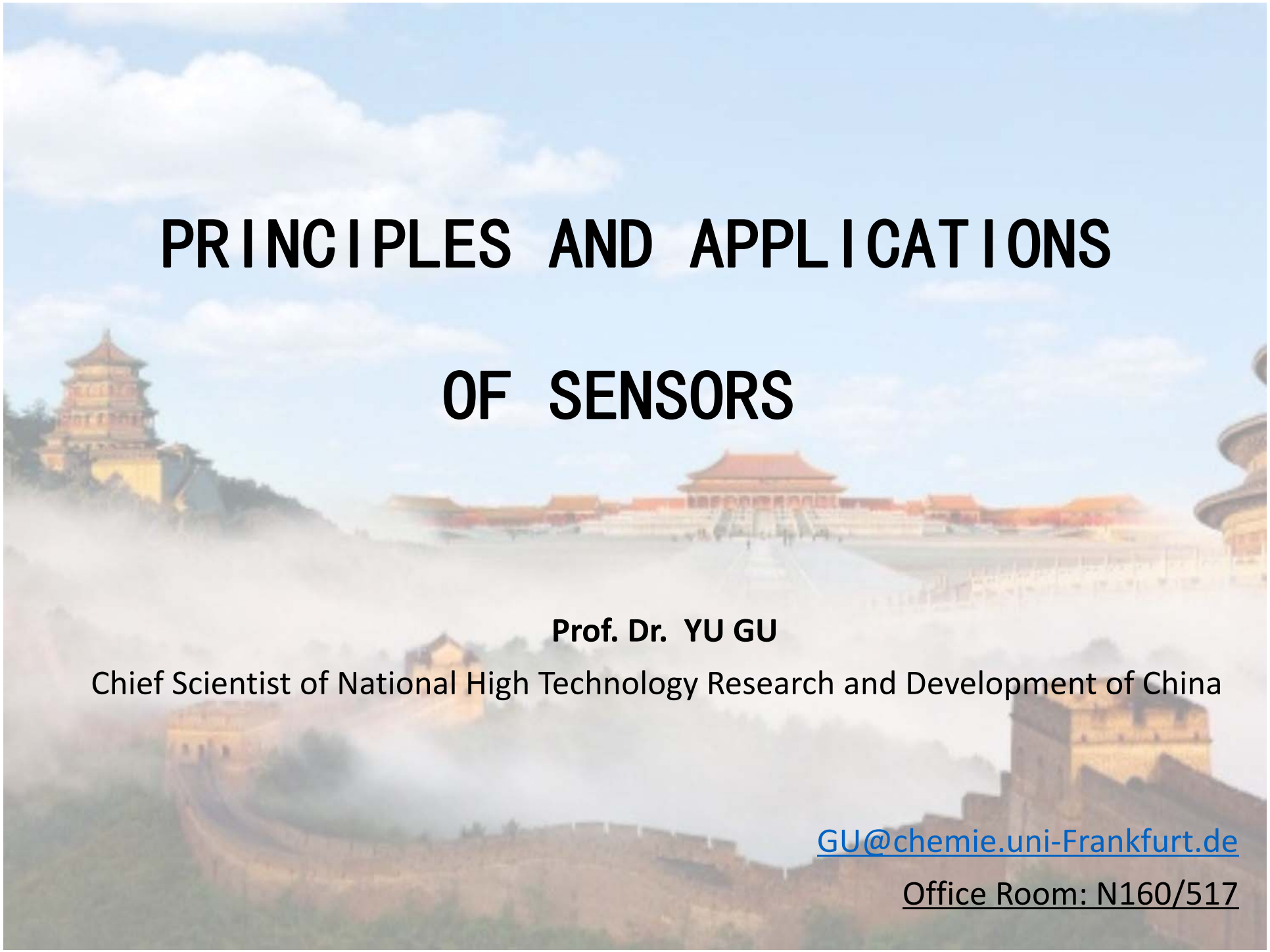

PRINCIPLES AND APPLICATIONS OF SENSORS

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Short CV

Basic studies: Belarus State University of Transport (1995-2001， Belarus), (Solid Mechanics)

Ph.D.: Russian Academy of Sciences (2001-2006) with academician I. Stravoidov, (Solid Mechanics)

Post-Doc: TsingHua University (2006-2008) with academician DaiNing Fang (Piezoelectric sensors)

Habilitation: Beijing University (2008-2010) (Piezoelectric sensors)

Professorships: Beijing Jiaotong University, University of Science and Technology Beijing, Beijing University of Chemical Technology

Research Interests:

Functional Materials,
New Sensors and MEMS,
Machine Learning

Short CV

Funding:

The total funds granted from the Chinese government to help finance my researches is 10 million euro (€) over the last ten years(from 2008-now).

1. Theory and technology of distributed energy system coordination management for smart cities, NSFC foundation (key project), No. U1501251, *4 yrs from 2016.1 to 2019.12, 0.36 million euro (€)*
2. Research and application of intelligent sensors and actuator materials, granted by National High Technology Research and Development of China, No. 2013AA030900, *3 yrs from 2013.1 to 2015.12, 5.25 million euro (€)*
3. Research of the application of new type sensors based on nano piezoelectric body in the area of biomedical, NSFC foundation, No. 61240041, *1 yr from 2013.1 to 2013.12, 0.3 million euro (€)*
4. Analysis and design of bio-piezoelectric sensors based on compound effects of mechanics and electric charge, NSFC foundation, No. 10972004, *3 yrs from 2010.1 to 2012.12, 0.9 million euro (€)*
5. Import, development, manufacture, and application to a equipment with a function of high-sensitive and recognition to chemical materials, granted by China-Belarus bilateral scientific and technological cooperation project, No. CB08-08, *3 yrs from 2008.10 to 2011.10, 0.6 million euro (€)*

… …

Publication Activities:

139 papers (110 papers were indexed by SCI data and 19 papers were indexed by EI data), 45 Chinese patents, and four books in Russian and one in English.

Two kinds of activities in the course:

Lecture （Monday and Wednesday ,14:00-16:00）
Seminar (Friday, 14:00-16:00)

course materials:

The notes

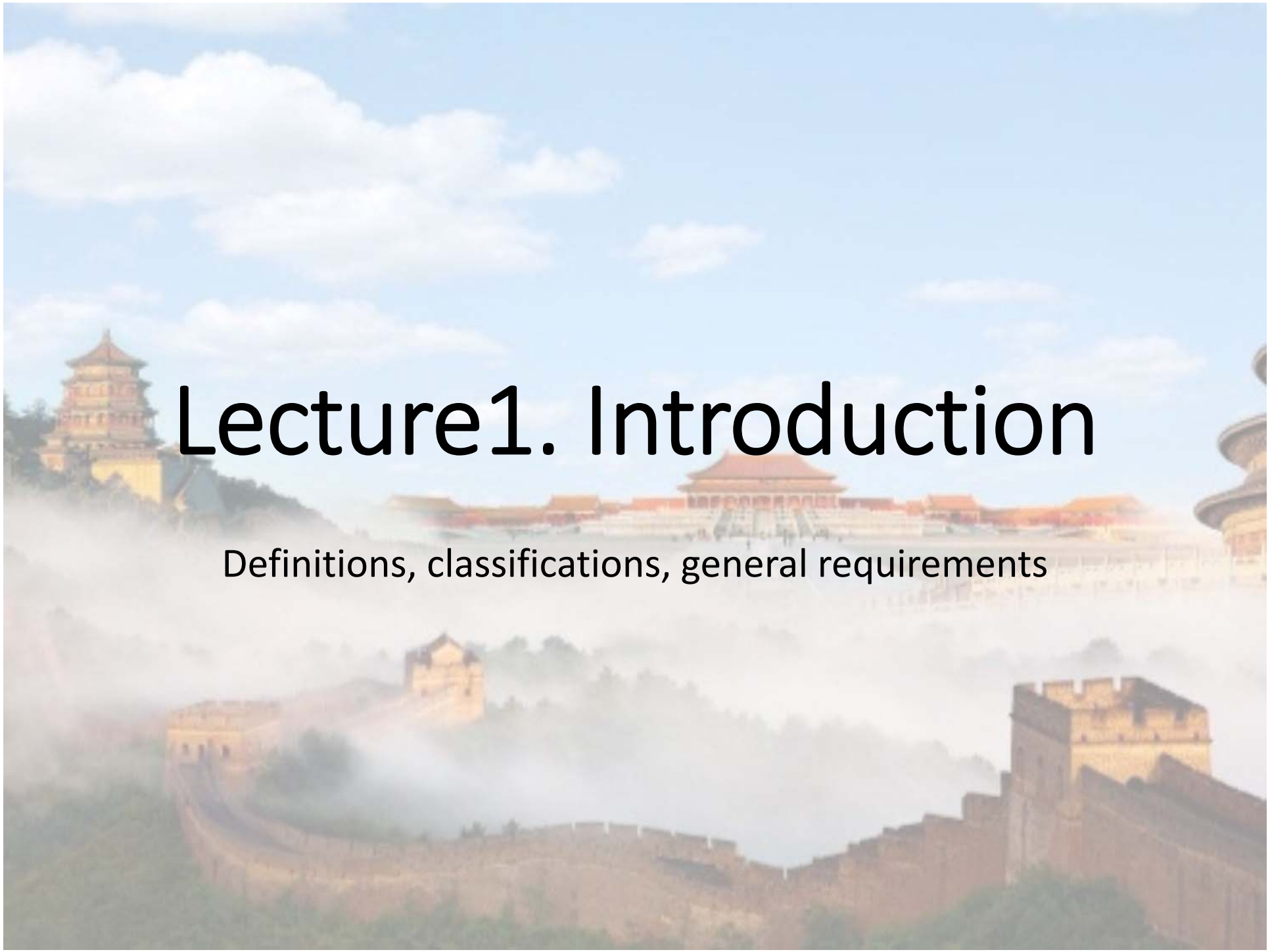
Grading Scheme:

Your overall grade will be determined based on the homework, and final exam. The value of each, expressed as percent of your grade, is given in the table below,

Item	% of Grade
Homework（discuss）	40
Final Exam	60

The date and time of the exam is given in the table below.

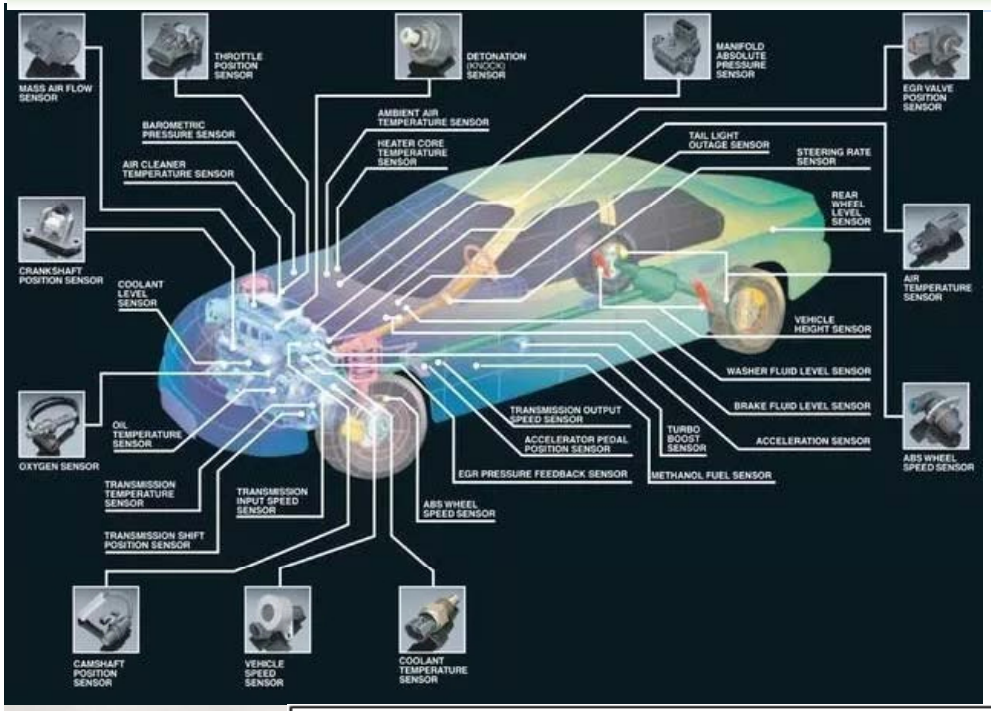
Exma	Date/Time
Final Exma	————————

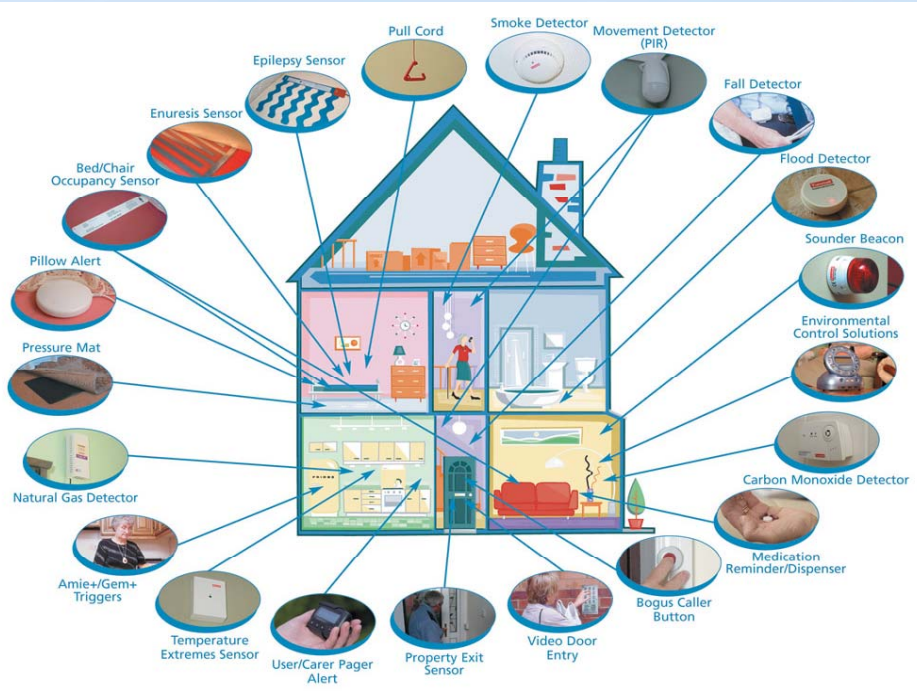


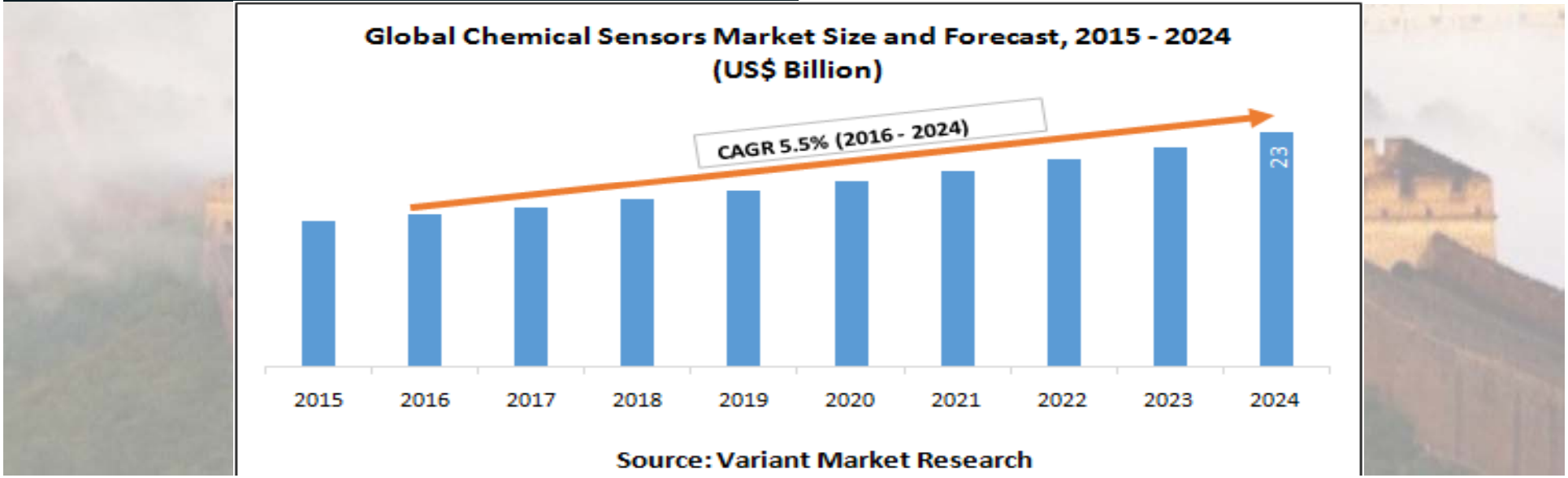
Lecture1. Introduction

Definitions, classifications, general requirements

Sensors Show Up in Every Aspect of Life







Some general statements

- Sensors/actuators are common
- Usually integrated in a system (never alone)
- A system of any complexity cannot be designed without them
- Very difficult to classify
- Difficult to get good data on them
- Definitions and terms are confusing

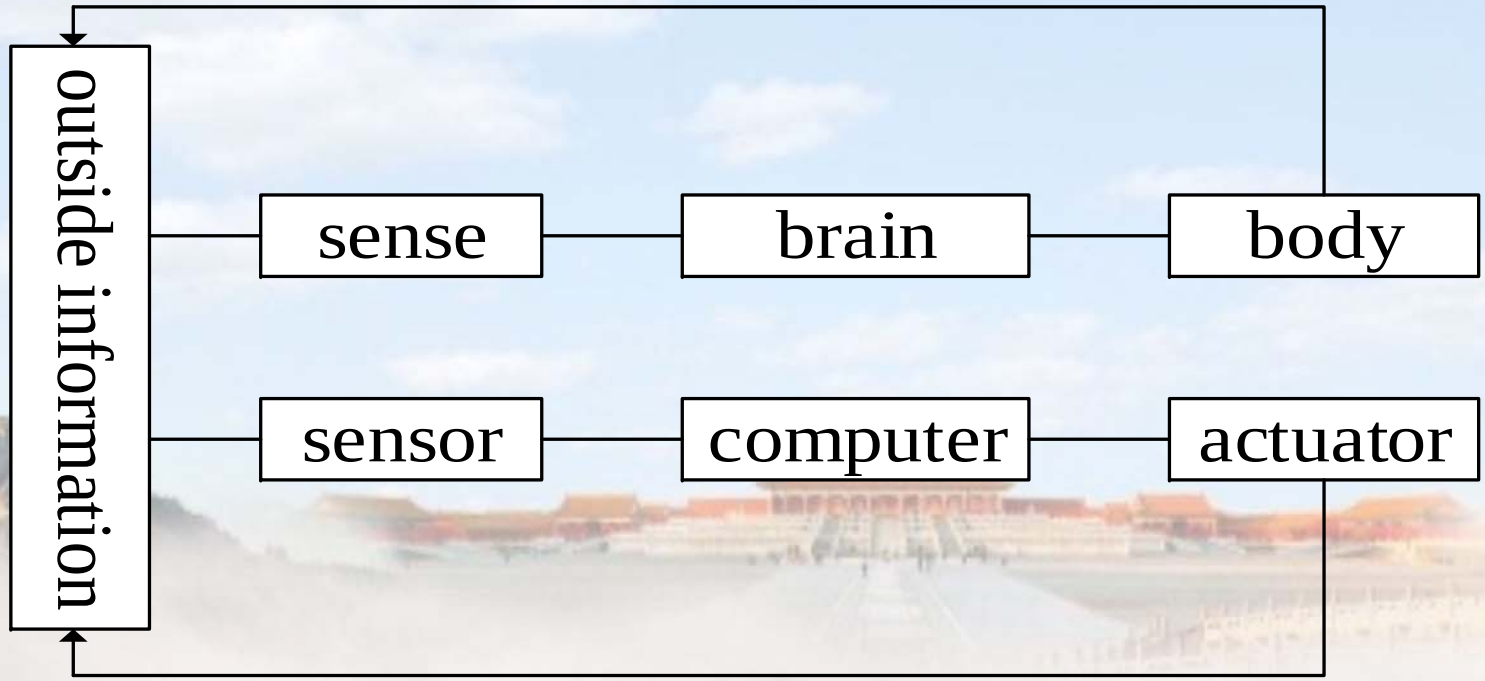


Fig. 1 Comparison between intelligent machine and human body structure

Definitions

- What are sensors and actuators?
- Why are they so difficult to classify?
- Too many principles involved
- Multi-discipline devices
- A mix of approaches to their design
- A mix of units and a range of complexities

Definitions - Sensors

- Also called: transducer, probe, gauge, detector, pick-up et cetera.
- Definitions *(no uniform)*
- A device that responds to a physical stimulus and transmits a resulting impulse. (New Collegiate Dictionary)

- A device, such as a photoelectric cell, that receives and responds to a signal or stimulus. (American Heritage Dictionary, 3rd ed., 1996)

Definitions - Sensors

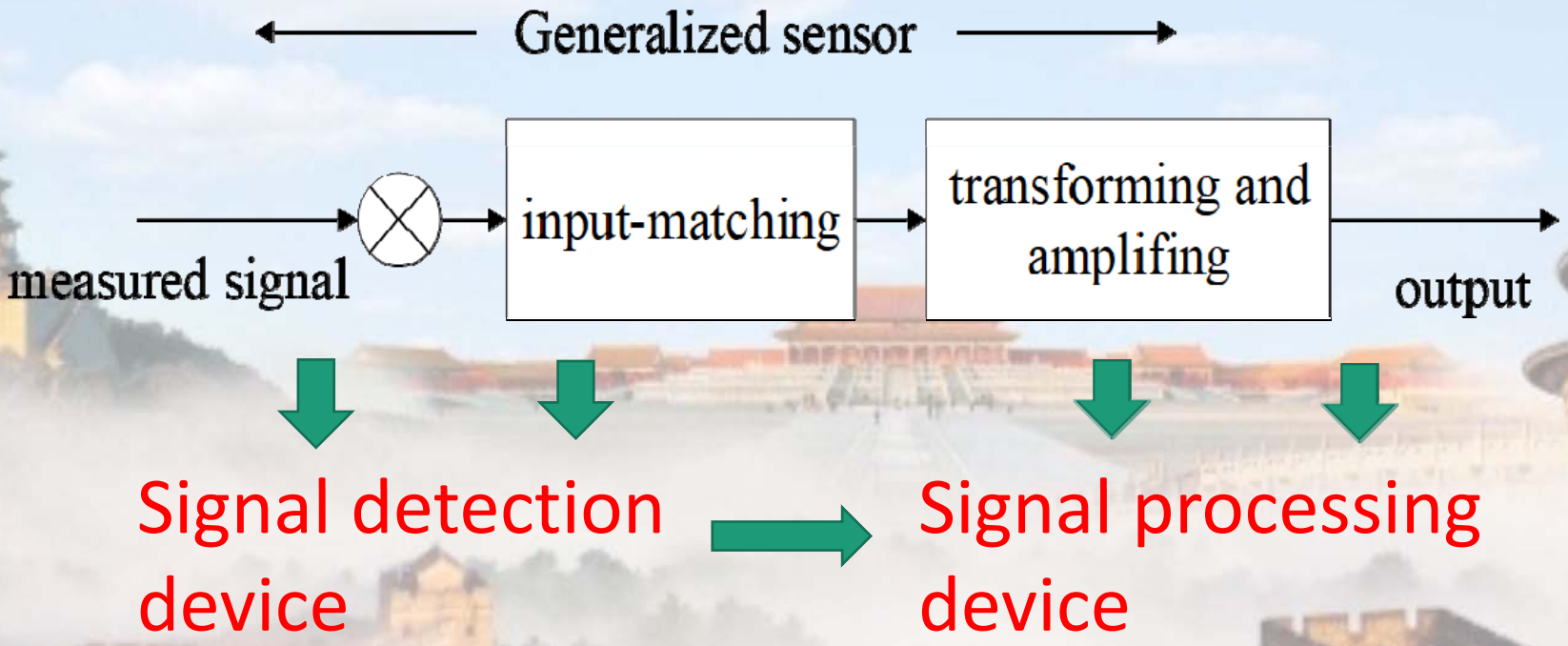


Fig.2 Block diagram of generalized sensor

Definitions - Sensors

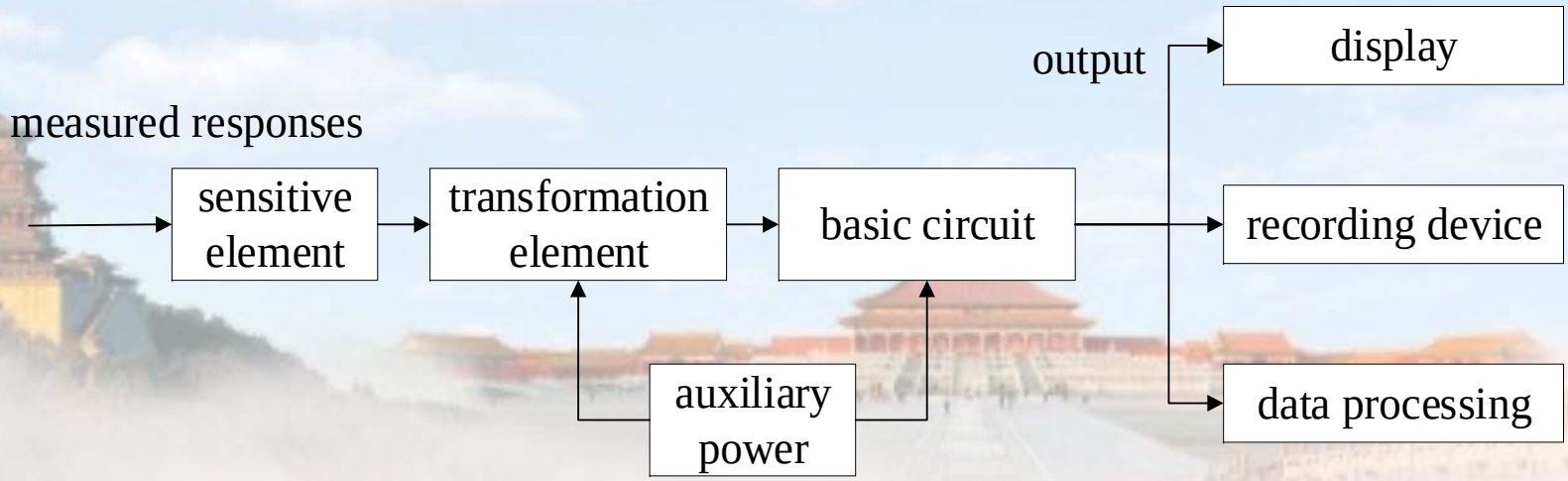


Fig. 3 Composition of sensor

Definitions - Transducer

A device that is actuated by power from one system and supplies power usually in another form to a second system. (New Collegiate Dictionary)

A substance or device, such as a piezoelectric crystal, that converts input energy of one form into output energy of another. (from: Trans-ducere – to transfer, to lead) (American Heritage Dictionary, 3rd ed., 1996)

Sensor - Transducer

IN USA , Sensor = Transducer

IN UK , Sensor = sensitive element

Transducer = Transducer

Measuring Transducer (only for Measuring)

IN JAPAN, Sensor = Sensing element

Transducer = Transducer

IN IEC (International Electrotechnical Commission),

Transducer = Transducer

Measuring Transducer (Sensor)

Sensor =a part of Measuring Transducer (Primary Element)

Definitions - Actuator

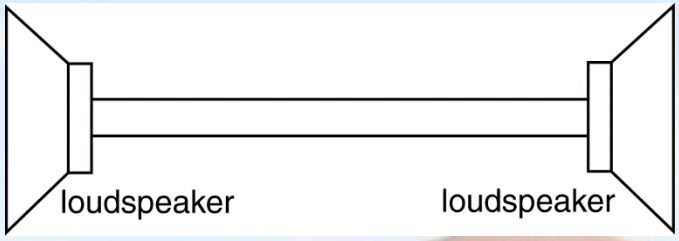
- A mechanism for moving or controlling something indirectly instead of by hand. (New Collegiate Dictionary)
- One that actuates; a mechanical device for moving or controlling something. (Webster, 3rd ed., 1999)

More confusion

- Transducer can mean:
  - sensor
  - actuator
  - transducer can be part of a sensor
  - sensor can be part of a transducer
- Many sensors can work as actuators (duality)
- Many actuators can work as sensors
- What is it then? - All of the above!

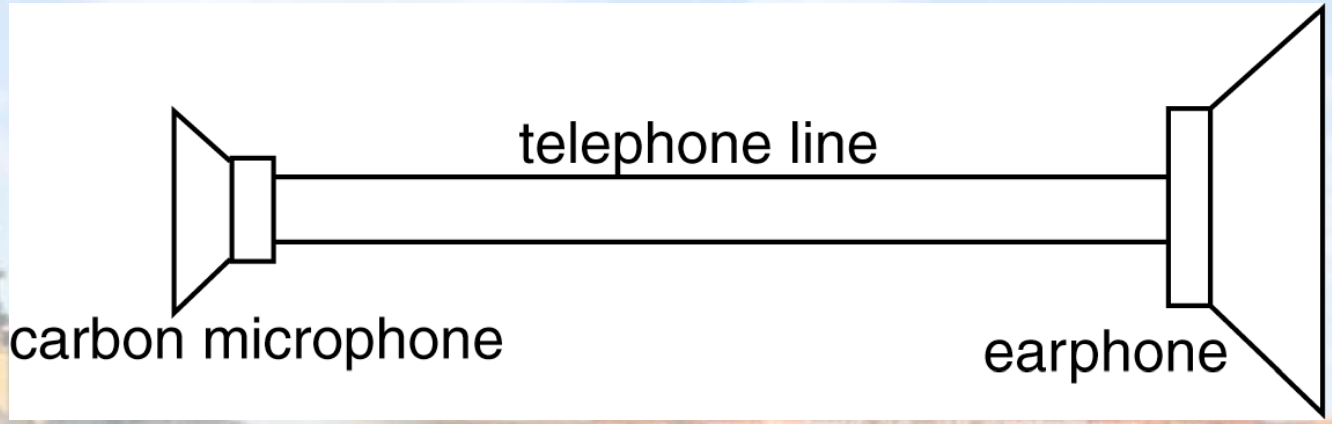
  Universal, Habitual： SENSORS

Example



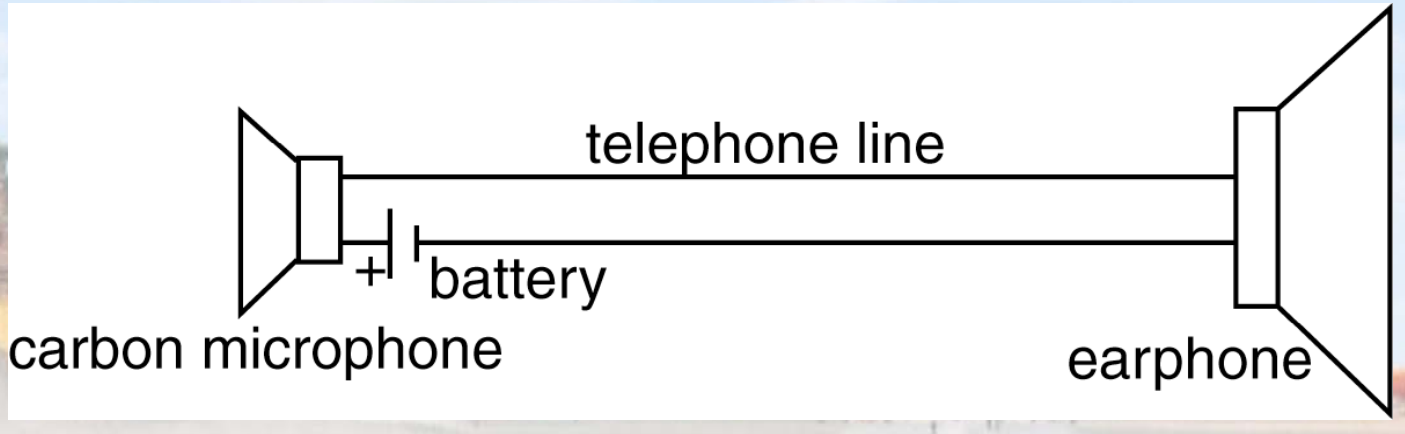
- Direct sensor actuator link (not always possible)
- Two transduction steps (sound-electrical and vice versa)
- Note: sensor/transducer are one and the same

Example



- Direct sensor actuator link
- Does not work:
- Sound is converted into change of resistance
- No transduction takes place (no change of energy)!
- Must add power to affect transduction
- Cannot work in opposite direction either

Example



- Transduction: pressure to current
- A telephone system has two of these!

Our definitions:

Sensor

- A device that responds to a physical stimulus.

Transducer

- A device that converts energy of one form into energy of another form.

Actuator

- A device or mechanism capable of performing a physical action.

Stimulus

- The quantity that is sensed.
- Sometimes called the measured.

Classification of Sensors and Actuators

- **Based on physical laws**
- **Based on Chemical laws**
- **Based on Biological laws (Biosensor)**

1. **Active and Passive sensors**
2. **Contact and non-contact sensors**
3. **Absolute and relative sensors**
4. **Other schemes**

1. Active and passive sensors

Active sensor: a sensor that requires external power to operate.

Examples: the carbon microphone, thermistors, strain gauges, capacitive and inductive sensors, etc. **Other name: parametric sensors**

Passive sensor: generates its own electric signal and does not require a power source.

Examples: thermocouples, magnetic microphones, piezoelectric sensors.

Other name: self-generating sensors

2. Contact and noncontact sensors

Contact sensor: a sensor that requires physical contact with the stimulus.

Examples: strain gauges, most temperature sensors

Non-contact sensor: requires no physical contact.

Examples: most optical and magnetic sensors, infrared thermometers, etc.

3. Absolute and relative sensors

Absolute sensor: a sensor that reacts to a stimulus on an absolute scale.

Examples: Thermistors, strain gauges, etc.,

Relative sensor: the stimulus is sensed relative to a fixed or variable reference.

Examples: Thermocouple measures the temperature difference, pressure is often measured relative to atmospheric pressure.

4. Other schemes

Classification by broad area of detection

- Chemical sensors
- Optical
- Mechanical
- Biological
- Etc.

Classification by physical law

- Photoelectric
- Magnetoelectric
- Thermoelectric
- Photomagnetic
- Etc.

4. Other schemes (cont.)

Classification by area of application

- Consumer products
- Healthy
- Transportation
- Scientific
- Etc.

Classification by specifications

- Sensitivity
- Stability
- Response time
- Operating temperature
- Etc.

Classification of actuators

All of the above

Classification of actuators by type of motion

- Linear
- Rotary
- One-axis
- Two-axes
- Three-axes
- **Etc.**

Classification of actuators

- Low power actuators
- High power actuators
- Micro power actuators
- **Etc.**

Sensing and actuating strategies

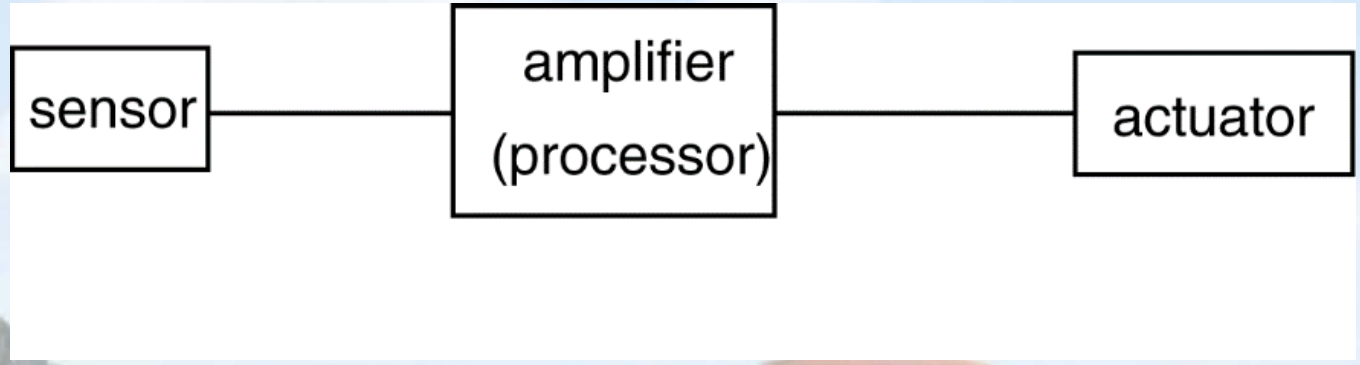
- Look at sensors based on broad area of detection.
- Discuss actuators wherever they fit with sensors
- Emphasize compatibility of classes of sensors and actuators.

Requirements for interfacing

Needs:

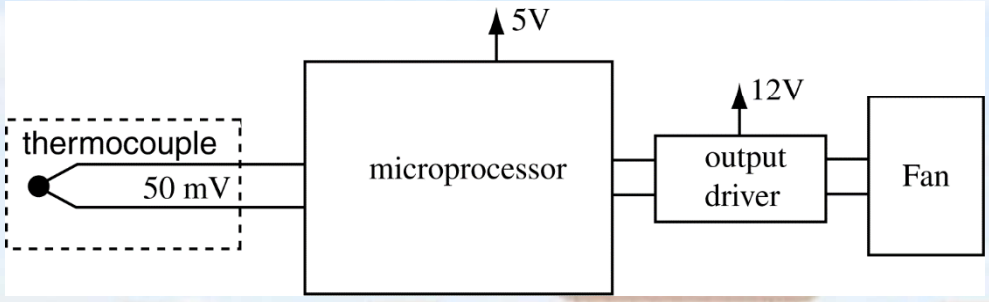
- Matching (impedances, voltages, currents, power)
- Transformations (AC/DC, DC/AC, A/D, D/A, VtoF, etc.)
- Matching of specifications (temperature ranges, environmental conditions, etc.)
- Alternative designs
- Etc.

Connection of sensors/actuators



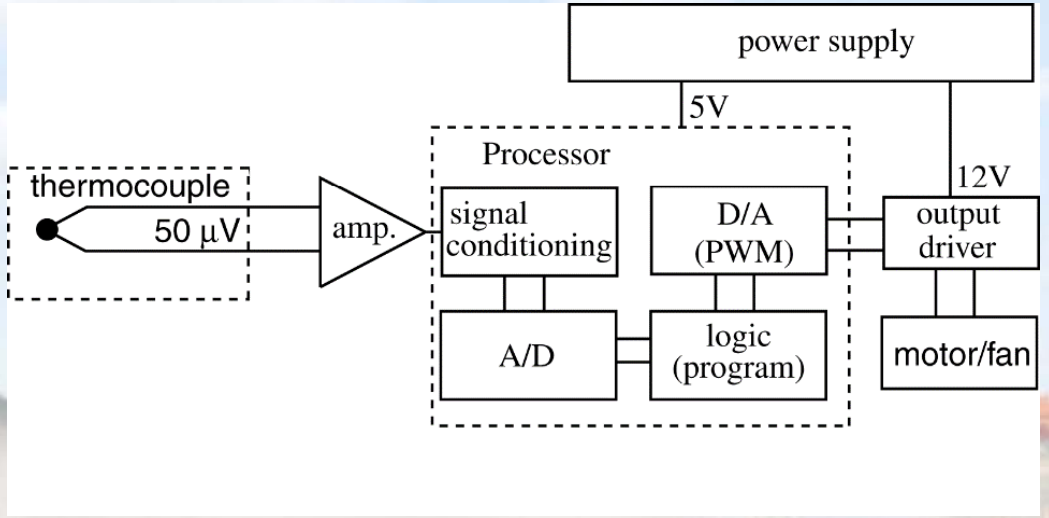
- The processor should be viewed as a general block
  - Microprocessor
  - Amplifier
  - Driver
  - Etc.
- Matching: between sensor/processor and processor/actuator

Example - Temperature control



- Sense the temperature of a CPU
- Control the speed of the fan to keep the temperature constant

Temperature control - implementation



- Sometimes the A/D and signal conditioning are separate from the processor
- The whole circuitry may be integrated into a “smart sensor”
- Match: impedance at input to amplifier and at processor

Units

- SI units in most cases
- Standard units when understanding warrants it (e.g. psi for pressure)
- Will avoid mixed units (a common problem in sensors and actuators)

Homework （Materials for the Seminar course）

- Please introduce the definitions, main uses and present the applications of two kinds of sensors from the list below:

Homework （Materials for the Seminar course）

Classification by broad area of detection	Classification by specifications	Classification by specifications	Classification by area of application
Electric sensors	Photoelectric	Accuracy	Consumer products
Magnetic	Magnetoelectric	Sensitivity	Military applications
Electromagnetic	Thermoelectric	Stability	Healthy
Acoustic	Photoconductive	Response time	Energy
Chemical	Thermomagnetic	Hysteresis	Manufacturing
Optical	Electrochemical	Frequency response	Transportation
Temperature	Magnitostrictive	Resolution	Automotive
Mechanical	Photomagnetic	Linearity	Avionic
Radiation	Thermoelastic	Operating temperature	Space
Biological	Photoelastic	Construction materials	Scientific


THANK YOU!