



Data Collection

Fall 2010

Number systems review

- ◆ Decimal
- ◆ Binary
- ◆ BCD (Binary Coded Decimal)
- ◆ Hex
- ◆ Octal

Getting data and what it means

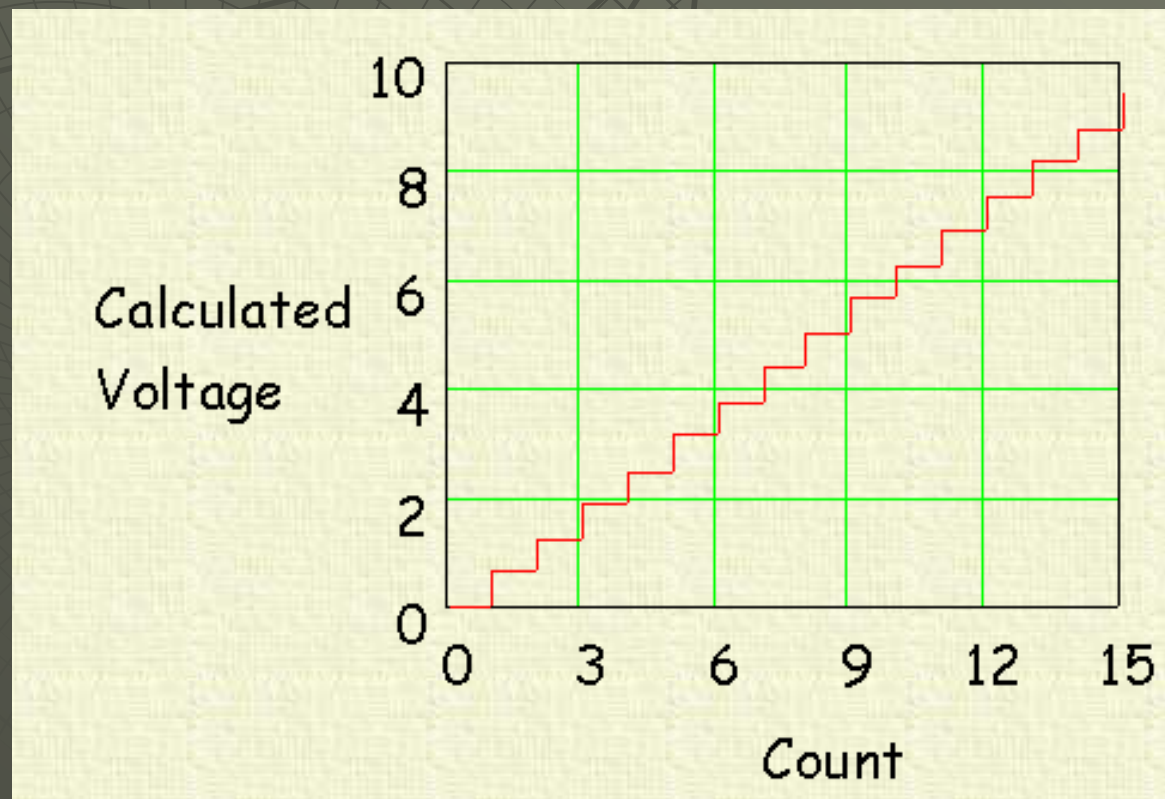
- ◆ The computer needs hardware to get data in.
- ◆ Analog data:
 - Analog to digital converter (A/D)
 - Converts analog data to binary.
 - Computer doesn't know what it means!

Analog to Digital Converter (A/D)

- ◆ Converts analog voltage into a digital representation.
- ◆ Bit resolution is # digital bits of the converter
- ◆ Bit “range” is the number of bit changes $(2^n - 1)$

A/D conversion

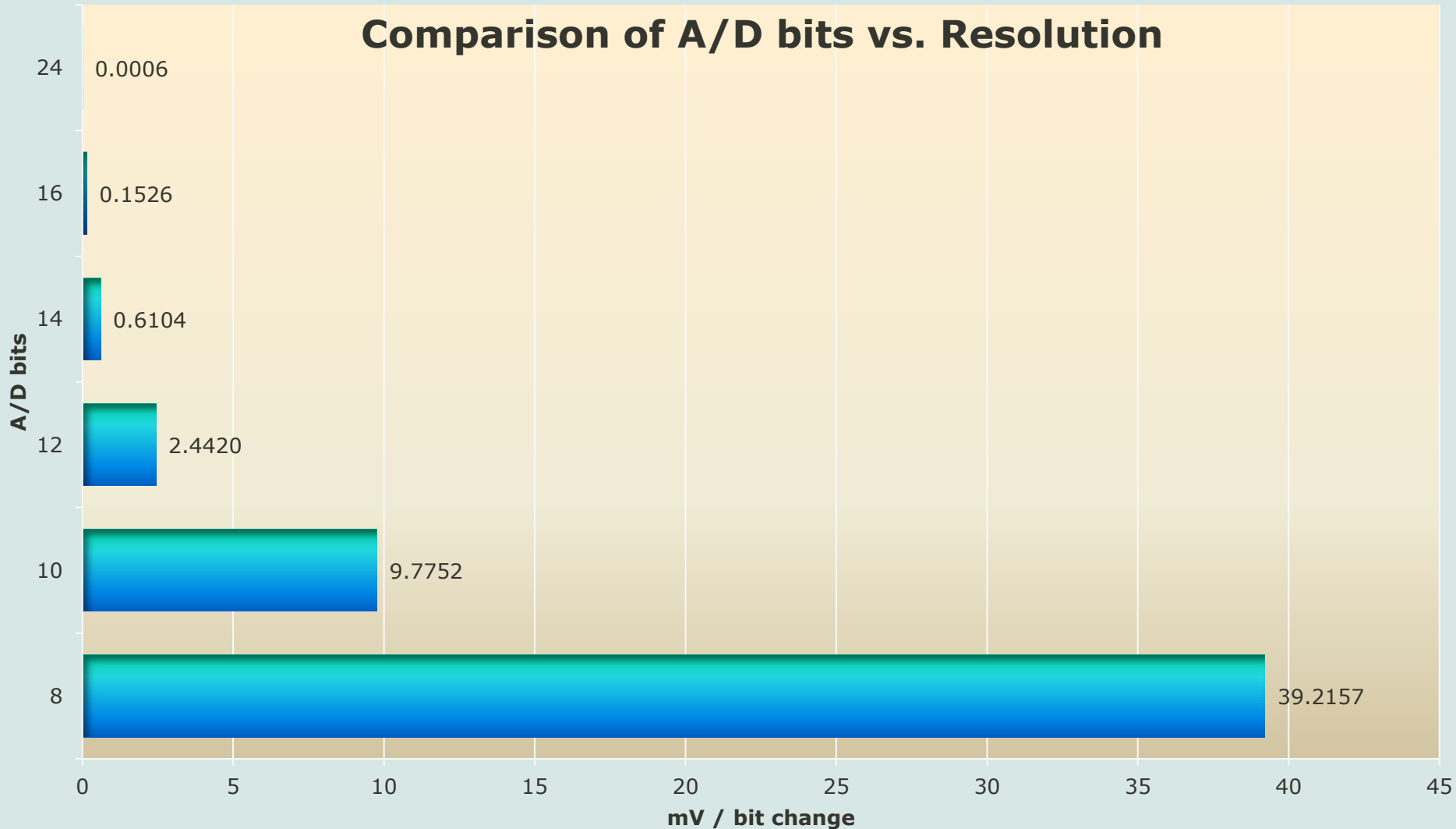
- ◆ Each bit change of the binary number represents a "value" of voltage



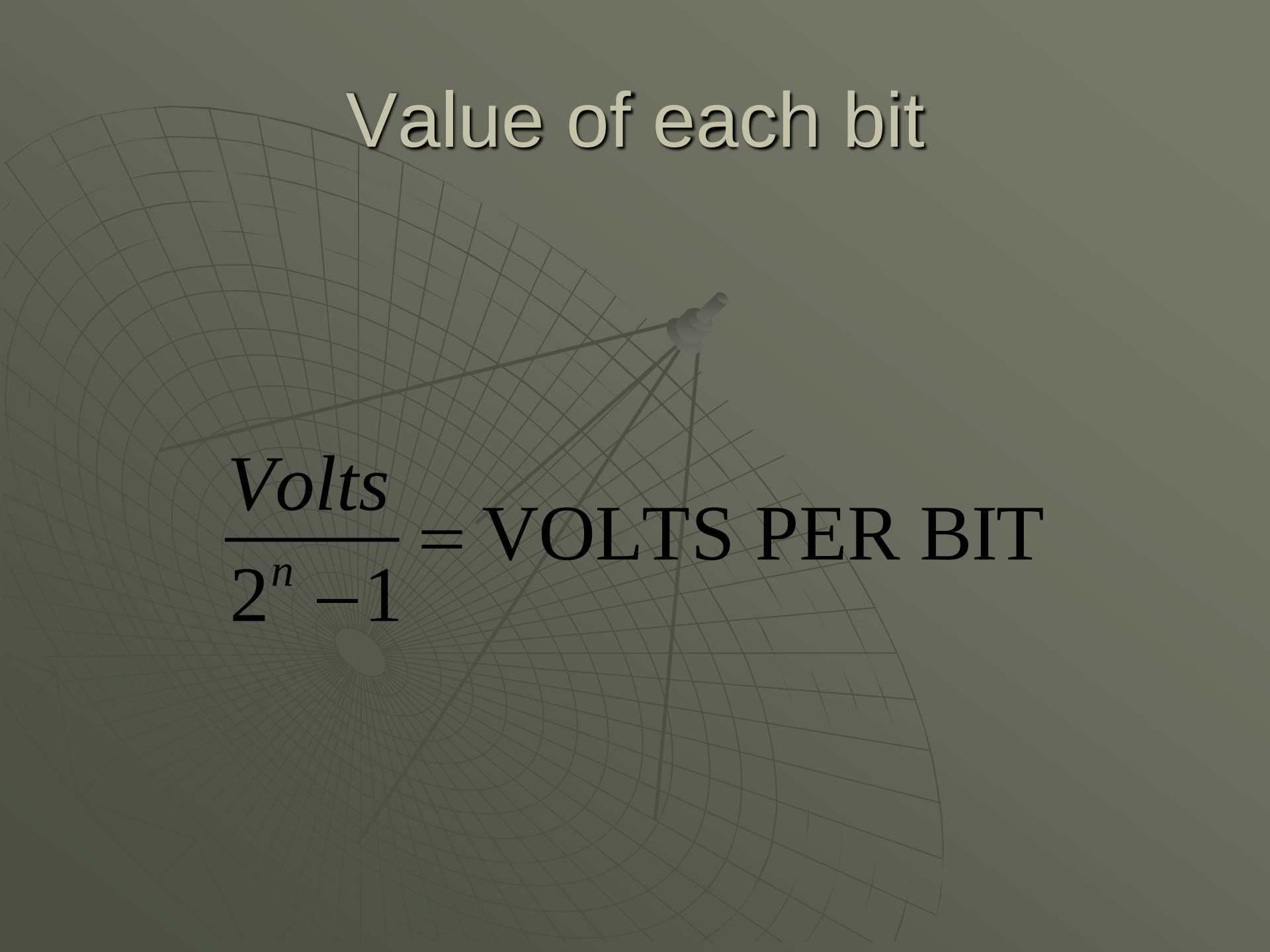
Compare bit depth

Min volts					0															
4 bit					Max volts	10		3 bit				2 Bit								
3 2 1 0					V/bit	0.667		2 1 0				1.429		1 0		3.333		bits	mV/bit	
0	0	0	0	0	0			0	0	0	0			0	0	0	0	8	39.215686	
1	0	0	0	1	0.667			1	0	0	1	1.429			1	0	1	3.333	10	9.775171
2	0	0	1	0	1.333			2	0	1	0	2.857			2	1	0	6.667	12	2.442002
3	0	0	1	1	2.000			3	0	1	1	4.286			3	1	1	10.000	14	0.610389
4	0	1	0	0	2.667			4	1	0	0	5.714							16	0.152590
5	0	1	0	1	3.333			5	1	0	1	7.143							24	0.000596
6	0	1	1	0	4.000			6	1	1	0	8.571								
7	0	1	1	1	4.667			7	1	1	1	10.000								
8	1	0	0	0	5.333															
9	1	0	0	1	6.000															
10	1	0	1	0	6.667															
11	1	0	1	1	7.333															
12	1	1	0	0	8.000															
13	1	1	0	1	8.667															
14	1	1	1	0	9.333															
15	1	1	1	1	10.000															

0 – 10 Volt converter



Value of each bit


$$\frac{\text{Volts}}{2^n - 1} = \text{VOLTS PER BIT}$$

Examples

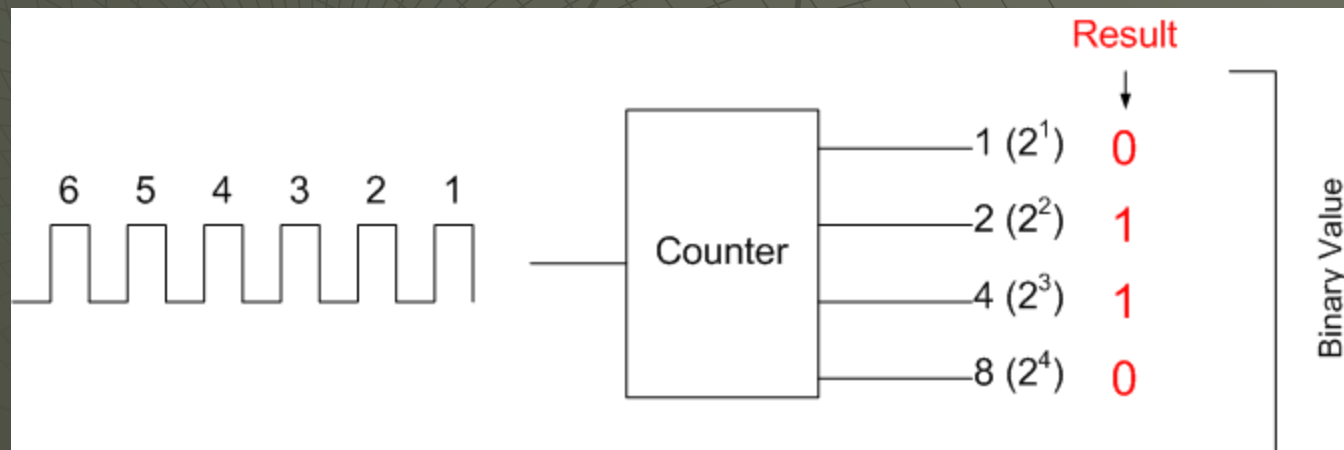
- ◆ **10 bit converter (0-10V)**
 - 1023 steps
 - 10 volt span
 - 9.775 mV per step
- ◆ **12 bit converter (+/- 10V)**
 - 4095 steps
 - 20 Volts span
 - 4.884 mV per step

Digital Devices

- ◆ Counter / Timer
 - Converts time or events to digital number
- ◆ Digital to analog converter
 - Converts digital number to a voltage
- ◆ Analog to digital converter
 - Converts a voltage to a digital number

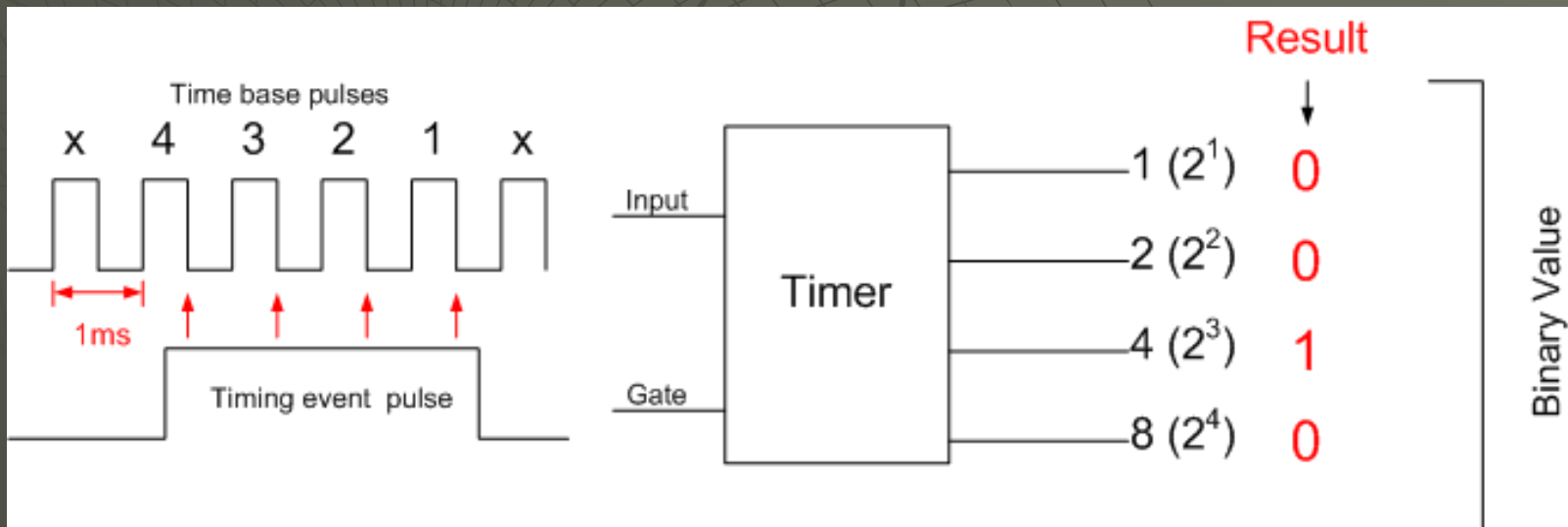
Digital Counter

- Counter is a device that outputs a binary value based on the number of pulses that have come in



Timer

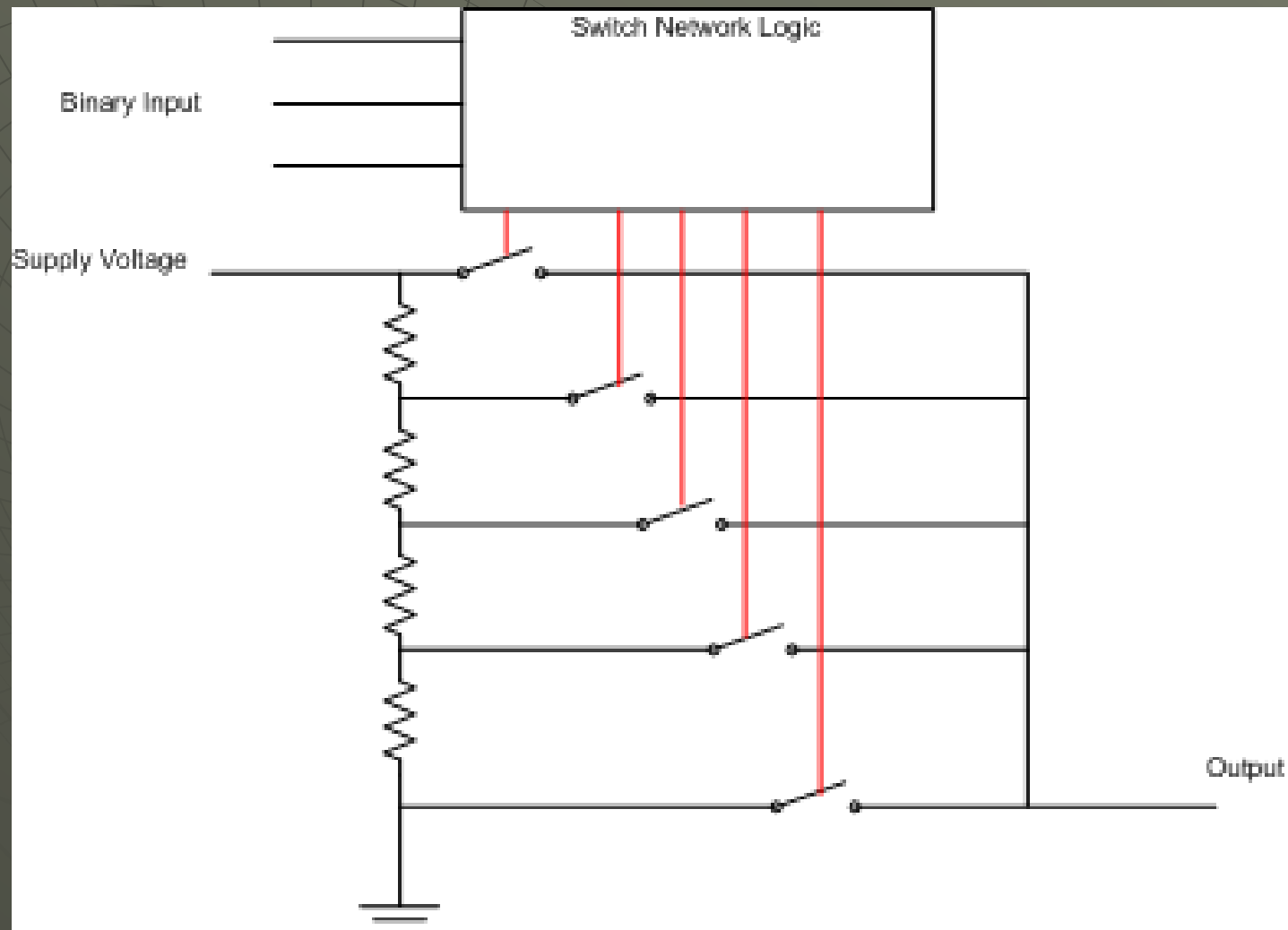
- ◆ Special purpose counter
- ◆ Counts time ticks per event
- ◆ Doesn't know what the time is, just that the ticks came by! Up to you to associate how much time each tick represents!



Digital to Analog (D/A)

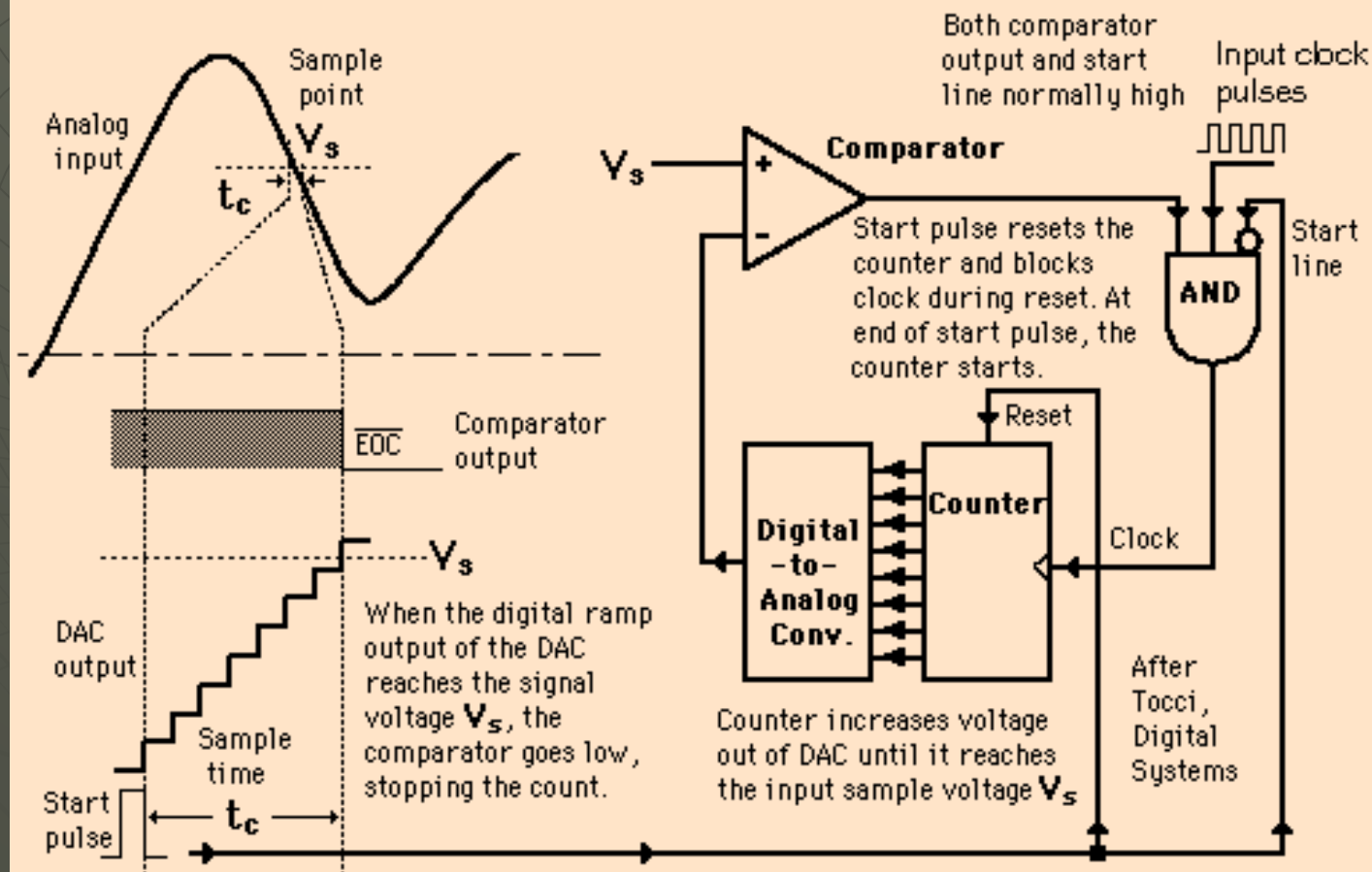
- ◆ Converts a binary number into an analog voltage
- ◆ Precision voltage divider with each bit “switching” resistors in or out.

Simplified D/A converter



A/D converter

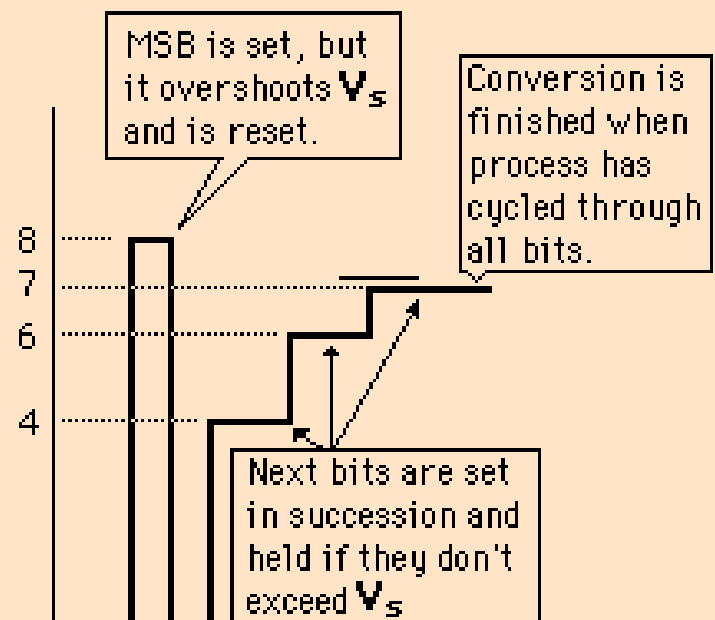
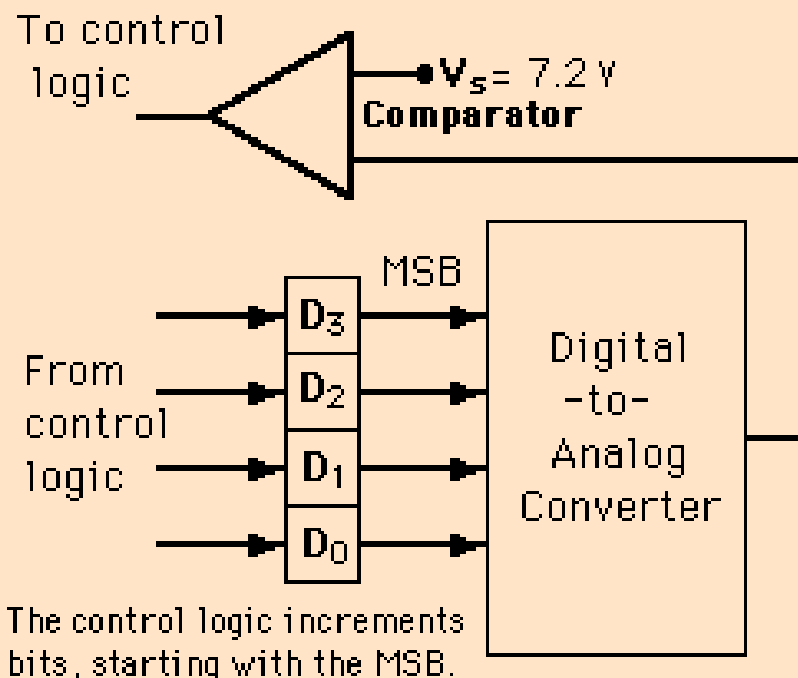
Digital Ramp ADC



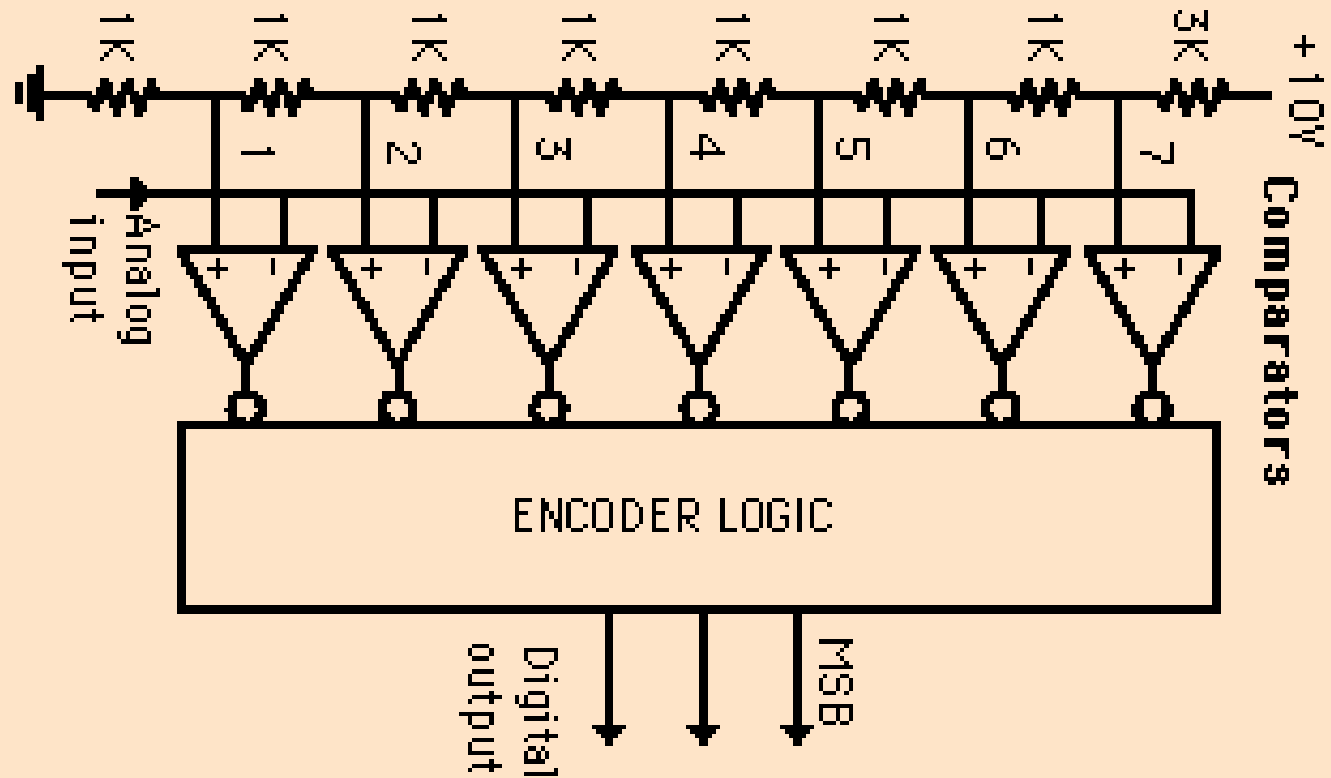
A/D converter

Successive Approximation ADC

Illustration of 4-bit SAC with 1 volt step size (after [Tocci, Digital Systems](#)).



Flash A/D converter





Speed. How fast is fast, and
why do we care?

Signal aliasing !!

Signal Aliasing

- ◆ When the representation of the signal does not match the real signal
- ◆ Generally caused by “undersampling” or when the sample clock is not sufficiently fast to generate an adequate number of samples per cycle.
- ◆ rule of thumb is 10 samples per cycle minimum.

Bi-directional voltage inputs

- ◆ Not all systems start at 0 volts input
- ◆ ± 10 , ± 5 are typical input values
- ◆ This creates a need for negative numbers.
- ◆ Reduces the resolution of positive voltage in half
- ◆ Most common methods are
 - Offset binary
 - Signed integers
 - 2's complement

Signed integers

- ◆ Drop the most significant figure to create a sign
- ◆ 8 bit `s0000000` maximum range is ± 128 instead

Offset binary

- ◆ -min is defined as 0
- ◆ 8 bit converter
- ◆ $256 = 10$
- ◆ $0 = -10$
- ◆ $128 =$ approximately zero
- ◆ **Possible to not have any binary representation of 0**

2's complement

- ◆ Positive numbers range from 0 to 127
- ◆ Negative numbers range from 255 to 128
- ◆ To make a number into 2's complement
 - 1) Invert the number (all 1's to 0's)
 - 2) Add 1 to the result

2's complement

Integer		2's Complement
Signed	Unsigned	
5	5	0000 0101
4	4	0000 0100
3	3	0000 0011
2	2	0000 0010
1	1	0000 0001
0	0	0000 0000
-1	255	1111 1111
-2	254	1111 1110
-3	253	1111 1101
-4	252	1111 1100
-5	251	1111 1011

Compare offset methods

					Min volts		-10																			
Offset Bin					Max volts		10		Signed Int							2's compliment										
3 2 1 0					V/bit		1.333		3 2 1 0					V/bit		1.429		3 2 1 0					V/bit		1.429	
0	0	0	0	0	-10			-7	1	1	1	1	-10.000			249	-7	1	0	0	1	-10.000				
1	0	0	0	1	-8.667			-6	1	1	1	0	-8.571			250	-6	1	0	1	0	-8.571				
2	0	0	1	0	-7.333			-5	1	1	0	1	-7.143			251	-5	1	0	1	1	-7.143				
3	0	0	1	1	-6.000			-4	1	1	0	0	-5.714			252	-4	1	1	0	0	-5.714				
4	0	1	0	0	-4.667			-3	1	0	1	1	-4.286			253	-3	1	1	0	1	-4.286				
5	0	1	0	1	-3.333			-2	1	0	1	0	-2.857			254	-2	1	1	1	0	-2.857				
6	0	1	1	0	-2.000			-1	1	0	0	1	-1.429			255	-1	1	1	1	1	-1.429				
7	0	1	1	1	-0.667			0	0	0	0	0	0.000			0	0	0	0	0	0	0.000				
8	1	0	0	0	0.667			1	0	0	0	1	1.429			1	1	0	0	0	1	1.429				
9	1	0	0	1	2.000			2	0	0	1	0	2.857			2	2	0	0	1	0	2.857				
10	1	0	1	0	3.333			3	0	0	1	1	4.286			3	3	0	0	1	1	4.286				
11	1	0	1	1	4.667			4	0	1	0	0	5.714			4	4	0	1	0	0	5.714				
12	1	1	0	0	6.000			5	0	1	0	1	7.143			5	5	0	1	0	1	7.143				
13	1	1	0	1	7.333			6	0	1	1	0	8.571			6	6	0	1	1	0	8.571				
14	1	1	1	0	8.667			7	0	1	1	1	10.000			7	7	0	1	1	1	10.000				
15	1	1	1	1	10.000																					

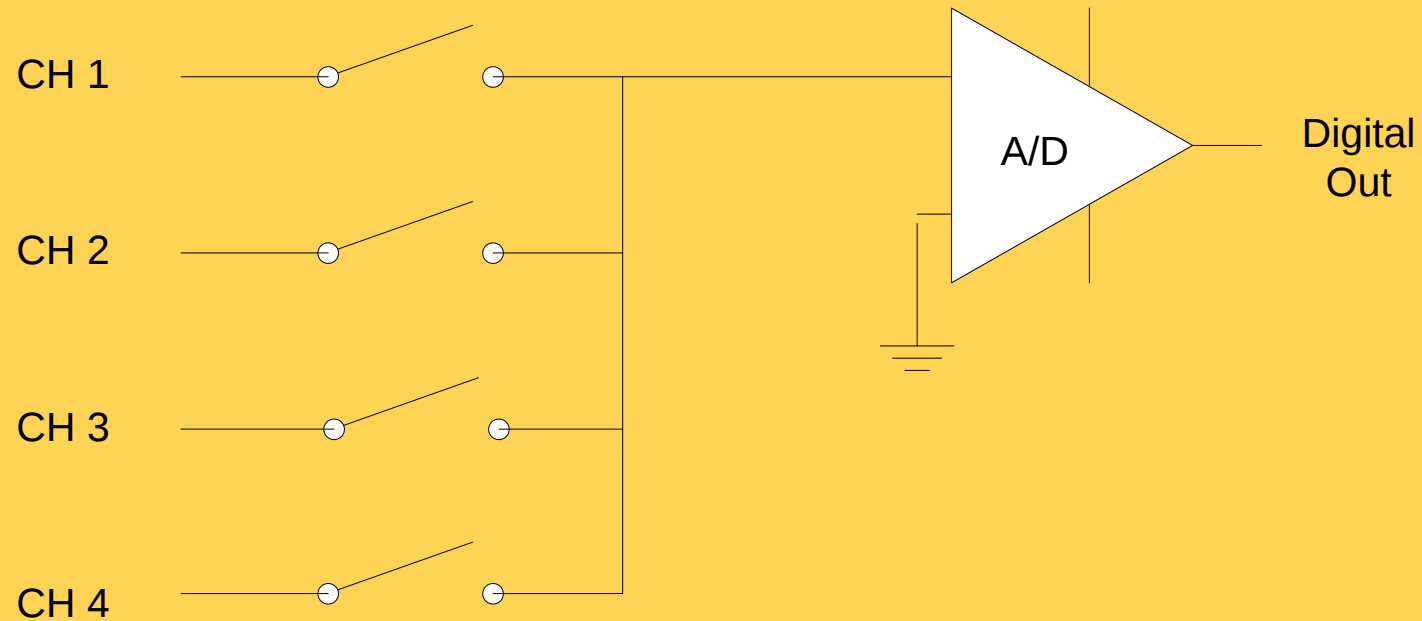
Physical connections

- ◆ Physical connections are how you actually attach the device to your daq card.
- ◆ Must pay attention to common grounds in your system to prevent ground loops

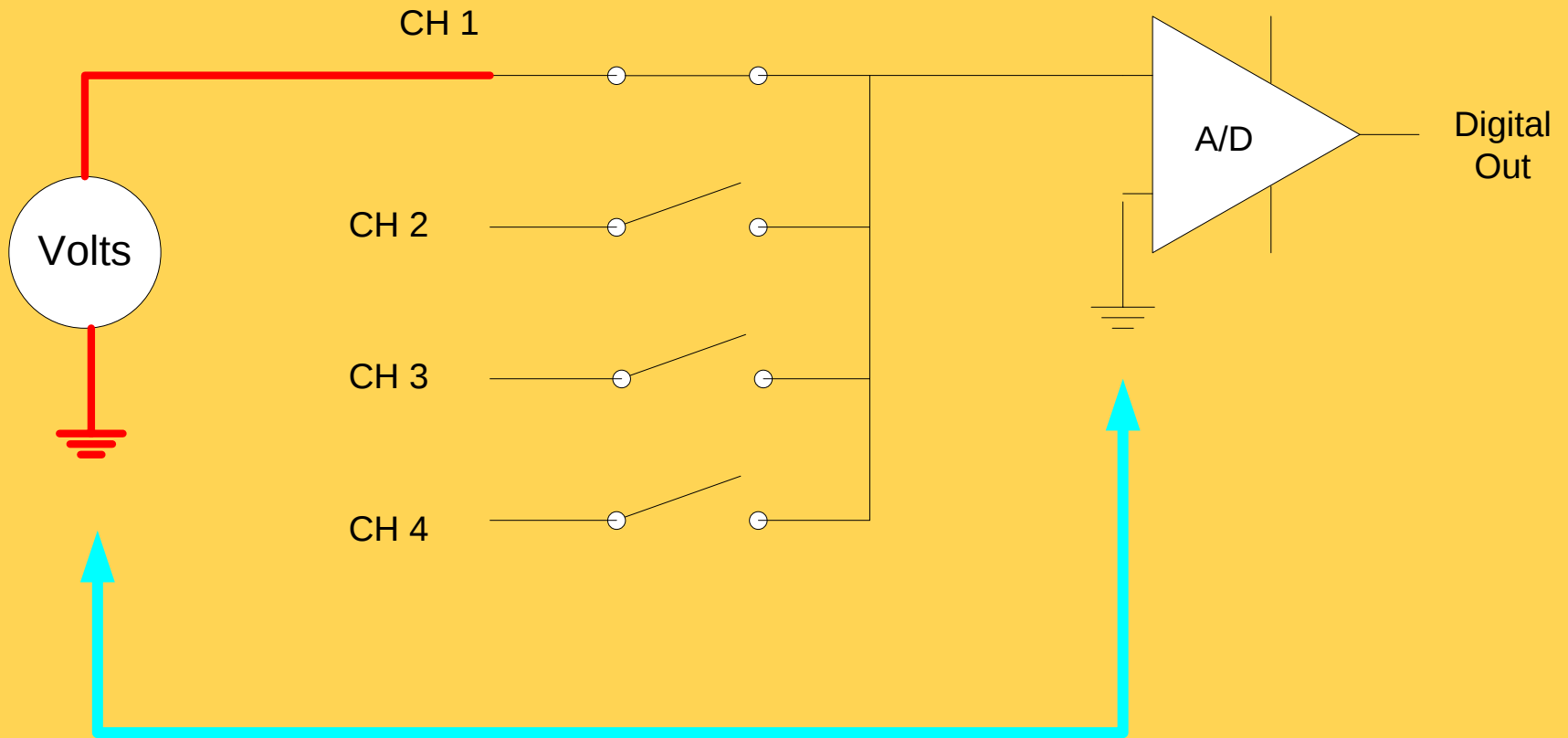
Ground loop

- ◆ A ground loop is an unintended current path through the common ground system.
- ◆ Can introduce noise
- ◆ Can distort or change calibration of readings

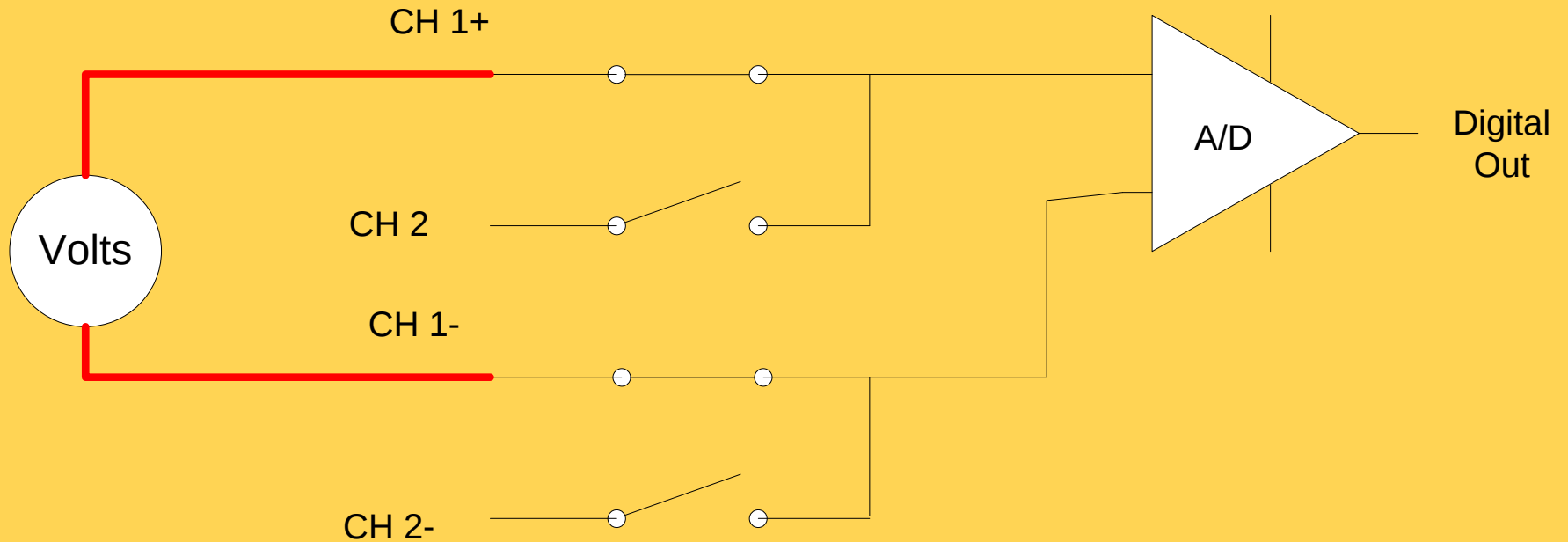
Multiple channels



Single ended



Differential Input

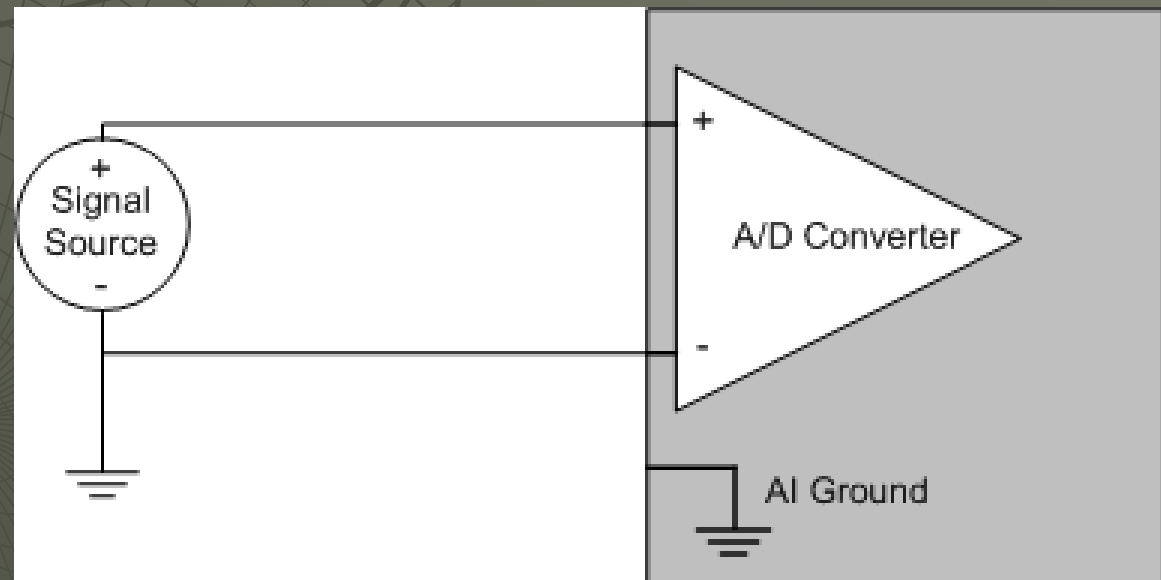


Why differential?

- ◆ Reduces noise
 - Noise is generated equally in both lines
 - The converter only measures the difference between the two lines
 - Known as **Common Mode Rejection**

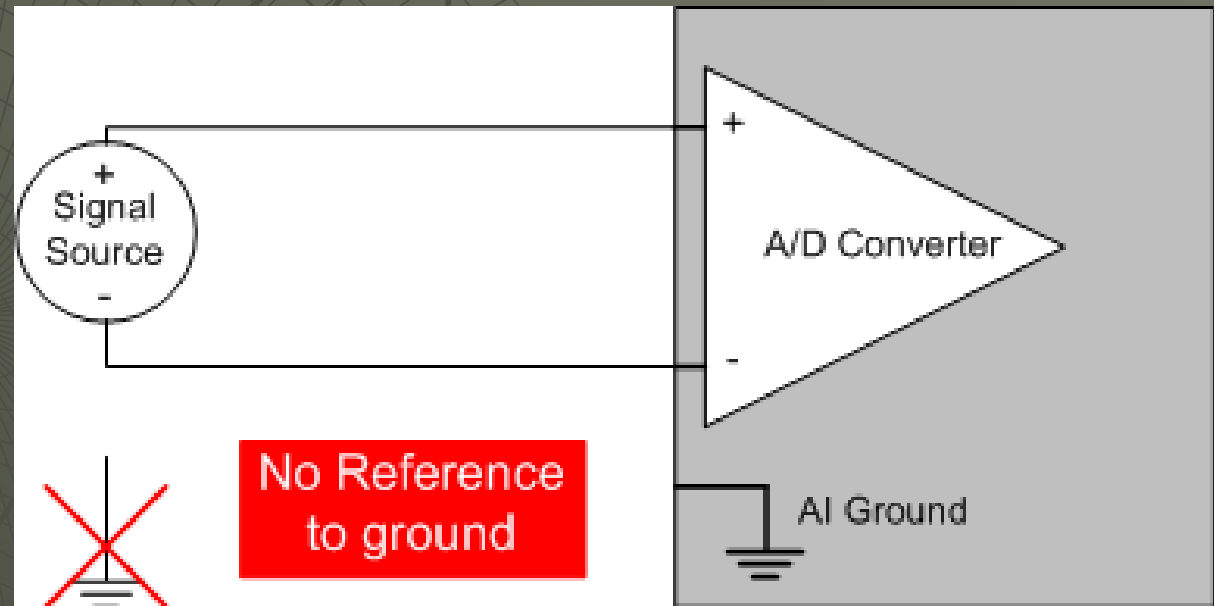
Ground referenced signal

- ◆ Signal source has a path to ground



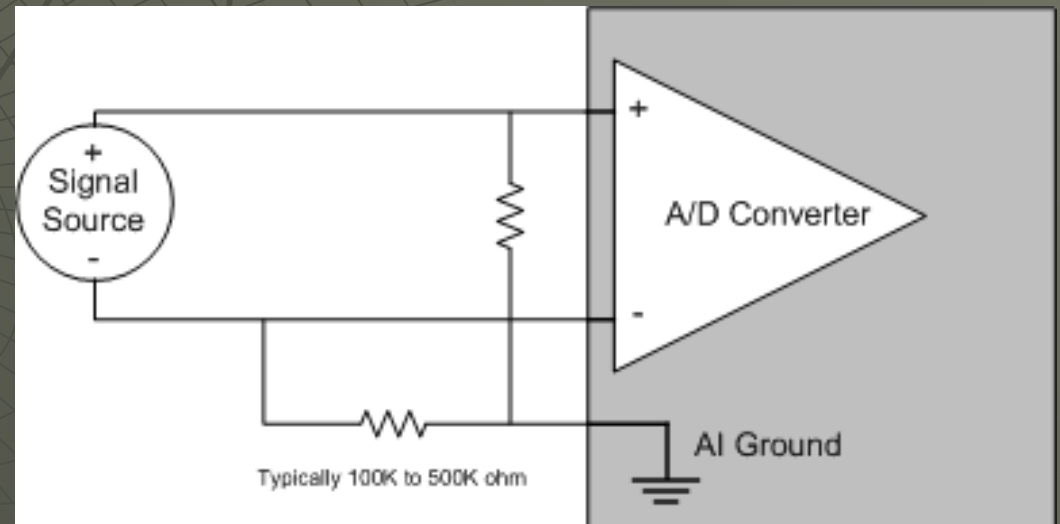
Floating Source

- While the voltage from line to line may be within spec, what is the voltage from either line to ground?



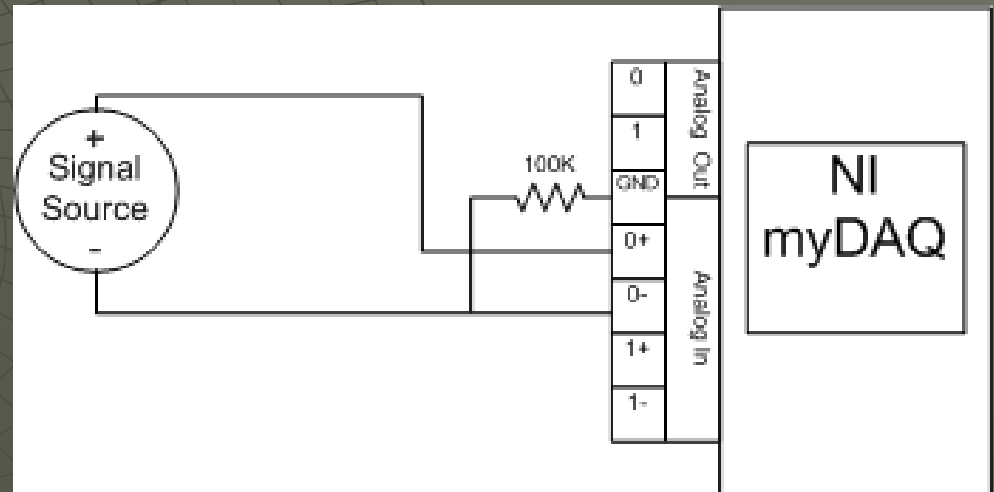
Add Bleed resistors

- ◆ Bleed resistors dissipate excess current to ground to create a reference.



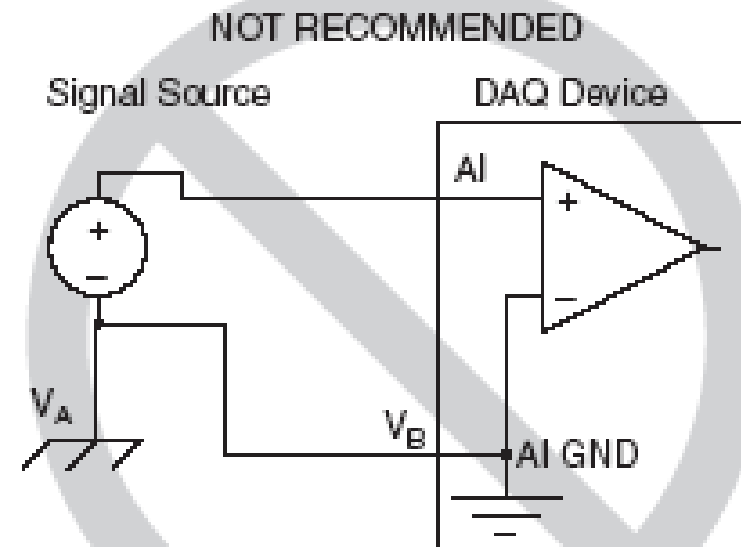
myDAQ

- ◆ Floating or grounded sources cause a ground loop through the USB connection. Add a resistor to the – input to solve this.



Single Ended

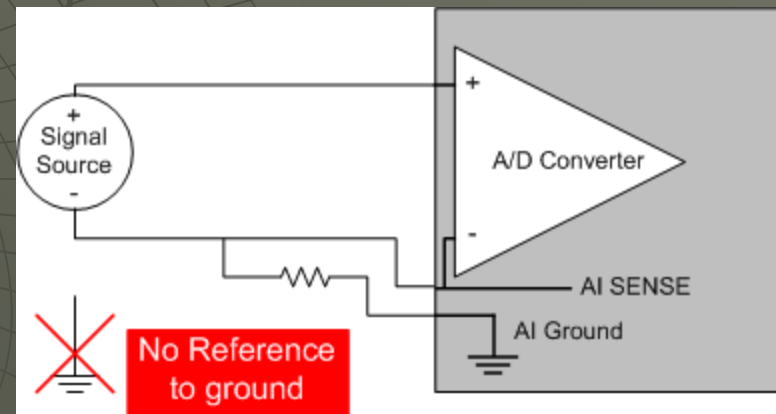
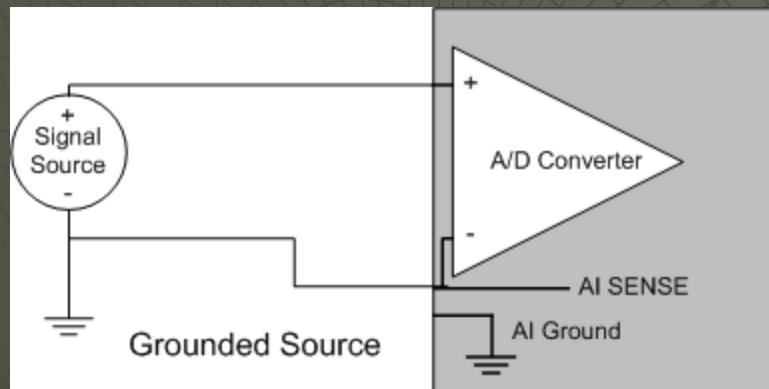
- ◆ This caused a lot of problems with early daq systems
- ◆ A lot of “inexpensive” systems still use this method.



Ground-loop potential ($V_A - V_B$) are added to measured signal.

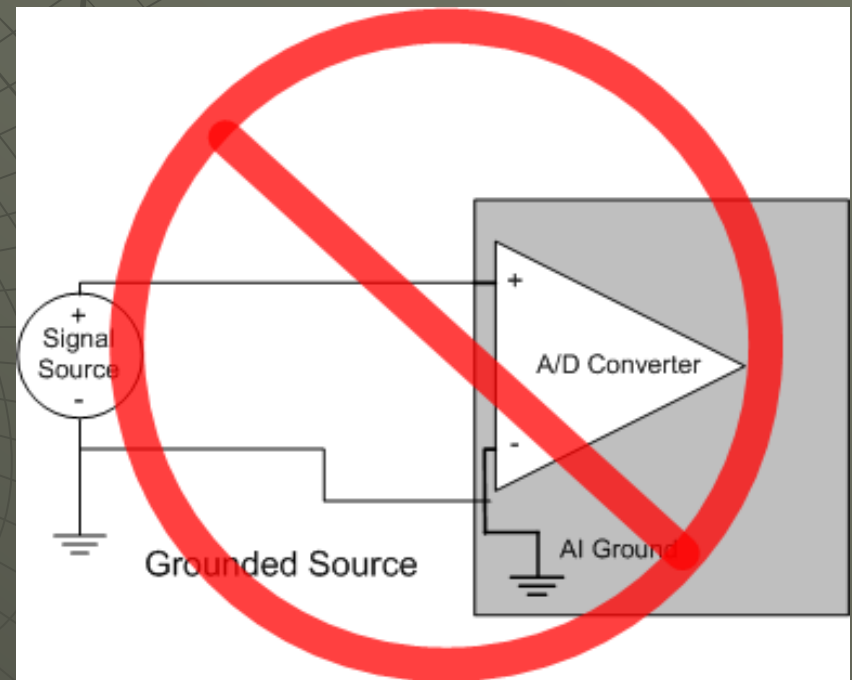
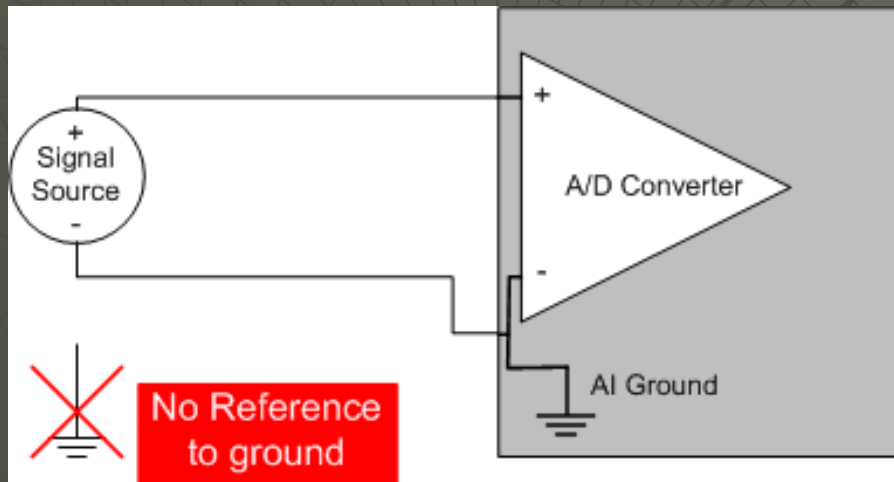
Non-Referenced Single Ended (NRSE)

- ◆ Some boards provide an AISENSE Line. This line is attached to the single ended “low” signal internally.



Referenced Single Ended (RSE)

- ◆ Low input connected internally directly to AI ground!



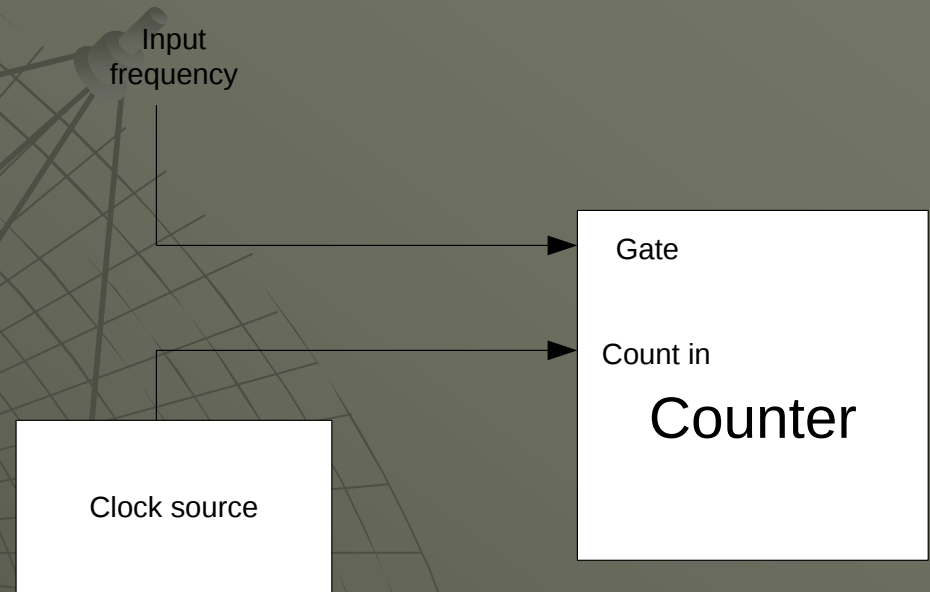
Timers and counters

- ◆ Most daq boards have timers and counters
 - Counters count the number of “events” that it sees on the input.
 - One event is the digital input changing from low to high
 - A timer is just a counter with a time clock on its input!

Timers

◆ Example

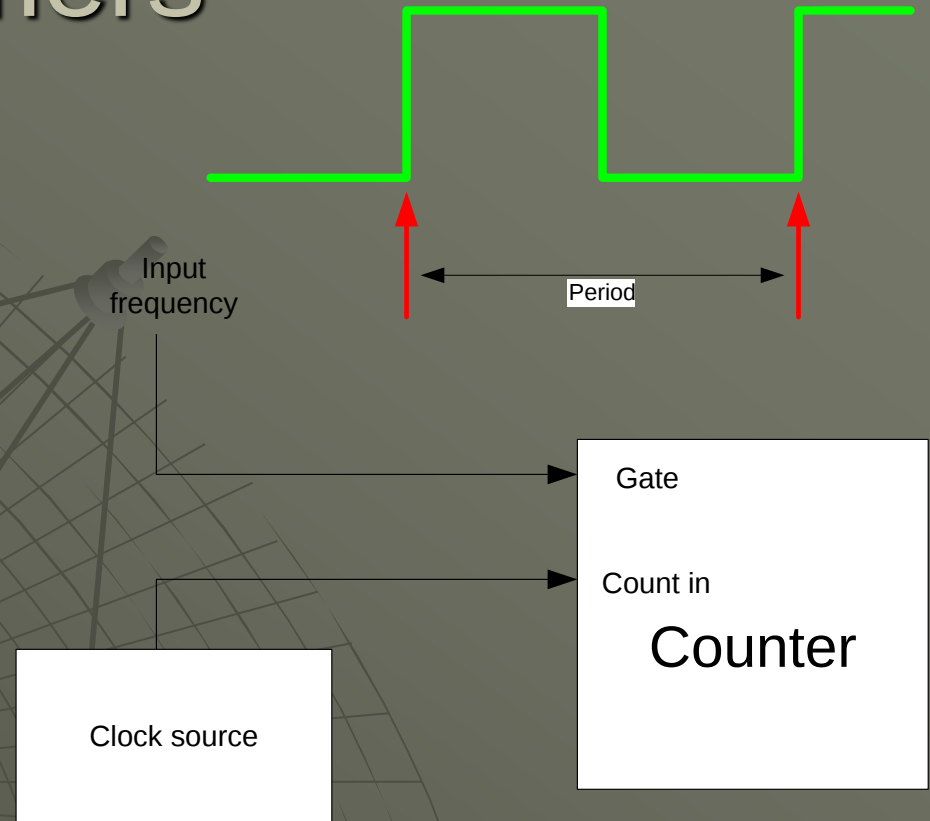
- 8 bit counter
- 1Khz clock source
- Each bit represents 1 ms
- Total time it can measure is 256 ms



Timers

◆ Example

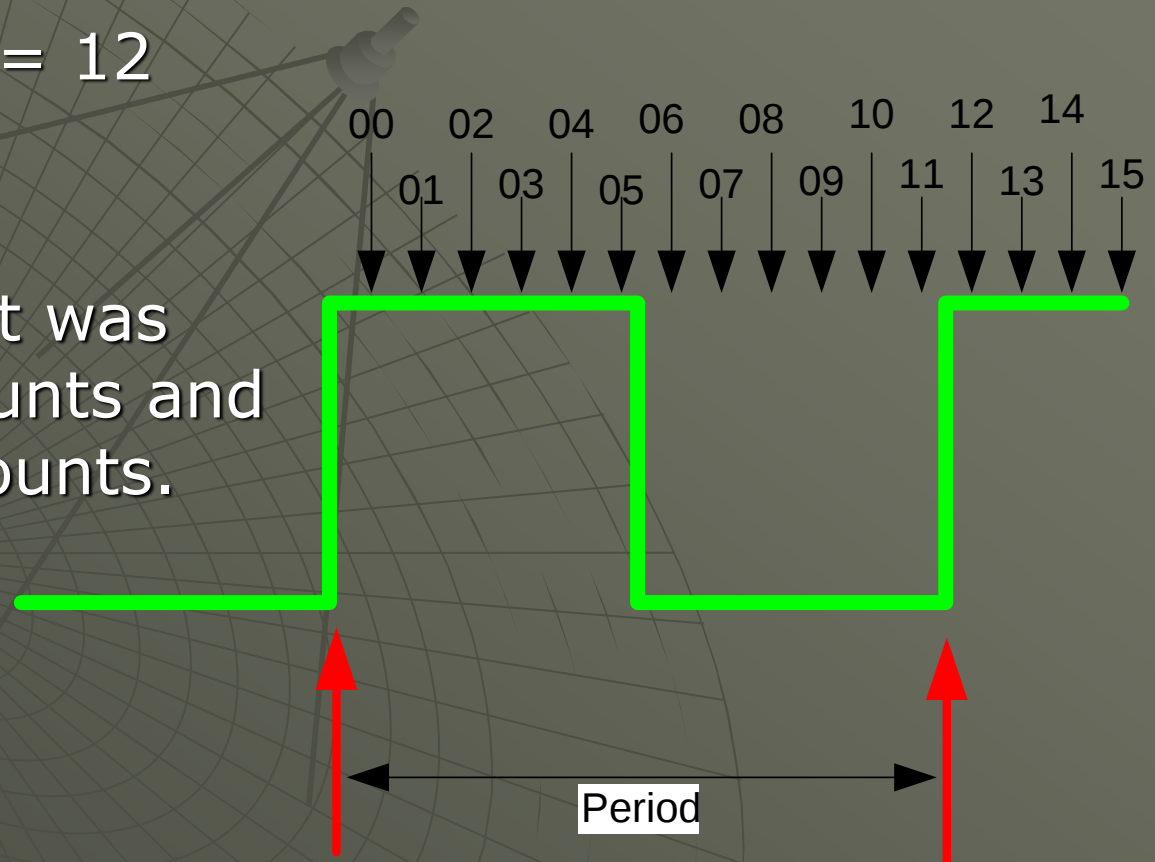
- Input signal measures the time from start of pulse to start of next pulse



Timers

◆ Example

- Total period = 12 counts
- This means it was low at 11 counts and high at 12 counts.

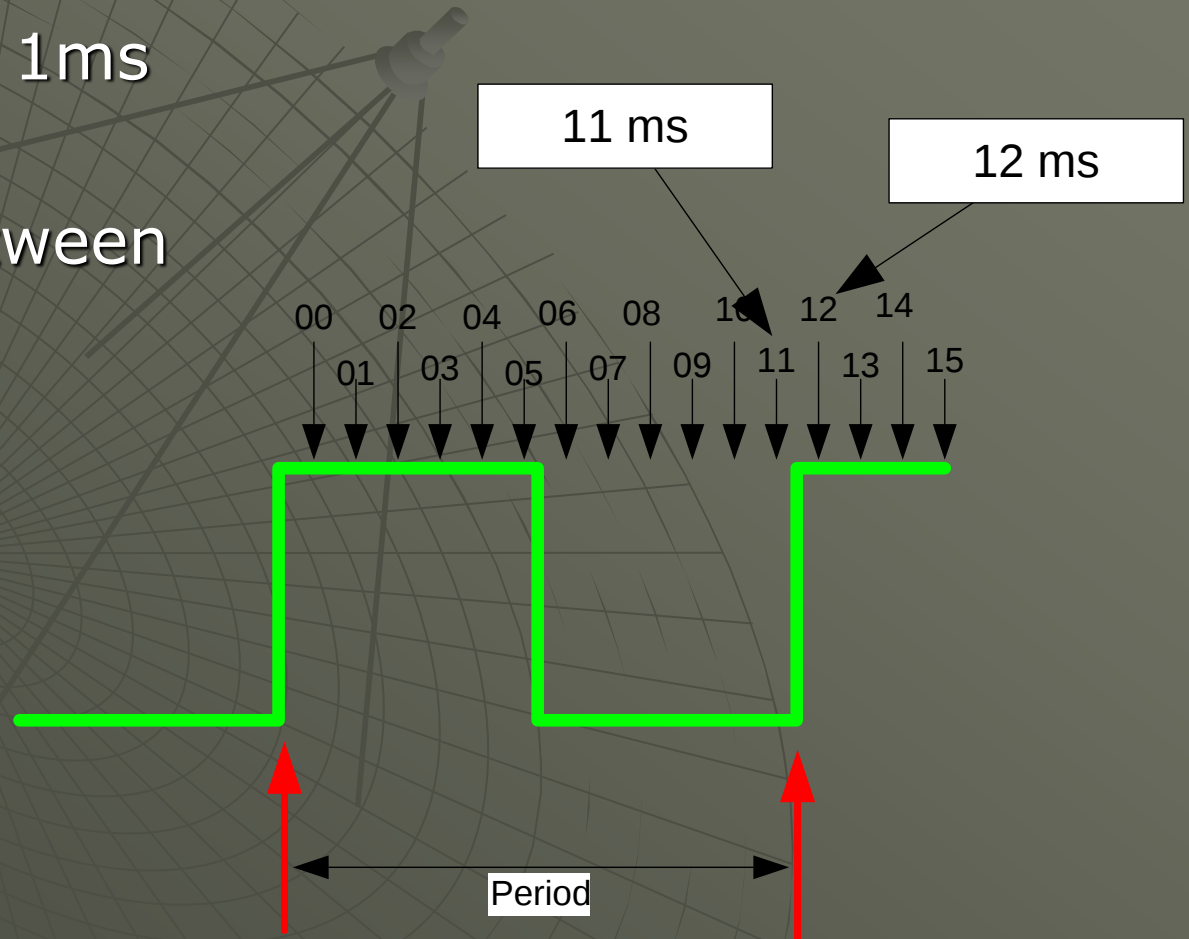


Timers

- ◆ Example

- Variance = 1ms

- Answer between 90 Hz and 83.3 Hz



How do we make this more accurate?

- ◆ WE NEED MORE BITS SCOTTY!!!



More bits = more resolution

- ◆ 8 bit maximum 250ms period
 - 1 KHz clock
 - 1ms / bit
- ◆ 16 bit maximum 250ms period
 - 256 KHz clock
 - 3.906 μ s /bit (.003906 ms)
 - 256 times more accurate!

Measuring signals

- ◆ We covered
 - Voltage
 - Time
- ◆ Lets look at Current:
 - Simple resistor and measure the voltage.

Resistance bridges



Thermocouples

- ◆ High resolution required
 - $< 1\text{mV}$ resolution
 - ◆ High bit count A/D converter
 - ◆ or high gain amplifiers before A/D
- ◆ Cold Junction Compensation
 - Assume that terminal block is isothermal
 - Measure the temperature of block to compensate for junction of TC wire to terminal block
 - ◆ Most common method is AD590