ECE 2EI4: Lecture #2

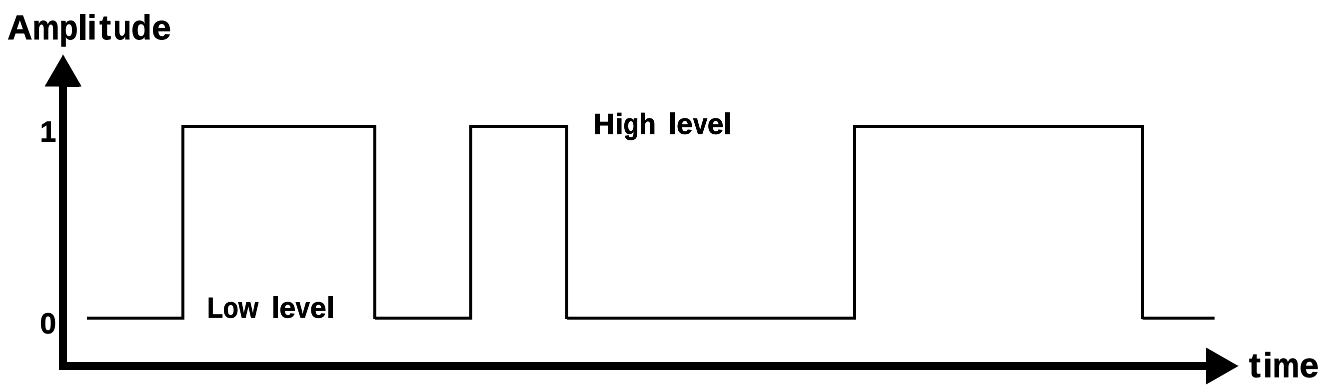
Introduction to Electronics

Jaeger Chapter 1, Spencer Chapter 1
1.10, 1.12, 1.15, 1.25, 1.26, 1.29, 1.32, 1.33

Outline/Learning Objectives:

- Digital and analog signals, DAC and ADC
- Notational conventions, R and G, types of sources, amplifiers, principle of superposition numeric precision.
- Miscellaneous useful information (pages 7 to16)

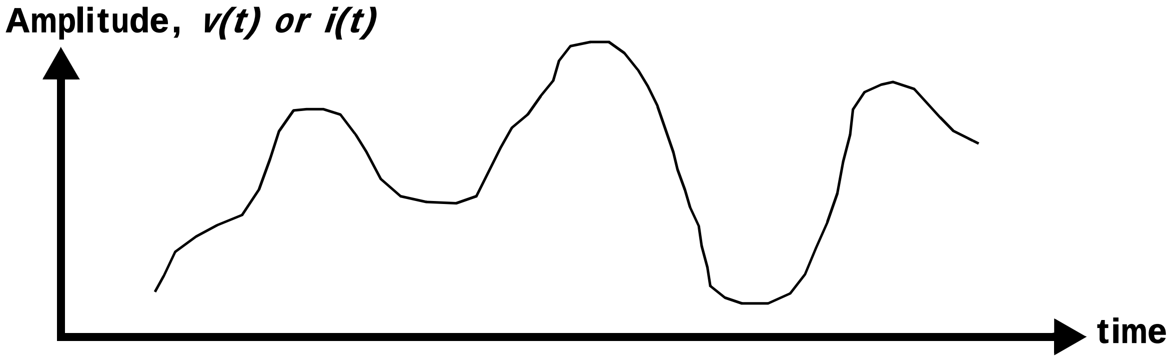
Digital Signals



V_H = 5, 3.3, 2.5, 1.5V (-0.8V in ECL) V_L = 0V (-2V in ECL)

Digital families - CMOS, NMOS, PMOS, TTL, ECL

Analog Signals

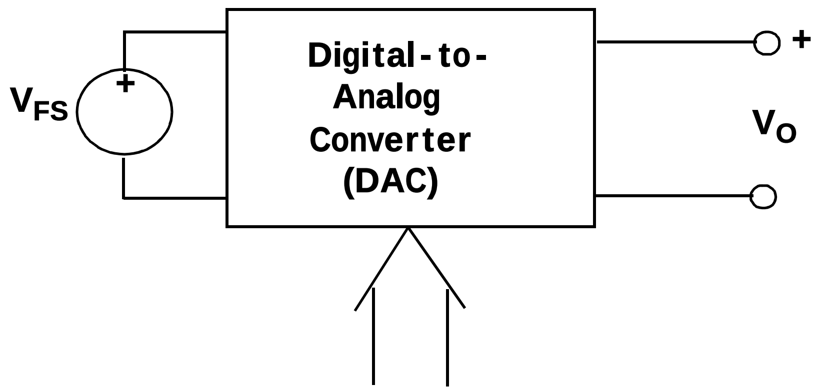


Analog processes - sense of vision, taste, smell, touch

Analog signals - temperature, humidity, pressure, light intensity or sound

Use analog transducer to convert analog signal into a i(t) or v(t) typically.

Digital-to-Analog Converter



Binary input data (b_1, b_2, b_3,....b_n)

$$V = (b_1 \cdot 2^{-1} + b_2 \cdot 2^{-2} + \cdot \cdot \cdot + b_n \cdot 2^{-n}) \bullet V_{FS} \text{ for } b_i \in \{0, 1\}$$

Typical values of V_{FS} are 2.5, 5, 5.12, 10 or 10.24V.

The LSB b_n or resolution of the DAC is $V_{LSB} = 2^{-n} \bullet V_{FS}$

The MSB b_1 of the DAC is $V_{MSB} = 2^{-1} \bullet V_{FS}$

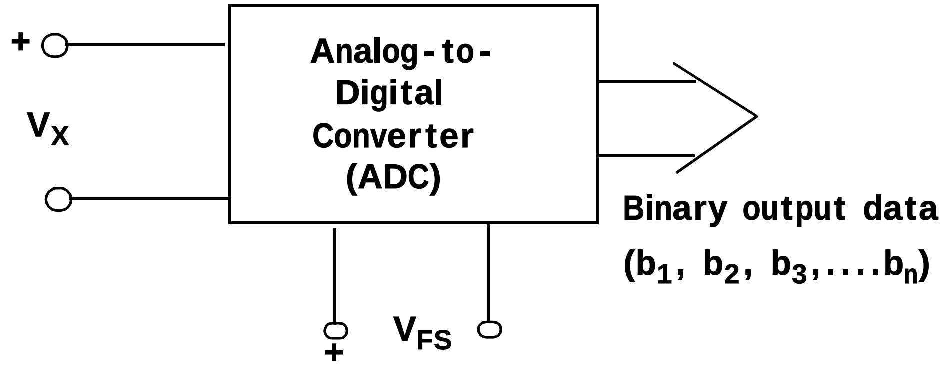
Example: 10 bit DAC, V_{REF} = 5.12V, input data $(11\ 0001\ 0001)_2$.

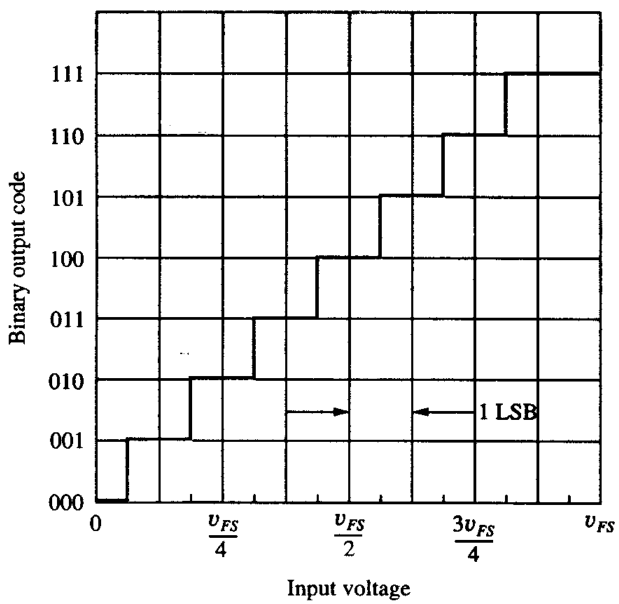
$$V_{LSB} = 5.12 \times 2^{-10} = 5mV$$

$$V_{MSB} = 5.12 \times 2^{-1} = 2.16V$$

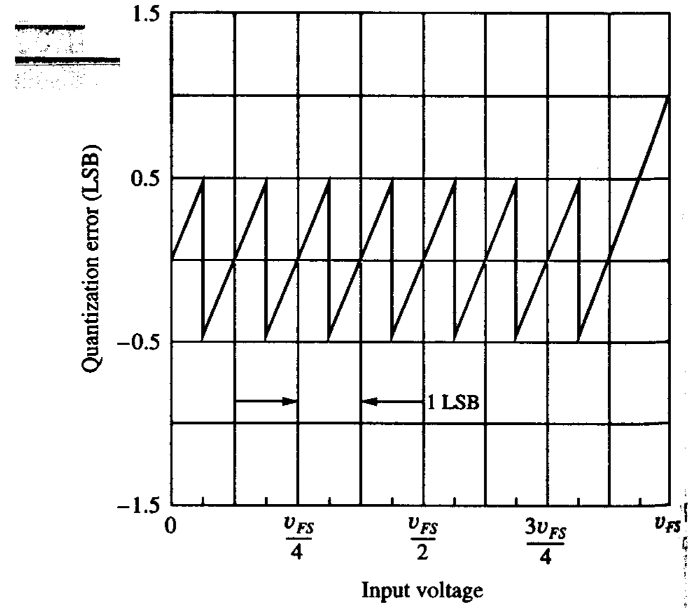
$$v_O = (2^{-1} + 2^{-2} + 2^{-6} + 2^{-10}) \times 5.12 = 0.7666 \times 5.12 = 3.925V$$

Analog-to-Digital Converter (ADC)





(a)



(b)

$$V_{\varepsilon} = \left| v_X - \left(b_1 \cdot 2^{-1} + b_2 \cdot 2^{-2} + \cdot \cdot \cdot + b_n \cdot 2^{-n} \right) \bullet V_{FS} \right|$$

Example: 8 bit ADC, V_{REF} = 5V. V_{LSB} = ? and 1.2V = ?

$$V_{LSB} = 5 \times 2^{-8} = 19.53 mV \qquad \frac{1.2}{5} \times 2^8 = 61.44 = 32 + 16 + 8 + 4 + 1 = (0011 \;\; 1101)_2$$

Notational Conventions

DC Components: V_{DC} or I_{DC}

Variations from DC values: v_{ac} or i_{ac}

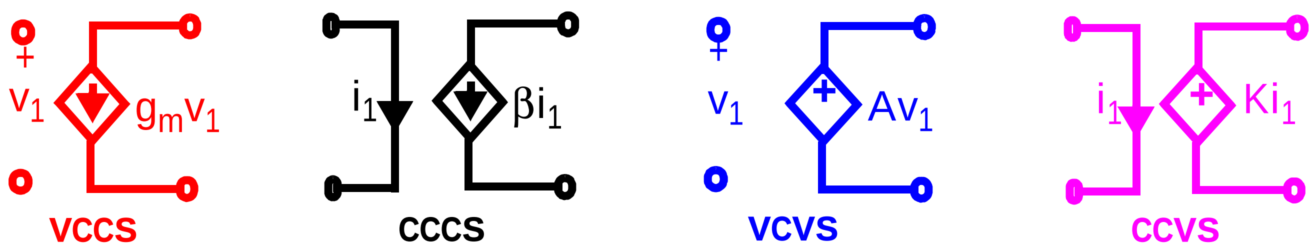
Total quantities: $v_T = V_{DC} + v_{ac}$ or $i_T = I_{DC} + i_{ac}$

$$v_{BE} = V_{BE} + v_{be} \text{ or } i_D = I_D + i_d$$

Resistance and Conductance

Conductance $G_X = \frac{1}{R_X}$ or $g_\pi = \frac{1}{r_\pi}$; G is Siemens (S) or mhos, R in Ohms (Ω)

Dependent Sources



Amplifiers - characteristics of analog signals are most often manipulated using linear amplifiers that affect the amplitude and/or phase of the signal without changing its frequency

Linearity - can apply the principle of superposition (the total effect of several causes acting simultaneously is the same as the sum of the effects of the individual causes acting one at a time)

Input signal - $v_s = V_s \sin(\omega_s t + \phi)$ or $\vec{V_s} = V_s \angle \phi$

Output signal - $v_o = V_o \sin(\omega_o t + \phi + \theta)$ or $\vec{V_o} = V_o \angle(\phi + \theta)$

Voltage gain - $A = \dfrac{v_o}{v_s} = \dfrac{V_o \angle(\phi + \theta)}{V_s \angle \phi} = \dfrac{V_o}{V_s} \angle \theta$

Amplitude of voltage gain is $\dfrac{V_o}{V_s}$ and phase shift is θ.

$\omega_s t, \phi, \theta$ must all have the same units - radians. π **radians = 180^0**

Numeric Precision

Components can have tolerances ranging from $\pm 1\%$ to $\pm 50\%$. Therefore, calculating more than three (3) significant digits is generally meaningless.

Three significant digits - 2.03 mA, 5.72 V, 0.0436 μA.

Please read the the remaining pages. It is useful information that is self-explanatory.

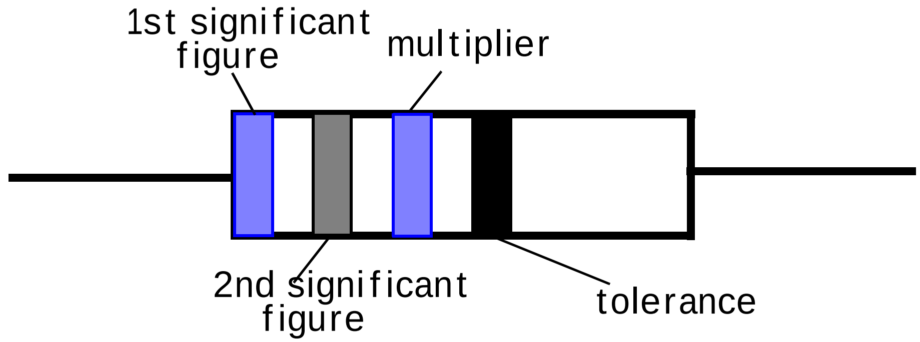


Table 1: Resistor Color Scheme

Significant Figures	Color	Multiplier	Color	Tolerance
0	Black	1	Black or	±20%
1	Brown	10	no color	±20%
2	Red	100	Silver	±10%
3	Orange	1,000	Gold	±5%
4	Yellow	10,000		
5	Green	100,000		
6	Blue	1,000,000		
7	Violet			
8	Gray			
9	White	0.1		
	Gold			
	Silver	0.01		

For example, blue, gray, blue and black would be 68×10^6 or 68 MΩ, 20% tolerance

Table 2: Frequencies of common signals

Category	Frequency Range
Audible sounds	20 Hz - 20 kHz
Baseband video television signals	0 - 4.5 MHz
AM radio broadcasting	540 - 1600 kHz
HF radio broadcasting	1.6 - 54 MHz
VHF television (channels 2 to 6)	54 - 88 MHz
FM radio broadcasting	88 - 108 MHz
VHF radio communication	108 - 174 MHz
VHF television (channels 7 to 13)	174 - 216 MHz
UHF television (channels 14 to 69)	470 - 806 MHz
Cellular telephones	824 - 892 MHz
Satellite television	3.7 - 4.2 GHz

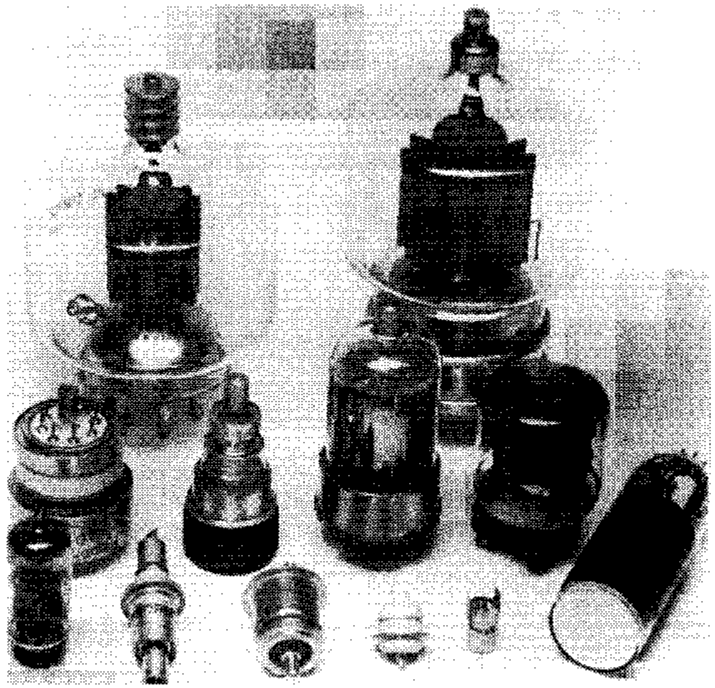
Review of History of Electronics

Table 3: Milestones in Electronics

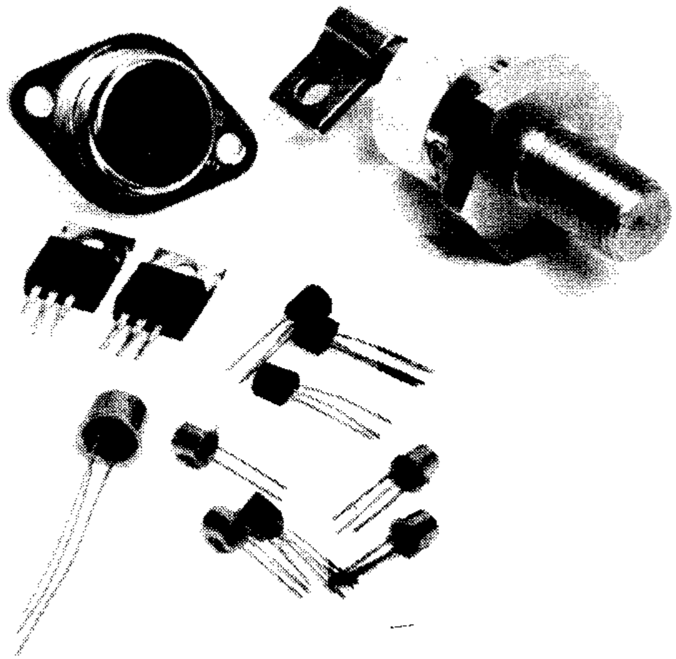
Year	Event
1884	American Institute of Electrical Engineers (AME) formed
1895	Marconi makes first radio transmissions
1904	Fleming invents diode vacuum tube - Age of Electronics begins
1906	Pickard creates solid-state point-contact diode (silicon)
1906	Deforest invents triode vacuum tube (audion)
1910-11	"Reliable" tubes fabricated
1912	Institute of Radio Engineers (IRE) founded
1907-27	First radio circuits developed from diodes and triodes
1920	Armstrong invents super heterodyne receiver
1925	TV demonstrated
1925	Lilienfeld files patent application on the field-effect device
1927-36	Multigrid tubes developed
1933	Armstrong invents FM modulation
1935	Heil receives British patent on a field-effect device
1940	Radar developed during World War 11-TV in limited use
1947	Bardeen, Brattain, and Shockley at Bell Laboratories invent bipolar transistors
1950	First demonstration of color TV
1952	Shockley describes the unipolar field-effect transistor
1952	Commercial production of silicon bipolar transistors begins at Texas Instruments

Table 3: Milestones in Electronics (Continued)

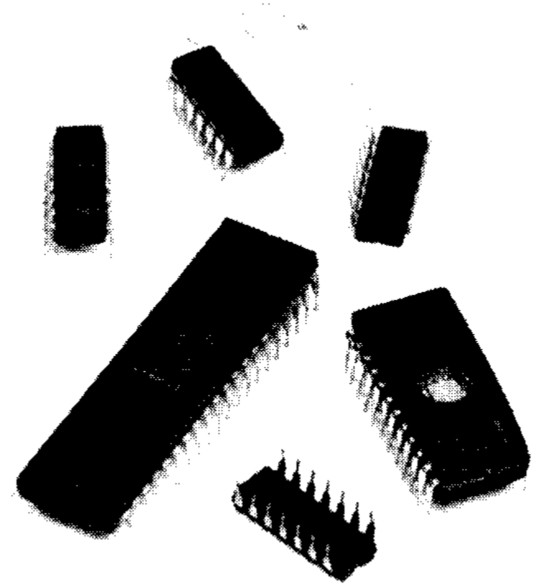
Year	Event
1956	Bardeen, Brattain & Shockley receive Nobel Prize - invention of bipolar transistors
1958	IC developed simultaneously by Kilby at TI; Noyce & Moore at Fairchild Semicon.
1961	First commercial digital IC available from Fairchild Semiconductor
1963	AIEE and IRE merge to become the IEEE: *Your* Professional Society!
1967	First semiconductor RAM (64 bits) discussed at the IEEE ISSCC
1968	First commercial IC Op-Amp -the μA-709-introduced by Fairchild Semiconductor
1970	One-transistor dynamic memory cell invented by Dennard at IBM
1971	4004 microprocessor introduced by Intel
1972	First 8-bit microprocessor-the 8008-introduced by Intel
1974	First commercial 1-kbit memory chip developed; 8080 microprocessor introduced
1978	First 16-bit microprocessor developed
1984	Megabit memory chip introduced
1995	Experimental gigabit memory chip presented at the IEEE ISSCC



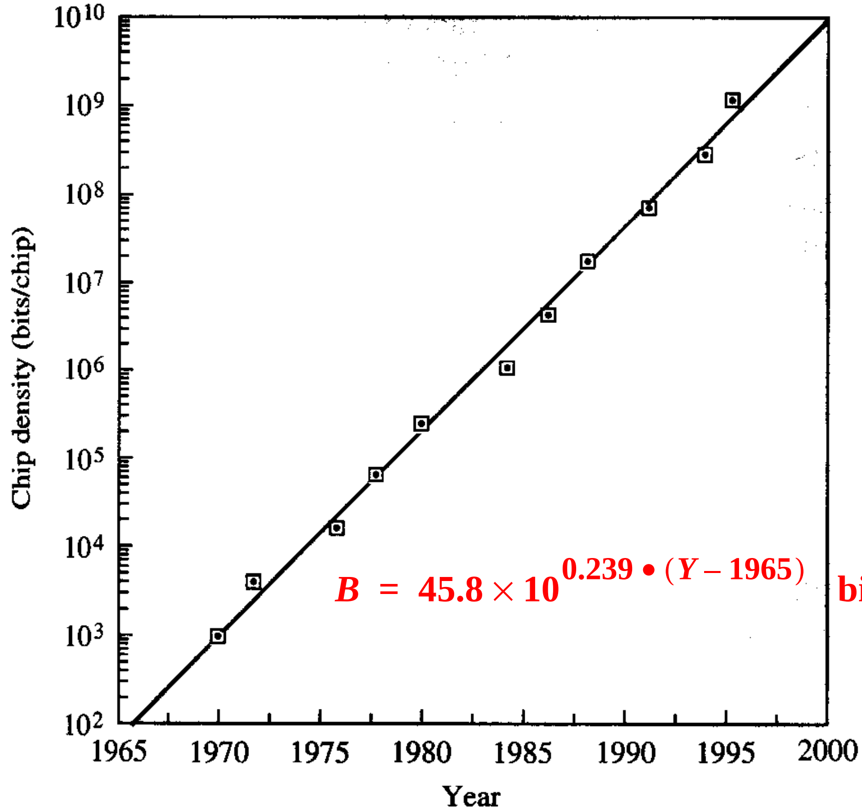
(a) **Vacuum Tubes**



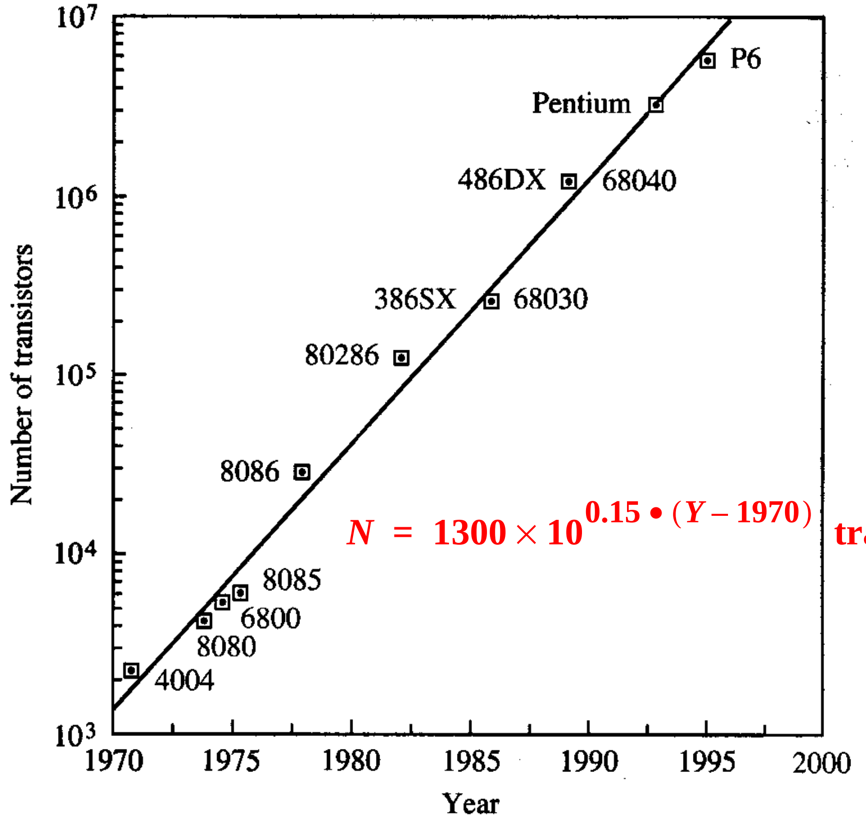
(b) **Individual Transistors**



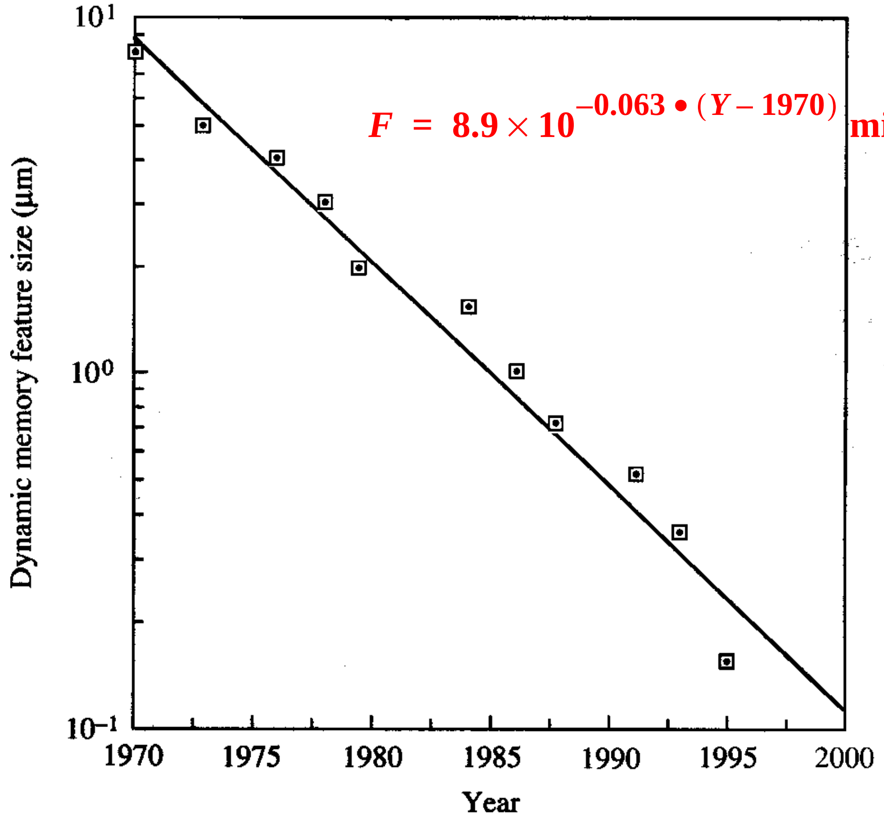
(c) **High Density ICs**



$$B = 45.8 \times 10^{0.239 \bullet (Y - 1965)} \text{ bits/chip}$$



$$N = 1300 \times 10^{0.15 \bullet (Y - 1970)} \text{ transistors}$$



$$F = 8.9 \times 10^{-0.063 \bullet (Y - 1970)} \text{ micron}$$

Table 4: Levels of Integration

Date	Historical Reference	Components/chip
1950	Discrete components	1-2
1960	SSI - Small-scale integration	$< 10^2$
1966	MSI - Medium-scale integration	10^2 - 10^3
1969	LSI - Large-scale integration	10^3 - 10^4
1975	VLSI - Very-large-scale integration	10^4 - 10^9
1990	ULSI - Ultra-large-scale integration	$> 10^9$