MSP430F2xx Family Enhancements and Features

Mike Mitchell
MSP430 Applications Engineer
Texas Instruments
Agenda

• Enhancements
• Application Examples
• Devices & Summary
MSP430 Products

Performance

Device
- Production
- Sampling
- Development
- Future

Signal Chain on Chip

5xx-Consumer
- 25 MIPS+
- 128-256 KB
- USB-Zigbee™

2xx-Catalog
- 16 MIPS
- 1-120KB
- 500 nA Stand By

4xx-Application Specific
- 8 MIPS
- 4-120KB
- LCD Driver

1xx-Catalog
- 8 MIPS
- 1-60KB

F = Flash
C = Custom ROM

© 2006 Texas Instruments Inc, Slide 3
MSP430F2xx – What’s Different

• Faster
• Lower power
• New peripherals
• Compatible migration path with the ‘1xx
• Great starting point for new applications
• Complete family of new devices planned
## MSP430F1xx Versus MSP430F2xx

<table>
<thead>
<tr>
<th>Feature</th>
<th>1xx</th>
<th>2xx</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU Clock</td>
<td>8MHz</td>
<td>16MHz</td>
</tr>
<tr>
<td>Wakeup</td>
<td>6us</td>
<td>1us</td>
</tr>
<tr>
<td>Stand-by</td>
<td>&lt;2uA</td>
<td>&lt;1uA</td>
</tr>
<tr>
<td>BOR</td>
<td>Some</td>
<td>ALL</td>
</tr>
<tr>
<td>Flash ISP</td>
<td>2.7V</td>
<td>2.2V</td>
</tr>
<tr>
<td>P1/2</td>
<td>-</td>
<td>Pull-up / Down</td>
</tr>
<tr>
<td>Oscillator</td>
<td>±20%</td>
<td>±2.5%</td>
</tr>
<tr>
<td>OscFault</td>
<td>HF</td>
<td>HF/LF</td>
</tr>
<tr>
<td>Watchdog</td>
<td>SW</td>
<td>SW</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Invalid Address</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Clock Fault</td>
</tr>
<tr>
<td>BSL</td>
<td>2^256</td>
<td>Hackproof</td>
</tr>
</tbody>
</table>

**2X faster**

**1/2 power**

**Improved**
F2xx 16MIPS On-Demand

Interrupt

Oscillator
F2xx Flash

- Fast <20us /byte ISP
- ISP down to 2.2V
- Interruptible ISP/Erase
- Reduced size 64B info memory segments
- Lock(able) info segment A
- Improved BSL security
- Protection against program/erase from accidental BSL entry
Achieving *Ultra-low Power*

- Max time in Ultra-low Power *LPM3* standby mode
- *Active* Performance on-demand
- Minimum active duty cycle
F2xx Basic Clock+

- LFXT1 XTAL Oscillator
  - <1uA LPM3 standby mode
  - XTAL CAPs programmable
  - OSCfault LF/(XT)
  - New VLO

- Improved DCO
  - < 1us 0-to-16MHz
  - ± 2.5% DCO
  - Programmable frequency

- VLO not in '21x1
### F2xx: No XTAL Required – DCO+

**calibrated DCO frequencies – tolerance at calibration**

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>( T_A )</th>
<th>VCC</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency tolerance at calibration</td>
<td></td>
<td>25°C</td>
<td>3 V</td>
<td>-1</td>
<td>(\pm 0.2)</td>
<td>+1</td>
<td>%</td>
</tr>
</tbody>
</table>

**calibrated DCO frequencies – tolerance over temperature \(0^\circ C - +85^\circ C\)**

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>( T_A )</th>
<th>VCC</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 MHz tolerance over temperature</td>
<td>0–85°C</td>
<td>3.0 V</td>
<td>-2.5</td>
<td>(\pm 0.5)</td>
<td>+2.5</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>8 MHz tolerance over temperature</td>
<td>0–85°C</td>
<td>3.0 V</td>
<td>-2.5</td>
<td>(\pm 1.0)</td>
<td>+2.5</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>12 MHz tolerance over temperature</td>
<td>0–85°C</td>
<td>3.0 V</td>
<td>-2.5</td>
<td>(\pm 1.0)</td>
<td>+2.5</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>16 MHz tolerance over temperature</td>
<td>0–85°C</td>
<td>3.0 V</td>
<td>-3.0</td>
<td>(\pm 2.0)</td>
<td>+3.0</td>
<td>%</td>
<td></td>
</tr>
</tbody>
</table>

**calibrated DCO frequencies – tolerance over supply voltage \(V_{CC}\)**

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>( T_A )</th>
<th>VCC</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 MHz tolerance over (V_{CC})</td>
<td>25°C</td>
<td>1.8 V – 3.6 V</td>
<td>-3</td>
<td>(\pm 2)</td>
<td>+3</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>8 MHz tolerance over (V_{CC})</td>
<td>25°C</td>
<td>1.8 V – 3.6 V</td>
<td>-3</td>
<td>(\pm 2)</td>
<td>+3</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>12 MHz tolerance over (V_{CC})</td>
<td>25°C</td>
<td>2.2 V – 3.6 V</td>
<td>-3</td>
<td>(\pm 2)</td>
<td>+3</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>16 MHz tolerance over (V_{CC})</td>
<td>25°C</td>
<td>3.0 V – 3.6 V</td>
<td>-3</td>
<td>(\pm 2)</td>
<td>+3</td>
<td>%</td>
<td></td>
</tr>
</tbody>
</table>

**calibrated DCO frequencies – overall tolerance**

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>( T_A )</th>
<th>VCC</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 MHz tolerance overall</td>
<td>I: -40–85°C</td>
<td>1.8 V – 3.6 V</td>
<td>-5</td>
<td>(\pm 2)</td>
<td>+5</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T: -40–105°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 MHz tolerance overall</td>
<td>I: -40–85°C</td>
<td>1.8 V – 3.6 V</td>
<td>-5</td>
<td>(\pm 2)</td>
<td>+5</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T: -40–105°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12 MHz tolerance overall</td>
<td>I: -40–85°C</td>
<td>2.2 V – 3.6 V</td>
<td>-5</td>
<td>(\pm 2)</td>
<td>+5</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T: -40–105°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16 MHz tolerance overall</td>
<td>I: -40–85°C</td>
<td>3.0 V – 3.6 V</td>
<td>-6</td>
<td>(\pm 3)</td>
<td>+6</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>T: -40–105°C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Loading DCO Calibration Data

<table>
<thead>
<tr>
<th>DCO Frequency</th>
<th>Calibration Register</th>
<th>Size</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 MHz</td>
<td>CALBC1_1MHz</td>
<td>byte</td>
<td>010FFh</td>
</tr>
<tr>
<td></td>
<td>CALDCCO_1MHz</td>
<td>byte</td>
<td>010FEl</td>
</tr>
<tr>
<td>8 MHz</td>
<td>CALBC1_8MHz</td>
<td>byte</td>
<td>010FDh</td>
</tr>
<tr>
<td></td>
<td>CALDCCO_8MHz</td>
<td>byte</td>
<td>010FCh</td>
</tr>
<tr>
<td>12 MHz</td>
<td>CALBC1_12MHz</td>
<td>byte</td>
<td>010FBh</td>
</tr>
<tr>
<td></td>
<td>CALDCCO_12MHz</td>
<td>byte</td>
<td>010FAh</td>
</tr>
<tr>
<td>16 MHz</td>
<td>CALBC1_16MHz</td>
<td>byte</td>
<td>010F9h</td>
</tr>
<tr>
<td></td>
<td>CALDCCO_16MHz</td>
<td>byte</td>
<td>010F8h</td>
</tr>
</tbody>
</table>

```c
BCSCTL1 = CALBC1_16MHz;               // DCO = 16MHz
DCOCTL = CALDCCO_16MHz;
```
VLO Specs

internal very low power, low frequency oscillator (VLO)

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TEST CONDITIONS</th>
<th>$T_A$</th>
<th>VCC</th>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f_{VLO}$ VLO frequency</td>
<td>-40–85°C</td>
<td>2.2 V/3 V</td>
<td>4</td>
<td>12</td>
<td>20</td>
<td></td>
<td>kHz</td>
</tr>
<tr>
<td></td>
<td>105°C</td>
<td>2.2 V/3 V</td>
<td>22</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$df_{VLO}/dT$ VLO frequency temperature drift</td>
<td>(see Note 1)</td>
<td>2.2 V/3 V</td>
<td>0.5</td>
<td></td>
<td></td>
<td></td>
<td>%/°C</td>
</tr>
<tr>
<td>$df_{VLO}/dV_{CC}$ VLO frequency supply voltage drift</td>
<td>(see Note 2)</td>
<td>1.8V – 3.6V</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>%/V</td>
</tr>
</tbody>
</table>

- Wide initial tolerance
- Temperature drift
- Voltage drift

Calibratable, just like 1xx DCO!

© 2006 Texas Instruments Inc, Slide 12
Calibrating the VLO

- Clock Timer_A from calibrated 1MHz DCO
- Capture with rising edge of ACLK/8 from VLO
- VLO = 8MHz/counts

Library coming soon!
Demo: LPM3 Using VLO

void main(void)
{
  BCSTL3 |= LFXT1S_2; // LFXT1 = VLO
  WDTCTL = WDT_ADLY_1000;
  IE1 |= WDTIE;
  // Configure P1/P2
  for (;;){
    _BIS_SR(LPM3_bits + GIE); // Enter LPM3
    _P1OUT ^= 0x01;
  }
}
#pragma vector=WDT_VECTOR
__interrupt void watchdog_timer(void){
  _BIC_SR_IRQ(LPM3_bits); // Clear LPM3 bits 0(SR)
}

• What is the measured current consumption?
F2xx Expanded Operating Range
F2xx: More Robust

**WDT+:**
- Watchdog or interval timer
- Selectable intervals
- Password protected
- Failsafe/protected clock

**System Enhancements:**
- Blank device > LPM4
- Invalid address reset
- BOR on every 2xx
All F2xx Have Zero Power BOR

- MSP430 BOR is always-on and zero-power
Agenda

- Enhancements
- Application Examples
- Devices & Summary
**F20x1 Tiny Power Saver**

- <1uA RTC Function
- DSP Power Sequencing
- Vcc Monitoring
- User Interface
- Tiny 4x4mm Footprint
F2xx Comparator A+

- Slope ADC
- Battery detect
- Reference generator
- Interrupt source
- Timer_A capture
- Expanded input multiplexer
- Multiplexer short for sample-and-hold
F20x1 Residential Thermostat

- <1uA total system power
- 10-bit slope ADC
- ± 1C/F
- No XTAL needed
- Very low cost
F2xx OA

- Single-supply
- Low-current
- Rail-Rail output
- Selectable settling time vs. current consumption
- Integrated R-ladder for PGA function
- 5 modes
  - GP
  - Unity buffer
  - Comparator
  - NI PGA
  - Inverting PGA

MSP430F22x4
F22x4 Glass Break Detector

- Integrated Solution
- 2ms sample interval
- VLO – no crystal required
- 50uA average current
- Real-time signal analysis

![Diagram of F22x4 Glass Break Detector circuit](image-url)
ADC10

- 10-bit ADC
- 200ksps+
- Autoscan
- Single
  Sequence
- Repeat-single
  Repeat-sequence
- Int/ext ref
- TA SOC triggers
- Data transfer controller

14-pin MSP430F2012
F20x2 Low-Cost Smoke Detector

- 8s sample interval
- 2uA average system power
- VLO – no crystal required
SD16_A

- 16-bit ΣΔ ADC
- 4.096 ksps
- Differential inputs
- 85db SINAD
- 32x PGA
- 18ppm 1.2V ref
- Temp sensor

14-pin MSP430F2013
F20x3 PIR Motion Detector

< 7uA total system power
  - ~5uA PIR
  - ~1uA Measurement
  - ~0.5uA MSP430 LPM3

• Fully programmable
  - Single-chip solution
  - Direct interface to SD16
  - VLO – no XTAL required

• Lower cost
F20x2/3 Universal Serial Interface

- Reduces CPU load
- SPI Mode
  - 8/16-bit Shift Register
  - MSB/LSB first
- I^2C Mode Support
  - START/STOP detection
  - SCL held after START
  - SCL held after counter overflow
  - Arbitration lost detection
- Fully Static Design
- Interrupt Driven
Data I/O

- Data shift register: up to 16 bits supported
- Number of bits TX’d & RX’d controlled by bit counter
- TX & RX is simultaneous
- Data I/O is user-defined: MSB or LSB first
- Bit counter automatically stops clocking after last bit & sets flag
- No data buffering!
USI Reduces CPU Load for SPI

```c
// Shift16_inout_Software
SR = DATA;
for (CNT=0x10; CNT>0; CNT--)
{
    P2OUT &= ~SDO;
    if (SR & 0x8000)
        P2OUT |= SDO;
    SR = SR << 1;
    if (P2IN & SDIN)
        SR |= 0x01;
    P2OUT |= SCLK;
    P2OUT &= ~SCLK;
}
```

```c
// Shift16_inout_USI
USISR |= DATA;
USICNT |= 0x10;
```

425 Cycles

10 Cycles

© 2006 Texas Instruments Inc, Slide 30
F20x2/3 USI Enables Practical I2C

- I2C Slave has as little as 4us from clock edge to data
- Traditional software-only solution allows for little else
- USI hardware enables practical and compliant I2C
- Code examples on the web

© 2006 Texas Instruments Inc, Slide 31
USI Clock Control

- Multiplexed input from up to 8 int/ext sources
- Configurable divider
- Auto-stop on interrupt: USIIFG
- Selectable phase and polarity
- Software clock: USISWCLK clock input bit
Universal Serial Communication I/F

- Ultra-low power
  - LPMx operation
- 2 individual blocks
- Double buffered TX/RX
- RX glitch suppression
- Baud rate generator
  - Flexible clock source
  - Automatic detection
  - Generation
- DMA enabled
- Interrupt driven
USCI Enhanced Features

• New standard MSP430 serial interface
• Auto clock start from any LPMx
• Two independent communication blocks

• Asynchronous communication modes
  ▪ UART standard and multiprocessor protocols
  ▪ UART with automatic Baud rate detection (LIN support)
  ▪ Two modulators support n/16 bit timing
  ▪ IrDA bit shaping encoder and decoder

• Synchronous communication modes
  ▪ SPI (Master & Slave modes, 3 & 4 wire)
  ▪ I2C (Master & Slave modes)
- UART with IrDA/LIN support or SPI
- Double buffered TX/RX
- Baud-rate generator with auto-baud rate detect
USCI_B

- I2C master/slave up to 400kHz or SPI
- Bit clock generator
- Double buffered TX/RX
New MSP430X CPU

- Architecture upgrade
- 100% code compatible
- 1MB unified memory map
- Extended addressing modes
  - Page-free 20-bit reach
  - Improved code density
  - Faster execution

MSP430F241x/261x

FFFF

64kB

Interrupt vectors
RAM
Peripherals

FFFFF

Code and Data Tables
F2xx: Every Little Bit Counts

- **Pull-up/down pin resistors**
  
<table>
<thead>
<tr>
<th>MIN</th>
<th>TYP</th>
<th>MAX</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>35</td>
<td>50</td>
</tr>
<tr>
<td>KΩ</td>
<td>KΩ</td>
<td>KΩ</td>
</tr>
</tbody>
</table>

- **XTAL capacitors**

- **DCO and VLO oscillators**
Agenda

• Enhancements
• Application Examples
• Devices & Summary
# New F2xx Multi-Purpose Devices

<table>
<thead>
<tr>
<th>Device</th>
<th>Pins</th>
<th>Flash/RAM</th>
<th>Features</th>
<th>Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>F20x1</td>
<td>14</td>
<td>2KB / 128B</td>
<td>TA2, Comp_A</td>
<td>Now</td>
</tr>
<tr>
<td>F20x2</td>
<td>14</td>
<td>2KB / 128B</td>
<td>TA2, USI, AC10</td>
<td>Now</td>
</tr>
<tr>
<td>F20x3</td>
<td>14</td>
<td>2KB / 128B</td>
<td>TA2, USI, SD16</td>
<td>Now</td>
</tr>
<tr>
<td>F21x1</td>
<td>20</td>
<td>8KB / 256B</td>
<td>TA3, Comp_A</td>
<td>Now</td>
</tr>
<tr>
<td>F22x2*</td>
<td>38/40</td>
<td>32KB / 1KB</td>
<td>TA3, TB3, USCI, ADC10</td>
<td>Now</td>
</tr>
<tr>
<td>F22x4*</td>
<td>38/40</td>
<td>32KB / 1KB</td>
<td>TA3, TB3, USCI, ADC10, (2)OPA</td>
<td>Now</td>
</tr>
<tr>
<td>F23x0*</td>
<td>40</td>
<td>32KB / 2KB</td>
<td>TA3, TB3, USCI, Comp_A, MPY</td>
<td>1Q07</td>
</tr>
<tr>
<td>F23x*</td>
<td>64</td>
<td>16KB/512B</td>
<td>TA3, TB3, USCI, ADC12</td>
<td>2Q07</td>
</tr>
<tr>
<td>F24x*</td>
<td>64</td>
<td>60KB/2KB</td>
<td>TA3, TB7, (2)USCI, ADC12</td>
<td>2Q07</td>
</tr>
<tr>
<td>F241x*</td>
<td>64/80</td>
<td>120KB / 8KB</td>
<td>TA3, TB7, (2)USCI, ADC12, MPY</td>
<td>1Q07</td>
</tr>
<tr>
<td>F261x*</td>
<td>64/80</td>
<td>120KB / 8KB</td>
<td>TA3, TB7, (2)USCI,ADC12, MPY, (2)DAC12, (3)DMA</td>
<td>1Q07</td>
</tr>
</tbody>
</table>

All devices include enhanced watchdog timer (WDT+) and enhanced basic clock system (BCS+)

* Planned Future device, in development
Summary

- Pin-compatible drop-ins
- Lower Power
- Faster
- Many upgraded peripherals
- Many new devices
**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 TI.

Reproduction of 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.

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, even if they are not represented by TI products as safe or suitable. Buyers are solely responsible for compliance with all laws regarding such applications, including but not limited to the U.S. Export Administration Regulations.

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:

<table>
<thead>
<tr>
<th>Products</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amplifiers</td>
<td>Audio</td>
</tr>
<tr>
<td>Data Converters</td>
<td>Automotive</td>
</tr>
<tr>
<td>DSP</td>
<td>Broadband</td>
</tr>
<tr>
<td>Interface</td>
<td>Digital Control</td>
</tr>
<tr>
<td>Logic</td>
<td>Military</td>
</tr>
<tr>
<td>Power Mgmt</td>
<td>Optical Networking</td>
</tr>
<tr>
<td>Microcontrollers</td>
<td>Security</td>
</tr>
<tr>
<td>RFID</td>
<td>Telephony</td>
</tr>
<tr>
<td>Low Power Wireless</td>
<td>Video &amp; Imaging</td>
</tr>
</tbody>
</table>

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2007, Texas Instruments Incorporated