Microcontrollers

Class 2: "Analog" I/O

March 14, 2011

Outline

- Review
- Analog Out
- Analog In

Outline

Outline

Demo Code

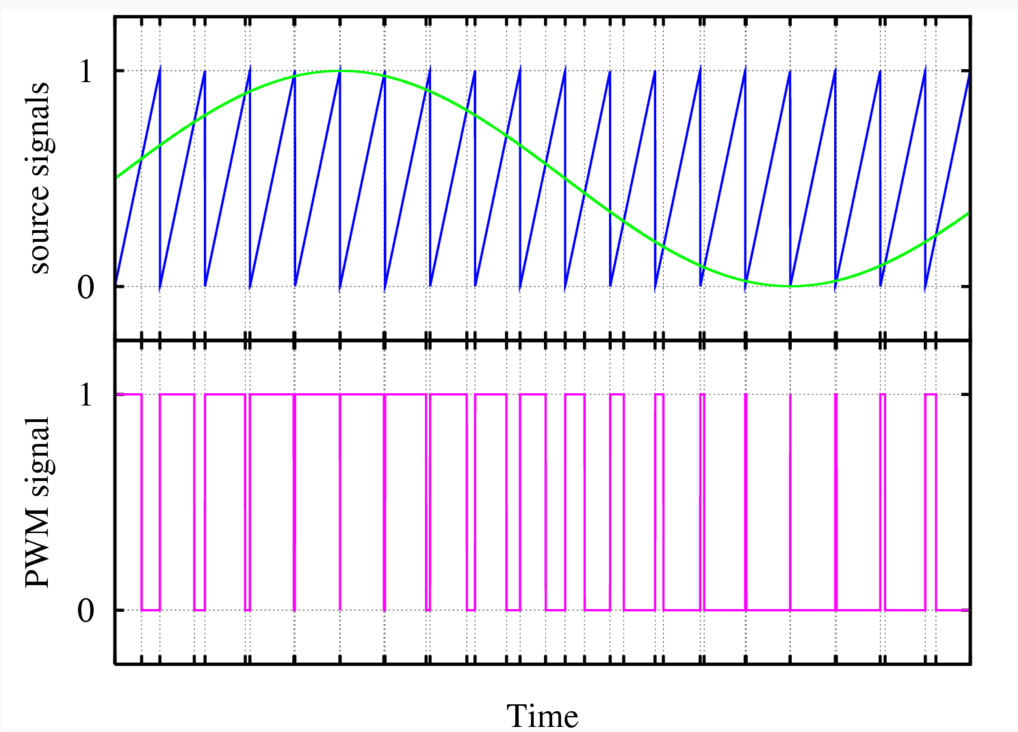
Outline

Pulse-Width Modulation

Faking Analog

- As we've seen, the output pins on the AVR put out 0v or 5v, depending on the values stored in the PORTx registers
- That's great for turning stuff on and off, but what about all the voltages in-between?
- We fake it by turning the pin on and off quickly
- *period* (or *frequency*): how long PWM pattern takes to repeat
- *duty cycle*: the percentage of the period is spent on
- Since our pin spends *dutycycle*% of the time at 5v and $(1 - dutycycle)$% at 0v,
  the average voltage (over one period) is $5v * dutycycle$

PWM



Example With LEDs

pwmDemo.c

- We want LED on for $x\%$ of the time:
- Count 0 to 255, with a slight delay
- Turn light on at 0
- Turn light off at $255 * x\%$
- Repeat.
- Want different brightnesses? Use different x.
- Bonus code: using array to store 8 brightness levels. Snazzy!

"Analog" or Analog?

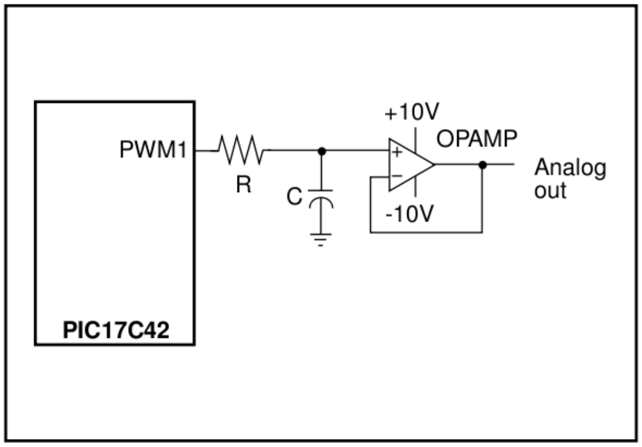
A Bit More Detail

- So we're not really outputting analog,
  just a very fast series of digital data
- With the LED example, our persistance of vision smooths it out for us
- PWM works for most other lights, motors, and even audio waveforms if the PWM period is short enough
- *But* there's a tradeoff: the PWM period divided by the shortest on/off time limits how much resolution you can acheive
- *Also* the issue of all those jaggy little step functions
  Simple RC filter can help a lot

RC Filter Example:

- ww1.microchip.com/downloads/en/AppNotes/00538c.pdf

FIGURE 4: RC FILTER CONNECTED TO PWM1 OF PIC17C42



Choosing, the -3 dB point at 4 kHz, and using the relation $RC = 1/(2 \bullet \pi \bullet f)$, we get R = 4 kΩ, if C is chosen as 0.01 μF:

R = 4.0 kΩ

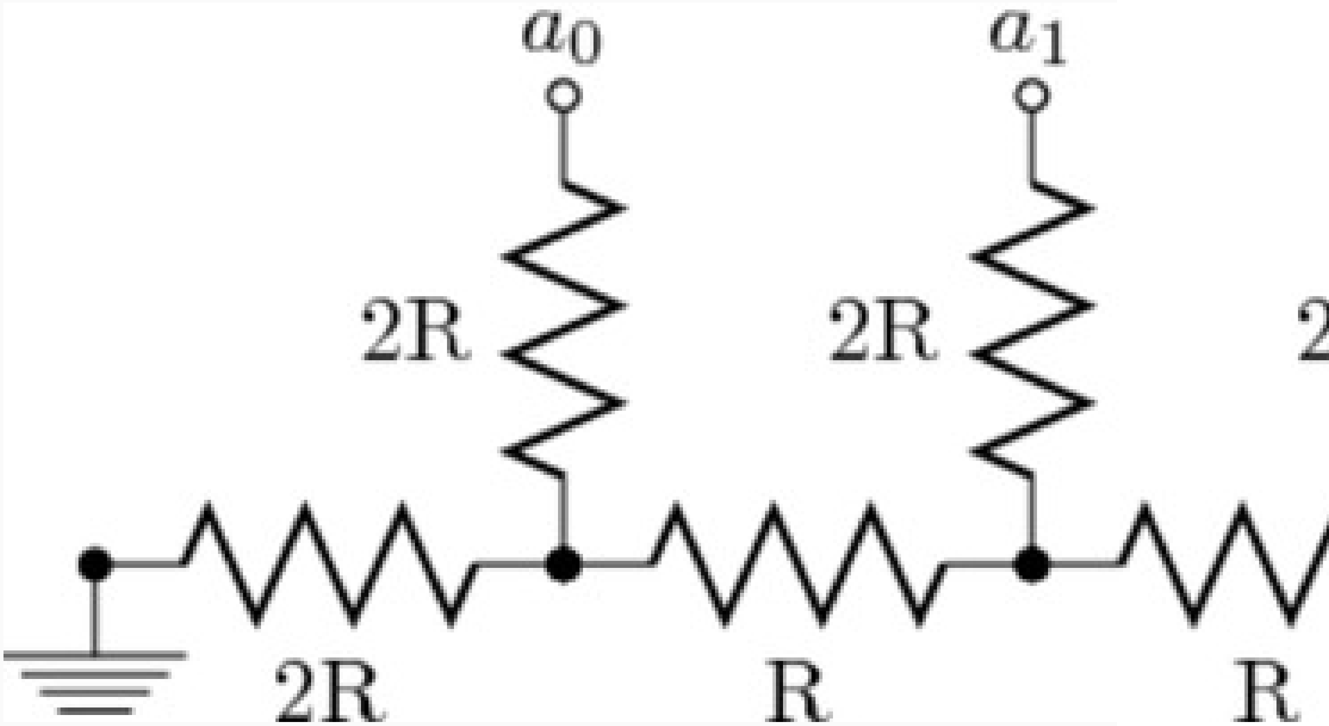
C = 0.01 μF

Digital-to-Analog Conversion

Get "real" analog by using a DAC

- If PWM isn't working for you: period too long, filtering bothersome, or insufficient bit depth...
- DAC: you give it a digital input, it spits out a given (analog) voltage value
- Specified by frequency and bit-depth
- Some take the digital input as serial data, some parallel
- B/c of digital audio market, there are tons of 44kHz 16-bit DACs out there
- There are many that are even faster!
- Here's one of my favorites that you can DIY: the R-2R DAC

R-2R DAC



Outline

Review

Analog Out

Analog In

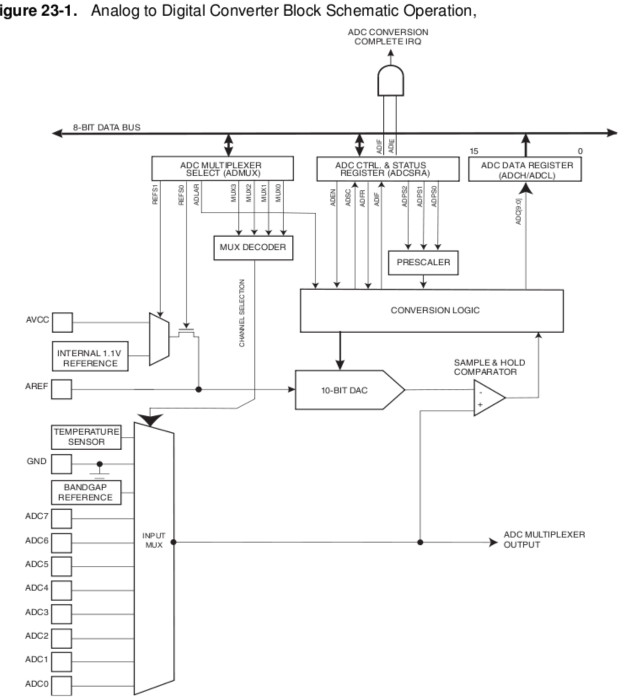
Analog-to-Digital Conversion

Theory and Hardware

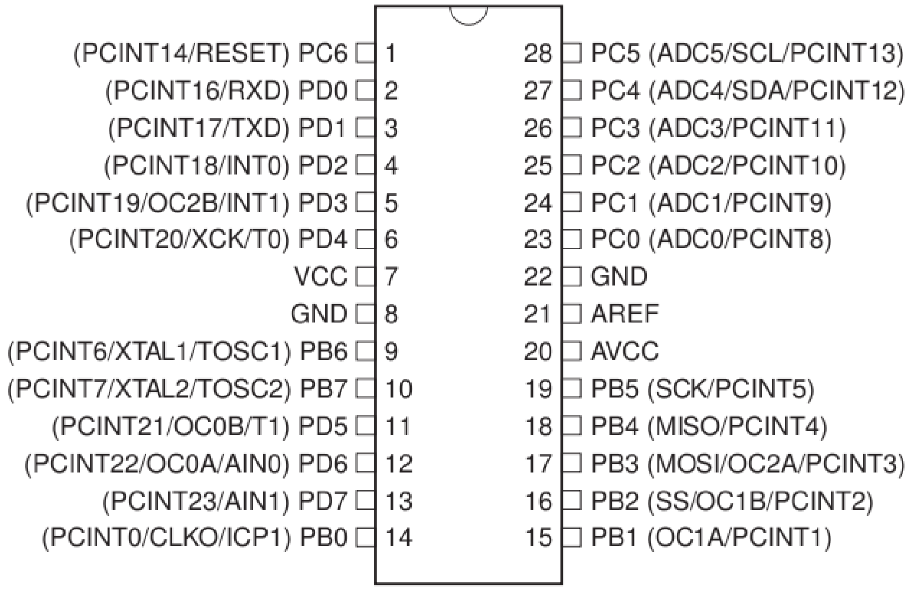
- ADC: Take an analog input voltage, determine its closest digital value
- Chip has dedicated ADC hardware that compares voltages
- ADC reference voltage (AREF) is the maximum value it can read
- Start at 1/2 AREF, see if the signal is higher or lower
- Then create either 1/4 or 3/4 AREF, compare again...
- Successive-approximation DAC
- The answers to the comparison questions are the voltage, in binary

ADC Hardware

Figure 23-1. Analog to Digital Converter Block Schematic Operation,



Pinouts



Using the AVR's ADC

It's All in the Configuration (p. 263)

- Two modes: sample-on-demand and free-running
- Unless timing is sensitive or you need low power operation, I use free-running mode
- Free-running mode: chip just keeps on sampling the ADC, writing the value in the ADCL and ADCH data registers
- Chip uses a 10-bit ADC, so need to write the 10 bits into two registers
- I usually just use 8 bits worth of ADC, shift the bits left (ADLAR = 1) and read out of ADCH
- Multiplexer: need to point it at the channel you're interested in reading (MUXn bits in ADMUX)
- Turn off the digital inputs on your ADC pins

Light Sensor Example

Wire it up!

- Cadmium Sulfide (CdS) light-dependent resistor gets less resistive in the light
- Using another resistor, we can create a voltage divider that depends on the light in the room
- I use a variable resistor (potentiometer) as the second one to allow us to adjust the sensitivity of our light meter
- Hook up one end of the CdS cell to VCC, and the other to PC0
- Hook up PC0 to one end of the variable resistor
- Hook up the wiper (middle) of the variable resistor to GND

The End

◂ Outline