ADC: Analog to Digital Conversion

- Converting an analog (continuous) voltage to digital (discrete) values
- Issues / performance metrics
  - Accuracy
  - Amplitude resolution / precision
  - Time resolution (samples per second)
  - Input range
  - Voltage reference
  - Noise
Types of ADC

- **Comparator**
  - “one bit ADC”
  - Building block inside other ADCs

- **Slope**
  - Measure time for voltage to reach a threshold...poor person’s ADC, can be done w/ digital input only (i.e. on micros with no ADC)
  - Ultra cheap

- **Successive approximation**
  - Binary search
  - 10-12 bits
  - Fairly fast --- can be Megasamples per sec (not on MSP430)
  - Until recently, the standard on micros

- **Flash**
  - Parallel comparison
  - Very fast
  - Requires a lot of HW...expensive

- **Sigma-Delta (on F2013)**
  - Value encoded via PWM, which is then averaged digitally
  - True “ADC” is in some sense single comparator
  - Slow but high precision
Physical quantity to be sensed... in this case a variable capacitance. Works for variable resistance also.
Demos here

- [http://www.falstad.com/circuit](http://www.falstad.com/circuit)
- Flash ADC simulation
  - Circuits → Analog / Digital → Flash ADC
- Sigma-Delta ADC simulation
  - Circuits → Analog / Digital → Delta-Sigma ADC
Sigma-Delta

- A one bit ADC (comparator) samples the signal much faster than the signal changes
- Current input – “raw output” ➔ error signal (Delta)
- Integrate error (Sigma)
- Run signal through 1 bit ADC to get “raw output”
- Feed raw output back; stats on “raw output” ➔ meas.

*Figure 9.18: Block diagram of a sigma-delta ADC. The loop forms the sigma-delta modulator, which is followed by a digital filter.*

From Davies
**SD_16A block diagram**

Inputs in differential pairs
If you want a single-ended measurement, make sure to ground 2\textsuperscript{nd} pin of pair

Multiplexer (SD16INCH)

Hi Z buffer (SD16BUF) ... missing from F2013

Prog. Gain Amp (SD16GAIN)

Ref voltage (SD16REFON) ... 1.2V

Oversampling ratio
SD16OSRx={32,64,128,256}

AD16LP... low power... reduces modulator frequency

Clock: MCLK, SMCLK, ACLK... Divided down according to SD16DIV and SD16XDIV

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†Not Implemented in MSP430x20x3 devices

*Figure 26-1. SD16_A Block Diagram*
More SD_16A

Interrupt: SD16_A1
  SD16IFG: set when new converted result available
  SD16OVIFG overrun...new value written before old sampled
  SD16IV: decode source of interrupt, like TAIV

- Conversion modes
  - Single...start by setting SD16SC (conversion bit)
  - Continuous

- Result
  - SD16MEMO
Analog input, Digital output formats

Figure 26-6. Input Voltage vs Digital Output
#include <msp430x20x3.h>
#define ADCDeltaOn 31 // ~0.5 Deg C delta
static unsigned int LastADCVal; // holds ADC temperature result
void main(void) {
    BCSCTL2 |= DIVS_3; // SMCLK/8
    WDTCTL = WDT_MDLY_32; // WDT Timer interval
    IE1 |= WDTIE; // Enable WDT interrupt
    P1DIR |= 0x01; // P1.0 to output direction
    SD16CTL = SD16REFON + SD16SSEL_1; // 1.2V ref, SMCLK
    SD16INCTL0 = SD16INCH_6; // A6+/-
    SD16CCTL0 = SD16SNGL + SD16IE; // Single conv, interrupt

    _BIS_SR(LPM0_bits + GIE); // Enter LPM0 with interrupt
}
#pragma vector=SD16_VECTOR
__interrupt void SD16ISR(void)
{
    if (SD16MEM0 <= LastADCVal + ADCDeltaOn)
        P1OUT &= ~0x01;                       // LED off
    else
        P1OUT |= 0x01;                        // LED on
    LastADCVal = SD16MEM0;                  // Store value
}

// Watchdog Timer interrupt service routine
#pragma vector=WDT_VECTOR
__interrupt void watchdog_timer(void)
{
    SD16CCTL0 |= SD16SC;                    // Start SD16 conversion
}
DAC quantization noise

From:
http://www.beis.de/Elektronik/DeltaSigma/DeltaSigma.html