

**LM2586,LM2588,LM2596,LM2671,LM2672,
LM2675**

Simple Techniques Minimize Cross-Coupling in Distributed Power Systems



南皇电子



Literature Number: SNVA561

Simple Techniques Minimize Cross-Coupling in Distributed Power Systems

Ravindra Ambatipudi
National Semiconductor Corporation

Introduction:

Distributed power supplies convert the AC line voltage to a lower unregulated DC voltage by using a transformer and a diode-bridge rectifier. As shown in *Figure 1*, this unregulated DC voltage is then converted to two or more tightly regulated DC voltages by using switching and/or linear regulators.

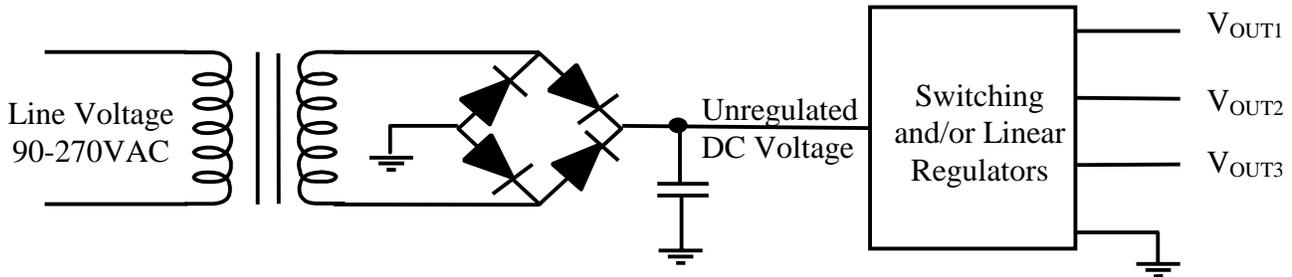


Figure 1 *Typical Distributed Power System*

Figure 2 shows a distributed power system that generates regulated 5V and 3.3V outputs. The unregulated DC voltage, generated from the AC line, varies between 12V and 25V and is converted to tightly regulated DC voltages using two Simple Switcher™ buck regulators. A flyback converter could have been used to perform this conversion, but it was not used because of the need for better output regulation. The two buck regulators are designed using the associated Simple Switcher design software, and their design specifications are as shown in *Table 1*.

Table 1:

Specifications	LM2596	LM2675
Switching Frequency	150kHz	260kHz
Input Voltage	12-25V	12-25V
Output Voltage	3.3V	5V
Output Power	10Watts	5Watts
Associated Software	SMS4.2.1	LM267X

As seen in *Figure 2*, the converters are using the same DC input source. With this simple connection, both output voltages are regulated to a tolerance of better than 5%. However, the noise performance will be poor and the converters will interfere or cross-talk with each other. In the above example, this interference can be observed in at least four different modes:

- a) Figure 3 shows the output ripple voltage of the LM2675 and LM2596 buck regulators. Because the LM2596 is a 150 kHz buck regulator, a 150 kHz ripple is expected at its output. However, as seen in *Figure 2*, a 260 kHz ripple is also observed at the LM2596 output.
- b) The frequency spectrum of the LM2596 output contains a 260 kHz frequency component (and its harmonics), as shown in *Figure 4*.
- c) The switch voltage waveform (*Figure 5*) indicates instability on the edges. However, the converter is designed for a stable loop gain, using Simple Switcher software. This instability is caused only due to interaction between the converters.
- d) When a transient is applied at one output, the effect of the transient is observed on the other output, as shown in *Figure 6*.

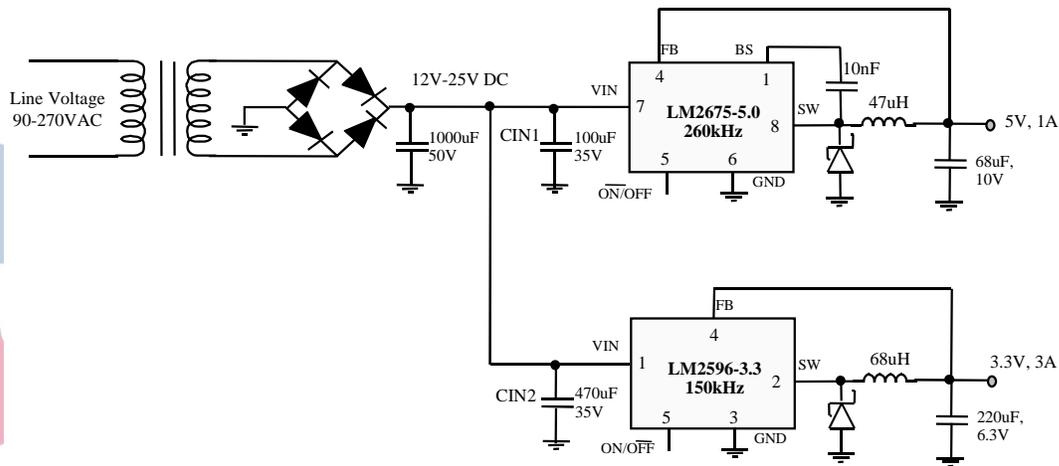


Figure 2: A distributed power system solution

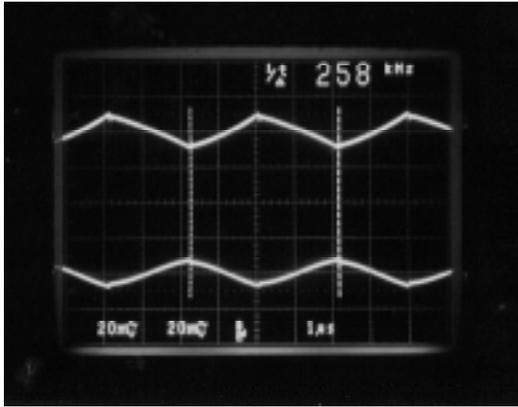


Figure 3- Top: LM2675 Output Ripple(260kHz, 1A) Bottom:LM2596 Output Ripple (150kHz, No-load) A 260 kHz ripple is observed on the LM2596 output

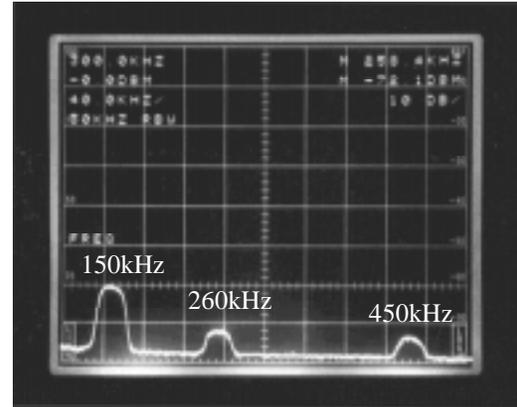


Figure 4: Frequency Spectrum of the LM2596 output(load current =0.5A on LM2596 and 1A on LM2675). A 260kHz frequency component (and its associated harmonics)is observed.

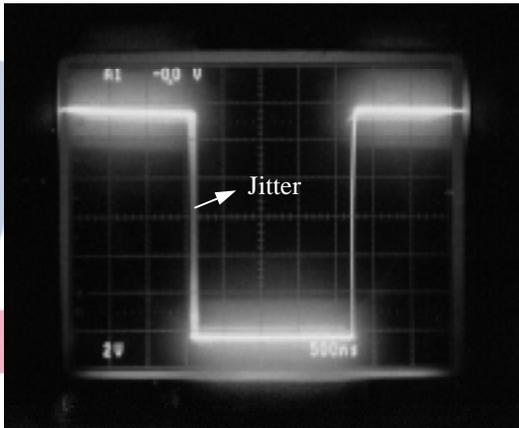


Figure 5: Instability is observed in the switch voltage waveform (pin 8 of LM2675) when a converter with different switching frequencies (LM2596) shares the Input line.

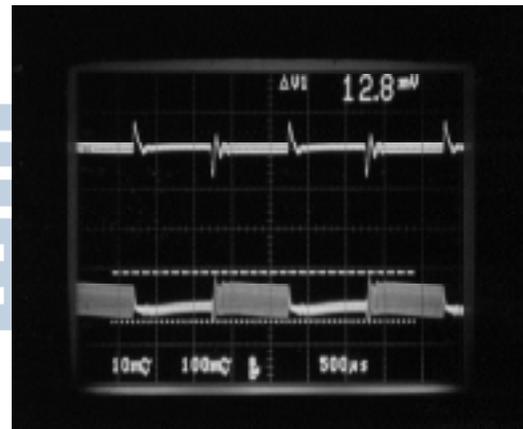


Figure 6: When a transient is applied on the LM2596 output, the effect of the transient is observed on LM2675 output.

This phenomenon is not unique to switching regulators, but is related to high frequency ripple rejection and transient response. If two linear regulators share the input line and a transient is applied on one output, then the effect of transient is observed on the other output. However, the interaction is less severe in linear regulators.

What causes the beat frequencies?

Figure 7 shows the closed-loop power supply ripple rejection (PSRR) of the LM2596 Simple Switchers under no load conditions. The closed-loop power supply ripple rejection (also known as audio-susceptibility) is a function of the loop gain for a voltage mode converter:

$$G_v = G_{vo}/(1+T) \quad (1)$$

where:

T = Loop gain

G_{vo} = Open-loop PSRR

G_v = Closed-loop PSRR

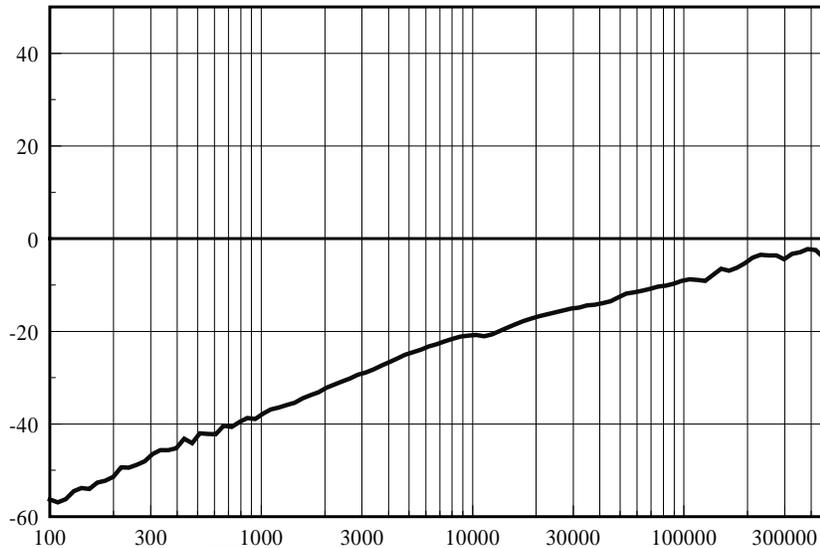


Figure 7: Audio-susceptibility or PSRR of the LM2596 switching regulator

In switching regulators, at very high frequencies near the switching frequencies, the loop gain is very low and the PSRR is poor. Any disturbance or noise at the input will appear at the output. The switching action of one converter creates a disturbance on the input line (*Figure 8*). Because the PSRR of other switching (or linear regulators) is very low at high frequencies, this disturbance will appear at the output of all other switchers and linear regulators connected to the input line. Also, the disturbance on the input line propagates to the circuit internal to the ICs. This introduces noise and instability in the circuit.



Figure 8: Bottom- A 260kHz disturbance appears on the input line(100mV/div)
Top-This disturbance is transmitted to the output of LM2596(20mV/div)

Reducing Cross Coupling

Two general approaches are used to reduce the cross-coupling interactions between different switching frequency regulators running from the same input power line. The easiest approach is to filter the undesired disturbance on the input line. For regulators with oscillators that can be controlled, synchronization of multiple regulators can eliminate the cross coupling effects.

Adding a filter minimizes cross coupling

Adding an inductor in the front end of each regulator can filter disturbances on the input power line, as shown in *Figure 9*. The inductor forms an LC filter with the regulator's input capacitor. As an example, if we wish to reject the 260kHz disturbance from the input to LM2596 by a factor of 100 (so that the 260kHz ripple seen on its output is minimized), then:

$$\frac{V_{in}}{V_f} = 100, \text{ or}$$

$$20\log\left(\frac{V_{in}}{V_f}\right) = 40\text{dB}$$

The LC filter provides an attenuation of 40 dB per decade. Select the LC filter pole frequency, f_p , so that at least 40dB attenuation is obtained at 260kHz. Therefore:

$$f_p = \frac{1}{2\pi\sqrt{L_f C_{in2}}} = 26\text{kHz} \quad (2)$$

Using Equation (2), C_{in2} and L_f can be calculated for the converter in *Figure 9*. *Figure 10* shows the reduction in 260 kHz disturbance on the input power line with the addition of the inductor. The output ripple voltage of the LM2596, frequency spectrum, switch voltage waveforms, and the transient response, are all improved by adding the filter inductance, as shown in *Figures 11, 12, 13, and 14*.

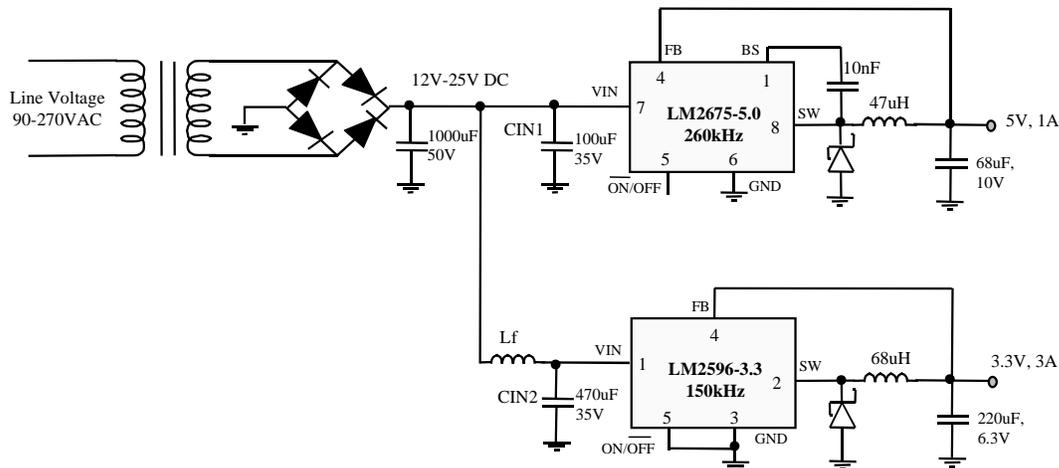


Figure 9: Adding the filter inductor, L_f at the front end of the converter improves the ripple rejection at higher frequencies

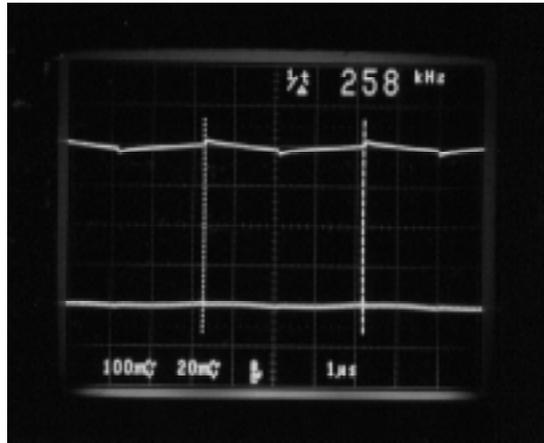


Figure 10: Disturbances on the input voltage being fed to LM2596, caused by LM2675, are filtered by the extra inductor

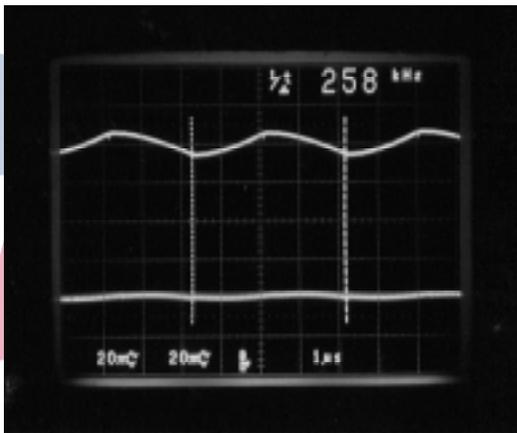


Figure 11- Top: LM2675 Output Ripple(260kHz, 1A) Bottom:LM2596 Output Ripple (150kHz,No-load) The 260 kHz ripple is attenuated at the output by the filter inductor.

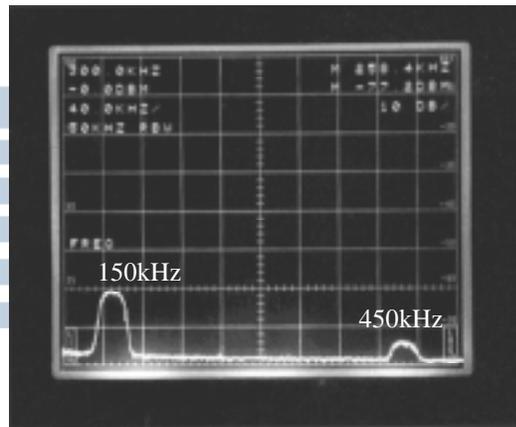


Figure 12: Frequency Spectrum of the LM2596 output. The 260kHz frequency component (and its associated harmonics)are attenuated by the filter inductor.

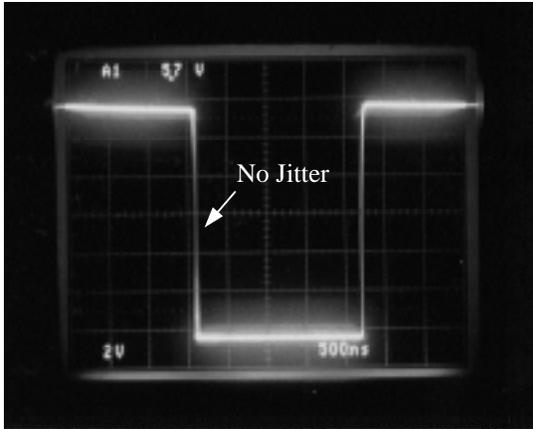


Figure 13 No jitter or instability is observed in the switch voltage waveform (with filter inductor)

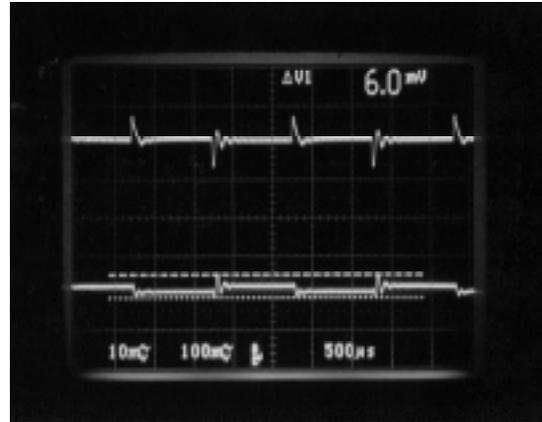


Figure 14 If a transient is applied to one output, the effect of the transient on the other output is reduced with the filter inductor.

Synchronization eliminates cross-coupling

As an alternative to filtering, synchronization can force the switching frequencies of two regulators to match that of an external source, such as another switching regulator or a system clock. It prevents similar (but not matching) switching frequencies from producing cross coupling. This also keeps the EMI generated within the system to a predictable set of frequencies. Both of these results make it easier to filter out switching noise in the system. As an example, in *Figure 15*, the LM2588 boost regulator has been synchronized to the LM2596 (150kHz) buck Simple Switcher to avoid cross coupling. The LM2586 (boost), LM2588 (boost), LM2671 (buck), and LM2672 (buck) Simple Switchers can all be synchronized.

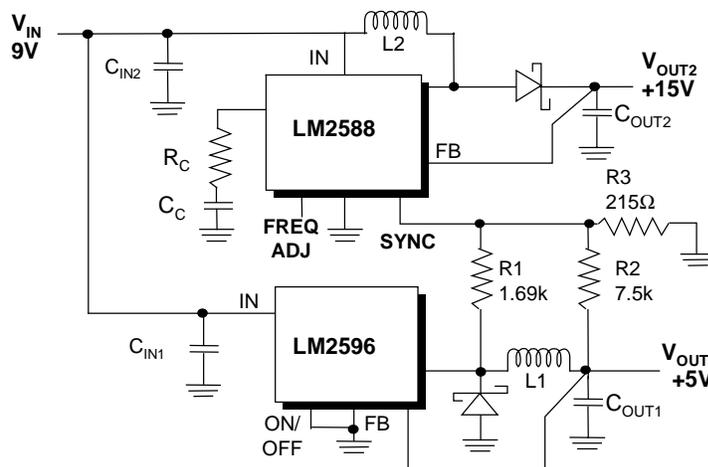


Figure 15 : Synchronizing LM2588 boost to LM2596 buck regulator to avoid beat frequencies

Acknowledgements:

The author is extremely grateful to Steven Hunt, Jon Cronk, Tim Regan, Wanda Garrett, and all my friends and colleagues for their valuable advice and continuous support.

#

References:

1. National Semiconductor Power ICs data book.
2. LM2586, LM2588, LM2596, LM2671, LM2672 data sheets.
3. “Power Conversion in Line-Powered Equipment”- National Semiconductor Application Note AN1061
4. “Adjust of Synchronize LM2586/88 Switching Frequency,” National Semiconductor Application Note AN1082.
5. “Switchers Made Simple, V4.2.1,” National Semiconductor.
6. “LM26xx Made Simple, V1.0,” National Semiconductor.



南皇电子

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

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

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI 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 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. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

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

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products

Audio	www.ti.com/audio
Amplifiers	amplifier.ti.com
Data Converters	dataconverter.ti.com
DLP® Products	www.dlp.com
DSP	dsp.ti.com
Clocks and Timers	www.ti.com/clocks
Interface	interface.ti.com
Logic	logic.ti.com
Power Mgmt	power.ti.com
Microcontrollers	microcontroller.ti.com
RFID	www.ti-rfid.com
OMAP Mobile Processors	www.ti.com/omap
Wireless Connectivity	www.ti.com/wirelessconnectivity

Applications

Communications and Telecom	www.ti.com/communications
Computers and Peripherals	www.ti.com/computers
Consumer Electronics	www.ti.com/consumer-apps
Energy and Lighting	www.ti.com/energy
Industrial	www.ti.com/industrial
Medical	www.ti.com/medical
Security	www.ti.com/security
Space, Avionics and Defense	www.ti.com/space-avionics-defense
Transportation and Automotive	www.ti.com/automotive
Video and Imaging	www.ti.com/video

TI E2E Community Home Page

e2e.ti.com

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2011, Texas Instruments Incorporated