Microcontrollers

Class 1: Serial and Digital I/O

March 7, 2011

Outline

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Quick Tour of the Board

Pins, Ports, and Their Registers

Boolean Operations

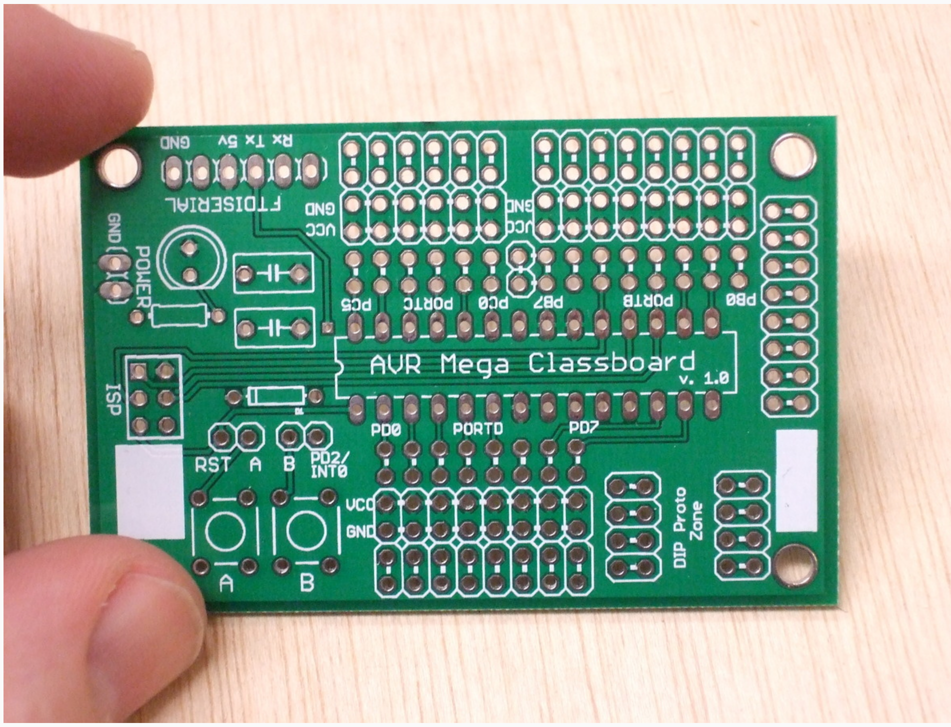
Cylon Eyes

Digital Input and Testing Particular Pin States

Debouncing

Serial Communications

See http://wiki.hacdc.org/index.php/Avr2011_kit



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- Quick Tour of the Board
- Pins, Ports, and Their Registers
- Boolean Operations
- Cylon Eyes
- Digital Input and Testing Particular Pin States
- Debouncing
- Serial Communications

Hello World Example

Blinkies!

- Last class, showed an example that turned a pin on and off
- Sections of the C code:
  preamble – includes and defines
  function definitions (didn't have any)
  main function (chip initialization and endless loop)
- The main loop twiddled a bit back and forth in a memory register, and that made Vcc and GND volts appear on a particular pin.
- But let's flesh that all out a little more...

Registers

Special memory locations

- Usually we think of memory as being a place to store info
- In micros, some special memory regions change the way the chip behaves: Registers
- DDRx register from initialization of LED blinking demo
- Writing a "one" to a bit in the DDRx register sets up a corresponding pin for output
- There's a similar mapping from the PORTx register to the output of the pins: writing a 1 to a bit in PORTx sets the corresponding pin at Vcc, 0 to GND
- When the pins are configured for input, the PIN registers read 0 if a low voltage is present on its pin, and 1 for high

Addressing the Pins

Writing bits to registers

- So, say we're working on PORTB, and we want to set pin PB2 and PB6 to 5v (to light up some LEDs)
- Write a 1 in the 2nd and 6th slots in the PORTB register
- Write it in binary directly: `PORTB = 0b01000100;`
- Write it using its decimal value: `PORTB = 68;`
- Write it in hex: `PORTB = 0x44;`
- Write it using a bit-value macro:
  `PORTB = _BV(2) | _BV(6);`

Outline

The Math

Bit-shift Operators

- <<: Left shift
- >>: Right shift

Binary logic

- & : AND
- |: OR
- ^: XOR
- ~: NOT

Bit-shifting

Left shift: <<

- Very handy: say you want a 1 in the pin-3 place: 00001000
- Start with 1: 00000001
- Shift it over 3:
  `1 << 3` = 00001000
- Or using the pin-name macros: `1 << PD3`
- `#define _BV(bit) (1 << (bit))`

Right shift: >>

- Start with 12: 00001100
- Shift 2: `12 >> 2` = 00000011
- Note that right-shift is like dividing by 2^n: handy
- (Similarly, left-shift is like multiplying by 2^n)

Using Shifts

Practical examples:

- `PORTD = (1 << 3);`
- `PORTD = (1 << PD3);`
- `PORTD = (1 << (1+2));`
- `j = 3; PORTD = (1 << j);`
- `j = 3; PORTD = _BV(j);`

Set Two Pins

Addition:

- Say we want PB3 and PB4 both on
- Add them together?
- `PORTB = _BV(PB3) + _BV(PDB);` will work
- After all:
$$\begin{array}{rl} & 00001000 \\ + & 00010000 \\ = & 00011000 \end{array}$$
- Works if you're just setting the port using `PORT = something;`
- But you never see bitwise addition. Why?

Turning Pins On

Why addition won't cut it

- What if you don't know (or care) what LEDs are already on, but you want to turn on PD3?
- `PORTD = PORTD + _BV(PD3);`?
- If PD3 is already on: $\begin{array}{rl} & 00000100 \\ + & 00000100 \\ = & 00001000 \end{array}$ Ouch!
- Could be worse: $\begin{array}{rl} & 01111100 \\ + & 00000100 \\ = & 10000000 \end{array}$
- We need an OR statement

Turning More Pins On

The OR statement: |

- `0b01000010 = _BV(1) | _BV(6)`, so it's as good as addition
- OR turns on a bit if this bit *or* that bit is on
- `PORTD = PORTD | _BV(PD3);`
- If PD3 is not on: $\begin{array}{rl} & 11000000 \\ | & 00000100 \\ = & 11000100 \end{array}$
- If PD3 is already on: $\begin{array}{rl} & 11000100 \\ | & 00000100 \\ = & 11000100 \end{array}$ Yay!
- Turn on PD3, PD4, PD5?
  `PORTD = PORTD | (_BV(PD3) | _BV(PD4) | _BV(PD5));`
- And here's a nice shorthand: $X = X + Y \quad \rightarrow \quad X += Y$
  `PORTD |= _BV(PD3) | _BV(PD4) | _BV(PD5);`

Turning Pins Off

The AND statement: &

* AND turns on a bit if this bit and that bit are *both* on

- ```
    11111110
  & 10001101
  = 10001100
  ```
- Can think of AND as masking out the the off bits
- Use it to turn off PD3: `PORTD &= 11110111?`
- `PORTD &= (_BV(PD7) | _BV(PD6) | ... skip PD3 ... | _BV(PD0) );`
- Works, but it sucks.

Turning Pins Off II

The NOT statement: ~

- There must be a better way to make 11110111
- `_BV(PD3)` = 00001000
- `~_BV(PD3)` = 11110111
- Turn off PD3: `PORTD &= ~_BV(PD3);`
- Turn off PD3 and PD4:
  `PORTD &= ~(_BV(PD3) | _BV(PD4));`
  Careful with those parentheses!
- Also remember this in terms of the fundamentals:
  ```
  PORTD &= ~((1 << PD3) | (1 << PD4));
  PORTD &= ~((1 << 3) | (1 << 4));
  ```
  ```

Toggling a Pin

The XOR statement: ^

- A lot of the time, it's handy to be able to toggle a bit
- `PORTD ^= _BV(PD3);`
-
```
     11111001
 ^   00001000
 =   11110001
```
-
```
     11110001
 ^   00001000
 =   11111001
```

Outline

One Last Part...

...then Cylon Eyes

- So we know how to turn on bits, and how to turn them off
- How do we make cylon eyes?
- Start with light 0 on.
  Turn off the 0th, turn on the 1st, pause
  turn off the 1st, turn on the 2nd, pause
  etc
- `PORTD &= ~_BV(PD0); PORTD |= _BV(PD1); delay`
  `PORTD &= ~_BV(PD1); PORTD |= _BV(PD2); delay` etc.
- `{PORTD &= ~_BV(i) ; PORTD |= _BV(i+1); delay }`
- And make `i` range from 0 to 7 and back again
  (being very careful about endpoints)

Basic Looping

The For loop

- `for(i=0; i < 7; i = i + 1){...}`
- Repeats the block in parentheses a bunch of times.
- First time, `i` $= 0$.
- Then it checks if `i` < 7.
  If not, it skips the block and moves on.
  If so, it executes the next command and then the block.
- So in our case, it executes the block with `i`$= 0, 1, 2, 3, 4, 5, 6$
  and then is done.
- `for(i=7; i > 0; i = i - 1){...}` and a different block
  will bring it back down
- `i`$= 7, 6, 5, 4, 3, 2, 1$

Digital Output: Summary

Configure, Write, Done

- So at this point, we're all set for doing all sorts of cool stuff with digital output
- First, set up the DDR for output (on pins of your choosing) by writing a 1 to the relevant bit
- The set the PORT register to set pins high or low, depending
- Loop, repeat

Outline

Initializing for Input

It almost seems too easy...

- To initialize for *output* set bit to one
  DDRx = _BV(whatever)
- For *input*, want to set the bit to zero instead.
- But zero is the default value. Done!

Initialization for Input

One wrinkle: Initialize a pullup resistor

- A pullup resistor ties the input pin to 5v (internally) when it's not pulled low from outside
- Often want a pullup with input
- Why? Simplest input circuit is a switch from pin to ground
- AVR's PORTn does double-duty.
  In output mode, controls output.
  In input mode, selects the pullup
- So often set PORTn to one to enable the pullup:
  `PORTB |= _BV(PB3);`

Reading the Input

Reading the input register

- Input values in the PINx register
- Can read them like `readIn = PINB;`
- `readIn` will contain an 8-bit number, each bit corresponding to the voltage state of all 8 of its pins.

Reading one pin: the most common case

- `PIND & _BV(PD3);`
- If PD3 has more than 1.25v on it, we'll get 00001000
- If PD3 has less than 1.25v on it, we'll get 00000000
- Test of pin state: `if((PIND & _BV(PD3)) == 0){...}` or `if(!(PIND & _BV(PD3))){...}`
- See *simplePushbutton.c*

Outline

The Real World

Switching Noise

- In reality, switches make/break contact a bunch of times as you press it
- Two pieces of metal touching, bending, with different resistance all over
- If you're trying to make a per-button-press device, this can cause troubles
- Symptom: Get multiple presses for what you thought was a single press
- Solution: Debouncing

Debouncing

Many Approaches

- Delay I: turn on after a short delay after first button press
- Delay II: wait short period of time after first press, test again if it's still pressed
- Integrate: test N times in a row, with a delay between, decide the button is pressed if more than M hits
- There are many others. There was even a Hackaday competition recently for favorite debounce algorithms (`http://hackaday.com/2010/11/09/debounce-code-one-post-to-rule-them-all/`)
- `http://www.ganssle.com/debouncing.htm`
- I'll send code around for you to experiment with
- Advertisement for Hardware Timers!

When To Debounce?

To Debounce

- When you're counting events
- When you need to know how long the button is held down
- When it's not really a button, but an analog voltage, and it spends a bunch of time in the dreaded 0.8v - 1.5v range

Or Not to Debounce

- When all you care about is on/off, don't mind the bounce
- When other parts of the code act as a delay

Outline

Simple Serial

The easiest way to get rich debugging info

- The microcontroller really comes into its own as an *interface*
- The USART serial port (and a USB serial cable) is the easiest way to get data to and from your computer
- AVR has a built-in hardware serial machine, all you have to do is load its buffer up
- This is your first include of a non-standard file: #include "USART88.h"
- If you're curious how I wrote them, the USART serial section of the datasheet is a good place to start. Dive in!
- ... or just look at examples and monkey it.

Using USART88.h

What Do the Functions Do?

- `#define BAUDRATE 9600`
- `initUART()`:
  uses BAUDRATE to set up the baud rate
  then some bits in the USART config register are set for stop bits and parity
- `transmitByte()`:
  wait for the USART busy flag to become unset
  load the data into the transmit buffer register
  walk away, letting the hardware serial do the rest
- `receiveByte()`:
  once initialized, the hardware USART is always receiving
  wait for the USART received-data flag to be set
  return the data

Serial Interfacing

For the Big Computer

- Screen: for terminal emulation
  `screen /dev/ttyUSB0` or even `screen /dev/ttyUSB0 9600`
- Python: pyserial `http://pyserial.sourceforge.net/` for everything else

Serial Ideas

Things I Have Done With USART Serial

- Control 4x4x4 LED cube from my desktop
- Simple menu system for a logging accelerometer
- GPS datalogger
- Parallax RFID readers
- Hook up 2 AVRs (radio, IR LED, wires)
- Debug, debug, debug!

The End

◂ Outline