Electric Circuits

Lecture 0 - Introduction

Instructor: Dr. Pingqiang Zhou

Fall 2016
Instructor

- Dr. Pingqiang Zhou
  - PhD in EE, U of Minnesota
  - ME in CS, Tsinghua

- Lecture
  - Monday, 10:15AM – 11:55AM
  - Wednesday, 10:15AM – 11:55AM (ODD week only!)
  - Venue: Teaching center 201

- Office hours
  - Friday, 8:30am – 9:30am
  - Venue: SEM 319
TAs (Lab Sessions)

• Class 1, Mon. 5:45PM - 8:20PM  
  ▪ TA: 黄景林 <huangjl>
• Class 2, Tue. 1PM – 3:45PM  
  ▪ TA: 陈晨 <chenchen2>
• Class 3, Tue. 5:45PM - 8:20PM  
  ▪ TA: 曹骐 <caoqi>
• Class 4, Thur. 1PM - 3:45PM  
  ▪ TA: 刘圣波 <liushb>
• Class 5, Fri. 1PM - 3:45PM  
  ▪ TA: 李诚 <licheng>

Venue: SIST 1A-101

2 students per group!
Find your partner by 9/14.
TAs (Discussion Sessions)

- Class 1, Thur. 3:55PM - 5:35PM
  - Veune: SIST 1A-104
  - TA: 马郁 <mayu>
- Class 2, Thur. 3:55PM - 5:35PM
  - Veune: SIST 1A-106
  - TA: 杨亚君 <yangyj>
- Class 3, Fri. 3:55PM - 5:35PM
  - Veune: SIST 1A-104
  - TA: 张一弛 <zhangych>
- Class 4, Fri. 3:55PM - 5:35PM
  - Veune: SIST 1A-106
  - TA: 吴秉翰 <wubh>
- Class 5, Fri. 3:55PM - 5:35PM
  - Veune: SIST 1A-108
  - TA: 谢功尚 <xiegsh>

Choose your class at (by 9/14)
http://www.sojump.hk/m/9645413.aspx?pvw=1
Workload/Grading Policy

• 11 homework assignments: $11 \times 2\% = 22\%$
• 11 lab assignments: $11 \times 2\% = 22\%
  ▪ NO late HW or Lab reports accepted!
• 2 midterms (15\% \times 2) + 1 final exam (20\%)
  ▪ Midterm 1: week 6, Oct. 17 (tentative)
  ▪ Midterm 2: week 11, Nov. 23 (tentative)
  ▪ Notify the instructor immediately if you miss an exam due to an unforeseeable event, and submit a note from your physician in case of illness.
  ▪ NO make-up exams!
• Quizzes (6\%)
  ▪ Quizzes are held in-class and will not be announced. There won’t be any makeup quizzes.
请务必遵守学术道德规范！

• 单次作业或者实验抄袭
  ▪ 抄袭与被抄袭者该次作业/实验均计零分，课程总成绩打九折。

• 累计两次作业或者实验抄袭
  ▪ 抄袭与被抄袭者相应作业/实验计零，课程总成绩均打七折。

• 累计三次作业或实验抄袭者，或者考试作弊者
  ▪ 课程总成绩计零，同时上报信息学院学术委员会公开处理。
Textbook

References


Major Areas of Electrical Engineering (EE)
What is Electrical Engineering (EE)?

• “EE is the profession concerned with systems that produce, transmit, and measure electric signals. Electrical engineering combines the physicist’s models of natural phenomena with the mathematician’s tools for manipulating those models to produce systems that meet practical needs.”

• “Electrical engineers design systems that have two main objectives:
  1. To gather, store, process, transport, and present information.
  2. To distribute, store, and convert energy between various forms.”
Electromagnetics

- Study and application of electric and magnetic fields.

[Source: Google Image]
Electronics

- Study and application of materials, devices and circuits used in *amplifying* and *switching* electrical signals.
Photonics

- An exciting new field that manipulates *photons*, instead of manipulating *electrons* in conventional computing, signal processing, sensing and communication.

[Source: Google Image]
Signal Processing

- Concerned with information-bearing electrical signals
  - Objective: extract useful information from electrical signals derived from sensors.
Communication Systems

- *Transport* information in electrical form.

![Diagram of Communication System](image-url)
Computer Systems

- *Process and store* information using electrical signals.
Control Systems

- Use electric signals to *regulate* processes.
Power Systems

- Convert energy to and from electrical form and transmit energy over long distances.
EE = Electrical Engineering?
EE Trichotomy

- **Devices**
  - You can “touch and feel” devices
  - Semiconductors are materials of choice
  - Information is ultimately represented by electrons (and ‘holes’) and/or photons

- **Circuits**
  - Interconnection of devices that performs a useful function
  - Digital circuits, analog circuits, “RF” and microwave

- **Systems**
  - The theory behind EE systems.
  - A model for the system that includes noise, non-linearity, feedback and dynamics.

[Source: Berkeley]
In a field as diverse as electrical engineering, does all its branches have anything in common?

Electric Circuit!

- an actual electrical system, as well as the *model* that represents it.
Electric Circuits
What will You Learn from “Electric Circuits”?  

• An *electric circuit* is an interconnection of electrical elements.

![Battery and Lamp Circuit](image)

• Theory: You will learn various *analysis* methods in lectures to analyze the behavior of such electric circuits.  
  - How does the circuit respond to a given input?  
  - How do the elements and devices in the circuit interact?  

• Practice: You will also learn how to *build and test* basic electric circuits through *labs* and *projects*!
Electrical Engineering Design

- An ideal circuit component: mathematical model of an actual electrical component.
- Circuit analysis plays a very important role in the design process.

[Nilsson: Electric Circuits]
Topics Covered in This Course (Tentative)

- **Basics:** currents, voltages; power/energy; circuit elements
- **DC circuits**
  - Basic circuit laws (Ohm, Kirchhoff, Wye-Delta etc.)
  - Circuit analysis: nodal analysis and mesh analysis
  - Circuit theorems: Thevenin, Norton, Superposition
  - Operational amplifiers: ideal, inverting/non-inverting, summing and difference
  - Inductance, capacitance and mutual inductance
- **Transient circuits**
  - First-order and second-order circuits
- **AC circuits**
  - Sinusoidal steady-state analysis and power calculations
  - Three-phase circuits; magnetically coupled circuits
  - Frequency response: transfer function; resonance; filters
- **Laplace transform, Fourier transform**
- **Two-port networks**
Some History of Electrical Engineering
Back to the Early 17th Century

- William Gilbert (1544 - 1603), English
  - First (?) electrical engineer - Designed *versorium*, a device to detect the presence of static electric charge.
  - Established the term *electricity*.

[Source: Wikipedia]
• Alessandro Volta (1745 – 1827), Italian
  ▪ In 1775, devised electrophorus, a device that can produce static electric charge.
  ▪ In 1796, developed voltaic pile, the first electrical battery.

[Source: Wikipedia]
• Andre-Marie Ampere (1775 - 1836), French
   The father of electrodynamics (classical electromagnetism)
   In the 1820s, defined the electric current and developed a way to measure it.
• Georg Simon Ohm (1789 - 1854), German
  - In 1827, quantified the relationship between the electric current and potential difference in a conductor, i.e., the “Ohm’s law”.

[Source: Wikipedia]
Michael Faraday (1791 - 1867), English

- In 1831, discovered *electromagnetic induction*.

One of Faraday's 1831 experiments demonstrating induction. The liquid battery (*right*) sends an electric current through the small coil (*A*). When it is moved in or out of the large coil (*B*), its magnetic field induces a momentary voltage in the coil, which is detected by the galvanometer (*G*).
Alternating Current (AC)

- Hippolyte Pixii (French, 1808 - 1835)
  - In 1832, built an early form of AC electrical generator, based on the principle of magnetic induction discovered by Faraday.

(Source: Wikipedia)
- James Clerk Maxwell (1831 - 1879), Scottish
  - Formulated the classical theory of electromagnetic radiation (Maxwell’s equations)

The electromagnetic waves that compose electromagnetic radiation can be imagined as a self-propagating transverse oscillating wave of electric and magnetic fields.

This diagram shows a plane linearly polarized EMR wave propagating from left to right. The electric field is in a vertical plane and the magnetic field in a horizontal plane. The electric and magnetic fields in EMR waves are always in phase and at 90 degrees to each other.

[Source: Wikipedia]
In 1830s, Electricity for Practical Use

- Cooke and Wheatstone’s first commercial telegraph in the world (1838), installed on the Great Western Railway (London, 21km).

- Morse and Vail’s system
  - Patented in the US in 1837.
  - West coast connected by 1861.

[Source: Wikipedia]
Bell (Scottish, 1847 - 1922)

- Alexander Graham Bell was the first to be awarded a patent for the electric telephone by the United States Patent and Trademark Office (USPTO) in March 1876.

- 10 March 1876 — The first successful telephone transmission of clear speech using a liquid transmitter when Bell spoke into his device, “Mr. Watson, come here, I want to see you.” and Watson heard each word distinctly.

[Source: Wikipedia]
Tesla (Croatia, 1856 - 1885)

- Best known for his contributions to the design of the modern alternating current (AC) electricity supply system.
- In 1891 Nikola Tesla demonstrate wireless transmission of signals and he suggested wireless telegraphy as an application.

AC electric generator  Artificial lighting  Wireless transmission

[Source: Wikipedia]
Wireless/Radio

- Started as wireless telegraphy. The history of the invention of the radio is very disputed.

- Guglielmo Marconi (Italian, 1874 - 1937) widely recognized as an early inventor although he played a more important role in commercializing the radio.
  - In 1895, he sent signals 1.5km.
  - Transatlantic in 1902.

[Source: Wikipedia]
Titanic Boost in Radio

- In 1912, the RMS Titanic sank in the northern Atlantic Ocean.
- Wireless radio transmissions (telegraph) were used to report the ship’s location.
- Britain's postmaster-general summed up, referring to the Titanic disaster, “Those who have been saved, have been saved through one man, Mr. Marconi...and his marvelous invention.”
First Audio Transmissions

- Reginald Fessenden: Invented amplitude-modulated (AM) radio, so that more than one station can send signals (as opposed to spark-gap radio, where one transmitter covers the entire bandwidth of the spectrum).

- On Christmas Eve 1906, Reginald Fessenden made the first radio audio broadcast, from Brant Rock, MA.
- Ships at sea heard a broadcast that included Fessenden playing O Holy Night on the violin and reading a passage from the Bible.

[Source: Wikipedia]
AM/FM Wireless Radio

- The dominant telegraph company of the time was Western Union. They had a monopoly on telegraphy and they dismissed telephony and radio.
- Telegraph gave way to audio transmission, mainly phone lines and broadcast radio.
- Frequency modulation (FM) was invented by Armstrong in 1935. FM has greater noise immunity than AM but requires more bandwidth.
Digital Communications

- By sampling a signal and quantizing it (turning it into finite precision numbers), we can easily store it using digital technology and we can also transmit it digitally.
- Audio signals, for example, need to be sampled at about 20,000 times per second and with a resolution of around 18 bits to completely retain the fidelity of the signal (for the human ear).
- Today information is still transmitted with AM and FM, but the amplitude and phase of the signal are mapped into a finite alphabet. These digital signals are more noise immune and can be coded (guarded) to prevent, correct, and detect errors in transmission.

[Source: Berkeley]
The Transistor

• Invented at Bell Laboratories on December 16, 1947 by William Shockley (seated at Brattain's laboratory bench), John Bardeen (left) and Walter Brattain (right).
  ▪ Inventors awarded Nobel Prize.

• Probably the most important event in Electronic Engineering history.

[Source: Berkeley]
Early Transistors

- Bell labs was the research lab of a telephone company. As such the importance of the transistor was not recognized by many of the business folks at AT&T.
- Device was flaky and low power compared to vacuum tubes, the workhorse device of the time (for signal amplification)
- In 1952 first transistorized radios appear. Compared to vacuum tube, transistors were compact.
  - Transistor radio was a revolutionary battery operated device.

Source: Berkeley
The Integrated Circuit (IC)

• First IC is invented by Jack Kilby of Texas Instruments and Robert Noyce of Fairchild Semiconductor (later founded Intel).

• In his patent application of February 6, 1959, Kilby described his new device as “a body of semiconductor material ... wherein all the components of the electronic circuit are completely integrated.” (2000 Nobel Prize in Physics)

[Source: Berkeley]
Why IC’s were Revolutionary?

• When building a complex circuit, most of the failures occur in the wiring and connections of wires.

• Printed circuit boards help improve reliability but they are physically large and discrete components are fairly expensive.

• ICs: Low cost mass production, monolithic, includes transistors and interconnect.

[Source: Berkeley]