Last Time

- Finite state machine implementation in code
- Connecting code to the computer architecture
  - Program counter
  - Status register
  - General registers
  - Assembly language

Today

- Another FSM example
- Analog input/output

Administrivia

- Homework 5 out by tonight
- Project 2 due Thursday
  - Your FSMs should be designed (and implemented)

- AME Faculty candidate talk today:

  Dr. Brian Argrow

  Small UAVs for Ad-Hoc Networking

  3:00, FH 214

FSM Toy Example

- What is the FSM?

A Comment About FSM Implementation in Code

- switch() statements are convenient for selecting between different pieces of code based on state
- But: may not be easy to use when processing events

Event Handling for the Vending Machine

```
case STATE_10cents:
   // $.10 has already been deposited
   switch(event) {
        case EVENT_NICKEL:   // Nickel
                state = STATE_15cents;  // Transition to $.15
                break;
        case EVENT_DIME:   // Dime
                state = STATE_20cents;  // Transition to $.2
                break;
        case EVENT_JOLT:   // Select Jolt
        case EVENT_BUZZ:   // Select Buzzwater
                display_NOT_ENOUGH();
                break;

        case EVENT_NONE:   // No event
                break;           // Do nothing

   };
   break;
```

Use of switch is simple in this case: a small number of events that can all occur in each state

Event Handling in More Complicated Domains

```
case STATE_FORWARD_SEARCH_LEFT:
   // Moving forward while searching left
   if(sensor[TURRET_LEFT] > 0 || sensor[TURRET_RIGHT > 0)) {
        // Event: we have found a beacon on the left
        turn_left();
        state = STATE_FORWARD_SEARCH_RIGHT;
   }else{
        // No event: handle actions taken while in this state
        drive_toward_beacon_front();
   };
   break;     // DON’T FORGET THE “BREAK”

case FOO:
        :
        :
        :
```

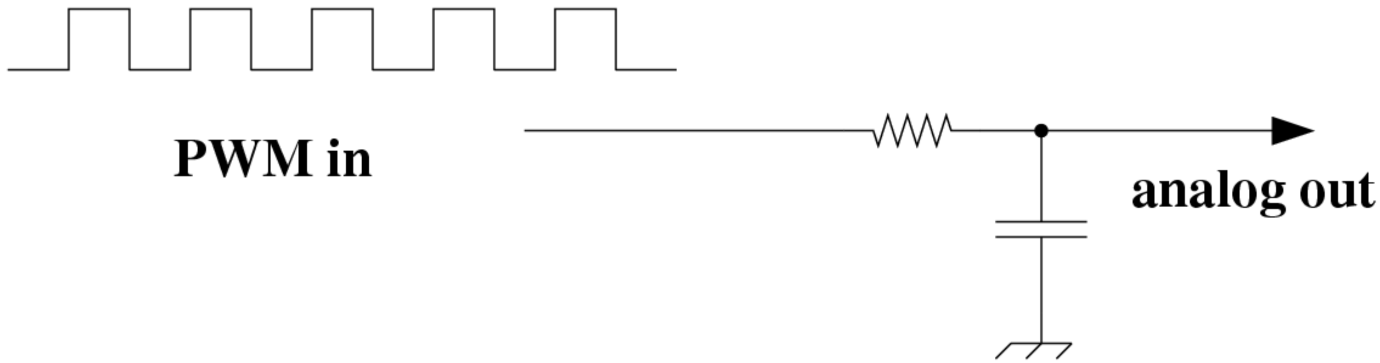
The “if” statement allows us to capture many different situations (or events) in one

Digital to Analog and Back

- Analog: encoding information using voltage
  - Many sensors use voltage as an output
  - Motors torque is determined by current passing through the motor
- Digital: encoding information with bits

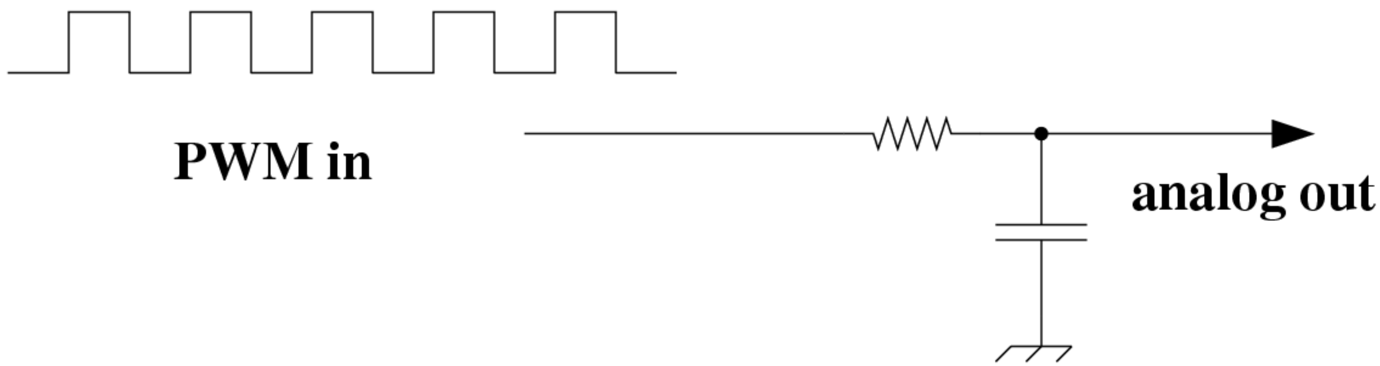
How to move between these?

Digital to Analog Conversion: Pulse Width Modulation



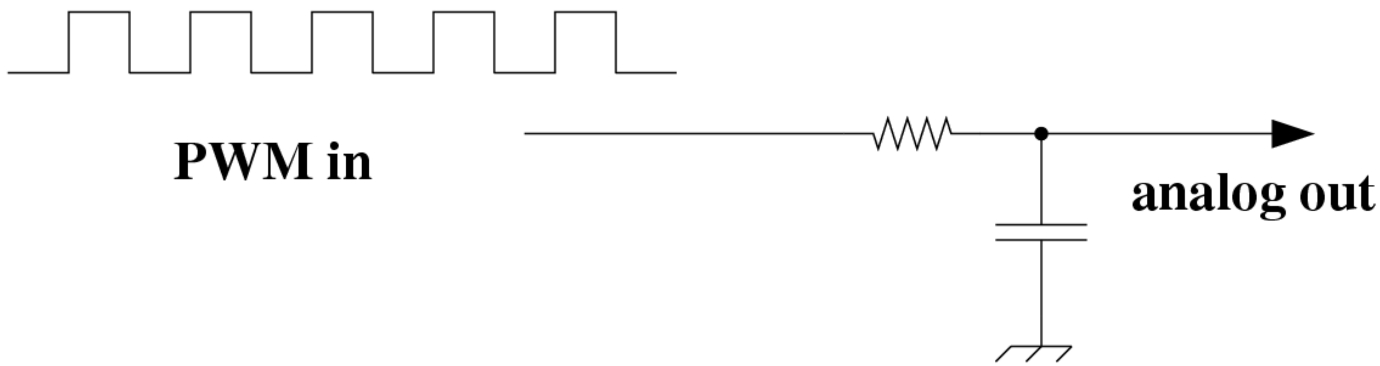
What does this circuit do?

Digital to Analog Conversion: Pulse Width Modulation



- Processor digital pin: generate PWM signal
- RC circuit “smooths” this PWM signal out
- Pulse width determines smoothed voltage

D2A: Pulse Width Modulation



- Easy to implement
- But:
  - Smoothed signal may not be smoothed enough
  - Filter induces a delay

Digital to Analog Conversion: Resistive Network

- Sometimes need faster response
- Solution: use multiple digital pins

Analog to Digital Conversion

- For a given voltage, what is the digital representation of the voltage?
- Common approach: successive approximation
  - Use a D2A converter to produce a voltage V
  - Compare this with the input voltage Vi
  - If different, then increase/decrease V
  - Repeat (stopping when V is close to Vi)

Last Time

- Relationship between analog and digital encoding of information
- D2A:
  - With pulse-width modulation
  - With resistive network
- A2D:
  - Successive approximation

Today

- Analog to digital with the Mega8
- Project 3: following air currents
- Interrupts

Administrivia

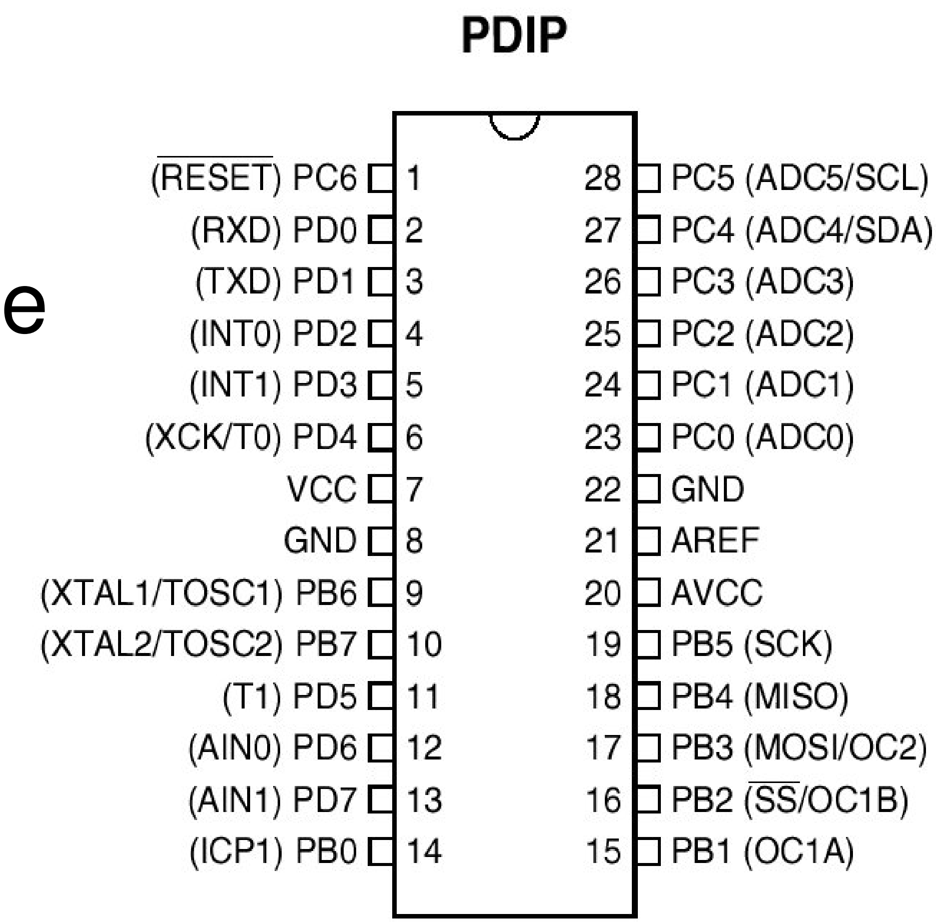
- Project 2 due today @5:00
  - Demonstration
  - Group report (pdf or postscript)
  - Personal report (raw text only!)
- Homework 5 is available on the web site
  - Due Tuesday

Robot Administrivia

- 3 functional robots right now
- A 4th will be ready early today
- The 5th won't be ready until sometime Friday

A2D in the Mega8

- The mega8 contains hardware that implements successive approximation
- 5 mega8 pins can be configured as analog input pins



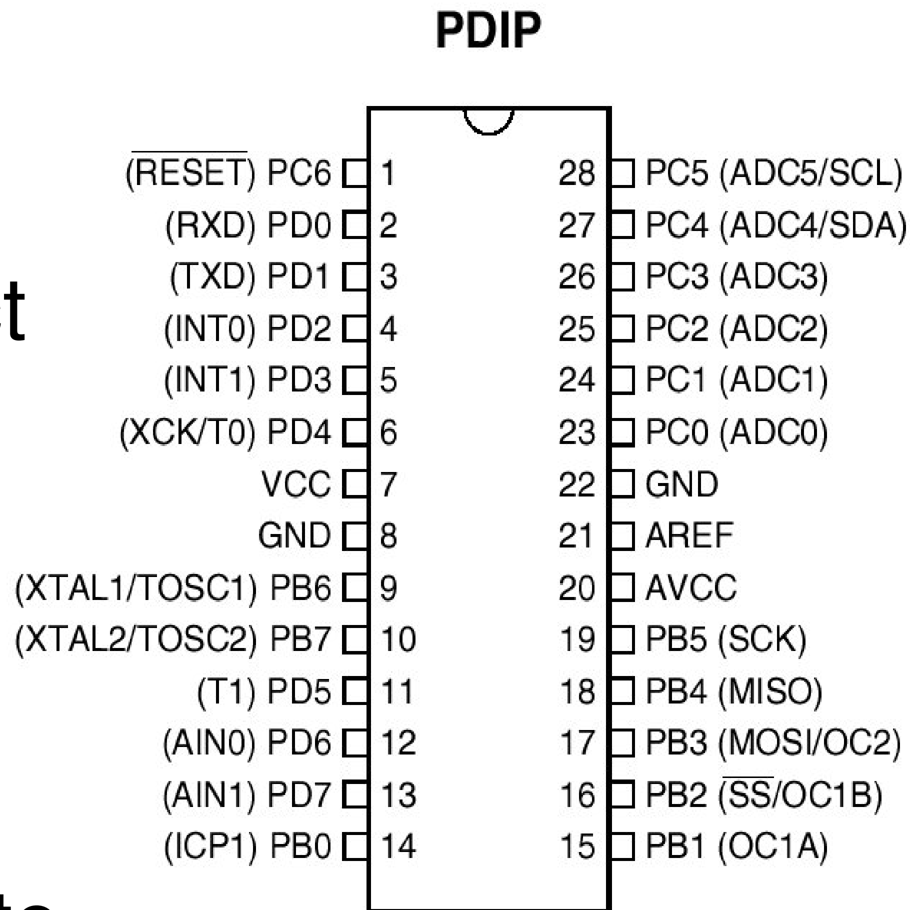
A2D in the Mega8

AVCC: connect to +5V

AREF: (optional) connect to +5V

- Measuring voltages between 0 and +5V

Connect input analog signal to the appropriate ADC pin



A Code Example

```
// Initialize adc
adc_set_reference(ADC_REF_AREF);        // Use the AREF reference pin
adc_set_adlar(0);                       // For our purposes, always use 0
adc_set_prescalar(ADC_PRESCALAR_128);  // Necessary with 16MHz clock
                                        //  and 10 bit resolution
// Turn on ADC Converter
adc_set_enable(ADC_ENABLE);


         :
         :
long val;

// Can do the following an arbitrary number of times

adc_set_channel(ADC_CHANNEL_0);         // ADC0
// Actually start a conversion
adc_start_conversion();

<Could go off and do something else for a while>

val = adc_read();  // Read the analog value
```

Analog Conversion Notes

- All functions are provided in oulib.c
- See oulib.h for the definition of constants

- Can get to the example code from the Atmel HowTo

  www.cs.ou.edu/~fagg/classes/general/atmel

Analog Conversion Notes

- Setting the maximum voltage:

```
adc_set_reference(ADC_REF_AREF);       // Use the AREF reference pin
```

- Can also used a fixed voltage (+2.56V):

```
adc_set_reference(ADC_REF_2p56V);
```

Analog Conversion Notes

- Determining how fast the conversion requires:

```
adc_set_prescalar(ADC_PRESCALAR_128);  // Necessary with 16MHz clock
                                       //  and 10 bit resolution
```

- Conversion requires:

  128 * 15 / 16000000 seconds

  – Can convert faster, but may not get the full 10-bit resolution

Analog Conversion Notes

- Reading out the value:

```
val = adc_read();        // Read the analog value
```

- Will receive a value between 0 and 0x3FF (1023)

Project 3

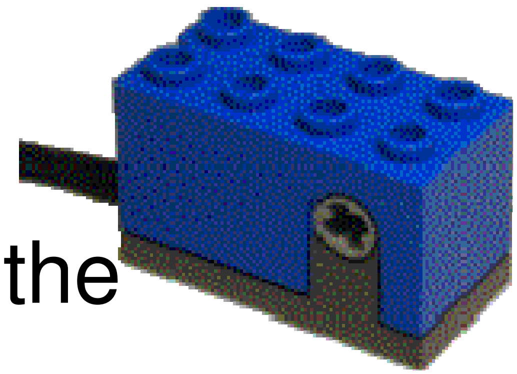
- Problem: follow the air currents
- Task:
  - Orient robot to face wind
  - Drive toward it
  - Stop when a beacon is observed on the left

Project 3

Sensing relative wind direction:

- Weather vane mounted on an **encoder**
- Encoder essentially tells us how orientation is changing – so we must integrate this signal to estimate position

Using the Lego Encoder



"Two-wire" interface

- One wire connected to ground, the other to an I/O pin
- Must first charge the sensor's power source (a capacitor):
  - Drive the pin high for ~3 ms
- Then read the sensor's state
  - "float" the pin
  - Read out the voltage

Using the Lego Encoder

The sensed voltage will be one of four values:

- 2.6V, 1.7V, 3.9V, and 4.5V
- We will refer to these as integer values 0, 1, 2, and 3, respectively

- As the shaft is rotated, the sensed voltage will change from one level to the next (in the given sequence)
- Rotation in the opposite direction yields the opposite order

Using the Lego Encoder

- … this give us a 2-bit counter (of sorts)
- But – for one complete rotation of the shaft, we will pass through this sequence a total of 4 times

How do we turn this information into absolute position?

Lego Encoder Caveats

- It is easy to miss the 4.5V level (due to sensor design)
- For the intermediate voltages (2.6V and 3.9V), a single analog sample cannot tell the difference between a stable voltage or a transient one

Project 3 Group Time

What is the FSM for the sensor processing of project 3?

- What are the states?
- For each state, what are the relevant events?
- What actions are taken for the events?
- Think carefully about how to handle the caveats

Once you have absolute position of the shaft, what is the code that turns this into steering commands? (give the pseudo-code)

Next Time

Project 3:

- Interrupt processing