8/17/2020

Brief History of Electronics

Date	Event	Inventor
1827	Ohm's Law published	Georg Ohm
1874	"Cat's whisker" point contact diode using a Pb crystal	Ferdinand Braun
1879	Cathode ray tube (CRT) device	Ferdinand Braun
1879	Edison carbon filament light bulb	Thomas Edison
1900	Radio communication system	Guglielmo Marconi
1906	Diode vacuum tube invented	John Fleming
1906	Triode vacuum tube (for amplifier/oscillator)	Lee de Forrest
1918	LC oscillator invented	Edwin Colpitts
1927	Television invented	Philo Farnsworth
1933	FM invented	Edward Armstrong
1939	pn junction invented	Russel Ohl
1940	Radar developed	
1946	ENIAC – 1st electronic computer	
1947	Bipolar junction transistor invented	Shockley, Brattain & Bardeen
1950	Electronic color television invented	John Baird
1952	First commercial transistor production	
1958	Integrated circuit (IC) invented	Jack Kilby
1960	Ruby laser invented	Theodore Maiman
1961	First commercial IC's	
1968	4000 Series CMOS IC's introduced	
1971	Intel 4004 microprocessor (4-bit)	
1974	Intel 8080 microprocessor (8-bit)	
1977	Radio Shack TRS-80 PC	
1977	VHS VCR introduced	
1981	IBM PC introduced	
1982	FCC authorized commercial cell phone service	
1982	Compact Disk (CD) commercially released	
1982	286 processor introduced	
1985	386 processor introduced	
1989	486 processor introduced	
1993	Pentium processor released	
1997	Pentium II processor released	
1999	Celeron processor released	
2009	U.S. switch to digital TV	

1) Electronic Signals : 2 Catagories : Analog Signals + Digital Signals

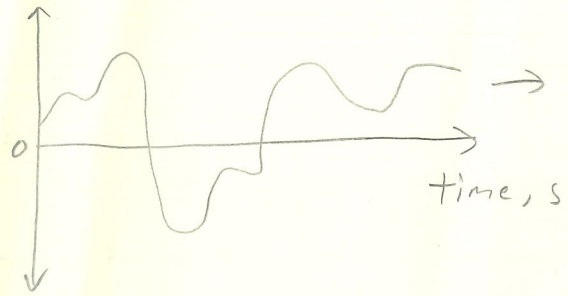
Analog Signals → have a continuous range of values.

Digital Signals → appear at only one of several discrete levels.

↳ subset : Binary Digital Signals : have only 2 discrete levels.

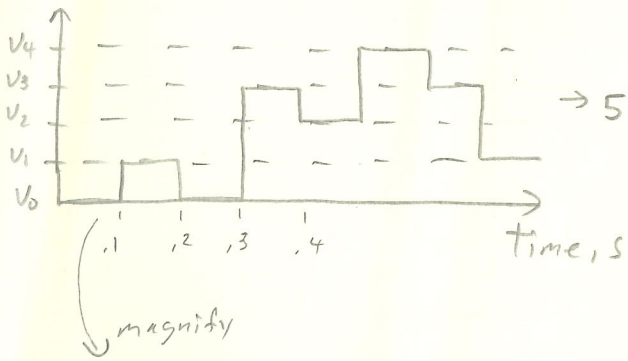
<u>Examples</u>

(1) V(t), V or I(t), A



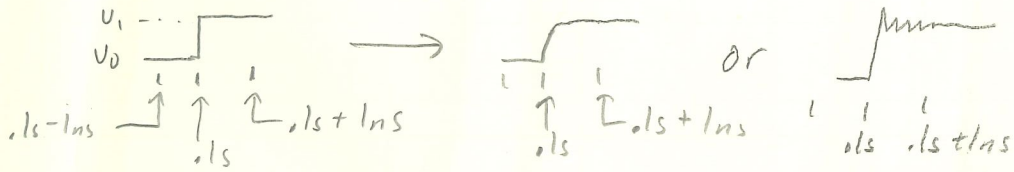
→ analog signal

(2) V(t), V



→ 5 discrete levels

∴ digital signal



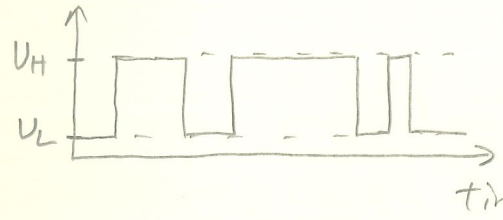
<u>IDEAL</u> <u>ACTUAL</u>

In reality : digital signals are really analog signals that approximate ideal digital signals

Also : a digital signal with <u>many</u> discrete steps approximates an analog signal

→ example : a 5V sinewave made up of 1000 5mV discrete levels

(3) $V(t), V$



→ Binary digital signal

→ has 2 levels or states : V_H and V_L

V_H ↑ V_{HIGH} V_L ↑ V_{LOW}

$V_H \equiv$ logical "1"

$V_L \equiv$ logical "0"

<u>Values for V_H and V_L</u>

(1) $V_H = 5V$ and $V_L = 0V$ → commonly used for many years

(2) but now : $V_L = 0V$ and $V_H = 3.3V$ or $2.5V$ or $1.5V$ is common

(3) also older ECL technology : $V_H = -0.8V$ and $V_L = -2V$

(4) also RS-232 : $V_H = +12V$ and $V_L = -12V$

a) More on Binary signals :

1 wire → 2 states : 1 or 0

2 wires : b_2, b_1 → 2 states each

b_1	b_2
0	0
0	1
1	0
1	1

} 4 possible values

∴ n wires → 2^n possible values represented

$n \equiv$ number of bits

ex: $n = 3$; 3 wires or 3 bits

b_1	b_2	b_3	Digital number
0	0	0	0
0	0	1	1
0	1	0	2
0	1	1	3
1	0	0	4
1	0	1	5
1	1	0	6
1	1	1	7

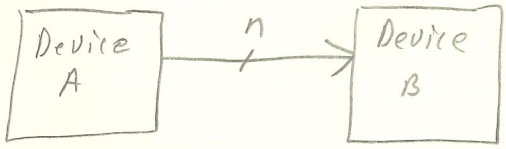
binary number

8 possible values $= 2^n \rightarrow n = 3$

$b_3 = b_n$ = changes states each step $\rightarrow b_n$ is the Least Significant Bit : LSB

b_1 = Most Significant Bit = MSB

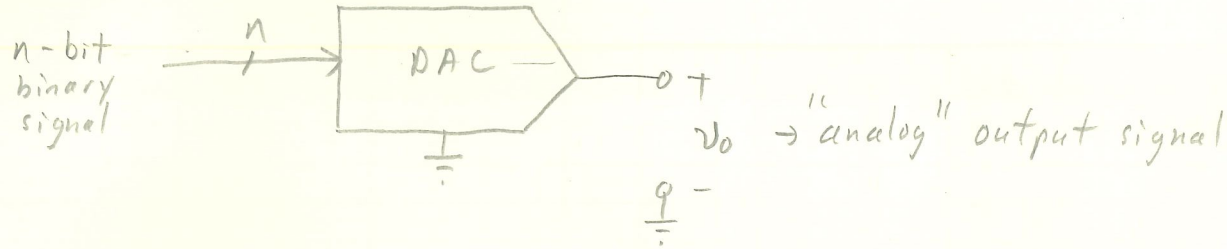
b_1, b_2 and b_3 $\rightarrow$ 3 wire bus : $n = 3$



binary signals on the n-wire bus originate at Device A (i.e. they are output from Device A) and travel into Device B (i.e. they are input into Device B)

2) A/D and D/A converters

a) D/A ≡ Digital to Analog Converter or DAC



DAC → V_{FS} ≡ Full Scale Reference Voltage

$$v_o = (b_1 2^{-1} + b_2 2^{-2} + \cdots b_n 2^{-n}) V_{FS}$$

b_1 = MSB and b_n = LSB

<u>example</u> : $n = 3$, $V_{FS} = 10V$

$$\therefore V_o = \left(\frac{b_1}{2} + \frac{b_2}{4} + \frac{b_3}{8}\right) 10$$

D	b_1	b_2	b_3	V_o (V)
0	0	0	0	0
1	0	0	1	1.25V
2	0	1	0	2.5V
3	0	1	1	3.75V
4	1	0	0	5.0V
5	1	0	1	6.25V
6	1	1	0	7.5V
7	1	1	1	8.75V

all possible DAC output values

DAC minimum voltage change = $V_{LSB} = 2^{-n} V_{FS} = 1.25V$

→ resolution of the converter

<u>Notice</u>

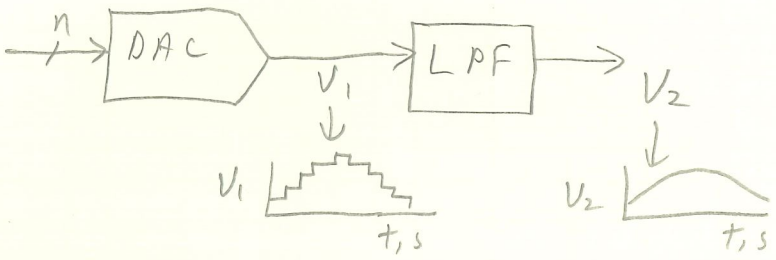
$v_o|_{min} = 0V$

$v_o|_{max} = V_{FS} - V_{LSB} = 8.75V$

by definition : DAC output is a multilevel digital signal

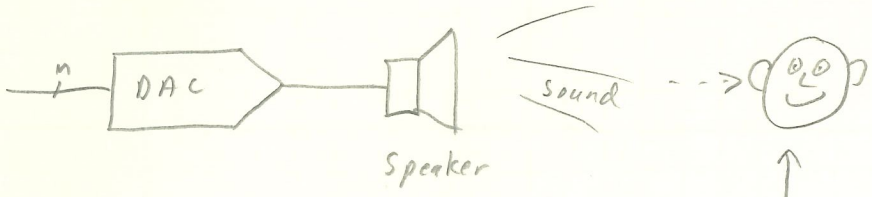
→ if n is large → DAC output approximates an "analog" signal

→ can low pass filter (LPF) the DAC output to get rid of the discrete level characteristics



The LPF does not always have to be electrical

<u>example</u>

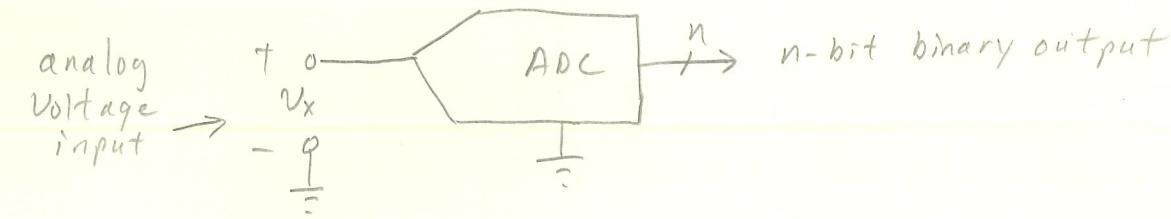


LSB changes at 40KHz rate

cannot hear above 20KHz

ear LPF's the audio signal

b) A/D ≡ Analog to Digital Converter or ADC

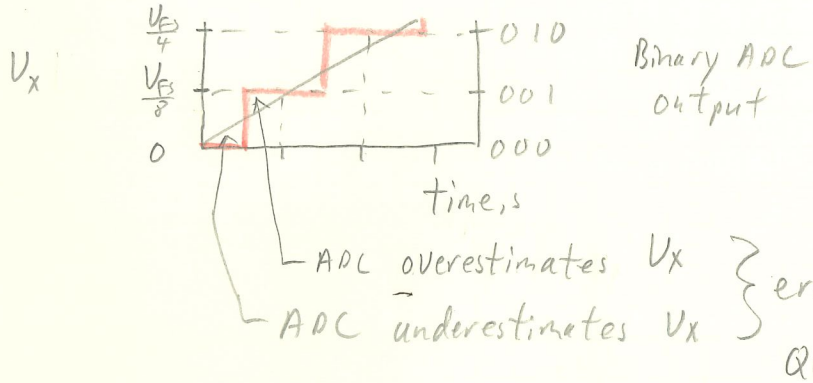


ADC: also has a V_{FS} reference voltage

ADC Response to V_x

	V_x	b_1	b_2	b_3	Digital
8-levels	0	0	0	0	0
	$\frac{1}{8} V_{FS}$	0	0	1	1
	$\frac{1}{4} V_{FS}$	0	1	0	2
	$\frac{3}{8} V_{FS}$	0	1	1	3
	$\frac{1}{2} V_{FS}$	1	0	0	4
	$\frac{5}{8} V_{FS}$	1	0	1	5
	$\frac{3}{4} V_{FS}$	1	1	0	6
	$\frac{7}{8} V_{FS}$	1	1	1	7

ADC has Quantization Error



Quantization Error decreases as n increases

3) Circuits Notation and Review

a) units → always include units

$1KV = 1000V$ $\qquad$ $K\Omega = 1000\,\Omega$

$1mV = 1\times10^{-3}\,V$ $\qquad$ $M\Omega = 1\times10^{6}\,\Omega$

$1\mu V = 1\times10^{-6}\,V$ $\qquad$ $m\Omega = 1\times10^{-3}\,\Omega$

$1nV = 1\times10^{-9}\,V$

b) Notational Conventions

① Total signal : may have a DC part and a time varying part
→ represented by lower case letter with capital subscripts :

ex: v_T , i_T , v_{BE}

② DC component : represented by capital letters with capital subscripts

ex: V_{DC} or I_D

③ time varying component : represented by lower case letters and subscripts

ex: v_s , i_{sig} , v_x

Example Total Signal : $v_{ADC} = V_{DC} + v_{sig}$

c) Resistance and Conductance

Resistance : R , $[R] = \Omega$ $\quad$ (Ω, $K\Omega$, $M\Omega$ ... used)

Conductance : G , $[G] = S$

$$G = \frac{1}{R}$$

$$G_x = \frac{1}{R_x} \quad \text{or} \quad g_\pi = \frac{1}{r_\pi}$$