MSP430 Advanced Technical Conference 2006

Hands-On: Implementing an RF link with MSP430 and CC1100

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Overview

- Introduction
- Target Hardware
- Library File Organization
- Lab Activities

What is the Library?

- Register read/write functions (MSP430 to CC1100/CC2500)
  - Read register
  - Write register
  - Read burst
  - Write burst
  - Status read
  - Command strobe write
  - CC1100/2500 reset
- CC1100/CC2500 are targeted at general-purpose ISM-band apps at 315/433/868/915 MHz and 2.4 GHz respectively
- Library based on *CC1100/CC2500 Examples and Libraries* from Chipcon
- SPI functions only; no protocol functions
- Demo application project included

What is the Library?

- Works with any SPI-capable MSP430 interface
  - **USART0**
  - **USART1**
  - **USCI_A0**
  - **USCI_A1**
  - **USCI_B0**
  - **USCI_B1**
  - **USI**
  - **Bit-bang I/Os**
- Hardware abstraction assists porting between MSP430 devices
- Not tested for other Chipcon devices
- Tested with MCLK between 1-8MHz and SMCLK dividers of /1 and /8

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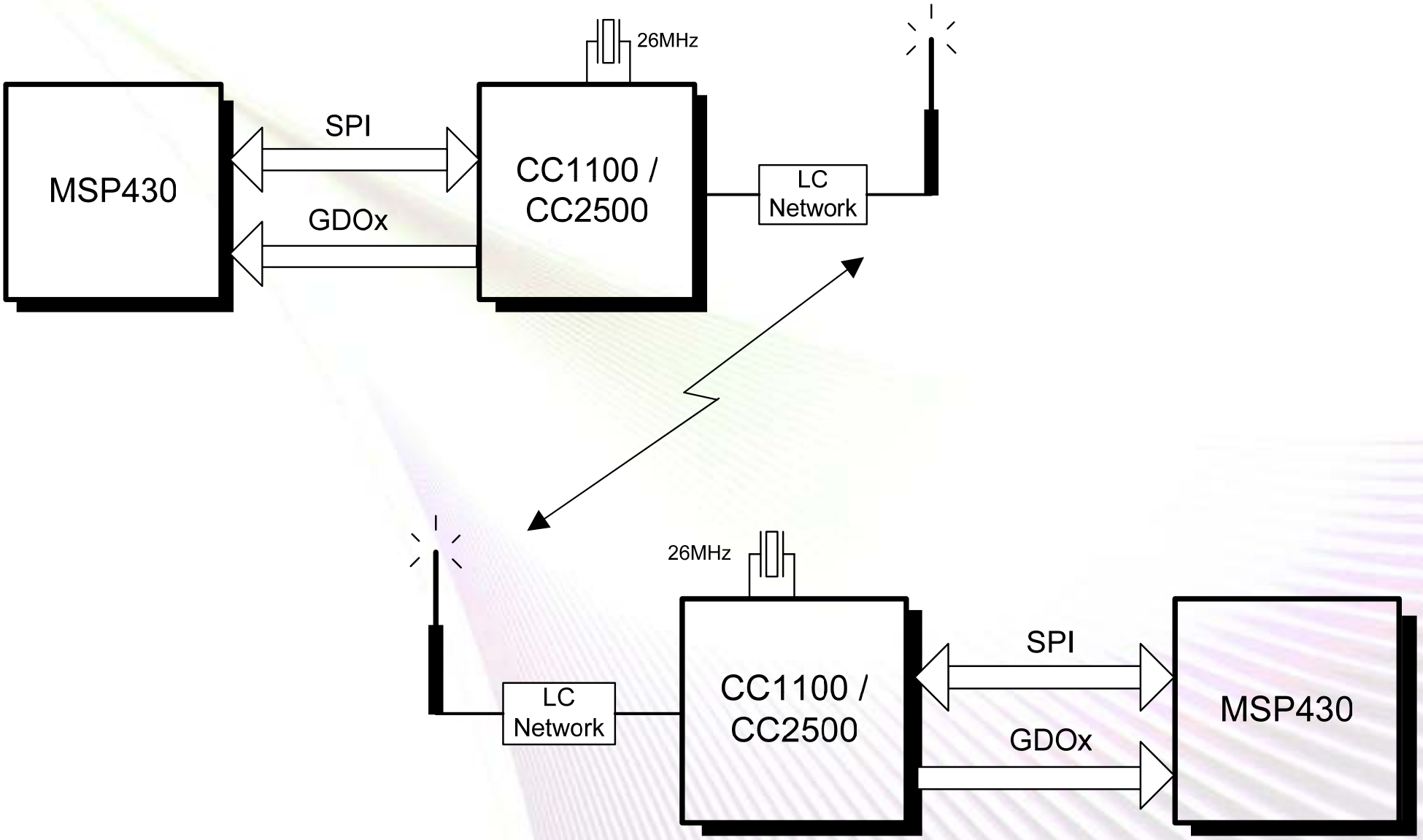
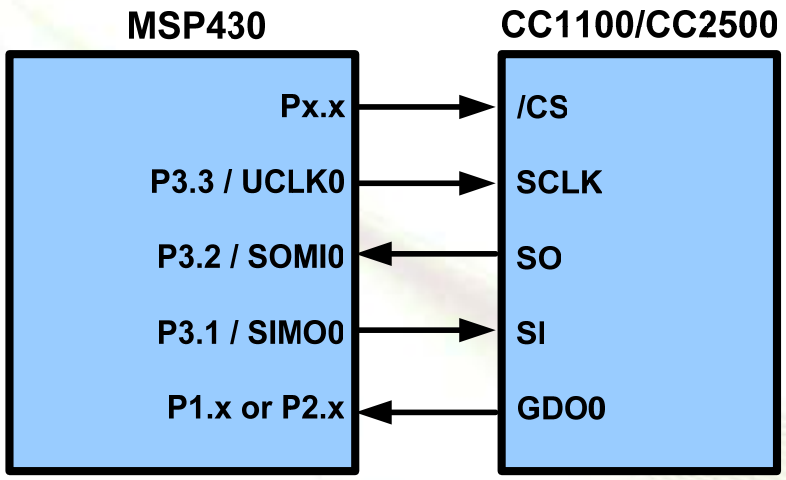
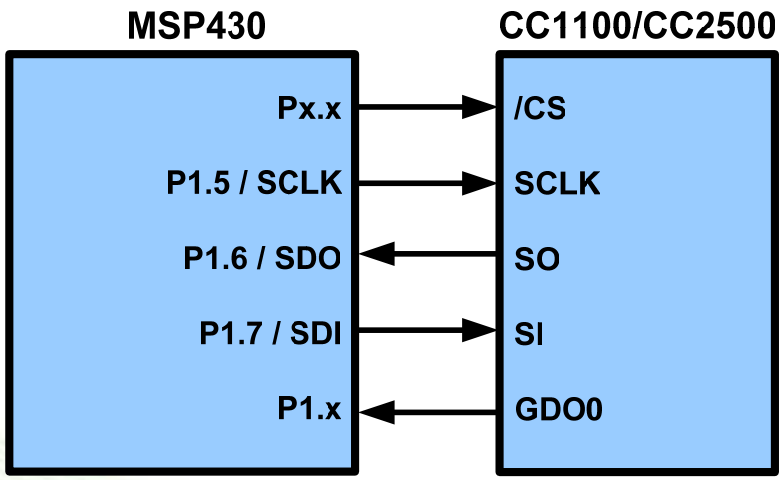
Target Hardware



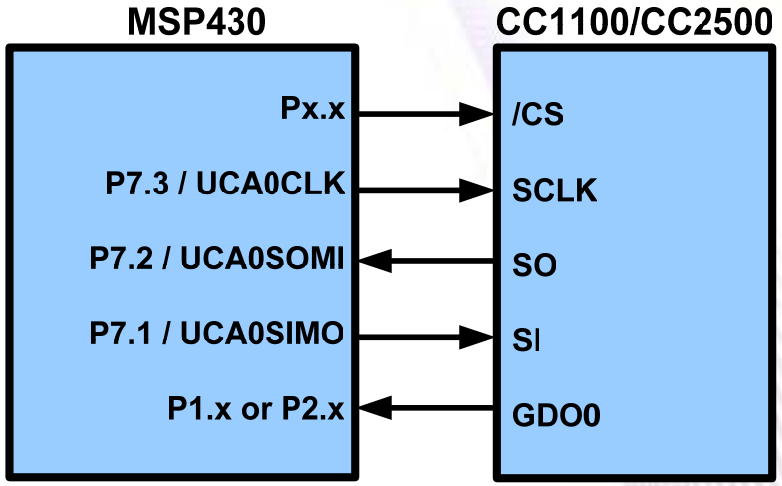
MSP430 SPI Interfaces



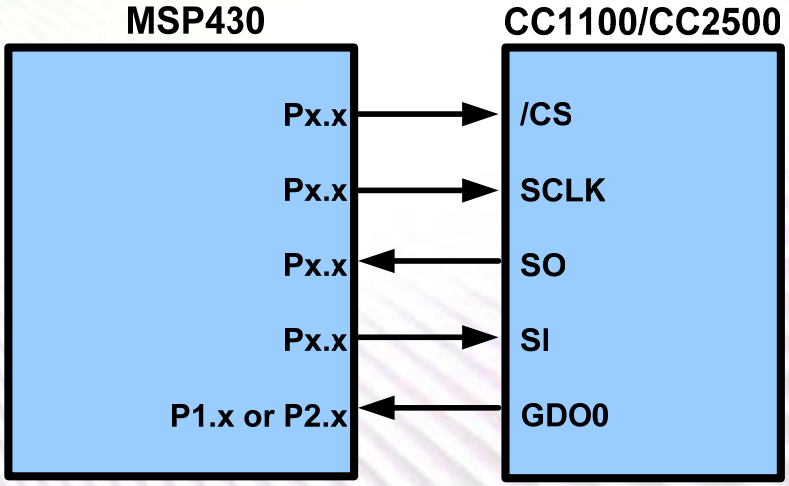
USART (USART0 shown)



USI



USCI (USCI_A0 shown)



BIT-BANG

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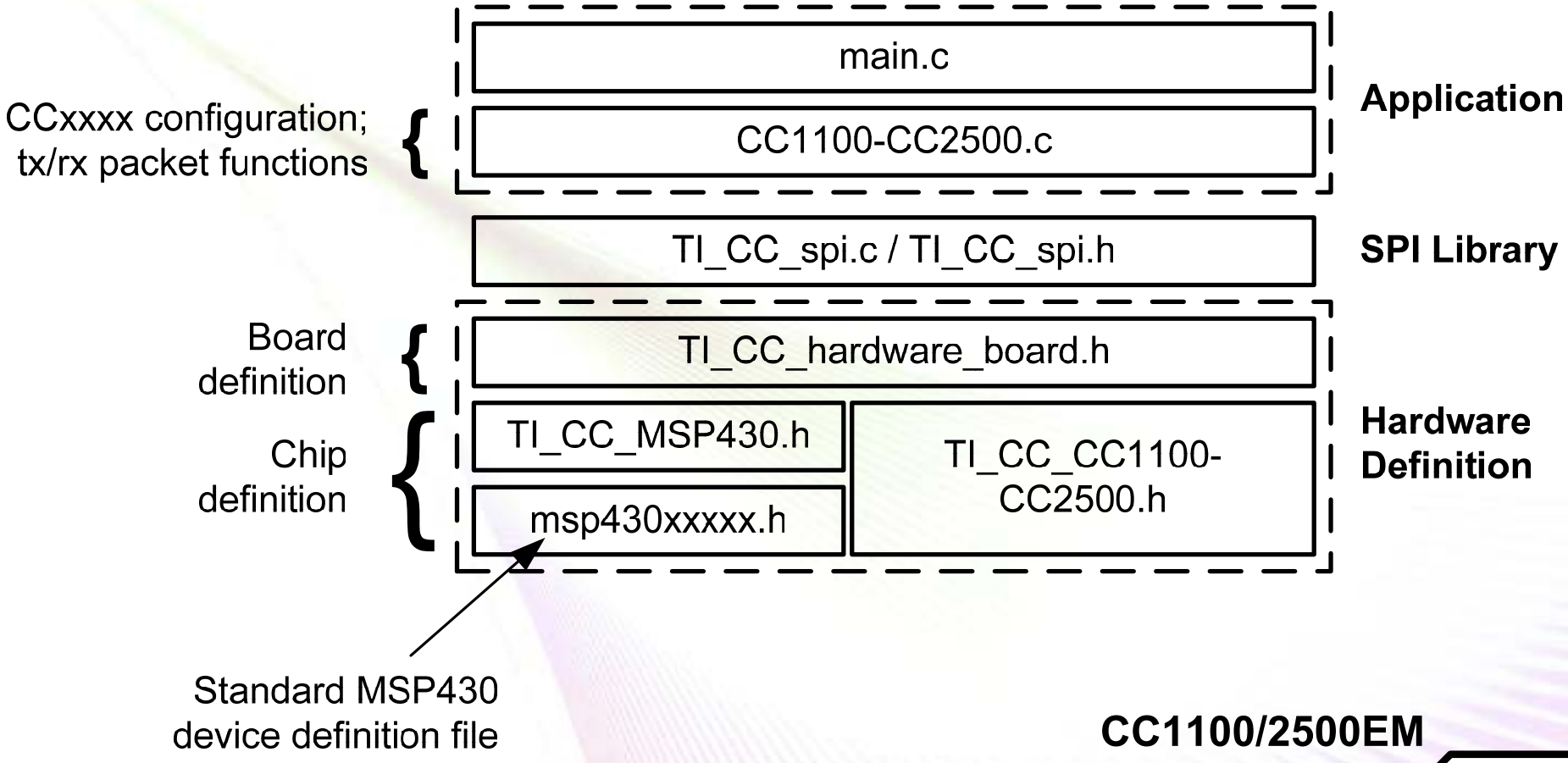
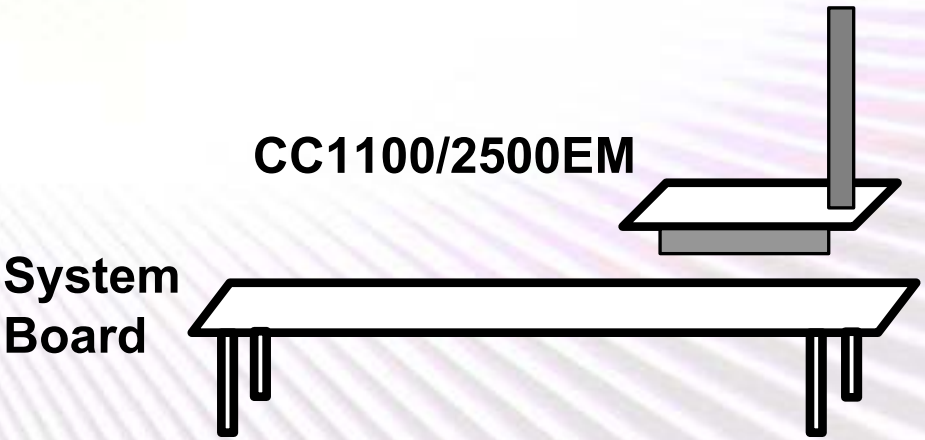
Demo Application Stack

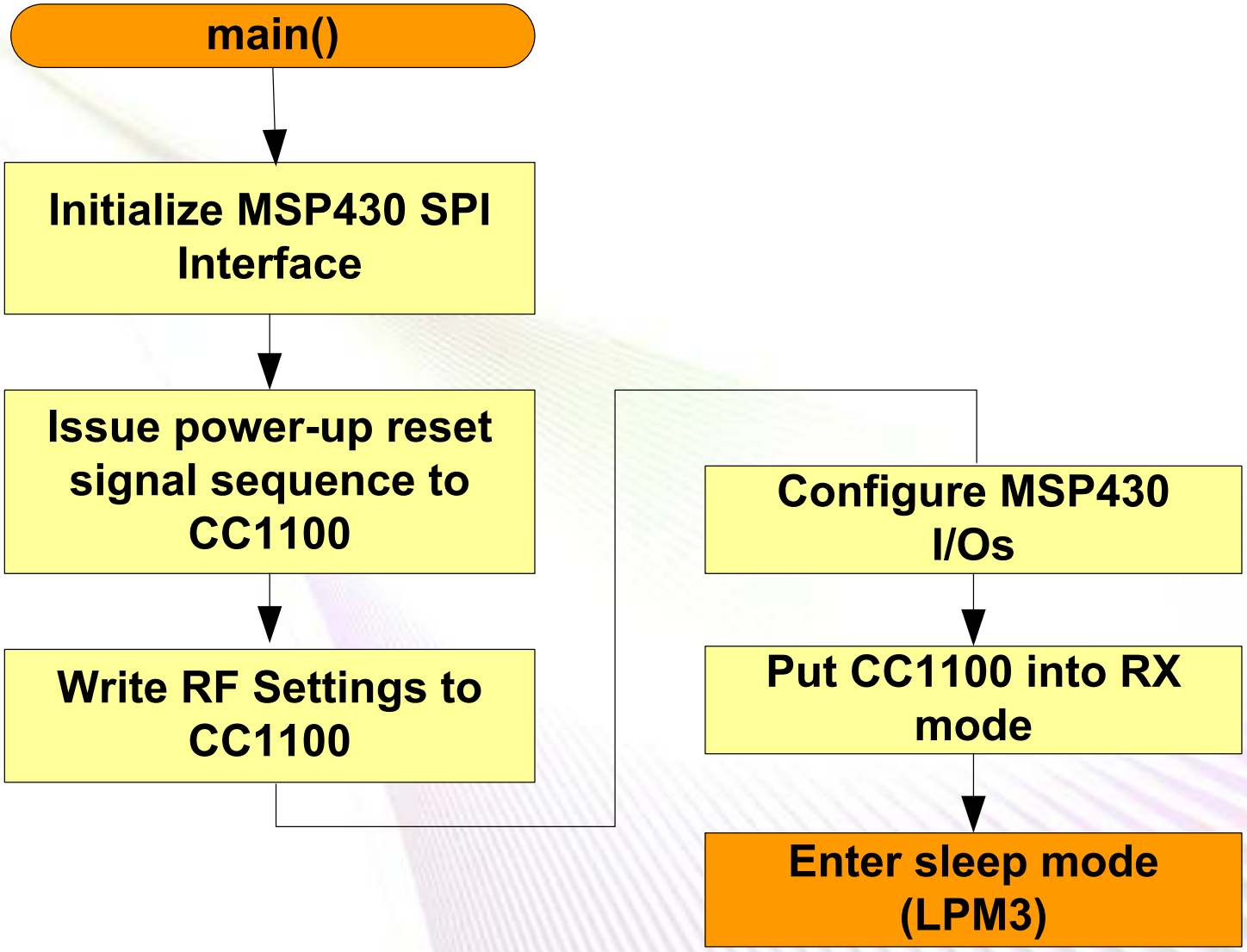




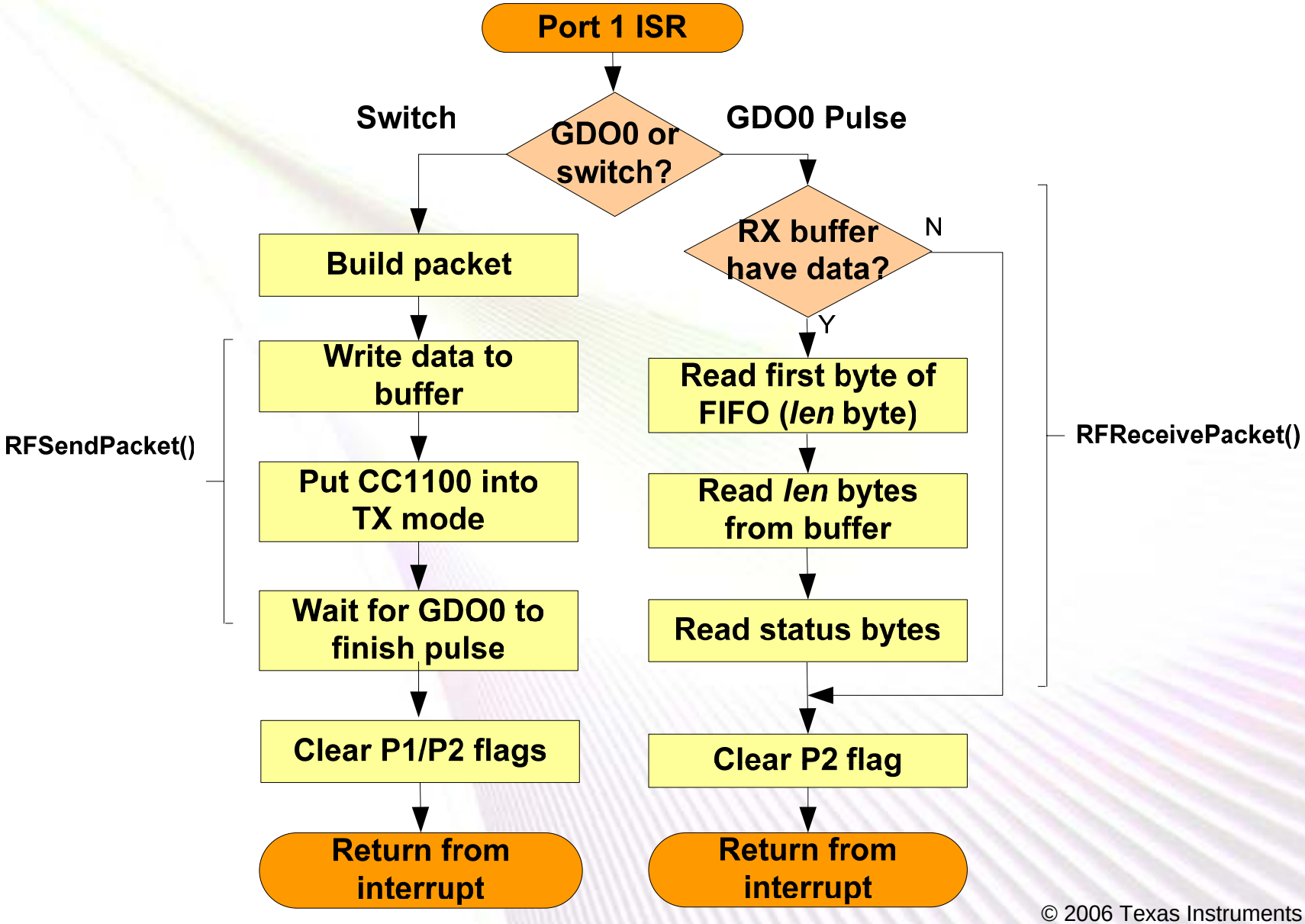
File Organization

TI_CC_CC1100-CC2500.h	Definitions specific to the CC1100/2500 devices
TI_CC_MSP430.h	Definitions specific to the MSP430 device
TI_CC_hardware_board.h	Definitions specific to the board (connections between MSP430 and CCxxxx)
TI_CC_spi.h	Function declarations for hal_spi.c
TI_CC_spi.c	Functions for accessing CC1100/CC2500 registers via SPI from MSP430

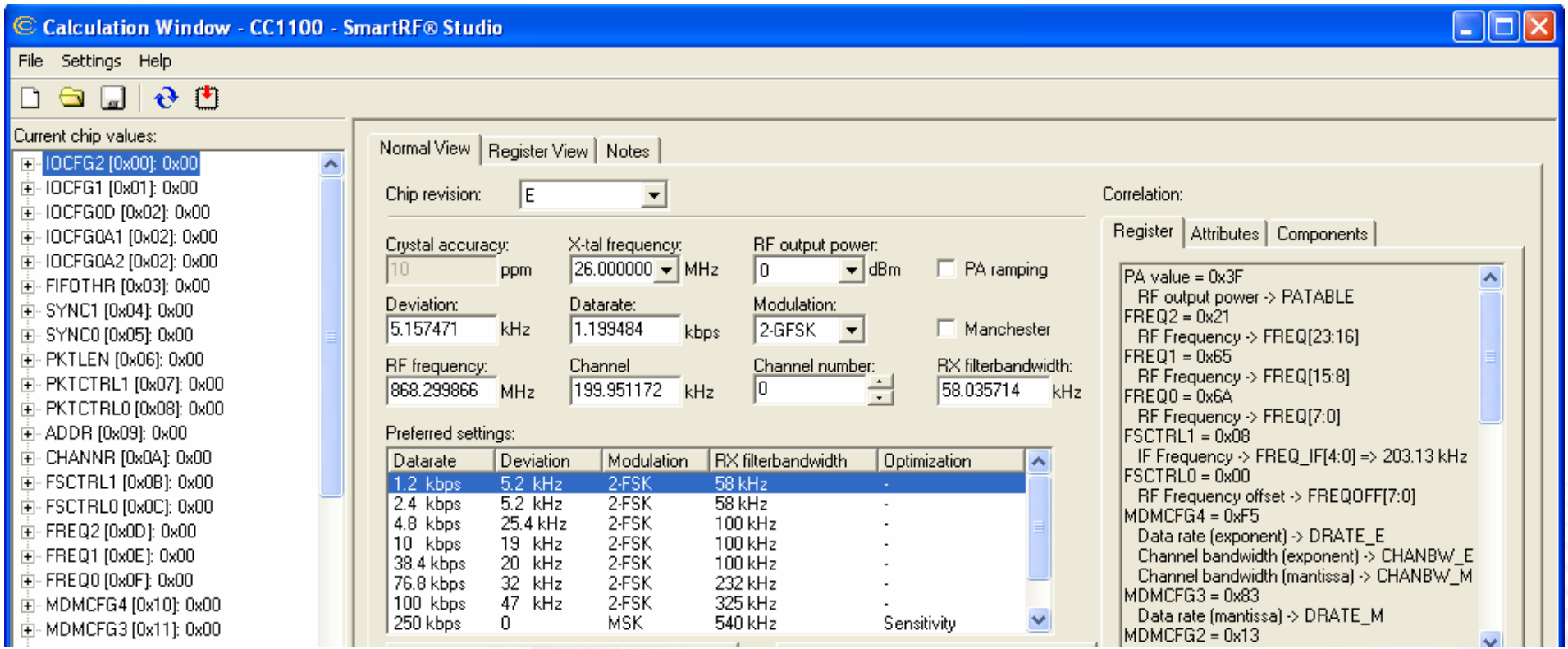
Demo Code Flowchart: main()



Demo Code Flowchart: Port_1 ISR



CC1100 Register Settings



- **Chipcon's SmartRF Studio software can assist in generating register contents**

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Lab Activities and Resources

- **What you're going to do**
  - Phase 1: Configure library for ATC board
  - Phase 2: Write function to receive packet from administrator
  - Phase 3: Write function to send packet to front screen

- **Resources**
  - Exercise code (on your CD)
  - Solution code (on your CD)
  - MSP430FG4619 datasheet extract (at your table)
  - CC1100 datasheet extract (at your table)
  - ATC board schematic (at your table)

Phase 1: Configuration of Library

- **The library hardware definition files are currently configured for different hardware. Required changes:**
  1. **Reference the appropriate device *.h file (msp430xG46x.h)**
  2. **Configure appropriate pins for SPI interface**
  3. **Configure non-SPI connections**

TI_CC_CC1100-CC2500.h	Definitions specific to the CC1100/2500 devices
→ TI_CC_MSP430.h	Definitions specific to the MSP430 device
→ TI_CC_hardware_board.h	Definitions specific to the board (connections between MSP430 and CCxxxx)
TI_CC_spi.h	Function declarations for hal_spi.c
TI_CC_spi.c	Functions for accessing CC1100/CC2500 registers via SPI from MSP430

Files in blue need to be modified

Configuration of Library: Select Intf

TI_CC_hardware_board.h

```
#define TI_CC_GDO0_PxOUT          P2OUT
#define TI_CC_GDO0_PxIN           P2IN
#define TI_CC_GDO0_PxDIR          P2DIR
#define TI_CC_GDO0_PxIE           P2IE
#define TI_CC_GDO0_PxIES          P2IES
#define TI_CC_GDO0_PxIFG          P2IFG
#define TI_CC_GDO0_PIN            0x10
.
.
.
//-------------------------------------
// SPI port selections.  Select which
// port will be used for interface to
// CCxxxx
//-------------------------------------
#define TI_CC_RF_SER_INTF  TI_CC_SER_INTF_USART1
```

- Configure which interface used for SPI
- Defined options are listed at bottom of TI_CC_msp430.h

Configuration of Library: Define Board

TI_CC_hardware_board.h

```
#define TI_CC_SW_PxIN          P1IN
#define TI_CC_SW_PxIE          P1IE
#define TI_CC_SW_PxIES         P1IES
#define TI_CC_SW_PxIFG         P1IFG
#define TI_CC_SW1              0x01
.
.
#define TI_CC_GDO0_PxOUT       P1OUT
#define TI_CC_GDO0_PxIN        P1IN
#define TI_CC_GDO0_PxDIR       P1DIR
#define TI_CC_GDO0_PxIE        P1IE
#define TI_CC_GDO0_PxIES       P1IES
#define TI_CC_GDO0_PxIFG       P1IFG
#define TI_CC_GDO0_PIN         0x04
.
.
#define TI_CC_CSn_PxOUT        P4OUT
#define TI_CC_CSn_PxDIR        P4DIR
#define TI_CC_CSn_PIN          0x04
```

- Define connections from ATC board:
  - **Switch**
  - **GDO0**
  - **/CS**

Configuration of Library: Select MSP430

TI_CC_msp430.h

```
#include "msp430xG46x.h"                  // Adjust according to the
                                          // MSP430 device being used.
// SPI port definitions                   // Adjust for chosen intf,
#define TI_CC_SPI_USART0_PxSEL  P3SEL    // according to the pin
#define TI_CC_SPI_USART0_PxDIR  P3DIR    // assignments in the
#define TI_CC_SPI_USART0_PxIN   P3IN     // chosen MSP430 datasheet.
#define TI_CC_SPI_USART0_SIMO   0x02
#define TI_CC_SPI_USART0_SOMI   0x04
#define TI_CC_SPI_USART0_UCLK   0x08

#define TI_CC_SPI_USCIA0_PxSEL  P3SEL
#define TI_CC_SPI_USCIA0_PxDIR  P3DIR
#define TI_CC_SPI_USCIA0_PxIN   P3IN
.
.
```

- Assign device-specific standard definition file
- Check the \430\inc directory within IAR's \Program Files listing

Configuration of Library: Define MSP430

TI_CC_msp430.h

```
#include "msp430xG46x.h"                  // Adjust according to the
                                          // MSP430 device being used.
// SPI port definitions                   // Adjust for chosen intf,
#define TI_CC_SPI_USART1_PxSEL   P4SEL // according to the pin
#define TI_CC_SPI_USART1_PxDIR   P4DIR // assignments in the
#define TI_CC_SPI_USART1_PxIN    P4IN  // chosen MSP430 datasheet.
#define TI_CC_SPI_USART1_SIMO    0x08
#define TI_CC_SPI_USART1_SOMI    0x10
#define TI_CC_SPI_USART1_UCLK    0x20

#define TI_CC_SPI_USCIA0_PxSEL   P3SEL
#define TI_CC_SPI_USCIA0_PxDIR   P3DIR
#define TI_CC_SPI_USCIA0_PxIN    P3IN
#define TI_CC_SPI_USCIA0_SIMO    0x10
.
.
```

- Define which MSP430 pins used for SPI functions for interface being used, referencing the MSP430 datasheet

Phase 1: Did you Pass?

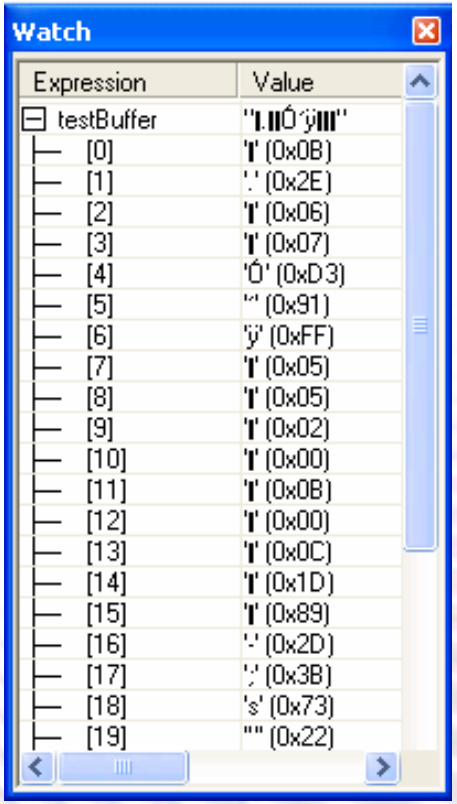
- This code reads back the data written in function writeRFSettings()
- Set breakpoint at TI_CC_SPIReadBurstReg() and step through code
- Set a watch on testBuffer[] and expand it in the “watch view”

```
// *** PHASE 1 TEST CODE ***
// To test the SPI connection, set a breakpoint to observe
// testBuffer after the burst read is executed.  The register
// settings should match the ones programmed in writeRFSettings()
  char testBuffer[0x3A];
  TI_CC_SPIReadBurstReg(TI_CCxxx0_IOCFG2, testBuffer, 0x3A);
  _NOP();
```

Phase 1: Did you Pass?

- Compare values to the ones programmed in writeRFSettings() in cc1100-cc2500.c
- Note that writeRFSettings skips some addresses

```
void writeRFSettings(void)
{
  TI_CC_SPIWriteReg(TI_CCxxx0_IOCFG2,    0x0B);
  TI_CC_SPIWriteReg(TI_CCxxx0_IOCFG0,    0x06);
  TI_CC_SPIWriteReg(TI_CCxxx0_PKTLEN,    0xFF);
  TI_CC_SPIWriteReg(TI_CCxxx0_PKTCTRL1,  0x05);
  TI_CC_SPIWriteReg(TI_CCxxx0_PKTCTRL0,  0x05);
  TI_CC_SPIWriteReg(TI_CCxxx0_ADDR,      0x02);
  TI_CC_SPIWriteReg(TI_CCxxx0_CHANNR,    0x00);
  TI_CC_SPIWriteReg(TI_CCxxx0_FSCTRL1,   0x0B);
  TI_CC_SPIWriteReg(TI_CCxxx0_FSCTRL0,   0x00);
  .
  .
```



Phase 2: Receiving a Packet

- CC1100 packets have an address field. The receiving CC1100 can filter according to address.
- There is a transmitter in this room, sending a set of packets every two seconds, each addressed to a table in the room. (See your table number.)
- Example: if there are 20 tables, the address set for each two-second sweep is {0x01, 0x02, 0x03,… 0x14}.
- Your job is to modify the code such that your CC1100 filters out all but your target address.
- Received packets are displayed via Hyperterminal.
- Tasks:
  - **Locate function writeRFSettings() and modify the address for your device (*TI_CCxxx0_ADDR*), such that it allows your packets to pass**
  - **Write function RFReceivePacket() that, when alerted by the CC1100 of a valid packet, reads the packet into the MSP430**

Phase 2: Modify Address

- Locate writeRFSettings (top of *cc1100-cc2500.c*)
- Convert your table # to hex and modify this function for your address
- Example: If you are table #11, set field to 0x0B

```
void writeRFSettings(void)
{
    TI_CC_SPIWriteReg(TI_CCxxx0_IOCFG2,   0x0B);
    TI_CC_SPIWriteReg(TI_CCxxx0_IOCFG0,   0x06);
    TI_CC_SPIWriteReg(TI_CCxxx0_PKTLEN,   0xFF);
    TI_CC_SPIWriteReg(TI_CCxxx0_PKTCTRL1, 0x05);
    TI_CC_SPIWriteReg(TI_CCxxx0_PKTCTRL0, 0x05);
    TI_CC_SPIWriteReg(TI_CCxxx0_ADDR,     0x0B);
    TI_CC_SPIWriteReg(TI_CCxxx0_CHANNR,   0x00);
    .
    .
```

Phase 2: Write RFReceivePacket()

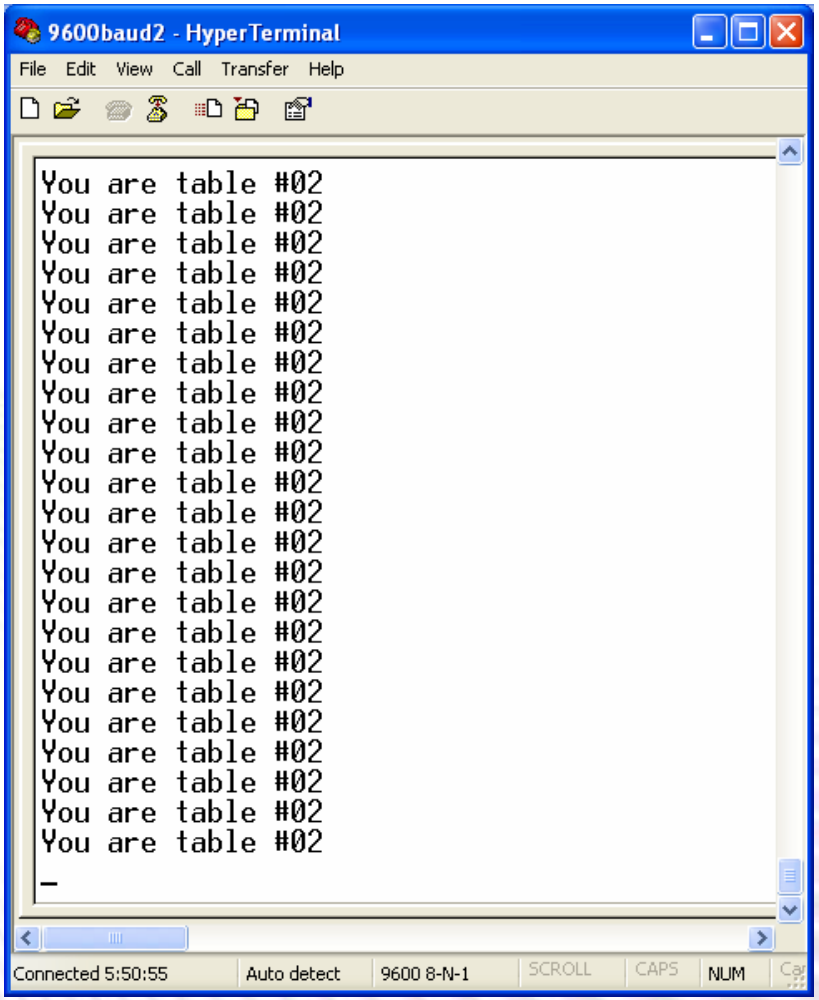
- Locate function RFReceivePacket (bottom of cc1100-cc2500.c)
- For context, locate and study PORT1_VECTOR in main(), from where it is called
- Fill in the blanks to finish RFReceivePacket
- Each blank is a SPI access, a call to the library
- Refer to file TI_CC_SPI.h for headers of the library functions
- Within RFReceivePacket(), there are directions and hints on how to solve

Phase 2: Write RFReceivePacket()

```
char RFReceivePacket(char *rxBuffer, char *length)
{
  char status[2];
  char pktLen;

  if ((TI_CC_SPIReadStatus(TI_CCxxx0_RXBYTES) & TI_CCxxx0_NUM_RXBYTES))
  {
    // read the first byte in the RX FIFO
    pktLen = TI_CC_SPI_____________(TI_CCxxx0_RXFIFO);

    // read the rest of the packet into rxBuffer
    TI_CC_SPI_____________(TI_CCxxx0_RXFIFO, rxBuffer, pktLen);
    *length = pktLen;

    // Read the two status bytes
    TI_CC_SPIReadBurstReg(TI_CCxxx0________, status, 2);

    return (char)(status[TI_CCxxx0_LQI_RX]&TI_CCxxx0_CRC_OK);
  }
  else return 0;
}
```

Phase 2: Did you Pass?

- If you run your code and a packet displays on HyperTerminal, indicating YOUR table (not someone else's), you passed!
- If you display more than one table number, you are using address 0x00 or 0xFF, which are broadcast addresses



Phase 2: Write RFReceivePacket()

- **Answers**

```
char RFReceivePacket(char *rxBuffer, char *length)
{
  char status[2];
  char pktLen;

  if ((TI_CC_SPIReadStatus(TI_CCxxx0_RXBYTES) & TI_CCxxx0_NUM_RXBYTES))
  {
    // read the first byte in the RX FIFO
    pktLen = TI_CC_SPIReadReg(TI_CCxxx0_RXFIFO);

    // read the rest of the packet into rxBuffer
    TI_CC_SPIReadBurstReg(TI_CCxxx0_RXFIFO, rxBuffer, pktLen);
    *length = pktLen;

    // Read the two status bytes
    TI_CC_SPIReadBurstReg(TI_CCxxx0_RXFIFO, status, 2);

    return (char)(status[TI_CCxxx0_LQI_RX]&TI_CCxxx0_CRC_OK);
  }
  else return 0;
}
```

Phase 3: Transmitting a Packet

- **There is a receiver node in the front of room, with Hyperterminal output directed to the screen**
- **Starter code contains a function that transmits a packet when the button is pressed. Your job is to write code that builds the packet in the appropriate format**
- **When the packet is received, it will be displayed on the screen**
- **The receiver node is operating at 868MHz instead of 915MHz, and it responds to address 0x43**
- **Tasks:**
  - Go to cc1100-cc2550.c and modify the carrier freq setting to 868MHz
  - Go to the Port1 ISR (called when switch is pressed); write code to build the packet, with a data field “We are table xx!”

Phase 3: Change the Carrier Freq

- **Modify the carrier frequency from 915MHz to 868MHz**

```
#include "include.h"
#include "TI_CC_CC1100-CC2500.h"

#define TI_CC_RF_FREQ  868  // 315, 433, 868, 915, 2400
```

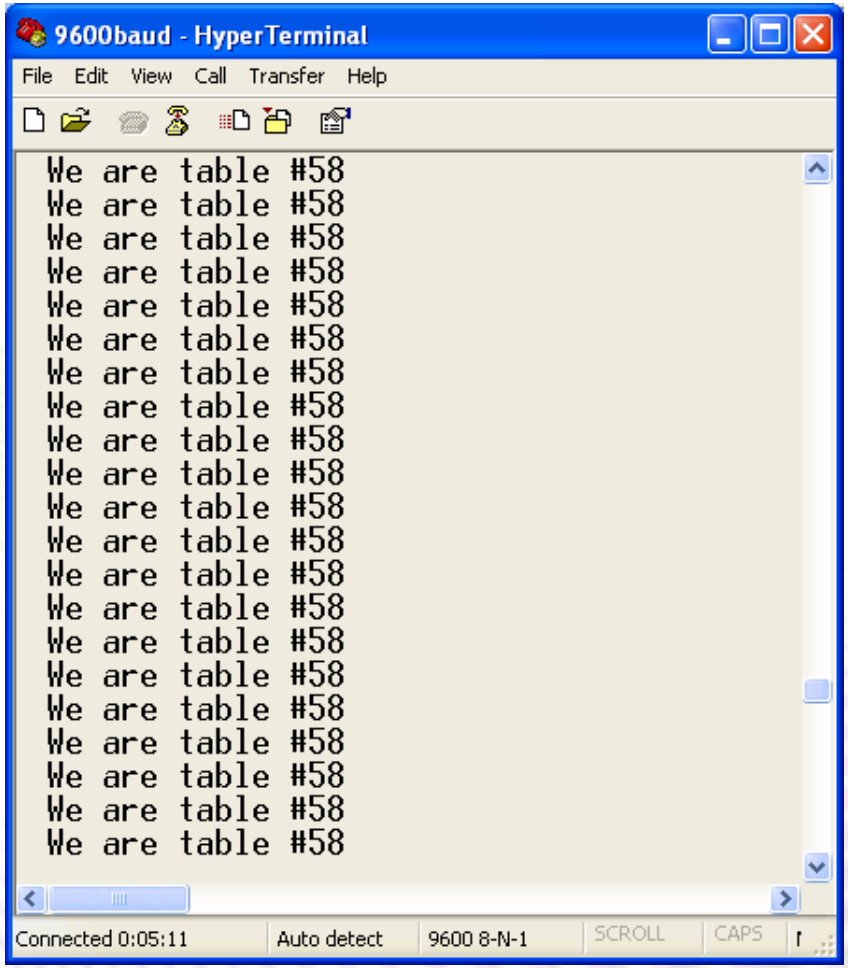
Phase 3: Build the Packet

- **Fill in the blanks with the correct values to build the packet**

```
__interrupt void port1_ISR (void)
{
  unsigned int i;
  const char kTableStr[] = "We are table #";

  if(P1IFG&TI_CC_SW1)                 // If interrupt comes from switch
  {
    txBuffer[0] = __;                 // Pkt length (not inc. len byte)
    txBuffer[1] = __;                 // Pkt address
    for(i=0;i<15;i++)                 // Copy the string
      txBuffer[2+i] = kTableStr[i];
    txBuffer[16] = ___;               // Table #, first digit
    txBuffer[17] = ___;               // Table #, second digit

    RFSendPacket(txBuffer, __);       // Send
}
```

Phase 3: Did you Pass?

- Your packet should display on the screen at the front of the room
- If packet formed incorrectly, it may be displayed in corrupted fashion or not displayed at all



Phase 3: Build the Packet

- Answers

```
__interrupt void port1_ISR (void)
{
  unsigned int i;
  const char kTableStr[] = "We are table #";

  if(P1IFG&TI_CC_SW1)                 // If interrupt comes from switch
  {
    txBuffer[0] = 0x17;               // Pkt length (not inc. len byte)
    txBuffer[1] = 0x43;               // Pkt address
    for(i=0;i<15;i++)                 // Copy the string
      txBuffer[2+i] = kTableStr[i];
    txBuffer[16] = '1';               // Table #12
    txBuffer[17] = '2';               //

    RFSendPacket(txBuffer, 18);       // Send
}
```

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