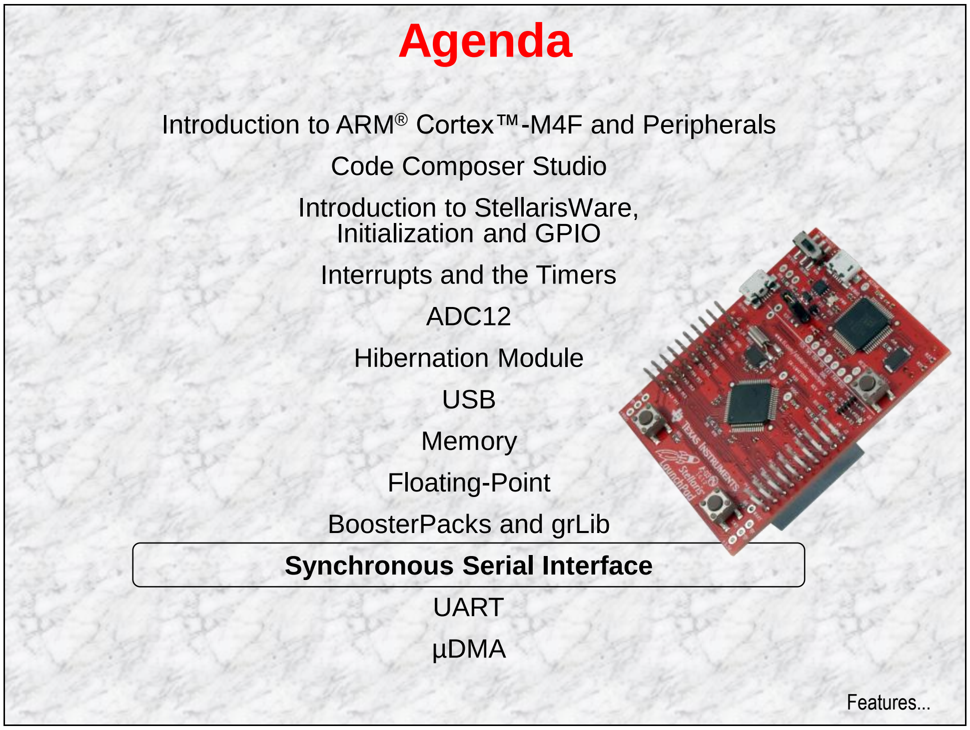
Synchronous Serial Interface

Introduction

This chapter will introduce you to the capabilities of the Synchronous Serial Interface (SSI) . The lab uses an Olimex 8x8 LED BoosterPack to explore programming the SPI portion of the SSI. In order to do the lab you will need to purchase the BoosterPack and make some modification to it.



Agenda

Introduction to ARM® Cortex™-M4F and Peripherals
Code Composer Studio
Introduction to StellarisWare,
Initialization and GPIO
Interrupts and the Timers
ADC12
Hibernation Module
USB
Memory
Floating-Point
BoosterPacks and grLib
Synchronous Serial Interface
UART
µDMA

Features...

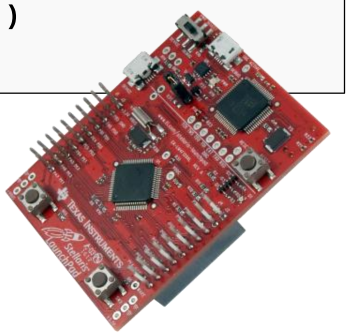
Chapter Topics

Features and Block Diagram

LM4F120H5QR SSI Features

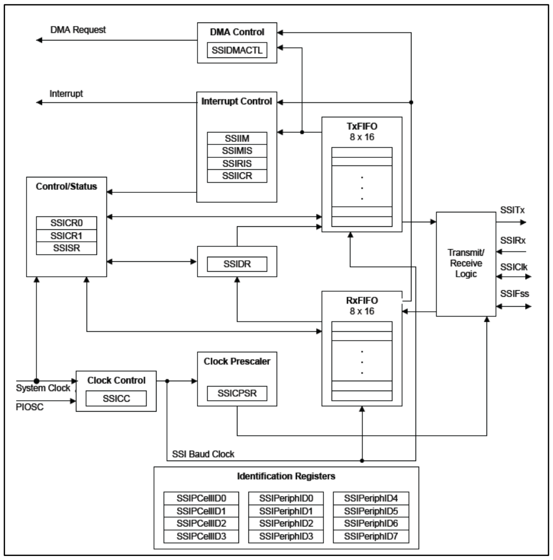
Four SSI modules. Each with:

- **Freescale SPI, MICROWIRE or TI Synchronous Serial interfaces**
- **Master or Slave operation**
- **Programmable bit clock rate and pre-scaler**
- **Programmable data frame size from 4 to 16-bits**
- **Separate Tx and Rx FIFOs (8 x16-bits)**
- **Interrupts and µDMA support**



Block Diagram ...

SSI Block Diagram



Signal Pinout (n = 0 to 3) …

SSInClk: SSI Module n Clock
SSInFss: SSI Module n Frame Signal
SSInRx: SSI Module n Receive
SSInTx: SSI Module n Transmit

Note that the LM4F120H5QR pins are extensively muxed with other signals.

The Pin Mux Utility can ease the programming. See:

www.ti.com/stellarispinmuxutility

Welcome to the Stellaris® PinMux Utility!

To begin, please select your device and click 'Go'

Device Series: LM4F12 series
Device: LM4F120H5QR

Interrupts...

Interrupts and µDMA Operation

SSI Interrupts

Single interrupt per module, cleared automatically

Interrupt conditions:

- Transmit FIFO service (when the transmit FIFO is half full or less)
- Receive FIFO service (when the receive FIFO is half full or more)
- Receive FIFO time-out
- Receive FIFO overrun
- End of transmission
- Receive DMA transfer complete
- Transmit DMA transfer complete

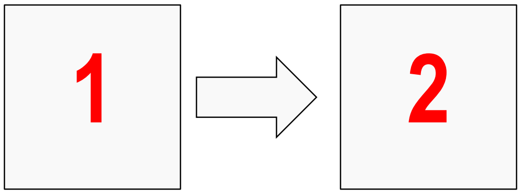
Interrupts on these conditions can be enabled individually

Your handler code must check to determine the source of the SSI interrupt and clear the flag(s)

Operation...

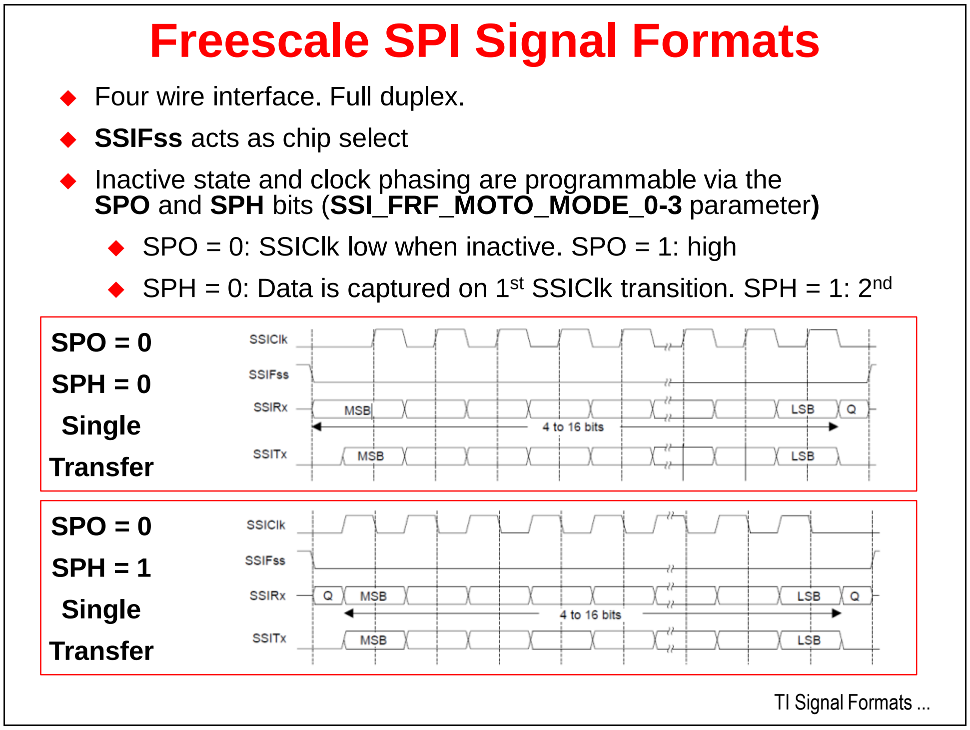
SSI µDMA Operation

- **Separate channels for Tx and Rx**
- **When enabled, the SSI will assert a DMA request on either channel when the Rx or Tx FIFO can transfer data**
- **For Rx channel:** A single transfer request is made when any data is in the Rx FIFO. A burst transfer request is made when 4 or more items is in the Rx FIFO.
- **For Tx channel:** A single transfer request is made when there is at least one empty location in the Tx FIFO. A burst transfer request is made when 4 or more slots are empty.



Signal Formats...

Signal Formats



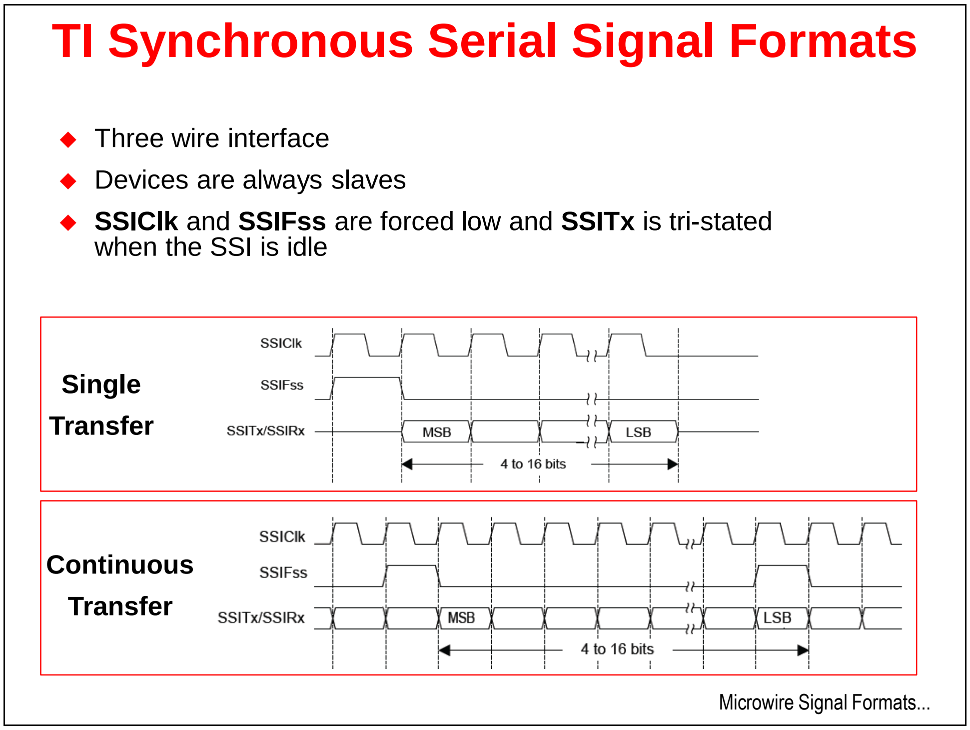
Freescale SPI Signal Formats

- Four wire interface. Full duplex.
- **SSIFss** acts as chip select
- Inactive state and clock phasing are programmable via the **SPO** and **SPH** bits (**SSI_FRF_MOTO_MODE_0-3** parameter**)**
  - SPO = 0: SSIClk low when inactive. SPO = 1: high
  - SPH = 0: Data is captured on 1st SSIClk transition. SPH = 1: 2nd

SPO = 0
SPH = 0
Single Transfer

SPO = 0
SPH = 1
Single Transfer

TI Signal Formats ...



TI Synchronous Serial Signal Formats

- Three wire interface
- Devices are always slaves
- **SSIClk** and **SSIFss** are forced low and **SSITx** is tri-stated when the SSI is idle

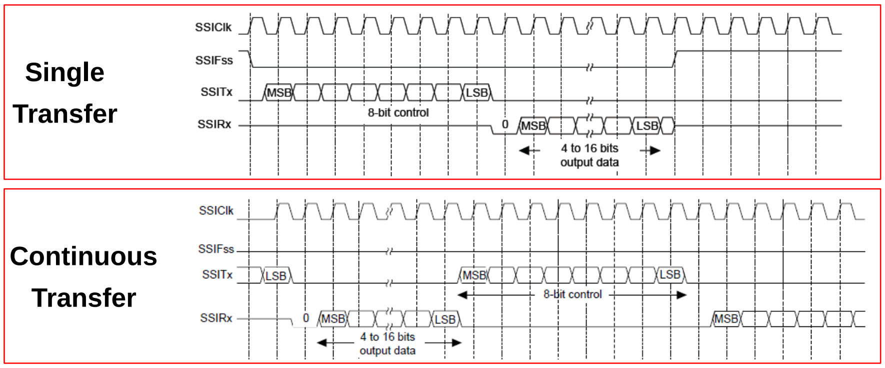
Single Transfer

Continuous Transfer

Microwire Signal Formats...

Microwire Signal Formats

- Four wire interface
- Similar to SPI, except transmission is half-duplex
- Master – Slave message passing technique

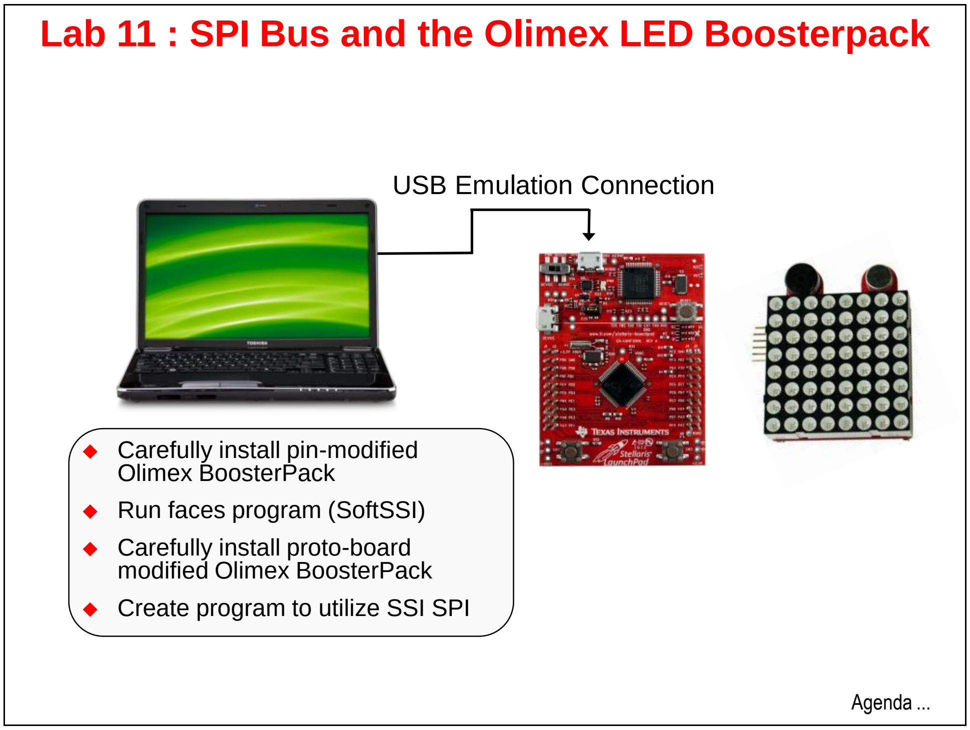


Lab...

Lab 11: SPI Bus and the Olimex LED BoosterPack

Objective

In this lab you will use the Olimex LED BoosterPack to explore the capabilities and programming of the SPI bus on the SSI peripheral.



Lab 11 : SPI Bus and the Olimex LED Boosterpack

USB Emulation Connection

- Carefully install pin-modified Olimex BoosterPack
- Run faces program (SoftSSI)
- Carefully install proto-board modified Olimex BoosterPack
- Create program to utilize SSI SPI

Agenda ...

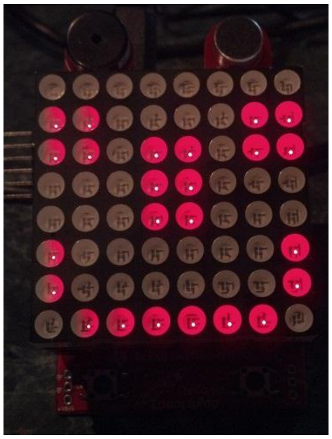
Procedure

Hardware

1. If you want to do this lab, you're going to need a BoosterPack with a SPI connection. I chose the Olimex 8x8 LED BoosterPack: (https://www.olimex.com/Products/MSP430/Booster/MSP430-LED8x8-B00STERPACK/).

   This BoosterPack is also available from Mouser Electronics (http://www.mouser.com/new/olimex/olimexLED8x8/)

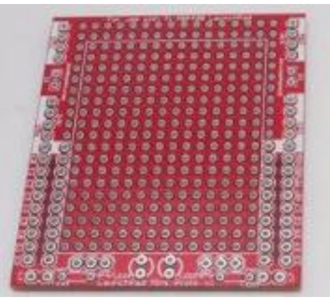
   The LED BoosterPack is cheap and fun, but there are two issues with it out of the box. The first is that it has male Molex pins rather than Molex female connectors. You can get two of these (http://www.mouser.com/ProductDetail/FCI/66951-010LF/?qs=sGAEpiMZZMs%252bGHln7q6pmxAVkKtOEC39jD0m1rF2xGE%3d) and solder them directly to the male pins. This way you can import, build and run the "faces" program located at `C:\StellarisWare\boards\ek-lm4f120xl-boost-olimex-8x8`

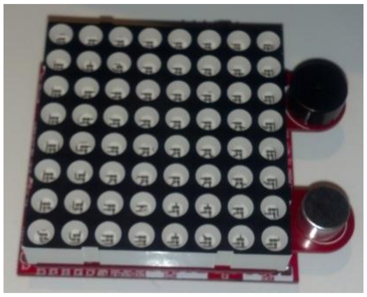
   

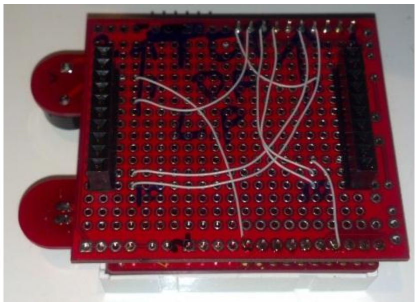
   This program is pretty cool but it has one little issue, which brings us back to the second problem with the Olimex BoosterPack. The pin-out on the Olimex BoosterPack does not match with any of the SSI module pin-sets on the Stellaris LaunchPad board (it actually matches an early version of the MSP430 LaunchPad).

   So the author of the "faces" program did what any good engineer would do, they made it work … with a software SPI port (SoftSSI). The programming of SoftSSI is virtually the same as programming the actual hardware, but for the purposes of this lab, that's not good enough.

2. So we need to connect the pins on the Olimex BoosterPack to the female headers that will mount on top of the LaunchPad board. Any small perf-board will do, but Joe's Bytes (http://joesbytes.com/10-ti-msp430-launchpad-mini-proto-board.html) has a nice proto-board that fits perfectly. I soldered the female headers on one side of the board in one direction and the Olimex BoosterPack on the other side with a 90 degree turn.







3. Comparing the Olimex BoosterPack schematic found at https://www.olimex.com/Products/MSP430/Booster/MSP430-LED8x8-B00STERPACK/resources/MSP430-LED-BOOSTERPACK-schematic.pdf to the Stellaris LaunchPad schematic, I came up with the following connections for the proto-board (There are a number of possible solutions here). Bear in mind that the correct way to number the BoosterPack pins is 1 to 10 from the top of the board to the bottom.

Olimex Header Pin	**Olimex Function**		**LaunchPad Header Pin**	**LM4F120H5QR Pin Name**	**Pin Function**
J1-7	SR_SCK	→	J2-10	PA2	SSI0CLK
J1-6	SR_LATCH	→	J2-9	PA3	SSI0Fss
J2-7	SR_DATA_IN	→	J1-8	PA5	SSI0Tx
J1-2	A_IN	→	J2-3	PE0	AIN3
J1-3	BUZ_PIN1	→	J1-9	PA6	GPIO
J1-4	BUZ_PIN2	→	J1-10	PA7	GPIO
J2-1	Ground	→	J2-1	Ground	-
J1-1	Vcc	→	J1-1	Vcc	-

4. While you've got the Olimex BoosterPack schematic out, take a look at the circuit. You'll see that the board is pretty simple; 16-bits of shift register, a Darlington seven transistor array (for drive strength) plus one more single transistor to make 8 and the 8x8 LED array. In order for the LEDs to light properly, the upper byte of the 16-bit word must be the bit-reversed version of the lower byte. That will be done in software.

   Since this lab concerns the SPI port, we're going to ignore the connections for the mic and buzzer.

Faces Code

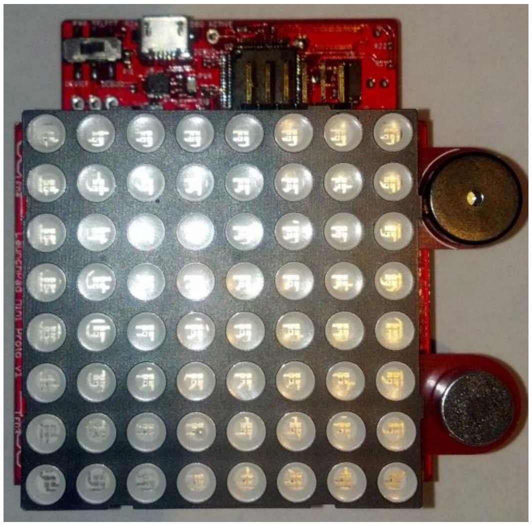
5. If you have one of the Olimex BoosterPacks and have connected the female headers to it, carefully connect it to your LaunchPad board. In Code Composer, import the faces project from `C:\StellarisWare\boards\ek-lm4f120xl-boost-olimex-8x8` into your workspace. Build, load and run the project. Poke around in the code if you like, but we'll go into detail building Lab11 that uses the SSI peripheral instead of the SoftSSI.

   When you're done, close the faces project.

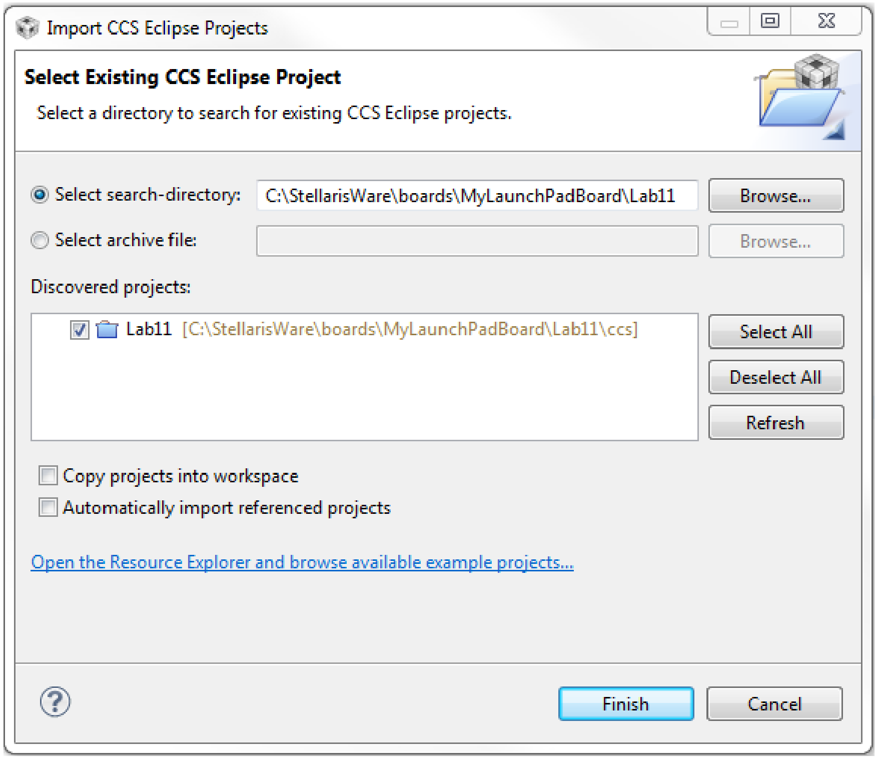
   Disconnect your LaunchPad board from the USB port, carefully remove the Olimix BoosterPack and re-connect your LaunchPad.

Import Lab11

6. If you have a proto-board modified Olimex BoosterPack, carefully connect it to the LaunchPad with the expansion pins towards the top of the LaunchPad as shown below. You may need to bend the power measurement jumper out of the way slightly:



7. Maximize Code Composer. Import Lab11 with the settings shown below. Make sure the Copy projects into workspace checkbox is not checked and click Finish.



Import CCS Eclipse Projects

Select Existing CCS Eclipse Project

Select a directory to search for existing CCS Eclipse projects.

● Select search-directory: C:\StellarisWare\boards\MyLaunchPadBoard\Lab11

○ Select archive file:

Discovered projects:

☑ Lab11 [C:\StellarisWare\boards\MyLaunchPadBoard\Lab11\ccs]

☐ Copy projects into workspace

☐ Automatically import referenced projects

Open the Resource Explorer and browse available example projects...

8. Expand the project and open `main.c` for editing. Place the following includes at the top of the file:

```
#include "inc/hw_memmap.h"
#include "inc/hw_ssi.h"
#include "inc/hw_types.h"
#include "driverlib/ssi.h"
#include "driverlib/gpio.h"
#include "driverlib/pin_map.h"
#include "driverlib/sysctl.h"
```

   We're going to need all the regular include files along with the ones that give us access to the SSI peripheral.

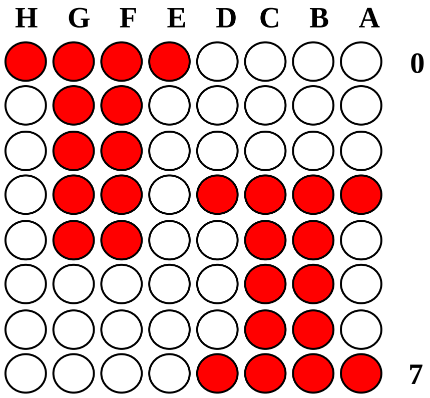
9. Skip a line for spacing and add the next three lines:

```
#define NUM_SSI_DATA 8
const unsigned char ulDataTx[NUM_SSI_DATA] =
{0x88, 0xF8, 0xF8, 0x88, 0x01, 0x1F, 0x1F, 0x01};
unsigned short g_pusTxBuffer[16];
```

   The "third" line is really part of the second one. This array of 8-bit numbers defines which of the LEDs in the array will be on or off in the following fashion, where red is on and the open circle is off. The last line defines our transmit buffer:

{A7-0, B7-0, C7-0, D7-0, E7-0, F7-0, G7-0, H7-0}

TOP



H	G	F	E	D	C	B	A	
●	●	●	●	○	○	○	○	0
○	●	●	○	○	○	○	○	
○	●	●	○	○	○	○	○	
○	●	●	○	●	●	●	●	
○	●	●	○	○	●	●	○	
○	○	○	○	○	●	●	○	
○	○	○	○	○	●	●	○	
○	○	○	○	●	●	●	●	7

10. Leave a line for spacing and add the following code. This code will take the 8-bit number from the array above and bit-reverse it front to back .Then those 8-bits will be concatenated (in the code that calls this function) with the original number to create a 16-bit number that will be sent over the SPI port.

```
// Bit-wise reverses a number.
unsigned char
Reverse(unsigned char ucNumber)
{
    unsigned short ucIndex;
    unsigned short ucReversedNumber = 0;
    for(ucIndex=0; ucIndex<8; ucIndex++)
    {
        ucReversedNumber = ucReversedNumber << 1;
        ucReversedNumber |= ((1 << ucIndex) & ucNumber) >> ucIndex;
    }
    return ucReversedNumber;
}
```

11. Leave a line for spacing and add the template for main() below:

```
int main(void)
{
}
```

12. Insert the next two lines as the first ones in `main`(). We'll need these variables for temporary data and index purposes.

```
unsigned long ulindex;
unsigned long ulData;
```

13. Leave a line for spacing and set the clock to 50MHz as we've done before:

```
SysCtlClockSet(SYSCTL_SYSDIV_4 | SYSCTL_USE_PLL | SYSCTL_OSC_MAIN | SYSCTL_XTAL_16MHZ);
```

14. Space down a line and add the next two lines. Since SSI0 is on GPIO port A, we'll need to enable both peripherals:

```
SysCtlPeripheralEnable(SYSCTL_PERIPH_SSI0);
SysCtlPeripheralEnable(SYSCTL_PERIPH_GPIOA);
```

15. Space down a line and add the following four lines. These will configure the muxing and GPIO settings to bring the SSI functions out to the pins. Since the BoosterPack only accepts data, we won't program the receive pin (pin 4).

```
GPIOPinConfigure(GPIO_PA2_SSI0CLK);
GPIOPinConfigure(GPIO_PA3_SSI0FSS);
GPIOPinConfigure(GPIO_PA5_SSI0TX);
GPIOPinTypeSSI(GPIO_PORTA_BASE,GPIO_PIN_5|GPIO_PIN_3|GPIO_PIN_2);
```

16. Next we need to configure the SPI port on SSI0 for the type of operation that we want. Given that there are two bits (SPH – clock polarity and SPO – idle state), there are four modes (0-3). Leave a line for spacing and add the next two lines after the last. Then double-click on `SSI_FRF_MOTO_MODE_0` and press F3 to see all four definitions in `ssi.h`:

```
SSIConfigSetExpClk(SSI0_BASE,SysCtlClockGet(),SSI_FRF_MOTO_MODE_0,SSI_MODE_MASTER,10000,16);
SSIEnable(SSI0_BASE);
```

    The API specifies the SSI module, the clock source (this is hard wired), the mode, master or slave, the bit rate and the data width.

17. The LED array has no latch, so the data must be continuously streamed in order for a static image to appear. We’ll do that with a `while`() loop, so add a lines for spacing and then add the `while`() loop below:

```
while(1)
{
}
```

18. We’re going to need to step through the data, sending each 16-bit word on at the time. Add the following `for`() construct inside the `while`() loop you just added:

```
for(ulindex = 0; ulindex < NUM_SSI_DATA; ulindex++)
{

}
```

19. Place the five lines below inside the `for`() construct you just added. Those lines have these functions:

    1) Create the 16-bit data word using the `Reverse`() function we added earlier

    2) Place the data in the transmit FIFO using a blocking function (a non-blocking version is also available)

    3) Wait until the data has been transmitted

```
ulData = (Reverse(ulDataTx[ulindex]) << 8) + (1 << ulindex);
SSIDataPut(SSI0_BASE, ulData);
while(SSIBusy(SSI0_BASE))
    {
    }
```

    Admittedly, this isn’t the most efficient technique. It would be less wasteful of CPU cycles to use the µDMA to perform these transfers, but we haven’t covered the µDMA yet.

Build and Load

20. Build and load the code. If you have errors, compare your `main.c` to the code below:

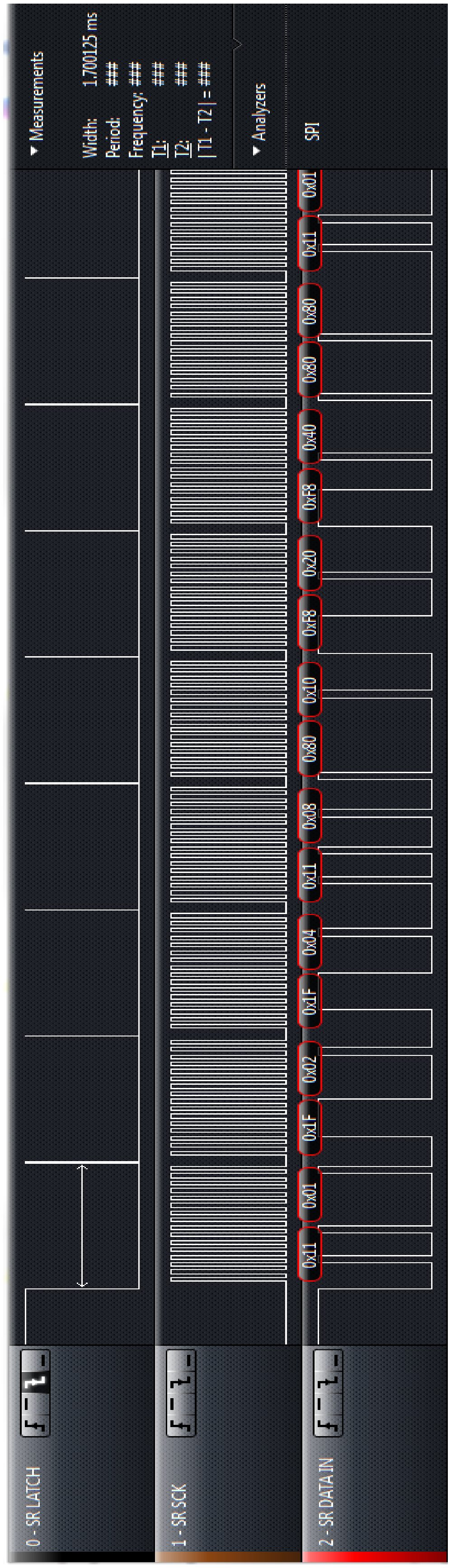
```
#include "inc/hw_memmap.h"
#include "inc/hw_ssi.h"
#include "inc/hw_types.h"
#include "driverlib/ssi.h"
#include "driverlib/gpio.h"
#include "driverlib/pin_map.h"
#include "driverlib/sysctl.h"

#define NUM_SSI_DATA 8
const unsigned char ulDataTx[NUM_SSI_DATA] =
{0x88, 0xF8, 0xF8, 0x88, 0x01, 0x1F, 0x1F, 0x01};
unsigned short g_pusTxBuffer[16];

// Bit-wise reverses a number.
unsigned char
Reverse(unsigned char ucNumber)
{
    unsigned short ucIndex;
    unsigned short ucReversedNumber = 0;
    for(ucIndex=0; ucIndex<8; ucIndex++)
    {
            ucReversedNumber = ucReversedNumber << 1;
            ucReversedNumber |= ((1 << ucIndex) & ucNumber) >> ucIndex;
    }
    return ucReversedNumber;
}

int main(void)
{
    unsigned long ulindex;
    unsigned long ulData;

    SysCtlClockSet(SYSCTL_SYSDIV_4 | SYSCTL_USE_PLL | SYSCTL_OSC_MAIN | SYSCTL_XTAL_16MHZ);

    SysCtlPeripheralEnable(SYSCTL_PERIPH_SSI0);
    SysCtlPeripheralEnable(SYSCTL_PERIPH_GPIOA);

    GPIOPinConfigure(GPIO_PA2_SSI0CLK);
    GPIOPinConfigure(GPIO_PA3_SSI0FSS);
    GPIOPinConfigure(GPIO_PA5_SSI0TX);
    GPIOPinTypeSSI(GPIO_PORTA_BASE,GPIO_PIN_5|GPIO_PIN_3|GPIO_PIN_2);

    SSIConfigSetExpClk(SSI0_BASE,SysCtlClockGet(),SSI_FRF_MOTO_MODE_0,SSI_MODE_MASTER,10000,16);
    SSIEnable(SSI0_BASE);

    while(1)
    {
            for(ulindex = 0; ulindex < NUM_SSI_DATA; ulindex++)
            {
                    ulData = (Reverse(ulDataTx[ulindex]) << 8) + (1 << ulindex);
                    SSIDataPut(SSI0_BASE, ulData);
                    while(SSIBusy(SSI0_BASE))
                    {
                    }
            }

    }

}
```

If you're still having problems you can find this code in the `Lab11/ccs` folder as `main.txt`.

Run and Test

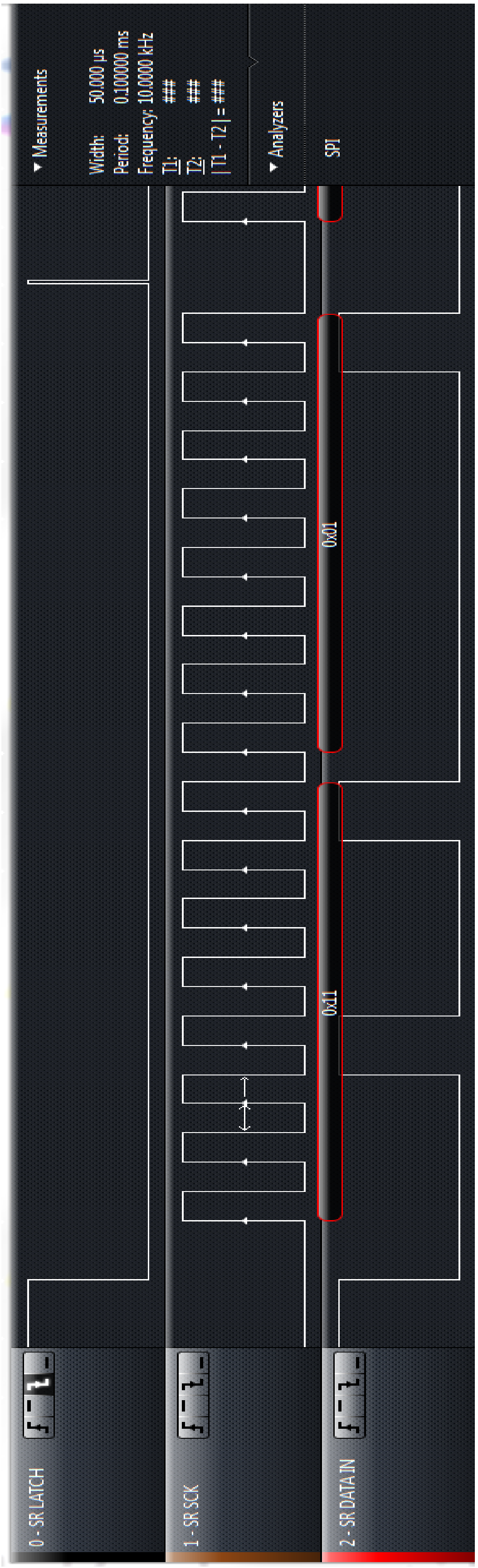
21. Run the code by clicking the Resume button. You should see "TI" displayed on the LED array. If you like you can play with the data structure to draw something different. Keep it clean.
22. If you have a SPI protocol analyzer, now would be a good time to dust it off and take a look at the serial data stream. These analyzers can save weeks troubleshooting communication problems. The screen captures on the next page were taken with a Saleae Logic8 logic analyzer/communications analyzer made by **Saleae LLC** (www.saleae.com) Beware of counterfeits!
23. When you're done, click the Terminate button to return to the CCS Edit perspective.
24. Right-click on Lab11 in the Project Explorer pane and close the project.
25. Disconnect your LaunchPad board from the USB port, carefully remove the Olimix BoosterPack and re-connect your LaunchPad.
26. Minimize Code Composer Studio.

You're done.



▾ Measurements

Width: 1.700125 ms
Period: ###
Frequency: ###
T1: ###
T2: ###
|T1 - T2| = ###



▾ Measurements

Width: 50.000 µs
Period: 0.100000 ms
Frequency: 10.0000 kHz
T1: ###
T2: ###
|T1 - T2| = ###