HERIOT WATT UNIVERSITY

Semiconductor Electronics

B39SE

Syllabus

Week 1: Fundamentals of semiconductors
Week 2: Atomic models
Week 3: Doping and carrier transport phenomena

Semiconductor fundamentals

Week 4: PN junction - Diodes
Week 5: PIN diode and JFET & MOSFET transistors

Diodes

Week 6: (Break)
Week 7: Bipolar Junction Transistor (BJT) - DC biasing
Week 8: BJT - AC analysis
Week 9: BJT – Frequency response

Transistor BJT

Week 10: Operational amplifiers and applications in linear regime
Week 11: Non-linear regime of OPAMPs and Diodes
Week 12: Diodes applications

Applications

Laboratories

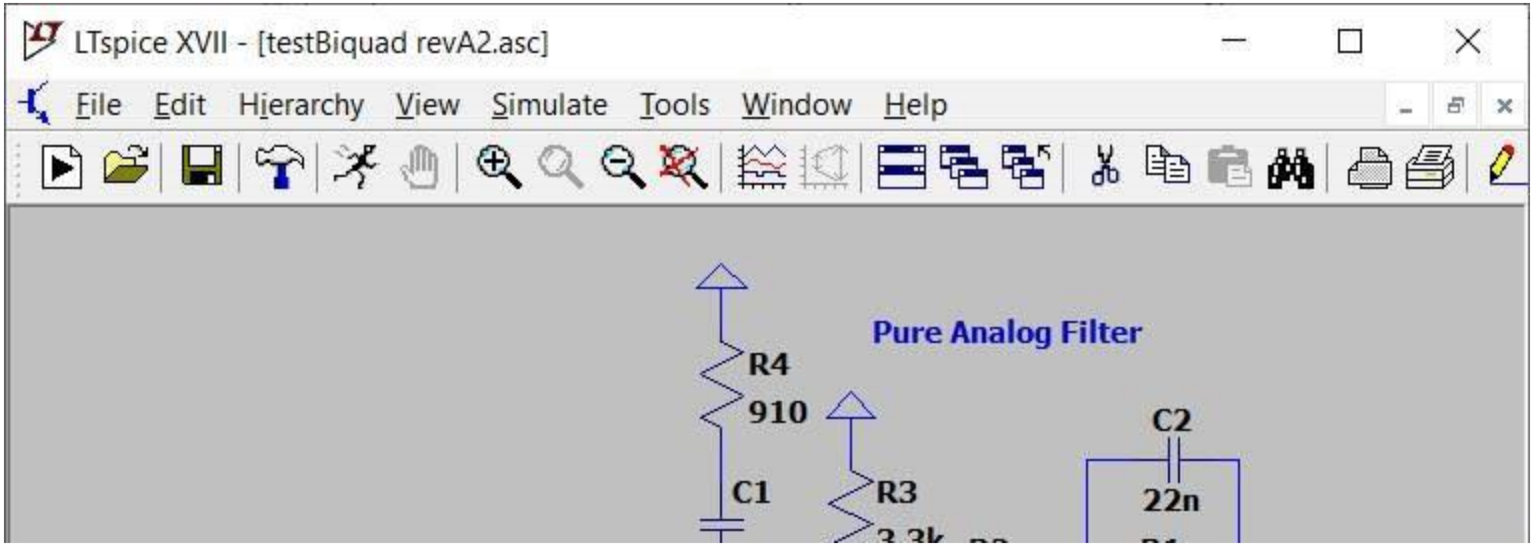
Lab 1: Photoelectric effect

Lab 2: Bandgap variation with temperature

Lab 3: BJT-Diodes

Lab 4: OPAMP

To be done at the university



Evaluation

Final exam: 60% of the overall mark
Class test (Week7): 20%
Lab report (contents Lab1-Lab3): 10%
Test about Labs (contents Lab1-Lab4): 10%

Calendar

Week	date	Activity	Marks
W1	9/4 9/6		
W2	9/14		
W3	9/21		
W4	9/25 9/27		
W5	10/9 10/11		
W6(break)			
W7	10/16 10/19	Mid-term TEST	20%
W8	10/26 11/2		
W9	11/8 11/13		
W10	11/15 11/22	Deadline Lab report	10%
W11	11/27 11/29		
W12	12/4 12/6	Lab Webtest	10%
		Final exam	60%

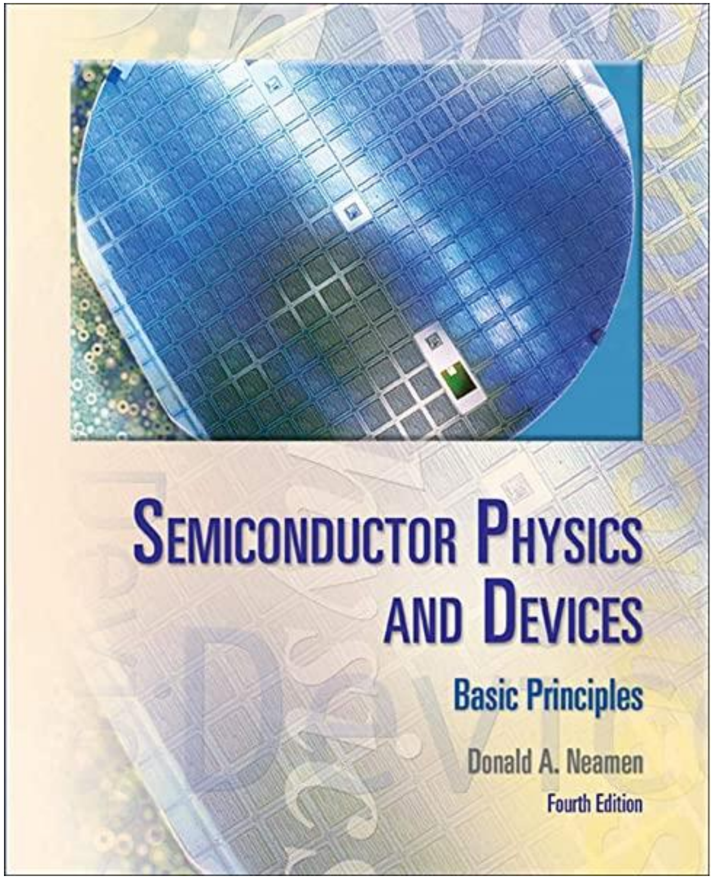
Important!
Progressive
learning

Calendar (The Weeks with Test, the Lectures will be Mondays and Wednesdays)

Week/ Date	**Learning Units**	**Labs** (lab sheets should be prepared for assessments)	Lectures Face-to-Face	**Assessments** (combination of theory and labs)
Week 1	Fundamentals of semiconductors			
Week 2	Atomic models			
Week 3	Doping and carrier transport phenomena			
Week 4	PN Junctions	Lab1+Lab2		
Week 5	Tunnel & PIN diodes. JFET and MOSFET Transistors	Lab1+Lab2		
Week 6	Consolidation Week			
Week 7	Bipolar Junction Transistor (BJT) - DC biasing			Class Test (20%)
Week 8	BJT - AC analysis	Lab3		
Week 9	BJT – Frequency response			
Week 10	Operational amplifiers and applications in linear regime			Lab Report deadline (10%)
Week 11	Non-linear regime of OPAMPs and Diodes	Lab4		
Week 12	Diodes applications			Labs test (10%)
Week 13				Final exam(60%)

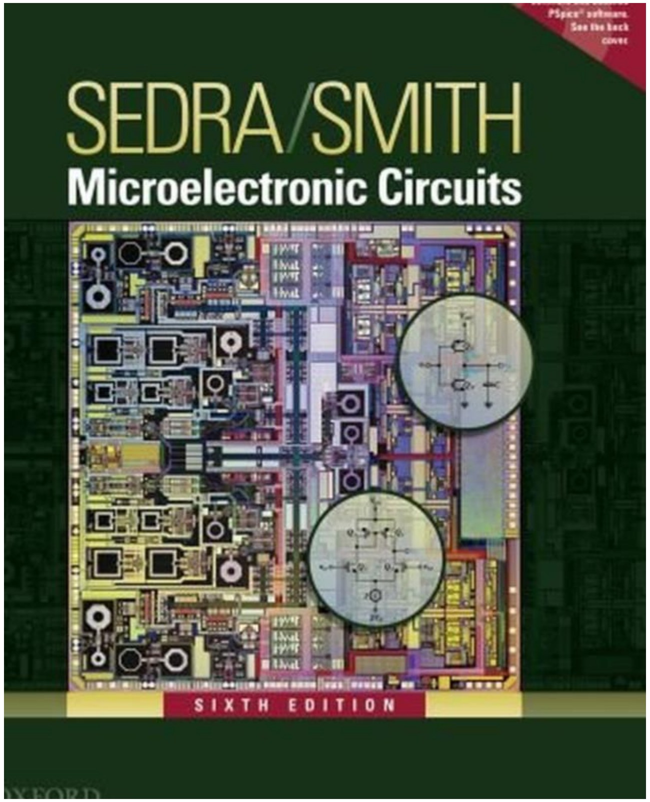
Reference Book

1. Semiconductors Physics and Devices, by Donald Neamen, McGrawHill (main textbook)
   (Useful for Weeks 1 to 5)



Reference Book

2. Microelectronics Circuits, by Sedra and Smith,
(Useful for Weeks 7 to 12)



ELECTRONIC CIRCUITS & DEVICES

Semiconductor Electronics

Objective:

To build on knowledge of the operating principles, technology, circuit analysis and to introduce techniques for the design of analogue circuits containing semiconductor devices.

Contents:

A. Semiconductor operating principles, silicon technology

B. Semiconductor physics

C. Analysis and design of analogue circuits containing semiconductor devices.

D. Development of circuit models for the components and use of these in analysis and design.

Analogue Circuit Design

Analogue vs digital

ANALOGUE:- Infinite number of values within a range

e.g. $0 \rightarrow 5V$, $0 \rightarrow 100mA$

DIGITAL:- Finite number of values within a range

e.g. 0,1,2,3,4,5V 0,10,20,30,40mA

ANALYSIS vs DESIGN

ANALYSIS:- prediction of circuit behaviour

DESIGN:- realisation of a required function

In order to DESIGN, the engineer must have a KNOWLEDGE of the BASIC BUILDING BLOCKS and how to use them. They can be COMBINED, MODIFIED as required, and ANALYSED to confirm design functionality.

The Importance of analogue electronics.

Misconceptions:

- Analogue electronics is old-fashioned and has been or will be replaced by digital electronics.
- Digital technology can do everything!

The Truth:

- ALL quantities in the real world are **ANALOGUE**
  Radio waves, sound waves, light and electronic signals in cables are all analogue.
- All interfaces between digital systems and the real world require analogue electronics.
- ANALOGUE electronics forms a vital part of many so-called digital systems, e.g. CD players, mobile phones, fax machines, computers, etc. Even DRAMs use analogue technology.
- As digital systems become faster the signal waveforms become analogue like.

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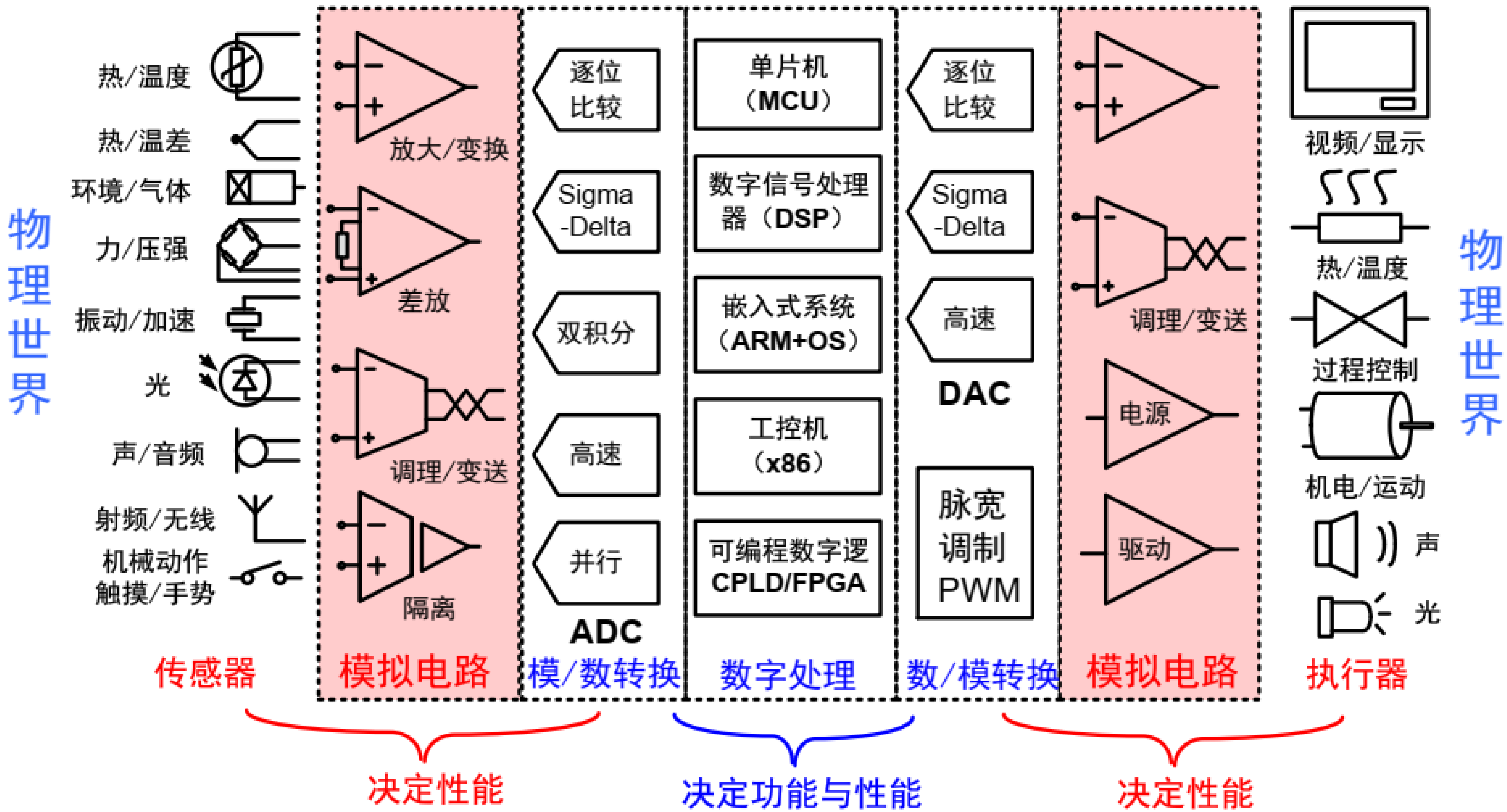

物理世界
热/温度
热/温差
环境/气体
力/压强
振动/加速
光
声/音频
射频/无线
机械动作
触摸/手势
放大/变换
差放
调理/变送
隔离
逐位
比较
Sigma
-Delta
双积分
高速
并行
ADC
单片机
（MCU）
数字信号处理器（DSP）
嵌入式系统
（ARM+OS）
工控机
（x86）
可编程数字逻
CPLD/FPGA
逐位
比较
Sigma
-Delta
高速
DAC
脉宽
调制
PWM
调理/变送
电源
驱动
视频/显示
热/温度
过程控制
机电/运动
声
光
物理世界
传感器
模拟电路
模/数转换
数字处理
数/模转换
模拟电路
执行器
决定性能
决定功能与性能
决定性能

Techniques of analysis & Design

SIMPLIFY CIRCUIT as much as possible.

- Use:- Device Models
  Equivalent Circuits
- Limit the range of operation.
- Make realistic assumptions.

LEARN

- Methods/ techniques.
- Models.
- Basic equations.

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OPAMP and its application------What

Week 10: Operational amplifiers and applications in linear regime
Week 11: Non-linear regime of OPAMPs and Diodes
Week 12: Diodes applications

Applications

※**Introduction to OPAMP** :

the basic op-amp models; symbol; transfer characteristics， etc.

※**OPAMP in Linear region**:

Linear operational Applications------Inverting/Non-inverting Amplifier; Integrator; Differentiator; Filters (basics, type and OPAMP filters)

※**OPAMP in Non-Linear region**:

waveform generators(Schmitt trigger; square wave generator; Triangular wave generator) Oscillators (concepts; Wein bridge oscillator)

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Analysis and design of analogue circuits containing semiconductor devices--------How?

Week 4: PN junction - Diodes
Week 5: PIN diode and JFET & MOSFET transistors
Diodes

Week 6: (Break)

Week 7: Bipolar Junction Transistor (BJT) - DC biasing
Week 8: BJT - AC analysis
Week 9: BJT – Frequency response
Transistor BJT

※**PN Junctions Basic stucture**:

Zero applied bias; Reverse applied bias; breakdown;

※**Diodes**:

Model, characteristics, Analysis of circuit with diodes; other applications(rectifier, smoothing capacitor);Zener Diodes.

※ **BJT (Bipolar Junction Transistor)**:

structure; DC biasing and configuration; BJT circuits(common base, common emitter, common collector configurations); AC analysis, etc.

※ **FET (Field Effect Transistor):**

JFET and MOSFET(characteristics, equivalent circuit, etc.)

Semiconductor Physics------Why

Week 1: Fundamentals of semiconductors
Week 2: Atomic models
Week 3: Doping and carrier transport phenomena

$\left.\right\}$ Semiconductor fundamentals

※**Fundamentals of semiconductors**:

Semiconductor Material(type of solids; space lattices; Bonding of Atoms in solids, etc.)

Fundamental Physics(photoelectric effect, quantification of energy)

※**Atomic models**:

Bohr atomic model, Quantum numbers; Band model

※**Doping and carrier transport phenomena**

Doped semiconductors; Carrier transport phenomena(Drift current in E field; Diffusion current)

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GENERAL DESIGN PROCEDURE

1. List the parameters which are known.
2. Using appropriate models, construct equivalent circuits and simplify.
3. Derive expressions for the known parameters in terms of the component values.
4. Simplify these expressions, to allow component values to be calculated.
5. Calculate the component values.
6. Check if the design meets the required spec. using the full expressions from (3). If not use these component values as initial estimates, and iterate to final solution using the full expressions .

NOTATION USED

Application	Symbol	Subscript	Examples
dc or average value	UPPERCASE	UPPERCASE	I_D, V_{BE}, I_C
Small signal or instantaneous value	lowercase	Lowercase	i_b, v_i, v_o
Total value = dc + small signal	lowercase	UPPERCASE	i_C, v_{CE}, v_S

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Contacts:-

If you have difficulty understanding something in the lectures or tutorial examples

a) ask during a lecture
b) ask at the tutorial sessions which will be held during the semester
c) email to *xfliu1@mail.xidian.edu.cn*
d) QQ group