THE SEMICONDUCTOR INDUSTRY

FROM A GRAIN OF SAND TECHNOLOGY EMERGES

Dr. Alaa Alani BSc PhD MIET CEng

ALKINDI SOCIETY OF ENGINEERS
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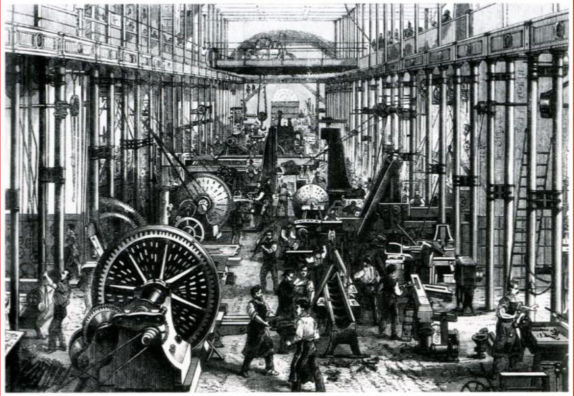
AGENDA

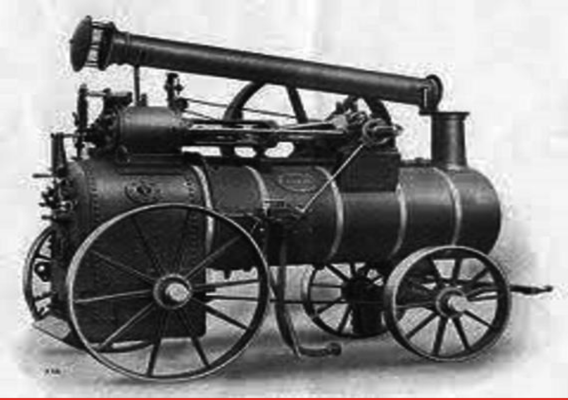
- History & Evolution
- Fourth Industrial Revolution
- Advances in Electronics
- Semiconductors
  - Design Flow
  - Manufacturing
  - Microprocessor Examples
  - Supercomputers
- Global Semiconductor Market
- Electronics in Various Countries
- The Middle East
- Challenges and Opportunities
- Q&A

HISTORY & EVOLUTION

- **First IR: 1760-1840**
  - Mechanisation
  - Iron production
  - Steam power
  - Chemical manufacturing

Great Britain

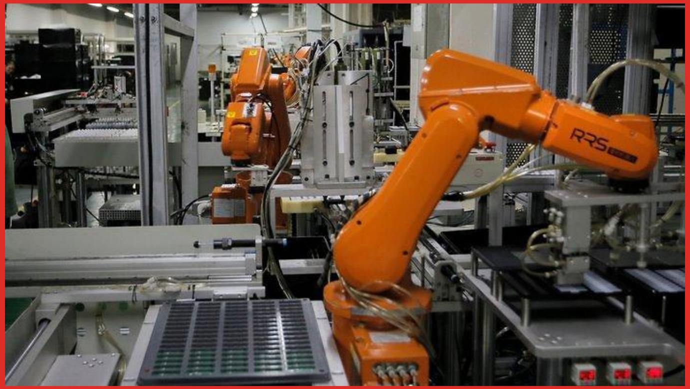




- **Second IR: 19th Century**
  - Rapid industrialisation
  - Production technology
  - Electrical power
  - Telegraph
  - Rail roads

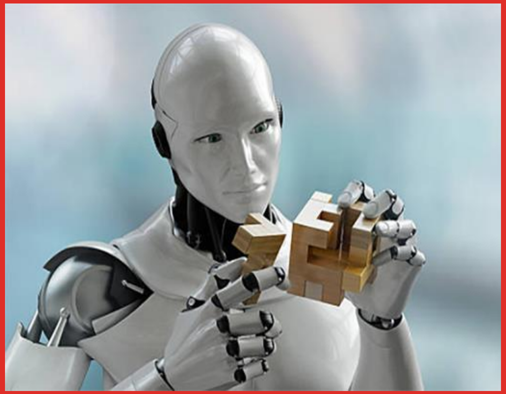
HISTORY & EVOLUTION (CONT.)

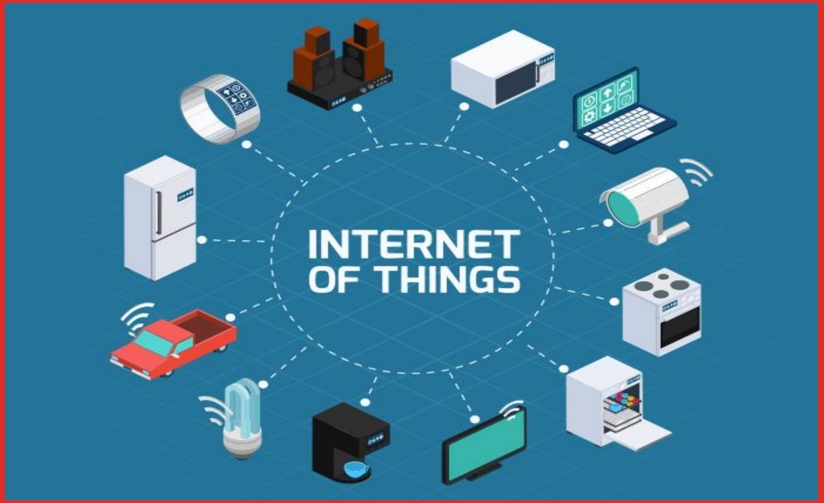
- **Third IR: 1950-1970**
    - Digitalisation
    - Computer
    - Communication technology
    - Information technology

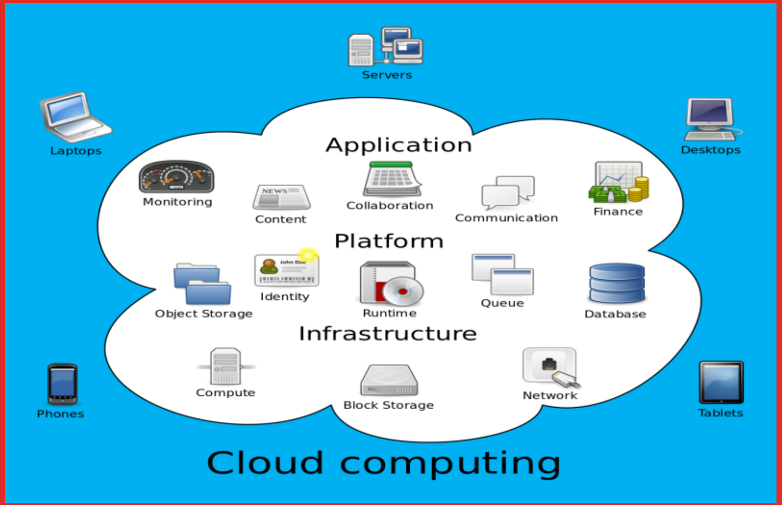


4TH INDUSTRIAL REVOLUTION

- **Fourth IR: Today**
  - Mix of science & technology
  - Robotics
  - Artificial intelligence
  - Deep learning
  - Internet of things
  - Cloud computing

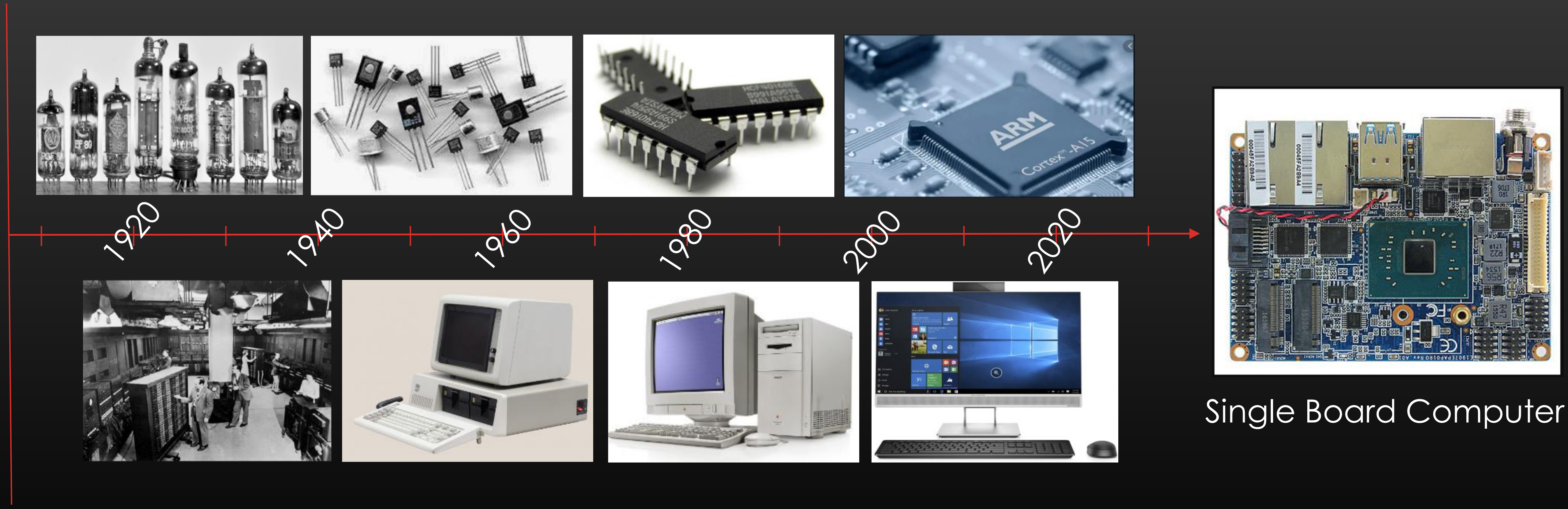






ADVANCES IN ELECTRONICS

Electronic Devices

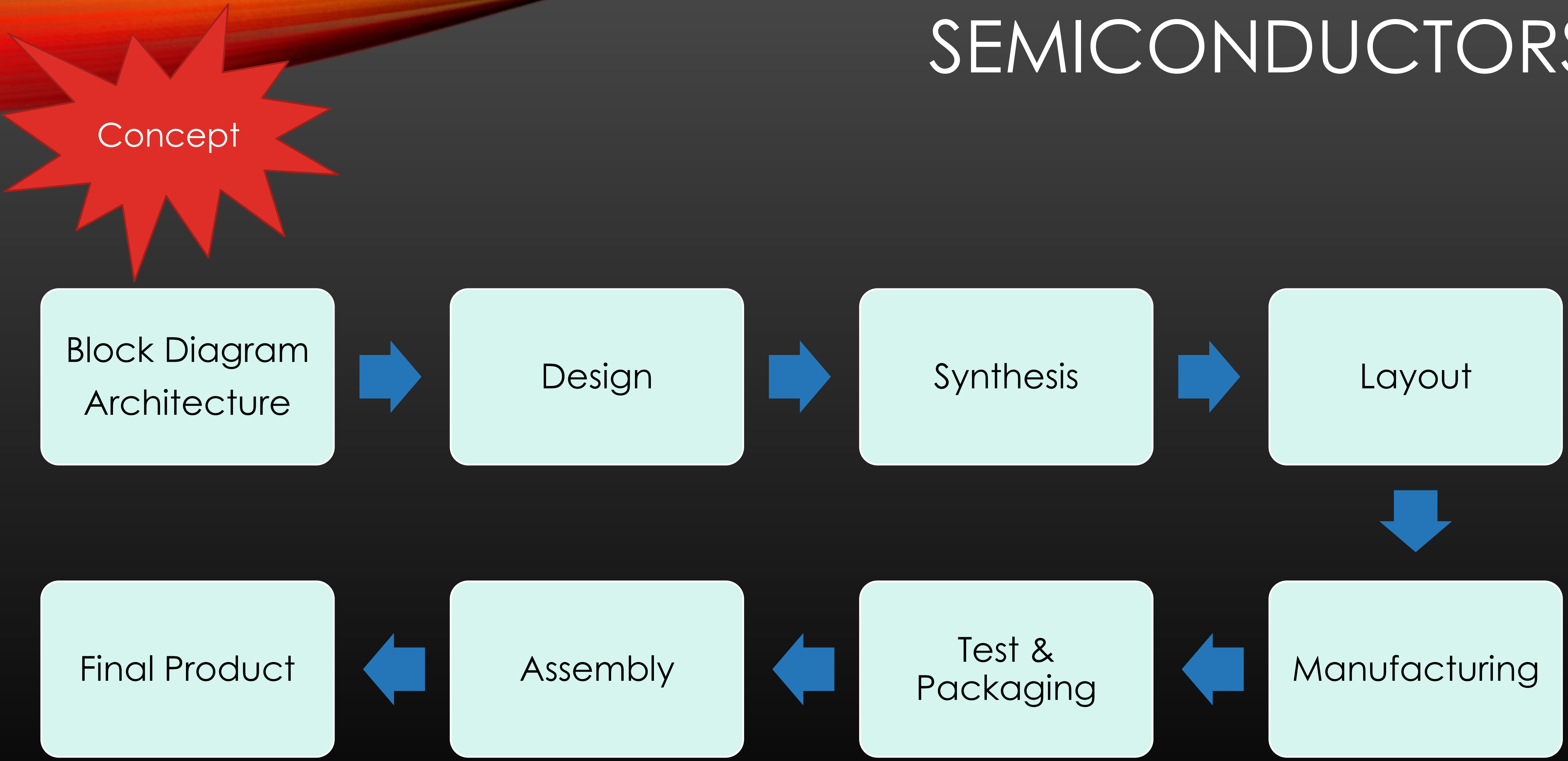


Computers

SEMICONDUCTORS

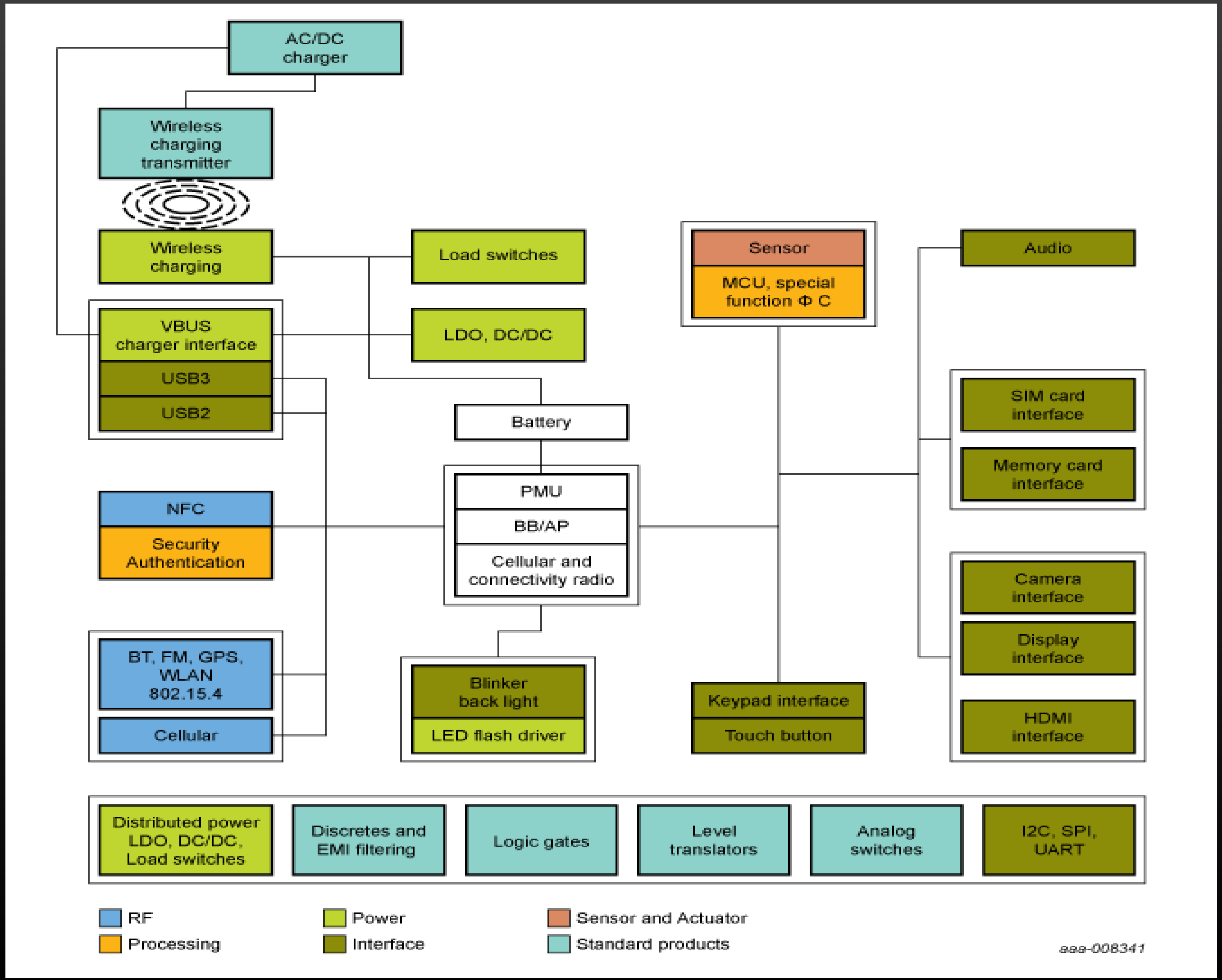
أشباه الموصلات

SEMICONDUCTORS



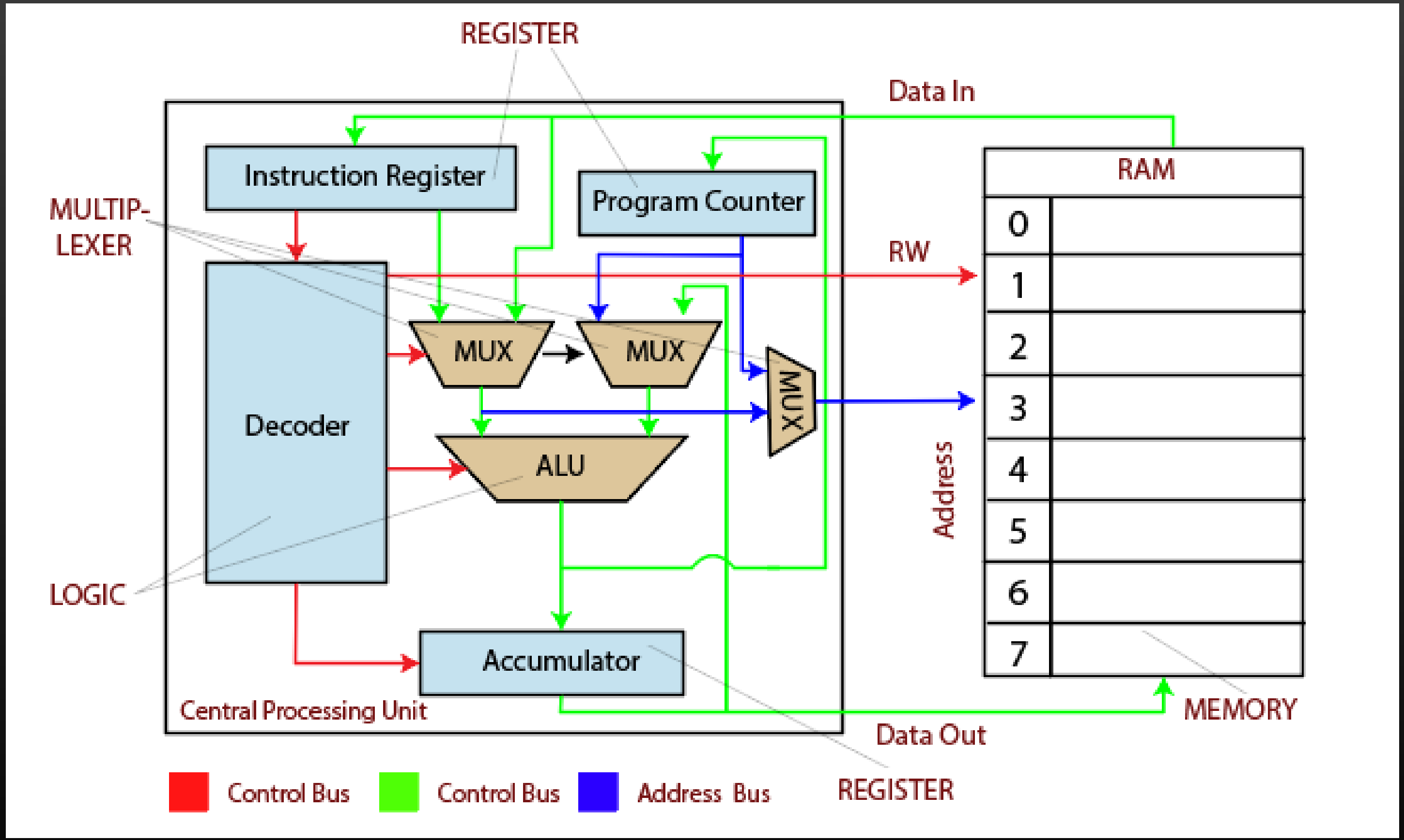
SEMICONDUCTORS

Block Diagram Architecture



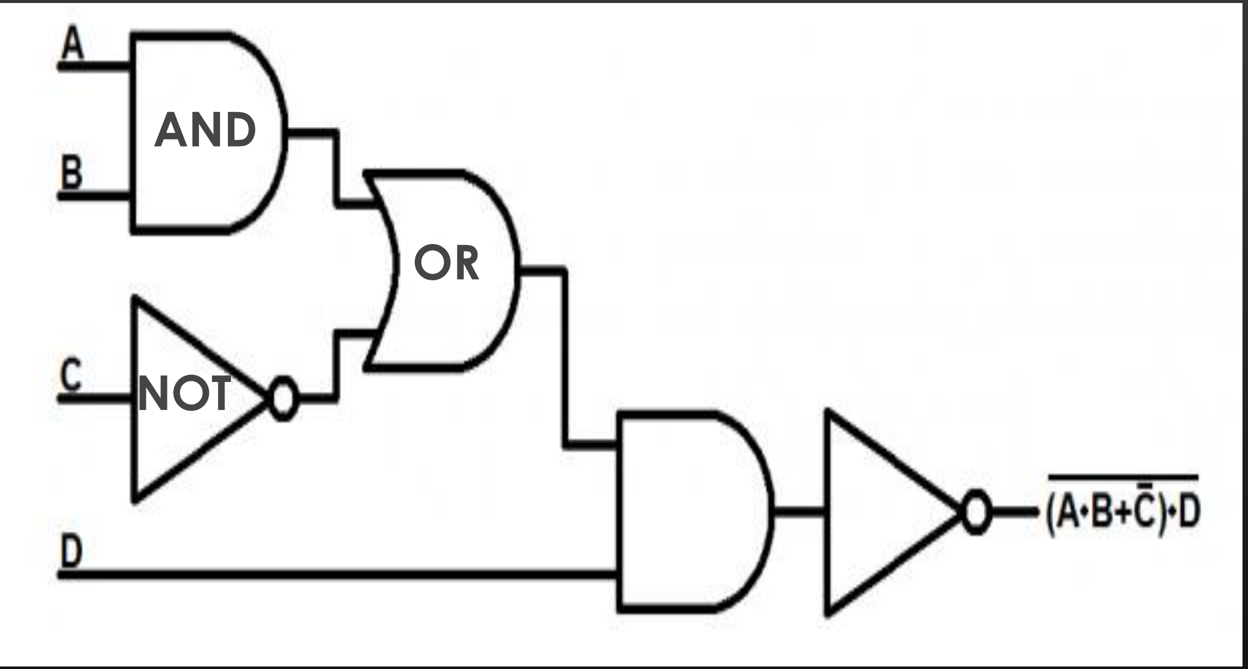
SEMICONDUCTORS

Design



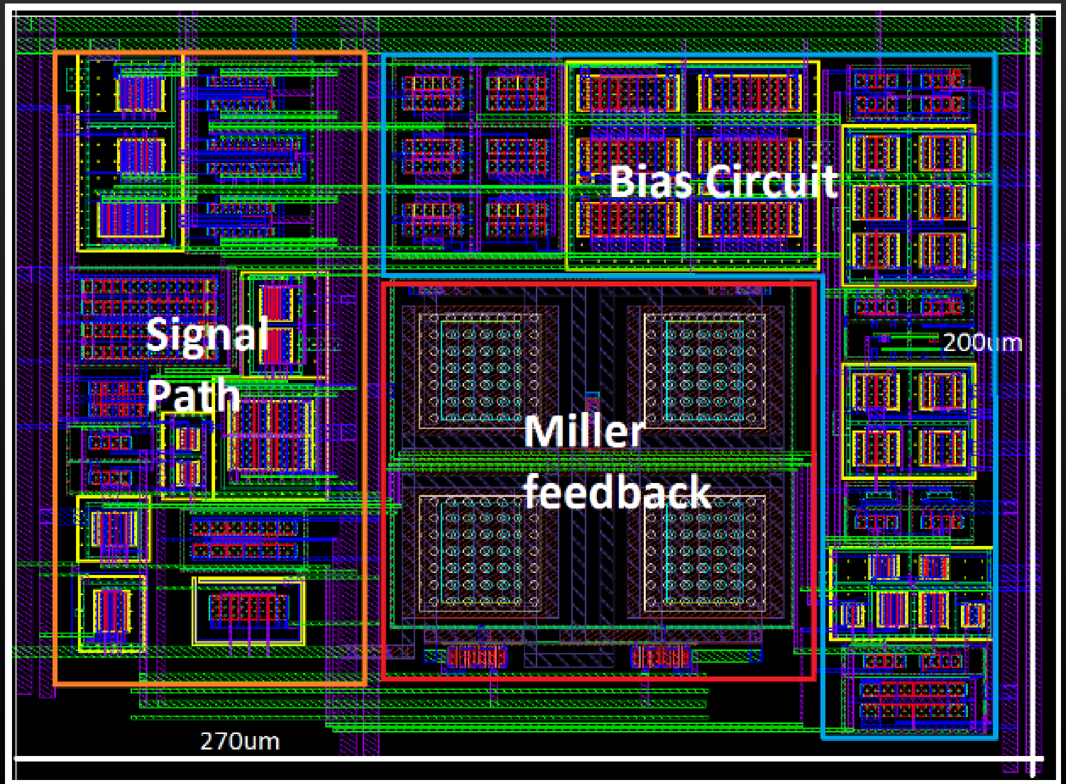
SEMICONDUCTORS

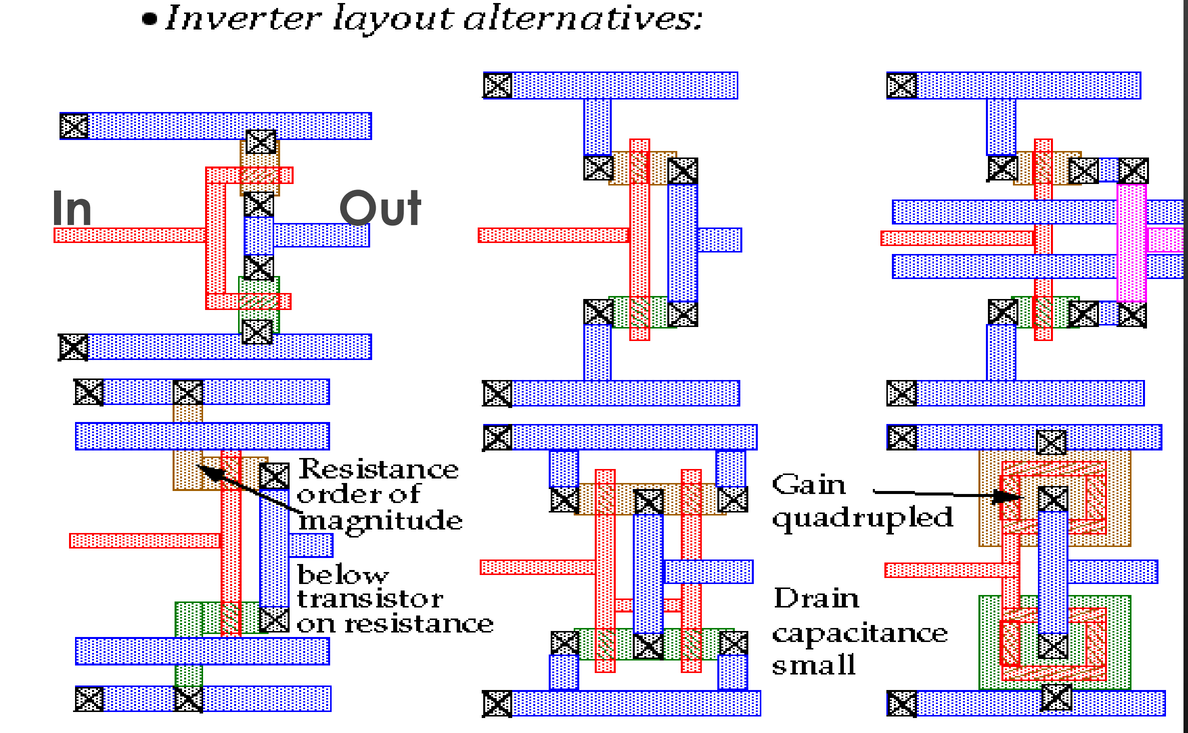
Synthesis



SEMICONDUCTORS

Layout

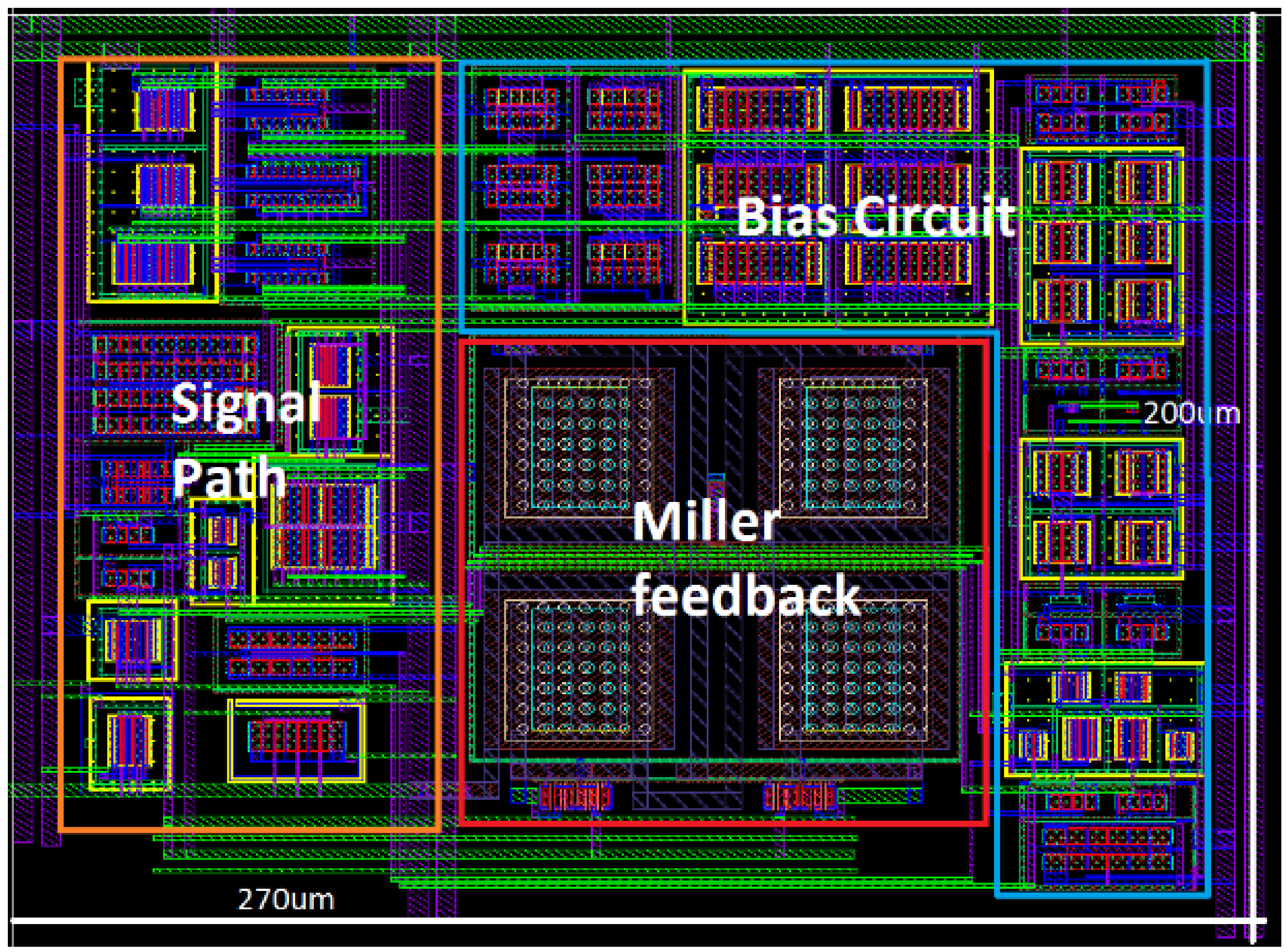




Basic Physical Design of Simple Logic Gates

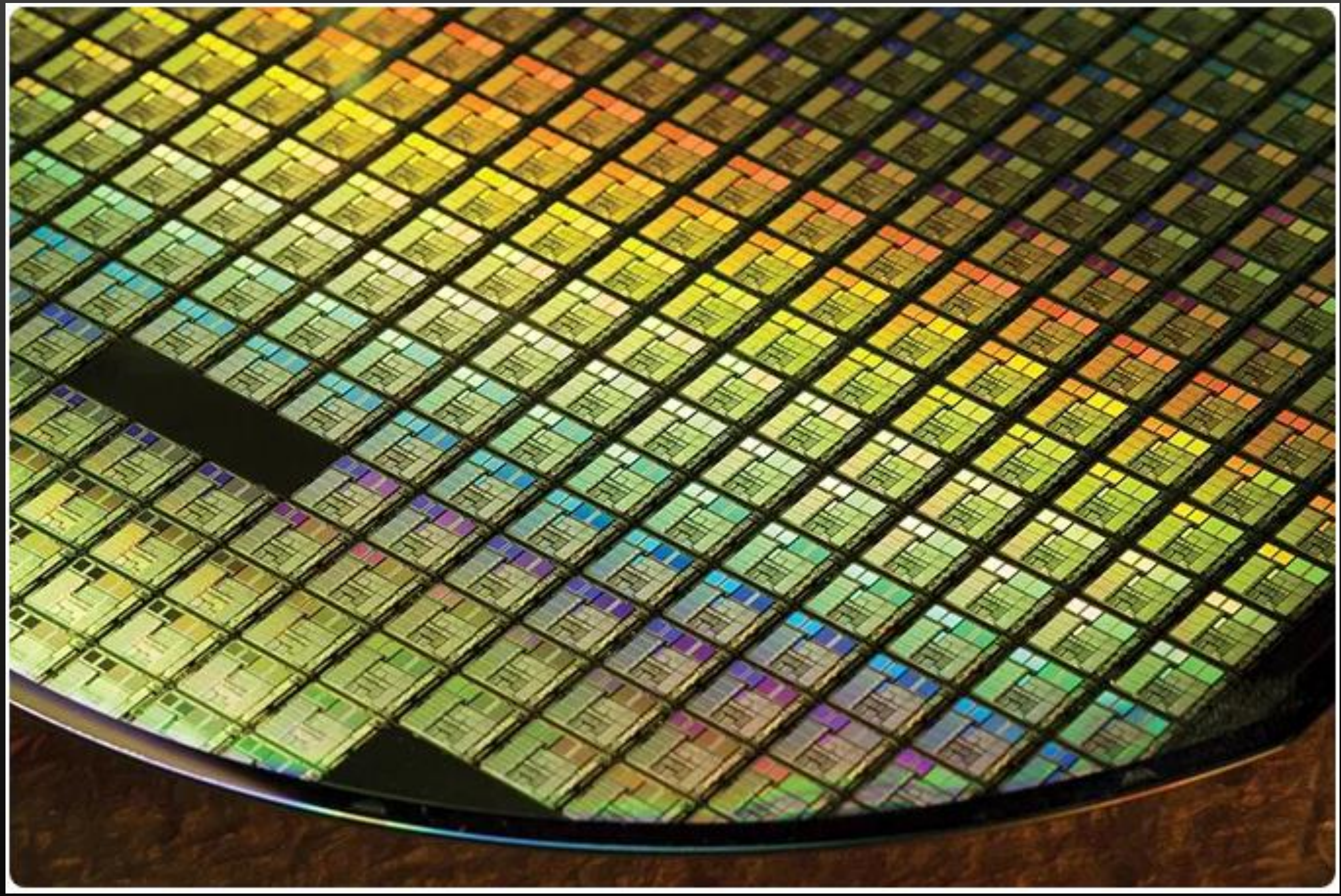
SEMICONDUCTORS

Layout



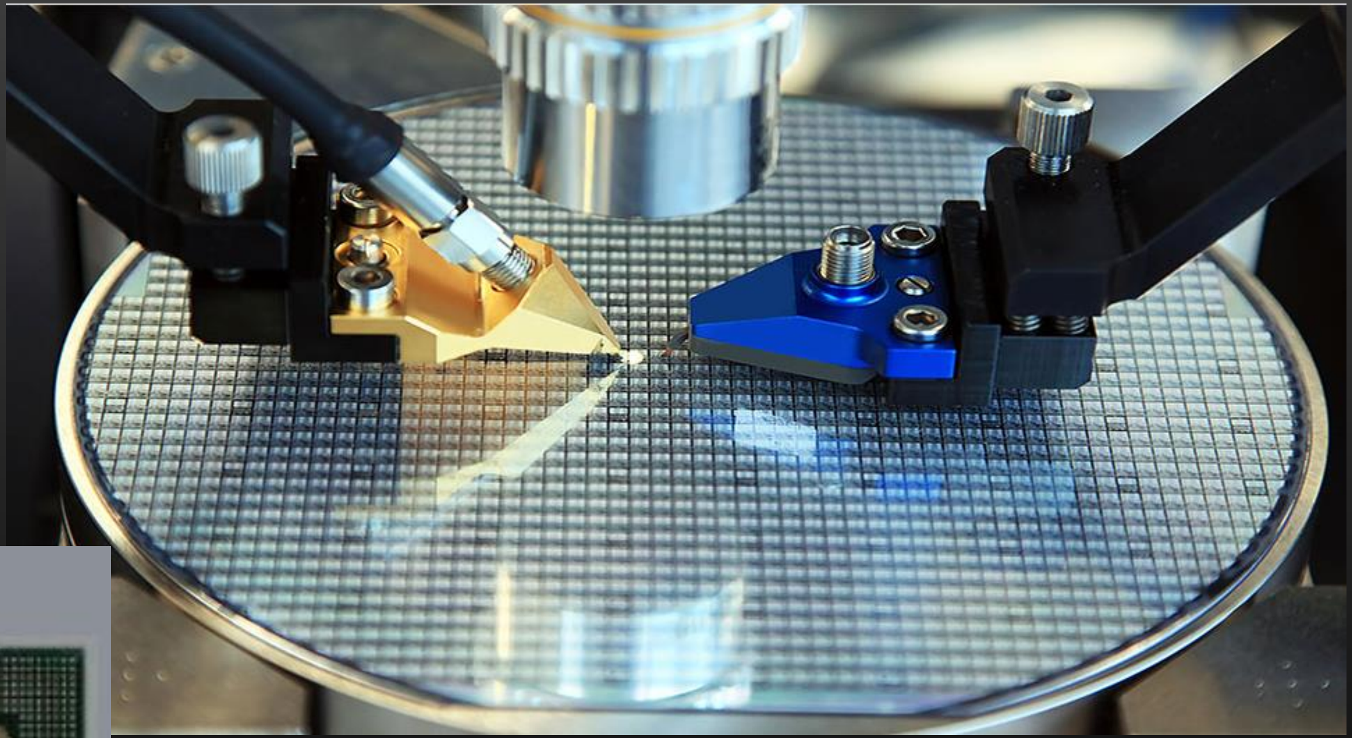
SEMICONDUCTORS

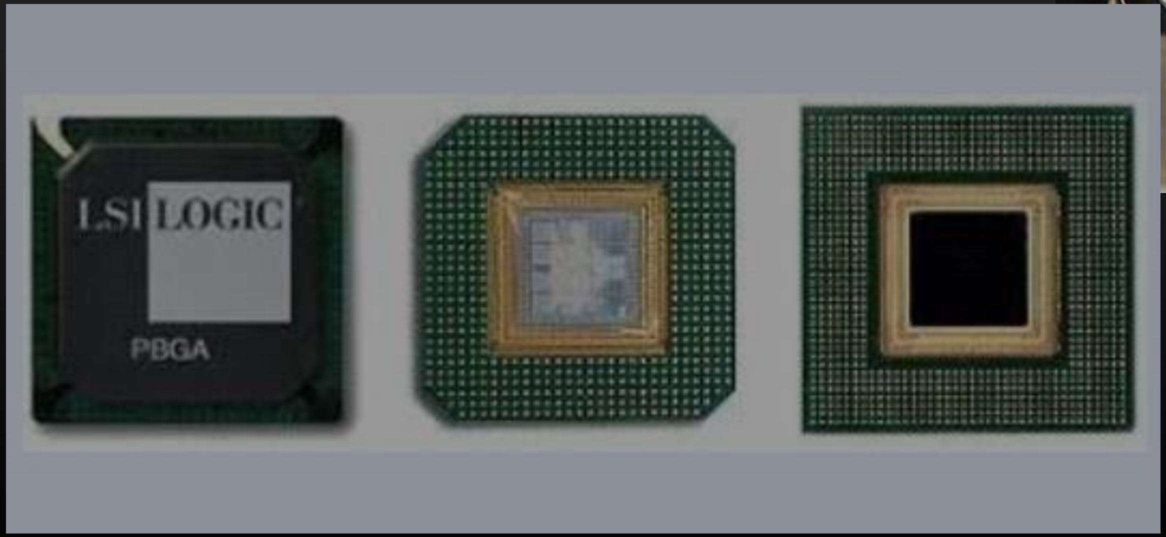
Manufacturing



SEMICONDUCTORS

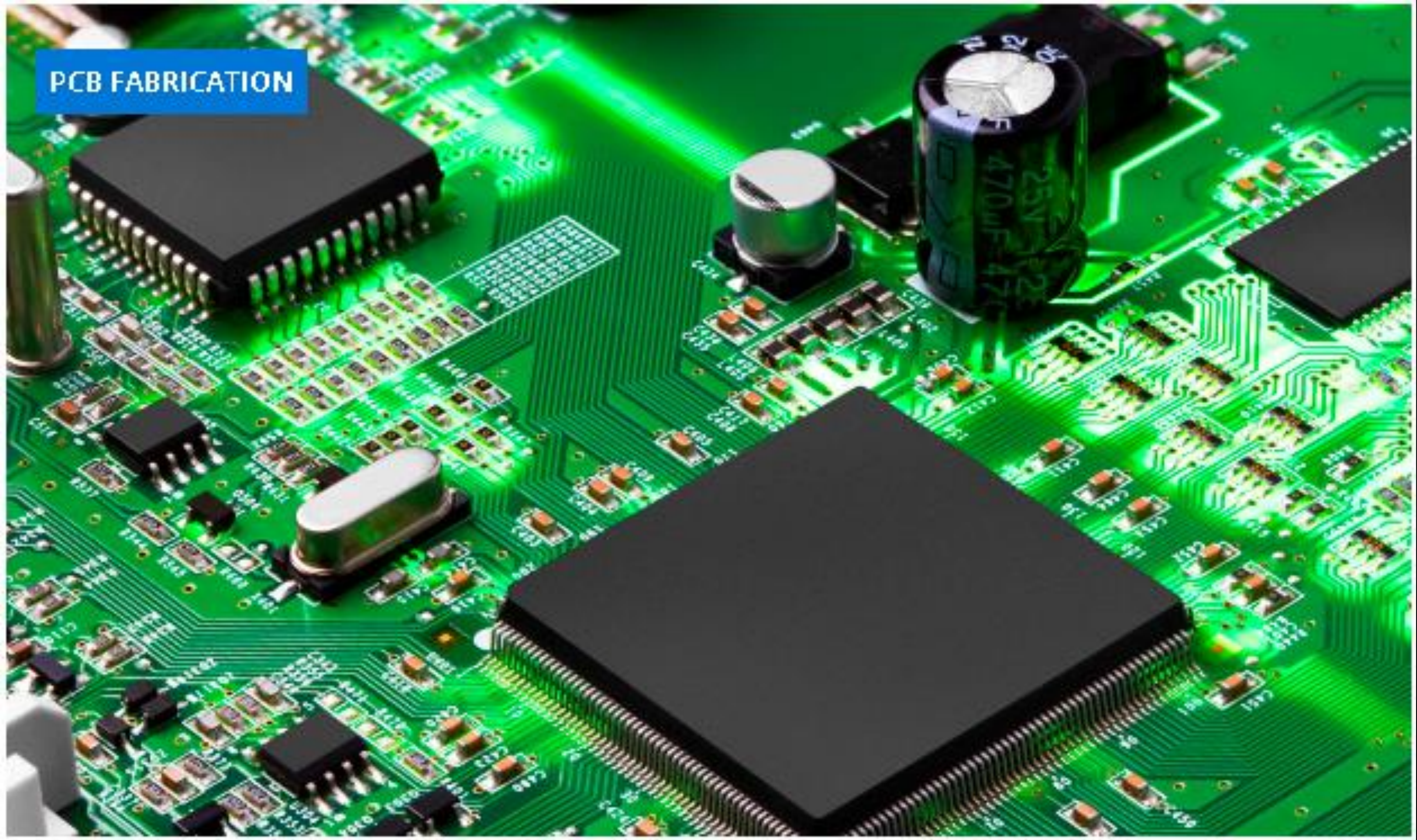
Test & Packaging





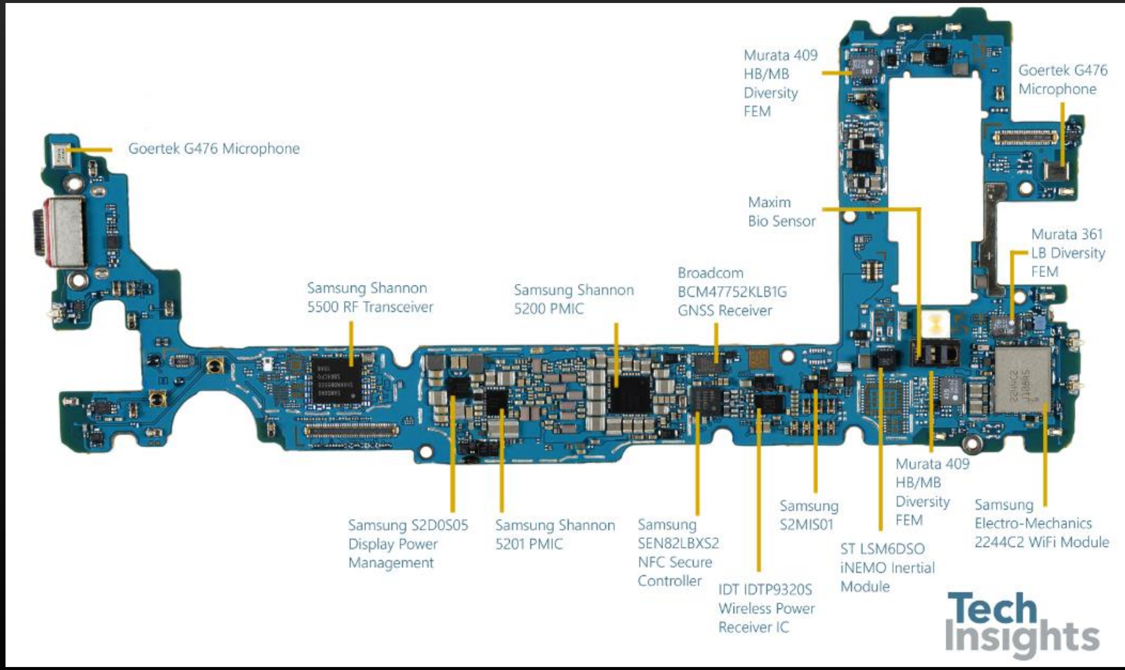
SEMICONDUCTORS

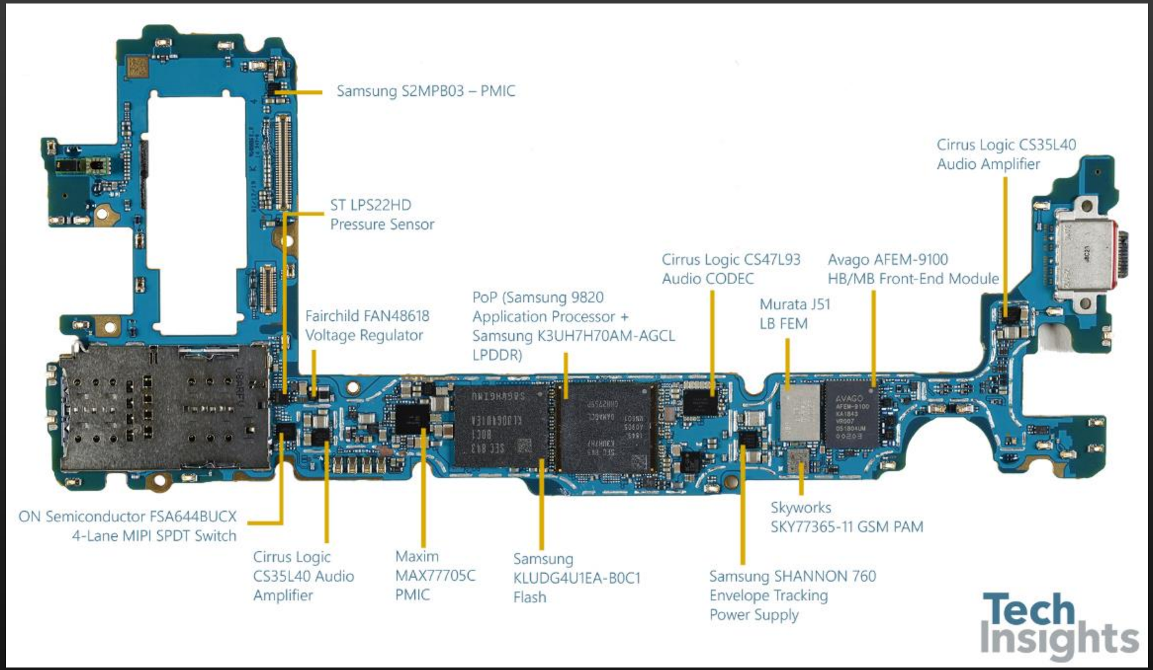
Assembly



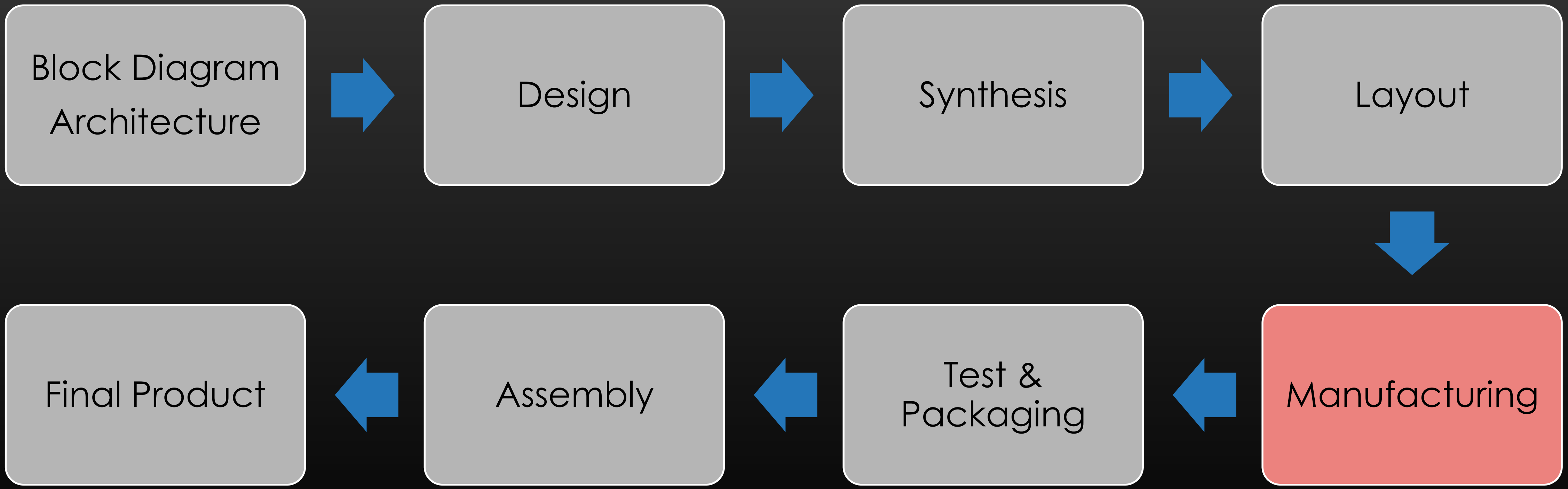
SEMICONDUCTORS

Final Product





SEMICONDUCTORS

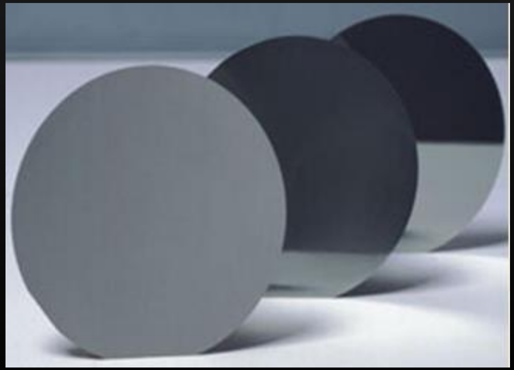


MANUFACTURING

- Step 1:
  - Get silica sand (silicon dioxide)
  - Mix with carbon and remove oxygen in high temperature
  - Treat with oxygen to purify to 99%
  - Grind to fine powder
  - Add hydrogen chloride and heat to 300 $^{\circ}$C
  - Distil to get ultra purity of 99.999999%

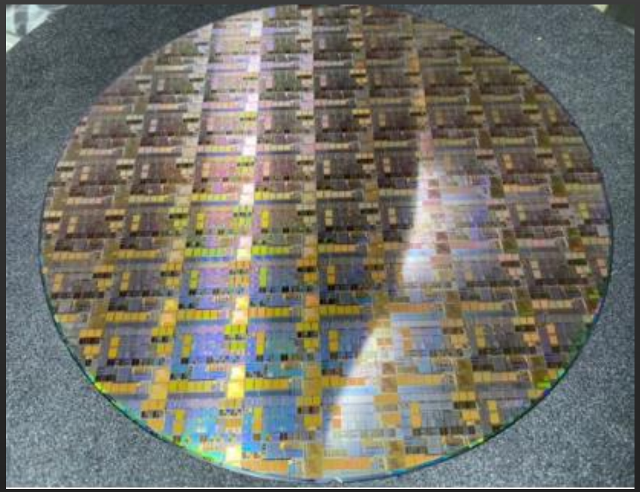
- Step 2:
  - Purify from polycrystalline structure
  - Melt silicon crystals in a quarts crucible at 1414 ^{O}C
  - Dip a tiny crystal into molten silicon to attract silicon while spinning
  - Create a cylinder of pure silicon of 300mm across

- Step 3:
  - Slice the silicon rod into discs of 775um thick
  - Lap the wafers by polishing with slurry
  - Treat with acids to make smoother wafers

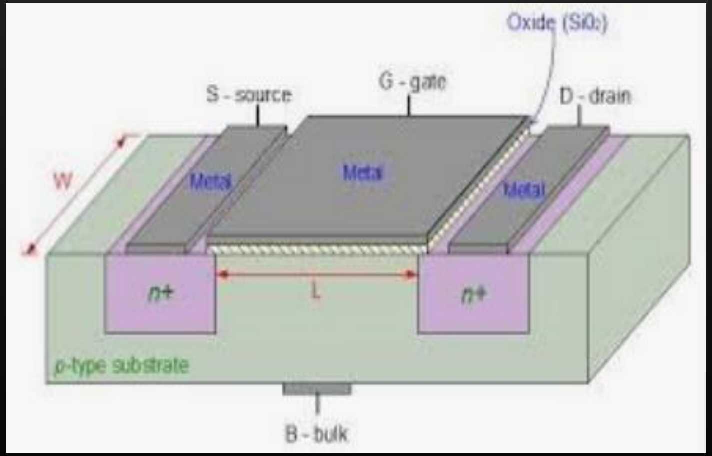


MANUFACTURING

- Step 4:
  - Heat up silicon wafers to create silicon dioxide
  - Make patterns using photoresist chemicals
  - Expose wafers to UV light through photographic mask
  - Move wafer in steps to repeat the process
  - Treat with chemicals to remove oxide and create patterns (circuit features)

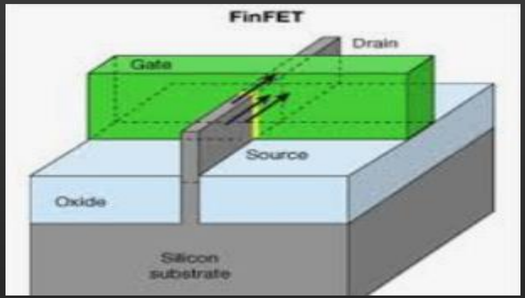


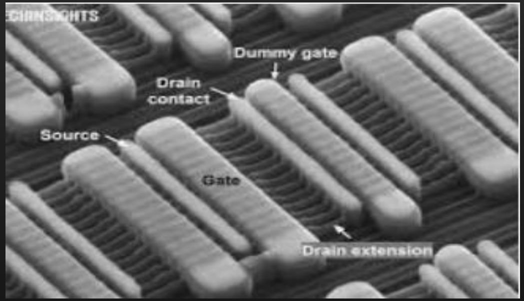
- Step 5:
  - The fundamental building of a transistor is called MOSFET (Metal Oxide Semiconductor Field Effect Transistor
  - MOSFETS are basically switches (either ON or OFF)
  - The wafer is blasted with boron ions blocked by the photoresist layer to direct the beam to precise locations to create a P-Well
  - A similar process using phosphorous ions creates N-Well
  - These wells are called drain and source

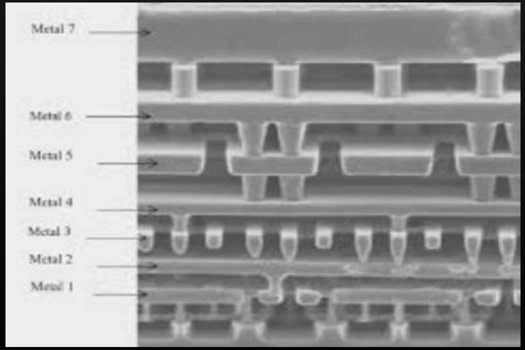


MANUFACTURING

- Step 6:
  - Transistors need a gate – an electrode covered by a thin layer of metal oxide sitting between the drain and source
  - Intel has invented a 3D gate called FinFET that allowed a drop of transistor size from 90 nm to 22nm (1nm = 1 millionth of a millimeter)
  - Billions of transistors on the wafer are formed
- Step 7:
  - Transistors are connected by ultra thin copper interconnects guided by a layer of photoresist
  - Holes or vias are filled with metal to form pins
  - Due to the high number of connections required multiple (6-11) layers of interconnects are required

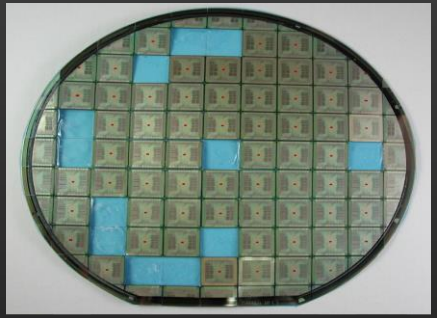


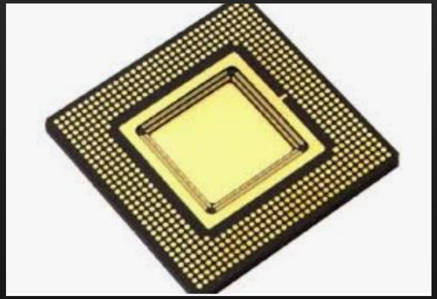




MANUFACTURING

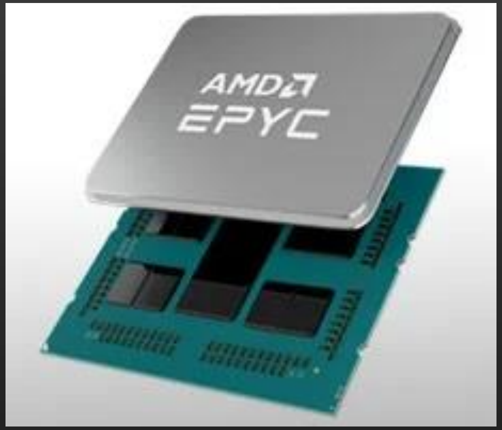
- Step 8:
  - Such an incredibly complex process is prone to potential problems, bad or defective chips will be discarded
  - A typical yield from a wafer is 80% although higher yields can be achieved in some processes
  - Wafers are tested using wafer probes that mark defective chips (also called dies)
  - Wafers are sliced into individual chips and sent for packaging
  - Packages provide strength and protect fragile dies from external contamination, stress, dust, etc.
  - Packaged dies are soldered down on printed circuit boards to be used in computers, mobile phones and other systems



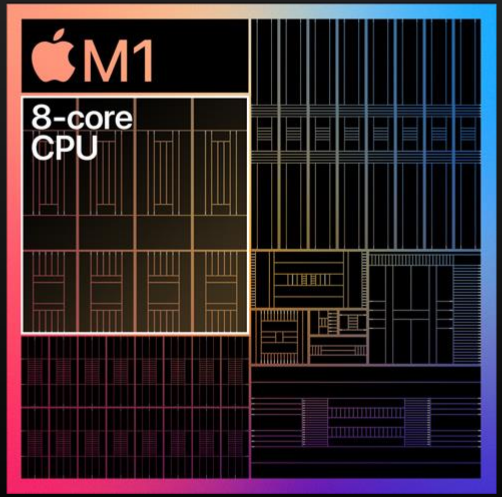


MICROPROCESSOR EXAMPLE

- Zen 2 (Epyc Rome)
  - AMD processor
  - TSMC 7nm FinFET
  - 39.54 billion MOSFETs
  - 8 dies in a single package



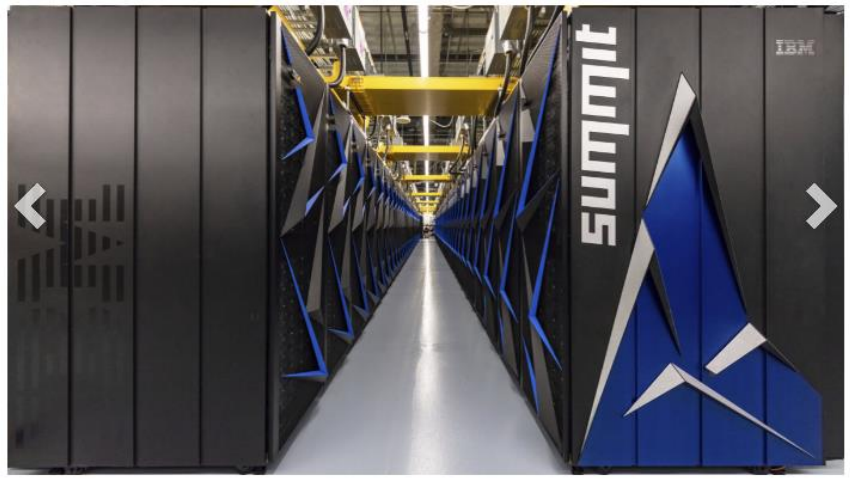
- Apple M1
  - 8 Core processor SoC
  - TSMC 5nm FinFET
  - 16 billion MOSFETs
  - Neural Network 11 trillion transaction per sec



SUPER COMPUTERS

- Summit
  - US Dept of Energy
  - 2,282,544 IBM Power 9 cores
  - 2,090,080 Nvidia Volta GV100 cores
  - Peak performance 187.66 peta flops ¥
  - 11.324 giga flops per Watt

- Tianhe-2A (Milky Way 2A)
  - China's National University of Defence
  - ~ 5million Intel Xenon and Matrix 2000 cores
  - Peak performance 61.4 peta flops
  - 3.325 giga flops per Watt



¥ = 1015 floating point operation per second

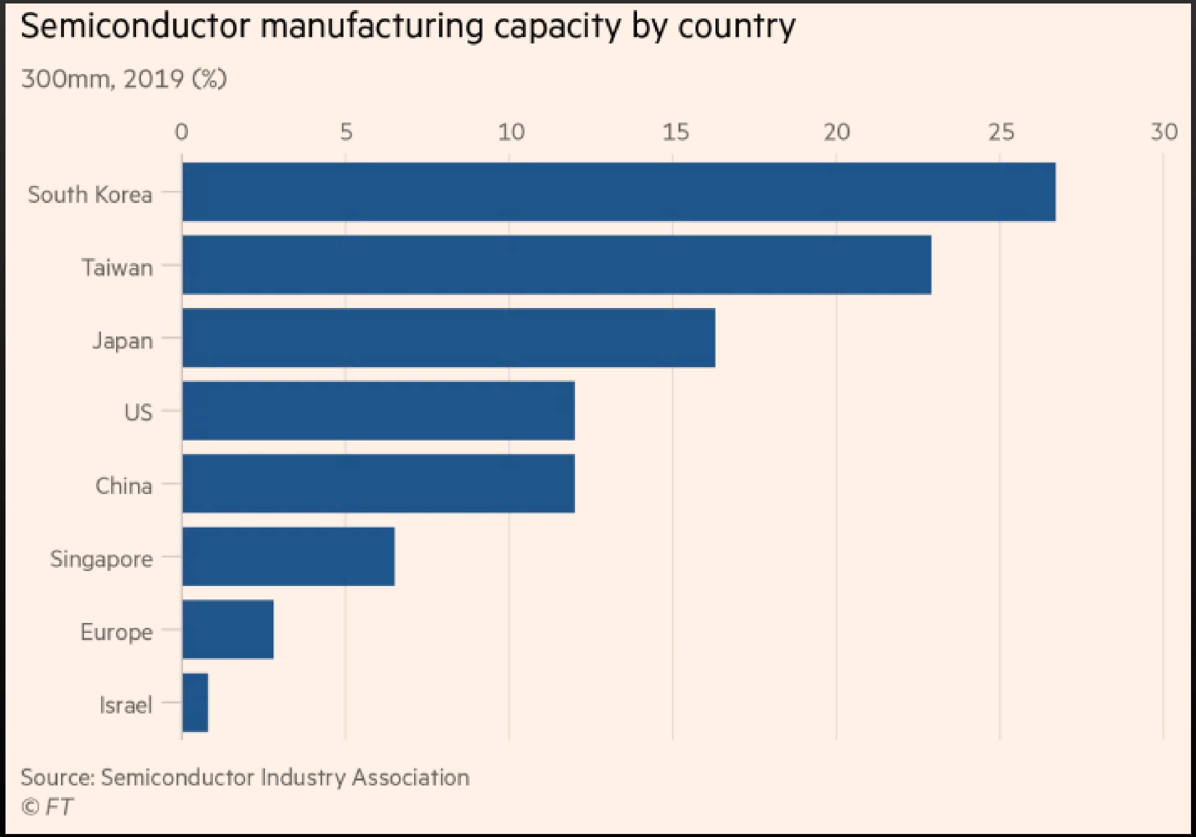
SEMICONDUCTOR MARKET

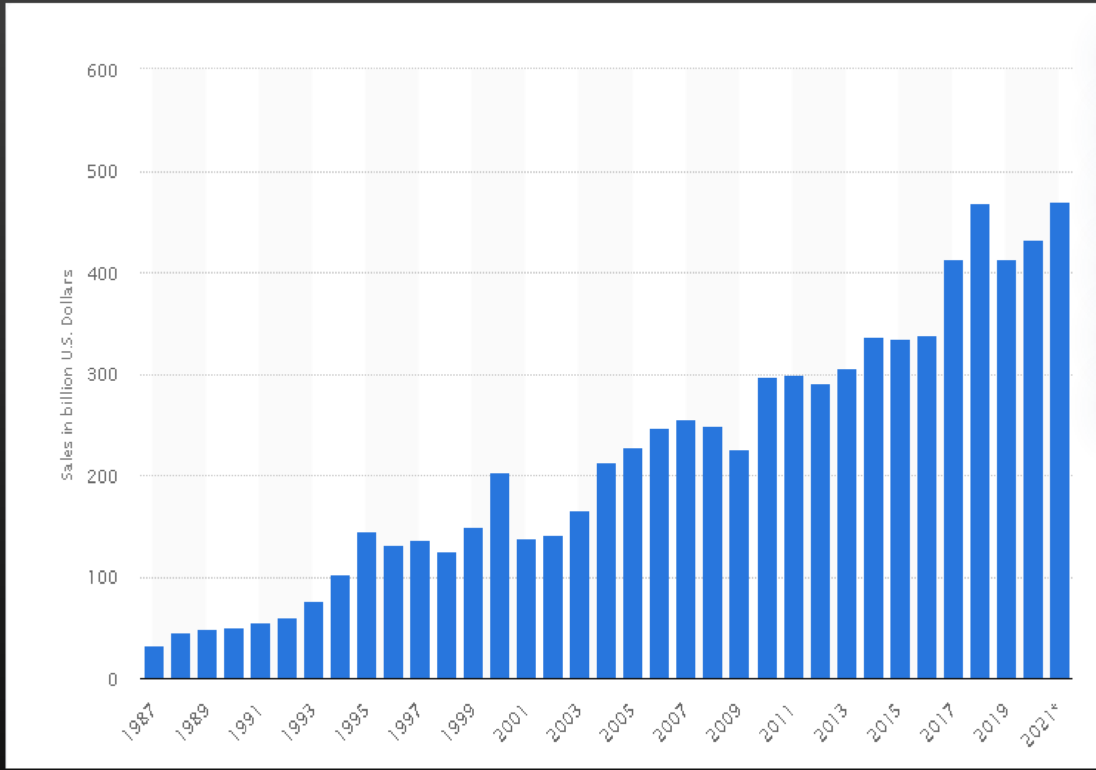
WAFER FABS

- TSMC ($47.78b) 28%
- UMC 13%
- SAMSUNG 11%
- SMIC 10%
- GF 7%
- XFAB
- TOWER JAZZ

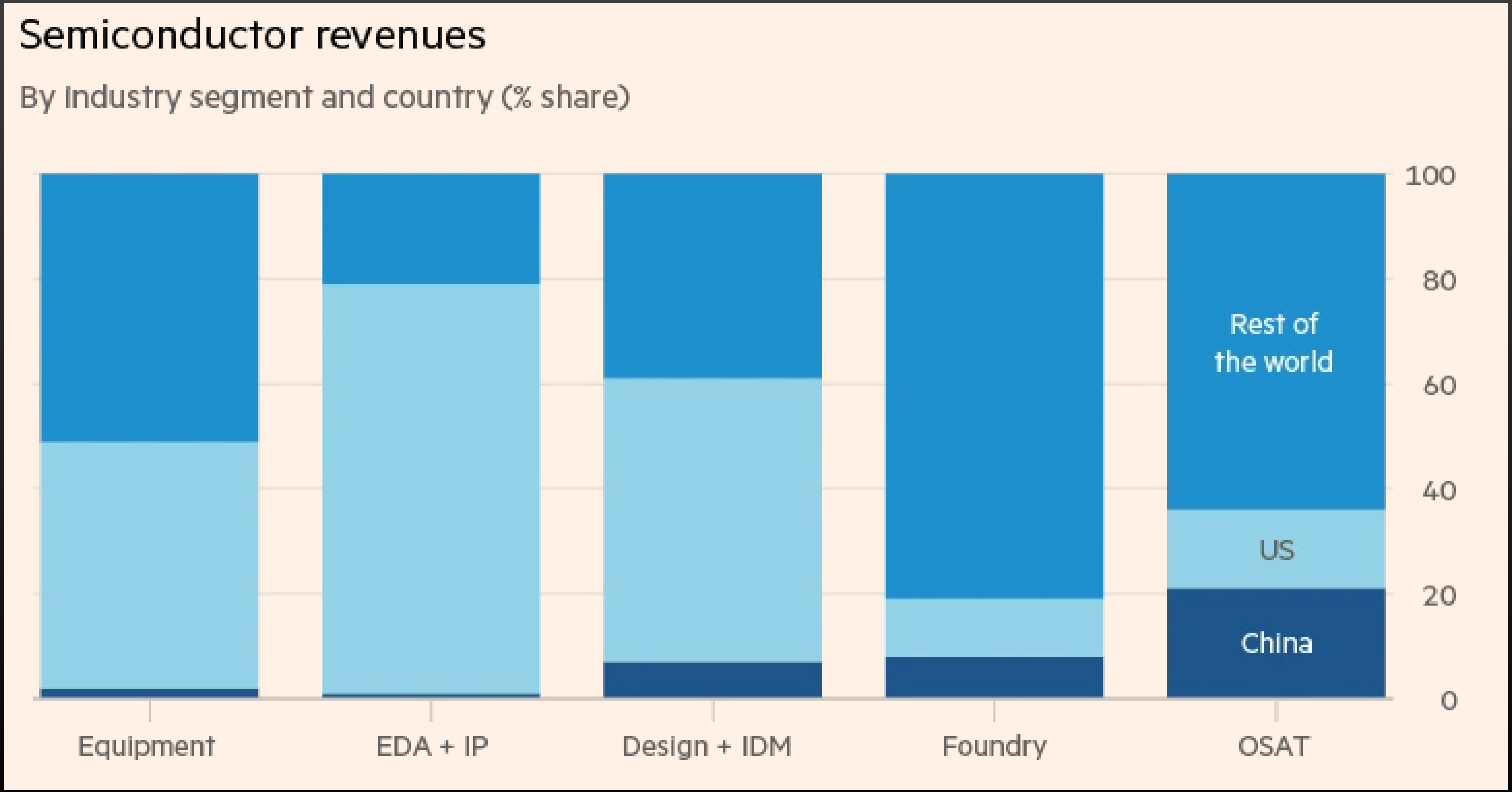
SEMICONDUCTOR MARKET

- Global Market Size
- Semiconductor sales $439 billion in 2020

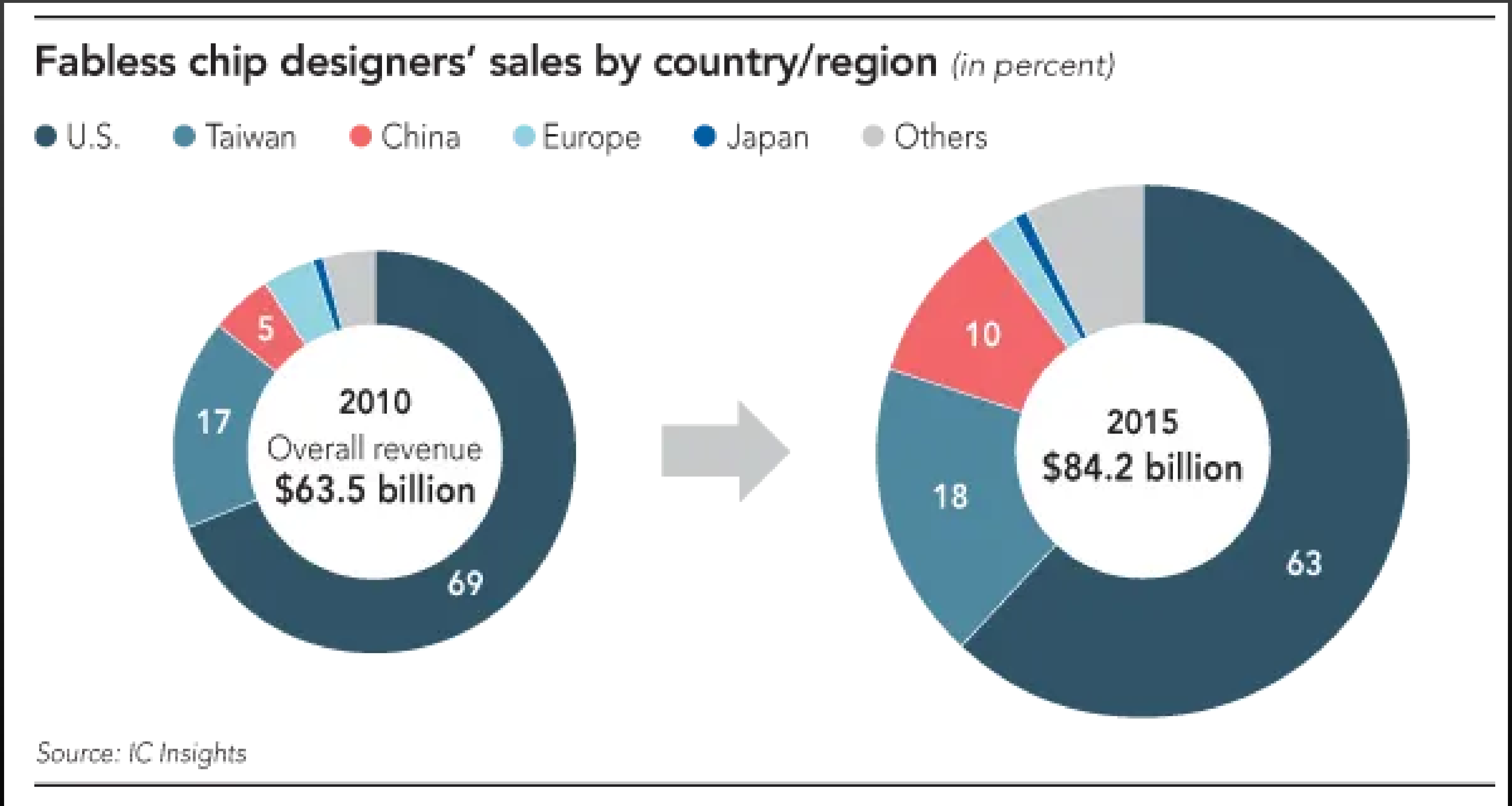




CHIP DESIGN MARKET

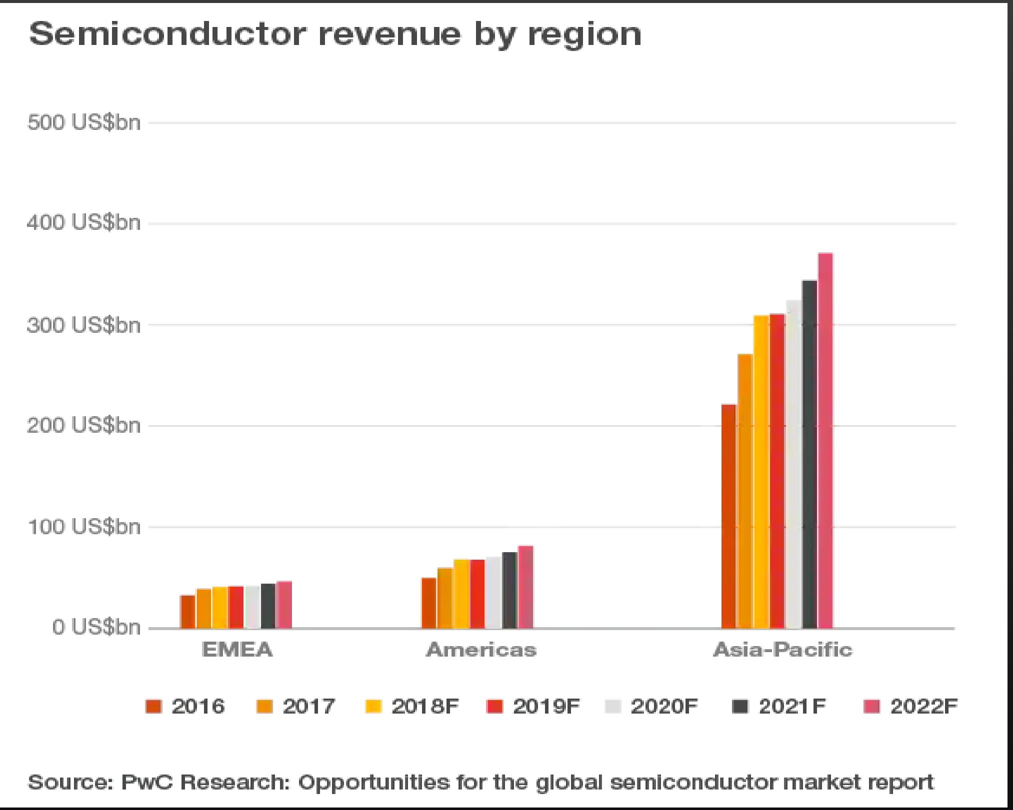


CHIP DESIGN MARKET



ELECTRONICS IN VARIOUS COUNTRIES

- Malysia: electronic exports $30bn in 2013
- Thailand: Electronic industry is valued at $100bn mainly automotive electronic parts
- The Philippines: Electronics shipments totalled $37.57bn in 2018
- Singapore: Electronic industry is valued at $37.4bn in 2017
- Israel: 5 Fabs and more than 15 fabless companies; 20,000 employees with annual revenues of $5bn
- Brazil: Semi Revenues $552.8m in 2019



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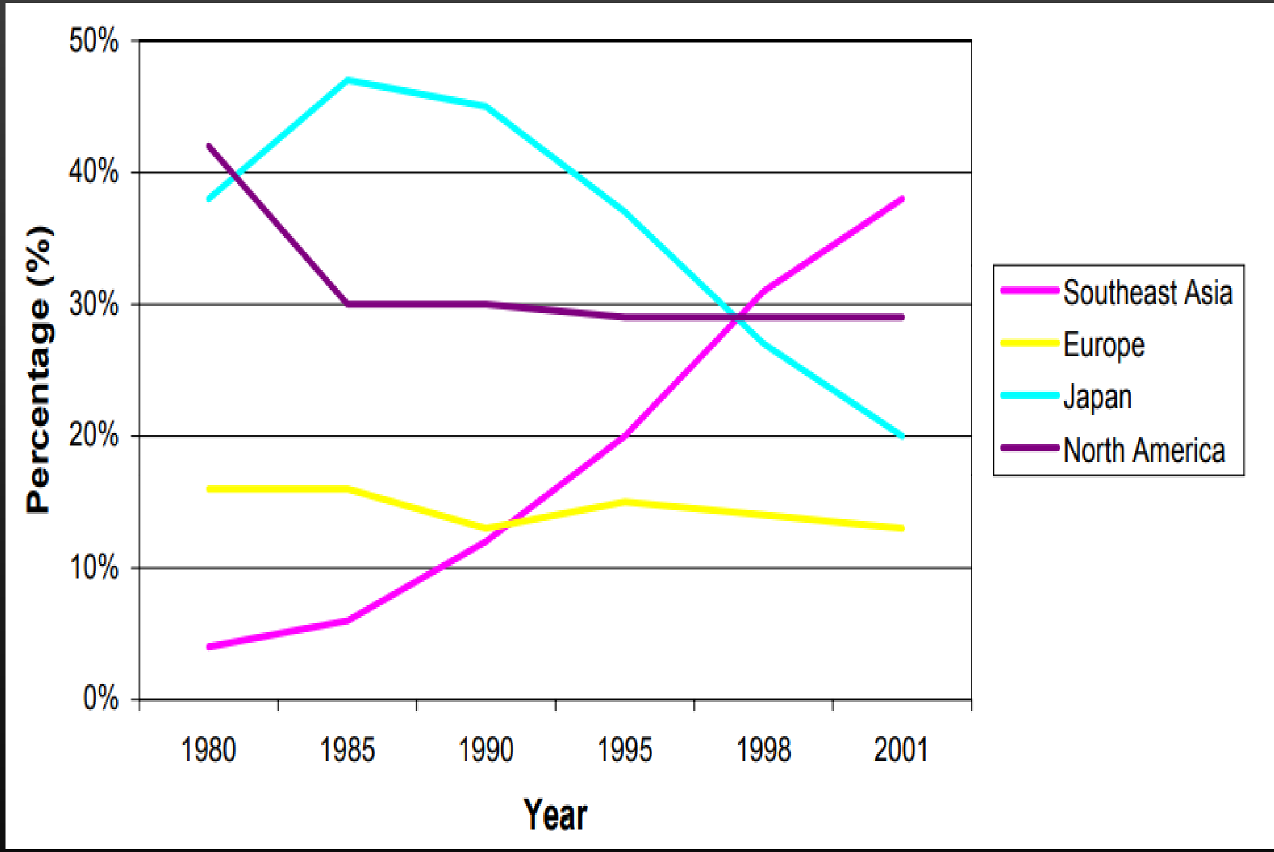

THE MIDDLE EAST

- Silicon Oasis was established in Dubai started Pilot Design Environment to establish the Dubai Circuit Design (DCD) centre in 2001
- Abu Dhabi established Advanced Technology Investment Company (ATIC) in 2008 which invested in AMD to create Global Foundry which is 100% owned by Abu Dhabi since 2012
- Masdar Institute of Science and Technology in Abu Dhabi collaborated with Global Foundry on 28nm SLP low-power bulk CMOS technology in 2014
- Egypt started tech start-up in 1993 with Anacad. In 2004, two chip design companies emerged to cater for customers in the ES, Europe and Asia. Currently, 17 fab-less companies form the semiconductor sector in Egypt
- Morocco was the first Arab country to enter semiconductor industry established by ST Micro – A French company in 2003. Acquired by Sondrel 2015
- Morocco manufactures and exports small devices and micro chips for wafer level optics (Nemotek 2009-15)

CHALLENGES AND OPPORTUNITIES

- Challenges
  - High capital
  - Lack of experienced engineers
  - Long term investment in R&D
  - Small national/regional markets (echo system)
  - Lack of knowledge of global semiconductor markets' needs

- Opportunities
  - Economic growth and diversity
  - Security: military, telecommunication, data, intelligence, etc.
  - Highly rewarding jobs
  - Creates local talents
  - Absorbs graduates and feeds into other sectors

THANK YOU

Q&A