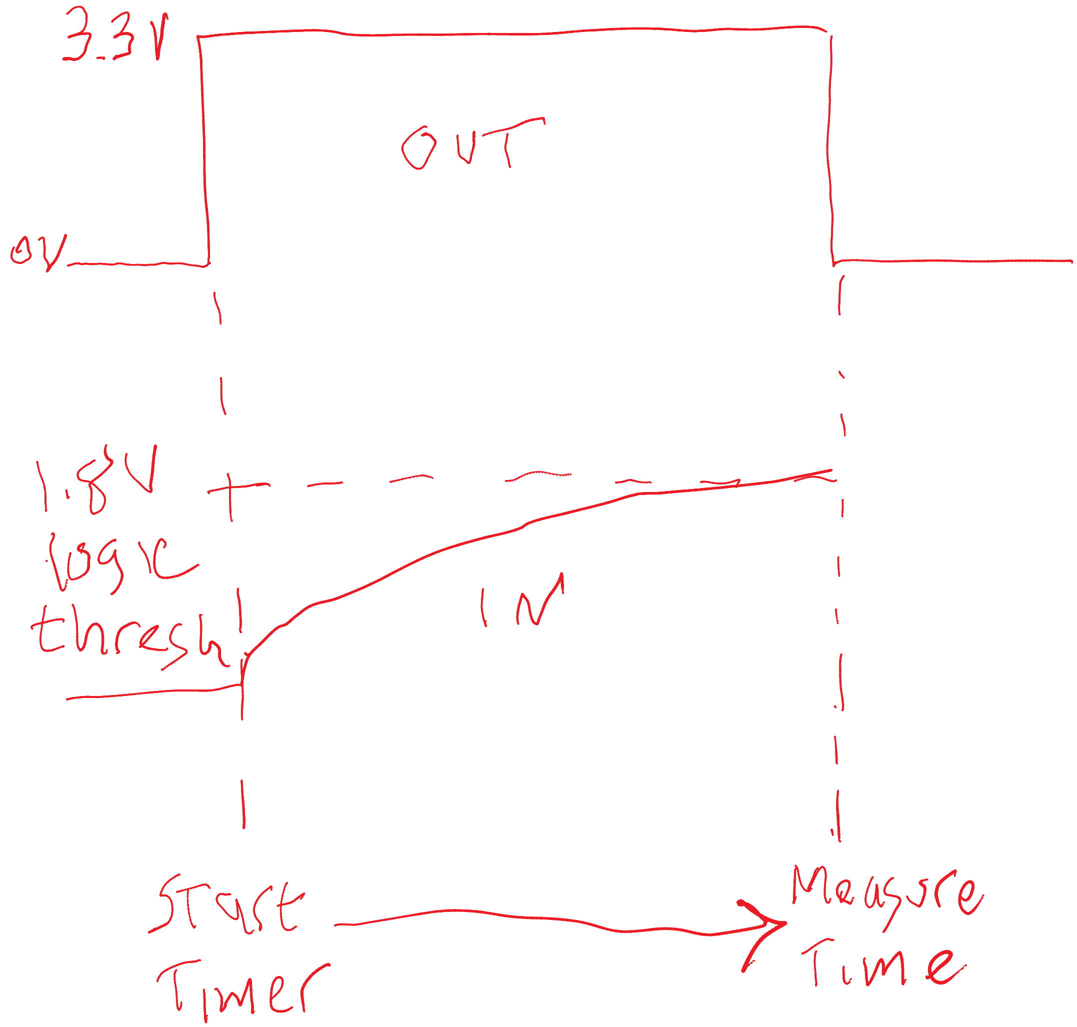
ADC: Analog to Digital Conversion

- 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

Slope ADC



Physical quantity to be sensed...in this case a variable capacitance. Works for variable resistance also.

Larger cap ⇒ larger RC charge time ⇒ larger measured time value

Demos here

- 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.

Mixed-Signal Systems: Analog Input and Output 439

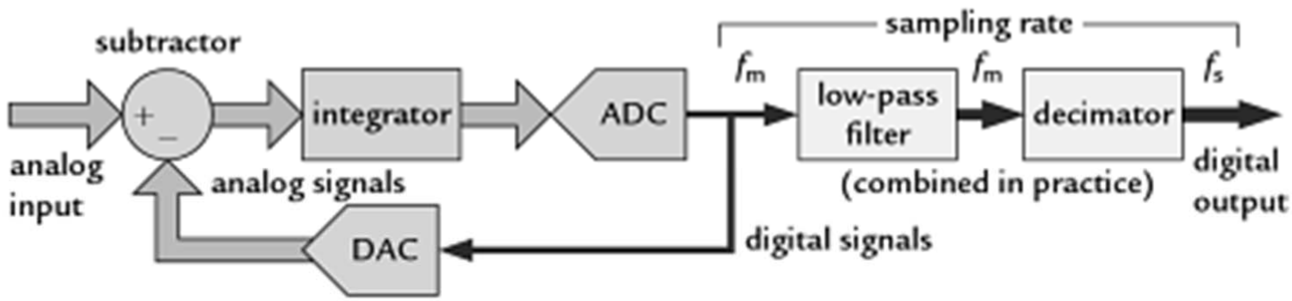


Figure 9.18: Block diagram of a sigma-delta ADC. The loop forms the sigma-delta modulator, which is followed by a digital filter. *From Davies*

SD_16A block diagram

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

Multiplexer (SD16INCH)

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

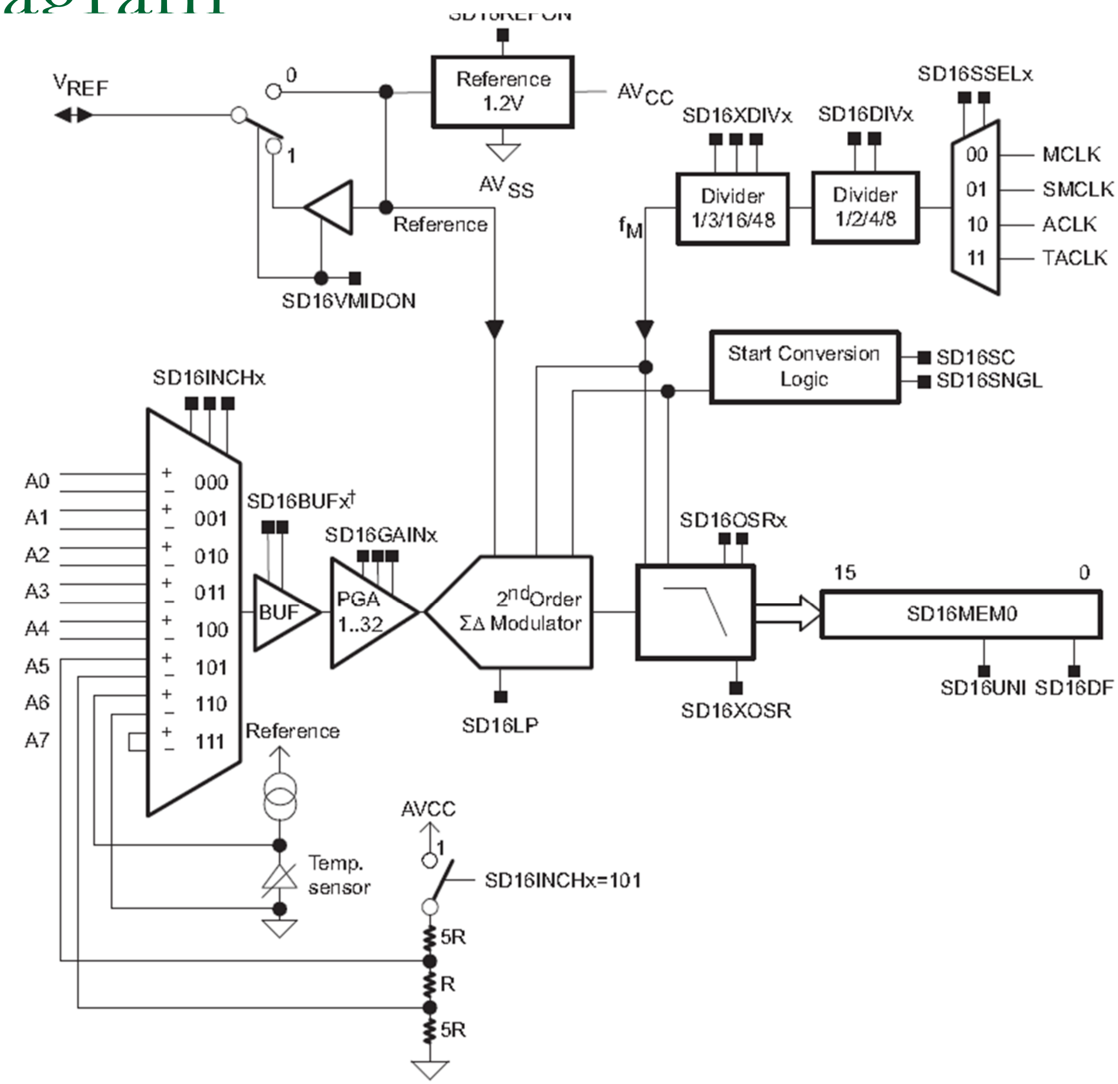
Prog. Gain Amp (SD16GAIN)

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



† 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

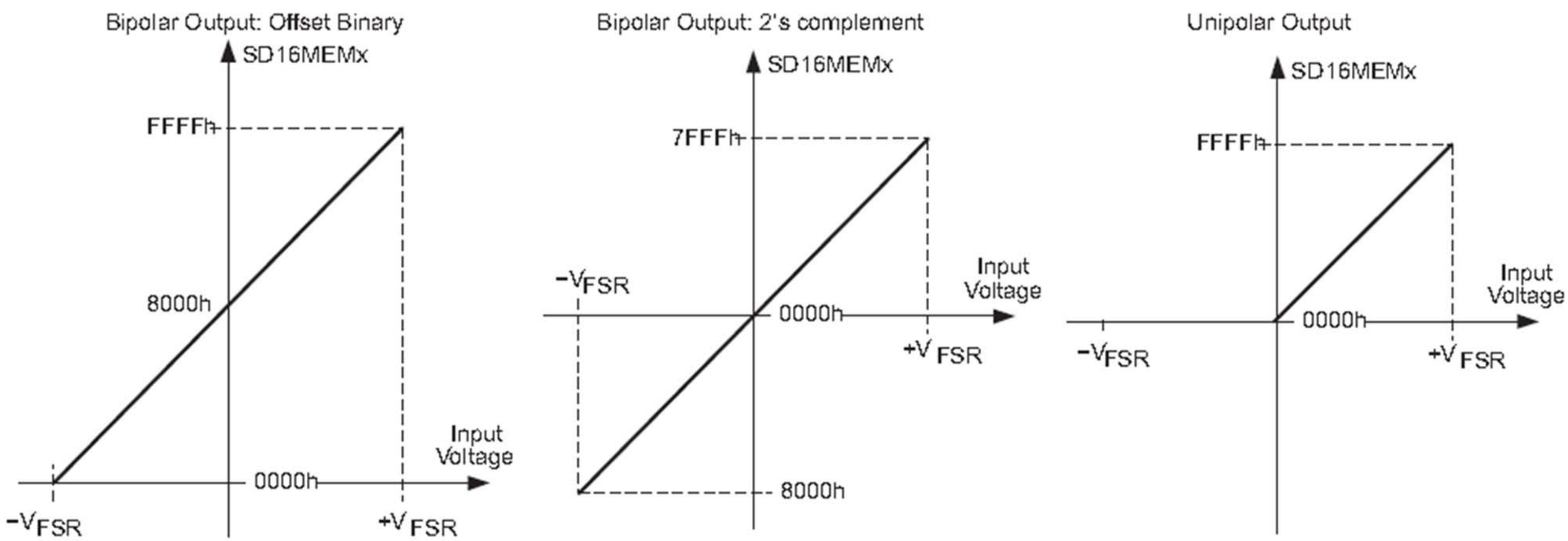


Figure 26-6. Input Voltage vs Digital Output

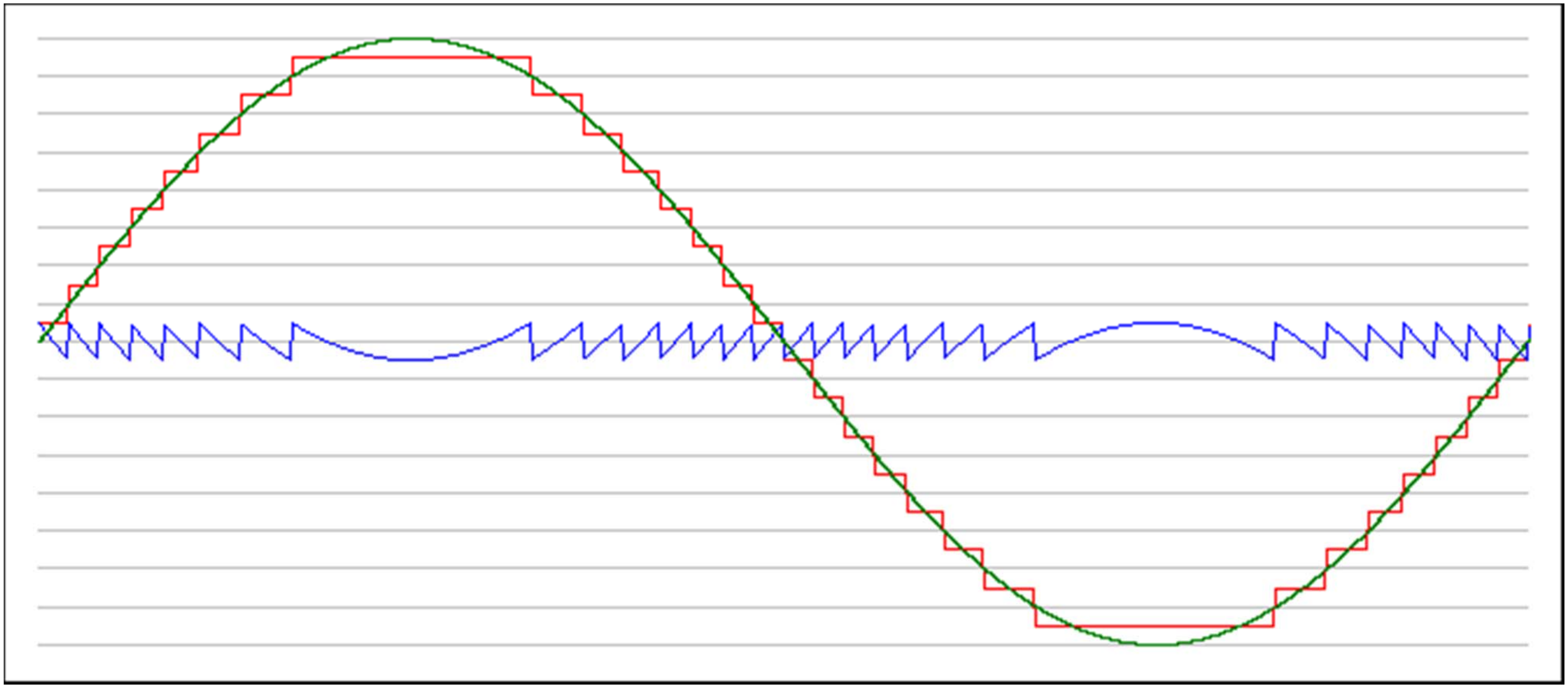
msp430x20x3_sd16A_02.c

```
#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
}
```

msp430x20x3_sd16A_02.c

```
#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