

MICROPROCESSORS A (17.383)

Fall 2010

Lecture Outline

Class # 06

October 19, 2010

Dohn Bowden

Today's Lecture

- Syllabus review
- Microcontroller Hardware and/or Interface
- Programming/Software
- Lab
- Homework
- Start Lab #3 - Seven Segment LEDs

Course Admin

Administrative

- Admin for tonight ...
 - Syllabus Highlights
 - Lab report for Lab # 2 is due TONIGHT
 - Pass back Exam #1

Syllabus Review

<i>Week</i>	<i>Date</i>	<i>Topics</i>	<i>Lab</i>	<i>Lab Report Due</i>
1	09/07/10	Intro, Course & Lab Overview, Microcontroller Basics	1	
2	09/14/10	PIC16F684 Overview and General Input/Output	1 con't	
3	09/21/10	Switches	2	
4	09/28/10	Seven Segment LEDs	2 con't	1
5	10/05/10	Examination 1		
X	10/12/10	No Class - Monday Schedule		
6	10/19/10	Analog to Digital Conversion	3	2
7	10/26/10	Analog to Digital Conversion con't	3 con't	
8	11/02/10	LCD Interface and Assembly Language	4	
9	11/09/10	Comparators	4 con't	3
10	11/16/10	Timers and Pulse Width Modulation (PWM)	5	
11	11/23/10	Mixed C & Assembly Programming/Course Project	Project	4
12	11/30/10	Examination 2		
13	12/07/10	Course Project	Project	5
14	12/14/10	Final Exam/Course Project Brief and Demonstration	Demo	

Pass back Exam #1 ...

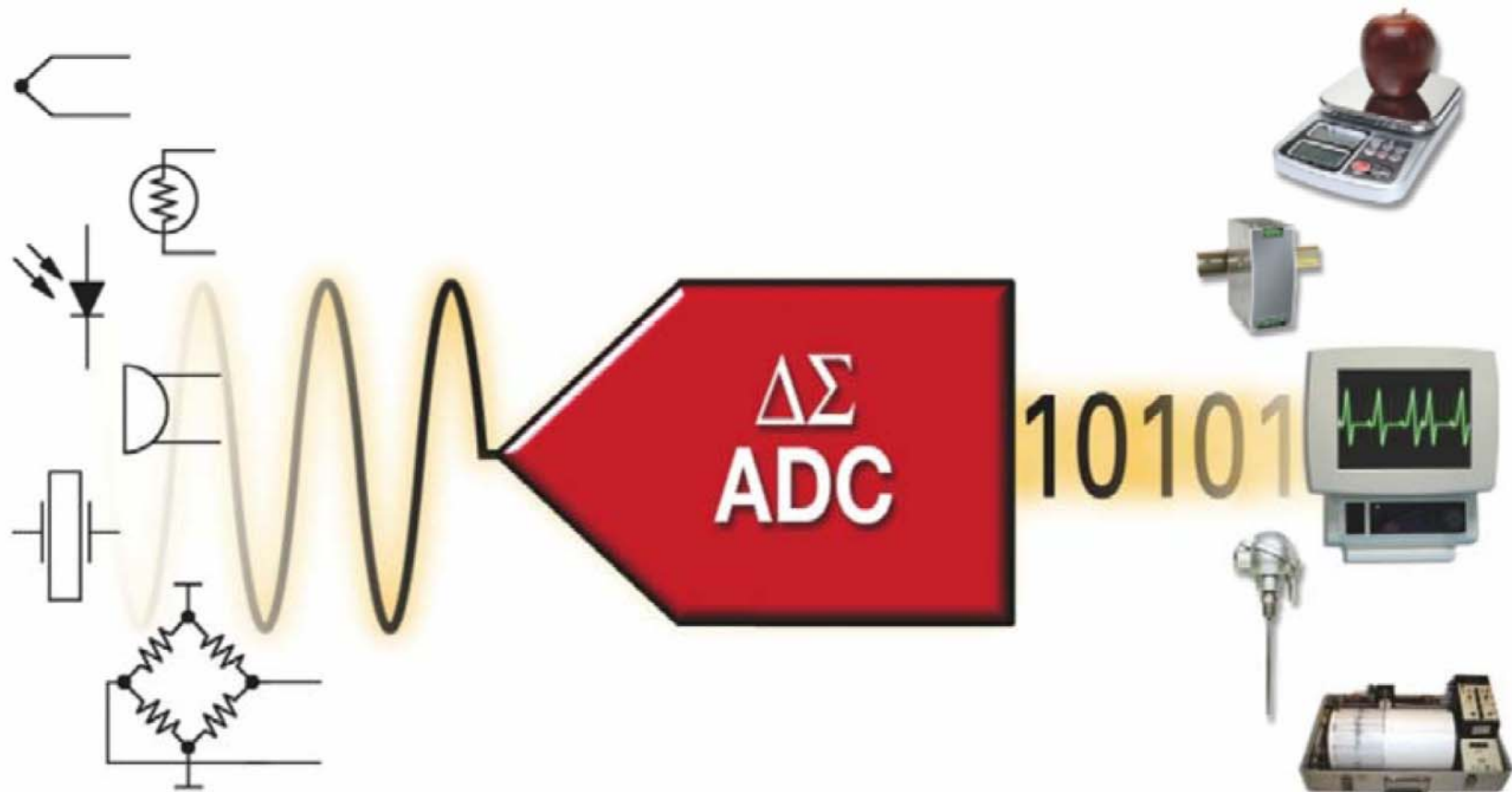
Microcontroller

Hardware

and / or

Interfaces

Analog To Digital Conversion Overview



PIC16F684 Hardware

- Thus far we have been discussing the digital input/output features of the PIC16F684
- We will now turn our attention to the analog features
 - Analog to Digital Conversion (ADC or A/D conversion)
 - Comparators (to be discussed during a future lecture)

Analog Signals

- Real world signals are analog
 - For example ... sensors
- We need to be able to take these signals and convert them to digital in order to be able to process them using the microcontroller
- The PIC16F684 is capable of performing the required conversion with it's built in analog to digital converter

Fundamentals

- Before we get into the specifics of the PIC16F684 A/D converter lets focus on the fundamentals of A/D conversions
- What is an *analog* signal?
 - An *analog* signal is **continuous** in amplitude & time within certain limits, i.e., it changes smoothly without interruptions
 - An example ...
 - a sinusoidal signal

Fundamentals

- What is a *digital* signal?
 - A *digital* signal is **discrete** in amplitude and time ...
 - i.e., it can only take certain specific values within certain limits at specific time intervals
 - When numbers are assigned to these steps (usually binary numbers) the result is a digital signal
 - An example ... a square wave is a 1-Bit digital signal with its high level being a binary '1' and its low level being a binary '0'

Analog to Digital Converter

- What is an *Analog-to-Digital converter*?
 - An *Analog-to-Digital converter* (ADC) is an electronic circuit that changes or converts a continuous analog signal into a digital signal without altering its critical content

Analog to Digital Converter

- How does an *Analog-to-Digital converter* work?
 - In the simplest terms ... an *Analog-to-Digital converter* ...
 - *Samples* an analog waveform at uniform time intervals ...
 - and ...
 - Assigns a digital value to each sample, which is called *Quantization*

The ADC Process

- Therefore, an *Analog-to-Digital Converter* carries out two processes ...

- *Sampling*

and ...

- *Quantization*

Sampling

- *Sampling* is ...
 - The reduction of a continuous signal to a discrete signal
 - Specifically ... *Sampling* is the process of analyzing the continuous analog signal with measurements taken at discrete and standard intervals
 - An example ... the conversion of a sound wave (a continuous-time signal) to a sequence of samples (a discrete-time signal)

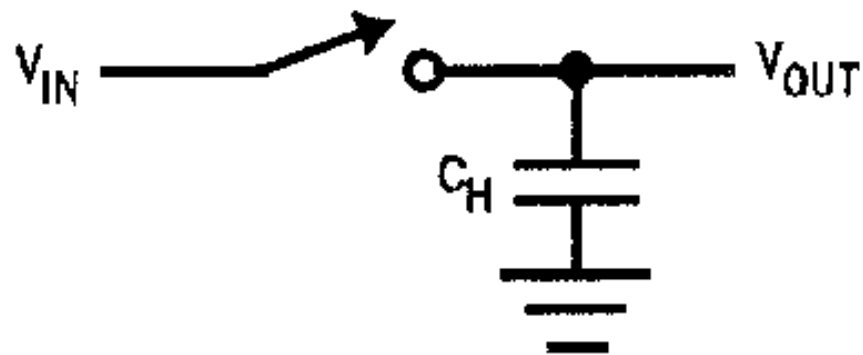
Hold

- In conjunction with sampling ... the device needs to be able to “*hold*” the signal for a finite amount of time ... why? ...
 - During the “*hold*” time ... the ADC will perform its function of converting the signal from analog to digital

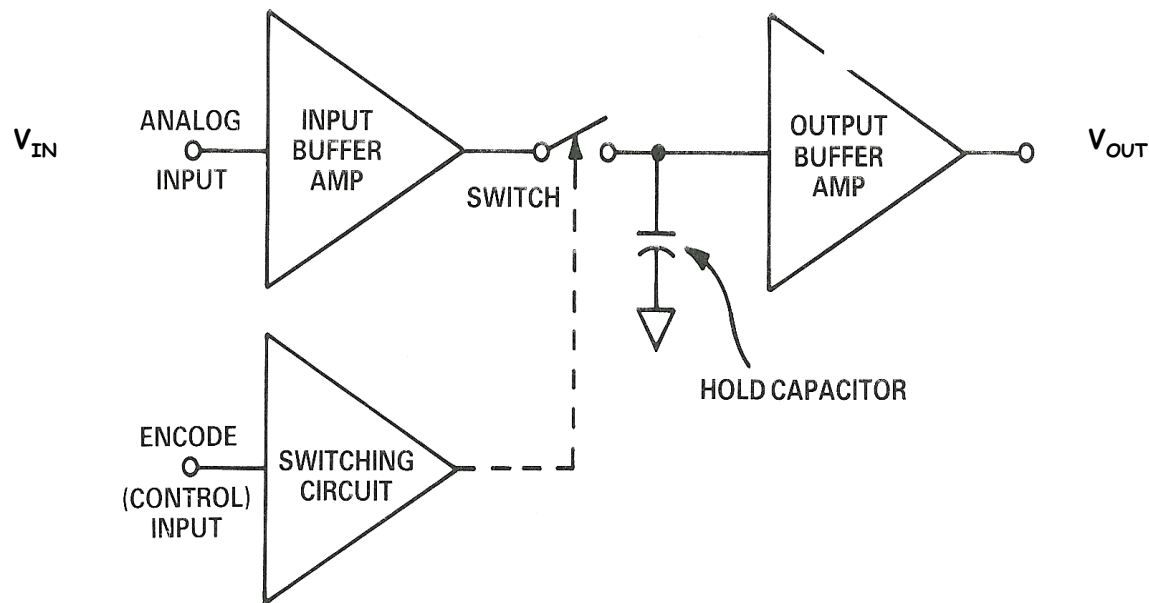
Hold

- The “*hold*” is performed via a storage capacitor
- Up to the time the “*hold*” is commanded ... the capacitor is tracking/sampling the signal

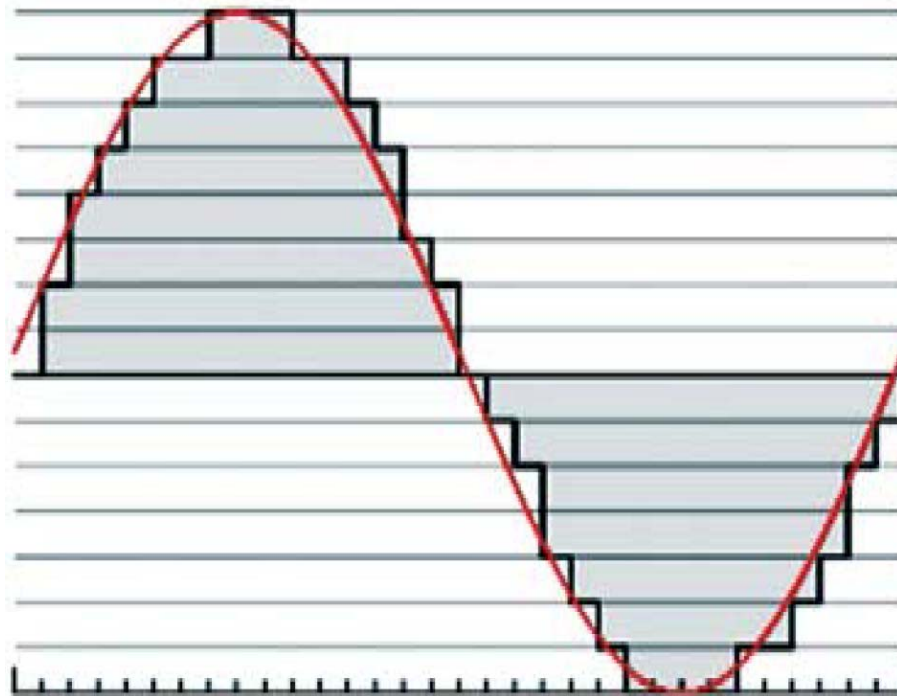
The Conceptual Sample and Hold Amplifier schematic



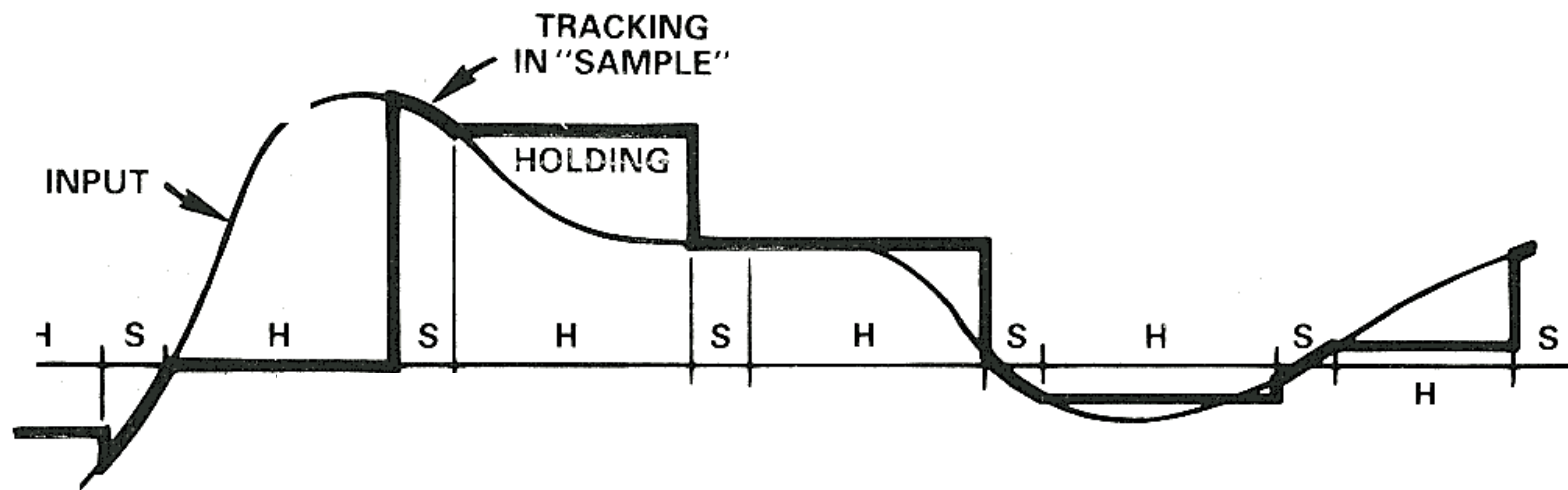
Practical basic Sample and Hold Amplifier schematics



Input signal and SHA output signal



Input signal and SHA output signal



Quantization

- *Quantization* is ...
 - The procedure of constraining something from a continuous set of values (such as the real numbers) to a discrete set (such as the integers)

Quantization

- The ADC represents an analog signal as a digital string of 1's and 0's with finite resolution
 - The ADC outputs a finite number of digital values ...
 - equal to 2^N
(where N is the number of bits of the ADC)

Amplitude Quantization

- *Amplitude Quantization:*

- The maximum amplitude range of an analog signal must be divided into a fixed number of small, equal intervals
- Each interval is then associated with a fixed binary number
 - The A/D Converter performs such a function
- Factors that must be specific for an A/D Converter:
 - The maximum range of analog input voltage
 - The output resolution (determined by the number of output bits)

Resolution

- **Resolution** ... Is a measure of the smallest change in analog input that can be discriminated by an A/D Converter
 - The more binary digits of output that are available ...
 - The more resolution that is possible, and ...
 - The more precision we can encode the analog signal
- The **resolution** of an '**N**' bit A/D converter with a voltage range of "**0 – X**" volts is ...

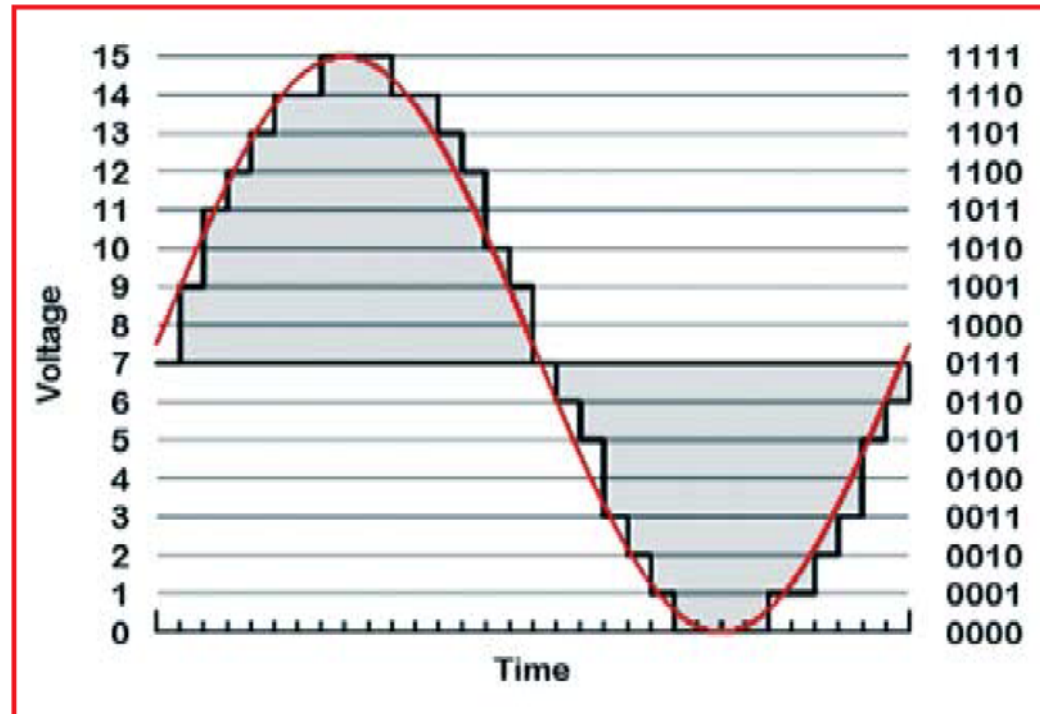
$$\frac{X - 0}{2^N}$$

Example

- For a 4 bit converter
- Zero to fifteen volts input range
- We have

$$\frac{X - 0}{2^N} = \frac{15}{2^4} = \frac{15}{16} = 0.9375 \text{ per volt}$$

Amplitude Quantization



Types of ADCs

- ADCs can be grouped into many different categories ...
 - Architecture type
 - Speed
 - Resolution
 - Power consumption

... to mention just a few

ADC ARCHITECTURES

- There are quite a few ADC architectures in the market today
- The most popular types are
 - Flash
 - Pipelined
 - Successive-approximation-register (SAR)
 - Sigma-delta (Σ - Δ)

The PIC16F684 Analog-to-Digital Converter

- Contains a Successive-approximation-register (SAR) type Analog to Digital converters
 - 10-bit resolution
 - 8 channels

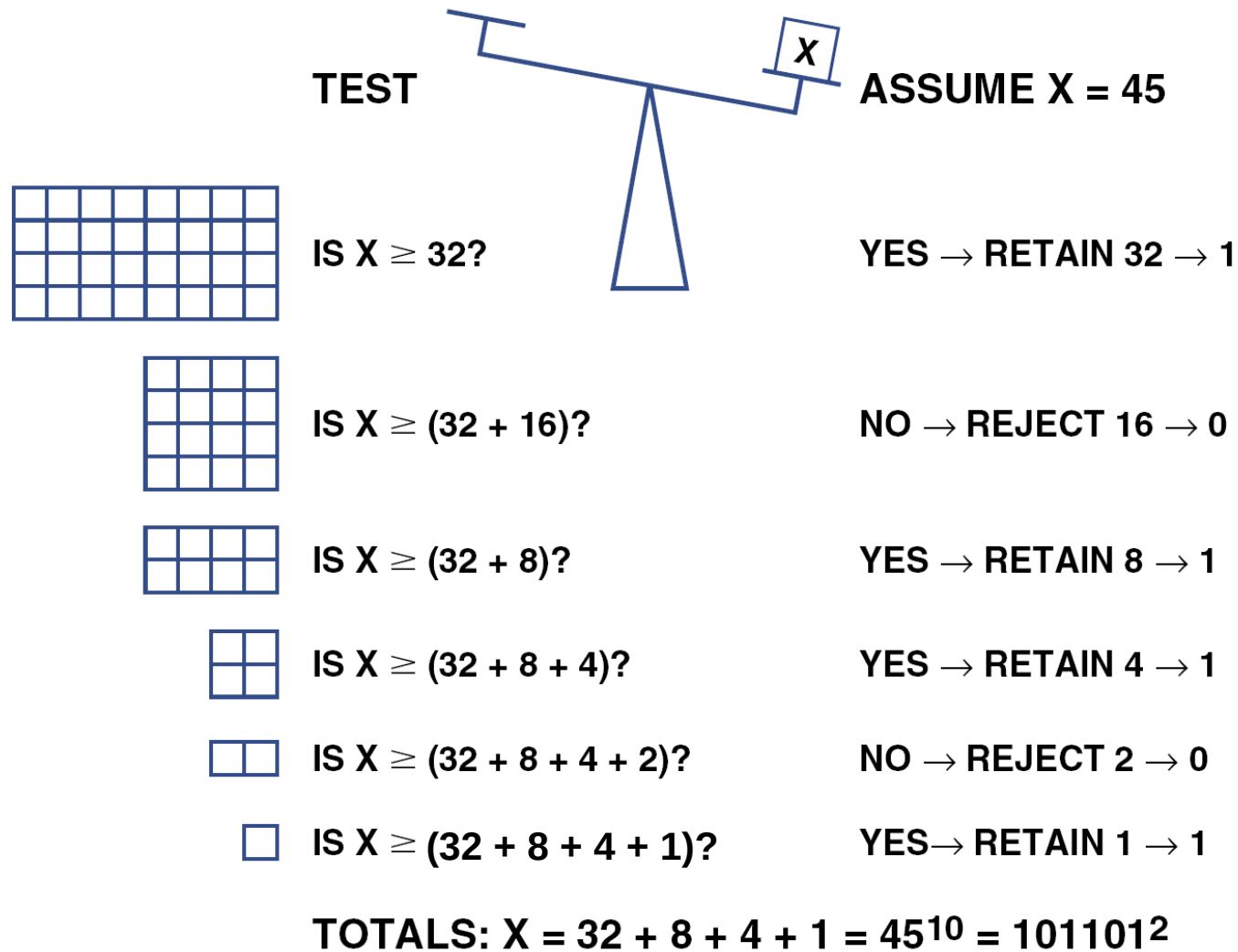
Successive-Approximation-Register or SAR ADC

- A **successive-approximation-register** or SAR ADC ...
 - Is more complex than some of the other ADC architectures
- But there are advantages to the complexity
 - The SAR ADC works by using a single comparator to compare the input analog voltage to an internal reference voltage for each bit in the conversion
 - Therefore ... the input signal needs to be compared ten times for an 10-bit resolution converter

Successive-Approximation-Register (con't)

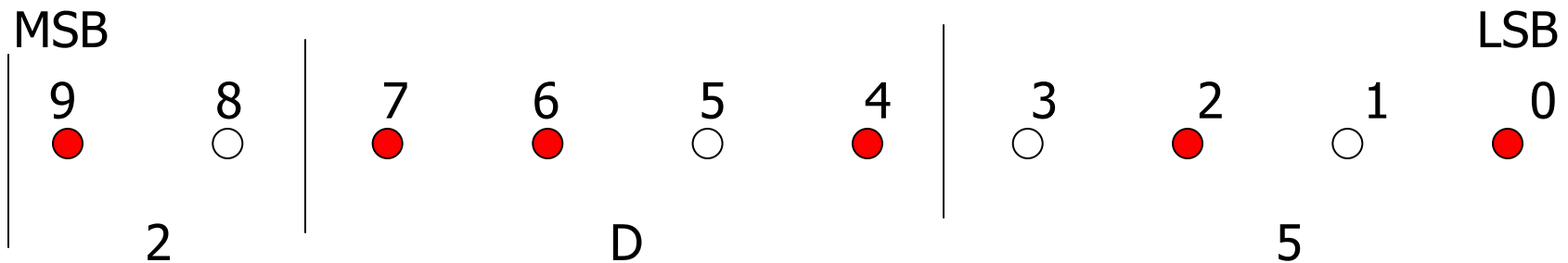
- As each comparison takes place ...
 - a binary value of the approximation is stored in a register
- As comparisons and approximations continues ...
 - The register shifts to the next most significant bit until the word is complete
- This architecture is not the fastest ... but ...
 - It can provide an accurate approximation of the analog signal

Successive Approximation ADC Algorithm



ADC Output

- LEDs (Digital) representation of Analog voltage ...



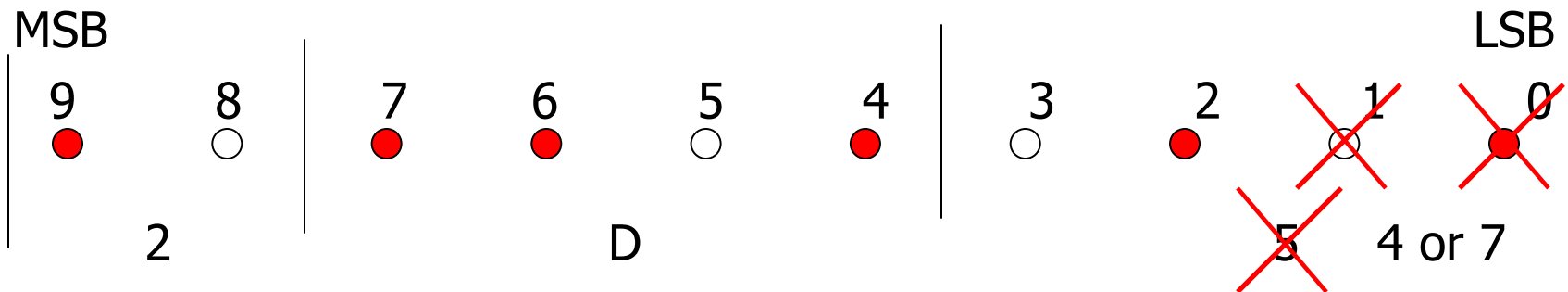
$$(\text{###h}) * (V_{\text{max}} / 2^N) = \text{voltage}$$

$$2D5h = 725_{10}$$

$$(2D5h) * (5 / 2^{10}) = 3.54 \text{ volts}$$

ADC Output – Minus bits 0 and 1

- LEDs (Digital) representation of Analog voltage ...



$$(\text{###h}) * (V_{\text{max}} / 2^N) = \text{voltage}$$

$$2D4h = 724_{10}$$

$$2D7h = 727_{10}$$

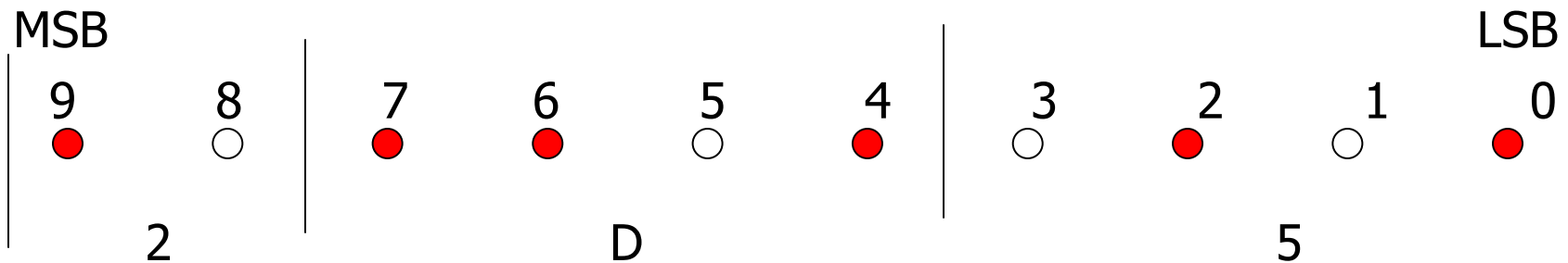
~~$$(2D5h) * (5 / 2^{10}) = 3.54 \text{ volts}$$~~

$$(2D4h) * (5 / 2^{10}) = 3.53 \text{ volts}$$

$$(2D7h) * (5 / 2^{10}) = 3.55 \text{ volts}$$

ADC Output – another method

- LEDs (Digital) representation of Analog voltage ...



$$(0bxxx) \cdot (V_{\max}/2^N) = \text{voltage}$$

$$(725_{10}) \cdot (5/2^{10}) = 3.54 \text{ volts}$$

$(2^0) \cdot 1 = 1$	$(2^5) \cdot 0 = 0$
$(2^1) \cdot 0 = 0$	$(2^6) \cdot 1 = 64$
$(2^2) \cdot 1 = 4$	$(2^7) \cdot 1 = 128$
$(2^3) \cdot 0 = 0$	$(2^8) \cdot 0 = 0$
$(2^4) \cdot 1 = 16$	$(2^9) \cdot 1 = \underline{512}$
	725

Next Lecture

- We will go through the commands to setup and utilize the A/D module
- The next Lab will utilize this function

Programming / Software

Programming

- Commands/instructions that we will encounter tonight
 - C commands - ***No new commands tonight***
 - PIC16F684 control - ***No new commands tonight***

Lab

Lab

- No new material to discuss
- Start Lab #3
- Breadboards will be handed out ... **THEY NEED TO BE RETURNED!!**
- 7-Segment LEDs ... **NEED TO BE RETURNED!!**
- Hard to find components ... **NEED TO BE RETURNED!!**

Next Class ...

Next Class Topics

- Configure the PIC16F684 ADC (read the data sheets)
- Finish Lab #3

HomeWork

Homework

1. Work on Lab #3
2. Lab #3 Report ... due November 09, 2010
3. Read the sections on the PIC16F684 ADC module in both the ...

PICmicro Mid-Range MCU Family Reference Manual

PIC16F684 Data Sheet

Time To ...
Start the Lab ...

References

1. PIC16F684 Data Sheet 41202F