

MSP430 Advanced Technical Conference 2006



Introduction to MSP430 Communication Interfaces

Christian Hernitscheck
MSP430 FAE Europe
Texas Instruments

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Agenda



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

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MSP430 Communication Modules

USART	USCI 	USI 
UART: <ul style="list-style-type: none"> - Only one modulator - n/a - n/a - n/a 	UART: <ul style="list-style-type: none"> - Two modulators support n/16 timings - Auto baud rate detection - IrDA encoder & decoder - Simultaneous USCI_A and USCI_B (2 channels) 	<p>---</p>
SPI: <ul style="list-style-type: none"> - Only one SPI available - Master and Slave Modes - 3 and 4 Wire Modes 	SPI: <ul style="list-style-type: none"> - Two SPI (one on each USCI_A and USCI_B) - Master and Slave Modes - 3 and 4 Wire Modes 	SPI: <ul style="list-style-type: none"> - Only one SPI available - Master and Slave Modes
I2C: (on '15x/16x only) <ul style="list-style-type: none"> - Master and Slave Modes - up to 400kbps 	I2C: <ul style="list-style-type: none"> - Simplified interrupt usage - Master and Slave Modes - up to 400kbps 	I2C: <ul style="list-style-type: none"> - SW state machine needed - Master and Slave Modes

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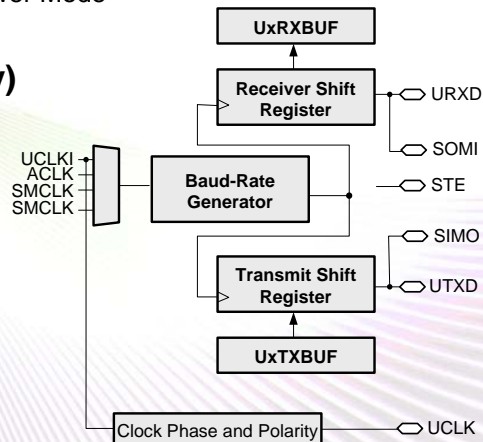
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USART

- **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**



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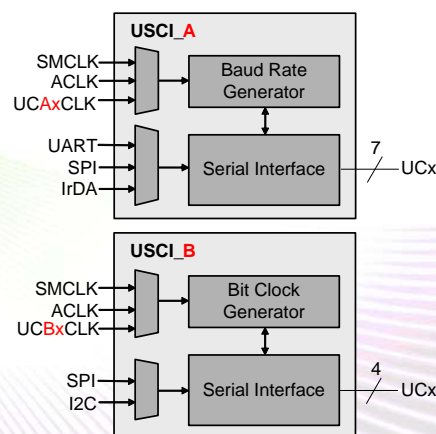
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Universal Serial Communication I/F

NEW

- **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**



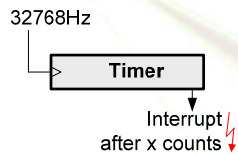
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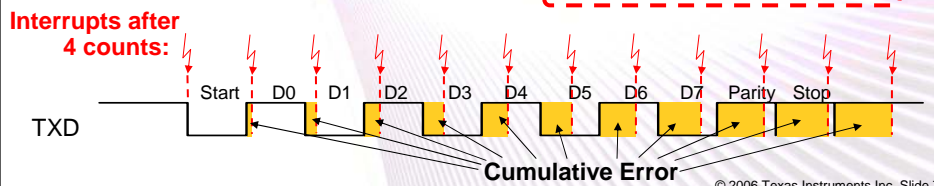
RS232 Software Solution

- **Example:** 9600 Baud using 32.768kHz clock source



```
_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 \Rightarrow Bit Time = 104.17us \leftrightarrow 3x 32768Hz clocks = 91.55us
 4x 32768Hz clocks = 122.07us



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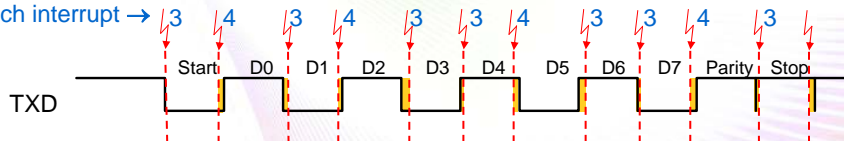
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Reducing Cumulative Error

- **Modulation reduces Cumulative Error:**

9600 Baud \Rightarrow Bit Time = 104.17us \leftrightarrow 3x 32768Hz clocks = 91.55us
 4x 32768Hz clocks = 122.07us

Redefine bit time
 at each interrupt \rightarrow



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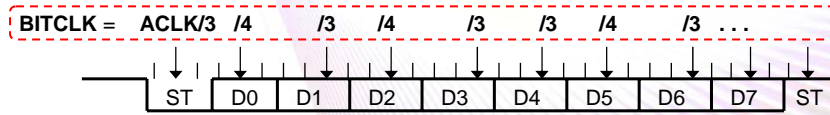
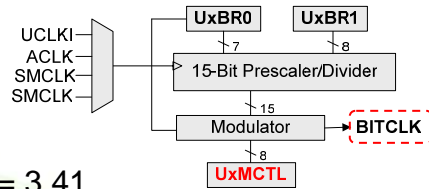
USART Baudrate Generator

9600 baud:

ACLK = 32768 Hz

Prescaler = $32768\text{Hz}/9600\text{baud} = 3.41$

UxBR1 | UxBR0 | UxMCTL = 00h | 03h | 4Ah



Content of UxMCTL is the modulation pattern

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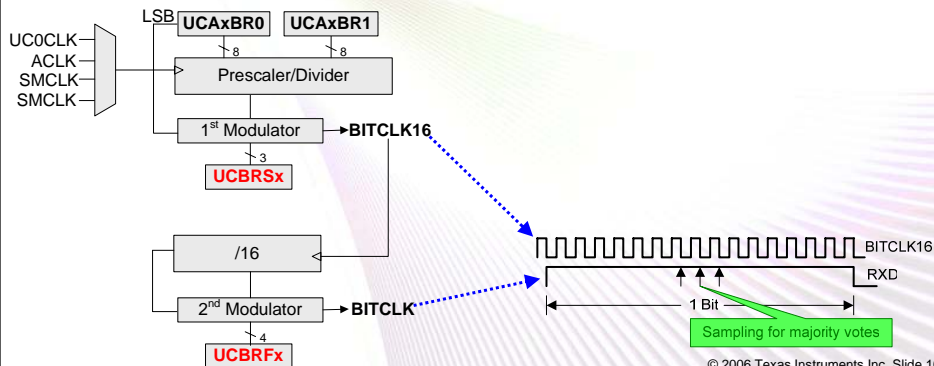
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USCI Baudrate Generator



- Oversampling Baud Rate Generation
- Two Modulators (UCBRs_x and UCBRF_x select modulation pattern)
- RX sampled using BITCLK16



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USART Initialization Sequence

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

Note: Initializing or Re-Configuring the USART Module

The required USART initialization/re-configuration process is:

- 1) Set SWRST (`BIS.B #SWRST, &UxCTL`)
- 2) Initialize all USART registers with SWRST = 1 (including UxCTL)
- 3) Enable USART module via the MEx SFRs (URXEx and/or UTXEx)
- 4) Clear SWRST via software (`BIC.B #SWRST, &UxCTL`)
- 5) Enable interrupts (optional) via the IEx SFRs (URXIE and/or UTXIE)

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

Please compare recommendations for USART Module in the MSP430 User's Guides.

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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.

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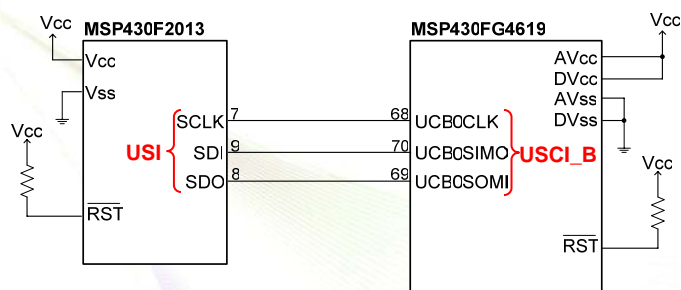
- USART, USCI, USI Comparison
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- SPI Communication
- I2C Communication
- Lab Activities

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SPI Example



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

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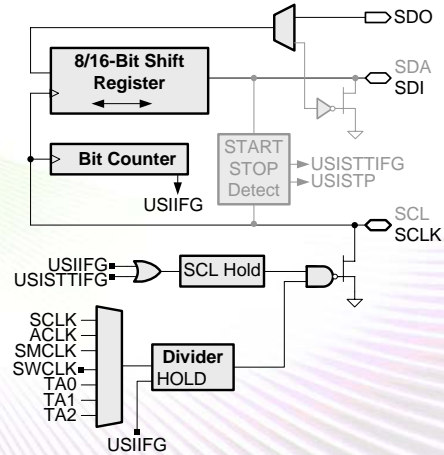
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Universal Serial Interface



- 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



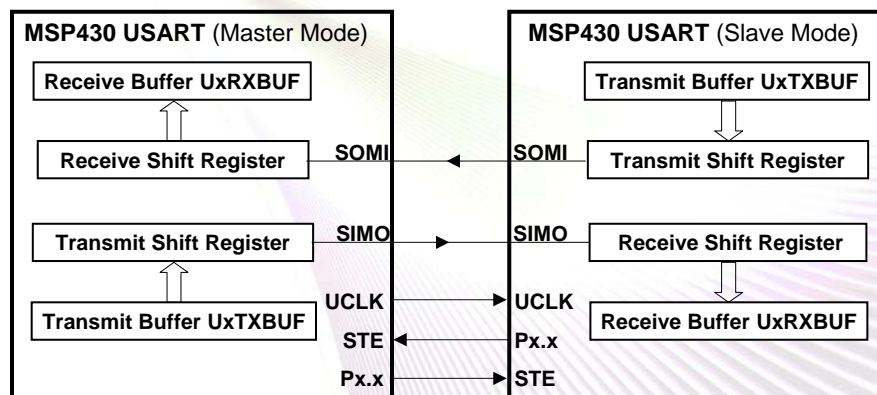
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USART SPI

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



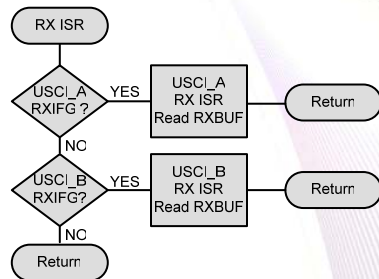
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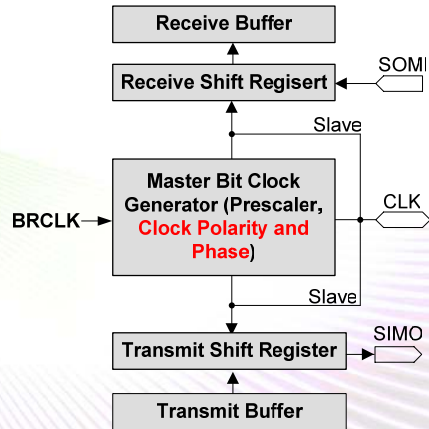


USCI: SPI Mode

- **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:



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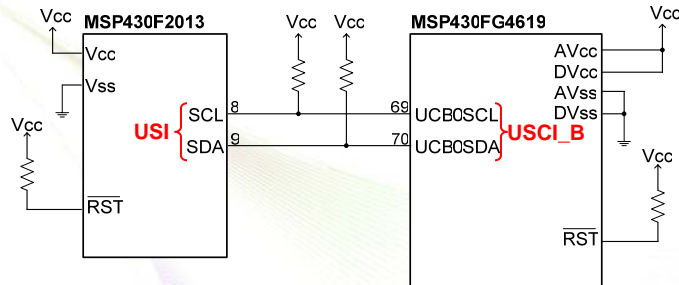
- USART, USCI, USI Comparison
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I2C-Bus Example



- **MSP430F2013:**

- USI I2C Slave Mode
- Data (2 Bytes) are sent via I2C

- **MSP430FG4619:**

- USCI I2C Master Mode
- Data (2 Bytes) are read via I2C

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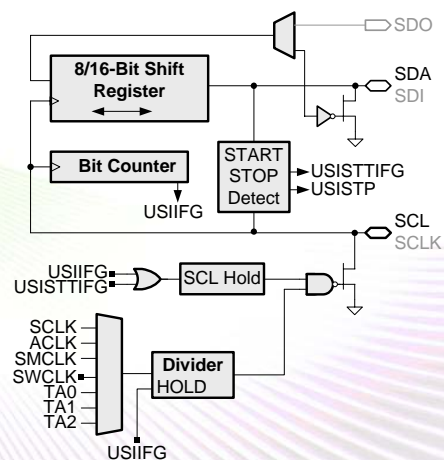
TEXAS INSTRUMENTS

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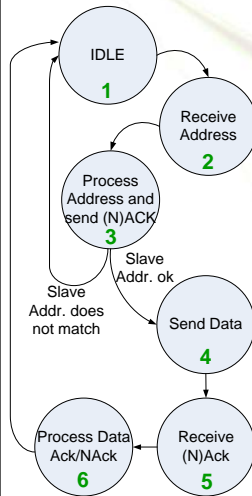
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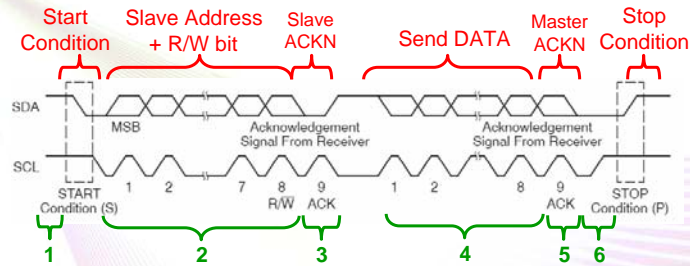
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USI: I2C Slave Transmitter

Software State Machine:



I2C Protocol:



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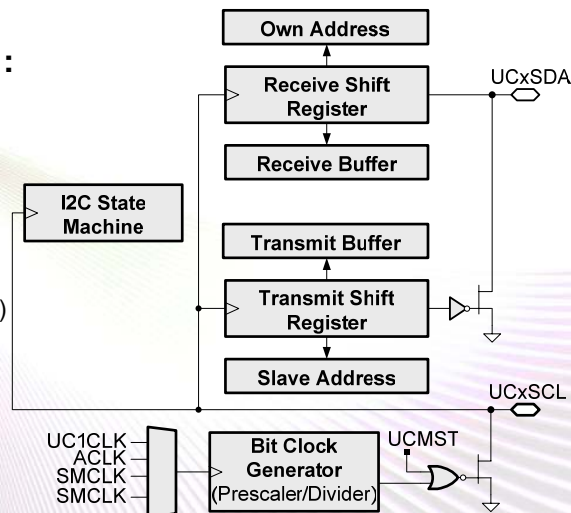
USCI: I2C Communication

• 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



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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)

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LAB 1: RS232 Communication

```
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=USCIABORX_VECTOR
__interrupt void USCIA0RX_ISR (void)
{
    while(!(IFG2&UCA0TXIFG));
    UCA0TXBUF = UCA0RXBUF; // TX -> RXed character
}
```

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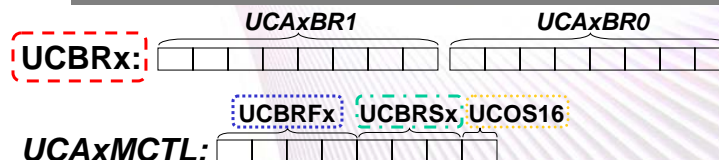
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LAB 1: Modify Baudrate

MSP430x4xx User's Guide/USCI Module Description:

Table 18–4. Commonly Used Baud Rates, Settings, and Errors; UCOS16 = 0

	BRCLK frequency [Hz]	Baud Rate [Baud]	UCBRx	UCBRs	UCBRFx	Max. TX Error [%]		Max. RX Error [%]	
UCA0CTL1 = UCSSEL_1;	32,768	1200	27	2	0	-2.8	1.4	-5.9	2.0
	32,768	2400	13	6	0	-4.8	6.0	-9.7	8.3
	32,768	4800	6	7	0	-12.1	5.7	-13.4	19.0
	32,768	9600	3	3	0	-21.1	15.2	-44.3	21.3
UCA0CTL1 = UCSSEL_2;	1,048,576	9600	109	2	0	-0.2	0.7	-1.0	0.8
	1,048,576	19200	54	5	0	-1.1	1.0	-1.5	2.5
	1,048,576	38400	27	2	0	-2.8	1.4	-5.9	2.0
	1,048,576	56000	18	6	0	-3.9	1.1	-4.6	5.7
	1,048,576	115200	9	1	0	-1.1	10.7	-11.5	11.3



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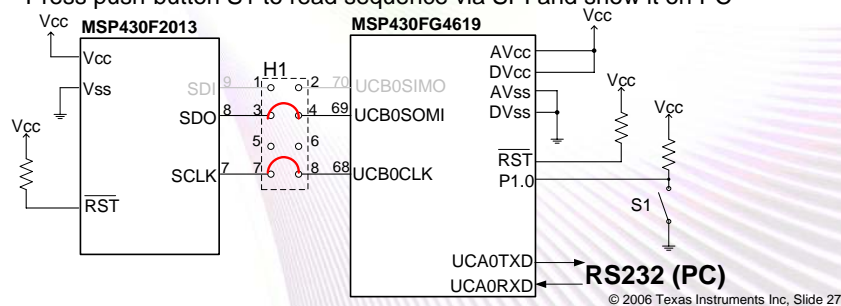
LAB 2: SPI with USI and USCI

1. MSP430F2013:

- Download code "msp430x20x3_usi_03_modified.c"

2. MSP430FG4619:

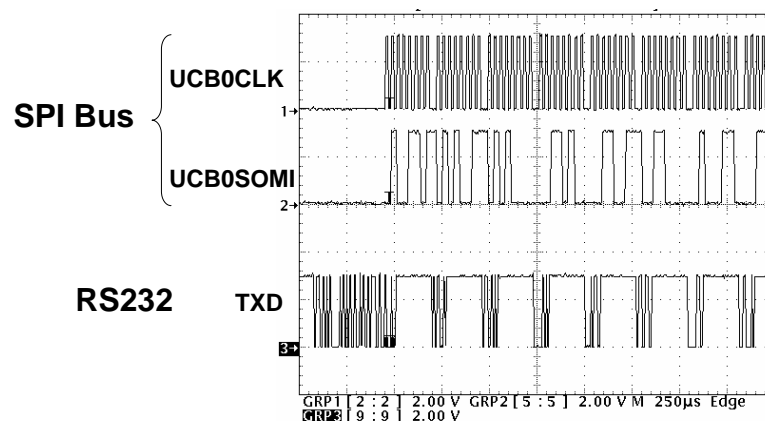
- Download code "msp430xG46x_uscib0_spi_01_modified.c"
- Check Jumper on connector H1 (3-4, 7-8)
- Connect RS232 (115kBaud, 8bit, no parity)
- Press push-button S1 to read sequence via SPI and show it on PC



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LAB 2: Scope Shot of SPI & RS232



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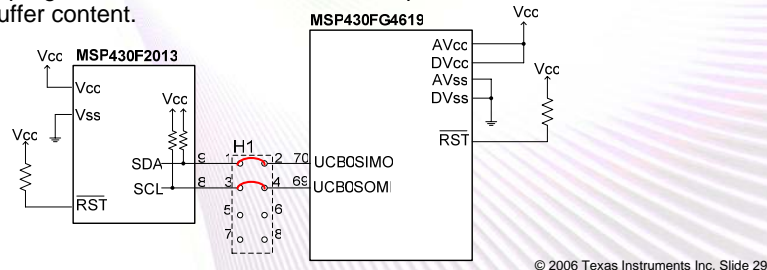
LAB 3: I2C with USI and USCI

1. MSP430F2013:

- Download code "msp430x20x3_usi_09_modified.c"

2. MSP430FG4619:

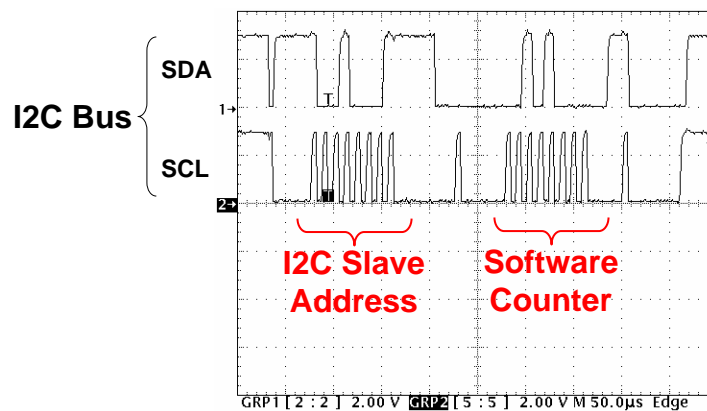
- Download code "msp430xG46x_uscib0_i2c_10_modified.c"
- Check Jumper on connector H1 (1-2, 3-4)
- Set breakpoint in main loop (look for comment "// Set BREAKPOINT >>here<<")
- Start program execution. As soon as breakpoint was detected check RxBuffer content.



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LAB 3: Scope Shot I2C Bus



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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)**

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