VE215 Introduction to Circuits

Sung-Liang Chen

Fall 2019

About me

- **1999 – 2003 B.S., Electrical Engineering National Taiwan University**
- **2003 – 2005 M.S., Electro-optical Engineering, National Taiwan University**

- **2007.09 – 2011.12 Ph.D., Electrical Engineering, University of Michigan**
- **2012.01 – 2013.03 Research Fellow, Radiology Department, University of Michigan**

- **2013.05 – present Assistant Professor, UM-SJTU Joint Institute, Shanghai Jiao Tong University**

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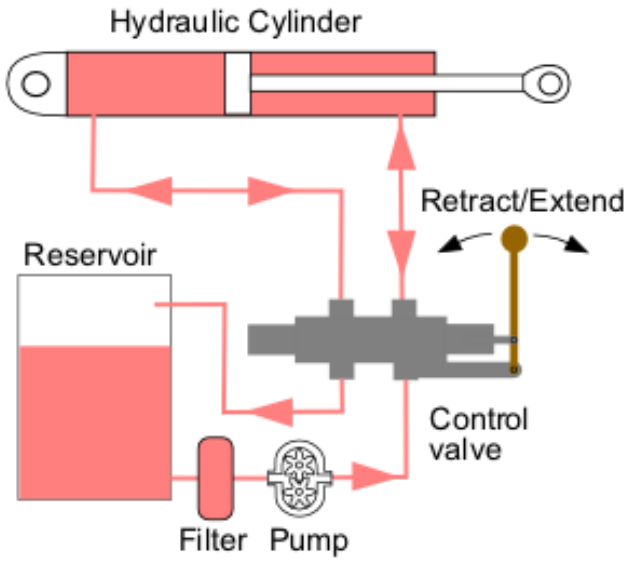
What are circuits?

Circuit–Merriam Webster's definition

- **a :** the complete path of an electric current including usually the source of electric energy
- **b :** an assemblage of electronic elements
- **c :** a two-way communication path between points (as in a computer)
- **d :** a neuronal pathway of the brain along which electrical and chemical signals travel

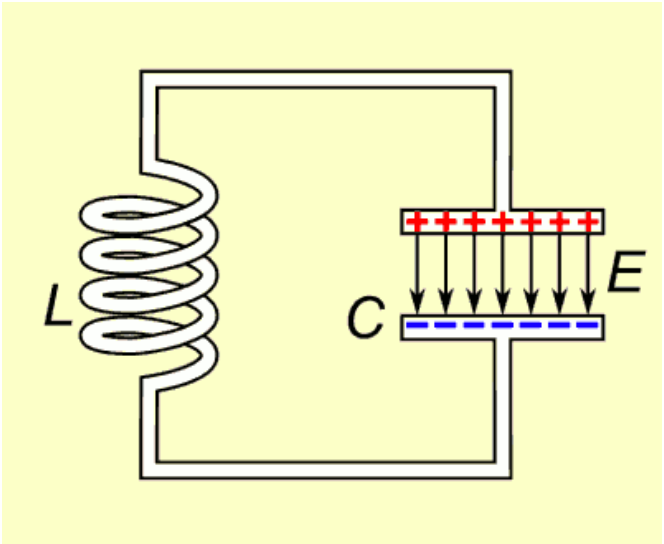
Circuit–Wikipedia's definition (part list)

- Circuit theory, the theory of accomplishing work by routing **electrons, gas, fluids, or other matter** through loops
- In **electrical engineering**
  - Electrical circuit
- In **fluid power** and **fluid mechanics**
  - Hydraulic circuit
  - Pneumatic circuit
- In **physics**
  - Magnetic circuit
- In **mathematics and computer science…**
- …



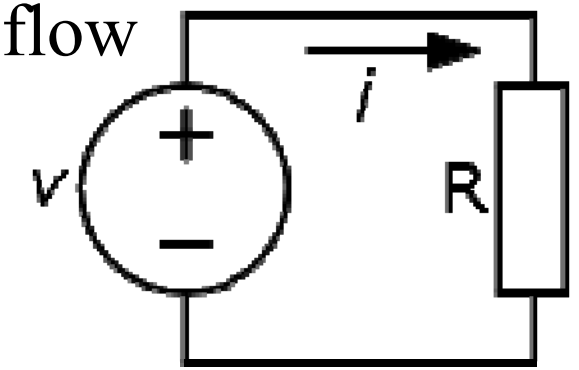
Circuit – Electrical Engineering

- In **electrical engineering**
  - Circuit analysis: V and I
  - Series and parallel circuits
  - LC circuit
  - Analog circuit or digital circuit
  - Integrated circuit
  - Mixed-signal integrated circuit



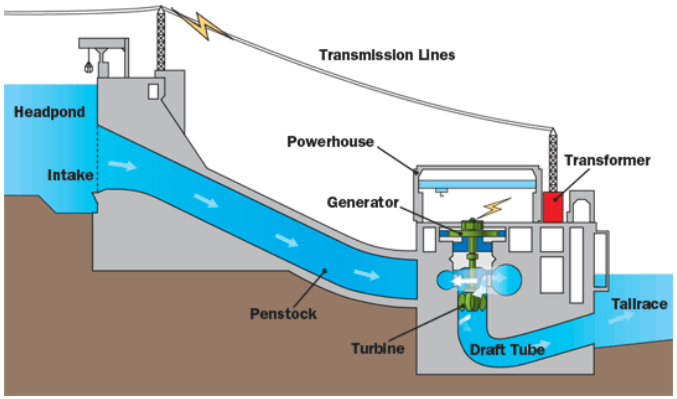
Electrical circuit

- An **electrical circuit is a path in which electrons** from a voltage or current source **flow**.
- Electric current flows in a **closed path**.
- A simple electrical circuit
  - A power source
  - A complete path for electrons to flow
  - A resistor as the load



Electrical circuits and electronic circuits

- **Electrical circuits**
  - Usually alternating current sources
  - Load: refrigerators, televisions, or microwave ovens; the output of a **hydroelectric power** generating station.



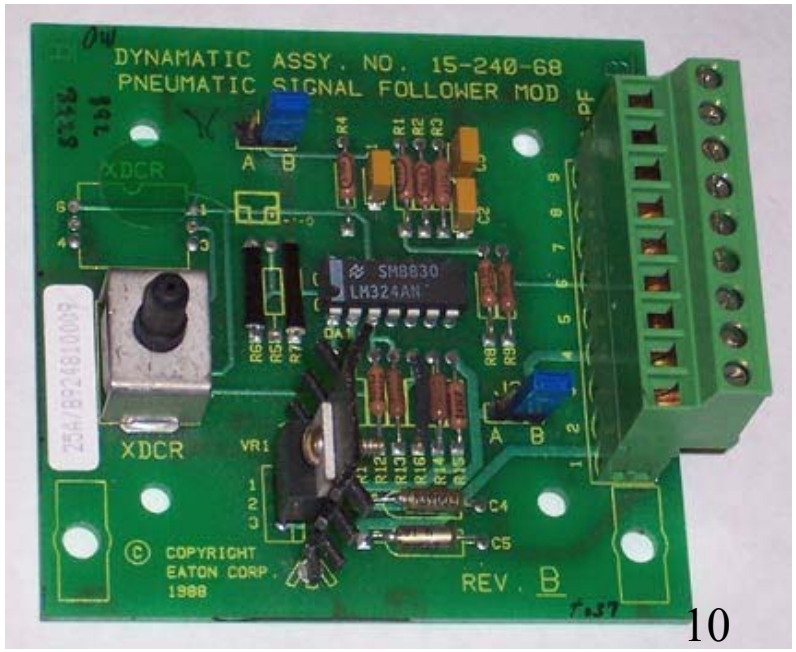
- **Electronic circuits**
  - Usually low voltage direct current sources
  - Load: the flash in a digital camera; the microprocessors.

More on electronic circuit

- Definition: An electronic circuit is composed of **individual electronic components**, such as resistors, transistors, capacitors, inductors and diodes, connected by conductive wires or traces through which electric current can flow.
- Function: The combination of components and wires allows various simple and complex operations to be performed:
  - signals can be amplified
  - computations can be performed
  - data can be moved from one place to another

Print circuit board (PCB)

- Circuits can be constructed of discrete components connected by individual pieces of wire.
- Today it is much more common to create interconnections **by photolithographic techniques** on a laminated substrate (a printed circuit board or PCB) and solder the components to these interconnections to create a finished circuit.

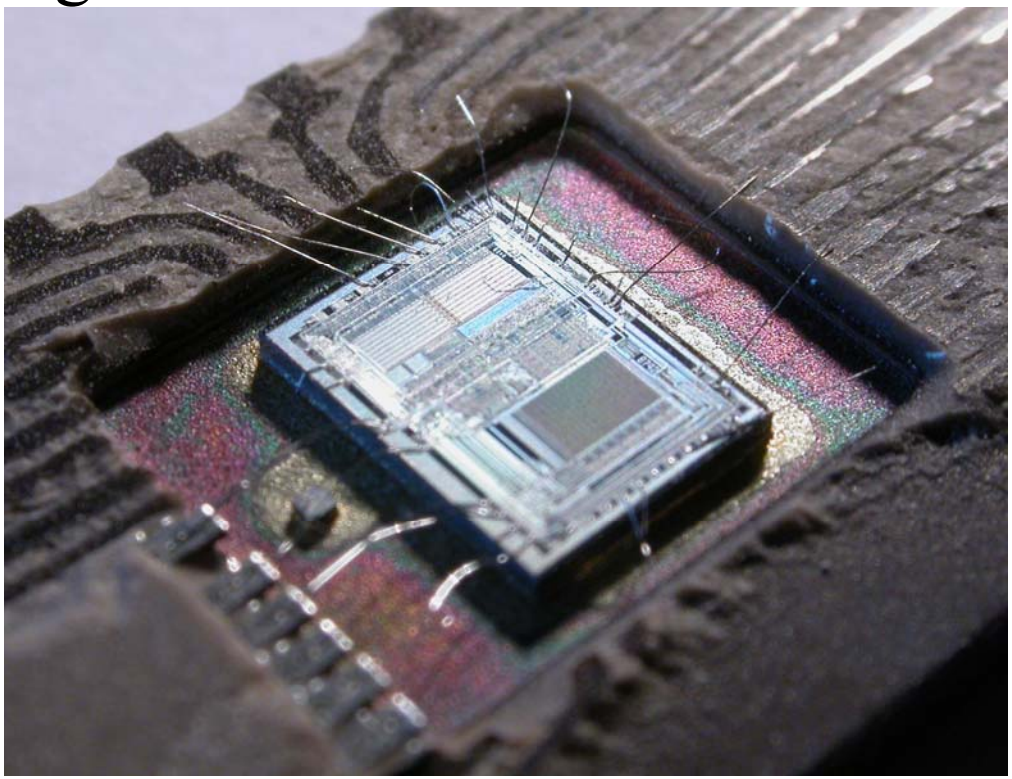


Markings on PCB

A	separable assembly
AR	amplifier
AT	attenuator; isolator
B	blower, motor
BT	battery
C	capacitor
CB	circuit breaker
CP	connector adapter, coupling
CN	capacitor network
D or CR	diode
D or VR	breakdown diode
DC	directional coupler
DL	delay line
DS	display, lamp
E	terminal
F	fuse
FD*	fiducial
FL	filter
G	generator, oscillator
GN	general network
H	hardware
HY	circulator, directional coupler
J	connector, jack, female
K	contactor, relay
L	coil, inductor, bead, ferrite bead
LS	loudspeaker, buzzer
M	meter
MG	motor-generator
MH*	mounting hole
MK	microphone
MP	mechanical part
P	connector, plug, male
PS	power supply
Q	transistor
R	resistor
RN	resistor network
RT	thermistor
S	switch
T	transformer
TB	terminal board, terminal strip
TC	thermocouple
TP**	test point, In-circuit test points
TZ	transzorb
U	inseparable assembly, IC pkg
V	electron tube
VR	voltage regulator
W	wire, cable, cable assembly
X	fuse holder, lamp holder, socket
Y	crystal, magnetostriction oscillator
Z	miscellaneous

Integrated circuit (IC)

In an IC, the components and interconnections are formed on the same substrate, typically a semiconductor such as silicon or (less commonly) gallium arsenide.



The die from an Intel 8742, an **8-bit microcontroller** that includes

- a CPU
- 128 bytes of RAM
- 2048 bytes of EPROM
- I/O

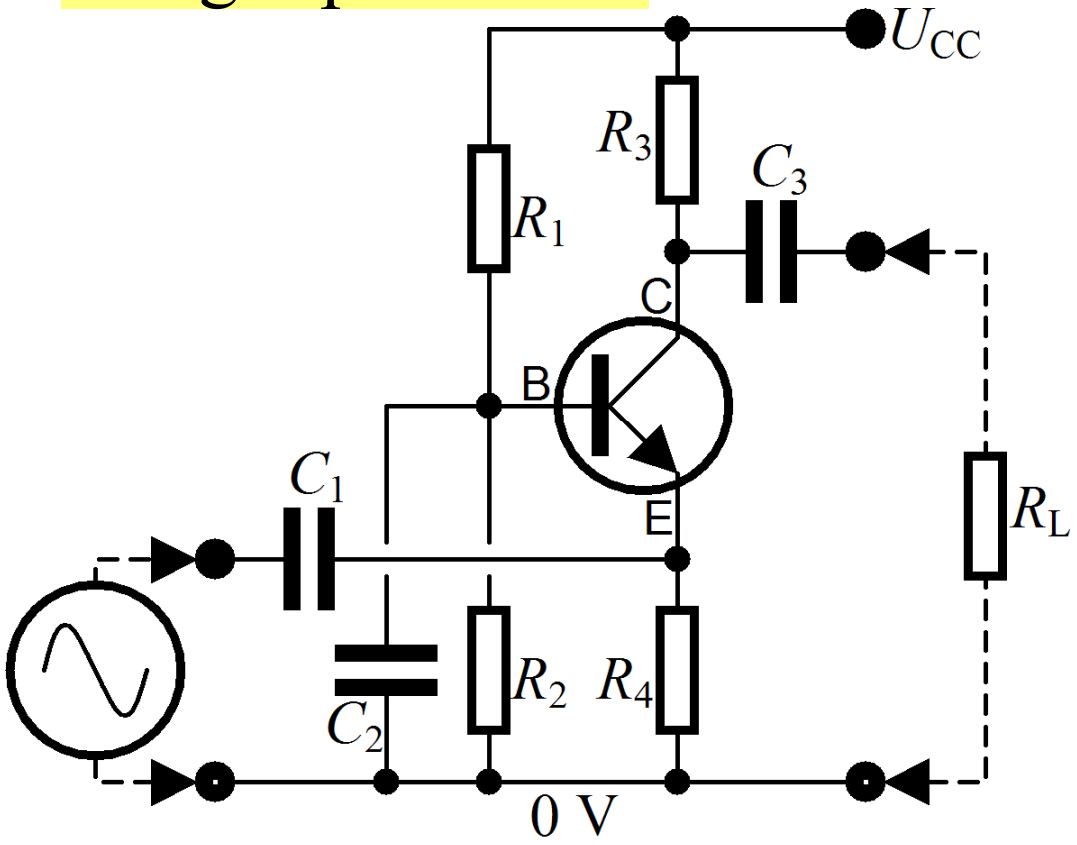
Categories of electronic circuit

- Analog circuits
- Digital circuits
- Mixed-signal circuits (a combination of analog circuits and digital circuits)

Analog circuits

模拟电路

- Current or voltage may **vary continuously** with time to correspond to the information being represented.

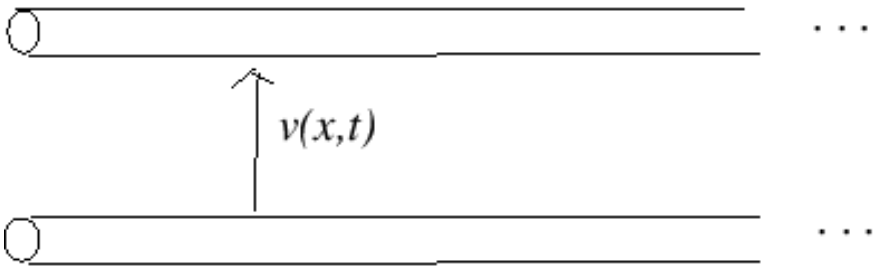


An analog circuit (a simple amplifier)

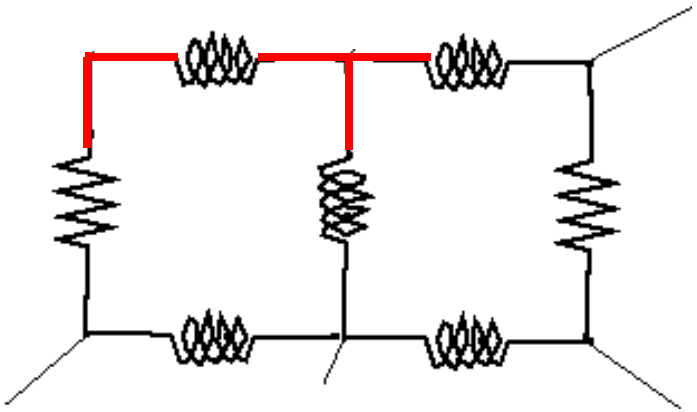
Lumped and distributed

- A lumped system: the dependent variables are a function of **time** alone.
- A distributed system: all dependent variables are functions of **time** and one or more **spatial** variables.

Distributed



Lumped



Applicability/Validity

- The lumped element model ($L_c << \lambda$):
  - Ignores the finite time it takes signals to propagate around a circuit.
  - The attributes of the circuit elements are **concentrated into idealized electrical components** (resistors, capacitors, and inductors, etc.) joined by a network of **perfectly conducting wires**.
- Distributed circuit model ($L_c \sim \lambda$):
  - When the circuit size is comparable to a wavelength of the relevant signal frequency.
  - Such considerations typically become important for circuit boards at frequencies above a GHz.

L_c: circuit's characteristic length; λ: circuit's operating wavelength

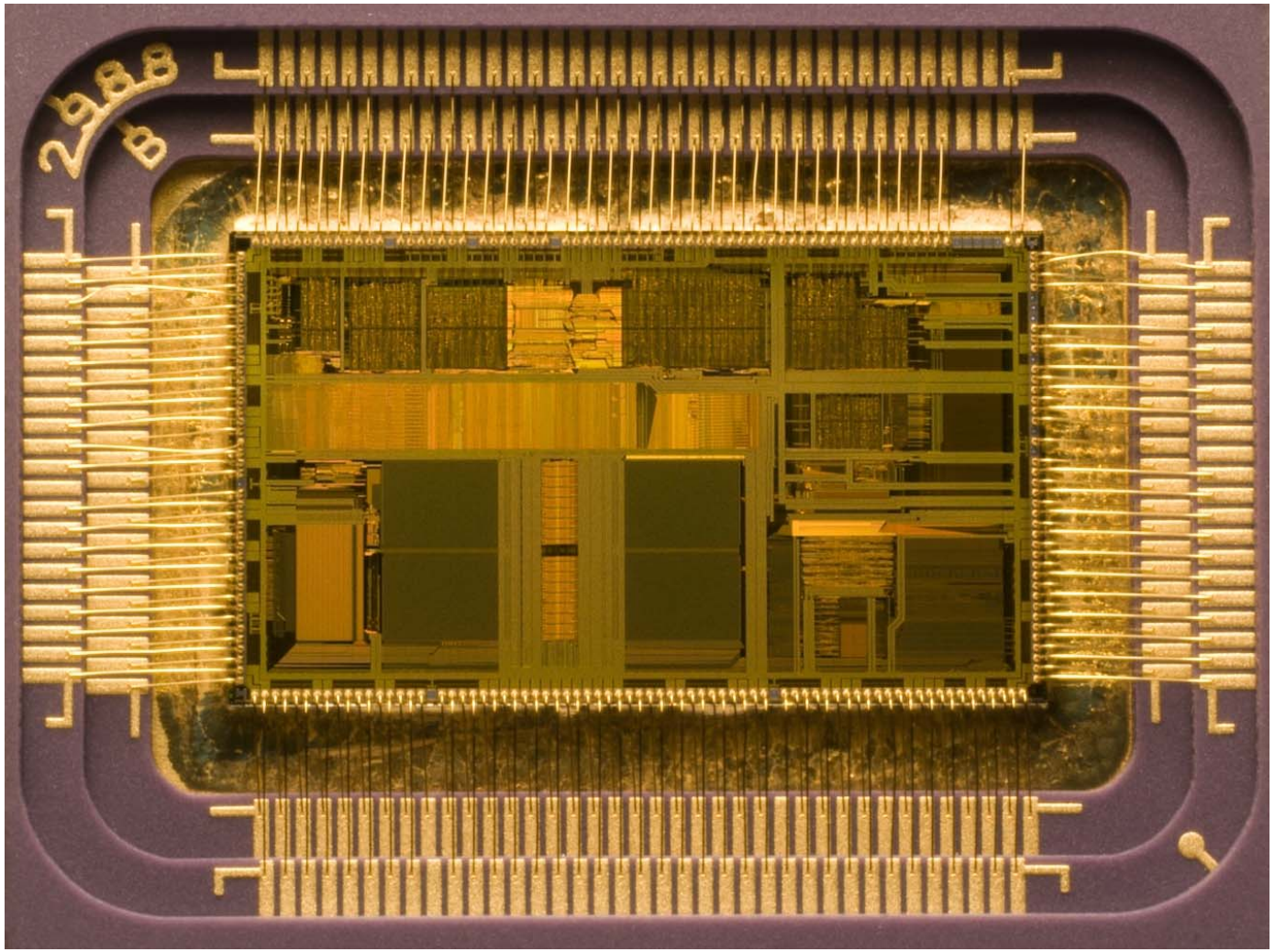
Digital circuits

- Electric signals take on **discrete values**, to represent logical and numeric values.
- In the vast majority of cases, **binary encoding** is used: one voltage (typically the more positive value) represents a binary '1' and another voltage (usually a value near the ground potential, 0 V) represents a binary '0'.
- Extensive use of transistors, interconnected to create logic gates that **provide the functions of Boolean logic**: AND, NAND, OR, NOR, XOR and all possible combinations thereof.

Digital circuits

- Advantages over analog circuits
  - Each logic gate regenerates the binary signal, so the designer **need not account for distortion, gain control, offset voltages, and other concerns** faced in an analog design.
  - Extremely **complex digital circuits** (billions of logic elements integrated on a single silicon chip) can be fabricated **at low cost**.
- Digital circuitry
  - General purpose computing chips, such as microprocessors
  - Custom-designed logic circuits, known as application-specific integrated circuit (ASICs).
  - Field-programmable gate arrays (FPGAs), chips with logic circuitry whose configuration can be modified after fabrication
- Applications
  - Ubiquitous in modern electronic devices

Digital circuits-microprocessor



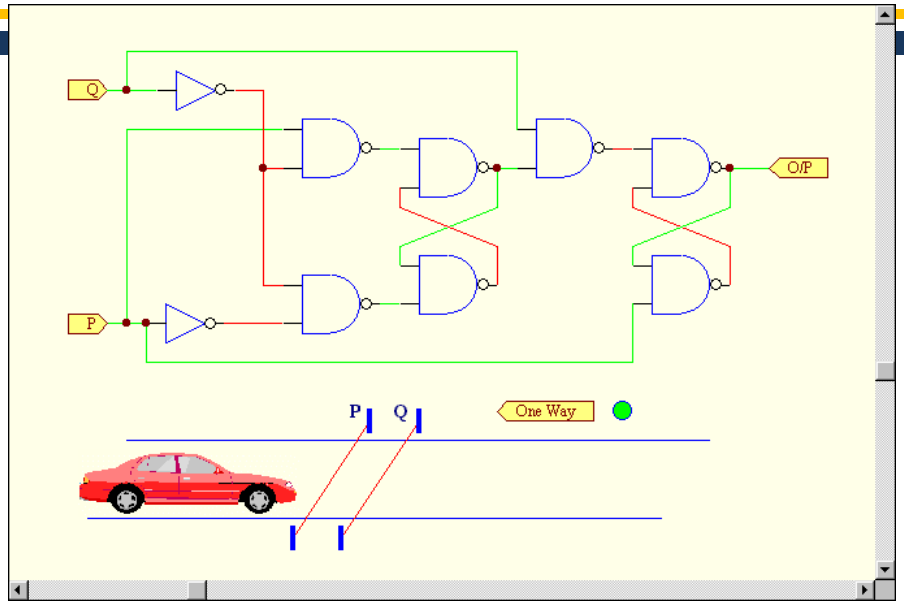
Intel 80486DX2
microprocessor

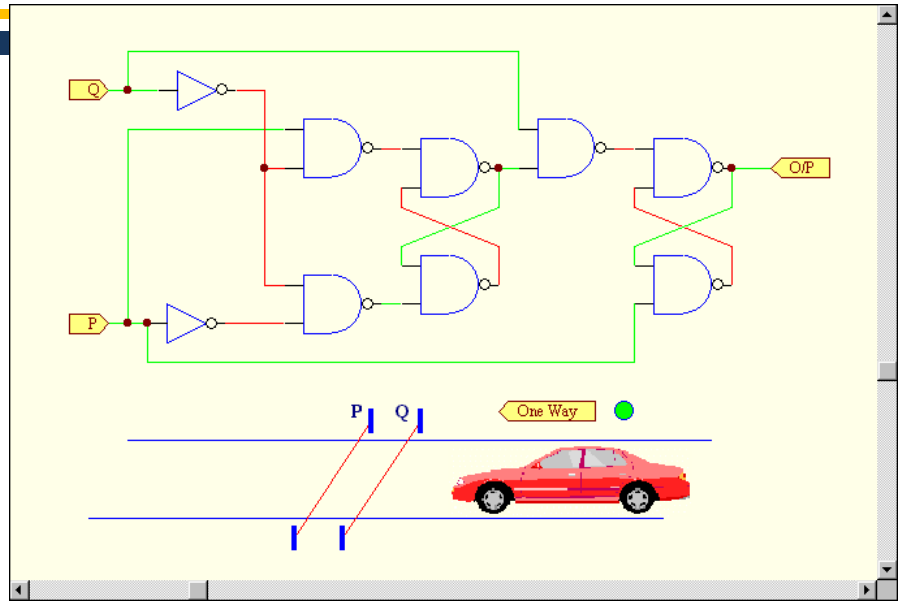
Digital circuits-FPGA

FPGA from Altera

FPGA from Xilinx

Sequential digital logic (example)





•Different results for P->Q (towards right) and Q->P (towards left)

• Car hits P line: P turned to 1; Car hits Q line: Q turned to 1

• Electrical line colors: A high (1) signal is shown in red and a low (0) signal is shown in green

• Whilst you are looking at the animation try to follow the signals propagating through the circuit using the rules for the gates (NOT and NAND here).

• Results:

  • P=1-> Q=1, output light becomes red.

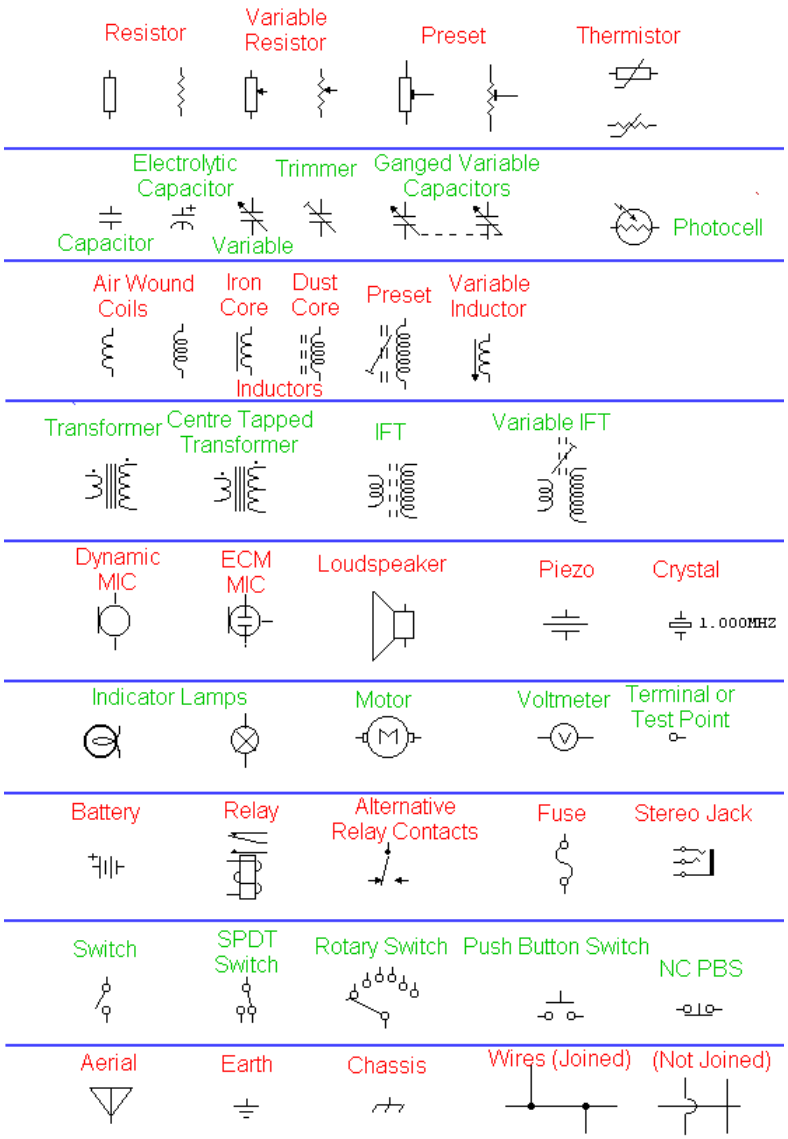
  • Q=1-> P=1, output light keeps green.

Mixed-signal circuits

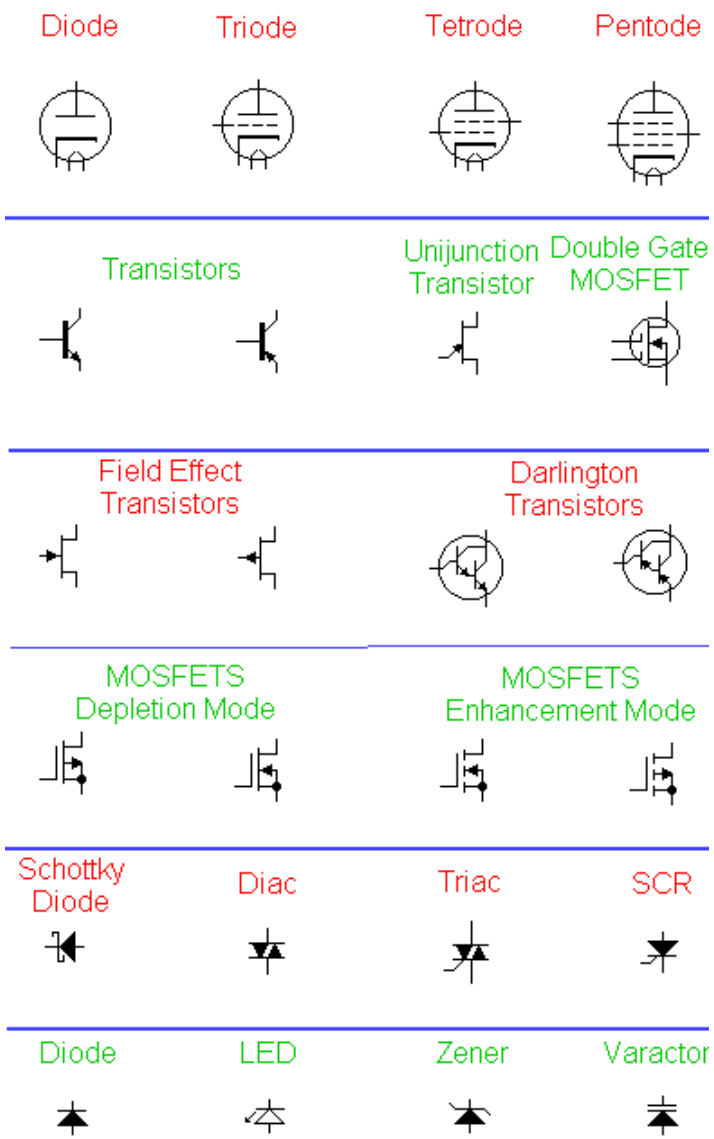
- Mixed-signal or hybrid circuits contain elements of both analog and digital circuits.
- Examples: Comparators, timers, phase-locked loops, analog-to-digital converters, and digital-to-analog converters (E.g., A laser marking machine).

- Most modern radio and communications circuitry uses mixed signal circuits. E.g, in a receiver:
  - Analog: amplification, frequency conversion
  - Digital: signal processing

Circuit symbols-passive components

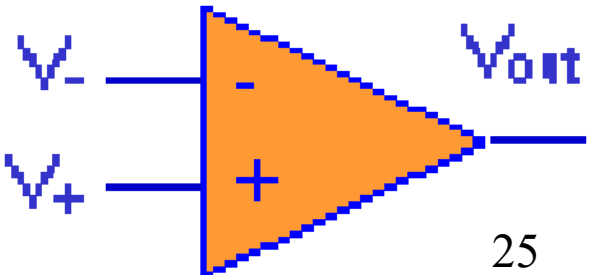


Circuit symbols-active components



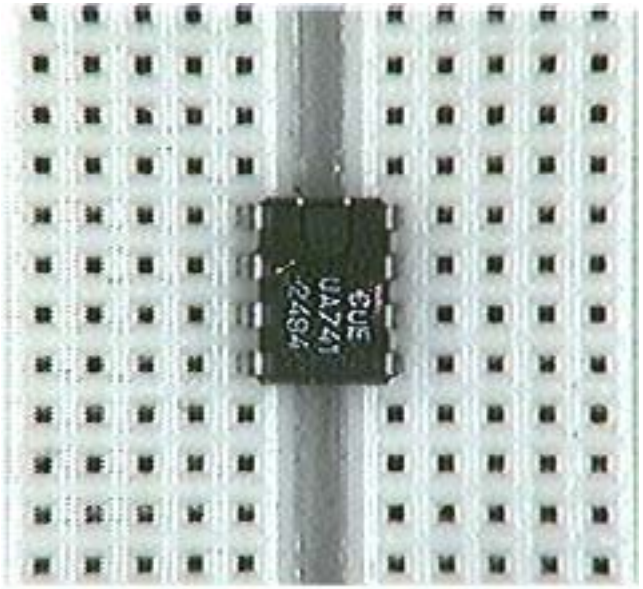
Example-operational amplifier

- Widely used in signal processing circuits, control circuits, and instrumentation
- An operational amplifier (op-amp) is a high gain, differential, voltage amplifier.
  - Voltage amplifier: the input is a voltage and the output is a voltage.
  - Typically, the gain is over 100,000
  - Differential amplifier: It actually amplifies the difference between two voltages.
- Symbol
  - V_{out} is the output voltage
  - V_+ is the non-inverting input voltage
  - V_- is the inverting input voltage

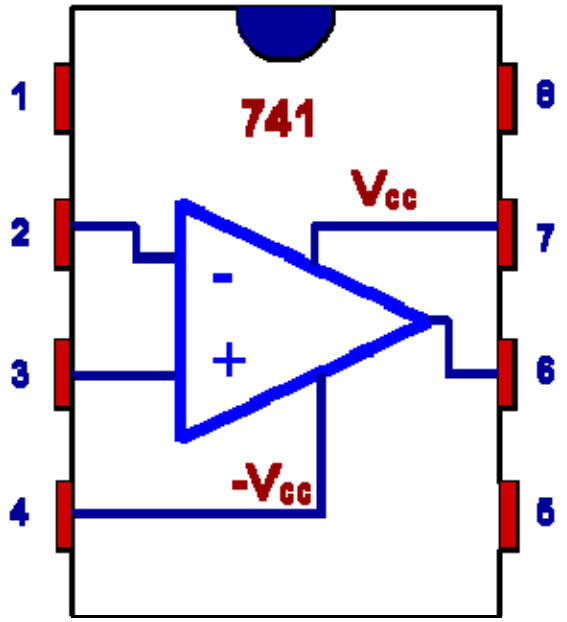


Example-operational amplifier

- The 741, a typical op-amp

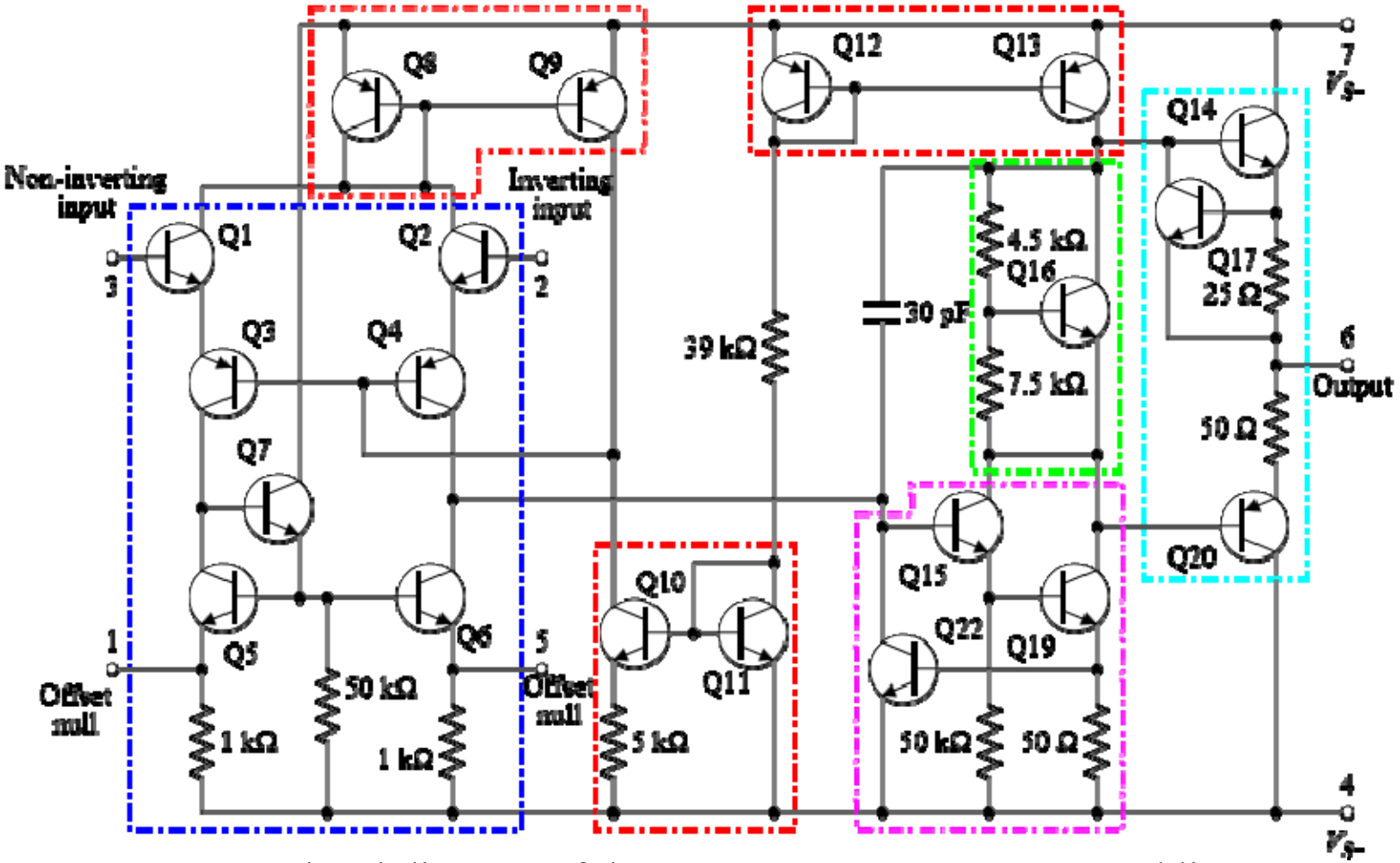


A typical op-amp on a circuit board



- Most op-amps today are ICs. Of course the actual size is smaller than the picture above!

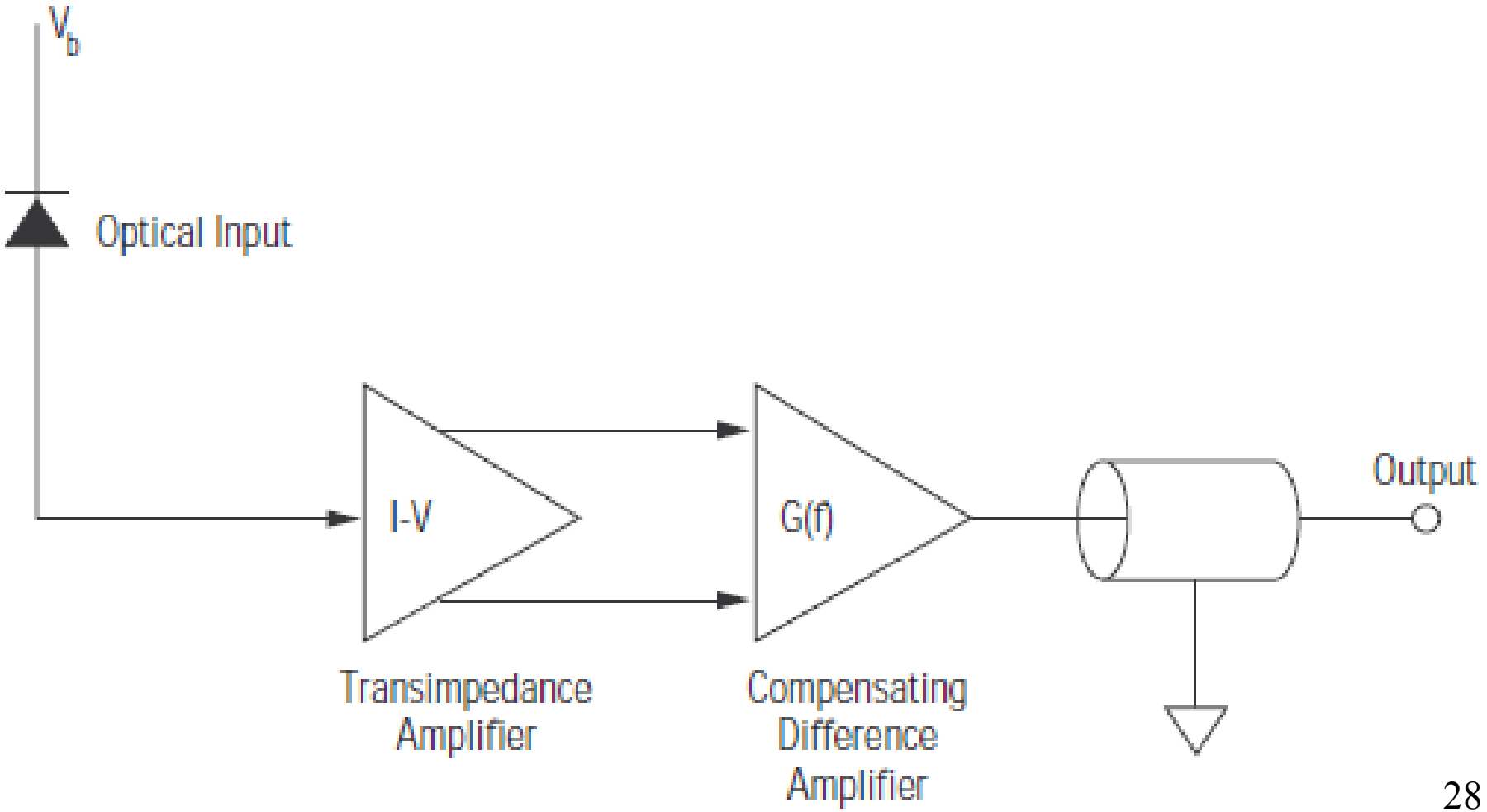
Example-operational amplifier



A component-level diagram of the common 741 op-amp. Dotted lines outline: current mirrors (red); differential amplifier (blue); class A gain stage (magenta); voltage level shifter (green); output stage (cyan).

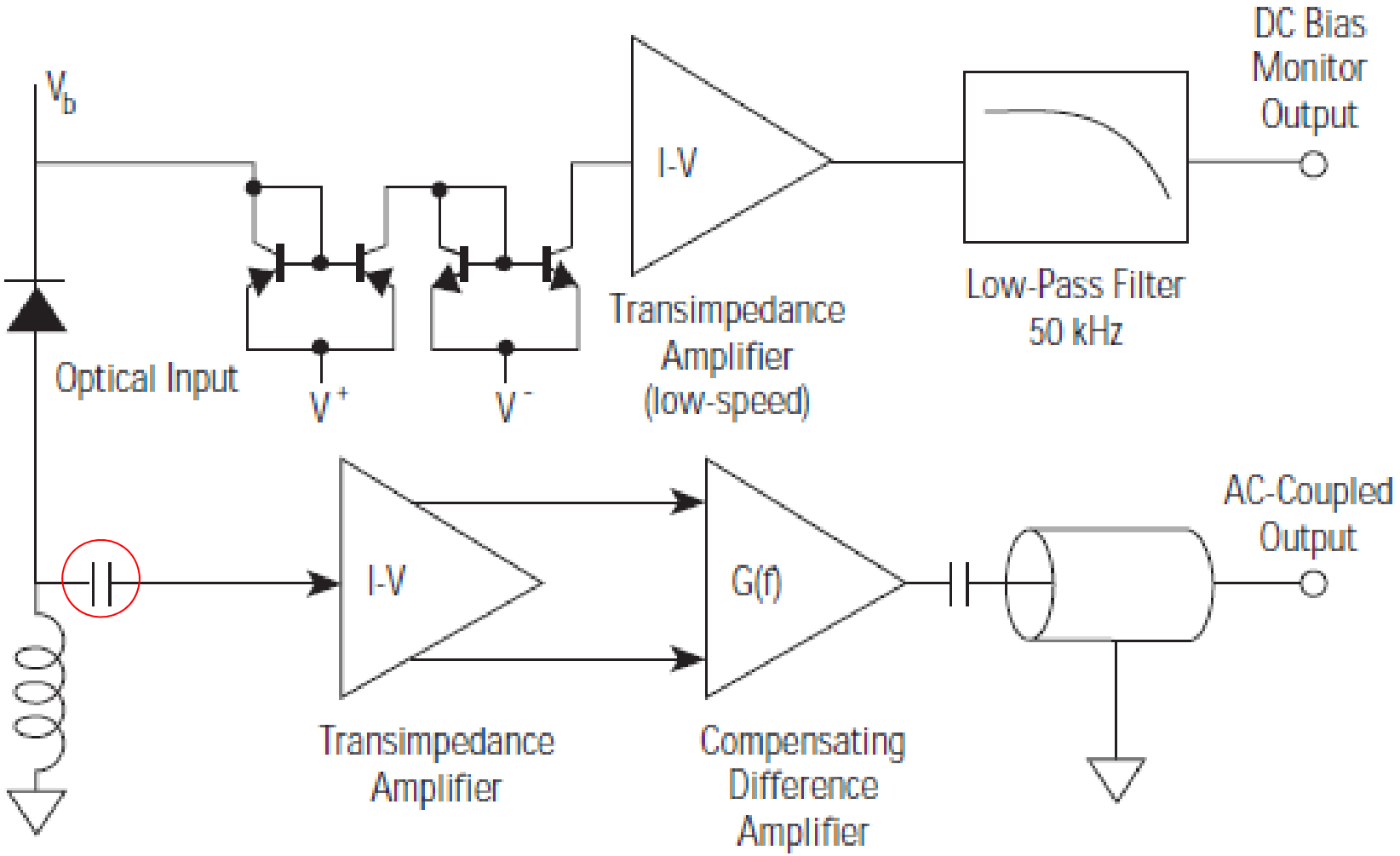
Example-a photodetector

- New Focus™ 1801



Example-a photodetector

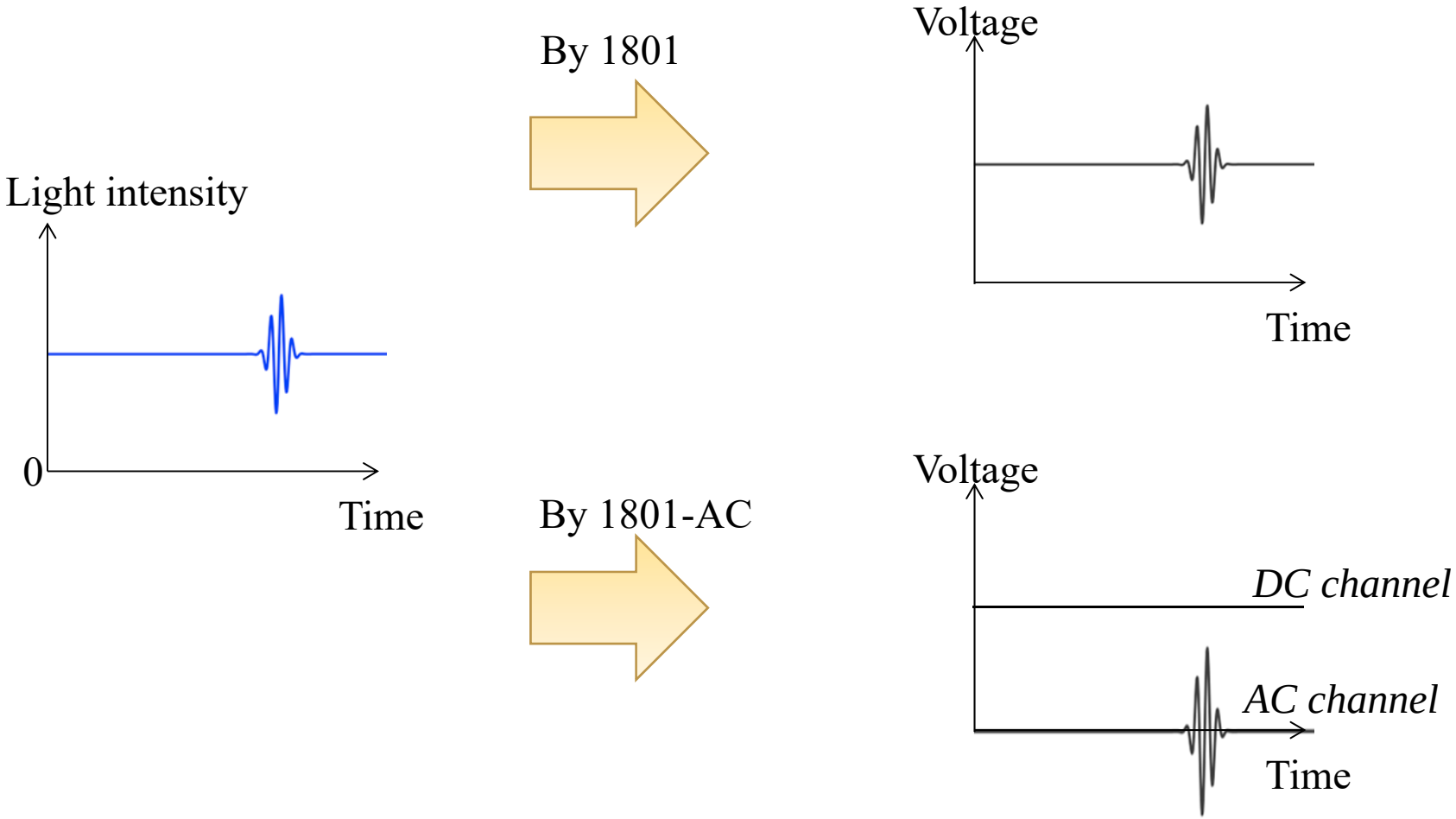
- New Focus™ 1801-AC



Example-a photodetector

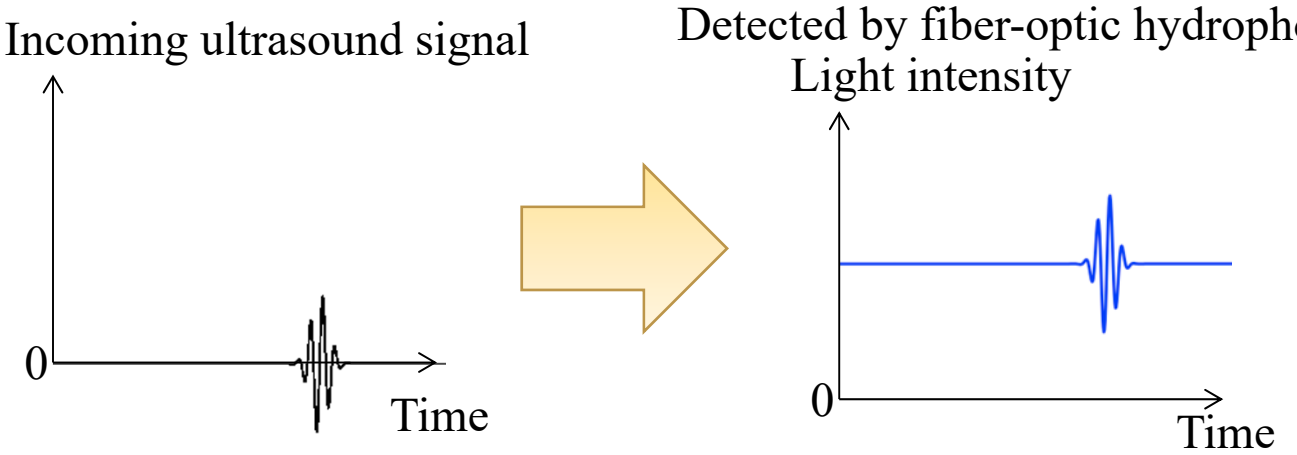
Optical signal input

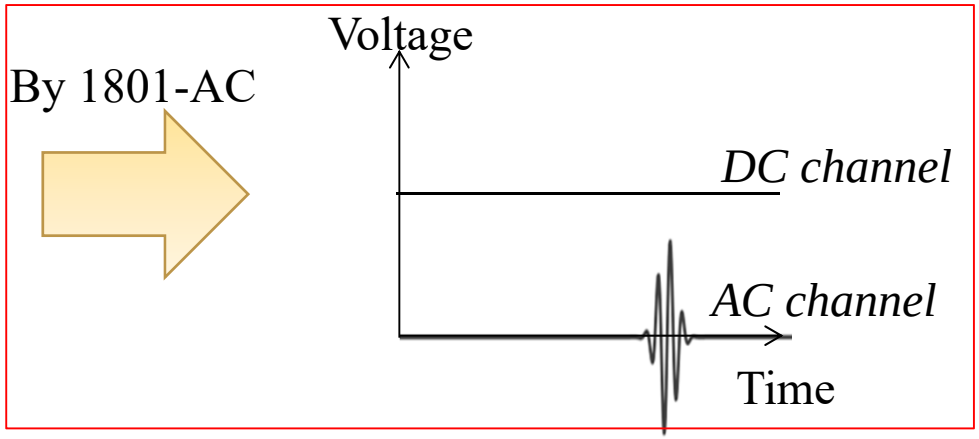
Electrical signal output



Application: Fiber-optic hydrophone

- Advantage: to amplify and extract **only** the small modulated signal (the useful signal)



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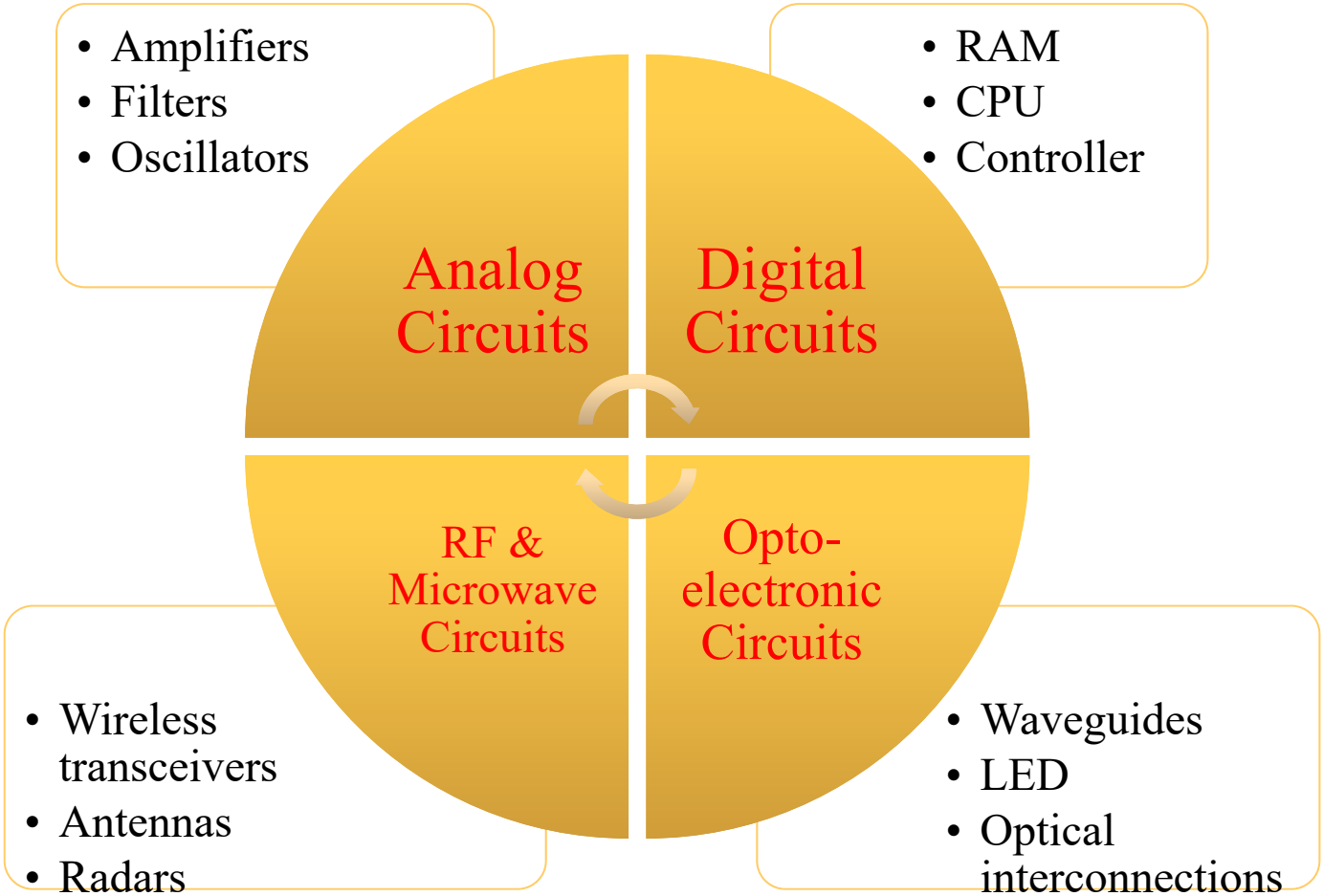
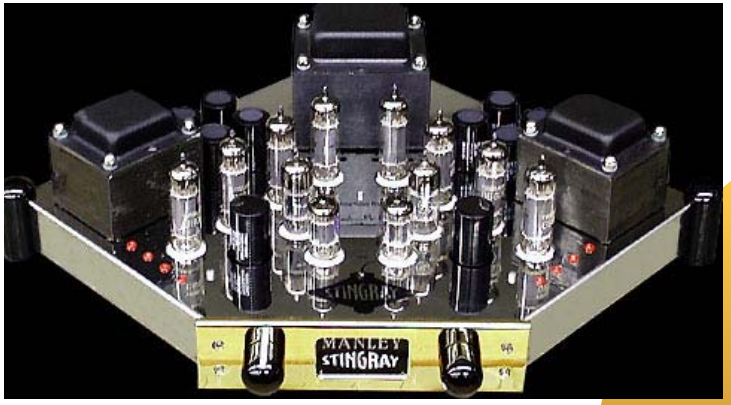
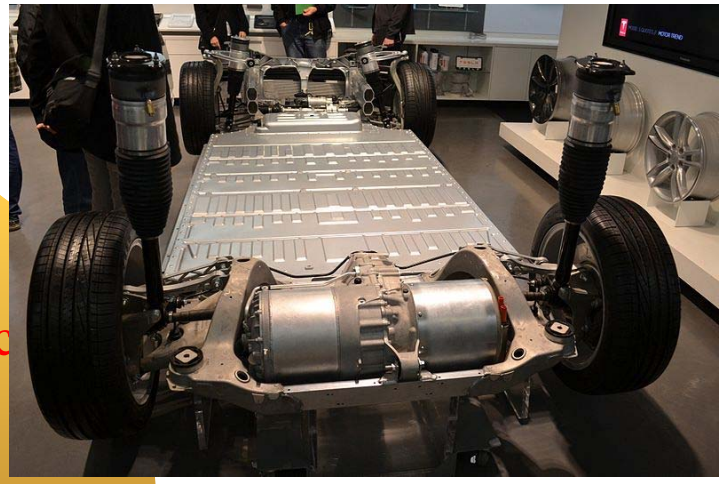
Circuit types



Circuit types



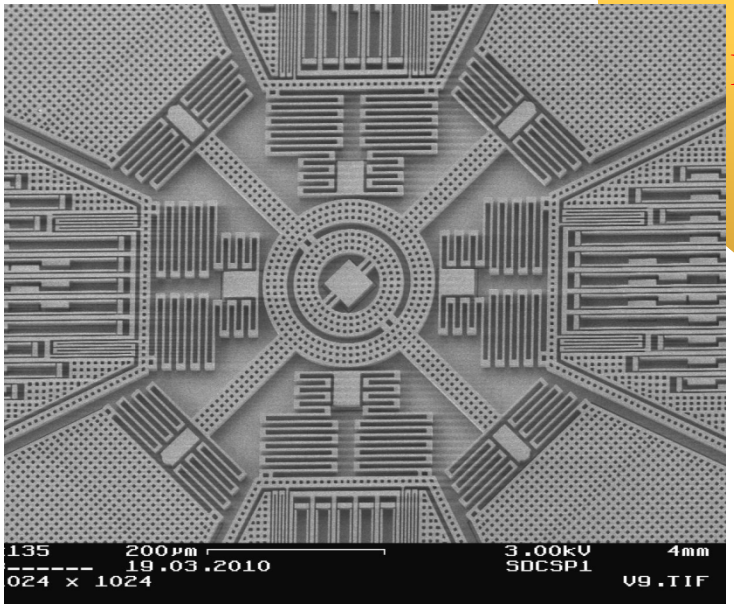


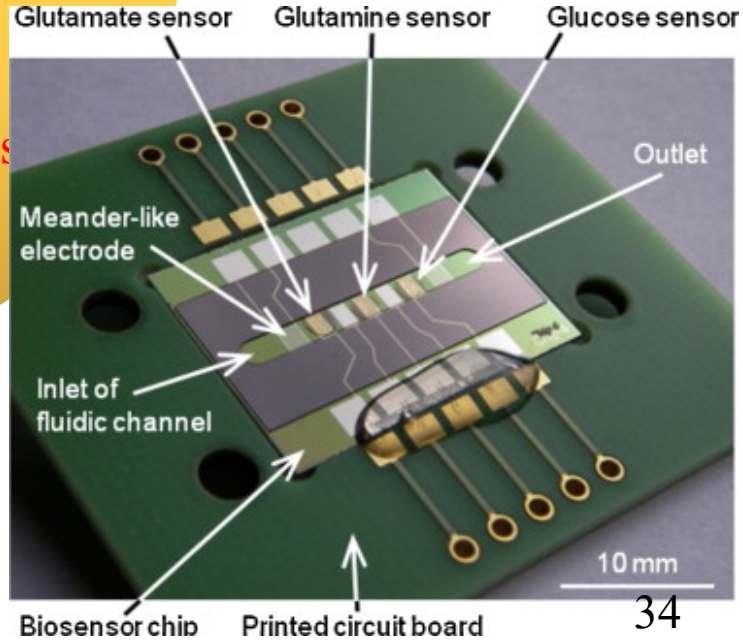
Electrical Circuits

Magnetic Circuits

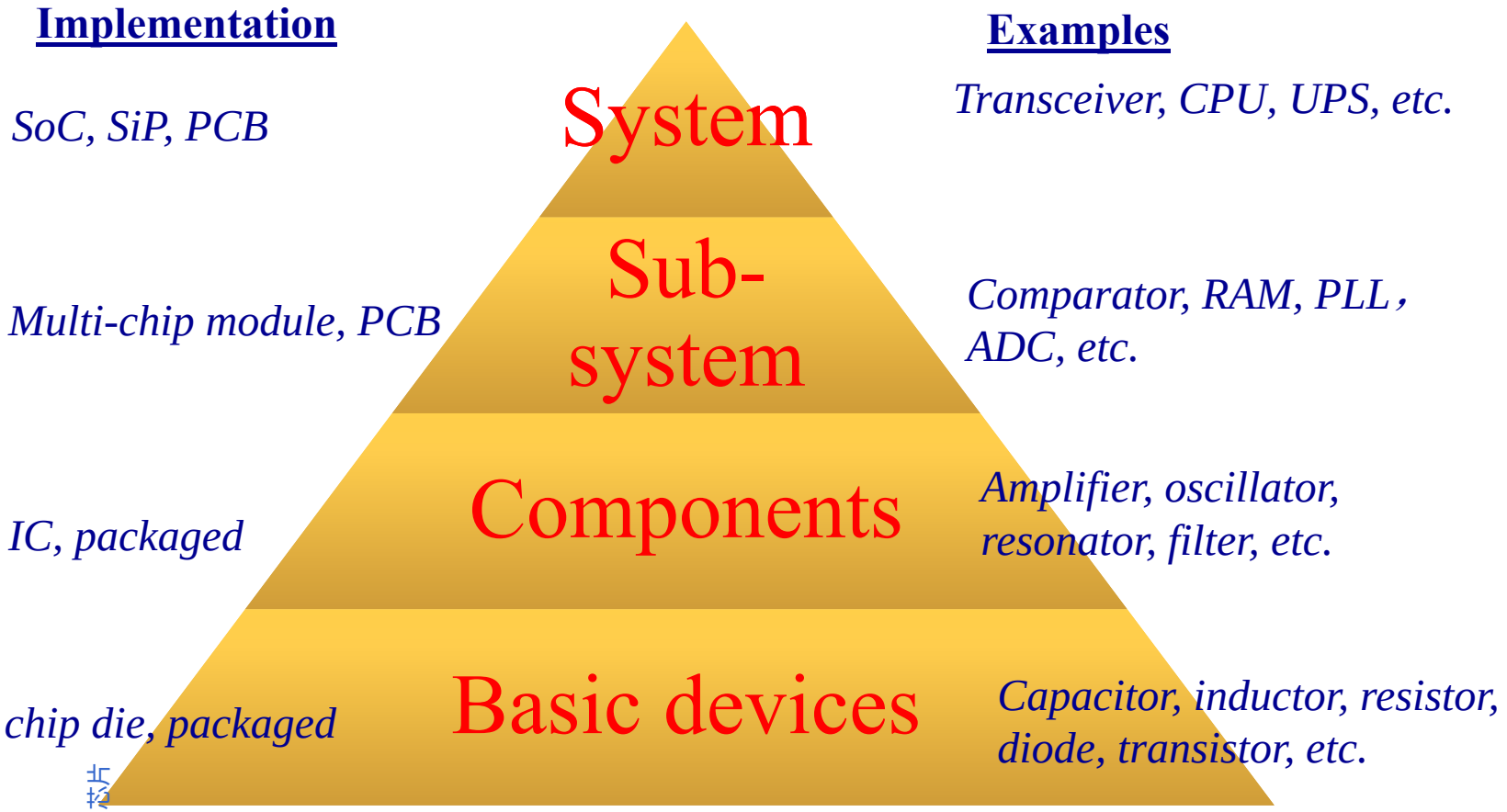
Mechanical Circuits

Bio Circuits





Circuit hierarchy



Circuit related curriculum in JI

Freshmen	Sophomore	Junior	Senior
• Math • Physics • Programming	• VE215 Introduction to Circuits • VE216 Signal and System • VE230 Electromagnetics • VE270 Introduction to Logic Design	• VE311 Analog circuits • VE320 Semiconductor • VE330 Electromagentics II • VE312 Digital Integrated Circuits • VE334 Optics	• VE413 Analog IC • VE411 RF Microwave Circuits • VE427 VLSI I • VE434 Photonics

My contact

- Office location:

  Rm. 428, JI Building

- Office tel:

  3420-6065 ext. 4281

- Email:

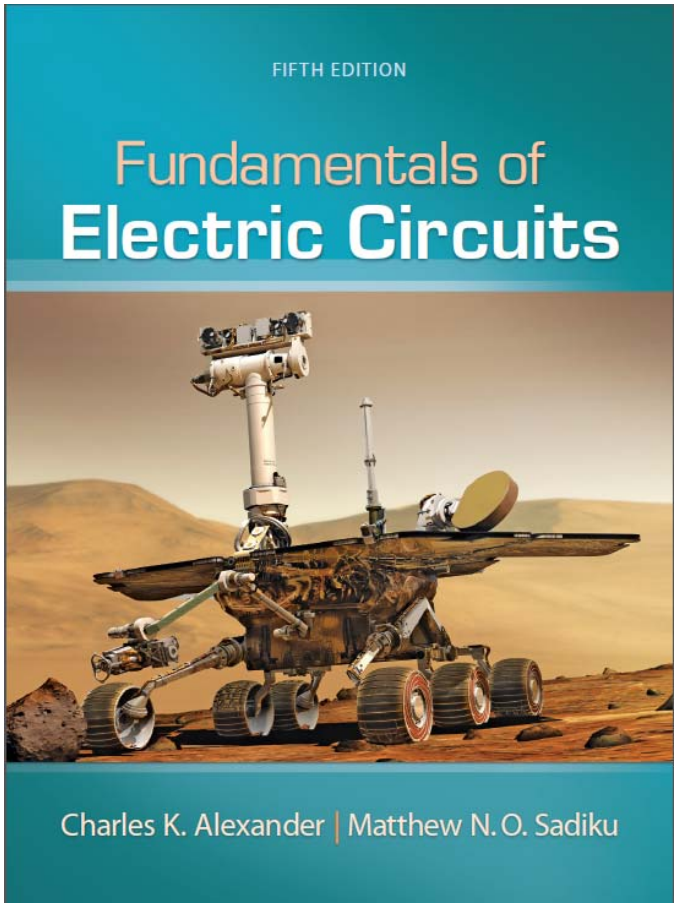
  sungliang.chen@sjtu.edu.cn

Course expectation and requirement

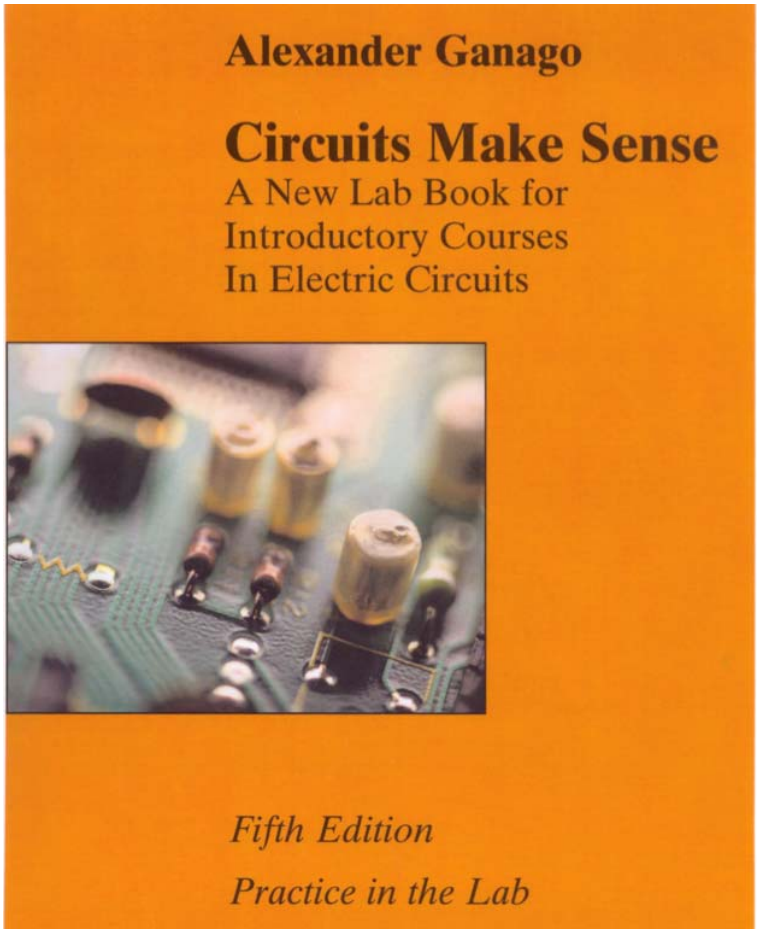
- Pre-requisites: VV156 or VV186, VG101
- Co-requisites: VP240 or VP260
- Basic college math and physics
  - Scalar & Vector
  - Differentiation & Integration
  - Electric Charge
  - Current & Voltage

Textbook

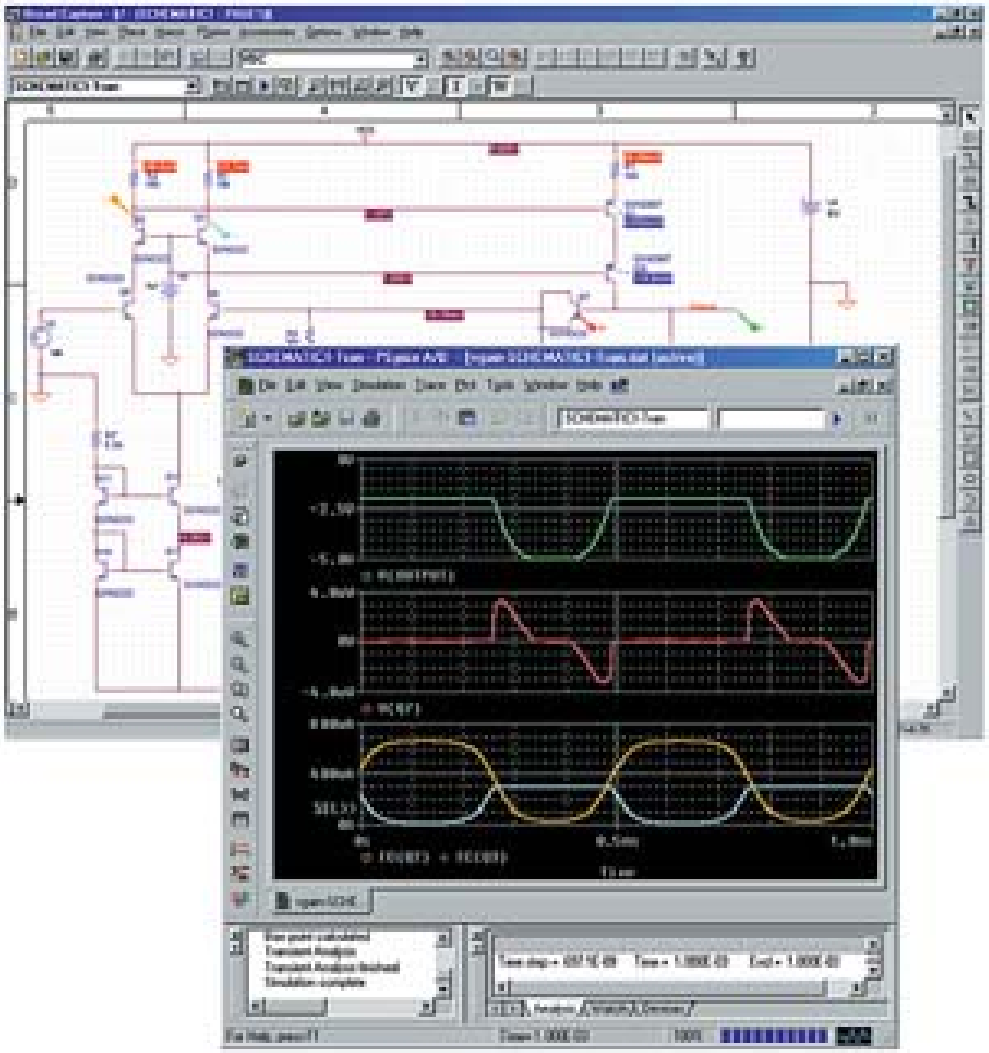
Main Textbook



Laboratory book



Computer Aided Design - CAD



- Pspice CAD tool to simulate most analog and digital circuits.
- Demo version available online for free.

http://www.cadence.com/products/orcad/pages/downloads.aspx#demo

Course schedule

- Lectures:
  - Monday 8:00 – 9:40 am
  - Wednesday 8:00 – 9:40 am
  - Friday 10:00 – 11:40 am (weeks 1−5)
- Recitation: TBD
- My office hours: Tu & We 2:00 – 3:00 pm
- TA office hours: TBD

Teaching assistants (TAs)

- Puyang Huang（黄浦阳），huangpuyang@sjtu.edu.cn
- Yunpeng Jiang（蒋云鹏），jyp9961@sjtu.edu.cn
- Ziming Zhao（赵子铭），zrq16sjtu@sjtu.edu.cn
- Qi Sun（孙琪），sqsq199987@sjtu.edu.cn

Grading policy

- In-class Quizzes 5%
- Homework 15%
  - 10 problem sets
- Lab 15%
  - 5 labs
- Midterm 1 20%
- Midterm 2 20%
- Final 25%

The JI Honor Code

- Personal integrity as students and professionals.
- Respect other people and their work.
- Respect yourself and your own efforts.
- Mutual trust.
- Applicable to all your academic activities here, including homework, quizzes, lab reports, projects and exams.
- Violations will be reported to the Honor Council.
  - Copy other student's homework, quizzes, lab reports, exams.
  - Illegal copy of online resource and academic literatures.
  - Helping others on the abovementioned activities.
  - Fake ID for exams.

Class rules

- Please do not come in late and do not get up to leave until the class is dismissed.
- You are responsible for all material covered in class, whether or not it is in the book.

Homework rules

- Homework will be assigned online at Canvas as scheduled. They are usually due one week later or specified otherwise. **One day automatic grace period; second day late penalty -25%; later no credit.**
- Students should complete the homework independently. Copy of others' homework is not allowed and is a violation to the Honor Code.
- Solutions will be posted on Sakai one week after the due date.

Exam rules

- There will be two midterm exams and one final exam. Each lasts 100 minutes.
- Students should complete the exam independently. No talk and collaboration are allowed.
- Closed book, cheat sheet may be allowed.
- No electronic devices except basic calculators will be allowed to use.

Week	Date	Lecture Topics	Homework	Labs
1	Sep 9	Introduction to Ve215, Basic concepts (Sections 1.3-1.7)		
	Sep 11	Basic laws (2.1-2.8)	HW1 issued	
	Sep 13	Moon Festival		
2	Sep 16	Methods of analysis (3.1-3.6)		
	Sep 18	Methods of analysis (3.7,3.9), Circuit theorems (4.1-4.4)	HW2 issued	
	Sep 20	Circuit theorems (4.5-4.8, 4.10)		
3	Sep 23	Operational amplifiers (5.1-5.5)	HW3 issued	
	Sep 25	Operational amplifiers (5.6-5.8, 5.10)		
	Sep 27	Capacitors and inductors (6.1-6.6)	HW4 issued	
4	Sep 30	No lecture, Midterm Exam 1		
	Oct 2	No lecture, National Holiday		
	Oct 4	No lecture, National Holiday		
5	Oct 7	No lecture, National Holiday		Lab1
	Oct 9	First-order circuits (7.1-7.4)		
	Oct 11	No lecture [course rescheduling]		
6	Oct 14	First-order circuits (7.5-7.7, 7.9)	HW5 issued	Lab2
	Oct 16	Second-order circuits (8.1-8.6)		
7	Oct 21	Second-order circuits (8.7-8.8, 8.10-8.11)	HW6 issued	Lab3
	Oct 23	Sinusoids and phasors (9.1-9.4)		
	Oct 25	Sinusoids and phasors (9.5-9.8) [make-up for Oct. 11]		
8	Oct 28	Sinusoidal steady-state analysis (10.1-10.6)		Lab4
	Oct 30	Sinusoidal steady-state analysis (10.7, 10.9)	HW7 issued	
9	Nov 4	No lecture, Midterm Exam 2		Lab5
	Nov 6	AC power analysis (11.1-11.6)		
10	Nov 11	AC power analysis (11.7-11.9)		
	Nov 13	Three-phase circuits (12.1-12.6)		
11	Nov 18	Three-phase circuits (12.7-12.8, 12.10)	HW8 issued	
	Nov 20	Magnetically coupled circuits (13.1-13.5)		
12	Nov 25	Magnetically coupled circuits (13.6-13.7, 13.9)	HW9 issued	
	Nov 27	Frequency response (14.1-14.3)		
13	Dec 2	Frequency response (14.4-14.6)	HW10 issued	
	Dec 4	Frequency response (14.7-14.8)		
14	Dec 9	No lecture, Final Exam		

Any questions?