Bit, Voltage-Output DACs	Free Samples
MAX5137	Pin-/Software-Compatible, 16-/12-Bit, Voltage-Output DACs	Free Samples
MAX5138	Low-Power, Single, 16-/12-Bit, Buffered Voltage-Output DACs	Free Samples
MAX5139	Low-Power, Single, 16-/12-Bit, Buffered Voltage-Output DACs	Free Samples
MAX514	CMOS Quad, 12-Bit, Serial-Input Multiplying DAC	Free Samples

MAX5141	+3V/+5V, Serial-Input, Voltage-Output, 14-Bit DACs	Free Samples
MAX5142	+3V/+5V, Serial-Input, Voltage-Output, 14-Bit DACs	Free Samples
MAX5143	+3V/+5V, Serial-Input, Voltage-Output, 14-Bit DACs	Free Samples
MAX5144	+3V/+5V, Serial-Input, Voltage-Output, 14-Bit DACs	Free Samples
MAX5150	Low-Power, Dual, 13-Bit Voltage-Output DACs with Serial Interface	Free Samples
MAX5151	Low-Power, Dual, 13-Bit Voltage-Output DACs with Serial Interface	
MAX5152	Low-Power, Dual, 13-Bit Voltage-Output DACs with Configurable Outputs	Free Samples
MAX5153	Low-Power, Dual, 13-Bit Voltage-Output DACs with Configurable Outputs	Free Samples
MAX5154	Low-Power, Dual, 12-Bit Voltage-Output DACs with Serial Interface	Free Samples
MAX5155	Low-Power, Dual, 12-Bit Voltage-Output DACs with Serial Interface	Free Samples
MAX5156	Low-Power, Dual, 12-Bit Voltage-Output DACs with Configurable Outputs	Free Samples
MAX5157	Low-Power, Dual, 12-Bit Voltage-Output DACs with Configurable Outputs	Free Samples
MAX5170	Low-Power, Serial, 14-Bit DACs with Voltage-Output	Free Samples
MAX5171	Low-Power, Serial, 14-Bit DACs with Force-Sense Voltage-Output	Free Samples
MAX5172	Low-Power, Serial, 14-Bit DACs with Voltage-Output	Free Samples
MAX5173	Low-Power, Serial, 14-Bit DACs with Force-Sense Voltage-Output	Free Samples
MAX5174	Low-Power, Serial, 12-Bit DACs with Voltage-Output	Free Samples
MAX5175	Low-Power, Serial, 12-Bit DACs with Force-Sense Voltage-Output	Free Samples
MAX5176	Low-Power, Serial, 12-Bit DACs with Voltage-Output	Free Samples
MAX5177	Low-Power, Serial, 12-Bit DACs with Force-Sense Voltage-Output	Free Samples
MAX5200	Low-Cost, Voltage-Output, 16-Bit DACs with Internal Reference in µMAX	Free Samples
MAX5201	Low-Cost, Voltage-Output, 16-Bit DACs with Internal Reference in µMAX	Free Samples
MAX5202	Low-Cost, Voltage-Output, 16-Bit DACs with Internal	Free Samples

	Reference in µMAX	
MAX5203	Low-Cost, Voltage-Output, 16-Bit DACs with Internal Reference in µMAX	Free Samples
MAX5204	Low-Cost, Voltage-Output, 16-Bit DACs in µMAX	Free Samples
MAX5205	Low-Cost, Voltage-Output, 16-Bit DACs in µMAX	Free Samples
MAX5206	Low-Cost, Voltage-Output, 16-Bit DACs in µMAX	Free Samples
MAX5207	Low-Cost, Voltage-Output, 16-Bit DACs in µMAX	Free Samples
MAX5230	3V/5V, 12-Bit, Serial Voltage-Output Dual DACs with Internal Reference	Free Samples
MAX5231	3V/5V, 12-Bit, Serial Voltage-Output Dual DACs with Internal Reference	Free Samples
MAX5234	Single-Supply 3V/5V, Voltage-Output, Dual, Precision 12-Bit DACs	Free Samples
MAX5235	Single-Supply 3V/5V, Voltage-Output, Dual, Precision 12-Bit DACs	Free Samples
MAX525	Low-Power, Quad, 12-Bit Voltage-Output DAC with Serial Interface	Free Samples
MAX5253	+3V, Quad, 12-Bit Voltage-Output DAC with Serial Interface	Free Samples
MAX526	Calibrated, Quad, Voltage-Output, 12-Bit DAC	Free Samples
MAX5264	Octal, 14-Bit, Voltage-Output DAC with Parallel Interface for ATE	
MAX527	Calibrated, Quad, Voltage-Output, 12-Bit DAC	Free Samples
MAX5270A	Octal, 13-Bit Voltage-Output DAC with Parallel Interface	
MAX5270B	Octal, 13-Bit Voltage-Output DAC with Parallel Interface	
MAX5290	Buffered, Fast-Settling, Dual, 12-/10-/8-Bit, Voltage-Output DACs	Free Samples
MAX5291	Buffered, Fast-Settling, Dual, 12-/10-/8-Bit, Voltage-Output DACs	Free Samples
MAX530	+5V, Low-Power, Parallel-Input, Voltage-Output, 12-Bit DAC	Free Samples
MAX5302	Low-Power, 12-Bit Voltage-Output DAC with Serial Interface	Free Samples
MAX5306	Low-Power, Low-Glitch, Octal 12-Bit Voltage-Output DACs with Serial Interface	Free Samples
MAX5307	Low-Power, Low-Glitch, Octal 12-Bit Voltage-Output DACs with Serial Interface	Free Samples

MAX531	+5V, Low-Power, Voltage-Output, Serial 12-Bit DACs	Free Samples
MAX5312	±10V, 12-Bit, Serial, Voltage-Output DAC	Free Samples
MAX532	Dual, Serial Input, Voltage-Output, Multiplying, 12-Bit DAC	Free Samples
MAX5322	±10V, Dual, 12-Bit, Serial, Voltage-Output DAC	Free Samples
MAX535	Low-Power, 13-Bit Voltage-Output DACs with Serial Interface	Free Samples
MAX5351	Low-Power, 13-Bit Voltage-Output DACs with Serial Interface	Free Samples
MAX5352	Low-Power, 12-Bit Voltage-Output DACs with Serial Interface	Free Samples
MAX5353	Low-Power, 12-Bit Voltage-Output DACs with Serial Interface	Free Samples
MAX536	Calibrated, Quad, 12-Bit Voltage-Output DACs with Serial Interface	Free Samples
MAX537	Calibrated, Quad, 12-Bit Voltage-Output DACs with Serial Interface	Free Samples
MAX538	+5V, Low-Power, Voltage-Output, Serial 12-Bit DACs	Free Samples
MAX539	+5V, Low-Power, Voltage-Output, Serial 12-Bit DACs	Free Samples
MAX5403	Dual, 256-Tap, Low-Drift, Digital Potentiometers in 10-µMAX	Free Samples
MAX5405	Dual, 256-Tap, Low-Drift, Digital Potentiometers in 10-µMAX	Free Samples
MAX541	+5V, Serial-Input, Voltage-Output 16-Bit DACs	Free Samples
MAX542	+5V, Serial-Input, Voltage-Output 16-Bit DACs	Free Samples
MAX5420	Digitally Programmable Precision Voltage Divider for PGAs	Free Samples
MAX5421	Digitally Programmable Precision Voltage Divider for PGAs	Free Samples
MAX543	Serial, CMOS, Multiplying, 12-Bit DAC in 8-Pin Package	Free Samples
MAX544	+5V, Serial Input, Voltage-Output 14-Bit DACs	Free Samples
MAX5441	+3V/+5V, Serial-Input, Voltage-Output, 16-Bit DACs	Free Samples
MAX5442	+3V/+5V, Serial-Input, Voltage-Output, 16-Bit DACs	Free Samples
MAX5443	+3V/+5V, Serial-Input, Voltage-Output, 16-Bit DACs	Free Samples
MAX5444	+3V/+5V, Serial-Input, Voltage-Output, 16-Bit DACs	Free Samples

MAX545	+5V, Serial Input, Voltage-Output 14-Bit DACs	Free Samples
MAX547	Octal, 13-Bit Voltage-Output DAC with Parallel Interface	Free Samples
MAX5500	Low-Power, Quad, 12-Bit Voltage-Output DACs with Serial Interface	Free Samples
MAX551	+3V/+5V, 12-Bit, Serial, Multiplying DACs in 10-Pin µMAX Package	Free Samples
MAX552	+3V/+5V, 12-Bit, Serial, Multiplying DACs in 10-Pin µMAX Package	Free Samples
MAX5530	Ultra-Low-Power, 12-Bit, Voltage-Output DACs	Free Samples
MAX5531	Ultra-Low-Power, 12-Bit, Voltage-Output DACs	Free Samples
MAX5532	Dual, Ultra-Low-Power, 12-Bit, Voltage-Output DACs	Free Samples
MAX5533	Dual, Ultra-Low-Power, 12-Bit, Voltage-Output DACs	Free Samples
MAX5534	Dual, Ultra-Low-Power, 12-Bit, Voltage-Output DACs	Free Samples
MAX5535	Dual, Ultra-Low-Power, 12-Bit, Voltage-Output DACs	Free Samples
MAX5541	Low-Cost, +5V, Serial-Input, Voltage-Output, 16-Bit DAC	Free Samples
MAX5544	Low-Cost, +5V, Serial-Input, Voltage-Output, 14-Bit DAC	Free Samples
MAX5580	Buffered, Fast-Settling, Quad, 12-/10-/8-Bit, Voltage-Output DACs	Free Samples
MAX5581	Buffered, Fast-Settling, Quad, 12-/10-/8-Bit, Voltage-Output DACs	Free Samples
MAX5590	Buffered, Fast-Settling, Octal, 12/10/8-Bit, Voltage-Output DACs	Free Samples
MAX5591	Buffered, Fast-Settling, Octal, 12/10/8-Bit, Voltage-Output DACs	Free Samples
MAX5621	16-Bit DACs with 16-Channel Sample-and-Hold Outputs	Free Samples
MAX5631	16-Bit DACs with 32-Channel Sample-and-Hold Outputs	
MAX5632	16-Bit DACs with 32-Channel Sample-and-Hold Outputs	Free Samples
MAX5633	16-Bit DACs with 32-Channel Sample-and-Hold Outputs	
MAX5661	Single 16-Bit DAC with Current and Voltage Outputs for Industrial Analog Output Modules	Free Samples
MAX5712	12-Bit, Low-Power, Rail-to-Rail Voltage-Output Serial DAC in SOT23	Free Samples
MAX5722	12-Bit, Low-Power, Dual, Voltage-Output DAC with Serial Interface	Free Samples
MAX5732	32-Channel, 16-Bit, Voltage-Output DACs with Serial Interface	Free Samples

MAX5733	32-Channel, 16-Bit, Voltage-Output DACs with Serial Interface	Free Samples
MAX5734	32-Channel, 16-Bit, Voltage-Output DACs with Serial Interface	Free Samples
MAX5735	32-Channel, 16-Bit, Voltage-Output DACs with Serial Interface	Free Samples
MAX5742	12-Bit, Low-Power, Quad, Voltage-Output DAC with Serial Interface	Free Samples
MAX5762	32-Channel, 16-Bit, Voltage-Output DACs with Serial Interface	
MAX5764	32-Channel, 16-Bit, Voltage-Output DACs with Serial Interface	
MAX5773	32-Channel, 14-Bit, Voltage-Output DACs with Serial Interface	
MAX5774	32-Channel, 14-Bit, Voltage-Output DACs with Serial Interface	Free Samples
MAX5775	32-Channel, 14-Bit, Voltage-Output DACs with Serial Interface	
MAX5812	12-Bit Low-Power, 2-Wire, Serial Voltage-Output DAC	Free Samples
MAX5822	Dual, 12-Bit, Low-Power, 2-Wire, Serial Voltage-Output DAC	Free Samples
MAX5839A	Octal, 13-Bit Voltage-Output DAC with Parallel Interface	
MAX5839B	Octal, 13-Bit Voltage-Output DAC with Parallel Interface	
MAX5842	Quad, 12-Bit, Low-Power, 2-Wire, Serial Voltage-Output DAC	Free Samples
MAX6033	Ultra-High-Precision SOT23 Series Voltage Reference	
MAX6126	Ultra-High-Precision, Ultra-Low-Noise, Series Voltage Reference	Free Samples
MAX9910	200kHz, 4µA, Rail-to-Rail I/O Op Amps with Shutdown	Free Samples
MAX9913	200kHz, 4µA, Rail-to-Rail I/O Op Amps with Shutdown	Free Samples
MAX9914	1MHz, 20µA, Rail-to-Rail I/O Op Amps with Shutdown	Free Samples
MAX9917	1MHz, 20µA, Rail-to-Rail I/O Op Amps with Shutdown	Free Samples
MX7245	Complete, 12-Bit, Voltage-Output Multiplying DAC	
MX7248	Complete, 12-Bit, Voltage-Output Multiplying DAC	
MX7521	CMOS, 14- and 12-Bit Multiplying DACs	Free Samples
MX7531	CMOS, 10-Bit Multiplying DAC	Free Samples

MX7534	Microprocessor-Compatible, 14-Bit DACs	Free Samples
MX7535	Microprocessor-Compatible, 14-Bit DACs	Free Samples
MX7536	µP-Compatible, 14-Bit DAC	Free Samples
MX7537	CMOS, Parallel Loading, Dual, 12-Bit Multiplying DAC	
MX7538	CMOS, µP-Compatible, 14-Bit DAC	Free Samples
MX7541	CMOS, 12-Bit Multiplying DAC	
MX7541A	CMOS, 12 Bit Multiplying D/A Converter	Free Samples
MX7542	CMOS, 12-Bit, µP-Compatible DAC	Free Samples
MX7543	CMOS, 12-Bit, Serial-Input DAC	Free Samples
MX7545	CMOS, Buffered, 12-Bit Multiplying DAC	Free Samples
MX7545A	CMOS 12-Bit Buffered Multiplying DACs	Free Samples
MX7547	CMOS, Parallel Loading, Dual, 12-Bit Multiplying DAC	Free Samples
MX7548	CMOS, 8-Bit-Compatible, 12-Bit DAC	Free Samples
MX7837	Complete, Dual, 12-Bit Multiplying DAC with 8-Bit Bus Interface	Free Samples
MX7839	Octal, 13-Bit Voltage-Output DAC with Parallel Interface	
MX7841	Octal, 14-Bit Voltage-Output DAC with Parallel Interface	
MX7845	Complete, 12-Bit Multiplying DAC	Free Samples
MX7847	Complete, Dual, 12-Bit Multiplying DAC with 8-Bit Bus Interface	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 4490: http://www.maximintegrated.com/an4490
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