# ELEG 5765 Fundamentals of Automotive Integrated Circuits

Lecture 1

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Course Summary

➢ Course content

Digital Automotive IC design

Industry EDA tools

➢ Project: 40%

➢ Exam: 40%

➢ Homework, quiz, etc.: 20%

➢ Q & A

One hour before class

Prerequisite

➢  Fundamentals of Digital Integrated Circuits

Gates, combinational and sequential circuits

➢  Verilog

Syntax, programming

Policy of the use of AI tools: Approach **1**

    Approach 1: Prohibit all use of AI tools

    Approach 2: Use only with prior permission

    Approach 3: Use only with explicit acknowledgement

    Approach 4: Use is freely permitted with no acknowledgement

Policy of the use of open-source materials: Approach **3**

    Mark the part from open-source materials explicitly with citation.

    Cannot exceed 30% of the total work load.

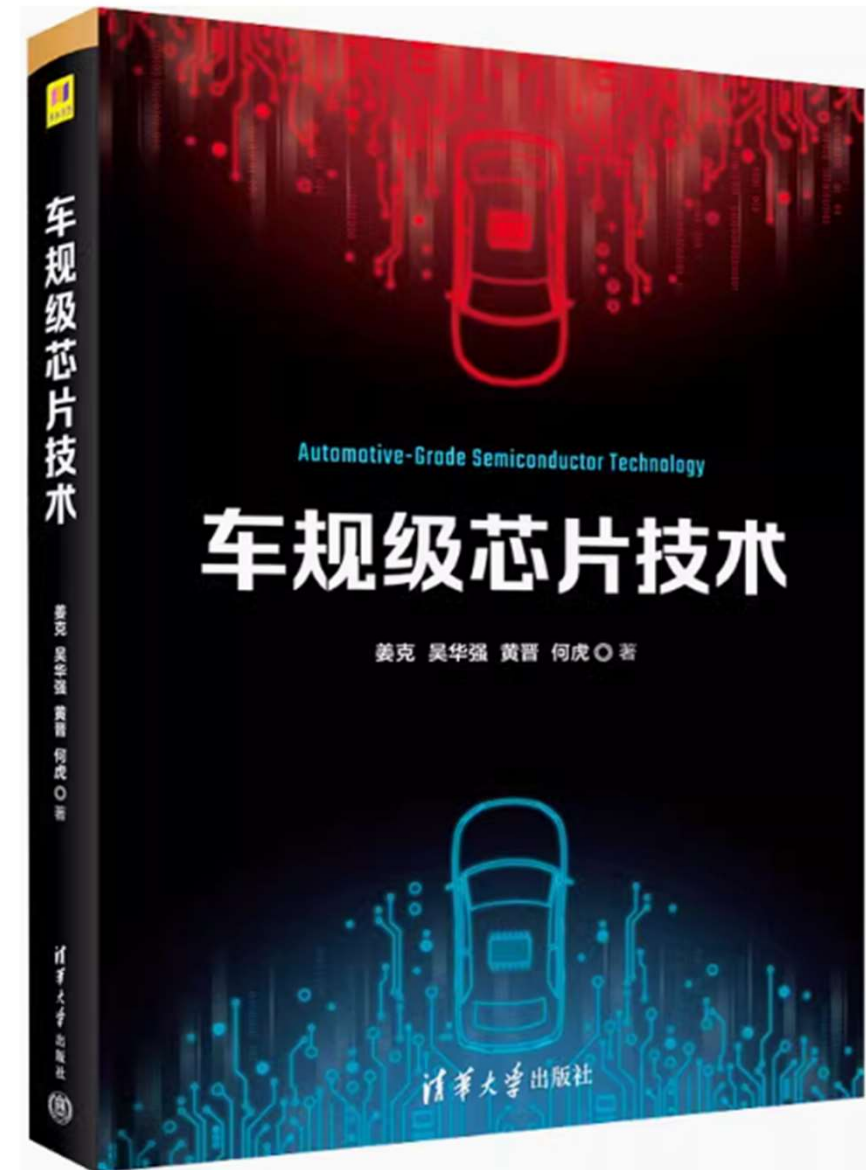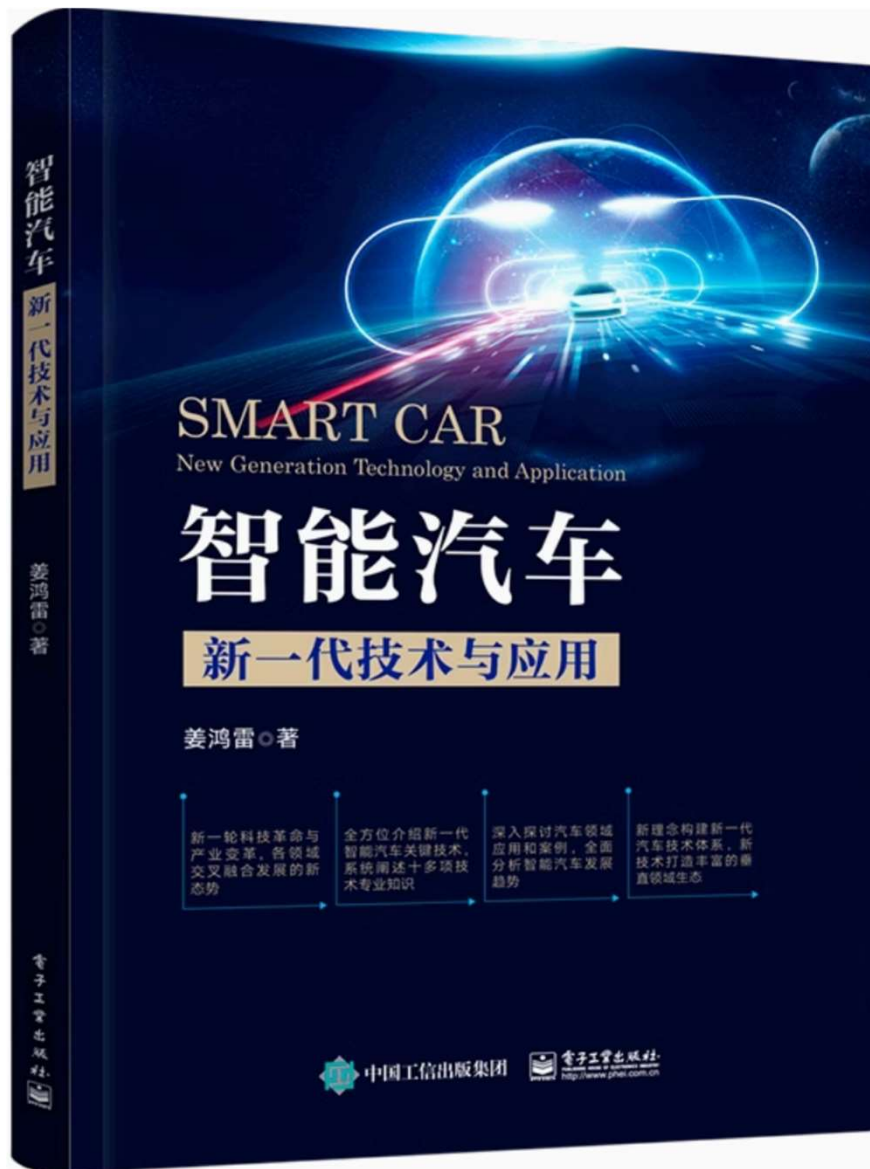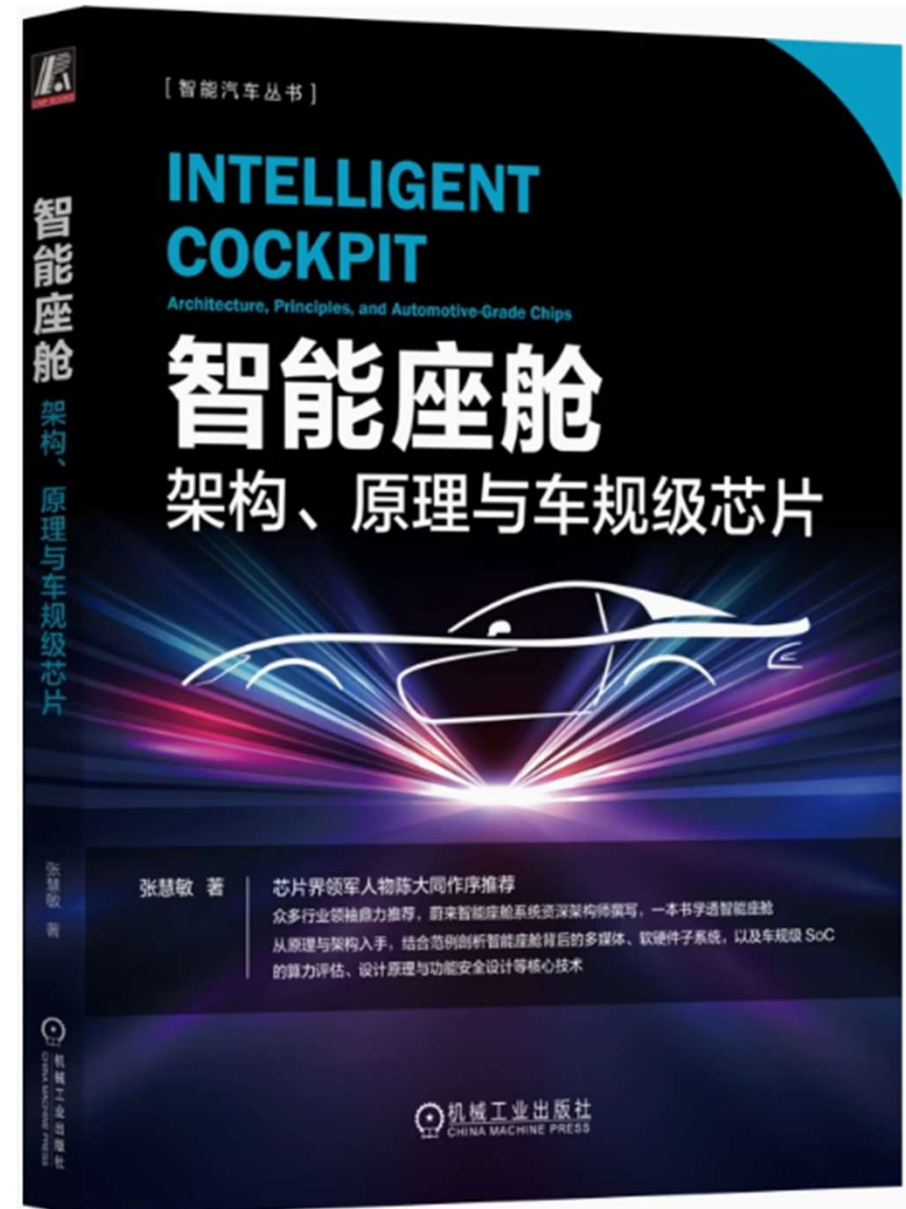    The material provided officially is not accounted for as.

Reference Materials

1. Books

2. IC specification

3. EDA tool specification

4. Open-source materials

香港中文大學
The Chinese University of Hong Kong

# Reference books: Automotive IC

# Reference books: IC & Verilog

# Lecture 1: Introduction to Automotive IC
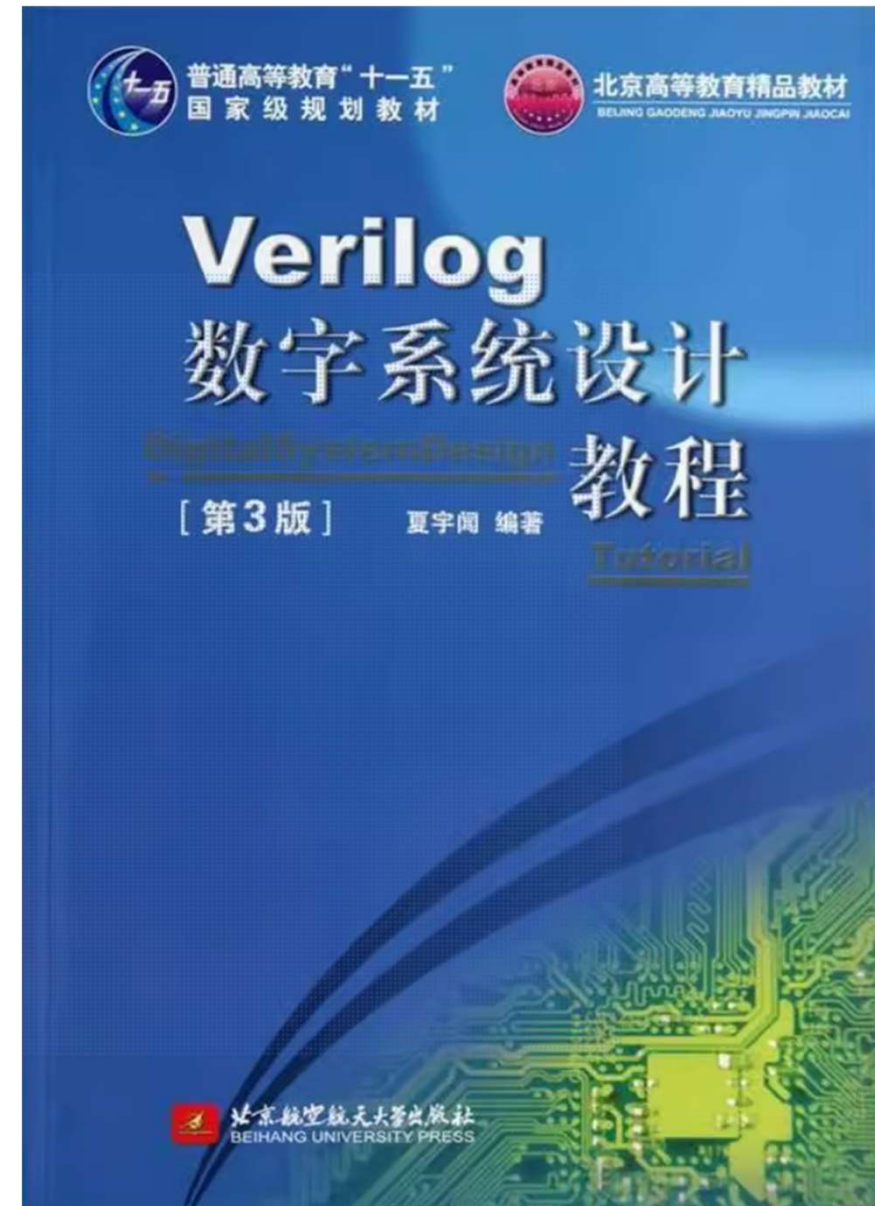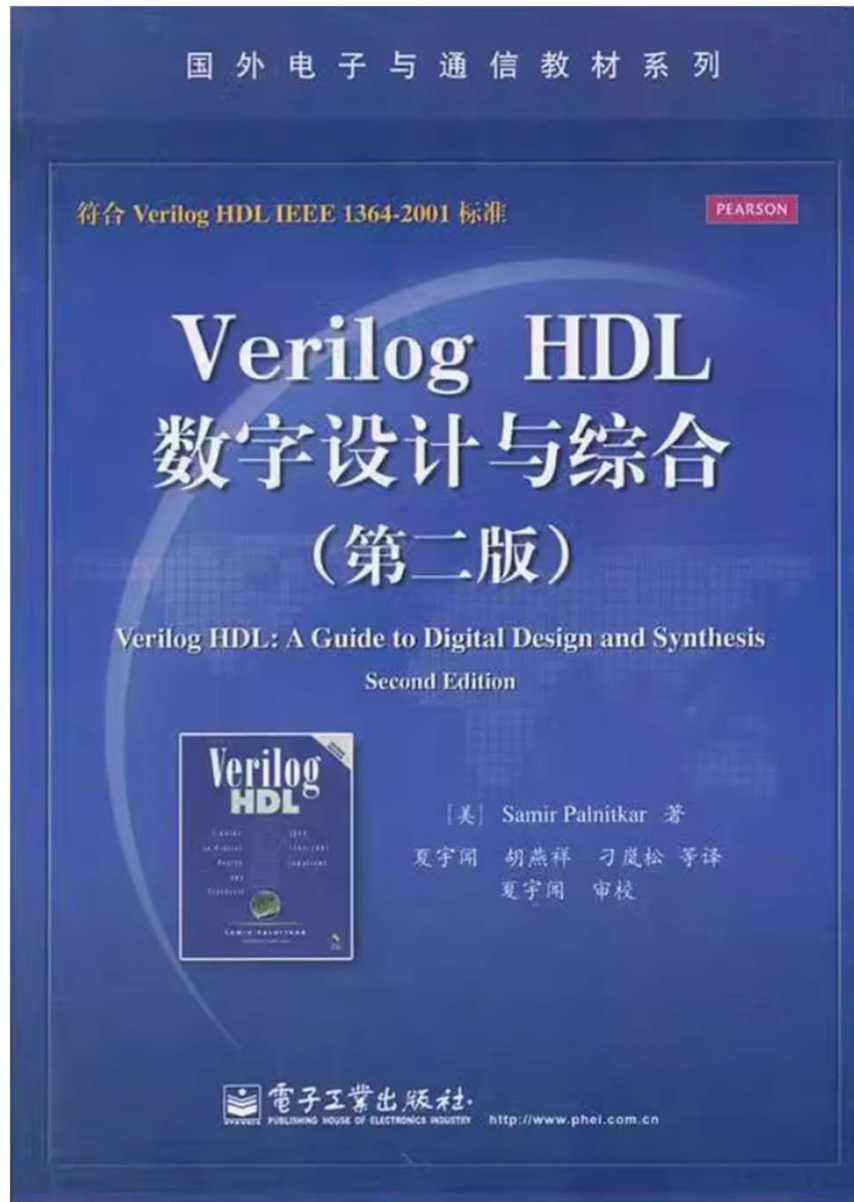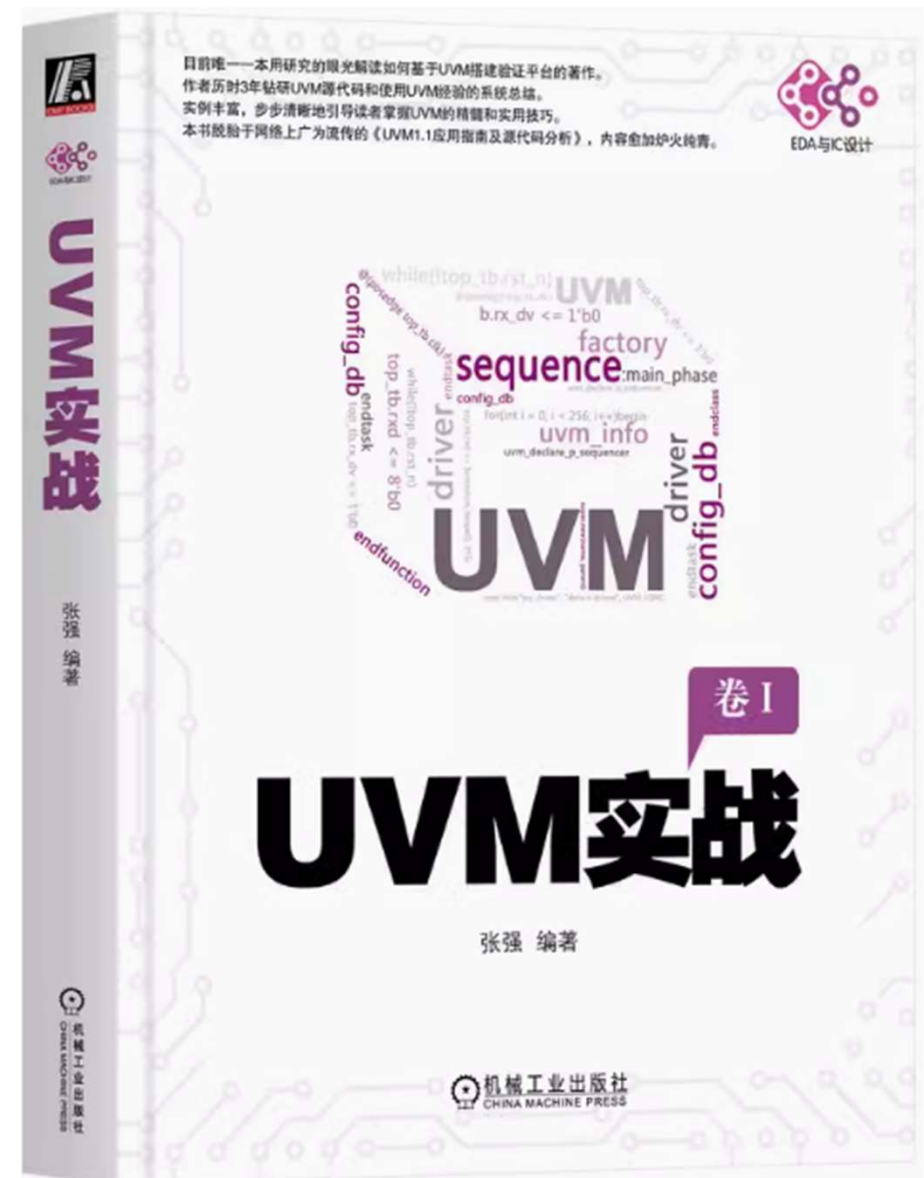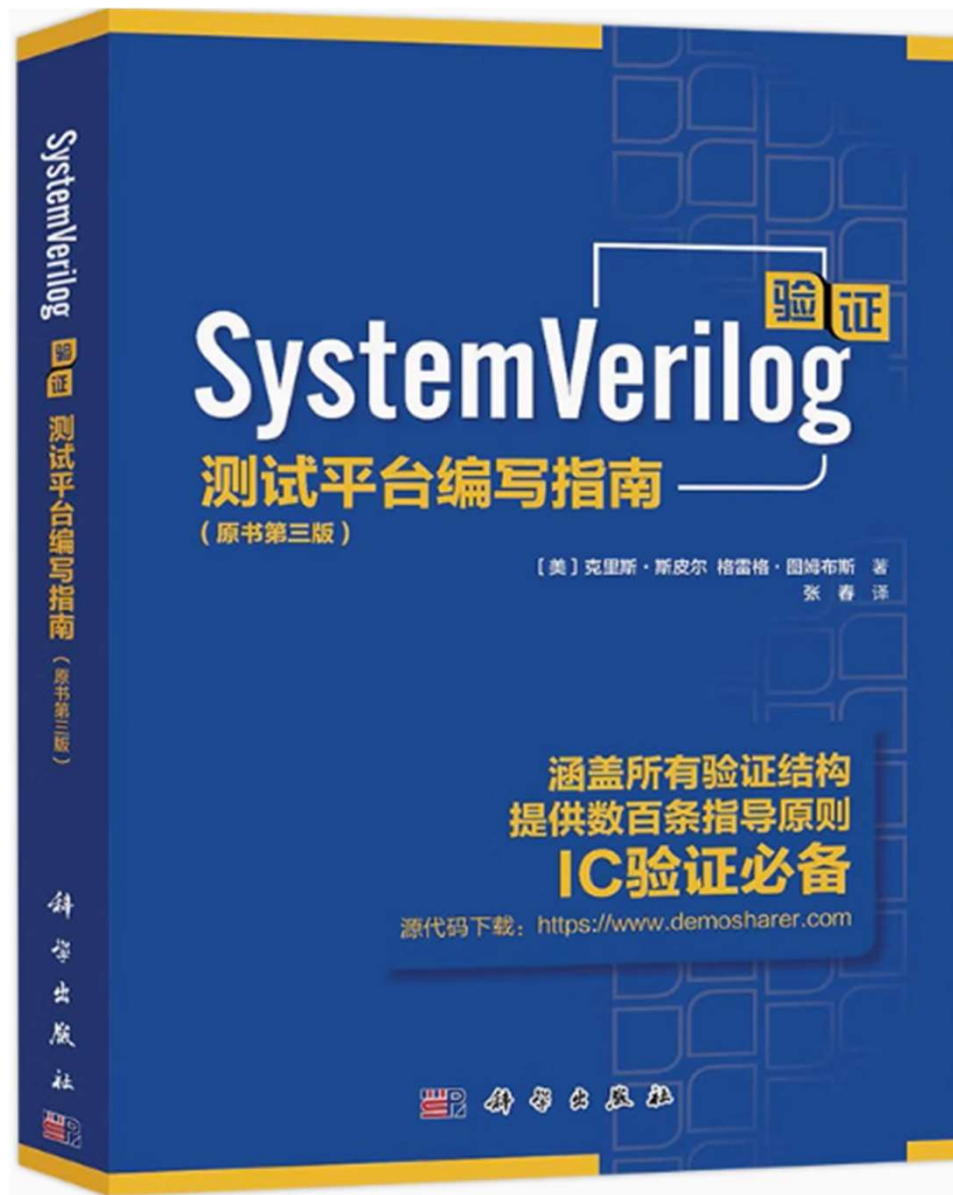
Outline

➢ Intelligent automobile

➢ Overview of automotive IC

➢ Fundamental of semiconductor

➢ Basics of Linux OS

➢ Basics of VCS

# Intelligent Automobile

# Trend of Future Automobile

- Electric          電動化
- Intelligent       智能化
- Networking     網聯化
- Multi-functional   多能化

# Software-defined Automobile

➢ Personalization

➢ Easy to update by software (Function, diagnose & repair)

➢ Component normalization

[Computer is a platform providing computing capability for application software which implement desired function]
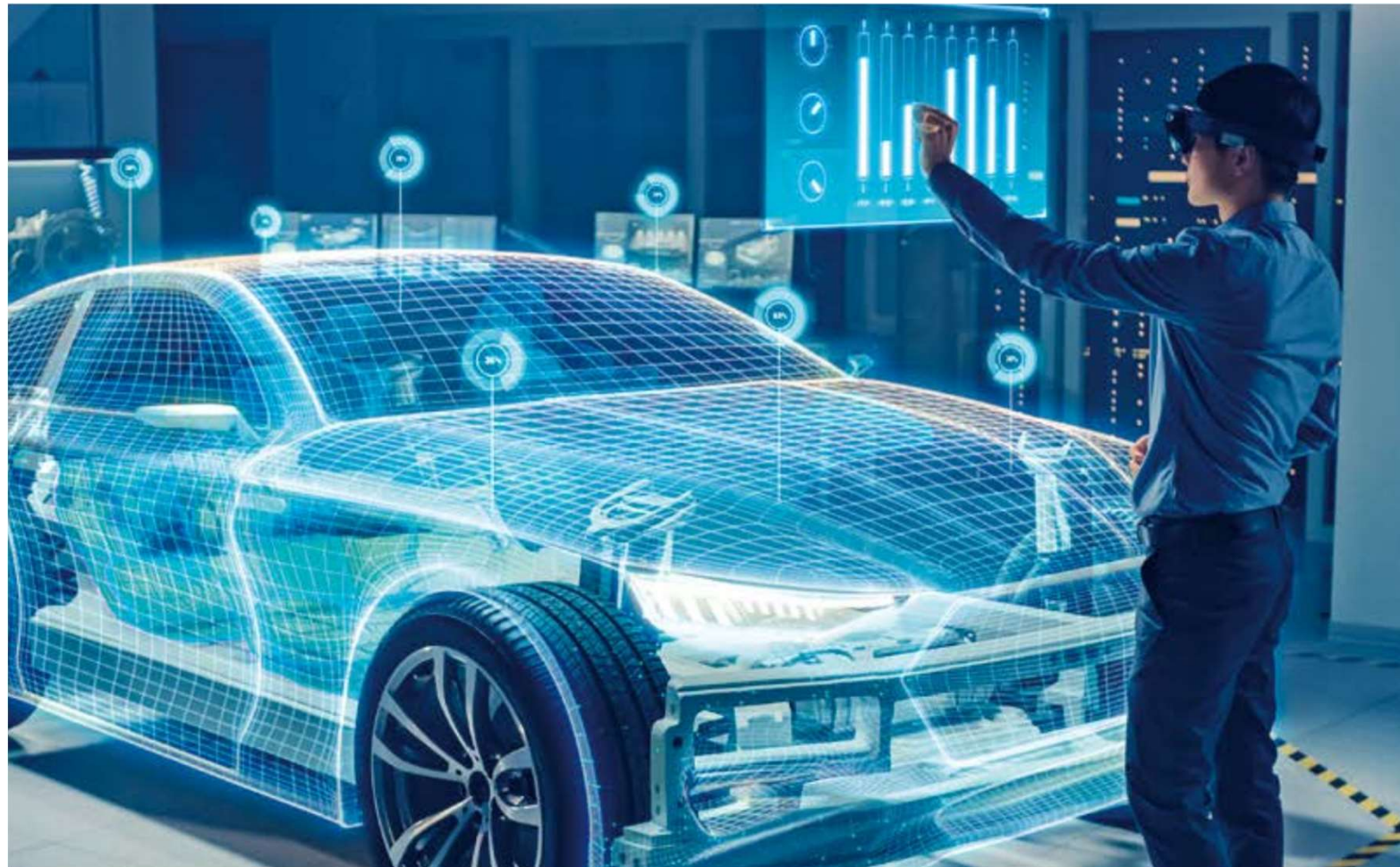
# Global Share of Automotive Car



**Chart 7: China car production share from 1% to 39% past 20 years**
Global share of automotive car production by country/region

China 39%

Europe* 13%

Japan 12%

US 3%
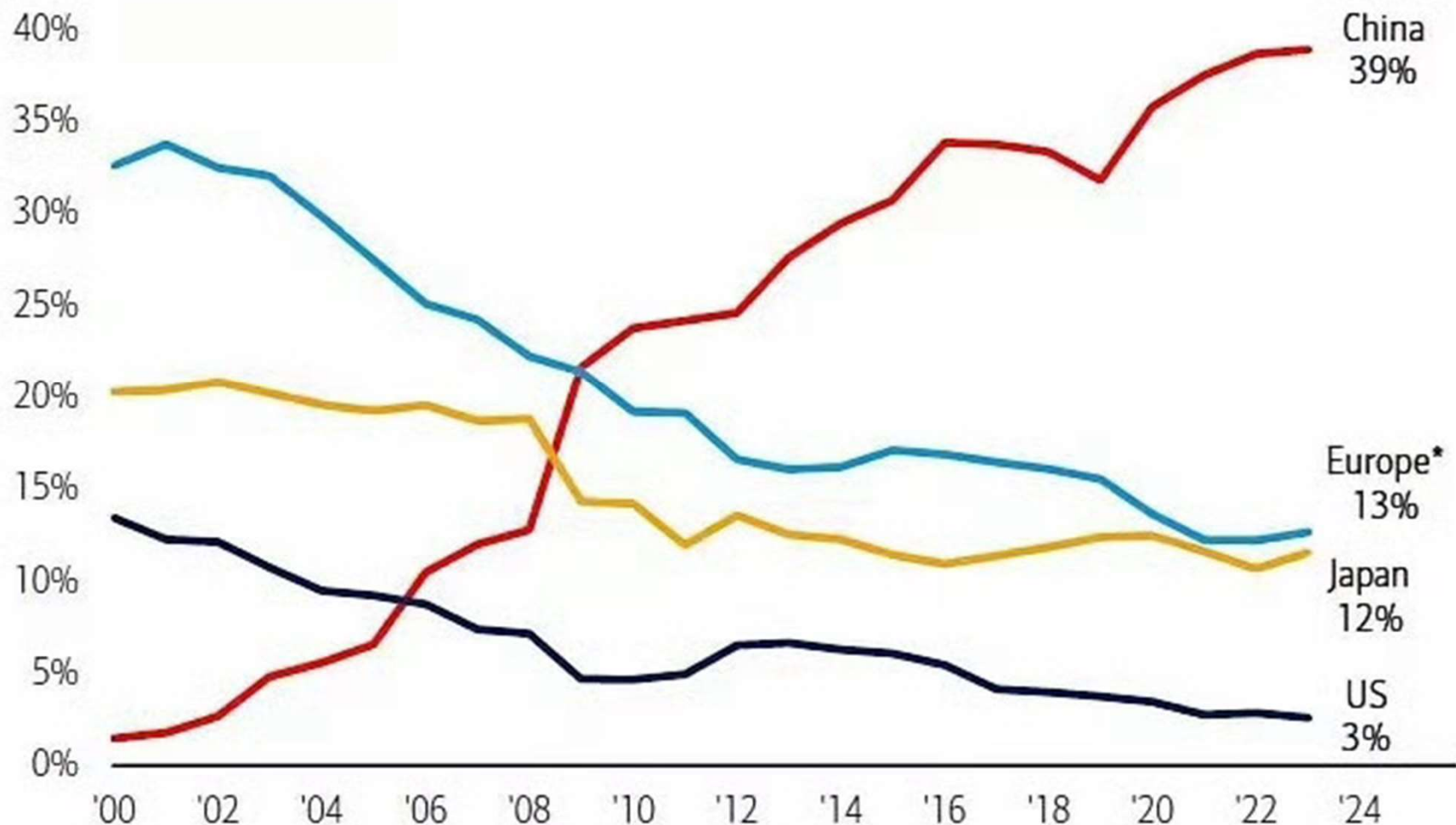
**Source:** Bloomberg, International Organization of Motor Vehicle Manufacturers. *Europe 'Big 5' = Germany, Spain, France, Italy, UK.

# Trend of Electric Vehicle Growth



Car production by fuel type

(Chart legend: ICE, Mild Hybrids, Full & Plug-in Hybrids and BEVs, Fuel Cell)

xEV penetration: >25% by 2023

xEV penetration: >50% by 2027
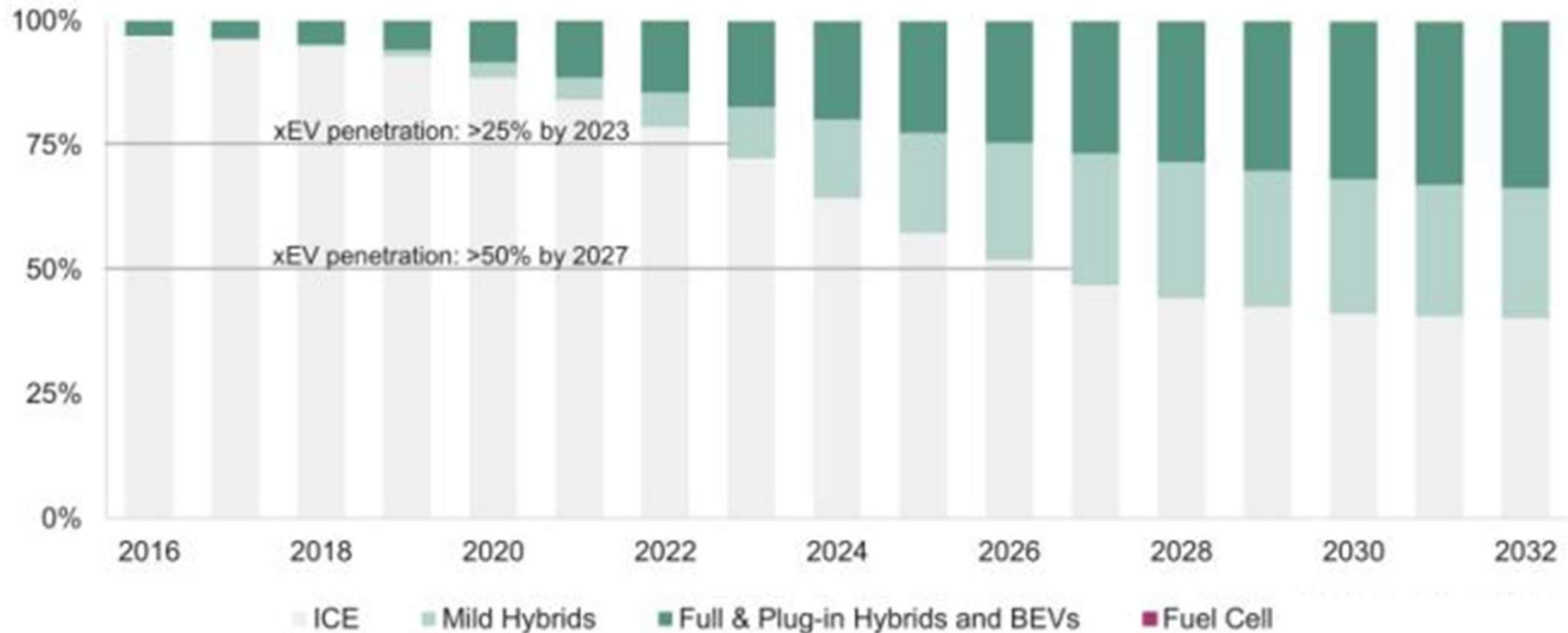
➢ Nowadays battery in-car can provide enough energy with acceptable cost.

➢ Fossil fuel power ➜ Electric power

➢ Easy to become intelligent

# Character Index of Automobile in 2030
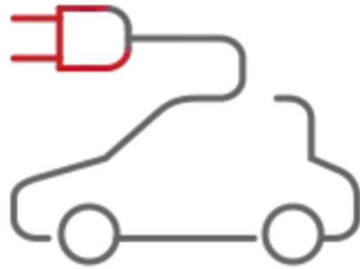
➢ Percent of Electrical Automobile

> 80%
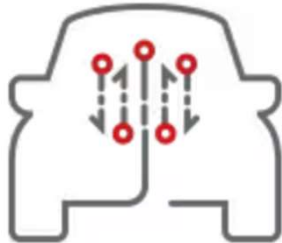
➢ Computing Power

> 5000 TOPS

➢ Percent of Self-driving Level beyond L3

> 30%
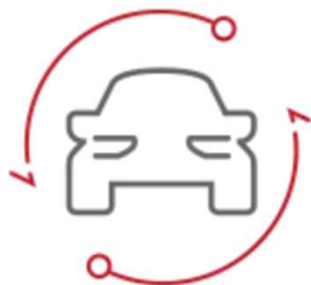
➢ Network Bandwidth

> 100 Gbps

# 广州市智能与新能源汽车产业链

## 上游

## 中游

### 感知系统

宇鸿电子
昌华精密光学
鹰瞰信息
巴尼菲科技
奥迪威传感
海格通信
润芯信息
泰斗微电子
粤芯半导体
图普网络科技有限公司
云从科技
佳都科技
……

### 高精度地图/定位系统

南方测绘
中海达测绘
都市圈网络科技
高深智图
百度地图
腾讯
导远电子
……

### 决策系统

小马智行
文远执行
小鹏汽车
……

### 控制系统

文远知行
小马智行
领世汽车
小鹏汽车
致远电子
瑞立科密汽车电子
电装投资有限公司
广州分公司
……

### 通信系统

华为
深圳金溢广州分公司
高新兴
京信通信
杰赛科技
致远电子
进强电子
德远科技
铁马车联网
通则康威智能科技
通达汽车电气
……

### 创新电动系统

广州华为电动
巨湾科技
宁德时代
日本电产
……

### 电池、电驱及其他三电件

天赐高新材料
鸿基创能
力柏能源
鸿森材料
时代广汽动力电池
广汽时代动力电池系统
鹏辉能源
银轮热交换系统
力达电器
智氢科技
舜华氢能
卡鲁新能源
氢驰科技
粤芯半导体
洺源科技
金亚隆新材料
……

### 汽车零部件

日立汽车系统
加特可(广州)自动变速箱
广州奥托立夫汽车安全系统
广州电装
广州恩梯恩裕隆传动系统
马瑞利(广州)
爱德克斯(广州)汽车零部件
……

### 车身、底盘及其他

广汽荻原模具冲压
祥鑫科技
中益机械
精乐汽车部件
中新汽车零部件
福耀玻璃
中新延锋彼欧汽车外饰件
凌云汽车零部件
恩梯恩裕隆传动系统
君国汽车配件
亚太汽车底盘系统
华智汽车部件
维思车用部件
延锋汽车饰件系统
……

### 制造装备

明珞汽车装备
顺天装备制造
擎天实业
广州五所环境仪器有限公司
广州锐格新能源科技有限公司
……

### 电子器件

新李汽车零部件
马瑞利汽车电子
阿尔华斯有限公司广州分公司
华望汽车电子
丰达电机
……

### 整车系统集成

广汽乘用车
广汽本田
广汽丰田
广汽埃安
广汽日野
北汽(广州)
东风日产
本田汽车
小鹏汽车
合创汽车
风神汽车
广汽比亚迪
本田汽车(中国)
广州广日专用汽车
成都大运广州分公司
……

### 人机交互

科大讯飞
飞歌汽车音响
索达信息科技
……

### 智能座舱

华为
星河智联
……

### 自动驾驶解决方案

文远知行　　滴滴沃芽
百度阿波罗　　小马智行
钛马车联网　　……

### 整车研究院/制制造业创新中心

广汽研究院
华为广州研发中心
广东省智能网联汽车创新中心
……

# Cost / Value Percentage of Semiconductor

From the point view of cost / value,

➢ Automobile is not mechanical product any more

➢ Instead, automobile is electronic product

Electronic (Hardware) + Software + Electric + Mechanical + Material

[Mobile phone is not phone any more but portable computer that can phone]



Figure: Cost contribution of automotive electronics and semiconductor content per car
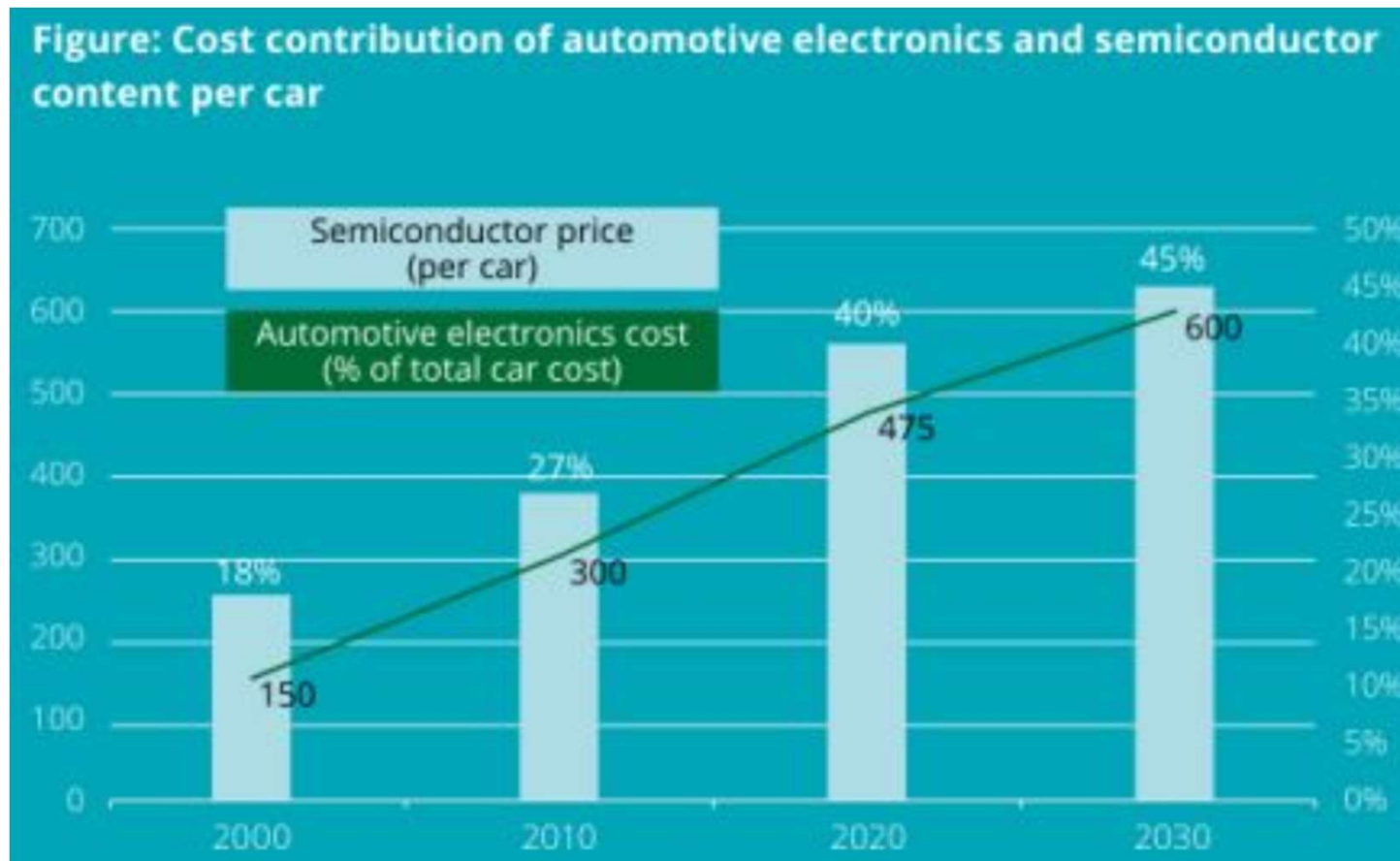
➢ Powerful function

➢ Acceptable cost, volume, energy consumption

➢ Integrated architecture

Central computing / control platform + Network (Outside & Inside)

# Types of Automotive IC



**Image sensors**
1 – 10 chips per car in 60% of cars
90nm to 28nm
~$10 per chip

**Microcontrollers**
15-80 chips per car in 100% of cars
130nm to 45nm
~$1 per chip

**Analog components**
10-100 chips per car in 100% of cars
180nm to 65nm
~$1 per chip

**Power discrete for xEV**
10-30 chips per car in 10% of cars
130nm to 65nm
< $5 per chip

Highly impacted by the chip shortage

Low impact of the chip shortage

**Computing ADAS (Camera)**
1 chip per car in 60% of cars
28nm mostly
~$35 per chip

**AI chips for autonomy**
1-2 chips per car in <1% of cars
14nm or below
~$150 per chip

➢ Fuel vehicle: up to 500 ICs

➢ Electric vehicle: more than 2000 ICs

# Examples of Automotive IC



**Applications examples**

**Body & convenience** (e.g. keyless entry, lighting)

**ADAS** (e.g. radar, camera system, LiDAR)

**Infotainment & telematics** (e.g. instruments cluster, telematics & connectivity)

**Chassis & safety** (e.g. automatic breaking, airbag control)

**Powertrain** (e.g. engine control unit, transmission control unit)

**Products examples**

**Analog IC** (e.g., amplifiers, voltage regulators)

**Discretes** (e.g., rectifiers, Silicon Carbide modules)

**Logic IC** (e.g., FPGA - Field Programmable Gate Arrays)

**Memory IC** (e.g., Flash memory, DRAM)

**Microcomponent IC** (e.g., Digital signal processor)

**Optical Semiconductor** (e.g., Light emitting diodes, image sensors)

**Sensors and Actuators**

The 5 levels of driving automation

# Levels of Driving Automation

| 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| The driver is **fully responsible** and permanently carries out all aspects of the driving tasks. | The driver can delegate either steering or accelerating/braking to the system. | The driver must **permanently** monitor the system. | In certain situations, the driver can turn **attention away** from the road, but must always be ready to take full control again. | The driver can transfer complete control to the system and devote himself to other activities. However, he can take control at any time if he wishes. | No driver needed. |
| No driver assistance systems. | The system will perform **one** of the driving tasks. | The system will perform **several** of the driving tasks. | The system can autonomously control the vehicle on **defined routes**. | The system is able to perform **all** driving tasks. | The system controls the vehicle autonomously under all conditions. |

**Manual Driving**        **Automation**

The IC requirement of L4/L5 is 10x of L0/L1

# Levels of Driving Automation

香港中文大學
The Chinese University of Hong Kong

| | ~2021 | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|---|
| 一汽 | **L2**<br>E-HS3 / E-HS9 | **L2**<br>暂无新车型规划 | **L3**<br>车型未知 | | **L4**<br>车型未知 |
| 长安 | **L2**<br>UNI-K / UNI-T | **L2**<br>UNI-V / 阿维塔11 / 欧尚Z6 / C385 | | | **L4**<br>车型未知 |
| 广汽 | **L2+**<br>AION LX | **L2++**<br>AION LX PLUS | **L2++**<br>传祺 车型未知 | **L4**<br>AH8 | |
| 上汽 | **L2**<br>RX5 MAX / i6 MAX | **L2**<br>飞凡R7 / 荣威 鲸 / MG ONE β版 | | | |
| 智己 | | **L2**<br>智己L7 | | | |
| 岚图 | **L2**<br>岚图 Free | **L2**<br>岚图 梦想家 | **L3**<br>岚图 H53 | | |

摇柄车窗        电动车窗

Why not just a switch to turn on/off the power supply of motor which lift up or down the window?

# IC Grade

| | 消费级 | 工业级 | 车规级 |
|---|---|---|---|
| 温度范围 | 0°C~70°C | - 40°C~ 85°C | - 40°C~ 125°C |
| 电路设计 | 防雷/短路保护/热保护 | +双变压设计/抗干扰/超高压保护 | +多重短路/多重热保护 |
| 工艺处理 | 防水 | +防潮/腐/霉 | +增强封装和散热 |
| 封装形式 | 塑料或树脂 | 塑料或树脂 | 金属 |
| 出错率 | < 3% | < 1% | 0 |
| 寿命 | 2~3年 | 5~10年 | 15年 |
| 持续供货时间 | > 2年 | > 5年 | > 30年 |
| 测试标准 | JEDEC | JEDEC | AEC-Q100 |
| 系统成本 | 线路板一体化设计，价格低廉但维护费用较高 | 积木式结构，每个电路均带有自检功能，造价稍高但维护费用低 | 积木式结构，每个电路均带有自检功能，并增强了散热处理，造价较高维护费用也较高 |
| 应用 | 手机、PC等数码产品 | 工业控制 | 汽车电子 |

| Robustness & Reliability |
|---|
| ICs/Circuits robust and stable against all influences, variations, failures, and defects in design, manufacturing, operation lifetime |

https://www.youtube.com/watch?v=X2UxtKLZnNo

Robots, equipment, industry facility, etc., need IC similar to automobile:

Function (More and more powerful / intelligent)

Robustness

# Tools

➢ **Linux**

➢ **Gvim**
　➢Text editor for coding RTL

➢ **VCS**
　➢for RTL simulation

➢ **DVE or Verdi**
　➢for viewing waveform

➢ **Design Compiler**
　➢for RTL compile

# Basics of Linux

➢ Basic commands

https://www.runoob.com/w3cnote/linux-common-command-2.html

https://cloud.tencent.com/developer/article/2375910

➢ Shell script

https://www.runoob.com/linux/linux-shell.html

➢ Makefile

https://zhaishuangdong.blog.csdn.net/article/details/106889661

https://blog.csdn.net/ZBraveHeart/article/details/123187908

# GVIM

➢ https://blog.csdn.net/qq_42759162/article/details/124733389

➢ https://blog.csdn.net/was172/article/details/90326173

# VCS

- https://www.synopsys.com/zh-cn/verification/simulation/vcs.html

- https://blog.csdn.net/Hide_in_Code/article/details/141792415

- https://cloud.tencent.com/developer/article/2111018

- https://blog.csdn.net/qq_39507748/article/details/115087549

- https://blog.csdn.net/burningCky/article/details/109891288

- https://blog.csdn.net/m0_57102661/article/details/135654223

# Verdi

➢ https://www.synopsys.com/zh-cn/verification/debug/verdi.html

➢ https://blog.csdn.net/immeatea_aun/article/details/80961258

# Design Compiler

- https://www.synopsys.com/implementation-and-signoff/rtl-synthesis-test/dc-ultra.html

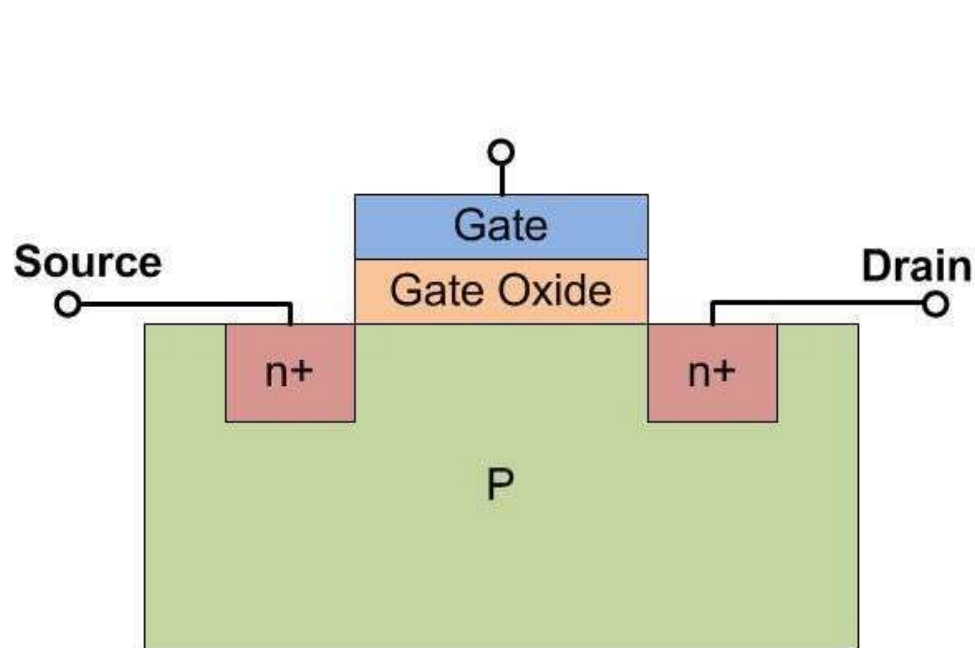- https://blog.csdn.net/qq_42759162/article/details/105541240

- https://zhuanlan.zhihu.com/p/129059203

# IC Layers

# FPGA Mechanism: LUT
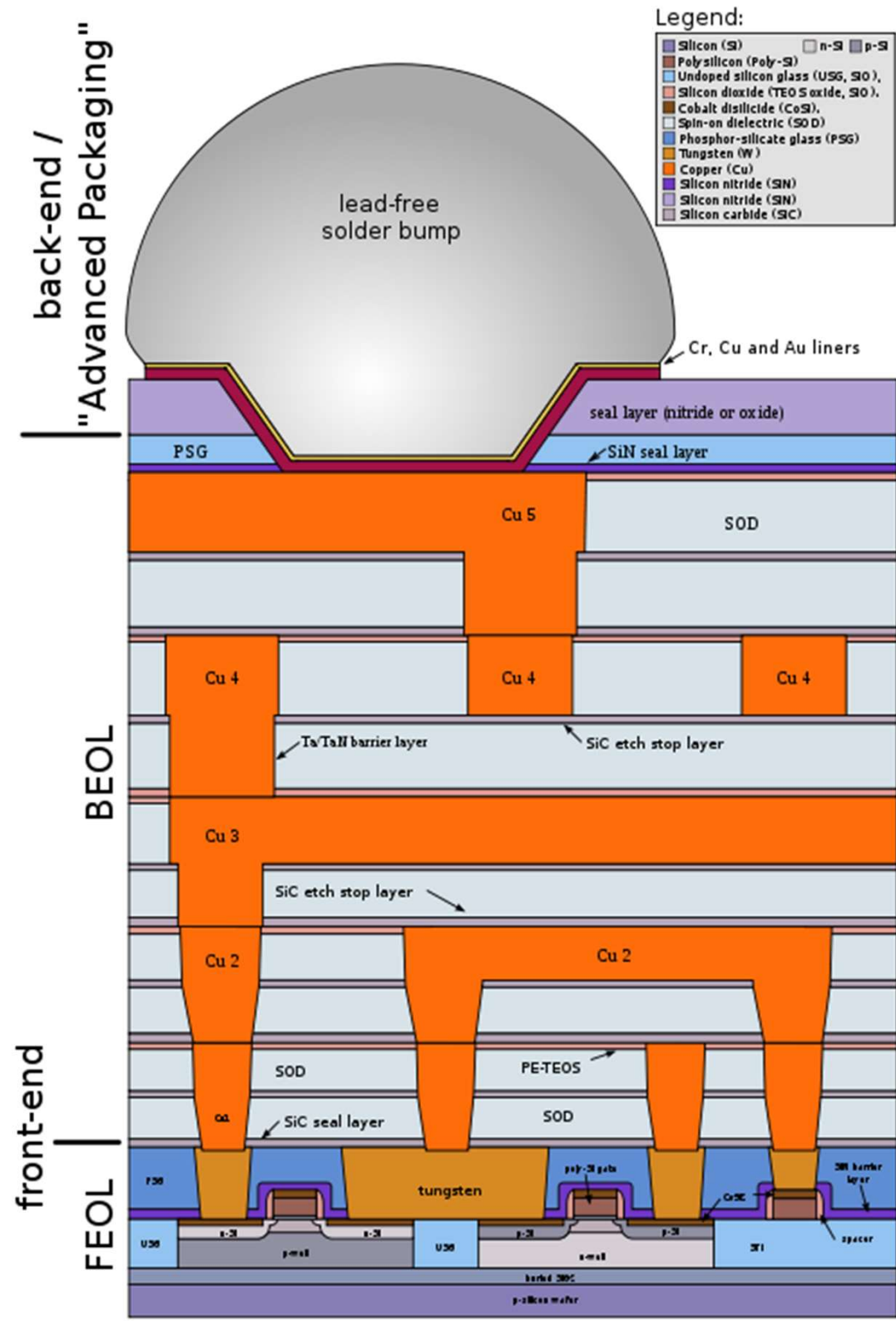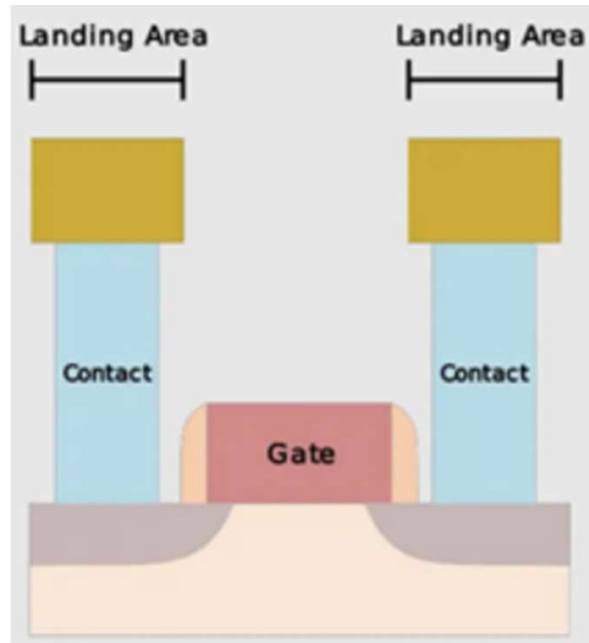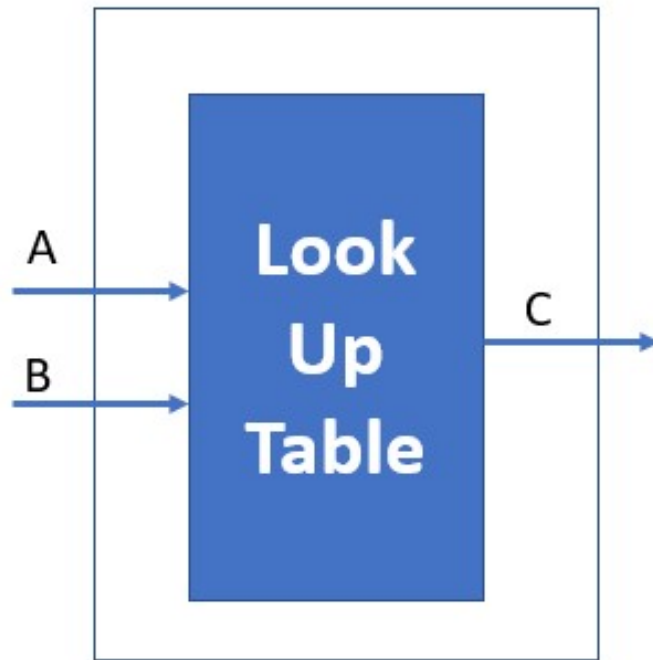
| Input A | Input B | Output C |
|---------|---------|----------|
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

➢ FPGA (Field Programmable Gate Array)

   ➢ Can be re-programmed to implement circuit of different logic

➢ Look Up Table (LUT)

   ➢ Basic logic unit in FPGA

➢ LUT works as "memory" to implement logic gate

   ➢ Output value is stored in "memory"

   ➢ Inputs work as the address of "memory"

   ➢ The logic of a gate is implemented by "reading memory"

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➢ https://fpga.eetrend.com/blog/2022/100561130.html

# Application of FPGA Chip

1. FPGA application
   1. Work as IC directly
   2. Work for verification

2. FPGA在HFT(高频交易)中有哪些具体应用
   https://www.zhihu.com/question/360382993

3. https://www.jumptrading.com/careers/?titleSearch=campus+intern

# Memory Types

➢ DRAM、SRAM、NAND Flash、NOR Flash、EEPROM、MRAM

➢ https://mp.weixin.qq.com/s/_5c16oYeeONpw_R4UrhEIg

# Flash

MOSFET
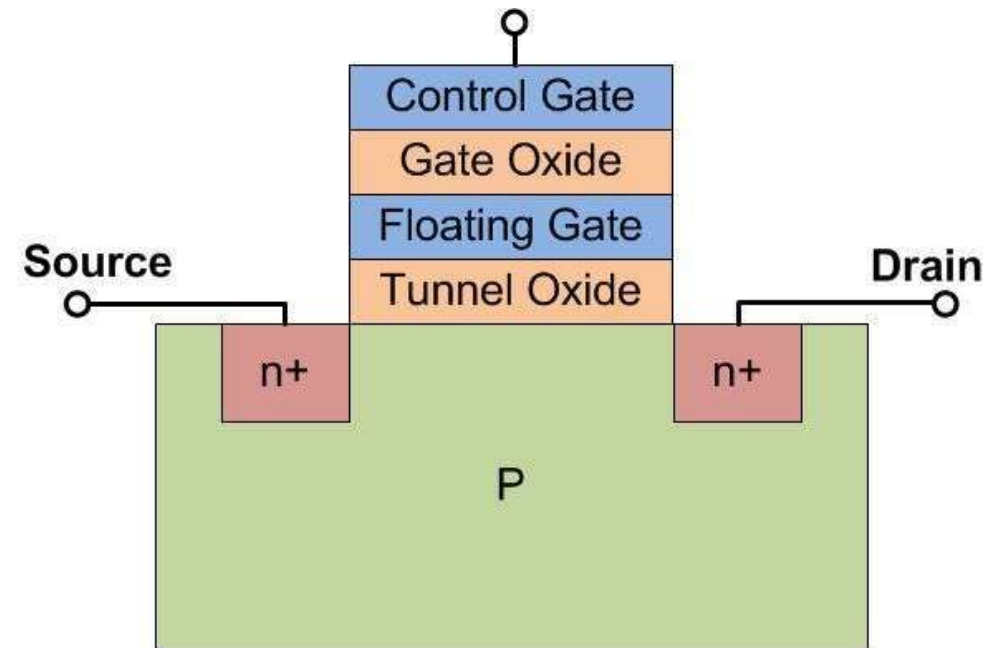


Floating Gate Transistor

➢ Floating gate to store charge

➢ Data (0/1) is represented by the voltage of floating gate

➢ Floating gate transistor works as the data storage unit of Flash memory

➢ Non-volatile (Data is still stored without power)

# SRAM
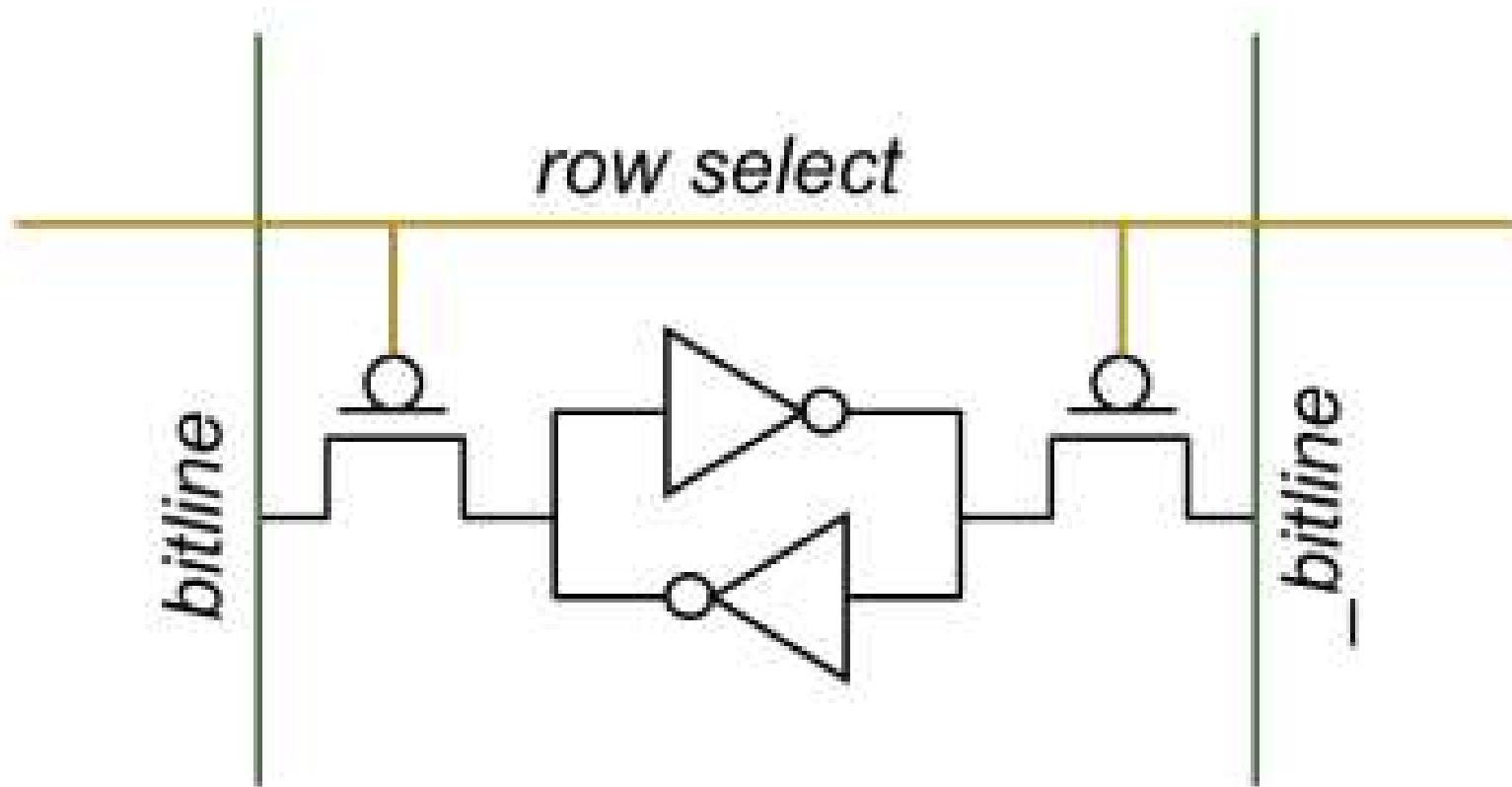
- ➢ 6T (Transistor) to store 1 bit of data
- ➢ Volatile (Data is lost without power)

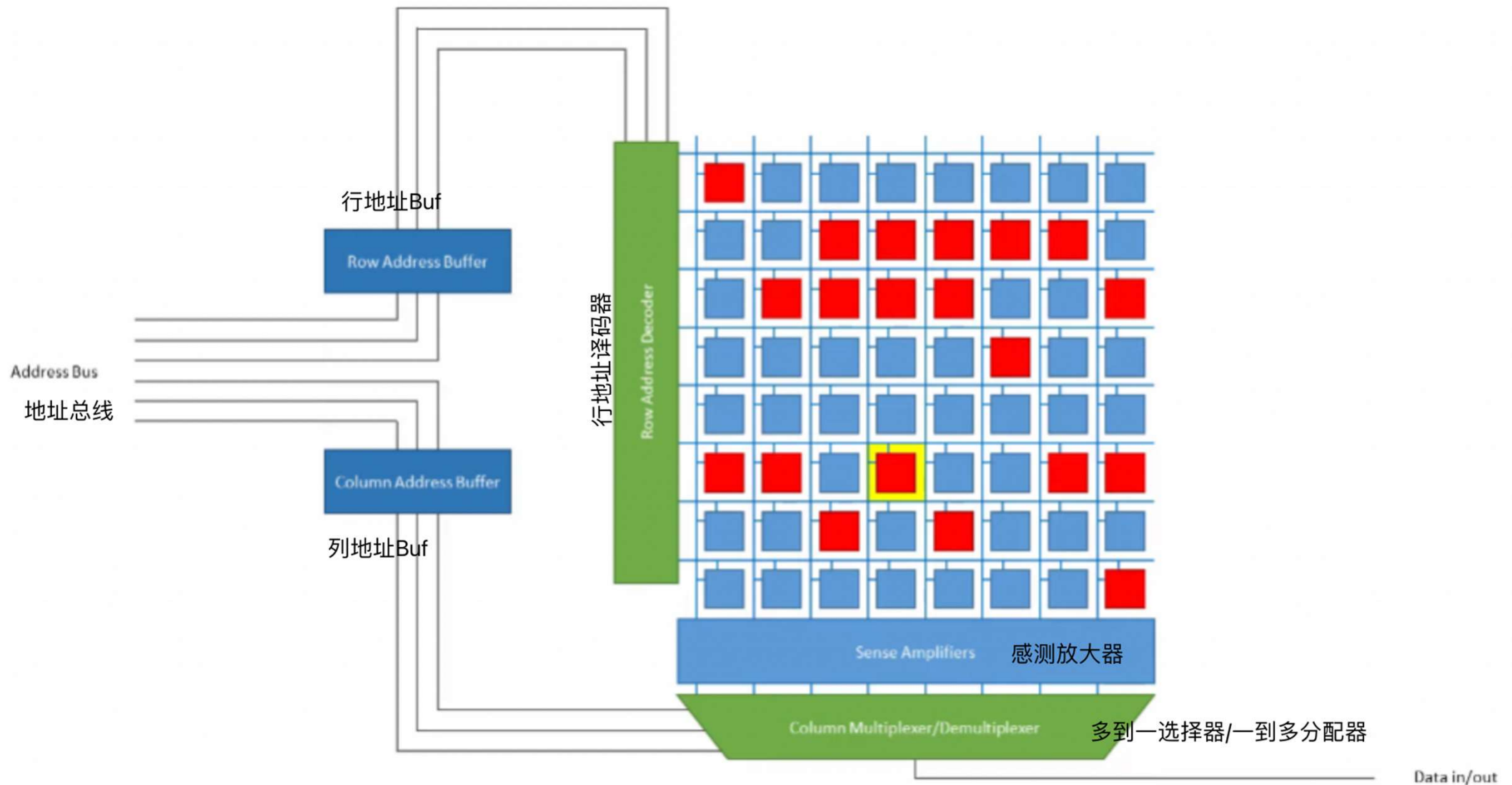DDR SDRAM: Double Data Rate Synchronous Random Access Memory
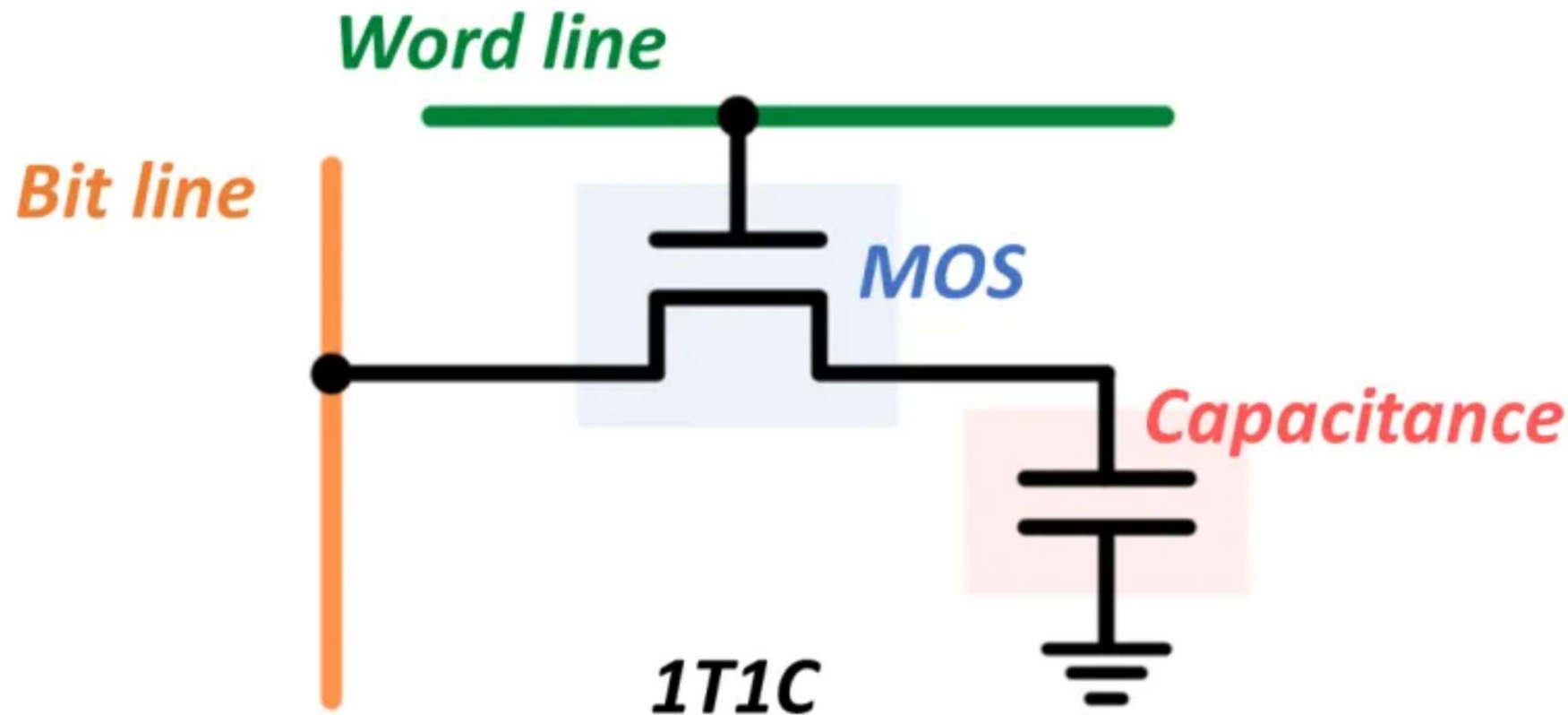


➢ 1T1C (1 Transistor 1 Capacitor) to store 1 bit of data

➢ Volatile (Data is lost without power)

➢ Need refreshing even with power

    ➢ Charge leaks within a short time (~us)

    ➢ Data (Charge) is rewritten before charge lost

# DRAM

➢ Word line & bit line: Address
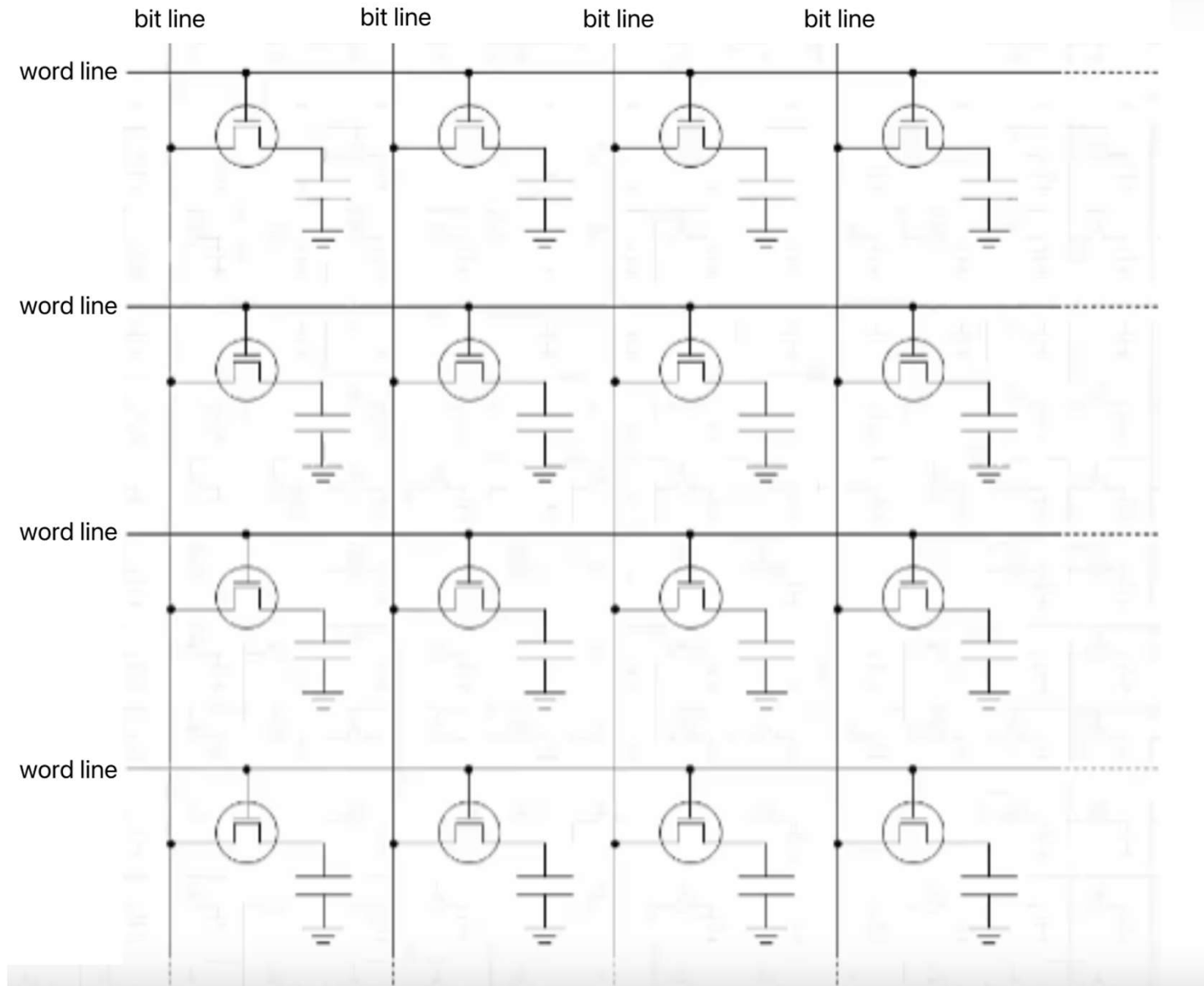
# RAM Address Decoder



- ➢ Data store unit: Store data
- ➢ Address decoder: Select desired storage unit to write or read data

# Companies with Automotive IC

➢ https://zhuanlan.zhihu.com/p/7624540801

➢ https://zhuanlan.zhihu.com/p/706944659