The EE 109 LCD Shield

- The LCD shield is a __________________ LCD that mounts on top of the Arduino Uno.
- The shield also contains five buttons that can be used as input sources.

How Do We Use It?

- By sending it _______ (i.e. _____________ one at a time) that it will display for us
- By sending it special _____________ to do things like:
  - Move the cursor to a ________________
  - ________ the screen contents
  - Upload new fonts/special characters
How Do We Communicate?

- The LCD uses a "parallel" interface (4-bits sent per transfer) to communicate with the µC (Note: µC => microcontroller)
- Data is transferred 4 bits at a time and uses 2 other signals (Register Select and Enable) to control ______ the 4-bits go and ______ the LCD should capture them

Commands and Data

- LCD contains ______ registers which it uses to control its actions: Command and Data
- A Register Select (RS) signal determines which register is the destination of the data we send it (RS acts like an address selector)
  - RS = ___, info goes into the command register
  - RS = ___, info goes into the data register
- To perform operations like clear display, move cursor, turn display on or off, write the command code to the command register.
- To display characters on the screen, write the ASCII code for the character to the data register.

How Do We Communicate?

- To send an 8-bit byte we must send it in two groups of 4 bits
  - First the _______ 4-bits followed by the _______ 4-bits
- RS=0 sets the destination as the command reg.
- RS=1 sets the destination as the data reg.
Another View

- Data from the Uno is transferred by placing four bits on the data lines (Port D bits 7-4).
- The Register Select (RS) line determines whether the data goes to the LCD's "Command Register" or "Data Register"
  - RS=0 => Command Register
  - RS=1 => Data Register
- The Enable (E) line acts as a ________ signal telling the LCD to capture the data and examine the RS bit on the 0-1-0 transition
  - Pulse must be held at 1 for at least 230ns according to LCD datasheet

Who's Job Is It?

- So who is producing the values on the RS and Data lines and the 0-1-0 transition on the E line?
- ______!! With your __________ (setting and clearing PORT bits)

Other LCD Interface

- Other LCD devices may use
  - Only one signal (a.k.a. serial link) to communicate between the µC and LCD
    - This makes wiring easier but requires more complex software control to "serialize" the 8- or 16-bit numbers used inside the µC
  - 8-data wires plus some other control signals so they can transfer an entire byte
    - This makes writing the software somewhat easier
LCD LAB PREPARATION

Step 1

- Mount the LCD shield on the Uno without destroying the pins
- Download the “test.hex” file and Makefile from the web site, and modify the Makefile to suite your computer.
- Run “make test” to download test program to the Uno+LCD.
- Should see a couple of lines of text on the screen.

Step 2

- Develop a set of functions that will abstract the process of displaying text on the LCD
  - A set of functions to perform specific tasks for a certain module is often known as an ______ (application programming interface)
  - Once the API is written it gives other application coders a nice simple interface to do high-level tasks
- Download the skeleton file and examine the functions outlines on the next slides

LCD API Development Overview

- Write the routines to control the LCD in layers
  - Top level routines that your code or others can use: ____________, ____________, initialize LCD, etc.
  - Mid level routines: write a byte to the command register, write a byte to the data register
  - Low level routines: controls the 4 data lines and E to transfer a nibble to a register
- Goal: Hide the ____________ about how the interface actually works from the user who only wants to put a string on the display.
Low Level Functions

- **lcd_writenibble(unsigned char x)**
  - Assumes RS is already set appropriately
  - Send four bits from ‘x’ to the LCD
    - Takes 4-bits of x and copies them to PD[7:4] (where we’ve connected the data lines of the LCD)
    - **SEE NEXT SLIDES ON COPYING BITS**
  - Produces a 0-1-0 transition on the Enable signal
  - Must be consistent with mid-level routines as to which 4 bits to send, MSB or LSB
  - Uses: logical operations (AND/OR) on the PORT bits

This will be your challenge to write in lab!
We will provide the remaining API code.

Mid-Level Functions

- **lcd_writecommand(unsigned char x)**
  - Send the 8-bit byte ‘x’ to the LCD as a command
    - Set RS to 0, send data in two nibbles, delay
    - Uses: **lcd_writenibble()**
- **lcd_writedata(unsigned char x)**
  - Send the 8-bit byte ‘x’ to the LCD as data
    - Set RS to 1, send data in two nibbles, delay
    - Uses: **lcd_writenibble()**

  - Could do as one function
    - **lcd_writebyte(unsigned char x, unsigned char rs)**

High Level API Routines

- **lcd_init()**
  - Does all the steps to initialize the LCD
  - See the lab writeup and follow it **exactly as written**
    - Uses: **lcd_writenibble(), lcd_writecommand(), delays**
- **lcd_moveto(unsigned char row, unsigned char col)**
  - Moves the LCD cursor to “row” (0 or 1) and “col” (0-15)
  - Translates from row/column notation to the format the LCD uses for positioning the cursor (see lab writeup)
    - Uses: **lcd_writecommand()**
- **lcd_stringout(char *s)**
  - Writes a string of character starting at the current cursor position
    - Uses: **lcd_writedata()**

Activity: Code-Along

- Assuming the **lcd_writecommand()** and **lcd_writedata()** functions are correctly written, code the high-level functions:
  - **void lcd_stringout(char* str);**
  - **void lcd_moveto(int row, int col);**
Copying Multiple Bits

- Suppose we want to copy a portion of a variable or register into another BUT _________ affecting the other bits
- Example: Copy the lower 4 bits of X into the lower 4-bits of PORTB…but leave the upper 4-bits of PORTB UNAFFECTED
- Assignment _______ work since it will overwrite ALL bits of PORTB
  - PORTB = x; // changes all bits of PORTB

Copying Into a Register

- Solution...use these steps:
  - Step 1: Define a _____ that has 1’s where the bits are to be copied
    #define MASKBITS 0x0f
  - Step 2: ______ those bits in the destination register using the MASK
    _______ &= ~MASKBITS
  - Step 3: Mask the appropriate field of x and then ______ it with the destination, PORTB
    PORTB |= ____________

Do We Need Step 2...Yes!!!

- Can’t we just do step 1 and 3 and OR the bits of x into PORTB
  #define MASKBITS 0x0f
  PORTB |= (x & MASKBITS);
- ______, because what if the destination (PORTB) already had some 1’s where we wanted 0’s to go...
  ...Just _______ wouldn’t change the bits to ____
- That’s why we need step 2
  - Step 2: Clear those bits in the destination register using the MASK
    PORTB &= ~MASKBITS;

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    PORTB &= ~MASKBITS;
Copying To Different Bit Locations

- What if the source bits are in a different location than the destination
  - Ex. Copy lower 4 bits of x to upper 4 bits of PORTB
- Step 1: Define a mask that has 1’s where the bits are to be copied
  - #define MASKBITS 0xf0
- Step 2: Clear those bits in the destination register using the MASK
  - PORTB &= ~MASKBITS
- Step 3: _____ the bits of x to align them appropriately, then perform the regular step 3
  - PORTB |= ((_____ & MASKBITS);

Coding a Byte Transfer to the LCD

Making Things Work Together

Does your code do the right thing?

- LCD lab required the program to generate an Enable (E) pulse.
- Example: The writenibble() routine controls the PB1 bit that is connected to the LCD Enable line.
  - PORTB |= (1 << PB1); // Set E to 1
  - PORTB &= ~(1 << PB1); // Clear E to 0
- Creates a 0→1→0 pulse to clock data/commands into LCD.
- But is it a pulse that will work with the LCD?
- Rumors circulated that the E pulse had to be made longer by putting a delay in the code that generated it.
- Don’t Guess. Time to read the manual, at least a little bit.
Check the LCD controller datasheet

Timing Characteristics

Figure 27  Write Operation

Check the generated code

• Can check the code generated by the compiler to see what is happening.
• For the creation of the E pulse the compiler generated this code:
  
  SBI    PORTB, 1 ; Set Bit Immediate, PORTB, bit 1  
  CBI    PORTB, 1 ; Clear Bit Immediate, PORTB, bit 1  

• According to the manual, the SBI and CBI instructions each take 2 clock cycles
• 16MHz ⇒ 62.5nsec/cycle, so pulse will be high for 125nsec

Check with the oscilloscope

Extend the pulse

• At 125nsec, the E pulse is not long enough although it might work on some boards.
• Can use _delay_us() or _delay_ms() functions but these are longer than needed since the minimum delay is 1us (=1000 ns) and we only need 230 ns
• Trick for extending the pulse by a little bit:
  
  PORTB |= (1 << PB1);  // Set E to 1  
  PORTB |= (1 << PB1);  // Add another 125nsec to the pulse  
  PORTB &= ~(1 << PB1);  // Clear E to 0
Better looking pulse

Extend the pulse (geek way)

- Use the “asm” compiler directive to embed low level assembly code within the C code.
- The AVR assembly instruction “NOP” does nothing, and takes 1 cycle to do it.
  ```c
  PORTB |= (1 << PB1);           // Set E to 1
  asm("nop"::);                 // NOP delays another 62.5ns
  asm("nop"::);
  PORTB &= ~(1 << PB1);         // Clear E to 0
  ```

Don’t guess that things will work

- When working with a device, make sure you know what types of signals it needs to see
  - Voltage
  - Current
  - Polarity (does 1 mean enable/true or does 0)
  - Duration (how long the signal needs to be valid)
  - Sequence (which transitions comes first, etc.)
- Have the manufacturer’s datasheet for the device available
  - Most of it can be ignored, but some parts are critical
  - Learn how to read it
- When in doubt ➔ follow the acronym used industry-wide: RTFM (read the *!@^-ing manual)