ELEC3221

# Digital IC & Sytems Design


Iain McNally

$\approx$ 10 lectures

Koushik Maharatna

$\approx$ 12 lectures

Basel Halak

$\approx$ 12 lectures


1001

ELEC3221 / ELEC6241

# Digital IC & Sytems Design
# SoC Design Techniques


Iain McNally

≈ 10 lectures

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ELEC3221 / ELEC6241- *module merge for 2016/2017*

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1001

# Digital IC & Sytems Design

- Assessment

  10% Coursework L-Edit Gate Design (BIM)

  90% Examination

- Books

  **Integrated Circuit Design**

  a.k.a. Principles of CMOS VLSI Design - A Circuits and Systems Perspective

  Neil Weste & David Harris

  Pearson, 2011

  **Digital System Design with SystemVerilog**

  Mark Zwolinski

  Pearson Prentice-Hall, 2010

Iain McNally

# Integrated Circuit Design

- Content
  - Introduction
  - Overview of Technologies
  - Layout
  - CMOS Processing
  - Design Rules and Abstraction
  - Cell Design and Euler Paths
  - System Design using Standard Cells
  - Wider View
- Notes & Resources

  `http://users.ecs.soton.ac.uk/bim/notes/icd`

# History

**1947** First Transistor

John Bardeen, Walter Brattain, and William Shockley (Bell Labs)

**1952** Integrated Circuits Proposed

Geoffrey Dummer (Royal Radar Establishment) - *prototype failed...*

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**1965** Moore's Law

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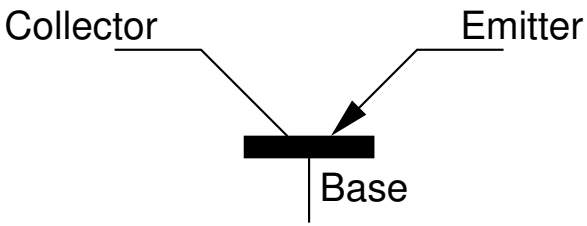
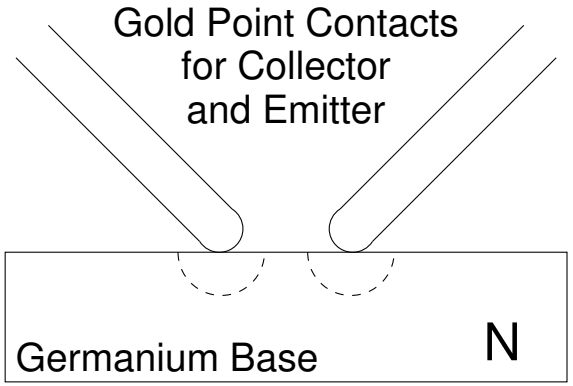
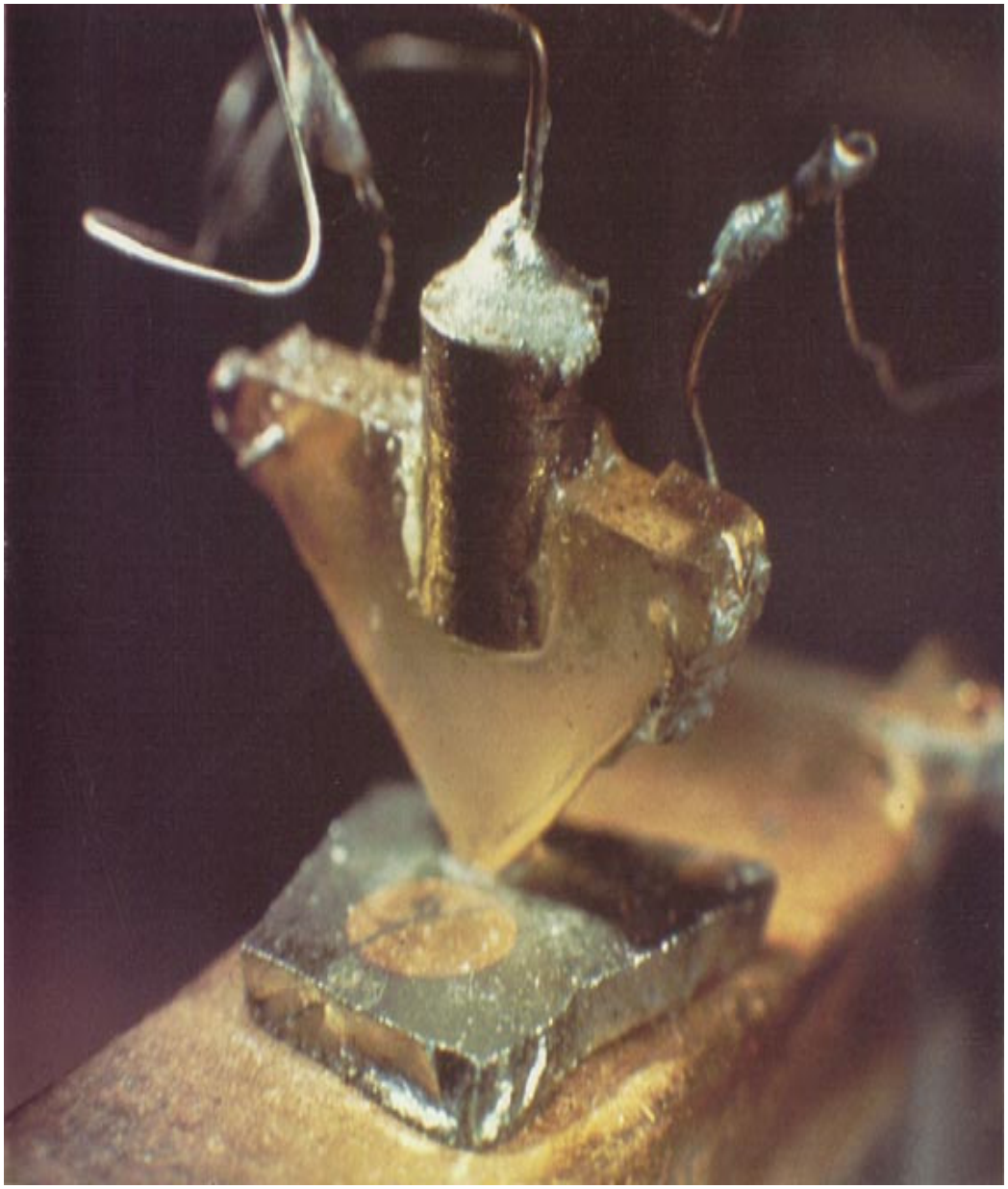
# 1947 Point Contact Transistor




Each contact creates a metal/semiconductor (Schottky) diode

Depletion regions are shown for zero bias voltage.



Source: Bell Labs

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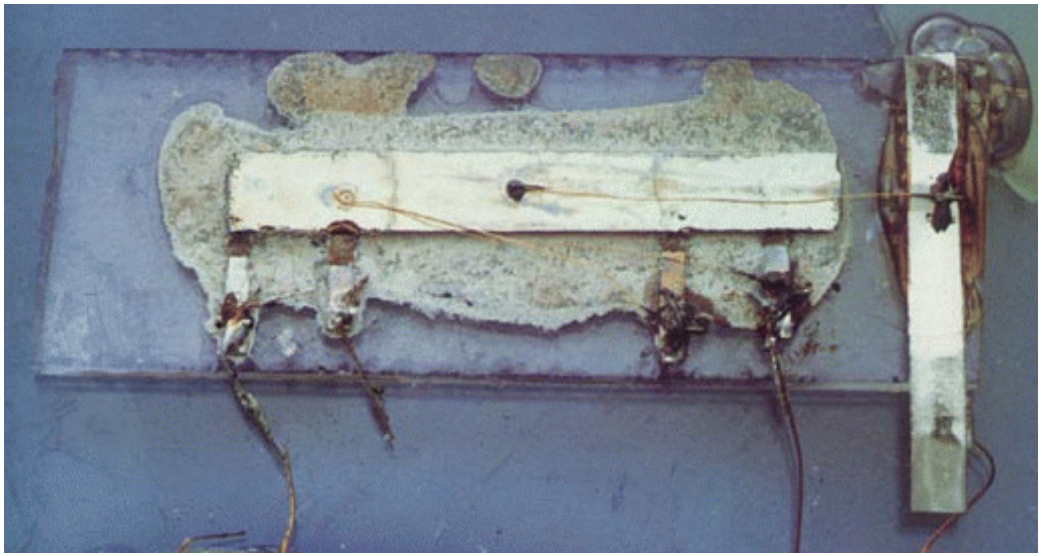
# 1958 First Integrated Circuit

1 Transistor

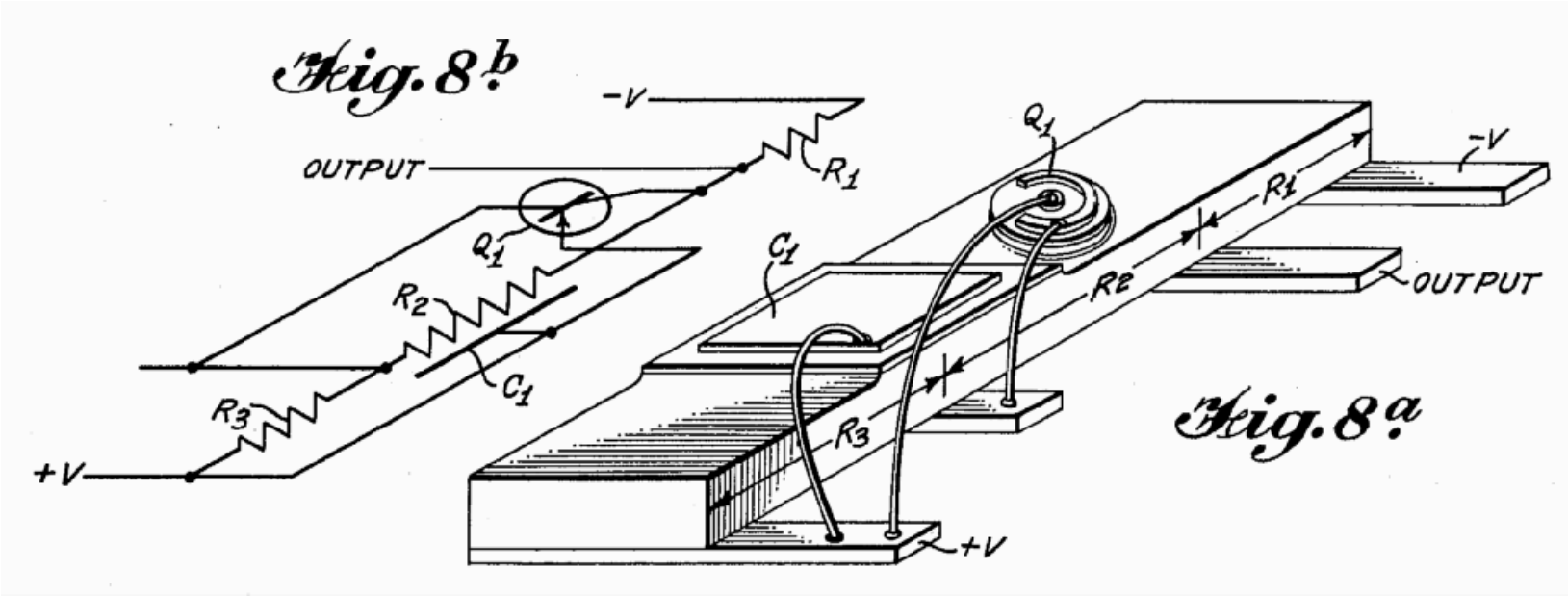
1 Capacitor

3 Resistors

Hand soldered interconnect



Source: Texas Instruments




Source: Jack Kilby (Patent Application)

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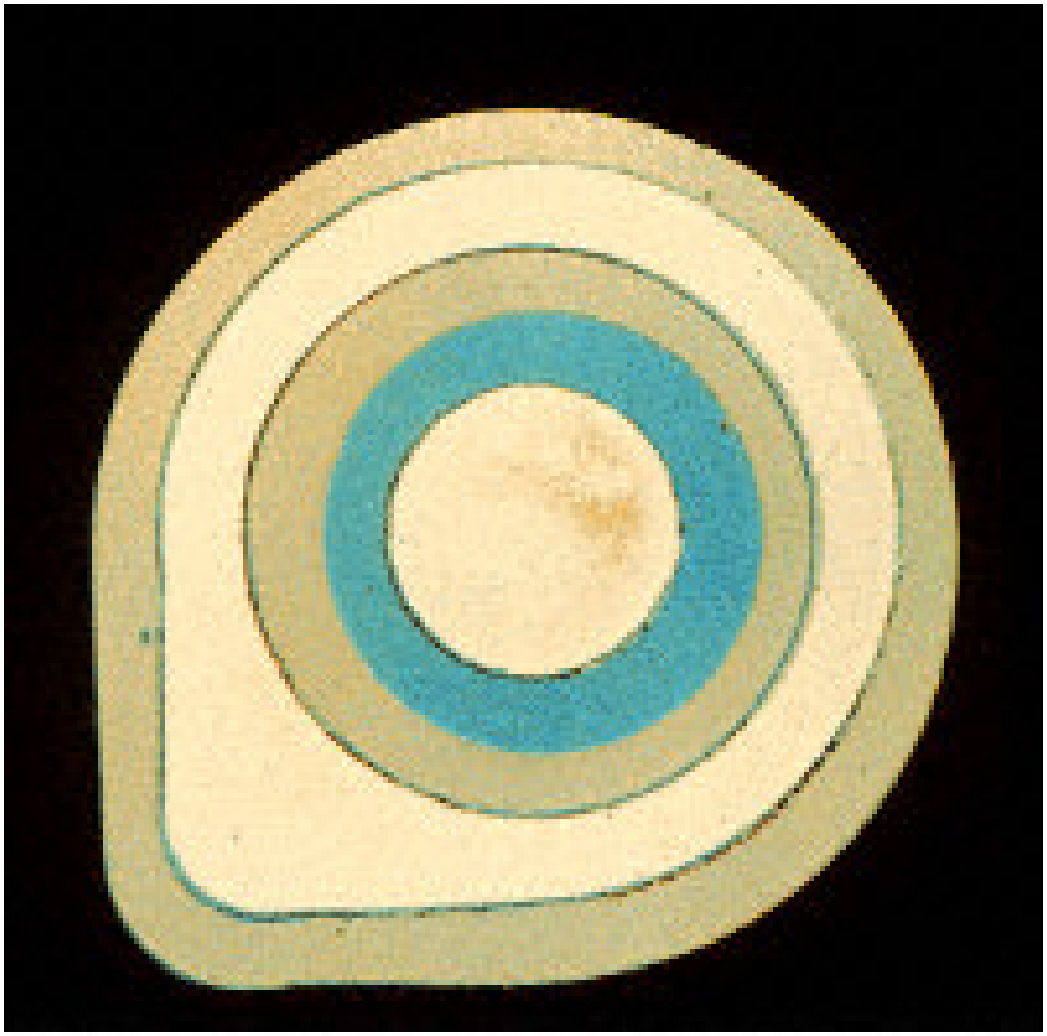

Source: Fairchild

April 25, 1961 R. N. NOYCE 2,981,877

SEMICONDUCTOR DEVICE-AND-LEAD STRUCTURE

Filed July 30, 1959 3 Sheets-Sheet 2

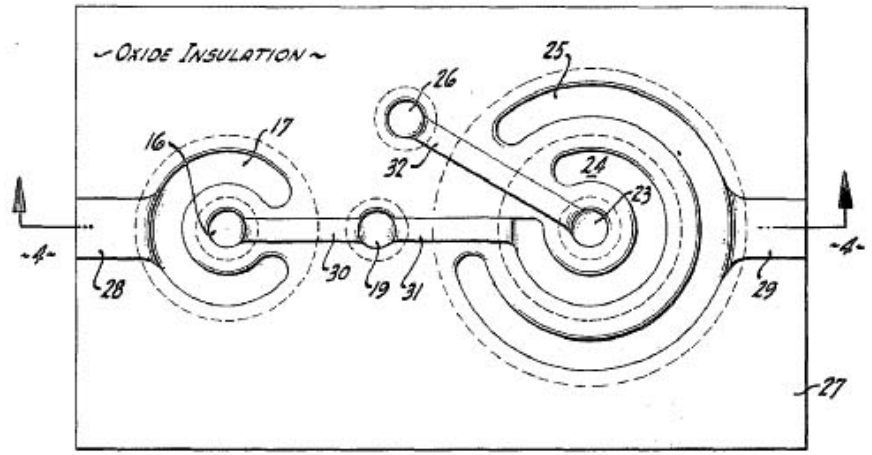


FIG. 3

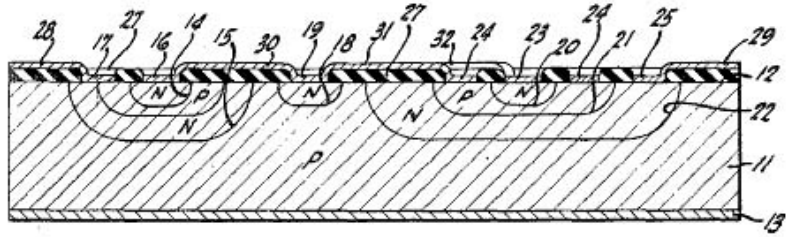


FIG. 4

Source: Robert Noyce (Patent Application)

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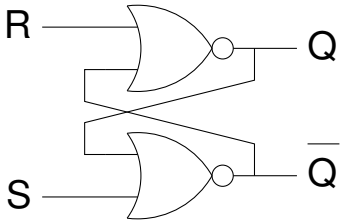
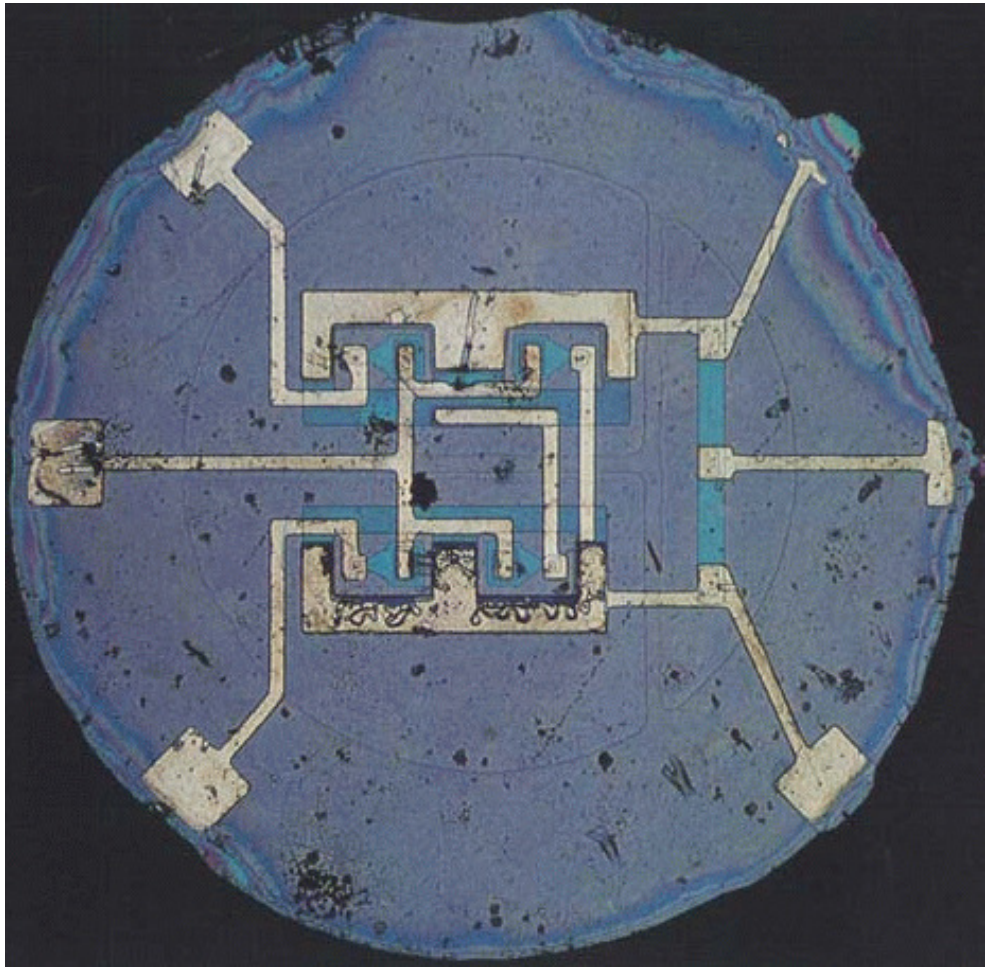
# 1961 First Commercial ICs

Fairchild Bipolar RTL RS Flip−Flop

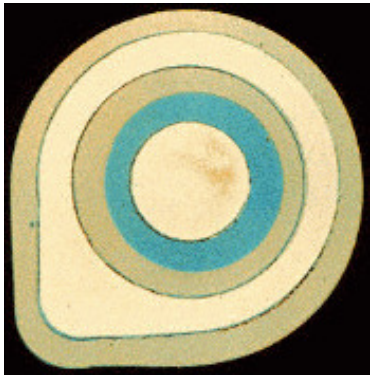


Source: Fairchild

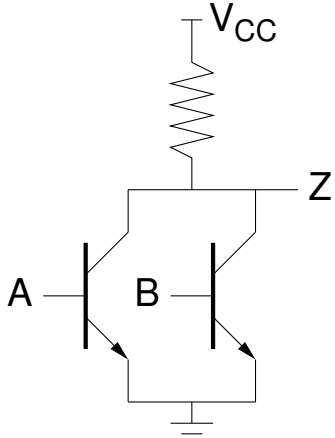
Using

- Planar Bipolar Transistors



Source: Fairchild

- Back to back PN junctions to provide isolation
- Integrated interconnect
- Resistor Transistor Logic




RTL NOR gate

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# Moore's Law

Predicts exponential growth in the number of components per chip.

## **1965 - 1975** Doubling Every Year

In 1965 Gordon Moore observed that the number of components per chip had doubled every year since 1959 and predicted that the trend would continue through to 1975.

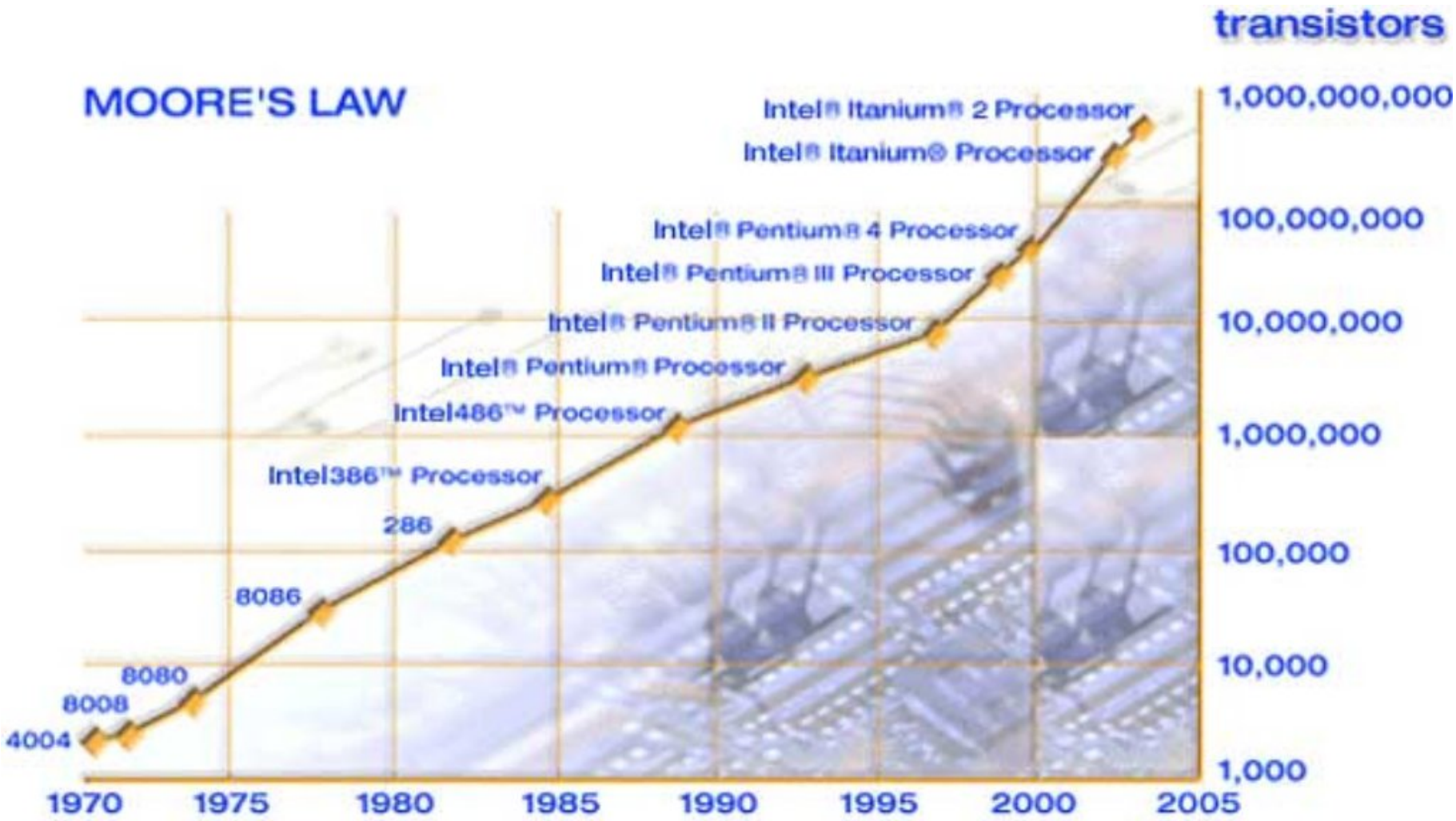
Moore describes his initial growth predictions as "ridiculously precise".

## **1975 - 201?** Doubling Every Two Years

In 1975 Moore revised growth predictions to doubling every two years.

Growth would now depend only on process improvements rather than on more efficient packing of components.

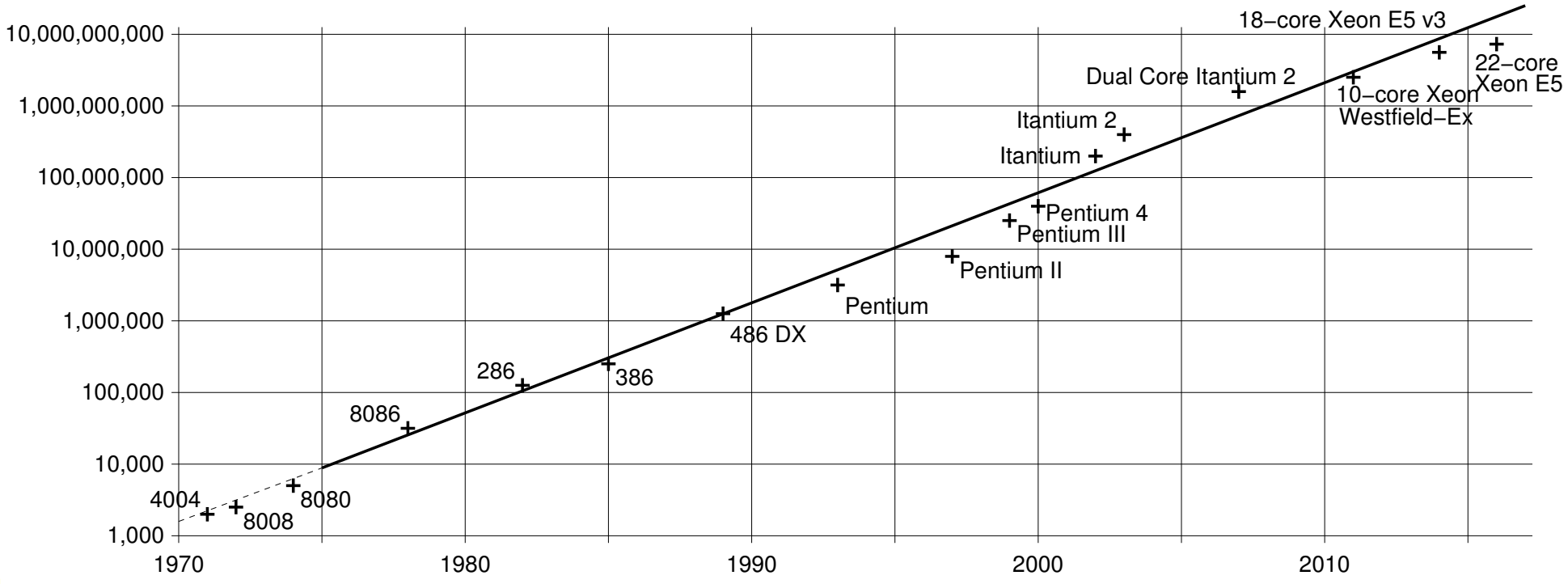
In 2000 he predicted that the growth would continue at the same rate for another 10-15 years before slowing due to physical limits.




Source: Intel

# History

## Moore's Law at Intel[1]




[1]Intel was founded by Gordon Moore and Robert Noyce from Fairchild

## Moore's Law; a Self-fulfilling Prophesy

The whole industry uses the Moore's Law curve to plan new fabrication facilities.

**Slower** - wasted investment

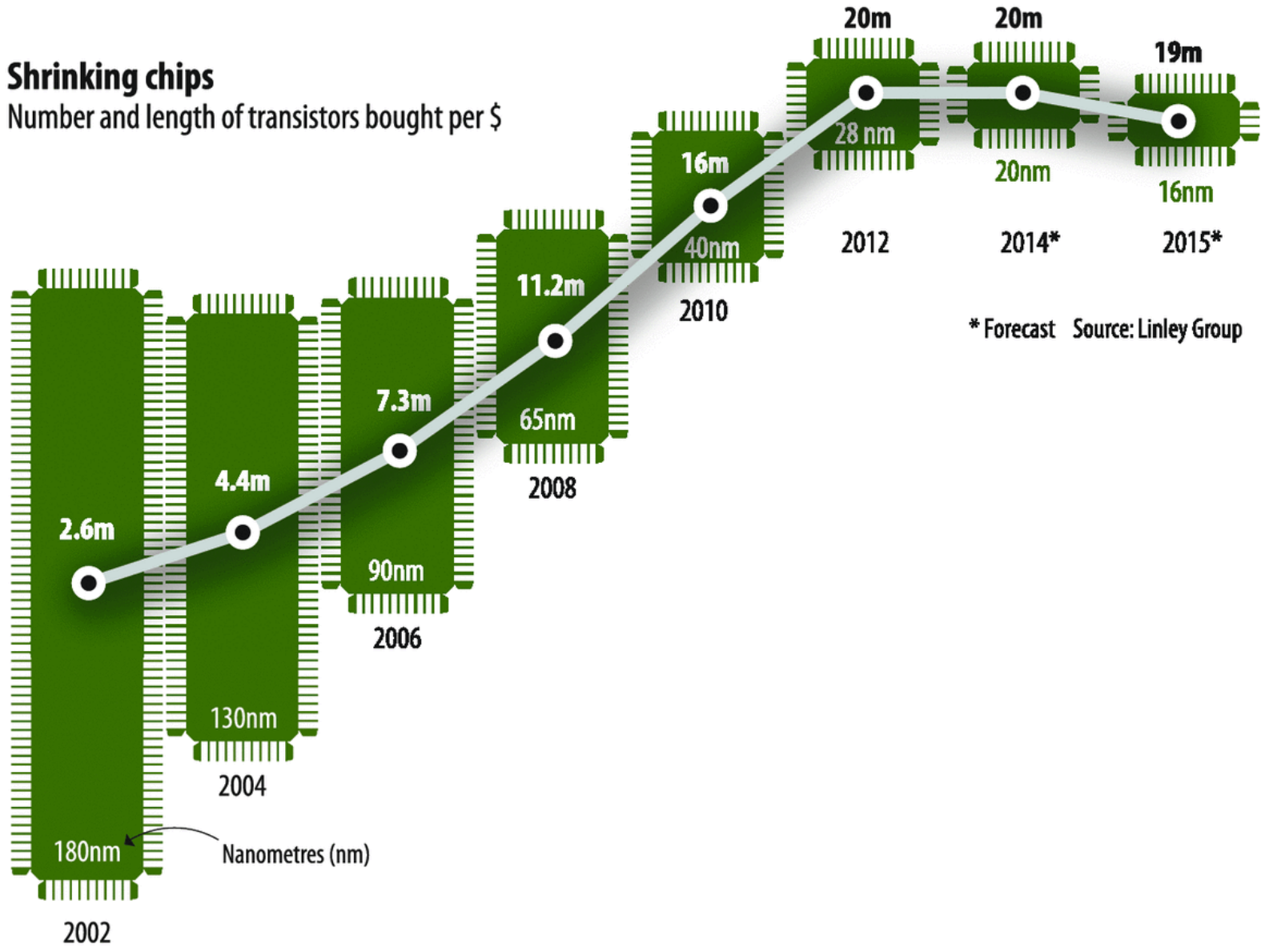
Must keep up with the Joneses[2].

**Faster** - too costly

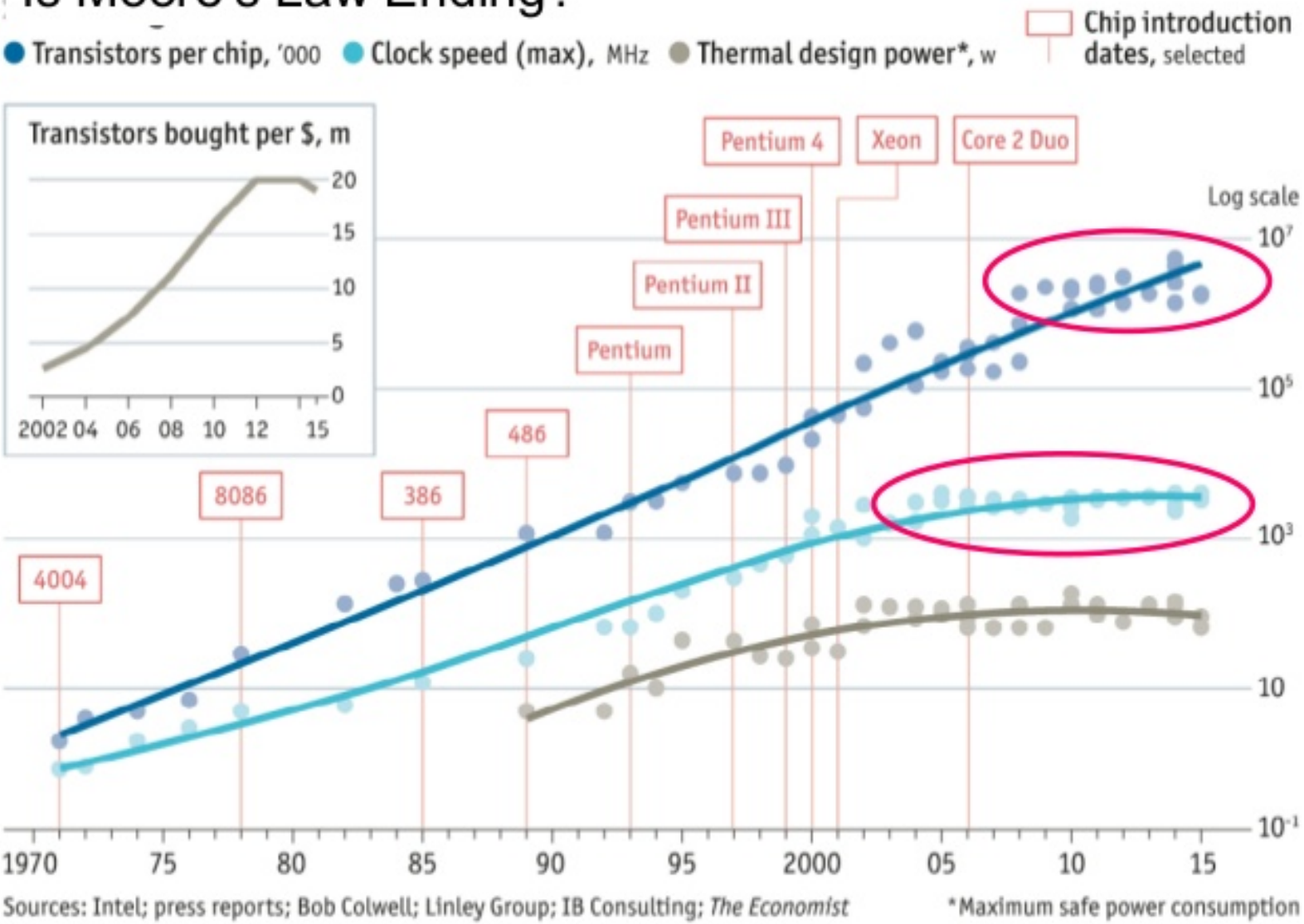
Cost of capital equipment to build ICs doubles approximately every 4 years.

*Moore's law is not dead (at least not quite), although there are worries that below 20nm, clever processing required for smaller transistors means that cost per transistor goes up rather than down.*

[2]or the Intels

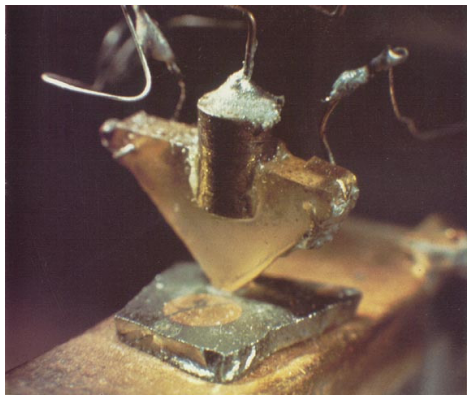

Shrinking chips
Number and length of transistors bought per $
2.6m
180nm
2002
4.4m
130nm
2004
7.3m
90nm
2006
11.2m
65nm
2008
16m
40nm
2010
20m
28 nm
2012
20m
20nm
2014*
19m
16nm
2015*
Nanometres (nm)
* Forecast Source: Linley Group

# Is Moore's Law Ending?

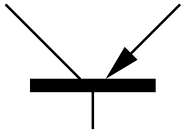



Economist, March 12-18, 2016

1947 Point Contact transistor

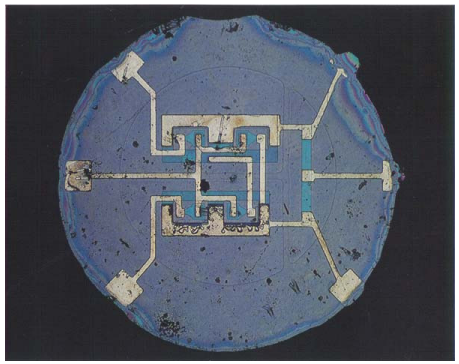


Source: Bell Labs

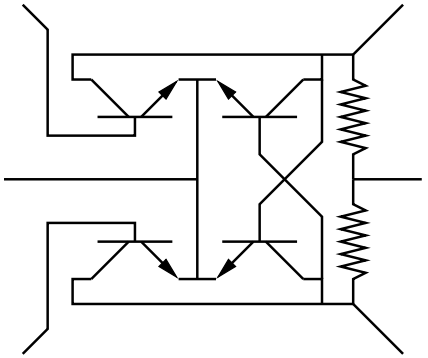


1961 Fairchild Bipolar RTL RS Flip–Flop

(4 Transistors)

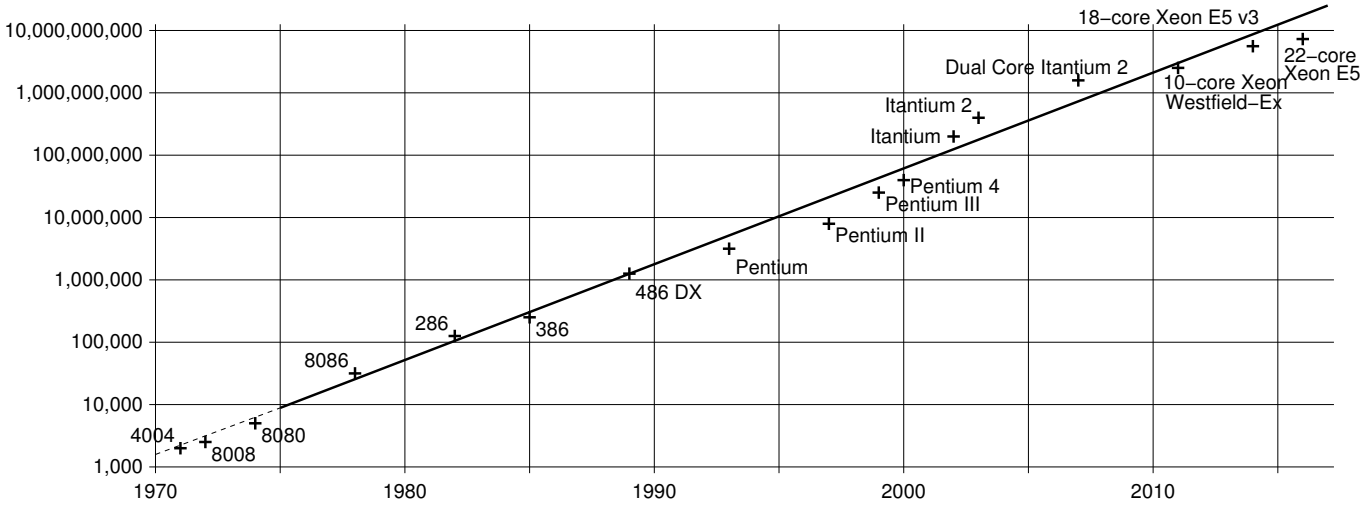


Source: Fairchild



Moore's Law (1965) Number of transistor has doubled every year and will continue to do so until 1975

Moore's Law (1975) Number of transistors will double every two years




Self–fulfilling Prophecy