

VE215 Introduction to Circuits

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JOINT INSTITUTE
交大密西根学院

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

What are circuits?

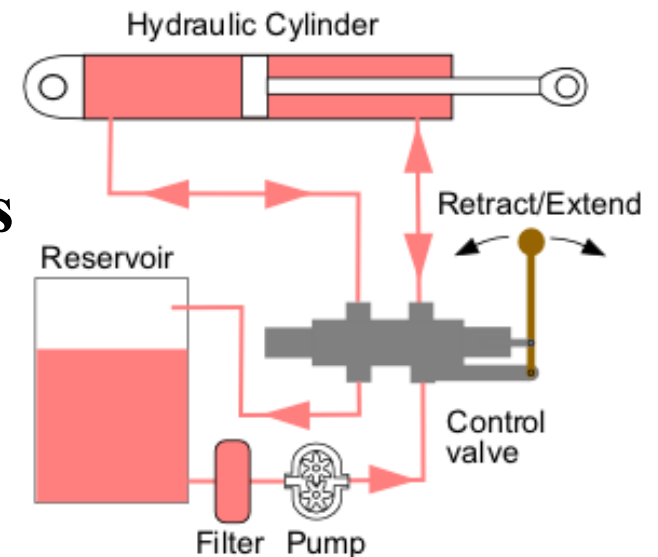
Circuit–Merriam Webster's definition

- **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



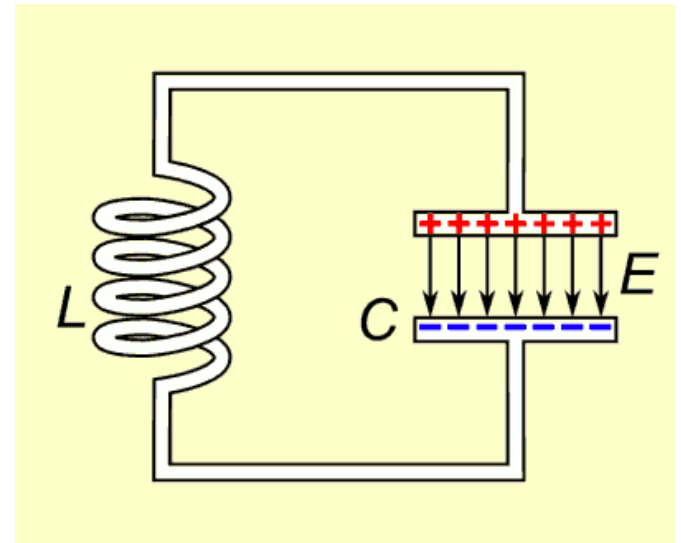
Circuit–Wikipedia's definition (part list)

- 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...**
- ...



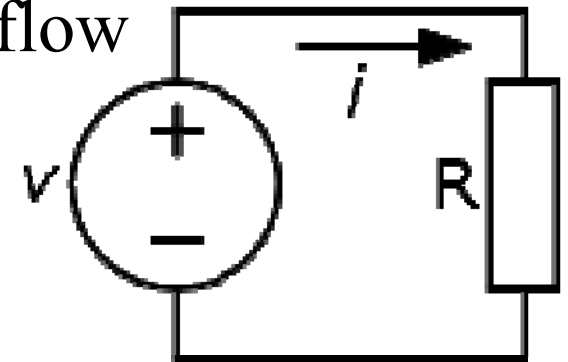
Circuit – Electrical Engineering

- 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

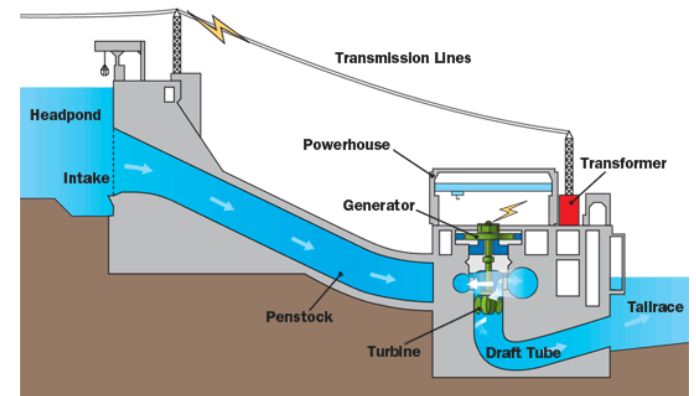
- An **electrical circuit** is a **path** in which **electrons** from a voltage or current source **flow**.
- Electric current flows in a **closed path**.
- A simple electrical circuit
 - A power source
 - A complete path for electrons to flow
 - A resistor as the load



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

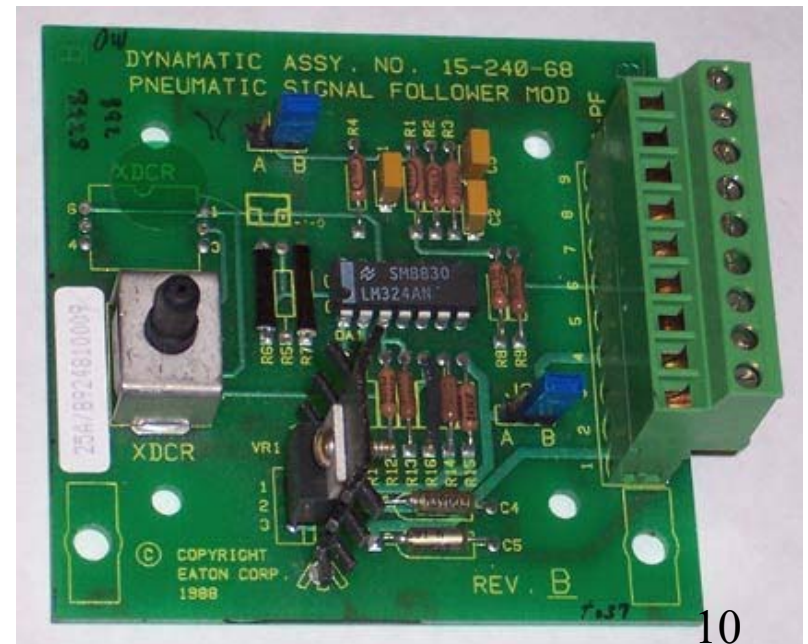
- Usually low voltage direct current sources
- Load: the flash in a digital camera; the microprocessors.

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.

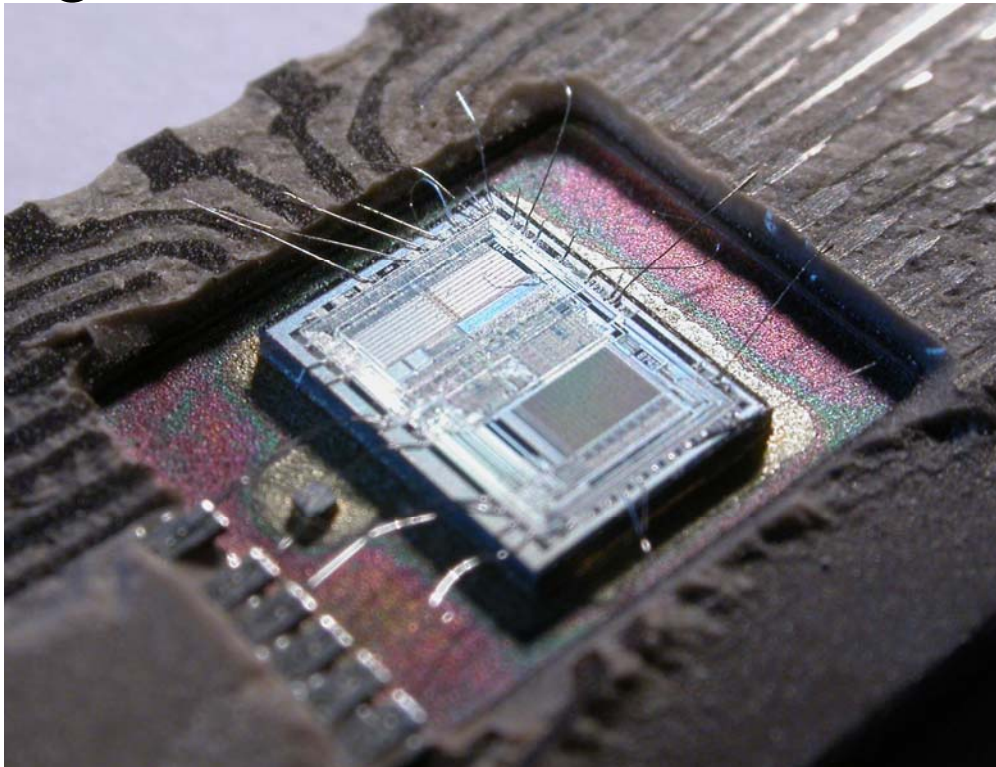


Markings on PCB

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

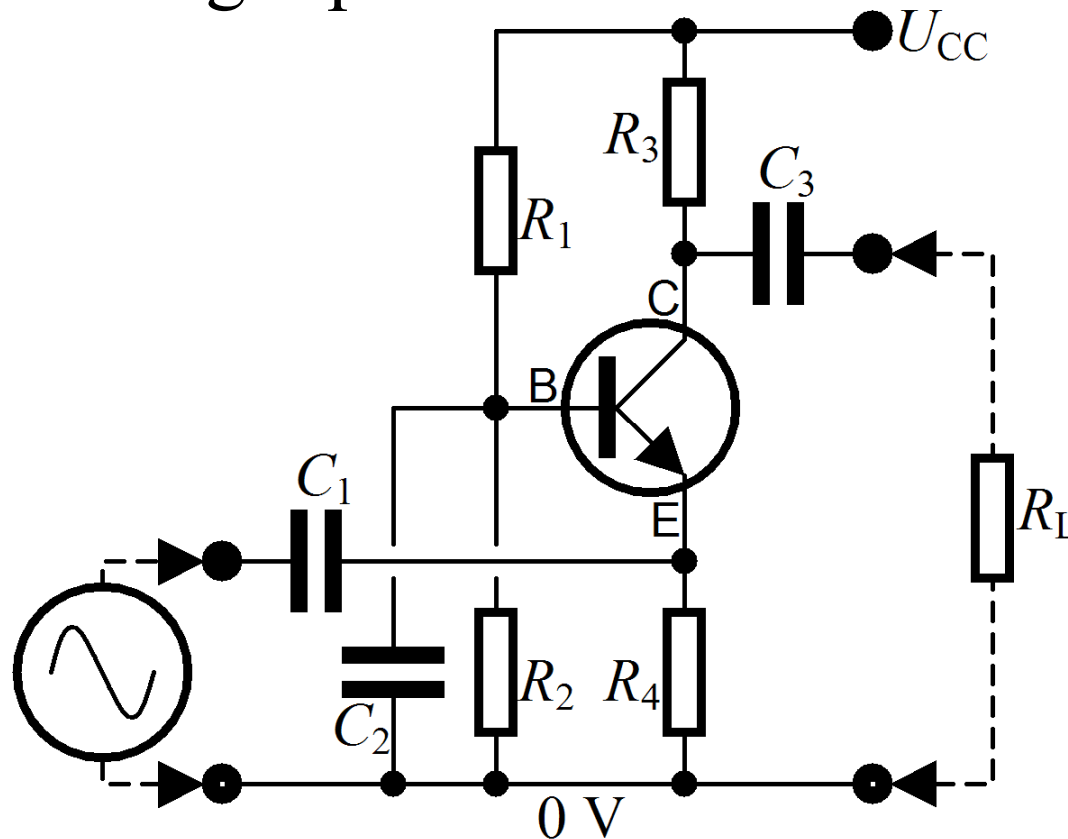
- a CPU
- 128 bytes of RAM
- 2048 bytes of EPROM
- I/O

Categories of electronic circuit

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

Analog circuits

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

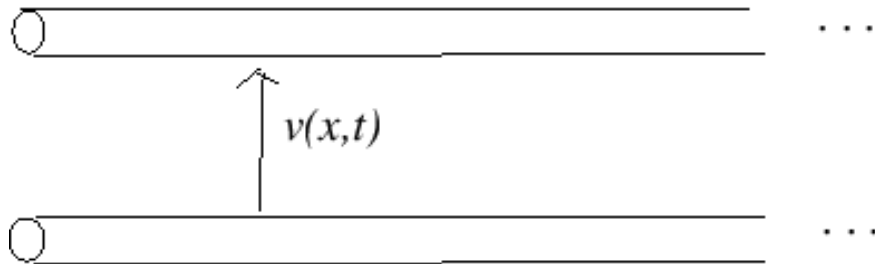


An analog circuit (a simple amplifier)

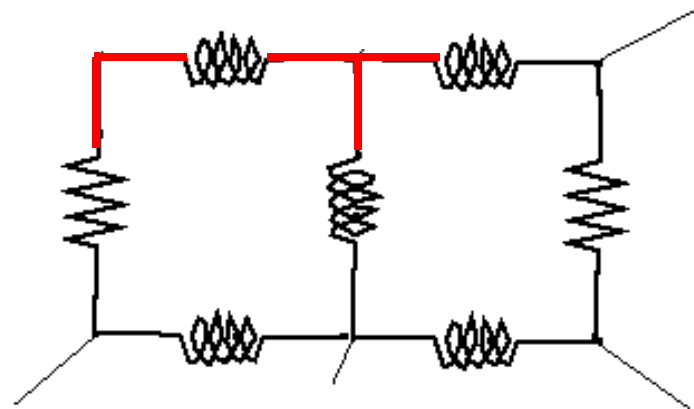
Lumped and distributed

- 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 ($L_c \ll \lambda$):
 - 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

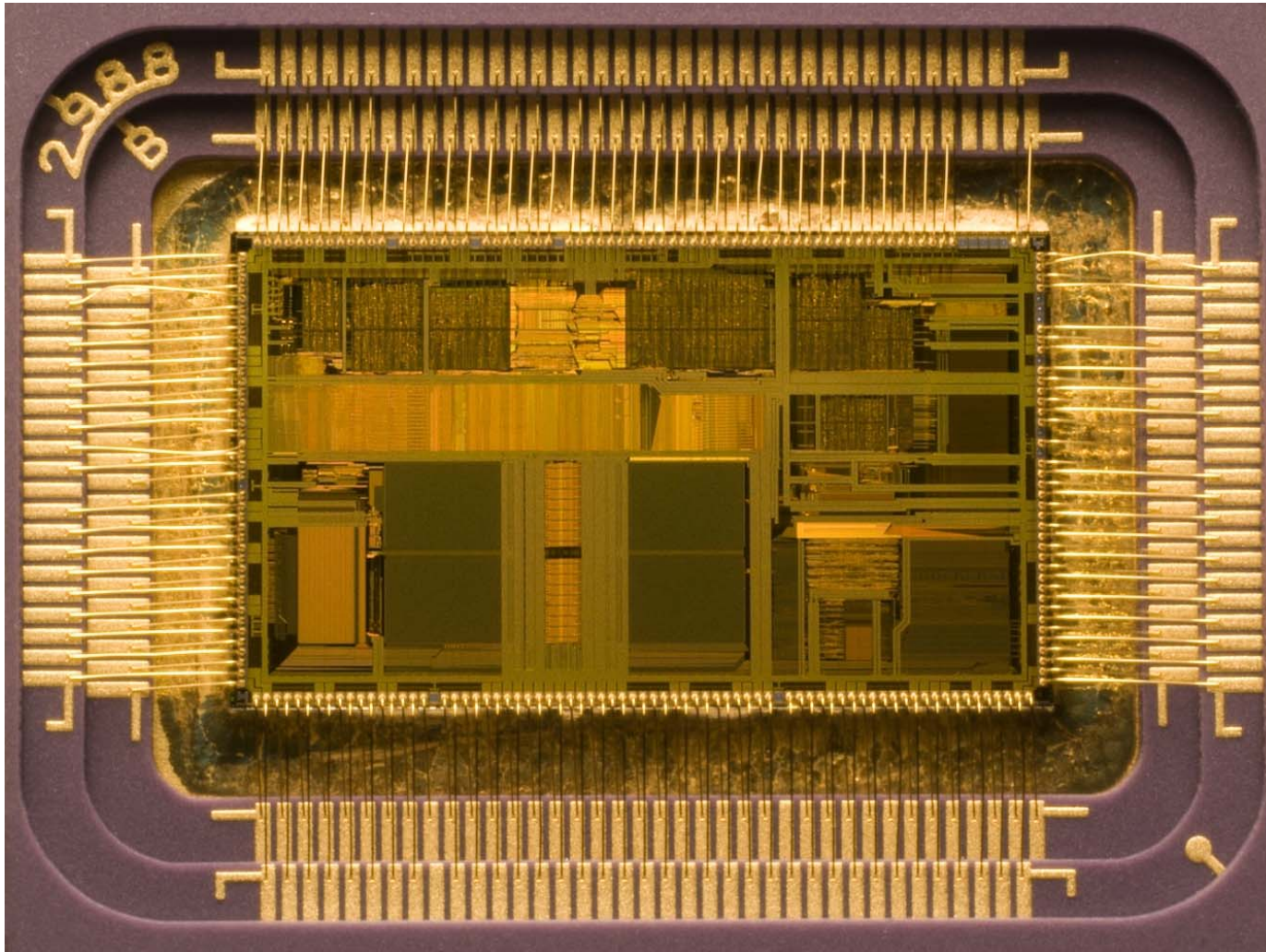
Digital circuits

- 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

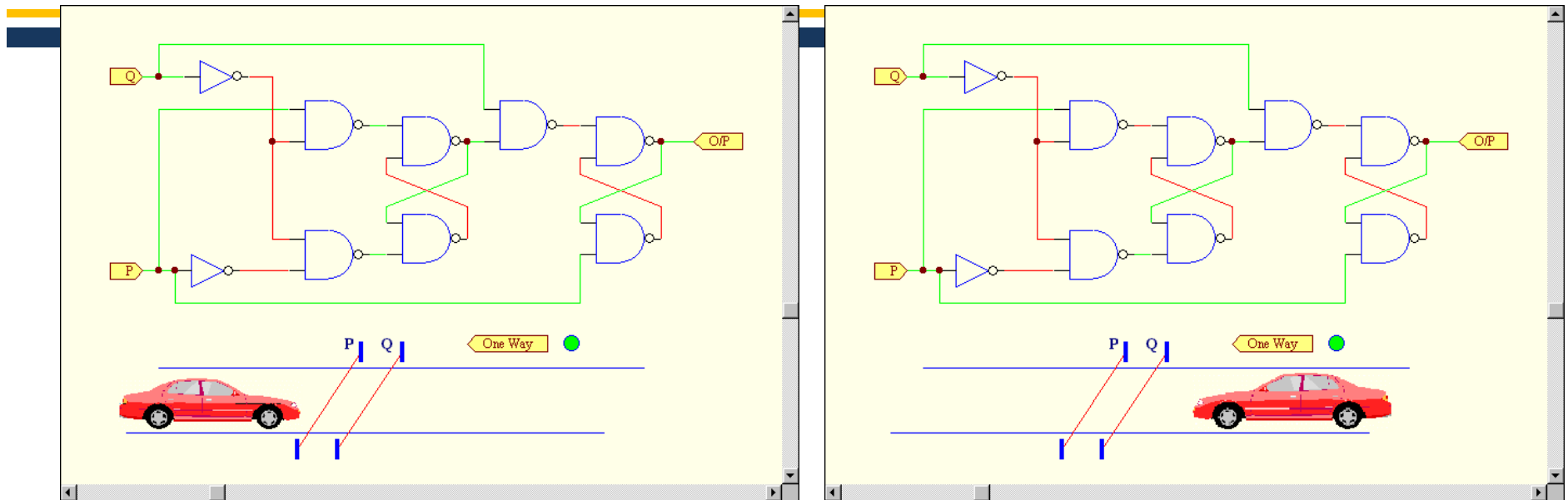


FPGA from Altera



FPGA from Xilinx

Sequential digital logic (example)














































- Different results for $P \rightarrow Q$ (towards right) and $Q \rightarrow P$ (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:
 - $P=1 \rightarrow Q=1$, output light becomes red.
 - $Q=1 \rightarrow P=1$, 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

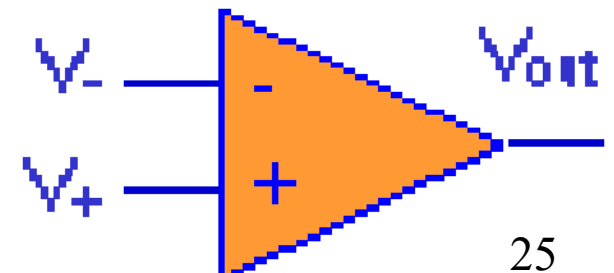
Resistor	Variable Resistor	Preset	Thermistor	
				
Capacitor	Electrolytic Capacitor	Variable	Trimmer	Ganged Variable Capacitors
				
Air Wound Coils	Iron Core	Dust Core	Preset	Variable Inductor
				
Transformer	Centre Tapped Transformer	IFT	Variable IFT	
				
Dynamic MIC	ECM MIC	Loudspeaker	Piezo	Crystal
				
Indicator Lamps		Motor	Voltmeter	Terminal or Test Point
				
Battery	Relay	Alternative Relay Contacts	Fuse	Stereo Jack
				
Switch	SPDT Switch	Rotary Switch	Push Button Switch	NC PBS
				
Aerial	Earth	Chassis	Wires (Joined)	(Not Joined)
				

Circuit symbols-active components

Diode	Triode	Tetrode	Pentode
			
Transistors		Unijunction Transistor	Double Gate MOSFET
			
Field Effect Transistors		Darlington Transistors	
			
MOSFETS Depletion Mode		MOSFETS Enhancement Mode	
			
Schottky Diode	Diac	Triac	SCR
			
Diode	LED	Zener	Varactor
			

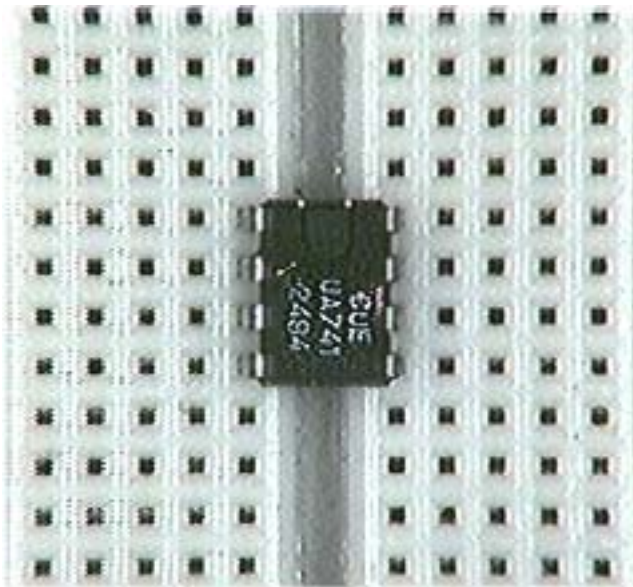
Example-operational amplifier

- 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

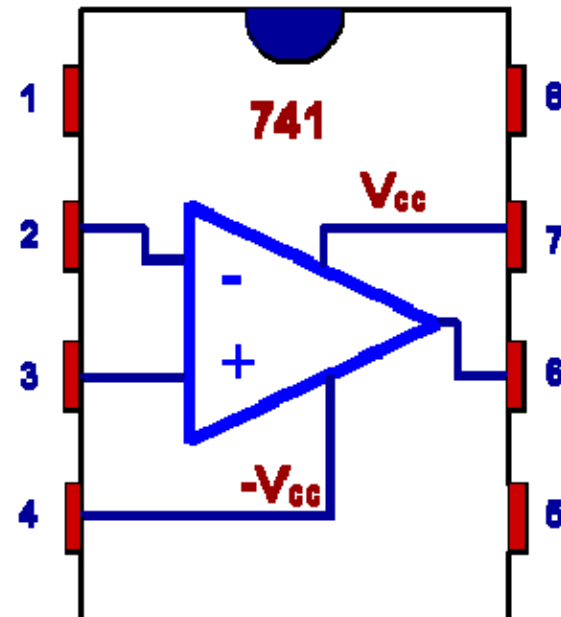


Example-operational amplifier

- The 741, a typical op-amp

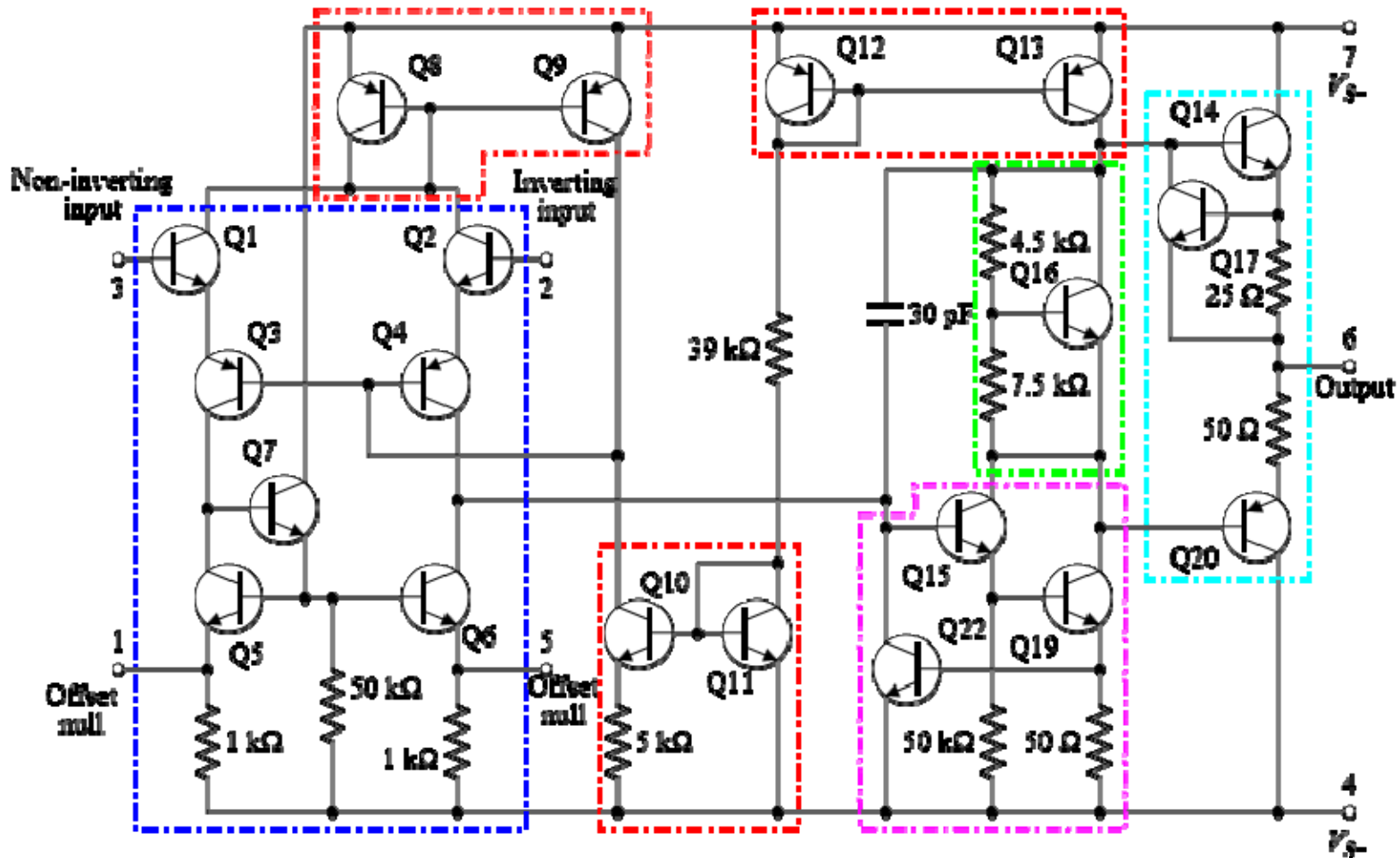


A typical op-amp on a circuit board



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

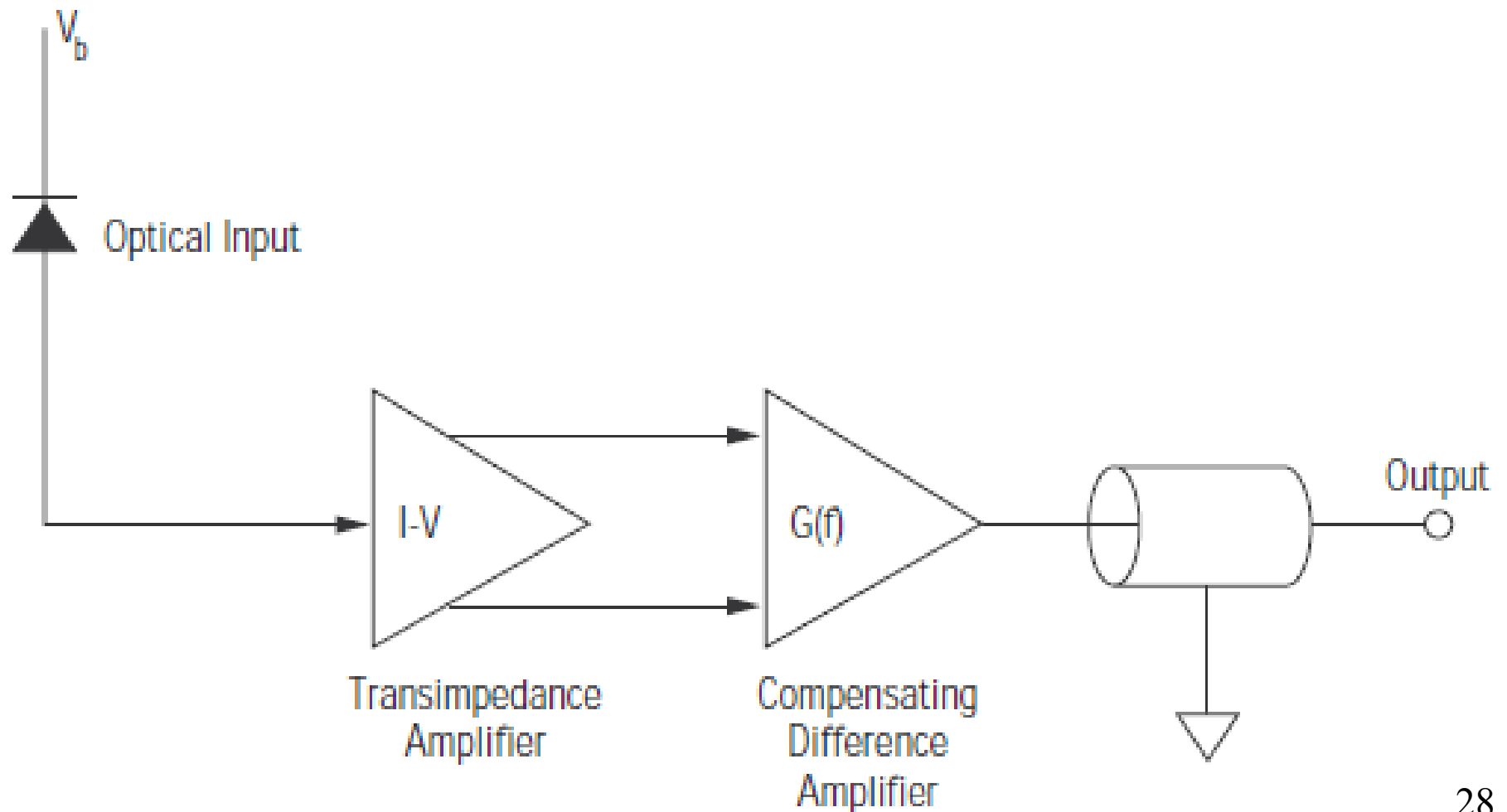
Example-operational amplifier



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).

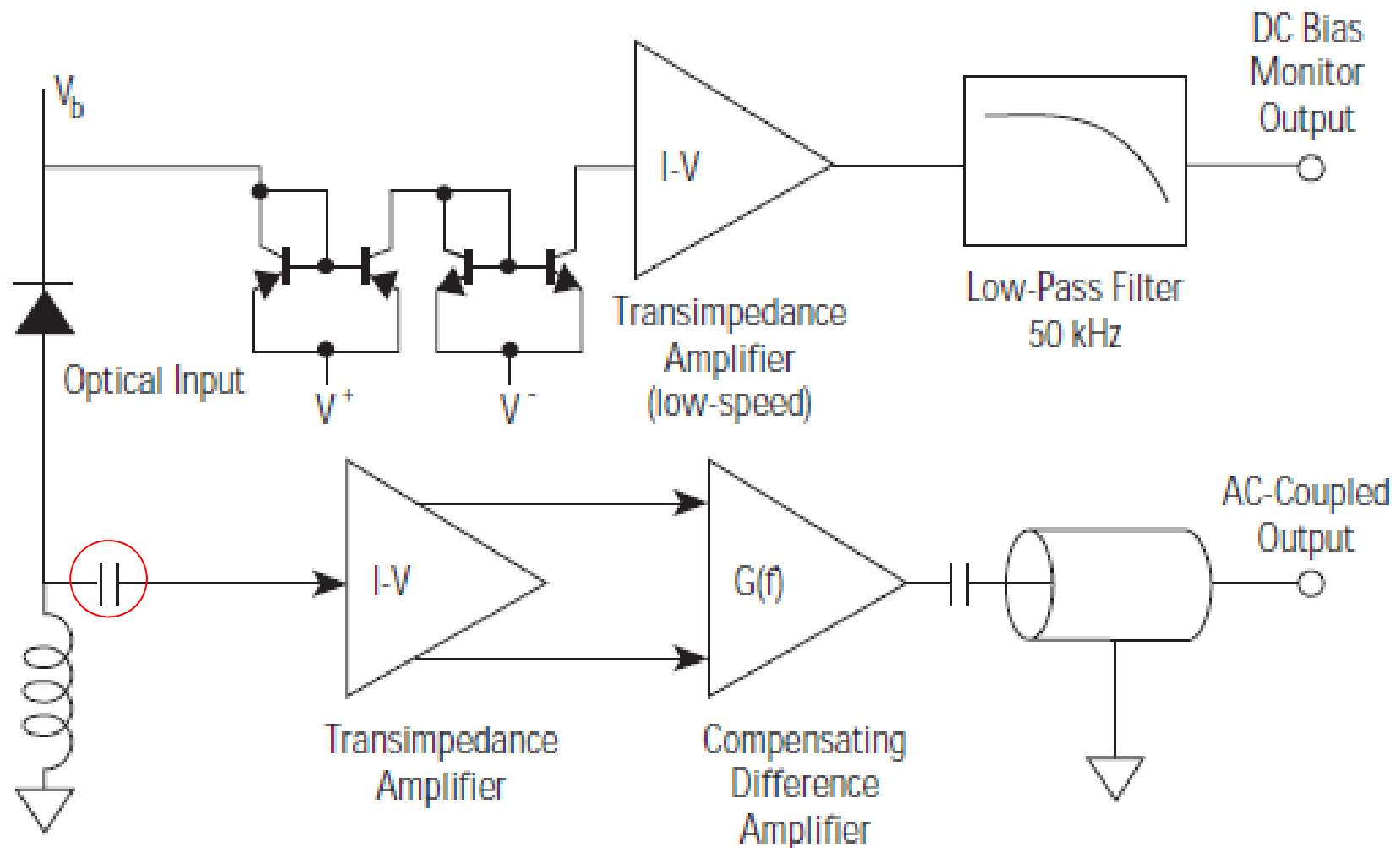
Example-a photodetector

■ New Focus™ 1801



Example-a photodetector

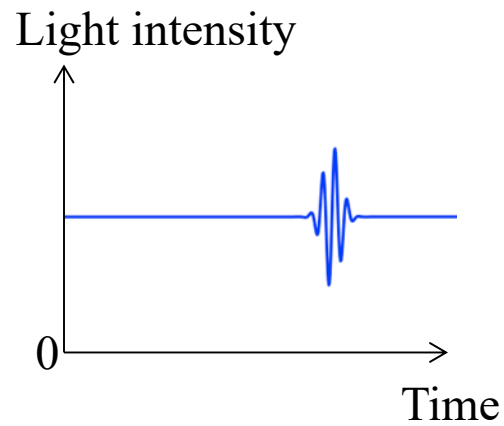
■ New Focus™ 1801-AC



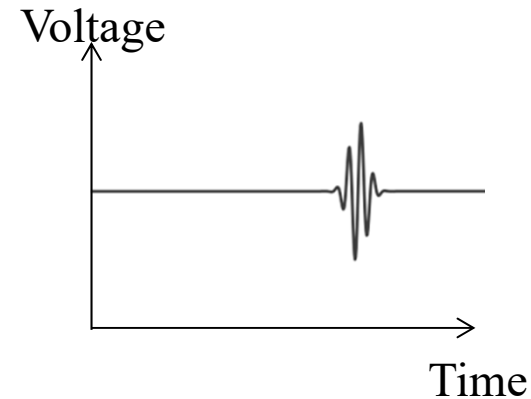
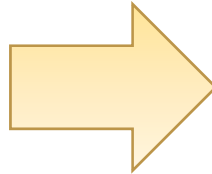
Example-a photodetector

Optical signal input

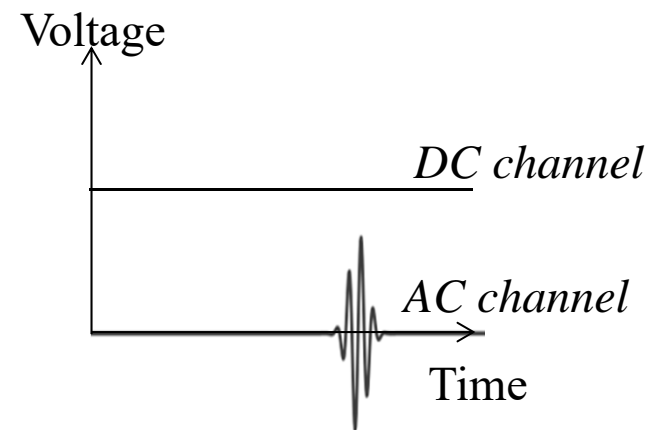
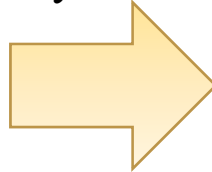
Electrical signal output



By 1801

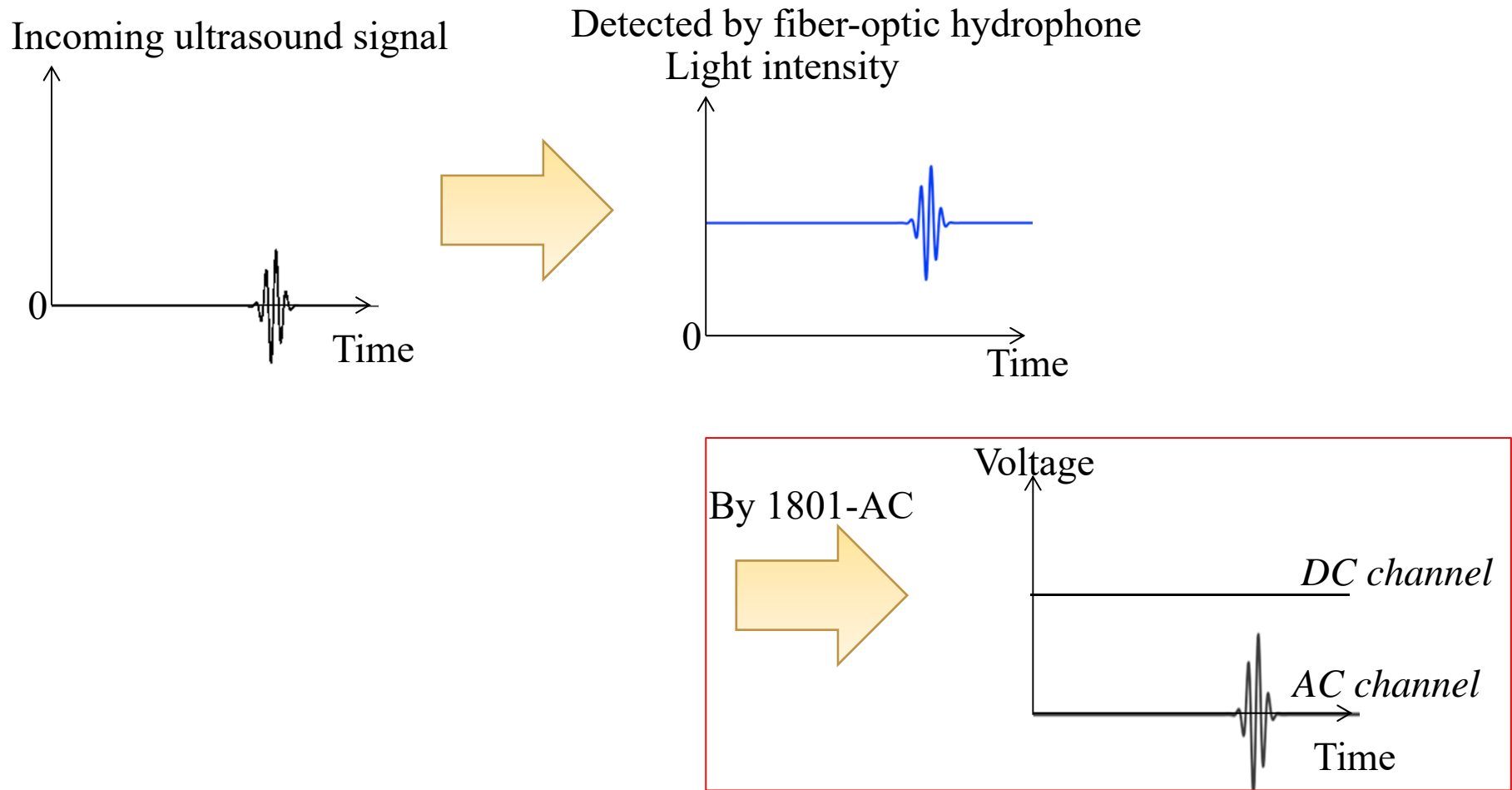


By 1801-AC



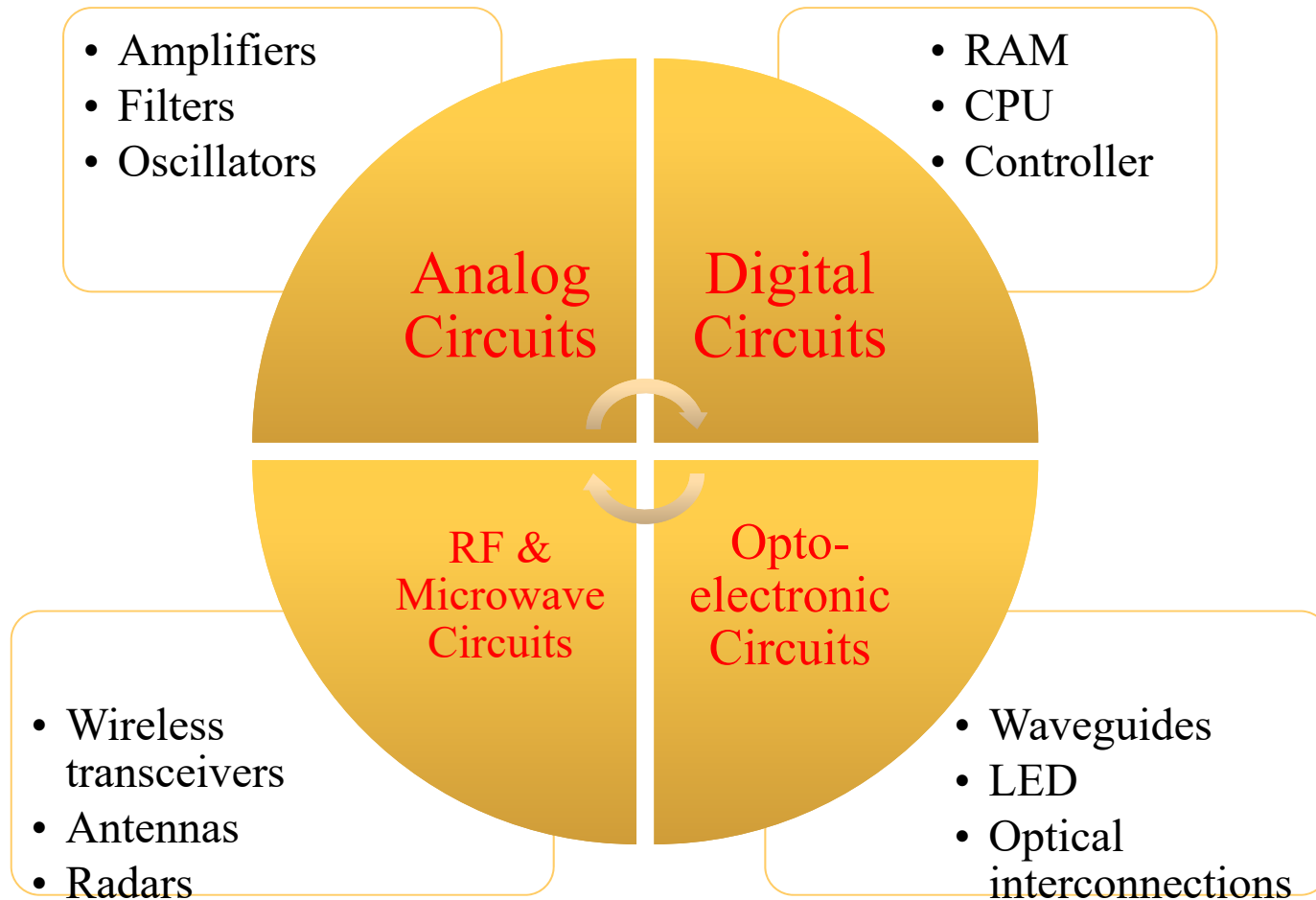
Application: Fiber-optic hydrophone

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





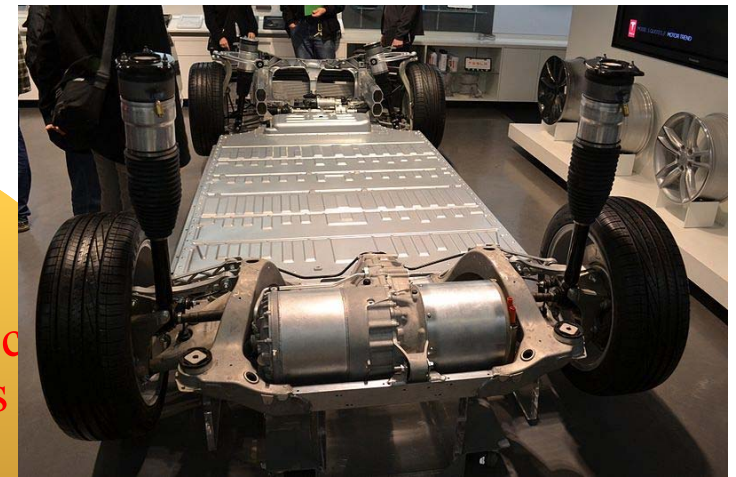
Circuit types



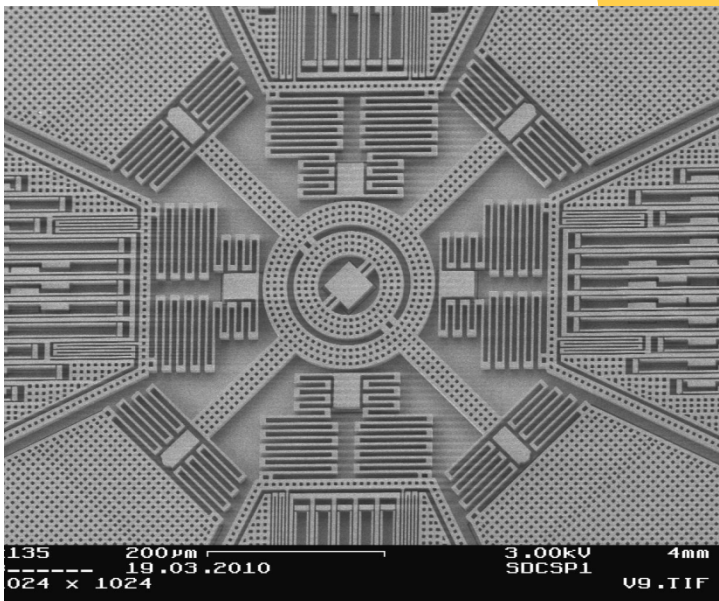
Circuit types



Electrical
Circuits

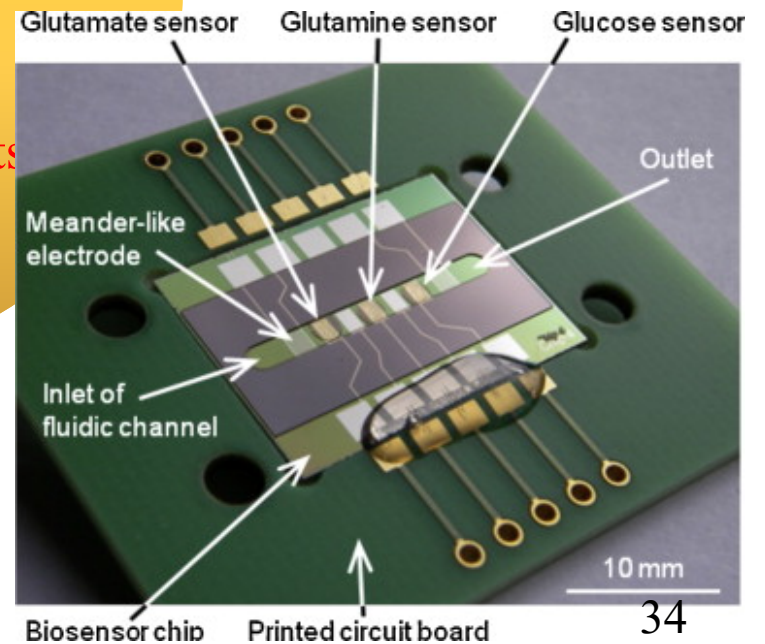


Magnetic
Circuits

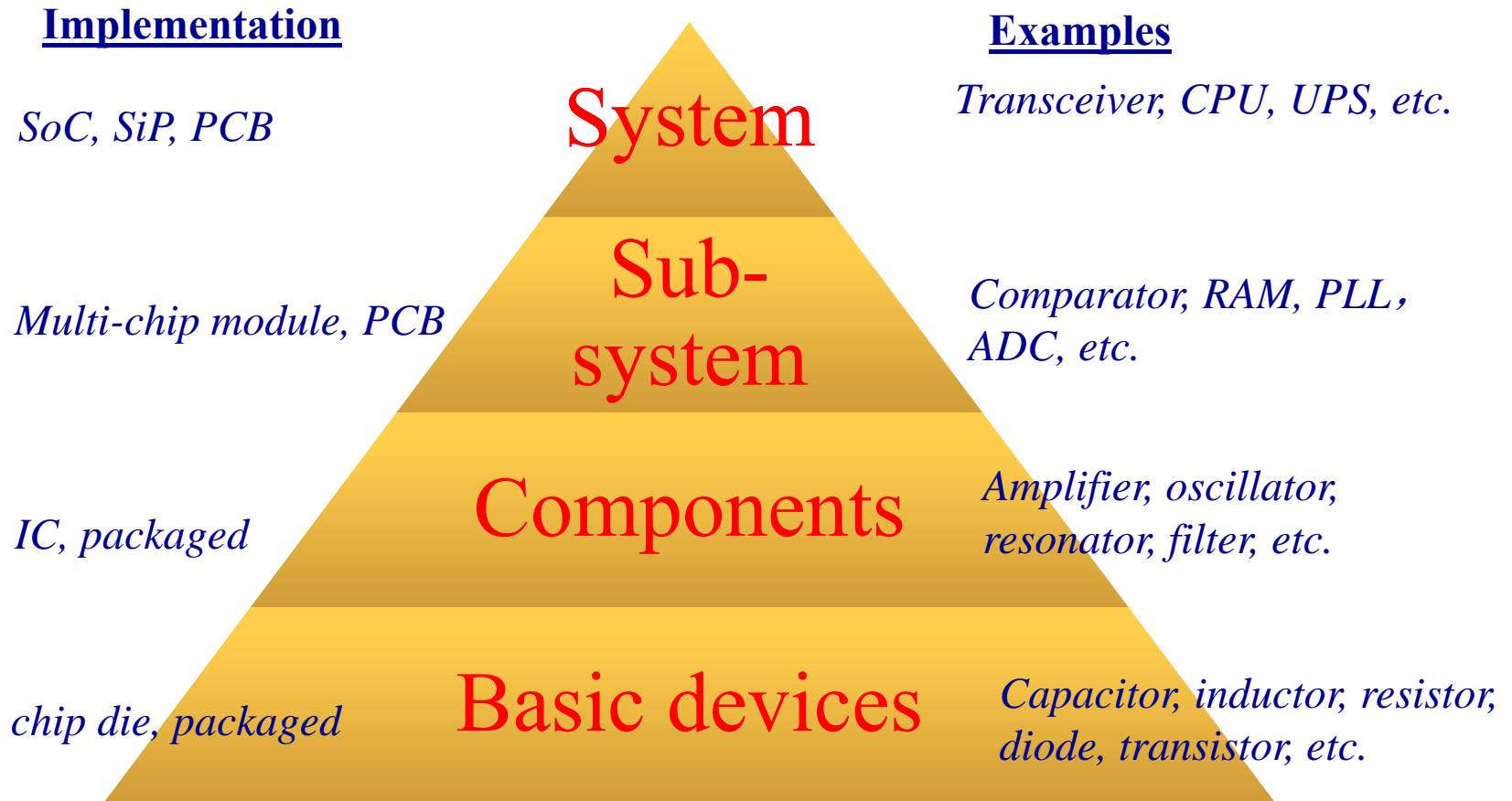


Mechanical
Circuits

Bio
Circuits



Circuit hierarchy



Circuit related curriculum in JI

Freshmen

- Math
- Physics
- Programming

Sophomore

- VE215
Introduction to Circuits
- VE216
Signal and System
- VE230
Electromagnetics
- VE270
Introduction to Logic Design

Junior

- VE311
Analog circuits
- VE320
Semiconductor
- VE330
Electromagnetics II
- VE312
Digital Integrated Circuits
- VE334
Optics

Senior

- 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:

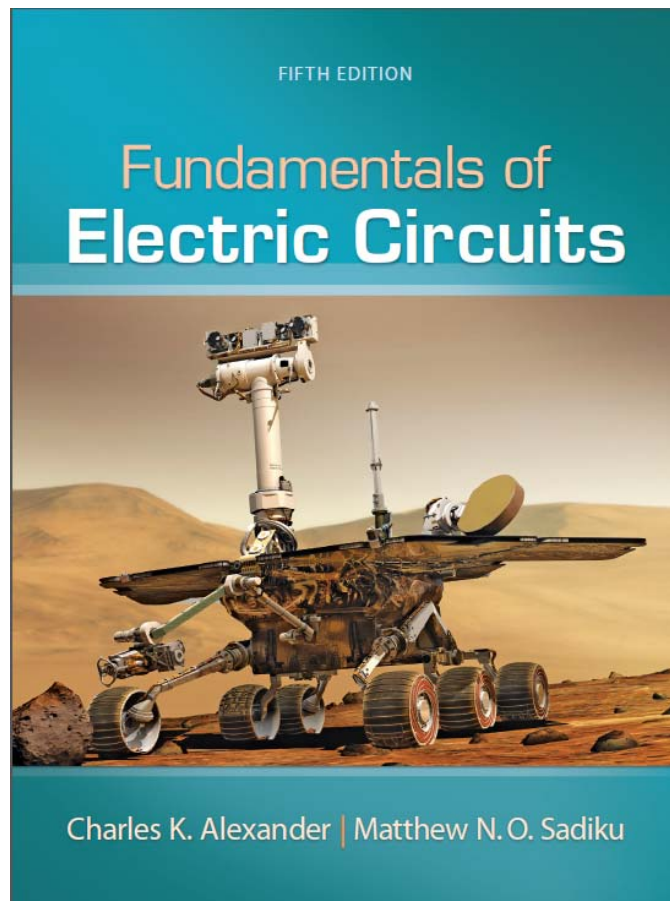
sungliang.chen@sjtu.edu.cn

Course expectation and requirement

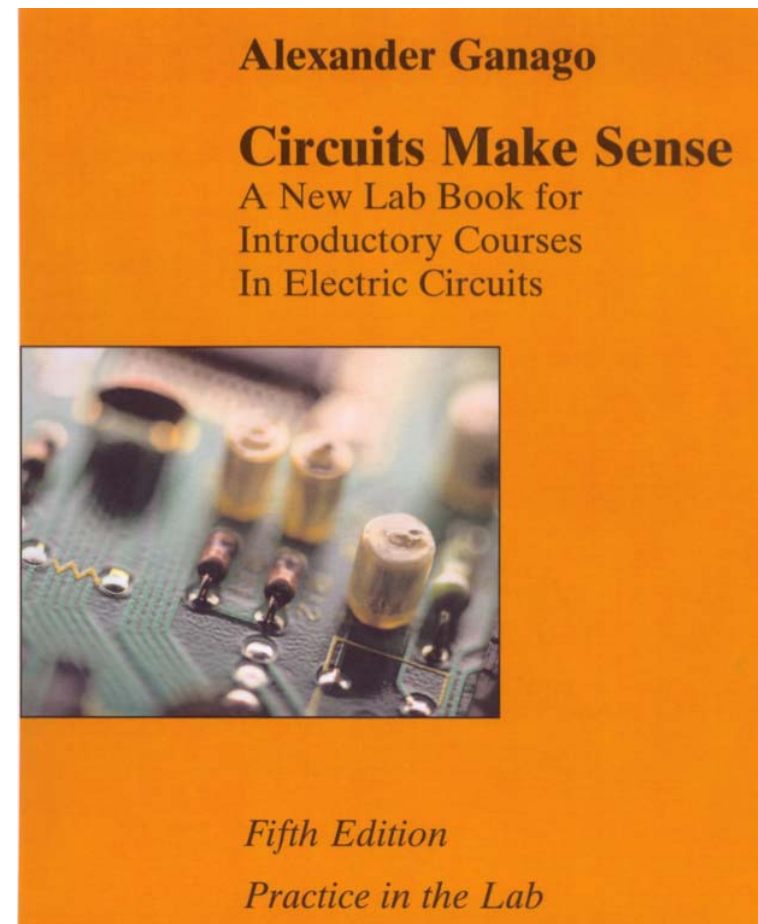
- Pre-requisites: VV156 or VV186, VG101
- Co-requisites: VP240 or VP260
- Basic college math and physics
 - Scalar & Vector
 - Differentiation & Integration
 - Electric Charge
 - Current & Voltage

Textbook

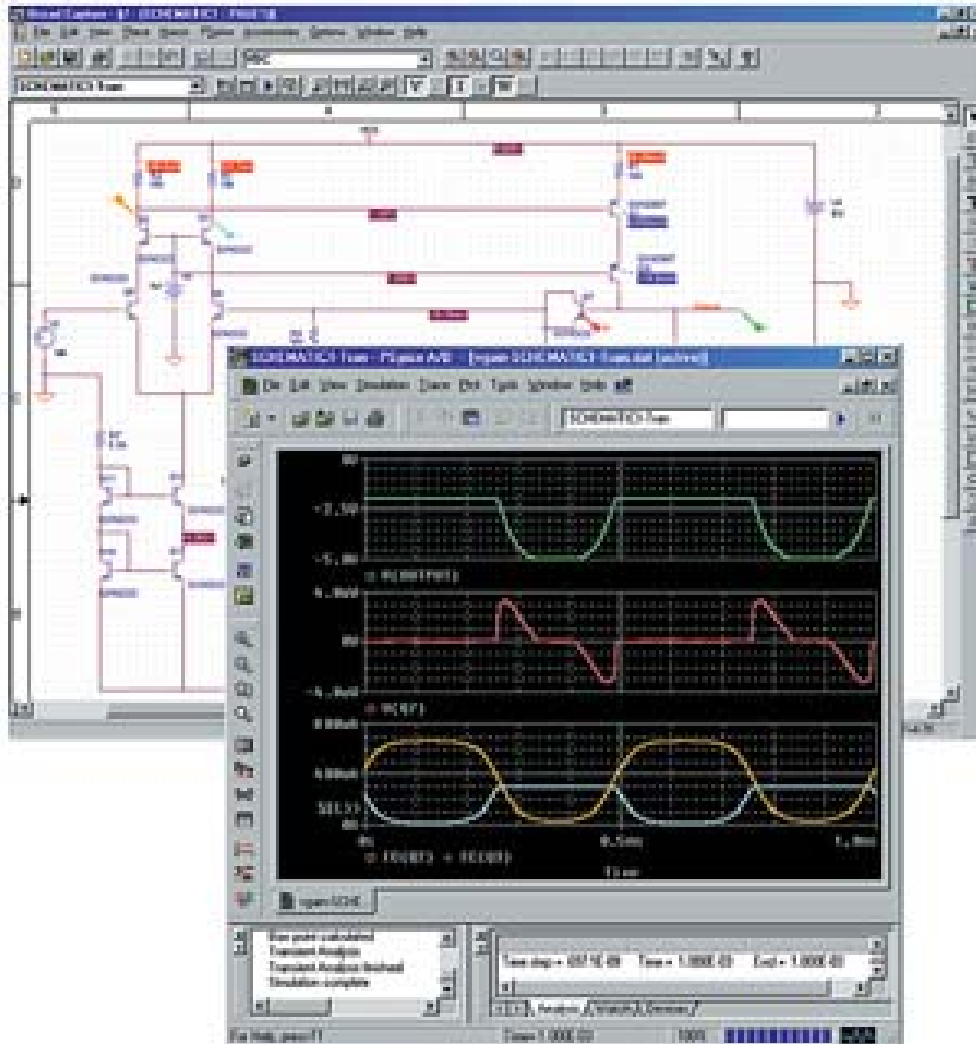
Main Textbook



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),
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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?