Application Report
SLOA148–June 2010

TAS57xx Dynamic Range Control

Brian Burk — *Audio and Imaging Products*

ABSTRACT

This application report provides background information, general equations, and instructions for proper use of the Texas Instruments TAS57xx series Dynamic Range Control (DRC). Topics include I^2C configuration, single-band and dual-band DRC, coefficient computation, device offerings, and user interface configuration.

Contents

1 Dynamic Range Control (DRC) 2
1.1 DRC Implementation 2
1.2 DRC Structure 3
2 Single-Band DRC Control 4
3 Dual-Band DRC Control 4
4 DRC Coefficients 4
5 Threshold, Offset, and Compression Computation 5
5.1 Threshold Parameter Computation 5
5.2 Slope Parameter Computation 5
5.3 DRC Offset Calculation 6
6 DRC Configuration Using the TAS57xx GDE 6
6.1 Opening the DRC Tool 6
6.2 Adjust DRC Parameters Using the Form 7
6.3 Adjust DRC Parameters using the Graph 7
7 Device Offerings 7

List of Figures

1 Dynamic Range Control 2
2 DRC Block Diagram 3
3 DRC Structure 4
4 DRC Configuration Tool 6
5 TAS57xx DRC Icon 7

List of Tables

1 Dual-Band DRC Control Inputs 4

Copyright © 2010, Texas Instruments Incorporated

1 Dynamic Range Control (DRC)

Dynamic Range Control (DRC) provides compression capabilities that allow audio signals to sound softer or louder depending on the input level. In Figure 1, the lines visually depict the DRC compressed output versus the audio input. The dashed line in this graph represents an uncompressed audio signal, but more specifically delineates a 0-dB control signal with a 1:1 slope, indicating the output levels equal the input levels.

The solid line, on the other hand, represents the effects of the DRC compression. This line varies based on the programmed DRC parameters and indicates the output levels may not vary in a 1:1 relationship with the input levels. When the solid line overlaps the dashed line (the control), the DRC is simply acting as an audio pass-through, but when the solid line diverges from the dashed line, the DRC output signal is softer or louder depending on the y-axis value.

The DRC input/output diagram is shown in Figure 1.

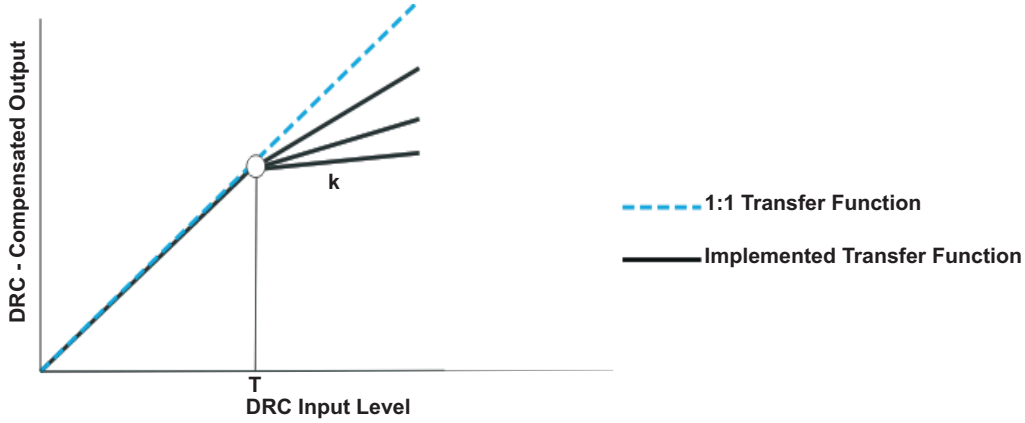

Figure 1. Dynamic Range Control

The DRC provides compression capabilities in the region above the threshold level (T). A programmable threshold level (T) sets the boundary of the two regions. The offset (O, boost or cut) controls the vertical axis offset of the solid line and can be defined by a programmable offset coefficient. The compression ratio (k) adjusts the slope of the compression in the region above threshold T and can be set by a programmable compression coefficient.

The DRC implements the composite transfer function by computing a 3.23-format gain coefficient from the output of the RMS estimator. The RMS estimates are calculated and compared on a sample-by-sample basis, and the largest of each sample group is used to compute the compression gain coefficient. The DRC parameters including the compression and timing control then are applied to the RMS estimate to obtain the final DRC coefficient. This DRC coefficient then is applied to a mixer block, whose input is the audio data. The mixer output is thus the DRC-adjusted audio data.

1.1 DRC Implementation

Figure 2 shows the three elements comprising the DRC: (1) an RMS estimator, (2) a compression coefficient computation engine, and (3) an attack/decay controller.

Copyright © 2010, Texas Instruments Incorporated

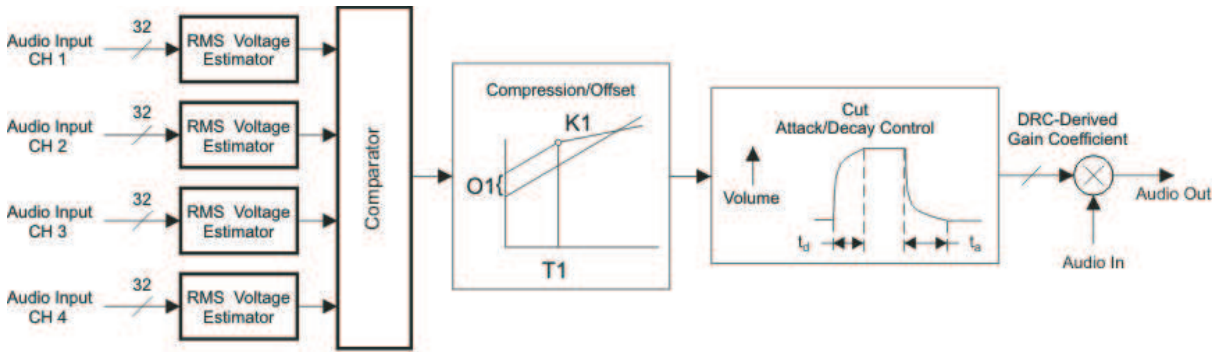

Figure 2. DRC Block Diagram

- RMS Estimator – This DRC element derives an estimate of the RMS value from the input audio data. For the DRC block shared by Ch1 through Ch4, the individual channel estimates are computed first. The outputs of the estimators then are compared, sample-by-sample, and the largest-valued sample is forwarded to the compression/expansion coefficient-computation engine. Two programmable parameters, ae and (1 – ae), set the effective time window over which the RMS estimate is made. For the DRC block shared by Ch1 through Ch4, the programmable parameters apply to both RMS estimators. The time window over which the RMS estimation is computed can be determined by

$$t_{window} = \frac{-1}{f_S \ln(1 - ae)} \quad (1)$$

- Compression Coefficient Computation – This DRC element converts the output of the RMS estimator to a logarithmic number, determines the region where the input resides, and then computes and outputs the appropriate coefficient to the attack/decay element. The programmable parameters, threshold (T), offset (O), and compression ratio (k), define the compression regions for both DRCs implemented by this element.
- Attack/Decay Control – This DRC element controls the transition time of changes in the coefficient computed in the compression/expansion coefficient computation element. Four programmable parameters define the operation of this element. Parameters ad and (1 – ad) set the decay or release time constant to be used for signal amplitude boost (expansion). Parameters aa and (1 – aa) set the attack time constant to be used for signal amplitude cuts (compression). The transition-time constants can be determined by

$$t_a = \frac{-1}{f_S \ln(1 - aa)} \quad (2)$$

$$t_d = \frac{-1}{f_S \ln(1 - ad)} \quad (3)$$

1.2 DRC Structure

Figure 3 shows how the TAS57xx DRC computes the coefficients to apply to an audio signal. Notice that both compression and timing (attack and decay) coefficients are used to get the overall DRC coefficient.

Copyright © 2010, Texas Instruments Incorporated

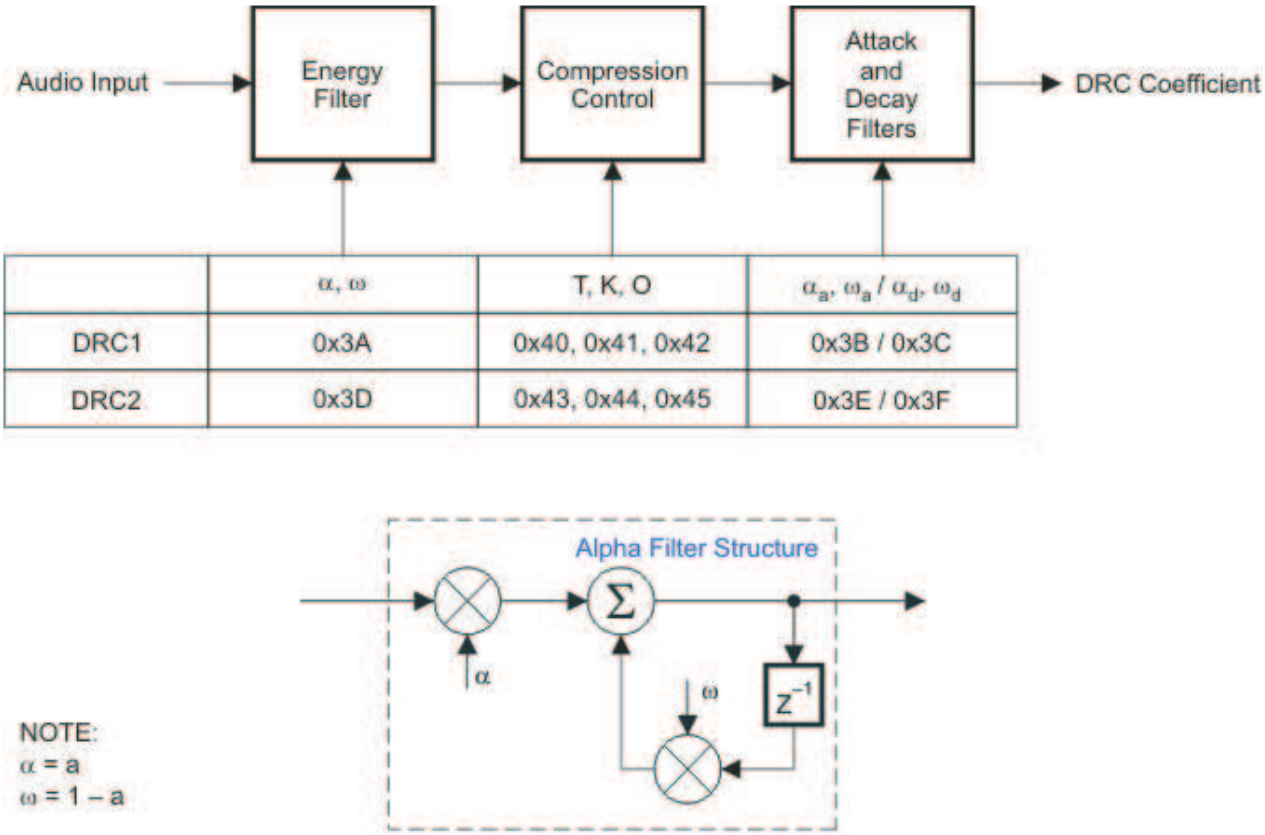

Figure 3. DRC Structure

2 Single-Band DRC Control

The single-band devices have one DRC and are capable of modifying the output signal for all channels. The advantage of single-band is that all audio will be attenuated proportionally producing the same, but compressed, sound as the original input.

3 Dual-Band DRC Control

The dual-band devices have two DRCs and are capable of modifying the output signal for different channel configurations. The TAS5705, TAS5706, and TAS5713 offer two DRCs, one which controls the satellite speakers and the other the subwoofer. The TAS5709, TAS5710, and TAS5711 offer two DRCs, which can be configured to control different audio bands and different channels depending on the multiplexer configuration within the device.

4 DRC Coefficients

This section discusses the programmable values for the TAS57xx single-band and dual-band devices, including the threshold, offset, compression ratio, and enable controls. Dual-band devices have two sets of control parameters, one for each DRC. These values are programmable via the I^2C interface.

Table 1. Dual-Band DRC Control Inputs

Bit 1	Bit 0	Description
X	0	Disable DRC1
X	1	Enable DRC1
0	X	Disable DRC2
1	X	Enable DRC2

Copyright © 2010, Texas Instruments Incorporated

Each DRC block has an independent enable/disable bit; the encoding for a dual-band device is shown in Table 1.

The DRC scheme has a single threshold, offset, and slope (all programmable).

- Thresholds T1 and T2 define the thresholds for DRC1 and DRC2, respectively.
- Offsets O1 and O2 define the gain coefficients for DRC1 and DRC2, respectively.
- The magnitudes of slopes k1 and k2 define the degree of compression to be performed above the threshold for DRC1 and DRC2, respectively.

The three sets of parameters are all defined in logarithmic space and adhere to the following rules.

- The maximum input sample into the DRC is referenced at 0 dB. All values below this maximum value then have negative values in logarithmic (dB) space.
- Thresholds T1 and T2 define, in dB, the boundaries of the regions of the DRC, as referenced to the RMS value of the data into the DRC. Zero-decibel (0-dB) threshold settings reference the maximum-valued RMS input into the DRC, and negative-valued thresholds reference all other RMS input levels. Positive-valued thresholds have no physical meaning and are not allowed. In addition, zero-valued threshold settings are not allowed.

  NOTE: The threshold settings must be programmed as 32-bit (9.23 format) numbers.

  NOTE: Zero-valued and positive-valued threshold settings are not allowed and cause unpredictable behavior if used.
- Offsets O1 and O2 define, in dB, the attenuation (cut) or gain (boost) applied by the DRC-derived gain coefficient at the threshold points T1 and T2, respectively. Positive offsets are defined as boosts, and thus cuts are negative numbers.
- Slopes k1 and k2 define the compression is to be performed within a given region and the degree of compression to be applied. Slopes are programmed as 26-bit (3.23 format) numbers.

5 Threshold, Offset, and Compression Computation

The following sections can be used to calculate the parameters used for DRC coefficient computation.

5.1 Threshold Parameter Computation

For thresholds,

$T_{db} = 6.0206T_{INPUT} + 24\ dB = 6.0206T_{SUB_ADDRESS_ENTRY} + 24\ dB$

The additional 24 dB in the threshold equation accounts for DRC headroom.

If, for example, it is desired to set T1 = –64 dB, then the subaddress entry required to set T1 to –64 dB is

$$T1_{SUB_ADDRESS_ENTRY} = \frac{t_{DB} - 24}{-6.0206} = -14.62 \quad (4)$$

T1 is entered as a 32-bit number in 9.23 format. Therefore,

T1 = –14.62 = 0 0000 1110.1001 1101 1101 0001 1101 101 = 0x074E E8ED in 9.23

5.2 Slope Parameter Computation

In developing the equations used to determine the subaddress input value required to realize a given compression or expansion within a given region of the DRC, the following convention has been adopted.

DRC Transfer = Input Increase : Output Increase

If the DRC realizes an output increase of n dB for every dB increase in the RMS value of the audio into the DRC, a 1:n expansion is being performed. If the DRC realizes a 1-dB increase in output level for every n dB increase in the rms value of the audio into the DRC, an n:1 compression is being performed.

For a 1:n expansion, the slope k can be found by : k = n – 1

For an n:1 compression, the slope k can be found by:

$$K = \frac{1}{N} - 1 \quad (5)$$

Copyright © 2010, Texas Instruments Incorporated

In compression (n:1), n is implied to be greater than 1. For compression, Equation 5 means –1 < k < 0 for n > 1. Thus k must always lie in the range k > –1.

$$\text{Compression equation: } k = -4 = \frac{1}{n} - 1 \rightarrow n = -\frac{1}{3} \rightarrow -0.3333{:}1 \text{ compression} \tag{6}$$

With k = –4 then, the output decreases 3 dB for every 1-dB increase in the RMS value of the audio into the DRC. As the input increases in signal amplitude, the output decreases in signal amplitude.

5.3 DRC Offset Calculation

The DRC offset is calculated by

$$G_{offset} = \frac{10^{(9_{gd}/20)}}{15.5} \tag{7}$$

6 DRC Configuration Using the TAS57xx GDE

The TAS57xx DRC configuration tool is a useful resource for adjusting the DRC settings. This tool has controls for adjusting the compression ratio, offset, threshold, attack, and decay. Figure 4 shows a picture of the DRC graphic user interface.

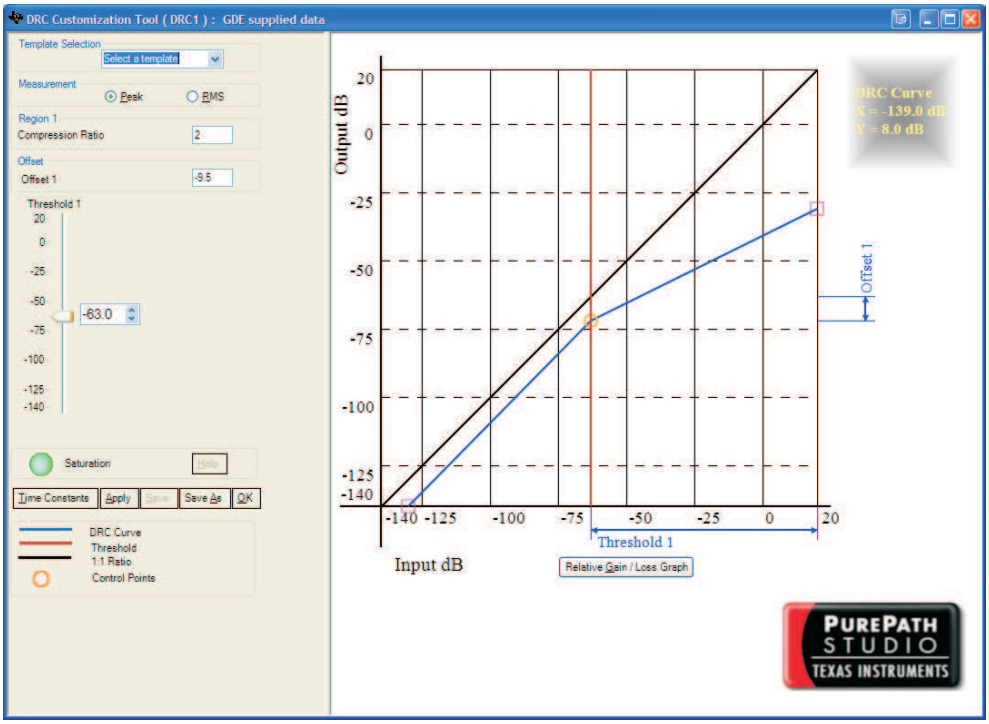

Figure 4. DRC Configuration Tool

6.1 Opening the DRC Tool

To open the DRC Configuration Tool, do the following:

1. Install the latest version of the TAS57xx Graphical Development Environment (GDE).
2. Open the GUI and select the appropriate TAS57xx device tab.
3. Open the DRC Configuration Tool by either double-clicking on the DRC icon or right-clicking > "Activate DRC GUI". See Figure 5.

Copyright © 2010, Texas Instruments Incorporated

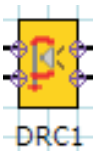

Figure 5. TAS57xx DRC Icon

6.2 Adjust DRC Parameters Using the Form

To adjust the DRC settings, use the fields on the left and:

1. Enter the values for compression ratio, offset, and threshold.
2. Update the time constants to the appropriate durations by clicking on the "Time Constants" button.
3. Click "Ok" in the Time Constants window.
4. Click "Apply" to update the graph and the TAS57xx device's control registers (if connected).

6.3 Adjust DRC Parameters using the Graph

To adjust the DRC parameters, use the graph on the right and:

1. Move the orange control point to the desired level.
2. Click "Apply" to update the graph and the TAS57xx device's control registers (if connected).
3. The compression ratio still needs to be set using the field on the left.
4. Update the time constants to the appropriate durations by clicking on the "Time Constants" button.
5. Click "Ok" in the Time Constants window.
6. Click "Apply" once more.

7 Device Offerings

The TAS57xx family of devices offers numerous options for dynamic range control. The following is a list of devices and the configuration options of the DRC(s).

- **TAS5705, TAS5706, and TAS5713 DRC Configuration**
  - The TAS5705, TAS5706, and TAS5713 are both dual-band DRC devices. These devices have two distinct DRC blocks. DRC1 controls the satellite channels, and DRC2 controls the subwoofer channel.
- **TAS5707 and TAS5708 DRC Configuration**
  - The TAS5707 and TAS5708 are single-band devices and offer a single DRC control for all output channels.
- **TAS5709, TAS5710, and TAS5711 DRC Configuration**
  - The TAS5709, TAS5710, and TAS5711 are dual-band devices and have two independent DRC blocks which can be configured to control any two audio bands. This allows for control of bass and treble, bass boost, and surround features.

Copyright © 2010, Texas Instruments Incorporated

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		**Applications**	
Amplifiers	amplifier.ti.com	Audio	www.ti.com/audio
Data Converters	dataconverter.ti.com	Automotive	www.ti.com/automotive
DLP® Products	www.dlp.com	Communications and Telecom	www.ti.com/communications
DSP	dsp.ti.com	Computers and Peripherals	www.ti.com/computers
Clocks and Timers	www.ti.com/clocks	Consumer Electronics	www.ti.com/consumer-apps
Interface	interface.ti.com	Energy	www.ti.com/energy
Logic	logic.ti.com	Industrial	www.ti.com/industrial
Power Mgmt	power.ti.com	Medical	www.ti.com/medical
Microcontrollers	microcontroller.ti.com	Security	www.ti.com/security
RFID	www.ti-rfid.com	Space, Avionics & Defense	www.ti.com/space-avionics-defense
RF/IF and ZigBee® Solutions	www.ti.com/lprf	Video and Imaging	www.ti.com/video
		Wireless	www.ti.com/wireless-apps

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2010, Texas Instruments Incorporated