Introduction to Electronics

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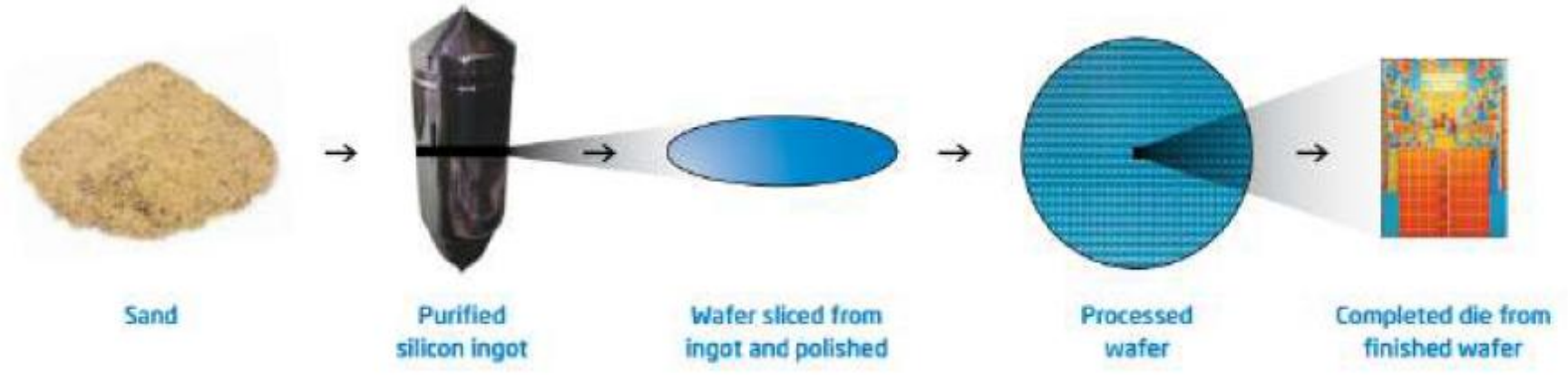
EE 101

Autumn 2015

EE101: Next steps

- Electronic circuits
  - Basic “semiconductor” components/devices
    - Diodes
    - Bipolar Junction Transistors (BJTs)
    - Metal-Oxide-Semiconductor (MOS) Field Effect Transistors (MOSFETs)
  - Typically, these components are “integrated” in electronic circuits → “Integrated Circuits” → “ICs”
    - Silicon chip with millions - billions of devices

Transforming Sand to Chips



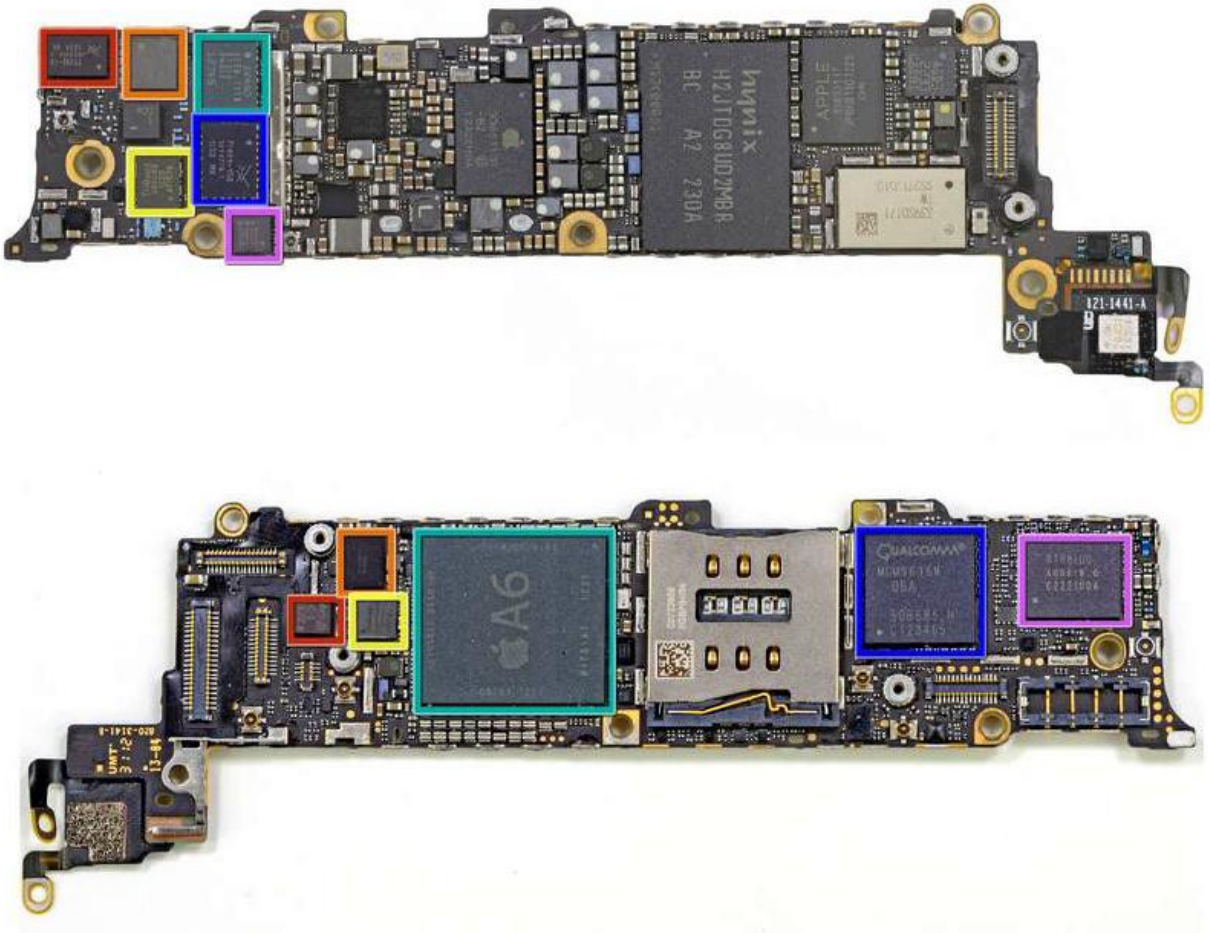
Source: Intel

- Silicon is used in >95% of all Integrated Circuits

iPhone 5

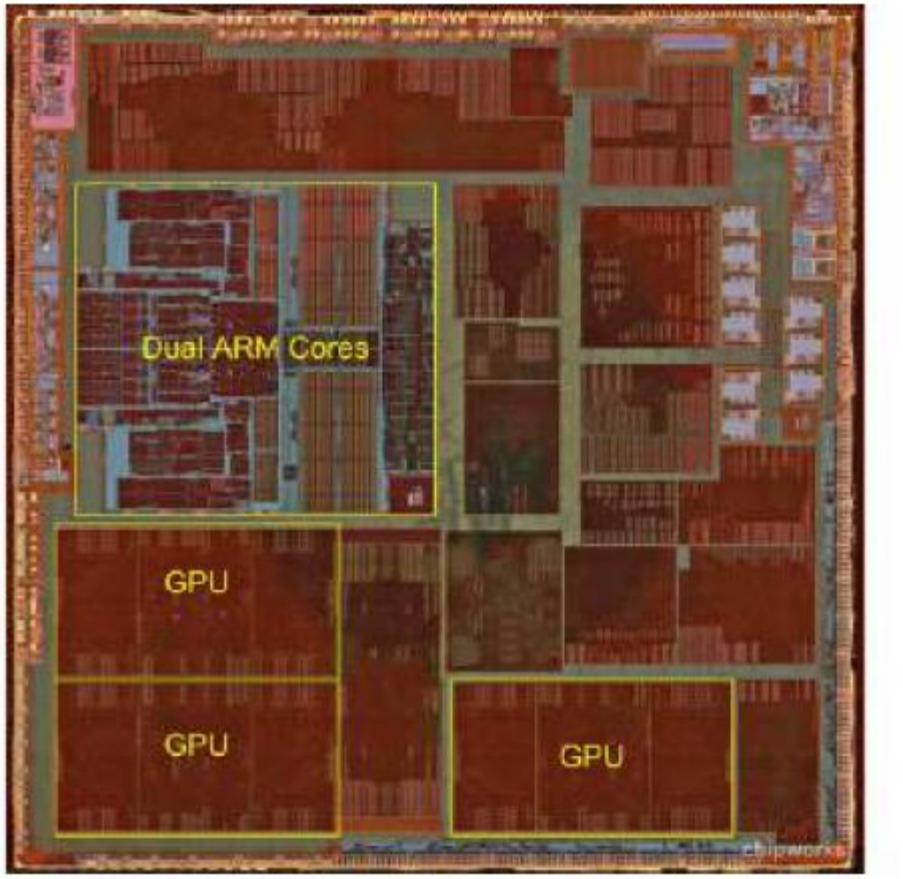
- Source: https://www.ifixit.com/Teardown/iPhone+5+Teardown/10525

iPhone 5 Logic Board



- Various ICs can be seen

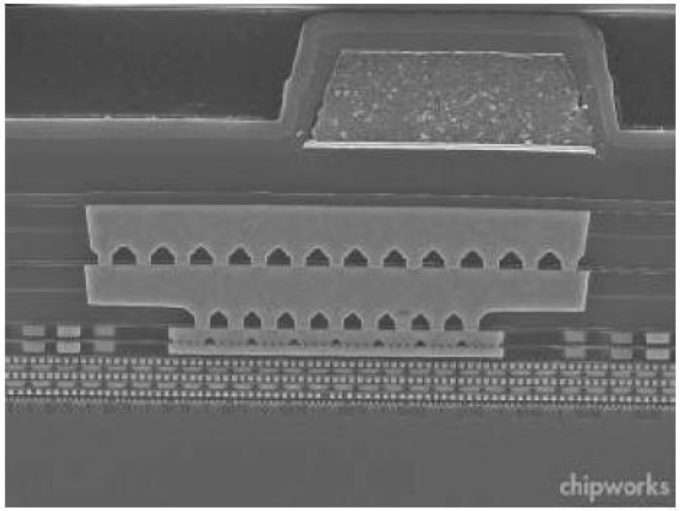
The Processor Chip

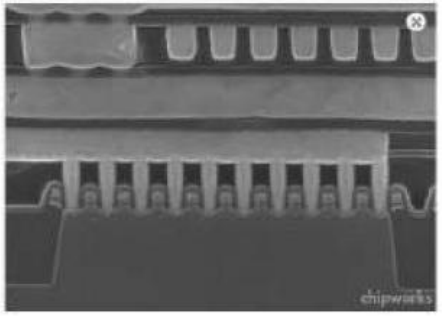


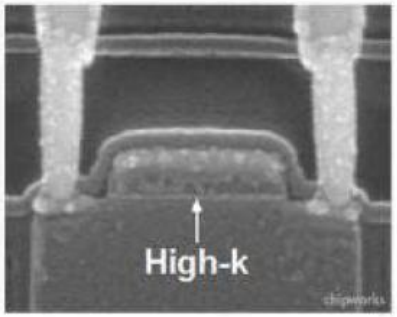
Source: chipworks.com

- Apple A6 processor (IC)

Cross-section the processor







- Various transistors, resistors, capacitors etc. are "integrated" on Silicon

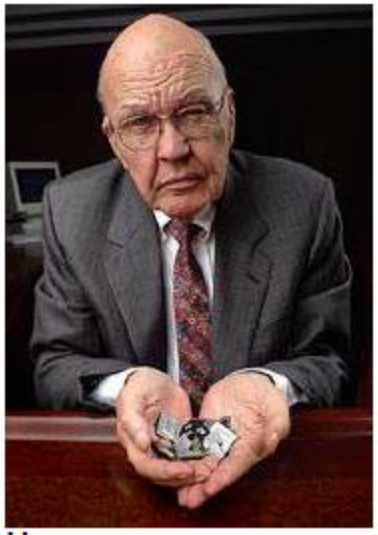
Processor Specs

- 32 bit, 1.3 GHz dual-core CPU
- Integrated 266 MHz triple-core graphics processing unit
- 1 GB of LPDDR2 RAM
- Integrated image signal processor
- Manufactured by Samsung on a High-κ metal gate (HKMG) 32 nm process
- Area 96.71 mm^2

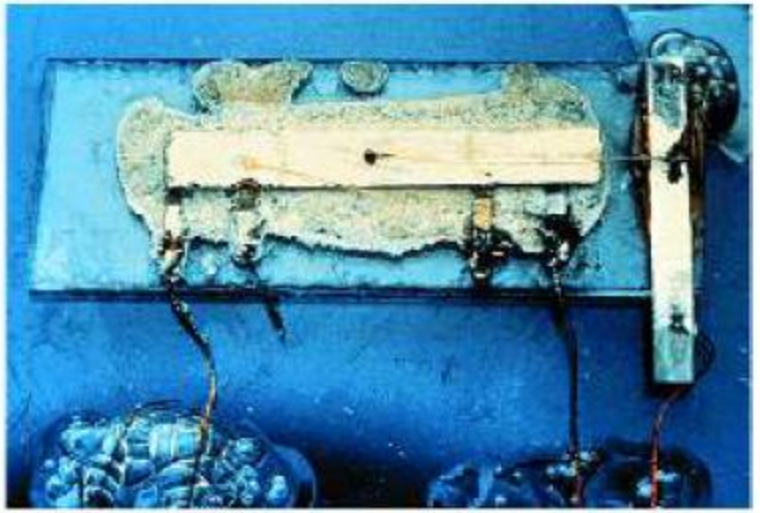
The Transistor

- John Bardeen, Walter Brattain and William Shockley
  - 1947, Bell Labs
  - Point contact Ge transistor

IC History

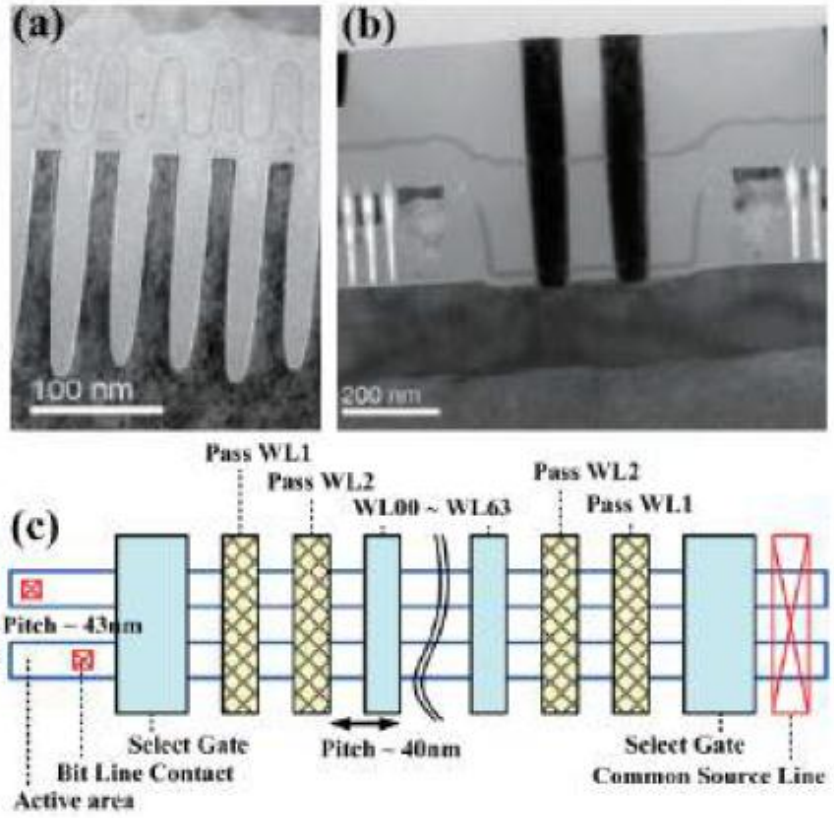


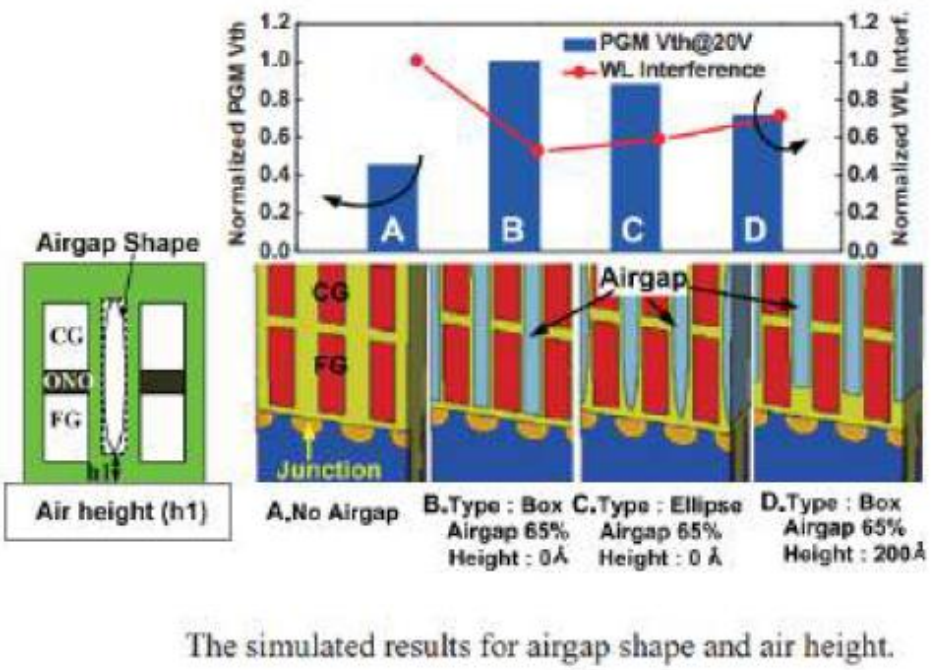
Jack Kilby



- Sept 12, 1958, Texas Instruments
- Phase shift oscillator at 1.3 MHz made of Ge, 7/16 x 1/16 inches
- 2000 Nobel Prize in Physics

iPhone Memory



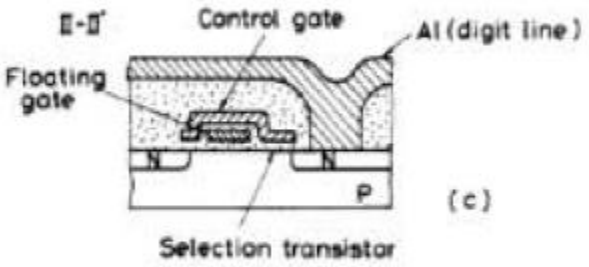


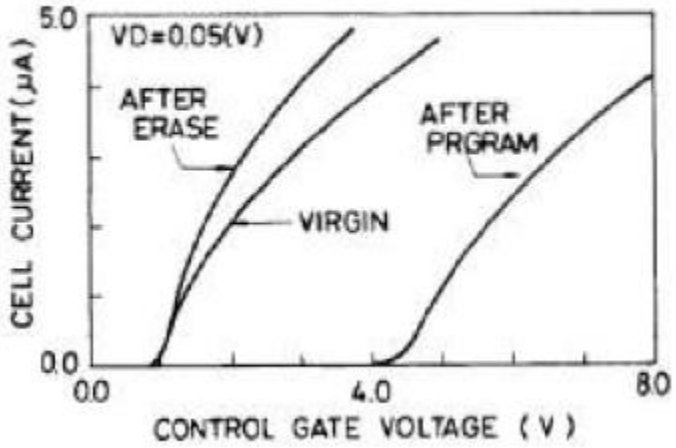
The simulated results for airgap shape and air height.

Source: K. W. Lee et al., VLSI 2012

- 128 Gb (16 GB) NAND Flash, 21 nm technology (2 bits per cell)

Flash Memory History



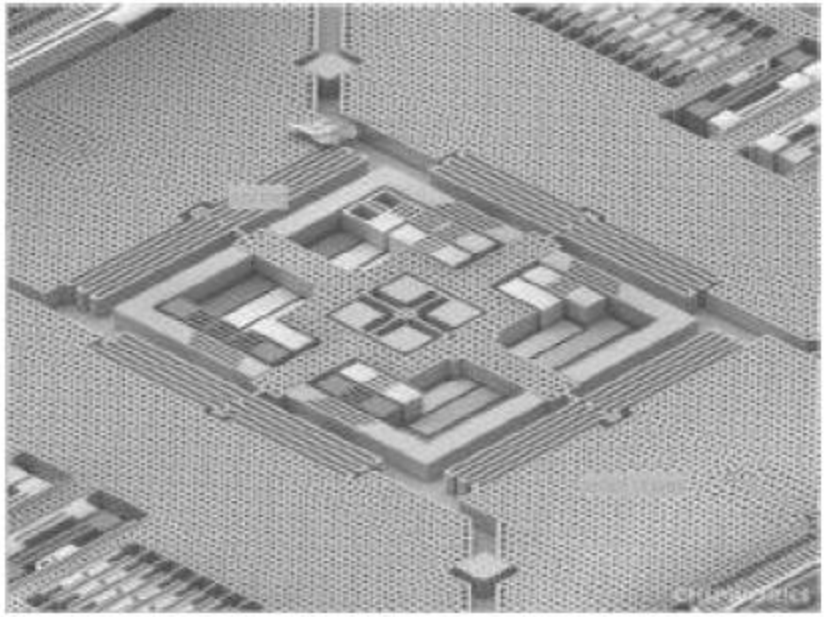


- Fujio Masuoka, IEDM 1984 Toshiba

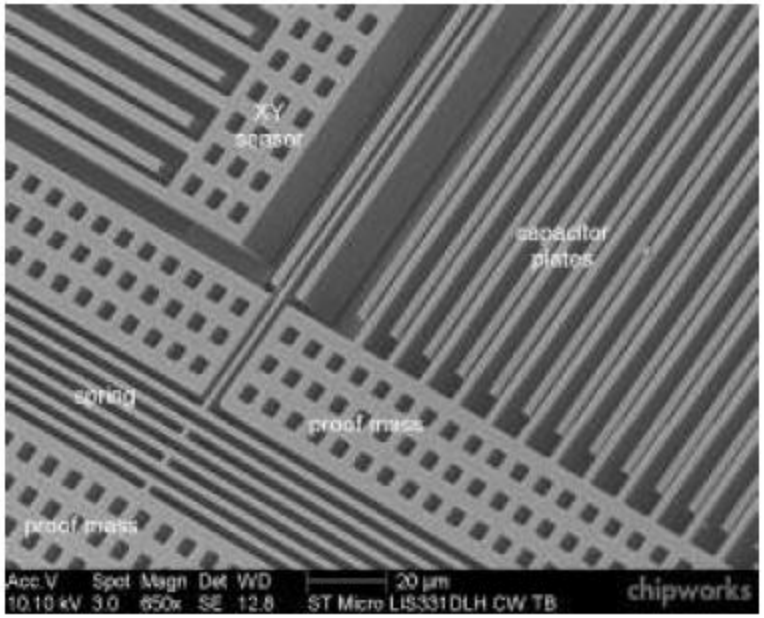
Other iPhone Chips

- Qualcomm PM8018 RF power management IC
- Broadcom BCM4334 Wi-Fi module
- Texas Instruments 27C245I touch screen SoC
- Broadcom BCM5976 touchscreen controller
- Qualcomm MDM9615M LTE modem
- Qualcomm RTR8600 Multi-band/mode RF transceiver

iPhone 5 Sensors



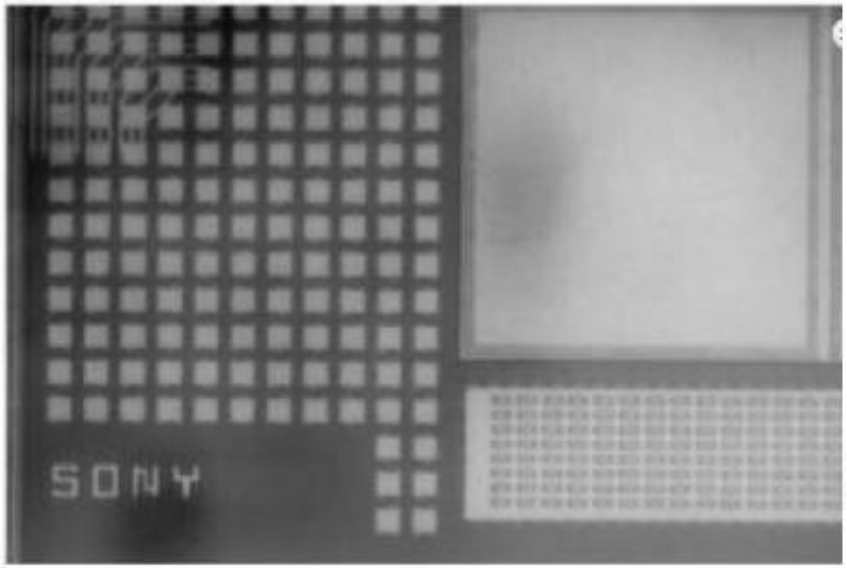
MEMS Gyroscope

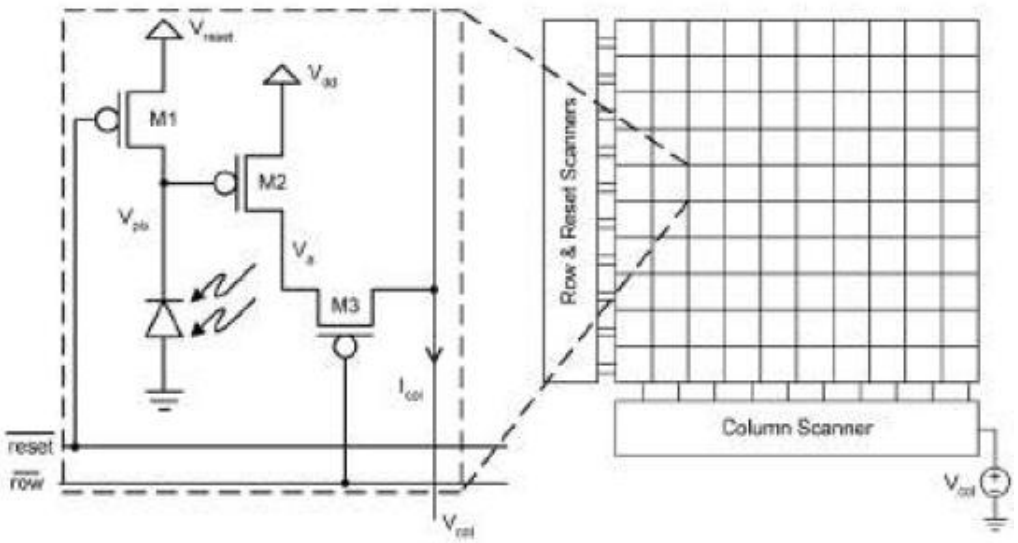


MEMS Accelerometer

- Gyroscope: Rotation Sensor
- Accelerometer: Motion Sensor

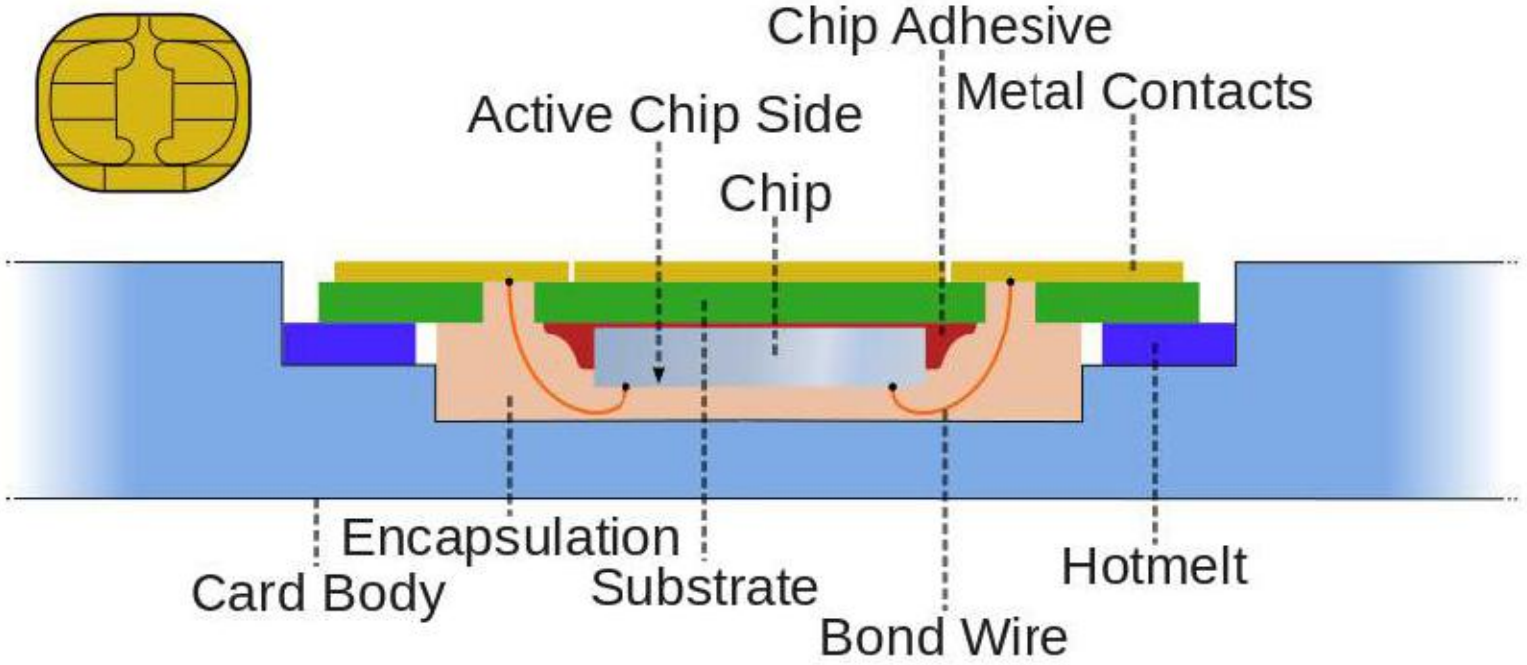
iPhone Camera





- Active Pixel Sensor (APS)
  - Also called CMOS Image Sensor
  - Also used in digital cameras, DSLRs

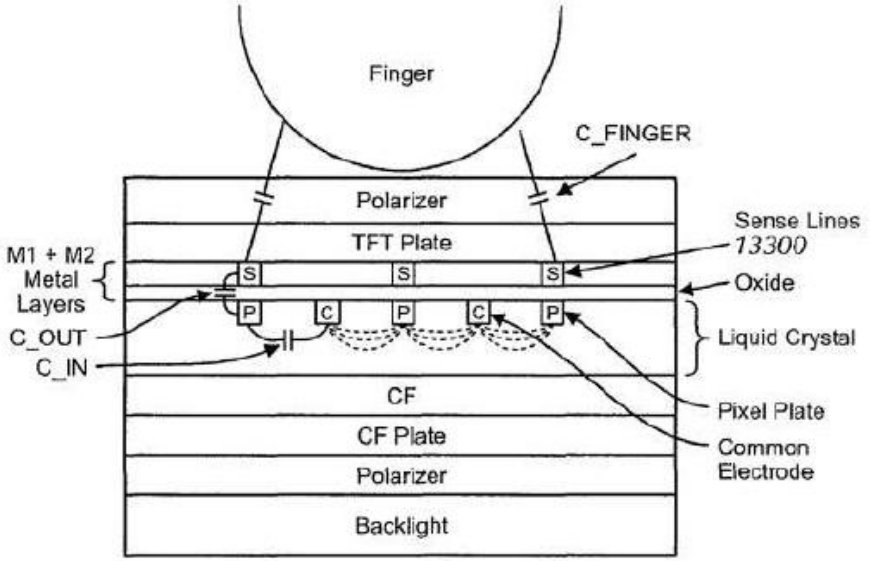
iPhone SIM Card



- Also an Integrated Electronic Circuit

iPhone 5 Touchscreen

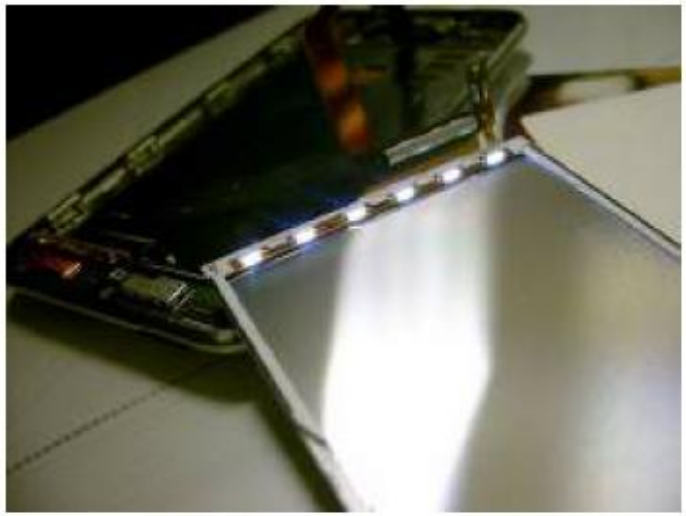
Bent Stumpe, CERN



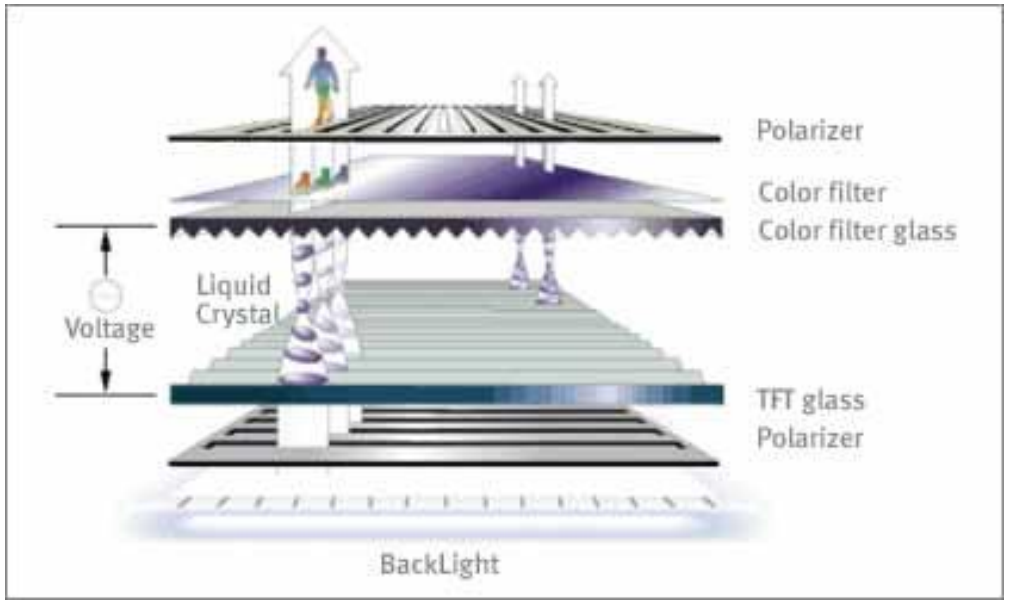
Capacitative touch screens

- Human touch can change the electrostatic field on top of a conducting oxide film and hence the capacitance
  - Location of the touch

iPhone Display

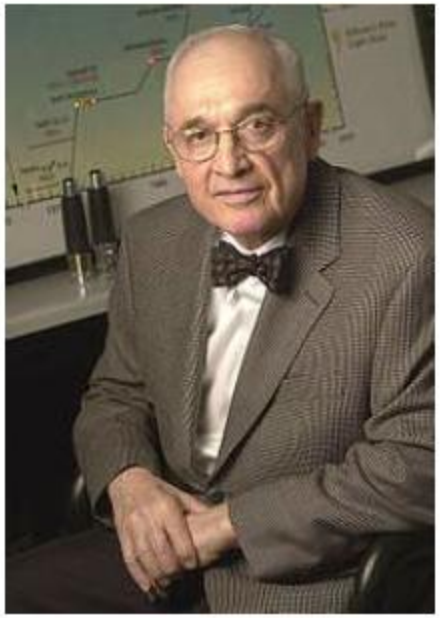


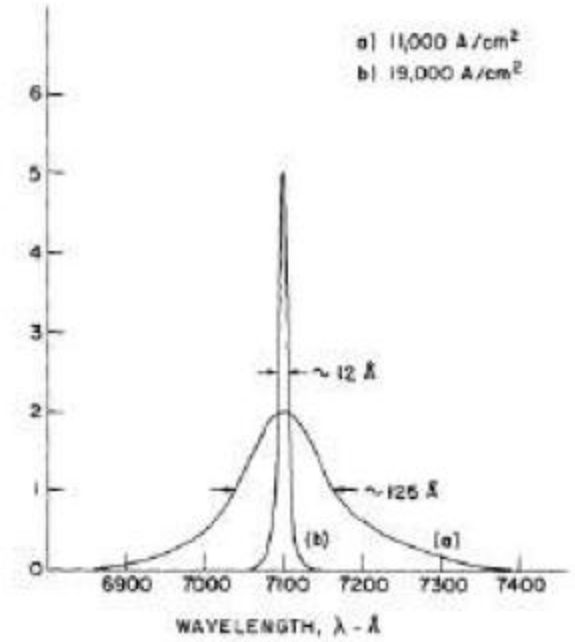
LED backlighting



- 336 PPI (Pixels per inch)

Display History





- Nick Holonyak Jr
- Coherent (visible) light emission from GaAsP junctions
  - Applied Physics Letters (1962)

Why build the iPhone?

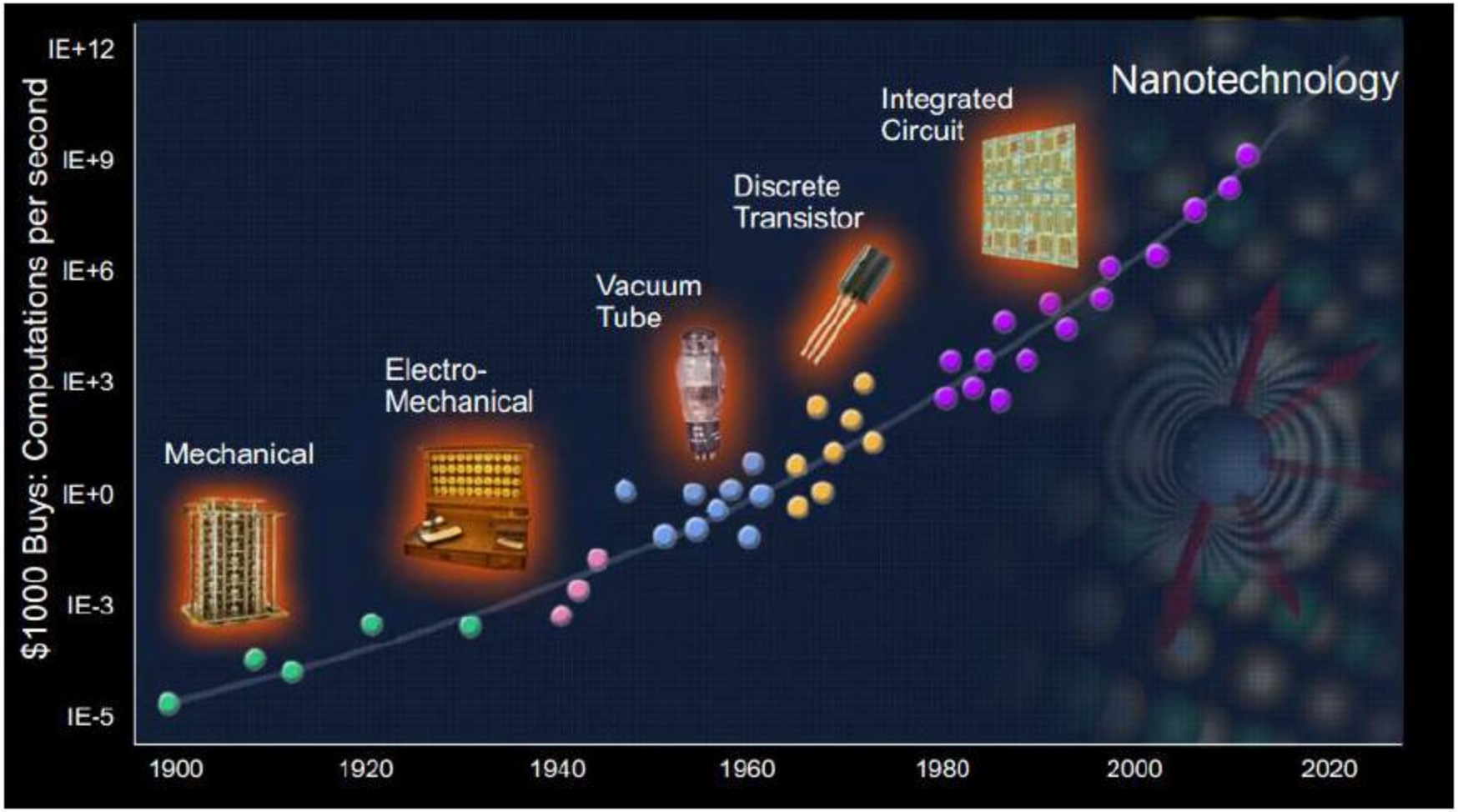
Preliminary iPhone 5 Bill of Materials and Manufacturing Cost Estimate Based on Virtual Teardown (Costs in U.S. Dollars)

Components / Hardware Elements	iPhone 5 Hardware Comments	iPhone 5 Model		
		16GByte	32GByte	64GByte
Pricing without Contract		**$649**	**$749**	**$849**
Total BOM Cost		**$199**	**$209**	**$230**
Manufacturing Cost		**$8.00**	**$8.00**	**$8.00**
BOM + Manufacturing		**$207**	**$217**	**$238**
Major Cost Drivers				
Memory				
NAND Flash		$10.40	$20.80	$41.60
DRAM	1GByte LPDDR2	$10.45	$10.45	$10.45
Display & Touchscreen		$44.00	$44.00	$44.00
Processor	A6 Processor	$17.50	$17.50	$17.50
Camera(s)	8 Megapixel + 1. 2 Megapixel	$18.00	$18.00	$18.00
Wireless Section - BB/RF/PA	Qualcomm MDM9615+RTR8600+Front End*	$34.00	$34.00	$34.00
User Interface & Sensors		$6.50	$6.50	$6.50
BT / WLAN	BTv4.0 + Dual-Band Wireless-N	$5.00	$5.00	$5.00
Power Management		$8.50	$8.50	$8.50
Battery	Assumed 1800mAh	$4.50	$4.50	$4.50
Mechanical / Electro-Mechanical		$33.00	$33.00	$33.00
Box Contents		$7.00	$7.00	$7.00

* - Assumed

Source: IHS iSuppli Research, September 2012

Computational Capability



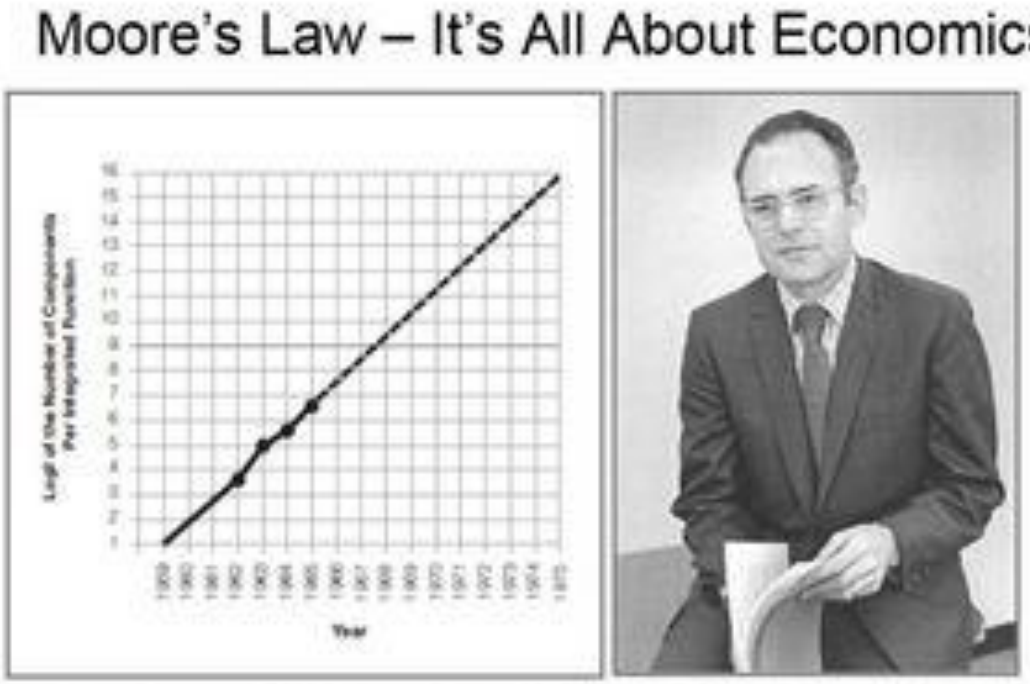
Source: Kurzweil 1999 - Moravec 1998

Levels of Integration in ICs

Integration level	Number devices	Approx. year
Small scale integration (SSI)	10 - 50	1959
Medium scale integration (MSI)	50 - 10^3	1960s
Large scale integration (LSI)	10^3 - 10^4	1970s
Very large scale integration (VLSI)	10^4 - 10^6	1980s
Ultra large scale integration (ULSI)	10^6 - 10^8	1990s
Giga scale integration	10^9 - 10^{10}	2000s

- Current research focus on “Exa-scale Computing”- 10^{18} flops

Moore's Law



- Integrating more components per chip
  - Roughly 2X every 18 months
  - Unit cost falls as number of components per chip increases

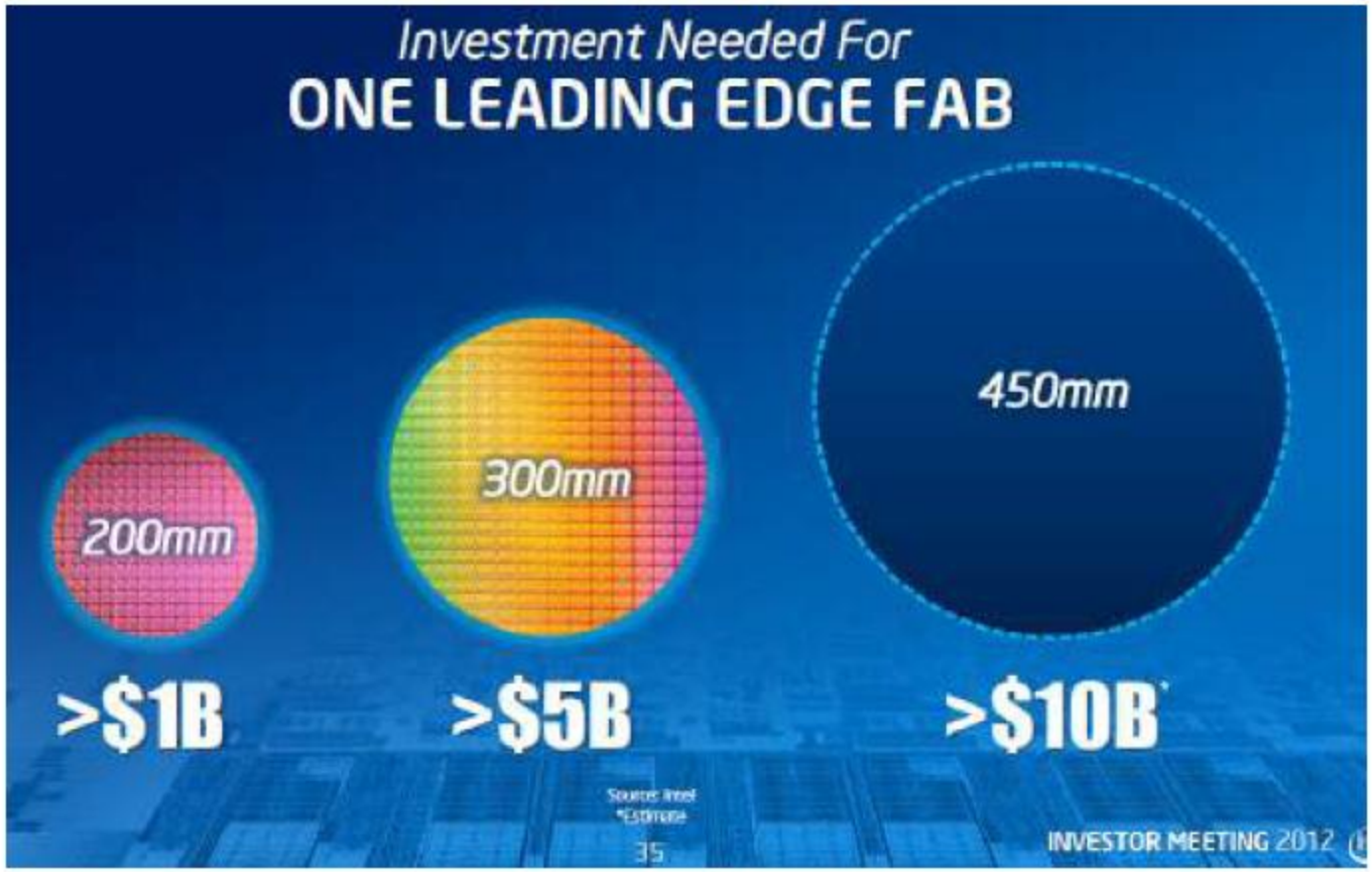
Moore's Law: Transistor Innovation

- Source: Intel

Average transistor price per year

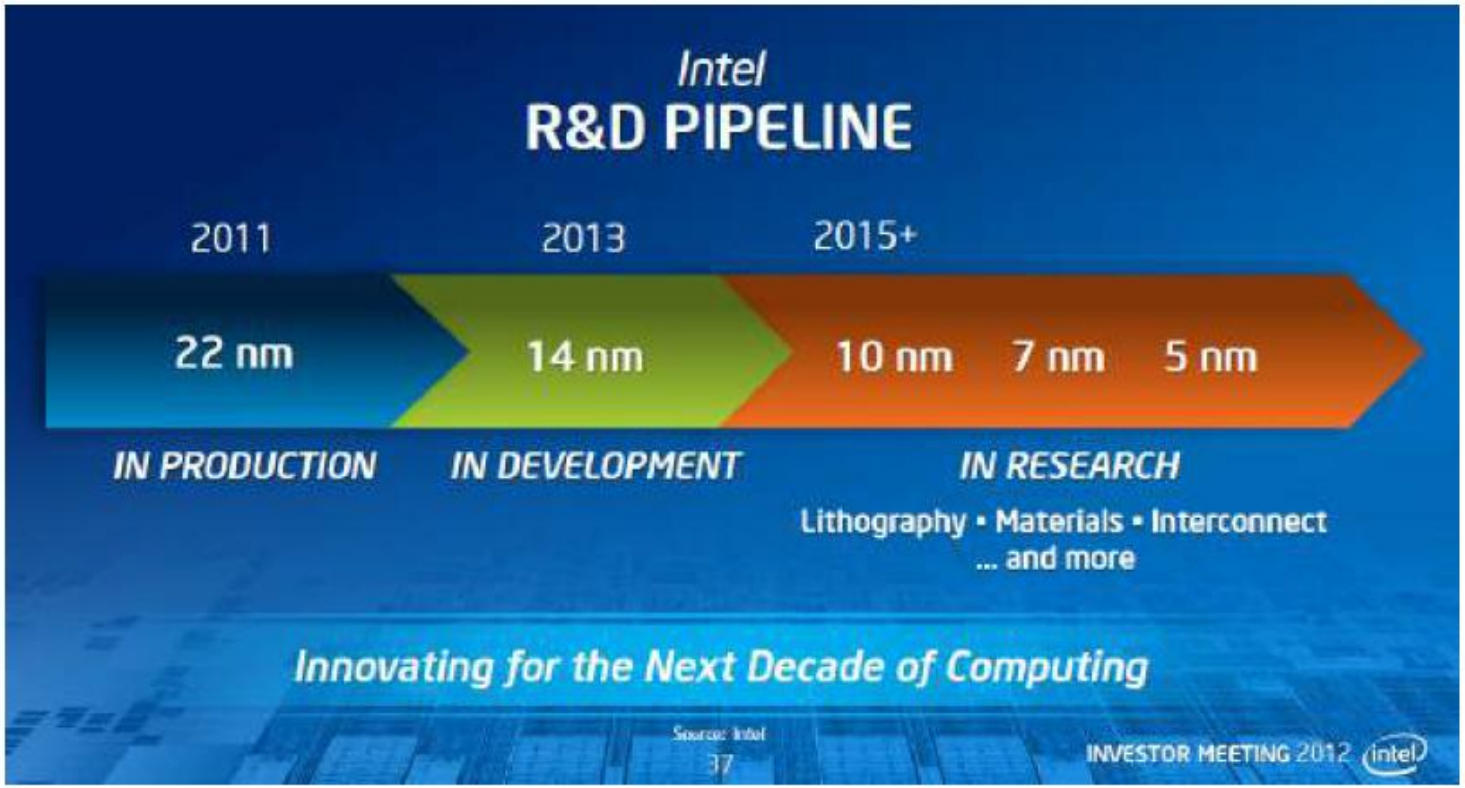
- Source: G. Moore

Price per FAB (IC factory)



- Source: Intel

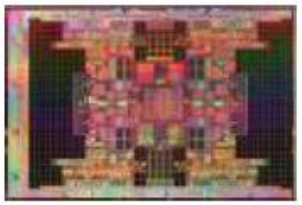
Moore's Law



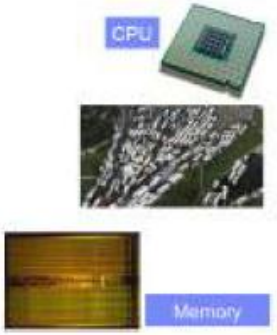
- Source: Intel

Microprocessor evolution: Latency perspective

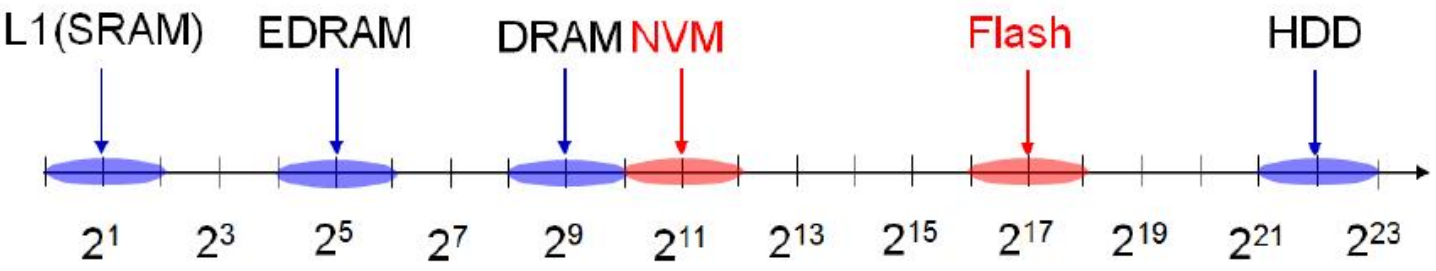
80486, circa 1990
1.2 Million Transistors



Tukwila, circa 2010
2 Billion Transistors



Source: www.intel.com



Typical access latency in processor cycles (@ 4 GHz)

- Source: Prof. M. Qureshi

Next Class

- Video on IC Manufacturing Process
- Introduction to semiconductor devices