Introduction to MSP430
Communication Interfaces

Christian Hernitscheck
MSP430 FAE Europe
Texas Instruments
Agenda

• USART, USCI, USI Comparison
• RS232 Communication
• SPI Communication
• I2C Communication
• Lab Activities
# MSP430 Communication Modules

<table>
<thead>
<tr>
<th>UART:</th>
<th>USCI:</th>
<th>USI:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Only one modulator</td>
<td>- Two modulators support n/16 timings</td>
<td>- - -</td>
</tr>
<tr>
<td>- n/a</td>
<td>- Auto baud rate detection</td>
<td></td>
</tr>
<tr>
<td>- n/a</td>
<td>- IrDA encoder &amp; decoder</td>
<td></td>
</tr>
<tr>
<td>- n/a</td>
<td>- Simultaneous USCI_A and USCI_B (2 channels)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SPI:</th>
<th>SPI:</th>
<th>SPI:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Only one SPI available</td>
<td>- Two SPI (one on each USCI_A and USCI_B)</td>
<td>- Only one SPI available</td>
</tr>
<tr>
<td>- Master and Slave Modes</td>
<td>- Master and Slave Modes</td>
<td>- Master and Slave Modes</td>
</tr>
<tr>
<td>- 3 and 4 Wire Modes</td>
<td>- 3 and 4 Wire Modes</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>I2C: (on ‘15x/’16x only)</th>
<th>I2C:</th>
<th>I2C:</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Master and Slave Modes</td>
<td>- Simplified interrupt usage</td>
<td>- SW state machine needed</td>
</tr>
<tr>
<td>- up to 400kbps</td>
<td>- Master and Slave Modes</td>
<td>- Master and Slave Modes</td>
</tr>
</tbody>
</table>

© 2006 Texas Instruments Inc, Slide 3
Agenda

• USART, USCI, USI Comparison

• RS232 Communication

• SPI Communication

• I2C Communication

• Lab Activities
USART

- Ultra-Low Power Support:
  - Auto-Start from any Low-Power Mode
- UART or SPI Mode
  (I2C on ‘F15x/’F16x only)
- Double Buffered TX/RX
- Baudrate Generator
- DMA enabled
- Error Detection
**Universal Serial Communication I/F**

- **Ultra-Low Power Support:**
  - Auto-Start from any Low-Power Mode

- **Two Individual Blocks:**
  - **USCI_A:**
    - UART with Lin/IrDA support
    - SPI (Master/Slave, 3 & 4 wire mode)
  - **USCI_B:**
    - SPI (Master/Slave, 3 & 4 wire mode)
    - I2C (Master/Slave, up to 400kHz)

- **Double Buffered TX/RX**

- **Baudrate/Bit Clock Generator:**
  - With Auto-Baud Rate Detect
  - Flexible Clock Source

- **RX glitch suppression**

- **DMA enabled**

- **Error Detection**
RS232 Software Solution

• Example: 9600 Baud using 32.768kHz clock source

```c
__interrupt void Timer_ISR()
{
    if (Data & 0x01) // check data bit 0
        SetOutput(); // bit0=1 → P1.0=1
    else
        ResetOutput(); // bit0=0 → P1.0=0
    Data = Data >> 1; // next bit
}
```

9600 Baud ⇒ Bit Time = 104.17us ↔ 3x 32768Hz clocks = 91.55us
4x 32768Hz clocks = 122.07us

Interrupts after 4 counts:

© 2006 Texas Instruments Inc, Slide 7
Reducing Cumulative Error

- Modulation reduces Cumulative Error:

9600 Baud ⇒ Bit Time = 104.17us ⇔ 3x 32768Hz clocks = 91.55us
4x 32768Hz clocks = 122.07us

Redefine bit time at each interrupt →

TXD

Start D0 D1 D2 D3 D4 D5 D6 D7 Parity Stop
USART Baudrate Generator

9600 baud:
ACLK = 32768 Hz
Prescaler = 32768 Hz / 9600 baud = 3.41
UxBR1 | UxBR0 | UxMCTL = 00h | 03h | 4Ah

Content of UxMCTL is the modulation pattern
USCI Baudrate Generator

- Oversampling Baud Rate Generation
- Two Modulators (UCBRSx and UCBRFx select modulation pattern)
- RX sampled using BITCLK16
USART Initialization Sequence

Recommended USART initialization/re-configuration process as shown in the MSP430 User’s Guide:

<table>
<thead>
<tr>
<th>Note: Initializing or Re-Configuring the USART Module</th>
</tr>
</thead>
<tbody>
<tr>
<td>The required USART initialization/re-configuration process is:</td>
</tr>
<tr>
<td>1) Set SWRST (B1S.B  #SWRST,&amp;UxCTL)</td>
</tr>
<tr>
<td>2) Initialize all USART registers with SWRST = 1 (including UxCTL)</td>
</tr>
<tr>
<td>3) Enable USART module via the MEx SFRs (URXEx and/or UTXEx)</td>
</tr>
<tr>
<td>4) Clear SWRST via software (B1C.B  #SWRST,&amp;UxCTL)</td>
</tr>
<tr>
<td>5) Enable interrupts (optional) via the IEx SFRs (URXIXEx and/or UTXIXEx)</td>
</tr>
</tbody>
</table>

Failure to follow this process may result in unpredictable USART behavior.

Please compare recommendations for USART Module in the MSP430 User’s Guides.
USCI Initialization Sequence

Recommended USCI initialization/re-configuration process as shown in the MSP430 User’s Guide:

```
Note: Initializing or Re-Configuring the USCI Module

The recommended USCI initialization/re-configuration process is:
1) Set UCSWRST (BIS.B #UCSWRST,&UCAxCTL1)
2) Initialize all USCI registers with UCSWRST = 1 (including UCAxCTL1)
3) Configure ports.
4) Clear UCSWRST via software (BIC.B #UCSWRST,&UCAxCTL1)
5) Enable interrupts (optional) via UCAxRXIE and/or UCAxTXIE
```

Please compare recommendations for USCI Module in the MSP430 User’s Guides.
Agenda

• USART, USCI, USI Comparison
• RS232 Communication
• SPI Communication
• I2C Communication
• Lab Activities
SPI Example

- 3 Wire Mode (MSP430 also supports 4-wire mode)
- Clock Phase and Polarity configurable
- Think about Start-up Behaviour
Universal Serial Interface

- Available on new MSP430x20xx family
- Supports I2C and SPI
- Programmable Data Length (up to 16-bits)
- Flexible Clock Source Selection

Provides efficient combination of cost & function for a software-friendly serial interface
USART SPI

- Supports Master and Slave Mode
- 3-pin and 4-pin SPI operation

MSP430 USART (Master Mode)

Receive Buffer UxRXBUF

Receive Shift Register

Transmit Shift Register

Transmit Buffer UxTXBUF

MSP430 USART (Slave Mode)

Transmit Buffer UxTXBUF

Transmit Shift Register

Receive Shift Register

Receive Buffer UxRXBUF

© 2006 Texas Instruments Inc, Slide 16
USCI: SPI Mode

- Take care about Clock Polarity and Phase settings
- USCI_A and USCI_B share TX and RX vector
- Software check detects correct ISR handle:

USCI SPI Block Diagram:

- Receive Buffer
- Receive Shift Register
- Master Bit Clock Generator (Prescaler, Clock Polarity and Phase)
- Transmit Shift Register
- Transmit Buffer

© 2006 Texas Instruments Inc, Slide 17
Agenda

• USART, USCI, USI Comparison
• RS232 Communication
• SPI Communication
• I2C Communication
• Lab Activities
I2C-Bus Example

• **MSP430F2013:**
  - USI I2C Slave Mode
  - Data (2 Bytes) are sent via I2C

• **MSP430FG4619:**
  - USCI I2C Master Mode
  - Data (2 Bytes) are read via I2C
**Universal Serial Interface**

- Available on new MSP430x20xx family
- Supports I2C and SPI
- Programmable Data Length (up to 16-bits)
- Flexible Clock Source Selection

*Provides efficient combination of cost & function for a software-friendly serial interface*
USI: I2C Slave Transmitter

Software State Machine:

1. IDLE
2. Receive Address
3. Process Address and send (N)ACK
   - Slave Addr. ok
   - Slave Addr. does not match
4. Send Data
5. Receive (N)Ack
6. Process Data Ack/NAck

I2C Protocol:

Start Condition

Slave Address + R/W bit

Slave ACKN

Send DATA

Master ACKN

Stop Condition
USCI: I2C Communication

• Compliance to I2C Specification V2.1:
  - 7-bit/10-bit addressing
  - General call
  - Start/Restart/Stop
  - Multi-master transmitter/receiver mode
  - Slave receiver/transmitter mode
  - Standard mode (100kbps) and fast mode (400kbps) support

• Flexible Bit Clock Generator

• Designed for Low Power
Agenda

• USART, USCI, USI Comparison
• RS232 Communication
• SPI Communication
• I2C Communication
• Lab Activities
LAB 1: Instructions

• Start IAR Embedded Workbench and create a new Project
• Add the file “msp430xG46x_uscia0_uart_01_115k_modified.c” to the project
• Configure the project options (PROJECT → OPTIONS)
• Download the code and start the code
• Check RS232 communication between PC and your ATC board (The demo code will echo back received characters)
• You may change the baud rate by modifying the marked code lines on the following slide (more information about these control registers can be found on slide 26)
LAB 1: RS232 Communication

```c
void main(void) // FILE: “msp430xG46x_uscia0_uart_01_115k_modified.c”
{
    WDTCTL = WDTPW+WDTHOLD; // Stop WDT
    FLL_CTL0 |= XCAP14PF; // Configure load caps
    //... check 32kHz oscillator
    P2SEL |= 0x030; // P2.4,5 = USCI_A0 RXD/TXD
    UCA0CTL1 |= UCSSEL_2; // SMCLK
    UCA0BR0 = 0x09; // 1MHz 115200
    UCA0BR1 = 0x00; // 1MHz 115200
    UCA0MCTL = 0x02; // Modulation
    UCA0CTL1 &= ~UCSWRST; // **Initialize USCI state machine**
    IE2 |= UCA0RXIE; // Enable USCI_A0 RX interrupt
    _BIS_SR(LPM0_bits + GIE); // Enter LPM0, interrupts enabled
}

// Echo back RXed character, confirm TX buffer is ready first
#pragma vector=USCIAB0RX_VECTOR
__interrupt void USCIA0RX_ISR (void)
{
    while(!(IFG2&UCA0TXIFG));
    UCA0TXBUF = UCA0RXBUF; // TX -> RXed character
}
```

© 2006 Texas Instruments Inc, Slide 25
# LAB 1: Modify Baudrate

## MSP430x4xx User’s Guide/USCI Module Description:

### Table 18–4. Commonly Used Baud Rates, Settings, and Errors, \( UCOS16 = 0 \)

<table>
<thead>
<tr>
<th>BRCLK frequency [Hz]</th>
<th>Baud Rate [Baud]</th>
<th>UCBRx</th>
<th>UCBRSx</th>
<th>UCBRFx</th>
<th>Max. TX Error [%]</th>
<th>Max. RX Error [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>32,768</td>
<td>1200</td>
<td>27</td>
<td>2</td>
<td>0</td>
<td>-2.8</td>
<td>1.4</td>
</tr>
<tr>
<td>32,768</td>
<td>2400</td>
<td>13</td>
<td>6</td>
<td>0</td>
<td>-4.8</td>
<td>6.0</td>
</tr>
<tr>
<td>32,768</td>
<td>4800</td>
<td>6</td>
<td>7</td>
<td>0</td>
<td>-12.1</td>
<td>5.7</td>
</tr>
<tr>
<td>32,768</td>
<td>9600</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>-21.1</td>
<td>15.2</td>
</tr>
<tr>
<td>1,048,576</td>
<td>9600</td>
<td>109</td>
<td>2</td>
<td>0</td>
<td>-0.2</td>
<td>0.7</td>
</tr>
<tr>
<td>1,048,576</td>
<td>19200</td>
<td>54</td>
<td>5</td>
<td>0</td>
<td>-1.1</td>
<td>1.0</td>
</tr>
<tr>
<td>1,048,576</td>
<td>38400</td>
<td>27</td>
<td>2</td>
<td>0</td>
<td>-2.8</td>
<td>1.4</td>
</tr>
<tr>
<td>1,048,576</td>
<td>56000</td>
<td>18</td>
<td>6</td>
<td>0</td>
<td>-3.9</td>
<td>1.1</td>
</tr>
<tr>
<td>1,048,576</td>
<td>115200</td>
<td>9</td>
<td>1</td>
<td>0</td>
<td>-1.1</td>
<td>10.7</td>
</tr>
</tbody>
</table>

**UCA0CTL1 | UCSSEL_1;**

**UCA0CTL1 | UCSSEL_2;**

**UCBRx:**

**UCAxBR1** | **UCAxBR0**

**UCBFRx | UCBRSx | UCOS16**

**UCAxMCTL:**

© 2006 Texas Instruments Inc, Slide 26
LAB 2: SPI with USI and USCI

1. MSP430F2013:
   - Download code “msp430x20x3_usi_03_modified.c”

2. MSP430FG4619:
   - Download code “msp430xG46x_uscib0_spi_01_modified.c”
   - Check Jumper on connector H1 (3-4, 7-8)
   - Connect RS232 (115kBaud, 8bit, no parity)
   - Press push-button S1 to read sequence via SPI and show it on PC
LAB 2: Scope Shot of SPI & RS232

SPI Bus

UCB0CLK

UCB0SOMI

RS232

TXD
LAB 3: I2C with USI and USCI

1. **MSP430F2013:**
   - Download code “msp430x20x3_usi_09_modified.c”

2. **MSP430FG4619:**
   - Download code “msp430xG46x_uscib0_i2c_10_modified.c”
   - Check Jumper on connector H1 (1-2, 3-4)
   - Set breakpoint in main loop (look for comment “// Set BREAKPOINT >>here<<“)
   - Start program execution. As soon as breakpoint was detected check RxBuffer content.
LAB 3: Scope Shot I2C Bus

I2C Bus

SDA

SCL

I2C Slave Address

Software Counter
Summary

• There are different solutions! MSP430’s peripheral communication modules helps you to reduce CPU loading

• Be aware about the initialization sequence of USART and USCI modules (follow the recommendations of the User’s Guides)

• Detailed module descriptions can be found in the MSP430 User’s Guides

• Code examples are available on the MSP430 homepage (www.ti.com/msp430)
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, and hereby release TI from all liability arising out of its use in such 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:

<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><a href="http://www.ti.com/audio">www.ti.com/audio</a></td>
</tr>
<tr>
<td>DSP</td>
<td>Automotive</td>
</tr>
<tr>
<td>Users</td>
<td><a href="http://www.ti.com/automotive">www.ti.com/automotive</a></td>
</tr>
<tr>
<td>Interface</td>
<td>Broadband</td>
</tr>
<tr>
<td>Logic</td>
<td>Digital Control</td>
</tr>
<tr>
<td>Military</td>
<td><a href="http://www.ti.com/digitalcontrol">www.ti.com/digitalcontrol</a></td>
</tr>
<tr>
<td>Power Mgmt</td>
<td>Military</td>
</tr>
<tr>
<td></td>
<td><a href="http://www.ti.com/military">www.ti.com/military</a></td>
</tr>
<tr>
<td>Microcontrollers</td>
<td><a href="http://www.ti.com/security">www.ti.com/security</a></td>
</tr>
<tr>
<td>RFID</td>
<td>Optical Networking</td>
</tr>
<tr>
<td>Low Power</td>
<td><a href="http://www.ti.com/opticalnetwork">www.ti.com/opticalnetwork</a></td>
</tr>
<tr>
<td>Wireless</td>
<td>Security</td>
</tr>
<tr>
<td></td>
<td>Telephony</td>
</tr>
<tr>
<td></td>
<td><a href="http://www.ti.com/telephony">www.ti.com/telephony</a></td>
</tr>
<tr>
<td></td>
<td>Video &amp; Imaging</td>
</tr>
<tr>
<td></td>
<td><a href="http://www.ti.com/video">www.ti.com/video</a></td>
</tr>
<tr>
<td></td>
<td>Wireless</td>
</tr>
<tr>
<td></td>
<td><a href="http://www.ti.com/wireless">www.ti.com/wireless</a></td>
</tr>
</tbody>
</table>

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