WHITE PAPER

Vijay Choudhary
Applications Engineer
Texas Instruments

TEXAS INSTRUMENTS

Wide V_{IN} power management ICs simplify design, reduce BOM cost, and enhance reliability

Introduction

Wide input rails are common in many electronic systems including communications infrastructure, automotive, and industrial systems. Input voltages as high as 100V need to be converted to 24V/12V/5V or other lower voltages that can be used by electronic systems. A typical solution for creating one or more low-voltage rails consists of a low-voltage integrated controller with additional drivers, FETs, and sometimes transformers. A high step-down ratio sometimes involves more than one power stage.

Increasingly, wide input voltage power management integrated circuits (ICs) that combine features previously available only at lower voltages are now available from many vendors at competitive prices. High-voltage power management ICs, such as TI's LM5000 series of integrated controllers and regulators, can simplify the design of high-voltage power management solutions. This paper presents various application scenarios where high-voltage capability up to 100V is required and explains how high-voltage power management integrated circuits can reduce component count, enhance reliability, and facilitate design reuse. Real world circuit examples from communication infrastructure, industrial, automotive, and consumer electronic systems demonstrate the potential benefits.

Operating voltage ratings

Power management ICs are available in various voltage ratings and have been available in lower voltage ratings for some time. Each new generation increases integration and drives down cost. Major analog vendors are building high-voltage custom processes where multiple voltage ratings can be achieved in the same process. Using different doping concentrations and clearance, more integrated features are becoming available at higher input voltages and at a competitive price.

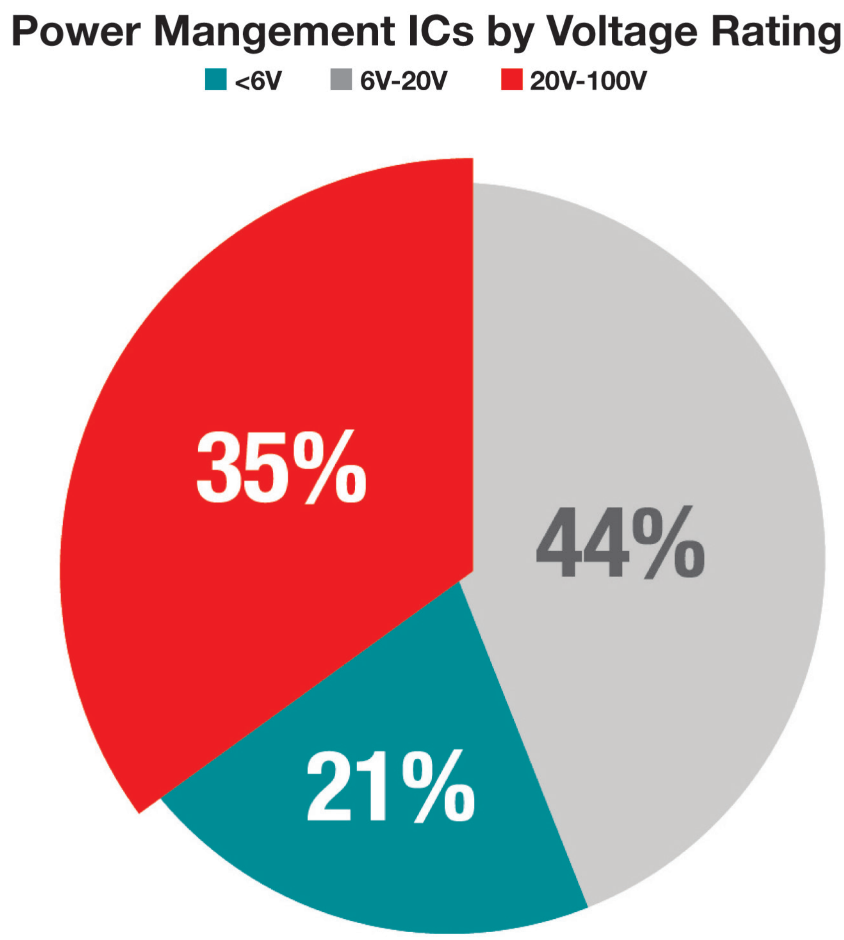


Figure 1. 35% of power management ICs (controllers and regulators) are rated above 20V. (Source: 2012 Databeans Incorporated)

Motivations for using Wide V_{IN} voltage integrated ICs

More than 35% of power management ICs currently in use handle an input range above 20V and wide input voltage range is common in industrial, automotive, and communications infrastructure systems. Even for many 12V and 24V systems, transient conditions approaching 100V are not uncommon and need to be considered. Systems that require high voltage (up to 100V) fall in three groups: 1) those that must operate at high-input voltages; 2) those that need to be protected against high-input voltages; and 3) many where the high voltage is desired for extra margin of safety and system robustness.

The first group consists of systems that need to operate properly at high-input voltages (40V-100V). Examples of high-voltage systems include Power over Ethernet (POE) line range of 37V-57V, and a 48V communication bus with a range of 36V-75V. This is where the high-voltage ICs have maximum impact. High-voltage ICs replace multiple discrete elements, and sometimes transformers that characterize the non-isolated supplies operating from high voltage. One example circuit operating from a 36V-72V line voltage is shown in *Figure 2*. The lower output voltage is used by driver and controller circuits.

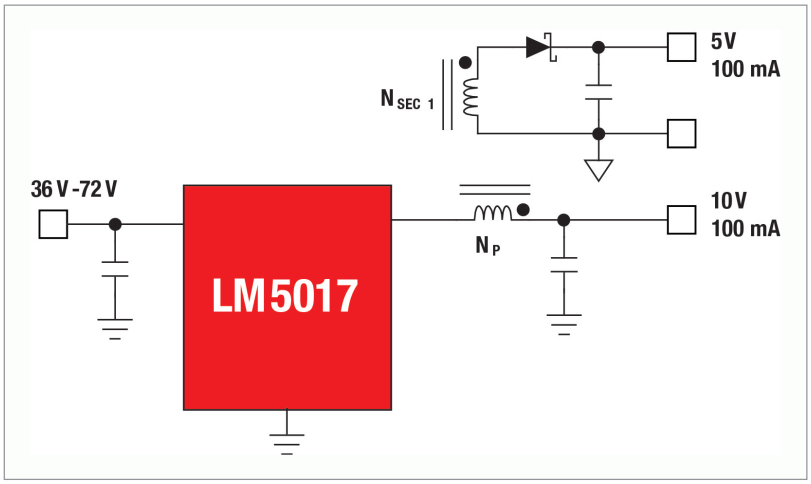


Figure 2. A Wide V_{IN}, multi-output converter operates from a wide-input range and reduces component count, when compared to discrete controller FET circuits.

The second group of applications typically operate from a fixed lower voltage rail, for example a 12V or 24V battery, such as in automotive (or truck) systems and industrial systems. Occasionally, however, the input line has spikes of 60V or higher. While the power management circuit is not supposed to operate and deliver power to its full capacity at these abnormally high voltages, nonetheless, it is expected not to fail or expose the downstream circuits to unsafe voltages.

Many of the ICs targeted for 12V/24V rails are rated for 20V or 28V. To protect these devices from higher voltage surges, usually some kind of protective clamp is used that limits the input voltage spikes to a level below the rated voltage. *Figure 3a* shows a 12V system with input clamp. These clamps add cost, area, and design time. A high-voltage IC, such as the LM5576, can provide seamless operation throughout the input voltage transient without requiring a low-voltage clamp protection circuit (*Figure 3b*).

For higher current applications, high-voltage controller ICs, such as LM5116-19, provide advanced features which include fixed frequency pulse-width modulation (PWM) operation with external sync, buck-boost operation (LM5118), and multi-channel operation (LM5119). A 3A buck converter for USB chargers is shown in *Figure 3c*. This buck converter can operate directly from 12V/24V automotive rails or 19V laptop charger ports.

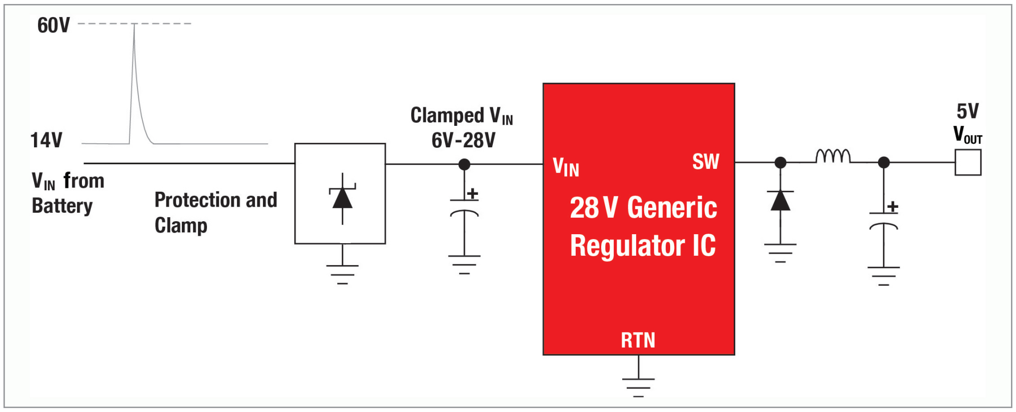


Figure 3a. A generic 24V regulator with in a battery-supplied system with voltage clamp for protection against input voltage surges.

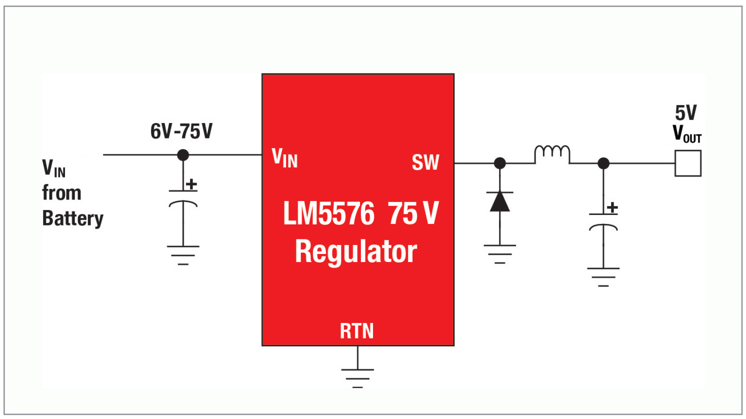


Figure 3b. Regulator with high-voltage rating eliminates the need for input clamp circuit.

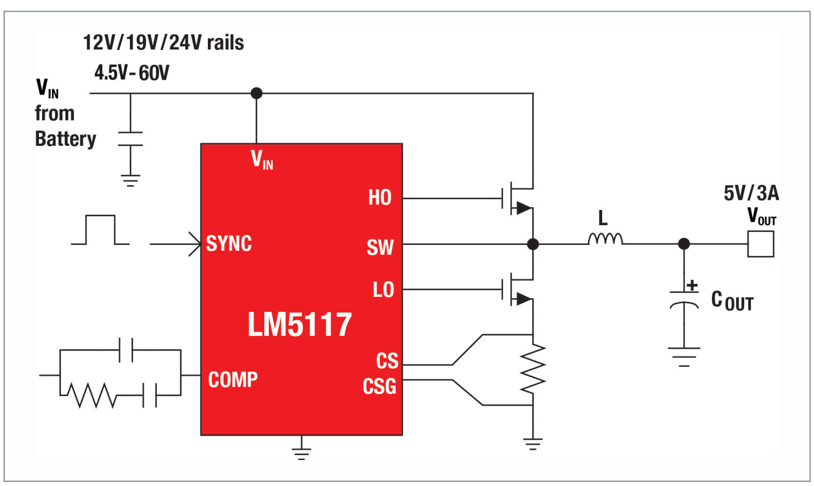


Figure 3c. A buck converter for a USB charging port can operate from 12V/24V automotive rails or 19V laptop charging rails.

Finally, there is a third group of applications for when the designer wants an extra margin of safety and robustness. Even though a lower voltage power management solution may work in theory, there are those un-characterized conditions that may happen only once in the lifetime of the product. Using a high-voltage integrated circuit that is just as easy to use as its low-voltage counterpart provides the designer peace of mind. The product now has an extra level of reliability that may make the defining difference in the quality of otherwise comparable products.

Power semiconductor devices are particularly sensitive to overvoltage. This is because the devices' operating and absolute maximum voltage ratings tend to be very close. Because of this, any design margin needed for a robust design must be considered by the designer when selecting power management ICs and passive components. Once a DC/DC controller or regulator with sufficient voltage margin has been selected, a lot of flexibility in design is available to the designer, as is explained in the rest of this article.

Design reuse using Wide V_{IN} power management ICs

Many designers tend to re-use a proven circuit with minor modifications for multiple input/output rails. This approach allows them to save significant effort when a new circuit is designed and debugged from scratch. The designer knows from experience the tricks, traps, and capabilities of an existing circuit. Additionally, the component selection, layout, and inventory management are simplified by reusing one building block instead of creating separate building blocks for each rail in the system. Certain arguments can be made in favor of selecting a more customized IC that is especially suited for a lower voltage application. Chief among these are the lower resistance associated with low-voltage integrated devices, lower cost, and possibly extra features. For low-current, lower power applications, the benefits of having a common pool of converter and regulator circuits usually outweighs the incremental improvement in performance offered by the lower voltage counter parts. This is truer now with the availability of high-voltage integrated regulators that come at a competitive cost. One such example is shown in *Figure 4*.

A standard constant on-time (COT) synchronous buck regulator circuit like the LM5017 can be used in multiple applications having different input and output rails. Repeated use saves both design and debug time.

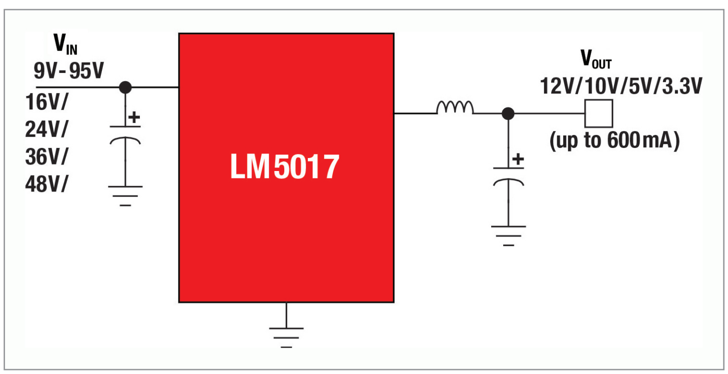


Figure 4. Different applications utilize nearly identical solutions using a high-voltage integrated synchronous buck converter.

Another scenario is presented in the system shown in *Figure 5.* The first stage converts from 19V-38V rails to a 16V rail, which is used for certain parts of the circuit. The second stage converts the 16V rail to a 3.3V rail. Using the same circuit as the starting point for both regulators reduces the effort in designing the overall power solution. The solution in *Figure 6* uses up to six (6) LMZ13608 modules in parallel to achieve a high-density 36V input power supply for up to 48A output current.

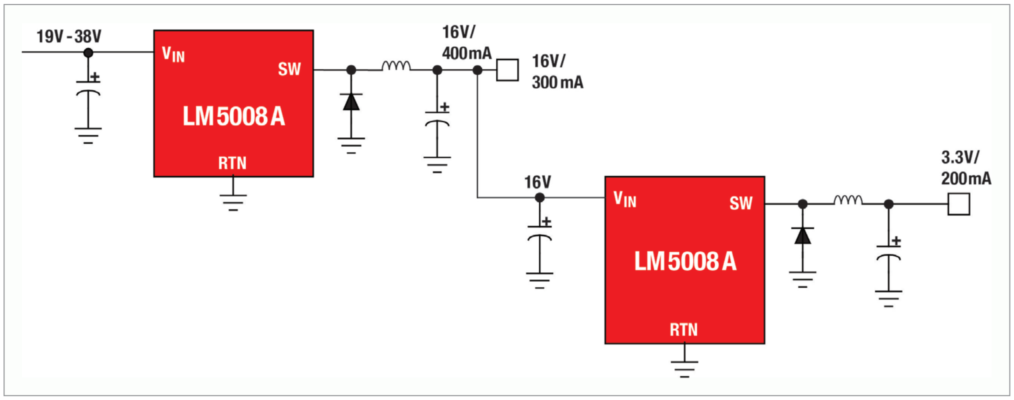


Figure 5. Two cascaded stages using a high voltage IC utilizes identical building blocks.

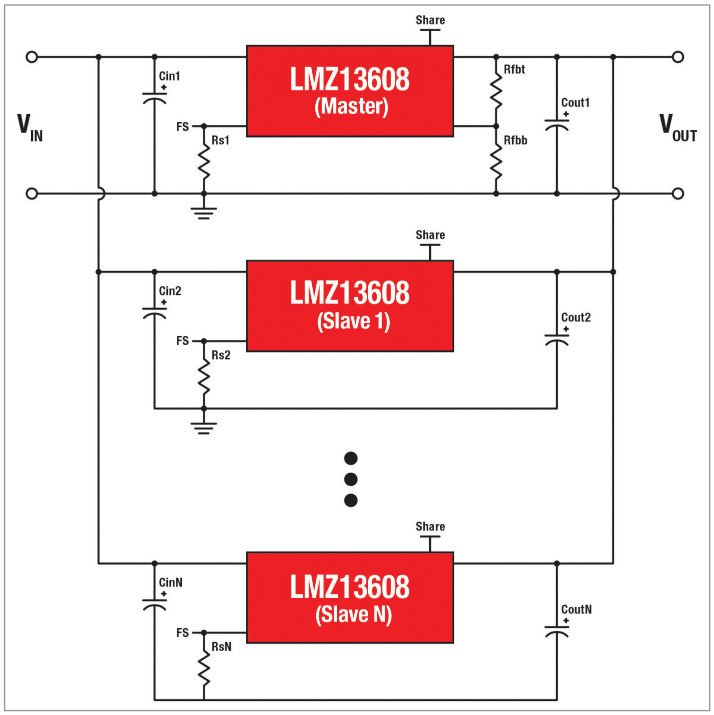
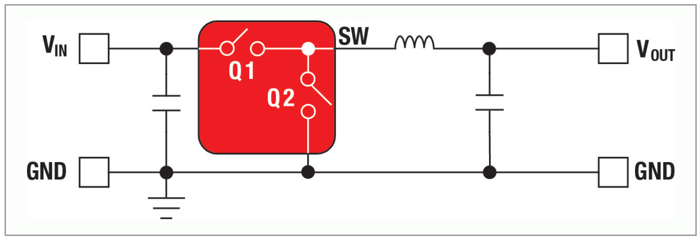


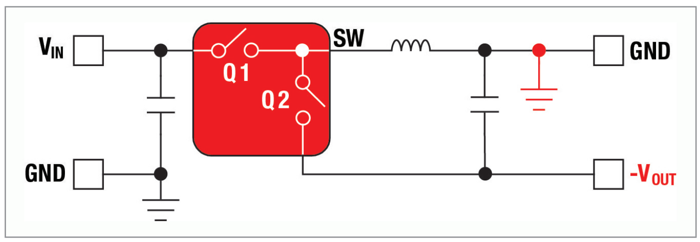
Figure 6. LMZ series power modules can be configured for load sharing to address output requirements above 10A.

Inverting rails using Wide V_{IN} ICs

Another area where high-voltage ICs can save the day is in generating negative voltage. It is common knowledge that a buck regulator IC can be used in an inverting buck-boost configuration to generate negative output rails from positive input voltage rails. On closer look, when used in an inverting buck-boost configuration, one discovers that the regulator "sees" a voltage equal to the sum of input and output voltage (VIN+VOUT) across its positive and return terminals. This is explained in *Figure 7*.



7a. Buck converter.



7b. Inverting buck-boost converter.

Figure 7. A buck regulator IC used to generate negative supply. The voltage across the IC is VIN+VOUT.

An application example is shown in *Figure 8* where a +24V rail is being converted to three different rails at 5V, 15V, and –15V. The LM5007, a high-voltage, step-down switching buck regulator IC, is being used to generate each of these rails. The negative –15V output is generated by using the LM5007 in the inverting buck-boost configuration. Although the input and output voltages are 24V and 15V respectively, the voltage across the regulator terminals is (24V+15V) = 39V. Even a 40V IC leaves very little design margin when utilized in this configuration. But since the LM5007 is rated for 75V, it provides sufficient design margin for transient spikes and input voltage variations. As outlined earlier, the designer saves time and cost by using one high-voltage IC and a common BOM for all three rails.

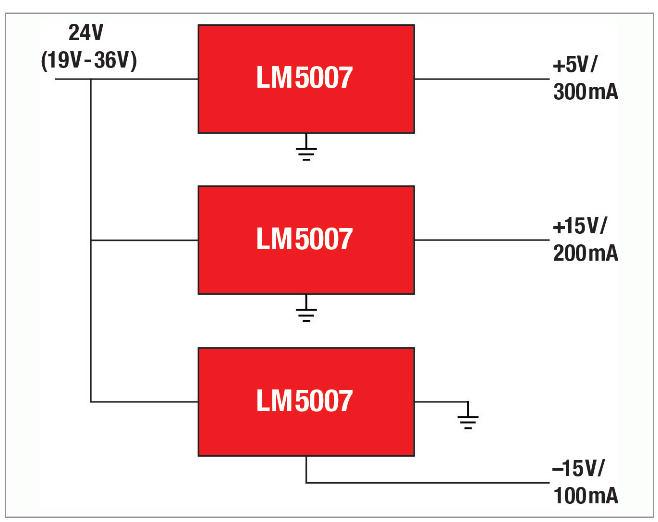


Figure 8. A block diagram for 24V to 5V/15V/–15V power conversion using a high-voltage regulator IC. High-voltage rating allows for input voltage variation and design margin.

Summary

With advances in high-voltage semiconductor devices, integrated power management ICs such as DC/DC controllers and regulators are now available from multiple analog companies. These integrated devices, such as the LM5000 series of high-voltage controllers and regulators, make it easy to create power management solutions that can operate or withstand up to 100V on the input rails. The high-voltage capability eliminates the cost and effort associated with designing input voltage clamping circuits needed when using lower voltage devices. Additionally, the high-voltage rating provides extra design margin, robustness and reliability in devices operating from 12V and 24V systems. Using higher voltage devices allows the designers to save time and effort by allowing reuse of a design or nearly identical designs for many different input and output voltage rails, thereby, eliminating the need to work with multiple stages or multiple circuits.

References

1. For more information on designing with TI's Wide V_{IN} portfolio of buck, boost, and buck-boost devices, visit: **www.ti.com/widevin**
2. For more information on current sharing and designing with SIMPLE SWITCHER® power modules, visit: **www.ti.com/powermodules**
3. Download a datasheet for the LM5017 100V synchronous buck regulator: **www.ti.com/product/lm5017**
4. Download a datasheet for the LM5085 75V PFET controller: **www.ti.com/product/lm5085**
5. Download a datasheet for the LMZ13608 36V SIMPLE SWITCHER module: **www.ti.com/product/lmz13608**

About the author

Vijay Choudhary is an applications engineer for TI's Power Products group where he is responsible for new applications, product development, and customer support. Vijay has more than a decade of power management engineering experience and has written various journal papers, articles, and application notes. Vijay received his Master of Science and PhD from Arizona State University, Tempe, Arizona, and has three patents pending. Vijay can be reached at **ti_vijaychoudhary@list.ti.com**.

E010208

Texas Instruments

SLYY037A

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as “components”) are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

TI assumes no liability for applications assistance or the design of Buyers’ products. Buyers are responsible for their products and applications using TI components. To minimize the risks associated with Buyers’ products and applications, Buyers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, machine, or process in which TI components or services are used. Information published by TI regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of significant portions of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI components or services with statements different from or beyond the parameters stated by TI for that component or service voids all express and any implied warranties for the associated TI component or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have ***not*** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265