

# 模拟与数字电路

## Analog and Digital Circuits



课程主页 扫一扫

第一讲：绪论、模拟与数字信号/系统

Lecture 1: **Course Introduction**

主讲：陈迟晓

Instructor: Chixiao Chen

# 提纲

- 课程导论
- 模拟与数字信号
- 模拟信号/数字信号的转换



# 课程目标与主讲人简介

- 面向智能科学与技术专业智能系统和芯片方向
- 旨在使学生掌握模拟电路、数字电路、数模混合信号电路的基本概念、基础理论和分析方法
- 重点培养学生在同时具有模拟与数字电路的智能感知系统、计算系统和SoC中分析问题的能力，为后续课程，打下坚实。

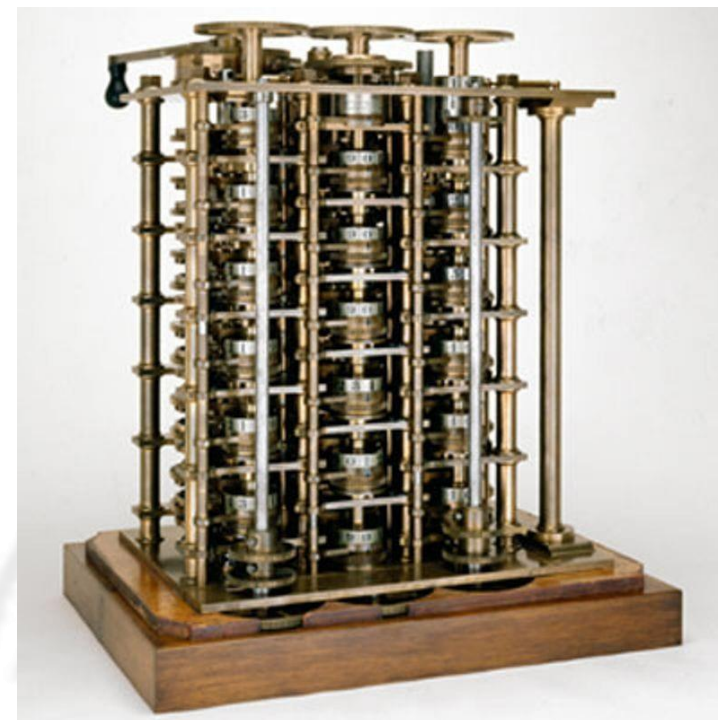
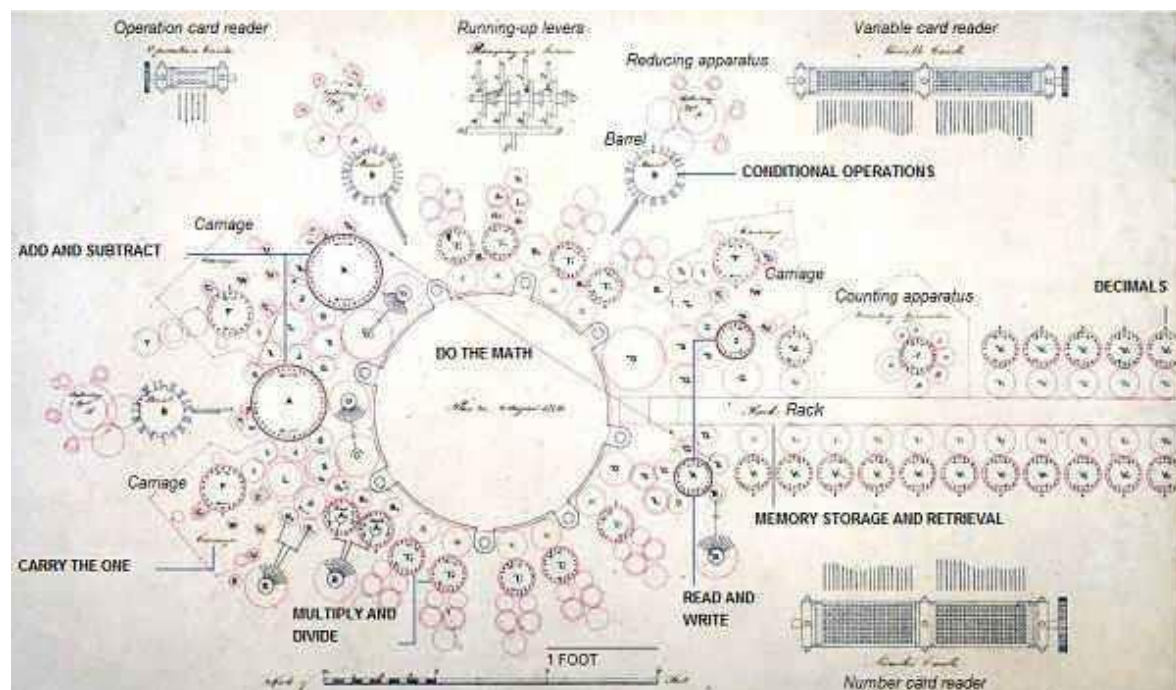


陈迟晓

- 复旦大学 微电子与固体电子学博士
  - 华盛顿大学 电子工程系博士后
  - 复旦大学 工研院 青年副研究员/硕导
- 研究领域：集成电路设计、人工智能芯片、  
数模混合信号电路设计、  
专用计算机体系结构

# 前 电子时代

- The Babbage Difference Engine
  - 1820 by Charles Babbage



# 半导体器件的发明

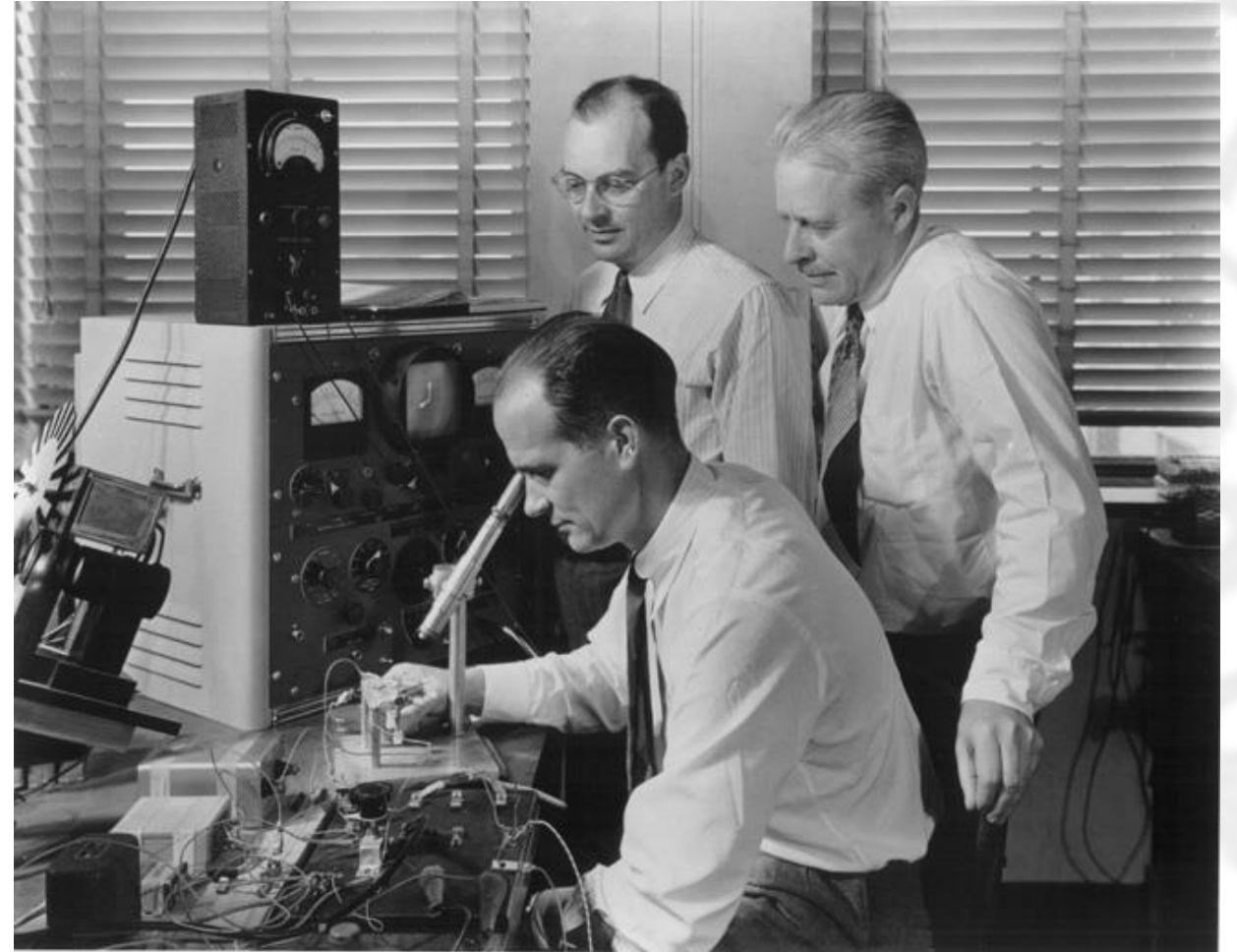
- Nobel Prize 1956

*for their research on semiconductors and  
their discovery of the transistor effect*



The first point contact  
transistor @ 1946, Dec.  
Bell Lab.

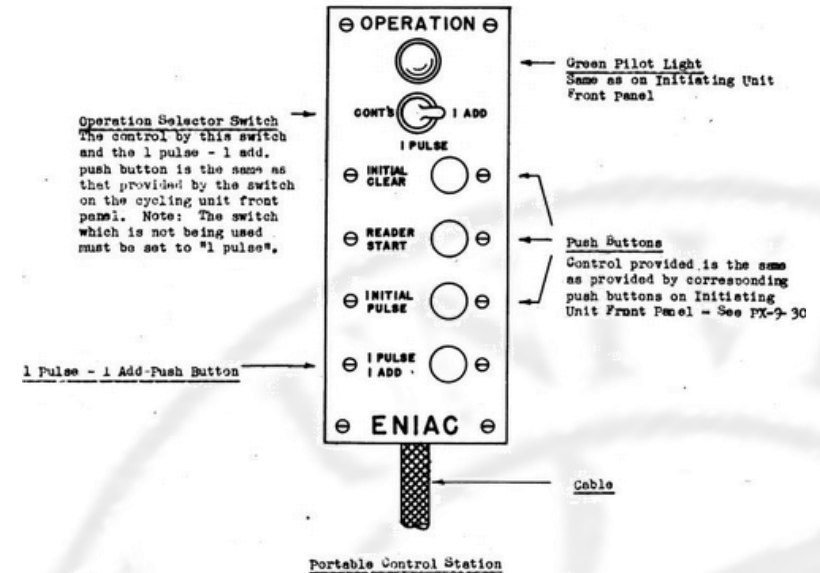
Transistor = transfer +  
resistor





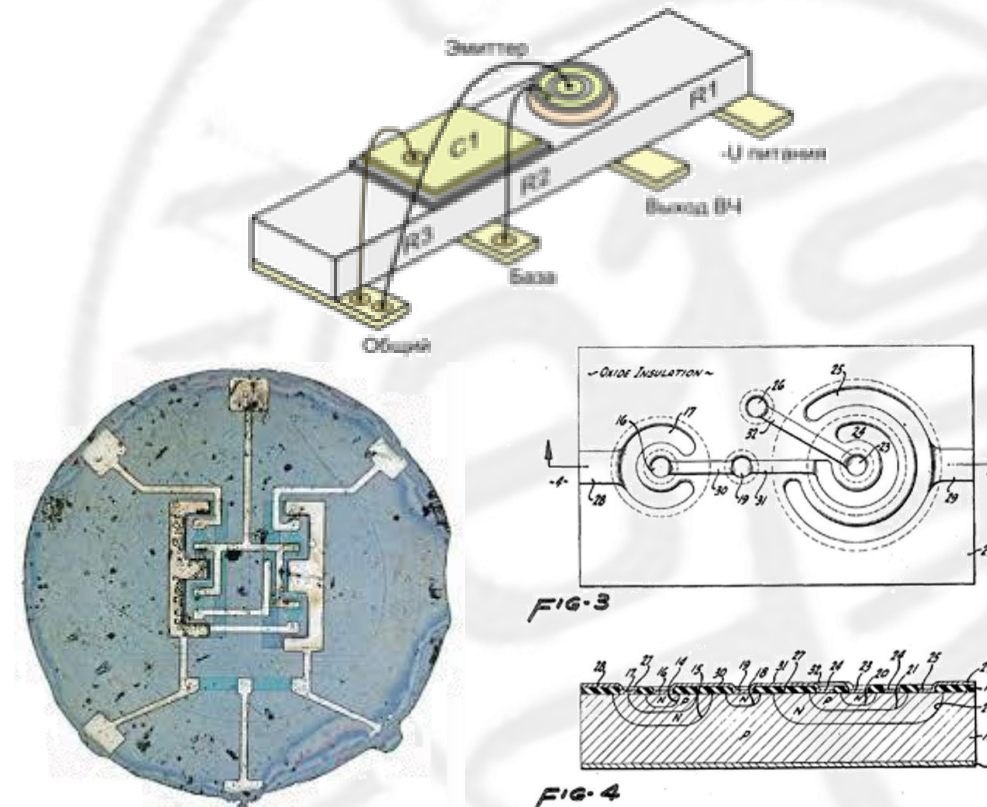
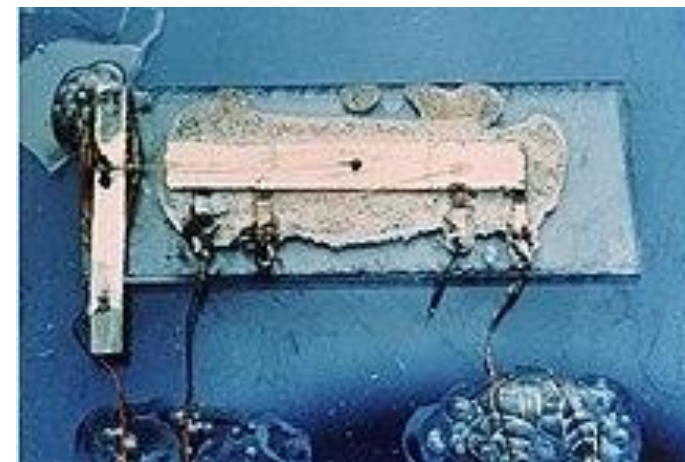
# 首台电子计算机

- ENIAC
  - Electronic Numerical Integrator and Computer
  - 1946 in University of Pennsylvania
  - 15m x 9m, 18000 vacuum tubes
  - First general programmable computer
  - Decimal system, achieve 5000 add/sec
  - applied for trajectory computing in WWII
  - An implementation of Turing Machine



# 集成电路的出现

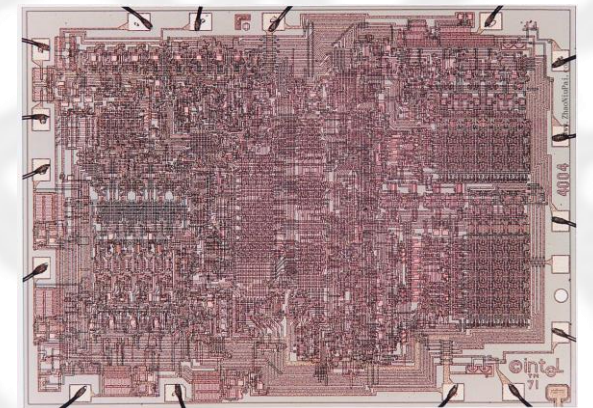
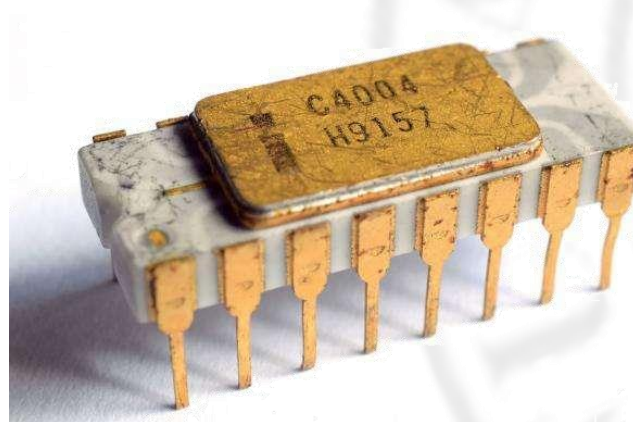
- Robert Noyce (FairChild) and Jack Kilby (TI)  
Nobel Prize 2000





# 早期集成电路代表——首颗处理器芯片

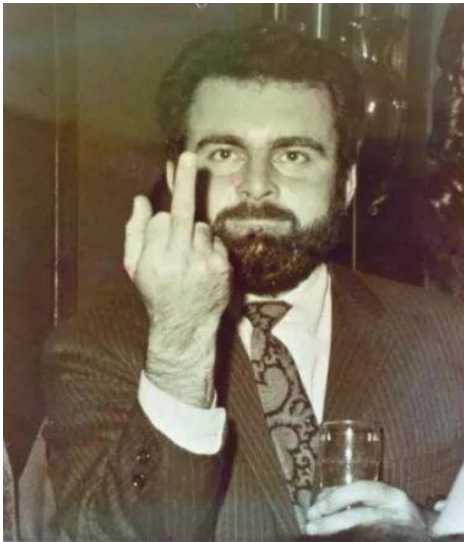
- Integrated Circuits
  - Shockley and Fairchild
  - Noyce and Moore founded Intel in 1969, and released the first CPU chip – Intel 4004
- Intel 4004
  - Von Neumann implementation on IC
  - Area: 3mm x 4mm, clock: 740kHz
  - ~60000 operations / second
  - Beginning of Moore's Law





# 早期集成电路代表——首颗运算放大器

- First amplifier designed by Widlar
  - $\mu\text{A}702 \rightarrow \mu\text{A}741$



# message to the competition is simple and straightforward.



We've laid it all out, so you can see it's very straightforward. From now on, National doesn't pour fuel on the fire. We're going to take care of the members of our industry and let the competition burn on their own.

We're the second largest manufacturer in the print sheet-metal product category and we're going to do 270,000 more boxes a year.

We're also going to do more sheet-metal products that will knock the competition right on their heels.

There's also a lot of things we're not going to do. We're not going to make a lot of products nobody wants. That's a guarantee.

We're not going to just make a new 16-sided die that our customers don't even want. Yet, Fairchild is now the best at it anyway.

We're not going to guarantee a shipment for September that we couldn't possibly deliver before Christmas. That's the old way.

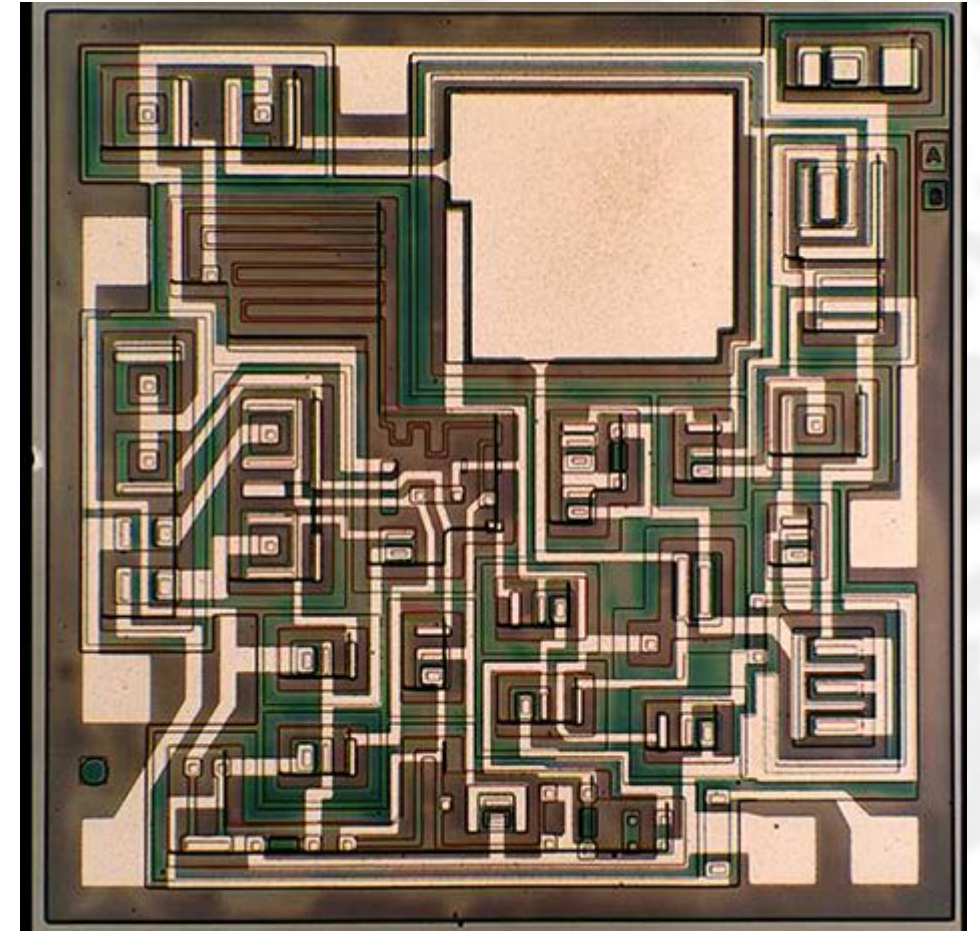
And we're not going to sit around on our hands waiting for the second to come to us. Motorola's concept of the customer as God is new.

In short, we're going to be damned hard to compete with.

You know where else also guarantees National Semiconductor Corporation?

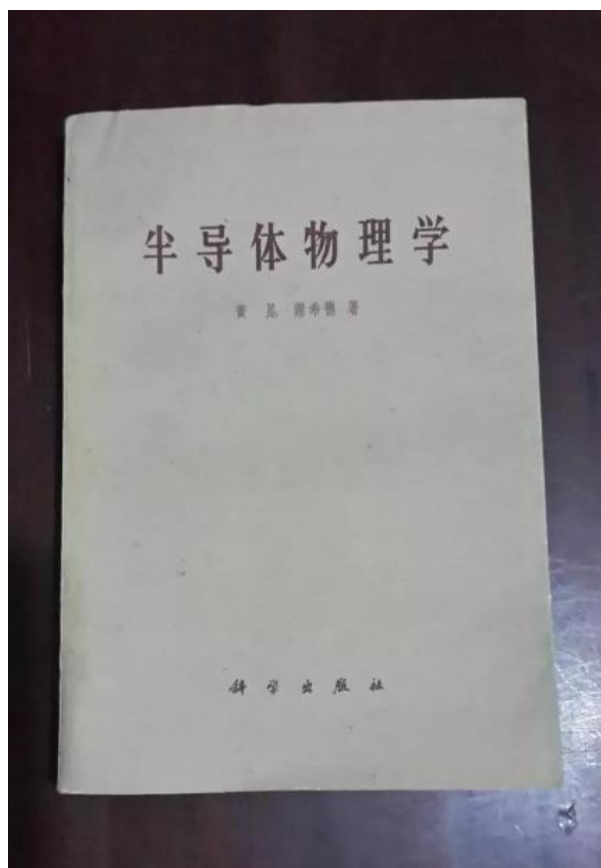
19400 Seven Courts Drive, Santa Clara, Calif. 95051  
Phone (408) 752-3000 / Telex (316) 539-6446

## National



# 复旦大学集成电路发展历史

- 中国半导体物理的起源



## 国务院学位委员会已投票通过设立“集成电路”一级学科

澎湃新闻记者 蒋子文

2020-08-02 14:16 来源：澎湃新闻

字号

据证券时报网报道披露，7月30日，国务院学位委员会会议投票通过集成电路专业将作为一级学科，并将从电子科学与技术一级学科中独立出来的提案。集成电路专业拟设于新设的交叉学科门类下，待国务院批准后，将与交叉学科门类一起公布。



# 电路课程路线图

- 基础课

《模拟电子学基础》 《信号与系统》

《数字逻辑基础》 《程序设计》

- 进阶课程

《模拟集成电路》 《高频/射频电路》

《数字集成电路》 《计算机体系结构》

- 高阶/研究生课程

《智能处理器专用体系结构》 《数据转换器》 《FPGA原理》

科技

芯片 (集成电路)

中国科学院大学

中国芯片

如何评价中国科学院大学「一生一芯」计划？对国产芯片的发展意味着什么？

🔖 圆桌收录 · 漫游科技宇宙 · 进行中

【#国科大本科生超硬核毕业证#】今天，@中国科学院大学 公布了首期“一生一芯”计划成果——在国内首次以流片为目标，由5位2016级本科生主导完成一款64位RISC-V处理器SoC芯片设计并实现流片，芯片能成功运行Linux操作系统以及学生自己编写的国科大教学操作系统UCAS-Core。今年6月2日，“一生一芯”团队学生代表向国科大毕业答辩委员会演示处理器芯片的功能，交出了一份超出预期的本科毕业设计“答卷”，也实现带着自己设计的处理器芯片毕业这一目标。据悉，这5位毕业生都将在中国科学院计算技术研究所读研究生，“参与一个更有挑战的项目，开发一款高性能乱序多发射RISC-V处理器核的设计”。（中青报·中青网记者 孙庆玲） [t.cn/A6yDJufr](https://t.cn/A6yDJufr) [t.cn/A6yDiPM3](https://t.cn/A6yDiPM3)[/cp]

关注问题

写回答

邀请回答

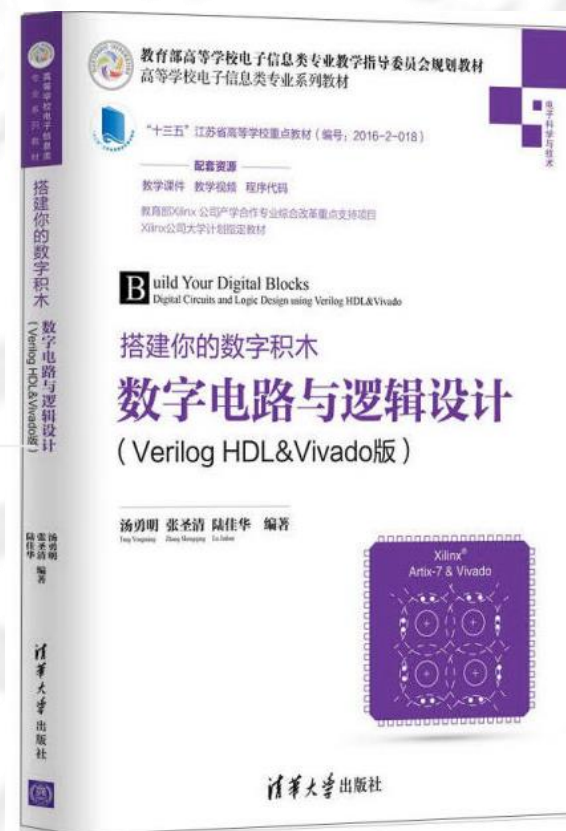
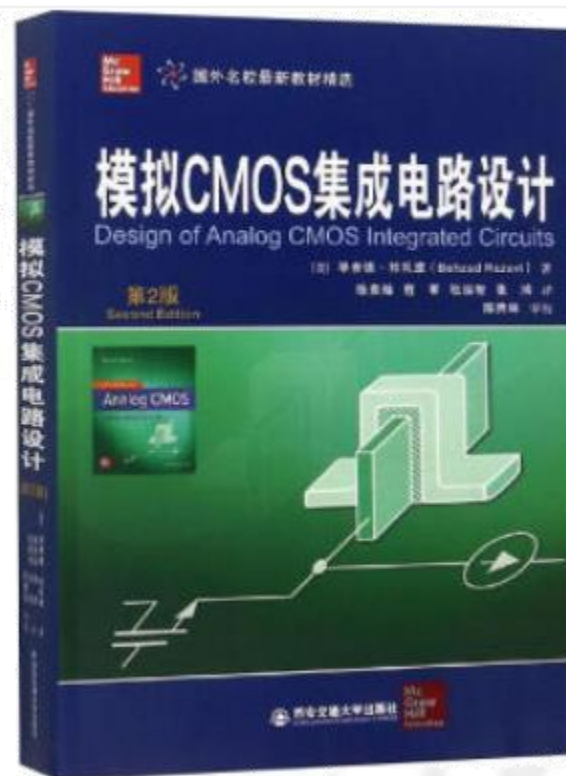
25 条评论





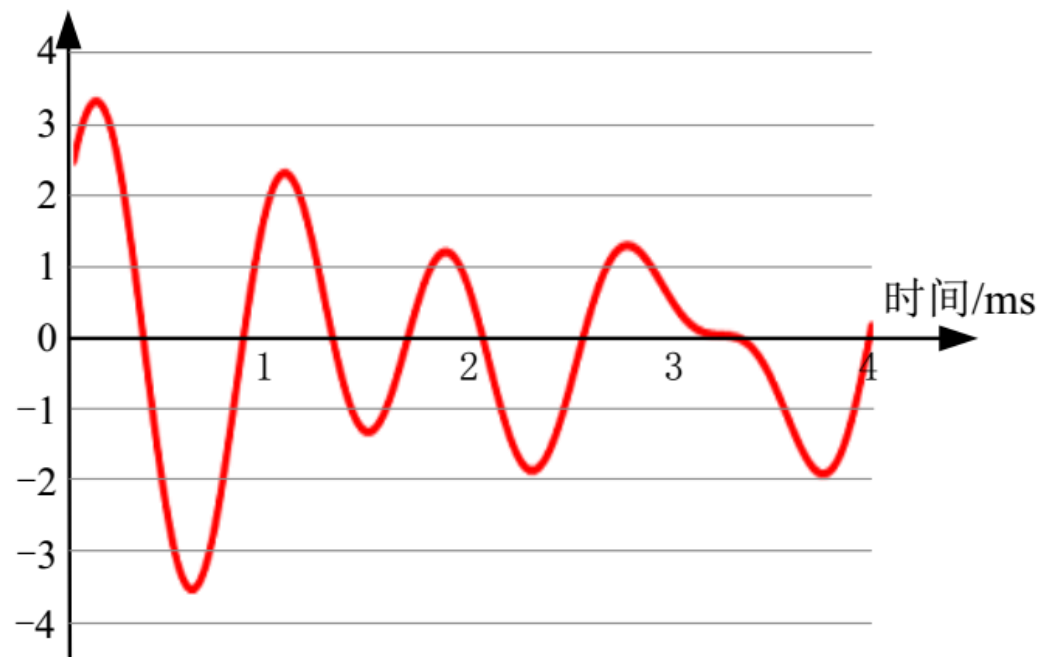
# 课程考核与安排

- 考勤 6%
  - 作业 24%
  - 期末Project 20%
  - 期中考试20%
  - 期末考试 30%
- 
- Project 内容： 基于FPGA开发板设计



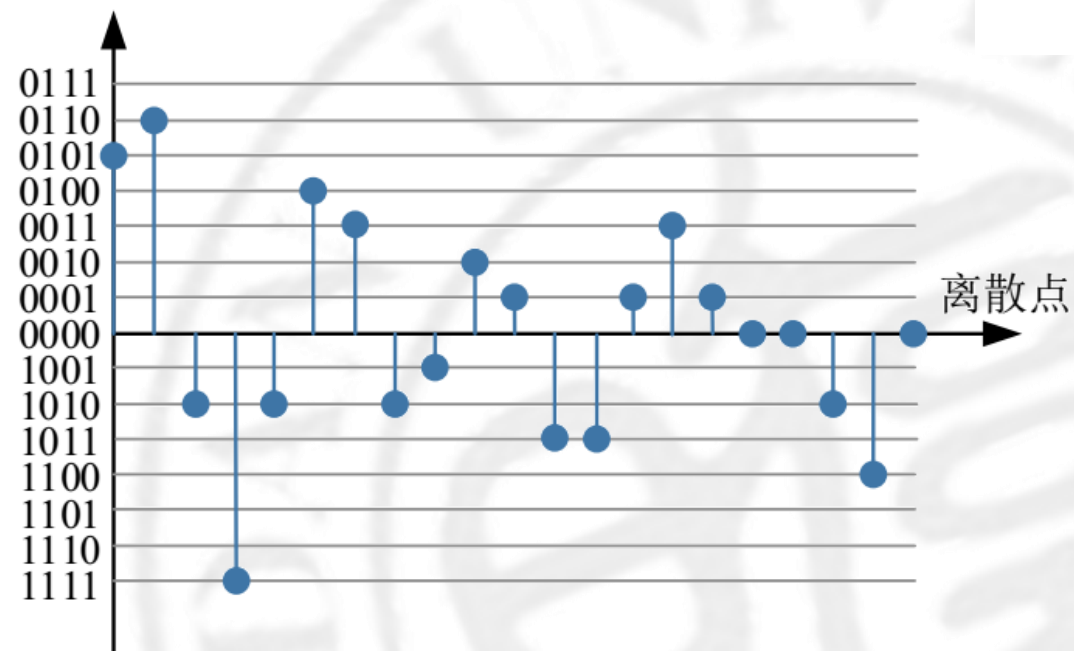
# 模拟信号 vs 数字信号

模拟信号  
电压/V



模拟信号

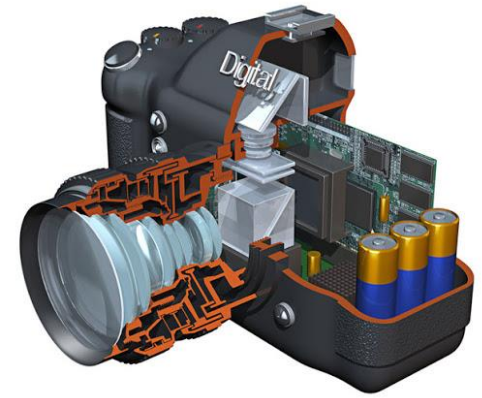
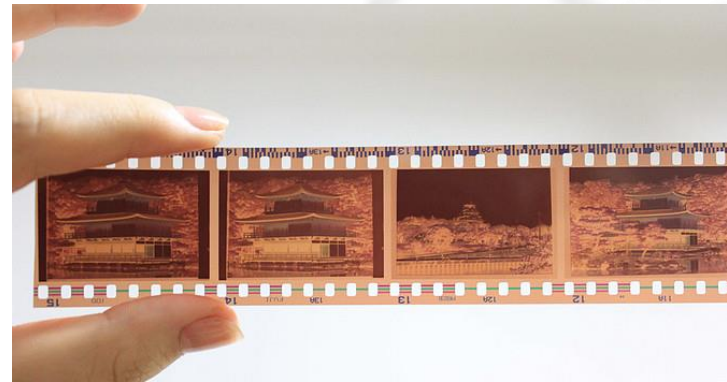
数字信号



数字信号

# The world is analog, why we need digital?

- These media process analog signals or digital signals?



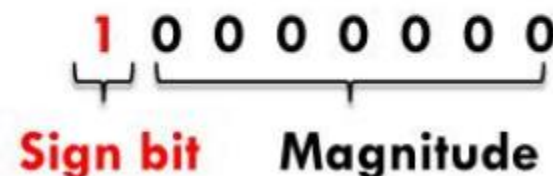
- The problems with analog signals are **noisy, weak (distorted through long distance)** and **hard to store**.



# 数字信号的表示方法

- 源码

- Thus, for  $n$ -bit word, the first bit is the **sign bit** and  $n-1$  bits represent the **magnitude** of the number.



- 反码 (1's complement)

- The 1's complement of an  $N$ -digits binary integer  $B$ :  
**1's complement =  $(2^N - 1) - B$**

- 补码 (2's complement)

- 2's complement =  $\begin{cases} 2^N - B, & B \neq 0 \\ 0, & B = 0 \end{cases}$

**Example :** Convert  $-5_{10}$  to 4-bit 1's complement

$$\begin{aligned} \text{1's complement} &= (2^4 - 1) - 5 \\ &= (16 - 1) - 5 \\ &= 10_{10} \rightarrow 1010_2 \end{aligned}$$

**Example 1:** Convert  $-5_{10}$  to 4-bit 2's complement

$$\begin{aligned} \text{2's complement} &= 2^4 - 5 \\ &= 16 - 5 \\ &= 11_{10} \rightarrow 1011_2 \end{aligned}$$

# 数字信号的表示方法

## 1's Complement Subtraction

- $16_{10} - 5_{10} \rightarrow 16_{10} + (-5_{10})$
- $\rightarrow 10000_2 + (11010_2)$

$$\begin{array}{r} 10000 \\ + 11010 \\ \hline 101010 \\ + 1 \\ \hline 01011 \end{array} \rightarrow 11_{10}$$

## 2's Complement Subtraction

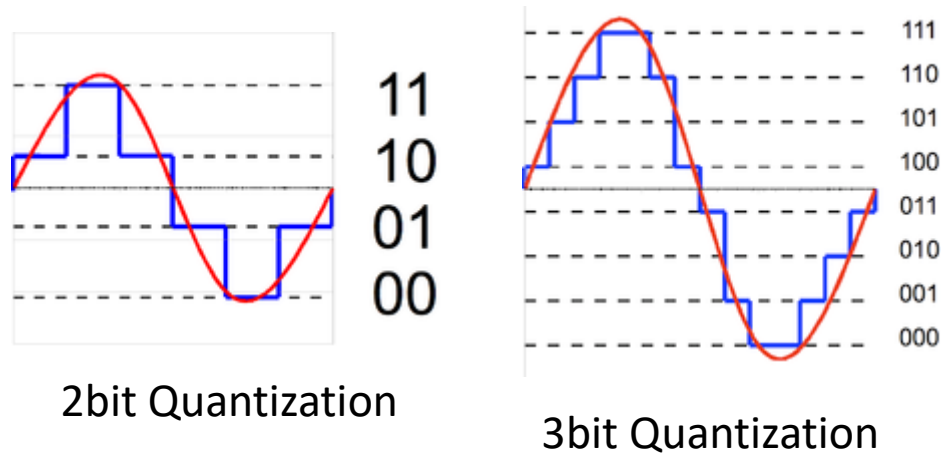
- $16_{10} - 5_{10} \rightarrow 16_{10} + (-5_{10})$
- $\rightarrow 10000_2 + (11011_2)$

$$\begin{array}{r} 10000 \\ + 11011 \\ \hline 101011 \end{array} \rightarrow 11_{10}$$

- Generating 2's complement is **more complex** than other representations.
- However, 2's complement arithmetic is **simpler** than other arithmetic.

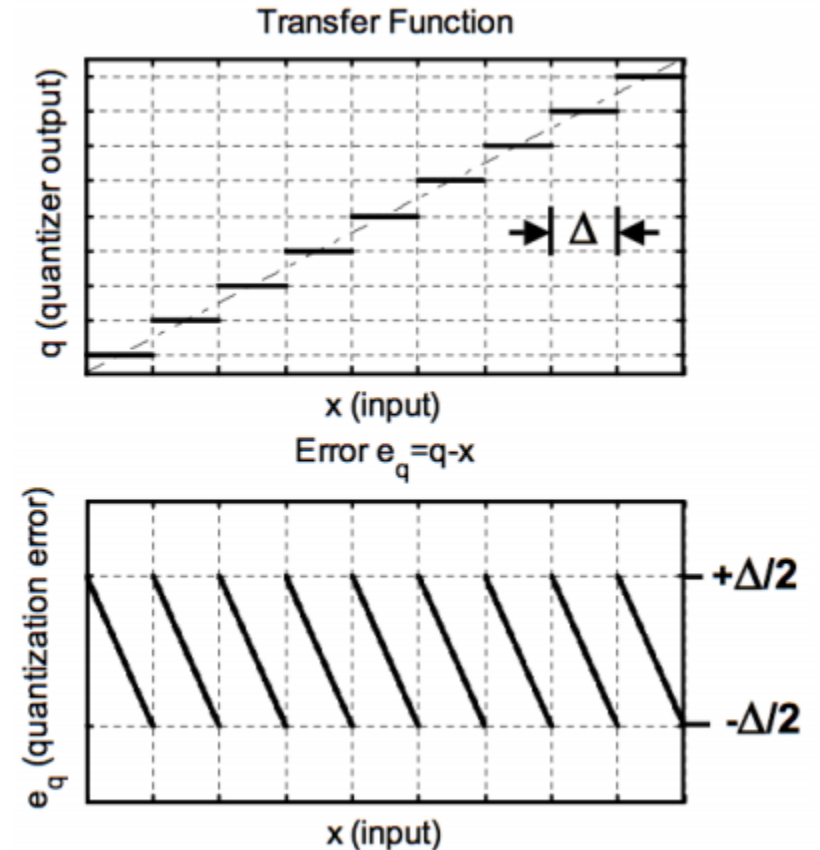
# 模拟与数字信号的转换——量化

- Quantization & resolution



- Quantization Error

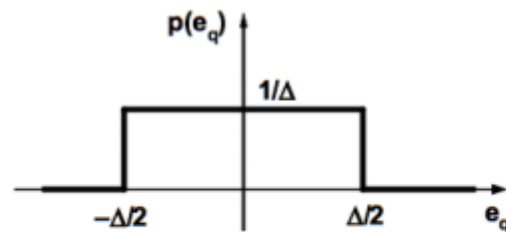
- The residual of the signals
- Quantization step  $\Delta \rightarrow$  Error Bounded by  $-\Delta/2, +\Delta/2$





# 量化噪声 与 信噪比

- Assumption:  $e_q(x)$  has uniform probability density



**Mean**

$$\bar{e} = \int_{-\Delta/2}^{+\Delta/2} \frac{e}{\Delta} de = 0$$

**Variance**

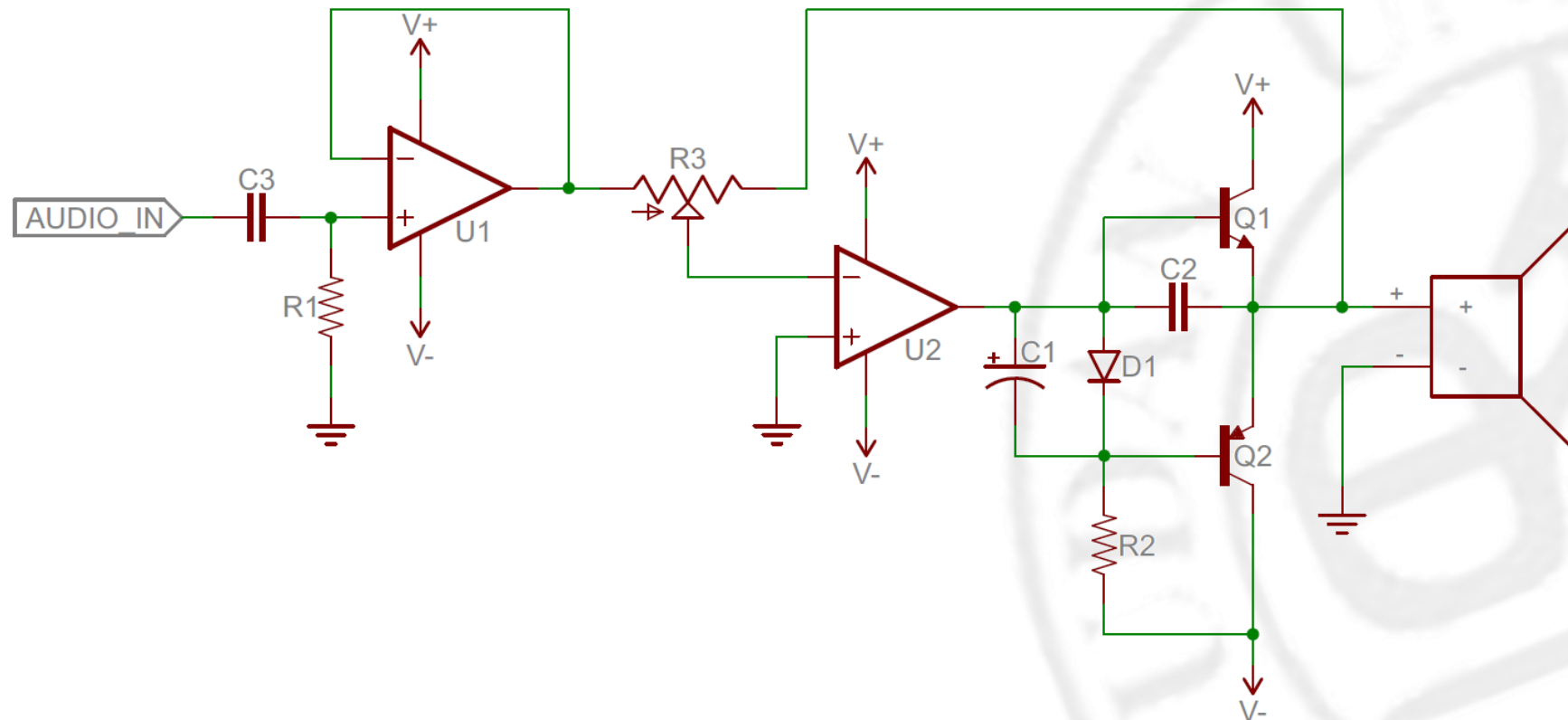
$$\overline{e^2} = \int_{-\Delta/2}^{+\Delta/2} \frac{e^2}{\Delta} de = \frac{\Delta^2}{12}$$

- For a  $B+1$  bit quantizer with a full-scale sinusoidal input,

$$\text{SQNR} = \frac{P_{\text{sig}}}{P_{\text{qnoise}}} = \frac{\frac{1}{2} \left( \frac{2^B \Delta}{2} \right)^2}{\frac{\Delta^2}{12}} = 1.5 \times 2^{2B} = 6.02B + 1.76 \text{ dB}$$

# 模拟电路

- The key function of the analog circuits is **amplifying**.



# 数字电路

- Big data and AI employs digital signal processing.

