

# High-definition haptics: Feel the difference!

**By ShreHarsha Rao**

*Product Line Manager, Haptics*

While most smartphone and tablet users already have experienced haptics, the term itself is mostly unknown to consumers. In its basic definition, “haptics” refers to the science of tactile feedback. The most basic form of haptics is when a cell phone vibrates, indicating either an incoming call or the arrival of a message in the phone’s inbox. In these cases, the user’s attention is grabbed by a tactile alert.

About one-third of smartphones include tactile feedback that extends beyond a vibration alert. A common example is the subtle vibrations a user feels when typing an email or texting. Each vibration confirms that a keystroke has registered. Users tend to commit fewer typing errors and have a more satisfactory experience when tactile feedback exists.

## Enhancing the user experience with haptics

More and more mobile devices such as cell phones and tablets are now touch-enabled. Touch interface is so intuitive that toddlers can unlock a smartphone and click on the YouTube icon to view the playlist. However, touch screens have one major limitation in that there is no physical or mechanical feedback for user interactions or alerts. Well-designed haptics can significantly enhance the overall user experience of a touch-enabled mobile device.

Haptics has more usage than just serving as an alert or typing confirmation. Standard gestures like swipe to unlock, pinch to zoom, and push/pull to scroll could have their own haptic/tactile signatures. The feedback could increase as the user zooms in to the maximum enlargement of the view. Faster scrolling could provide faster tactile feedback. If this kind of context-sensitive feedback were combined with audiovisual feedback, the resulting consumer experience would be highly satisfactory and intuitive.

Haptics also brings in an element of fun. Many people play games on their mobile devices. Tactile feedback can be used to make the gaming experience significantly better. For example, in a first-person shooter game, the shooter could actually feel the weapons being fired. The user could

feel crashes and bumps in a racing game, feel tension when releasing the string in the popular Angry Birds game, feel the guitar strings or piano keys, and so on. The possibilities are as endless as the game developer’s imagination!

## Inertial haptic actuators (ERMs/LRAs)

The standard haptics in a cell phone is due to a small motor called the eccentric rotating mass actuator (ERM). As the motor is driven with a voltage and starts to spin, a vibration is felt. A haptic driver chip drives this motor differentially, so the motor spins when a positive voltage is applied and brakes when reverse polarity, or a negative voltage, is applied. This works perfectly for vibration alerts. However, trying to use an ERM for other haptic applications, like gaming, quickly runs down the battery.

The ERM is inertial and needs overdrive to spin faster. Start-up time, defined as the time it takes for the motor to reach 90% of the rated acceleration, is usually in the range of 50 to 100 ms. Braking or stopping the motor involves a similar time frame. For a very simple haptic event like a click, the overhead is about 100 to 200 ms. If the application demands repeated haptic events, the latency associated with motor-based haptics may be undesirable.

Another aspect of the ERM is the buzzing or audible noise associated with the spinning motor. This is less of a concern if the haptic feedback is combined with audio feedback. However, in a silent conference room, everyone can hear the motor as someone types a message. The ERM also has few discernible haptic effects that can be generated by the user. The vibration frequency and amplitude are tied to a single control voltage.

Another type of inertial actuator, the linear resonant actuator (LRA), is used in some smartphones for haptics and vibration alerts. The LRA is of a different mechanical construction than the ERM. It consists of spring-mounted mass and vibrates in a linear motion. The LRA must be driven at a narrow resonant frequency. It also tends to have a slightly better start-up time than the ERM.

Depending on the manufacturer, start-up time varies from 40 to 60 ms (Figure 1). This offers a slight improvement over the ERM start-up time of between 50 and 100 ms. By modulating the resonance-carrier amplitude, it is possible to produce a variety of different haptic effects.

### High-definition haptics

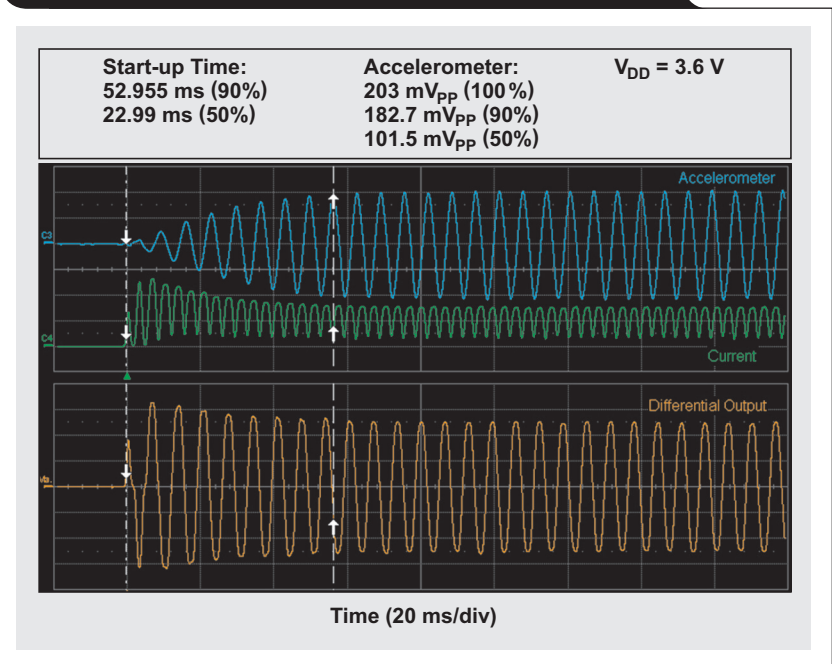
Just as high-definition (HD) TV offers higher resolutions than standard-definition TV to create a sharper and more discernible image, HD haptics lets users feel more discernible vibration effects than the buzz of inertial actuators. Piezoelectric (piezo) or ceramic haptic actuators are used to implement HD haptics and offer compelling differences from ERMs/LRAs).

### Piezo actuators

When differential voltage is applied across both ends of a piezo actuator, it bends or deforms, generating a vibration. Piezo actuators need high voltage to deform. Depending on the manufacturer, voltage can vary from 50 to 150 V<sub>PP</sub>. At higher voltages, the number of required piezo layers decreases; so at 150 V<sub>PP</sub> the piezo actuator has approximately 4 layers, whereas at 50 V<sub>PP</sub> there may be as many as 16 to 24 layers. At higher voltages, due to the reduced number of layers, the piezo actuator's capacitance is lower. In other words, less current is needed to drive lower-capacitance haptic actuators.

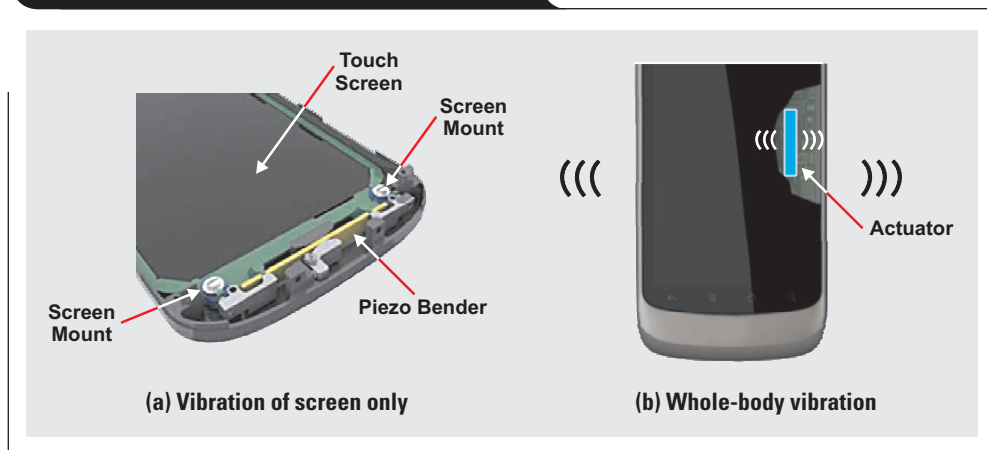
Piezo actuators are available as disks or as rectangular strips, also called benders. Piezo disks deform vertically

**Figure 1. Typical start-up time of an LRA is 40 to 60 ms**



and can be used for z-axis vibration. Piezo benders can be mounted directly to a “floating” touch screen to vibrate only the screen (Figure 2a). Piezo benders can also be mass mounted in a small module that can be mounted to the device's case or PCB to provide vibration for the whole device (Figure 2b). Piezo modules have become popular because mechanical integration is easy.

**Figure 2. Form factors for piezo actuators**



### What makes piezo actuators HD?

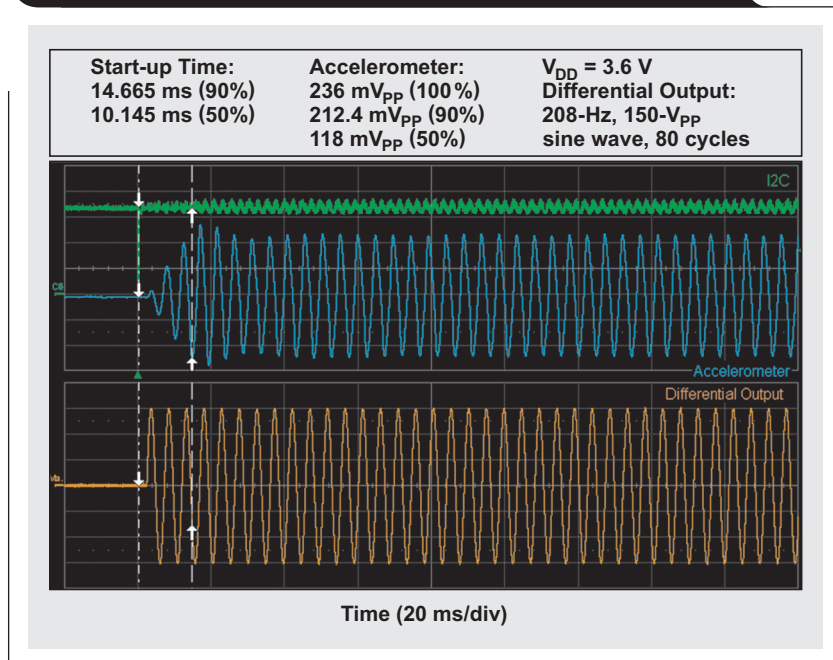
Four key elements differentiate piezo actuators from inertial actuators:

1. *Faster start-up time*: Due to inherent mechanical properties of piezo actuators, start-up time is very fast—typically less than 15 ms, which is three to four times faster than ERMs. Compared to ERMs, the duration of the

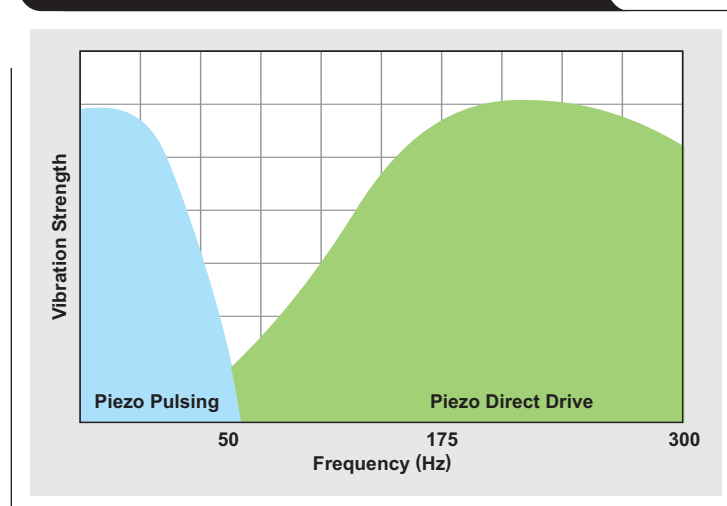
overall haptic event may be shortened by 70 ms. This is further illustrated in Figure 3.

2. *Higher bandwidth*: The higher bandwidth of piezo actuators, illustrated in Figure 4, provides a more detailed haptic palette with a greater number of effects.
3. *Lower audible noise*: Unlike ERMs, piezo actuators have no spinning mass to create mechanical noise.

**Figure 3. Typical start-up time of a piezo module is ~14 ms**



**Figure 4. Higher bandwidth of piezo actuators (ideal model)**



4. *Stronger vibration:* Piezo modules tend to generate higher vibration strengths. Figure 5 shows the acceleration characteristics of a commercially available piezo module, and Figure 6 shows the acceleration characteristics of a commercially available LRA. It can be seen that the piezo actuator generated a peak-to-peak acceleration of 3 G<sub>PP</sub>, compared to less than 1.5 G<sub>PP</sub> in the case of the LRA. This higher vibration strength implies that piezo modules are a great candidate for bigger-screen smartphones and tablets.

**Current consumption of piezo actuators**

Even though piezo actuators need higher voltage than standard inertial actuators, the actual current consumption is lower than that of ERMs and on a par with that of LRAs (see Table 1).

**Conclusion**

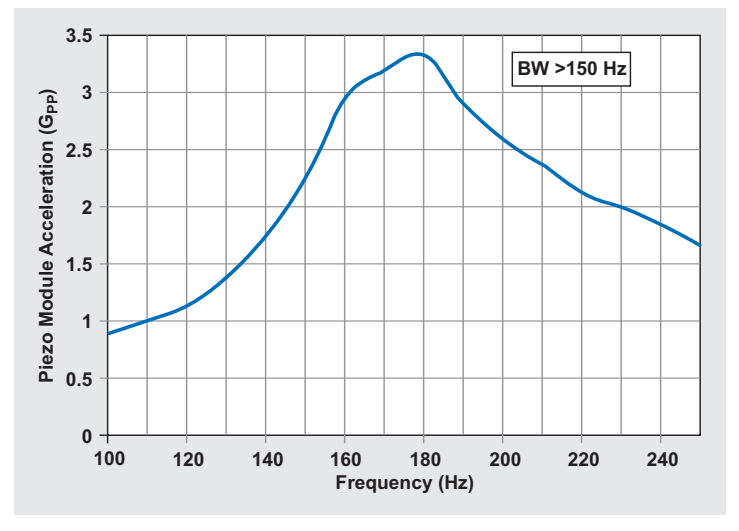
Piezo actuators deliver significant performance and cost advantages compared to inertial actuators. Their faster start-up time helps create sharp and crisp clicks for keyboard applications. Their higher bandwidth helps create more user-perceivable haptic effects that are critical for gaming applications. The stronger vibration strength of piezo actuators can be used to generate haptic feedback for bigger consumer devices like tablets and e-readers. Overall, piezo haptics offers compelling features to enhance the tactile feedback experience and helps improve the overall user experience of mobile devices.

Texas Instruments (TI) offers both analog-input (DRV8662) and digital-input (DRV2665) piezo haptic drivers that interface with a wide variety of piezo actuators on the market. TI also has demos that let designers “feel the difference.”

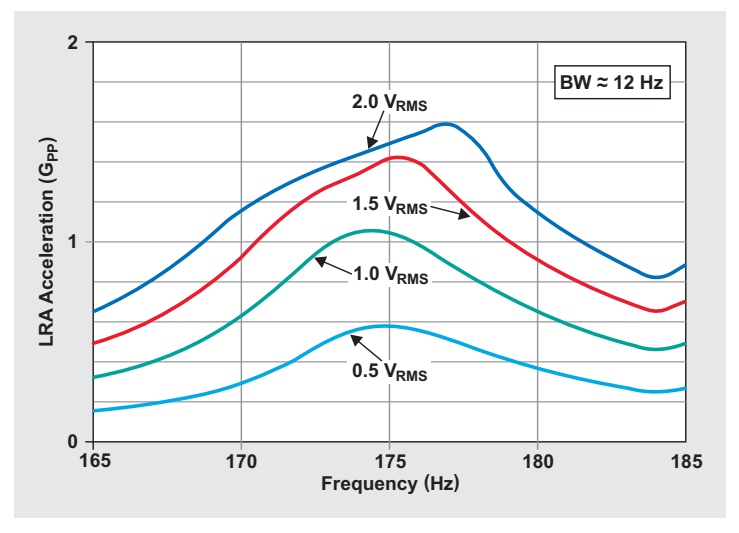
**Related Web sites**

- [www.ti.com/haptics-ca](http://www.ti.com/haptics-ca)
- [www.ti.com/product/DRV2665](http://www.ti.com/product/DRV2665)
- [www.ti.com/product/DRV8662](http://www.ti.com/product/DRV8662)

**Figure 5. Acceleration characteristics of a piezo module**



**Figure 6. Acceleration characteristics of an LRA**



**Table 1. Power consumption of haptic actuators**

USAGE	PIEZO ACTUATOR (mAh)	LRA (mAh)	ERM (mAh)
Per 25 phone calls	2.685	1.497	3.540
Per 50 text messages	25.660	11.869	27.480
Per 4 hours of e-mail access	28.076	12.150	29.078
Crossword game (60 min)	1.094	0.487	1.150
DoodleJump game (30 min)	6.270	3.975	8.170
Shooting game (30 min)	24.976	37.777	61.558
Total power	88.761	67.755	130.975
Discharge percentage of 1200-mAh battery	7.4%	5.6%	10.9%

# TI Worldwide Technical Support

---

## Internet

### TI Semiconductor Product Information Center Home Page

[support.ti.com](http://support.ti.com)

### TI E2E™ Community Home Page

[e2e.ti.com](http://e2e.ti.com)

## Product Information Centers

<b>Americas</b>	Phone	+1(972) 644-5580
<b>Brazil</b>	Phone	0800-891-2616
<b>Mexico</b>	Phone	0800-670-7544
	Fax	+1(972) 927-6377
	Internet/Email	<a href="http://support.ti.com/sc/pic/americas.htm">support.ti.com/sc/pic/americas.htm</a>

### Europe, Middle East, and Africa

Phone	
European Free Call	00800-ASK-TEXAS (00800 275 83927)
International	+49 (0) 8161 80 2121
Russian Support	+7 (4) 95 98 10 701

**Note:** The European Free Call (Toll Free) number is not active in all countries. If you have technical difficulty calling the free call number, please use the international number above.

Fax	+ (49) (0) 8161 80 2045
Internet	<a href="http://www.ti.com/asktexas">www.ti.com/asktexas</a>
Direct Email	<a href="mailto:asktexas@ti.com">asktexas@ti.com</a>

### Japan

Phone	Domestic	0120-92-3326
Fax	International	+81-3-3344-5317
	Domestic	0120-81-0036
Internet/Email	International	<a href="http://support.ti.com/sc/pic/japan.htm">support.ti.com/sc/pic/japan.htm</a>
	Domestic	<a href="http://www.tij.co.jp/pic">www.tij.co.jp/pic</a>

### Asia

Phone	
International	+91-80-41381665
Domestic	<u>Toll-Free Number</u>
<b>Note:</b> Toll-free numbers do not support mobile and IP phones.	
Australia	1-800-999-084
China	800-820-8682
Hong Kong	800-96-5941
India	1-800-425-7888
Indonesia	001-803-8861-1006
Korea	080-551-2804
Malaysia	1-800-80-3973
New Zealand	0800-446-934
Philippines	1-800-765-7404
Singapore	800-886-1028
Taiwan	0800-006800
Thailand	001-800-886-0010
Fax	+8621-23073686
Email	<a href="mailto:tiasia@ti.com">tiasia@ti.com</a> or <a href="mailto:ti-china@ti.com">ti-china@ti.com</a>
Internet	<a href="http://support.ti.com/sc/pic/asia.htm">support.ti.com/sc/pic/asia.htm</a>

**Important Notice:** The products and services of Texas Instruments Incorporated and its subsidiaries described herein are sold subject to TI's standard terms and conditions of sale. Customers are advised to obtain the most current and complete information about TI products and services before placing orders. TI assumes no liability for applications assistance, customer's applications or product designs, software performance, or infringement of patents. The publication of information regarding any other company's products or services does not constitute TI's approval, warranty or endorsement thereof.

A011012

E2E is a trademark of Texas Instruments. All other trademarks are the property of their respective owners.

## 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 JESD46C and to discontinue any product or service per JESD48B. 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 which meet ISO/TS16949 requirements, mainly for automotive use. Components which have not been so designated are neither designed nor intended for automotive use; and TI will not be responsible for any failure of such components to meet such requirements.

### Products

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

### Applications

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

**TI E2E Community** [e2e.ti.com](http://e2e.ti.com)