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Hungary-Romania
Cross-Border Co-operation
Programme 2007-2013

European Union
European Regional Development Fund

"Realization of Hungarian-Romanian R&D Laboratory for the Development of Major Projects in Polluted Terrain Cleaning"
HURO/0802/100

Bacteria growth sensing

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Oradea, 14th of December 2012

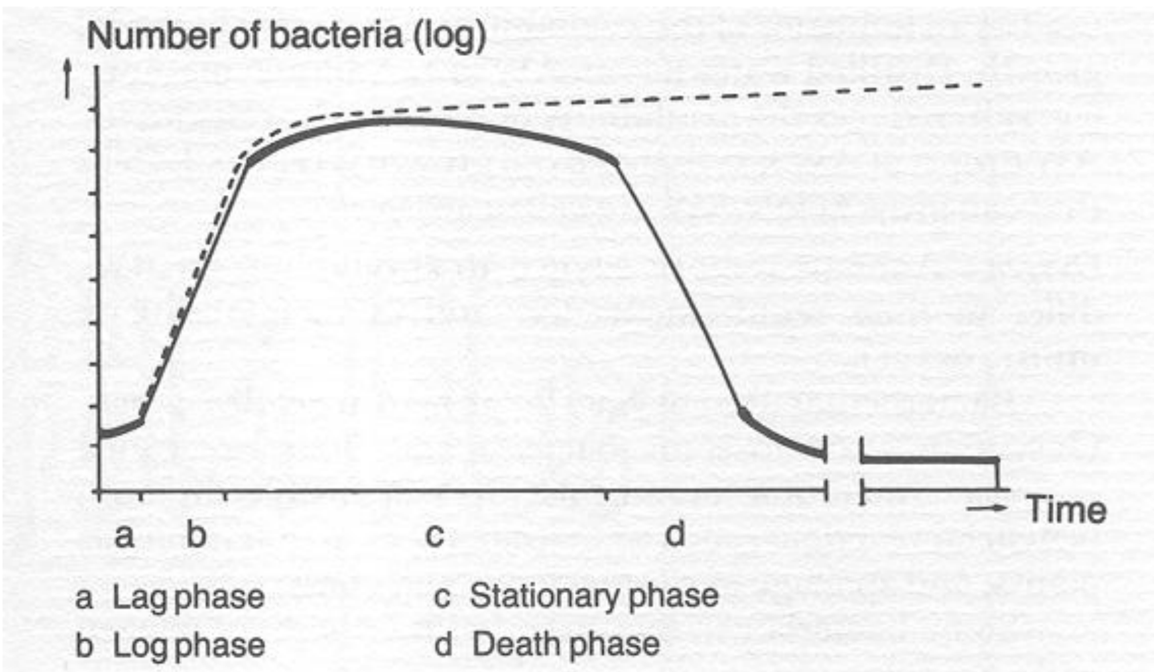
Microorganisms

- A microorganism (from the Greek: μικρός, mikrós, "small" and ὀργανισμός, organismós, "organism"; also spelled micro-organism, micro organism or microörganism) or microbe is a microscopic organism that comprises either a single cell (unicellular), cell clusters, or multicellular relatively complex organisms.
- The study of microorganisms is called microbiology, a subject that began with Anton van Leeuwenhoek's discovery of microorganisms in 1675, using a microscope of his own design.
- Microorganisms are very diverse; they include all of the prokaryotes, namely the bacteria and archaea; and various forms of eukaryote, comprising the protozoa, fungi, algae, microscopic plants (green algae), and animals such as rotifers and planarians. Some microbiologists also classify viruses as microorganisms, but others consider these as nonliving.

- Most microorganisms are unicellular (single-celled), but this is not universal, since some multicellular organisms are microscopic, while some unicellular protists and bacteria, like Thiomargarita namibiensis, are macroscopic and visible to the naked eye.
- Microorganisms live in all parts of the biosphere where there is liquid water, including soil, hot springs, on the ocean floor, high in the atmosphere and deep inside rocks within the Earth's crust. Microorganisms are critical to nutrient recycling in ecosystems as they act as decomposers. As some microorganisms can fix nitrogen, they are a vital part of the nitrogen cycle, and recent studies indicate that airborne microbes may play a role in precipitation and weather.
- Microbes are also exploited by people in biotechnology, both in traditional food and beverage preparation, and in modern technologies based on genetic engineering. However, pathogenic microbes are harmful, since they invade and grow within other organisms, causing diseases that kill humans, other animals and plants.

Bacterial growth

- Bacterial growth refers to an increase in cell numbers rather than an increase in cell size. The process by which bacterial cells divide to reproduce themselves is known as binary transverse fission. The time taken from cell formation to cell division is called the generation time. The generation time can therefore be defined as the time taken for the cell count to double.
- The curve shown in Figure 9 shows the phases of bacterial growth following inoculation of bacteria into a new growth medium.



- The following phases can be identified:

1. Lag phase: There is usually some delay in growth following inoculation of bacteria into a new medium, during which time the bacteria adapt to the medium and synthesise the enzymes needed to break down the substances in the growth medium.
2. Log phase: Once the bacteria have adapted to the new medium they start to reproduce quickly and their numbers multiply evenly for each increment of time. A plot of the log number of cells against time gives a linear relationship: this is therefore called the log phase. The cells are at their greatest activity in this phase. Transferring cultures to a fresh medium at regular intervals can maintain the cells in an active state. An active culture can rapidly dominate any new environment.
3. Stationary phase: As the bacteria dominate the growth medium, they deplete the available nutrients or toxic waste products accumulate, slowing the rate of reproduction. At the same time, cells are dying off: A state of equilibrium is reached between the death of old cells and formation of new cells, resulting in no net change in cell numbers. This phase is called the stationary phase.
4. Death phase: In the next phase the formation of new cells ceases and the existing cells gradually die off: This is called the death phase.

- The log phase can be prolonged by removing toxic waste, by adding more nutrients or both.

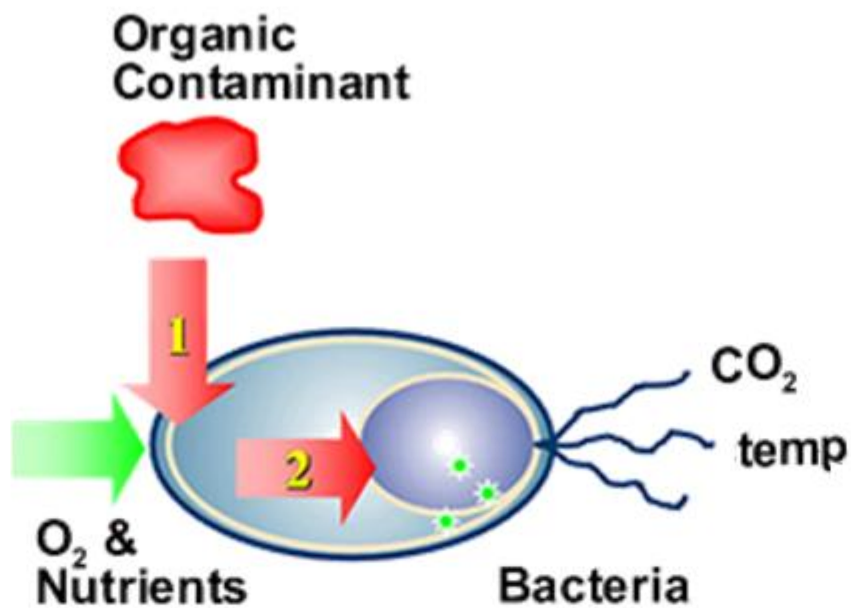
Factors affecting bacterial growth

- Bacterial growth is affected by (1) temperature, (2) nutrient availability, (3) water supply, (4) oxygen supply, and (5) acidity of the medium.
  - **Temperature:** Theoretically, bacteria can grow at all temperatures between the freezing point of water and the temperature at which protein or protoplasm coagulates. Somewhere between these maximum and minimum points lies the optimum temperature at which the bacteria grow best.
  - Temperatures below the minimum stop bacterial growth but do not kill the organism. However, if the temperature is raised above the maximum, bacteria are soon killed. Most cells die after exposure to heat treatments in the order of 70°C for 15 seconds, although spore-forming organisms require more severe heat treatment, e.g. live steam at 120°C for 30 minutes.
  - Bacteria can be classified according to temperature preference: Psycrophilic bacteria grow at temperatures below 16°C, mesophilic bacteria grow best at temperatures between 16 and 40°C, and thermophilic bacteria grow best at temperatures above 40°C.
  - **Water:** Bacteria cannot grow without water. Many bacteria are quickly killed by dry conditions whereas others can tolerate dry conditions for months; bacterial spores can survive dry conditions for years. Water activity (AW) is used as an indicator of the availability of water for bacterial growth. Distilled water has an AW of 1. Addition of solute, e.g. salt, reduces the availability of water to the cell and the AW drops; at AW less than 0.8 cell growth is reduced. Cells that can grow at low AW are called osmophiles.

- **Nutrients:** Bacteria need nutrients for their growth and some need more nutrients than others. Lactobacilli live in milk and have lost their ability to synthesise many compounds, while Pseudomonas can synthesise nutrients from very basic ingredients.
- Bacteria normally feed on organic matter; as well as material for cell formation organic matter also contains the necessary energy. Such matter must be soluble in water and of low molecular weight to be able to pass through the cell membrane. Bacteria therefore need water to transport nutrients into the cell.
- If the nutrient material is not sufficiently broken down, the micro-organism can produce exo-enzymes which split the nutrients into smaller, simpler components so they can enter the cell. Inside the cell the nutrients are broken down further by other enzymes, releasing energy which is used by the cell.
- **Oxygen:** Animals require oxygen to survive but bacteria differ in their requirements for, and in their ability to utilise, oxygen.
- Bacteria that need oxygen for growth are called aerobic. Oxygen is toxic to some bacteria and these are called anaerobic. Anaerobic organisms are responsible for both beneficial reactions, such as methane production in biogas plants, and spoilage in canned foods and cheeses.
- Some bacteria can live either with or without oxygen and are known as faculative anaerobic bacteria.
- **Acidity:** The acidity of a nutrient substrate is most simply expressed as its pH value. Sensitivity to pH varies from one species of bacteria to another. The terms pH optimum and pH maximum are used. Most bacteria prefer a growth environment with a pH of about 7, i.e. neutrality.
- Bacteria that can tolerate low pH are called aciduric. Lactic acid bacteria in milk produce acid and continue to do so until the pH of the milk falls to below 4.6, at which point they gradually die off. In canning citrus fruits, mild heat treatments are sufficient because the low pH of the fruit inhibits the growth of most bacteria.

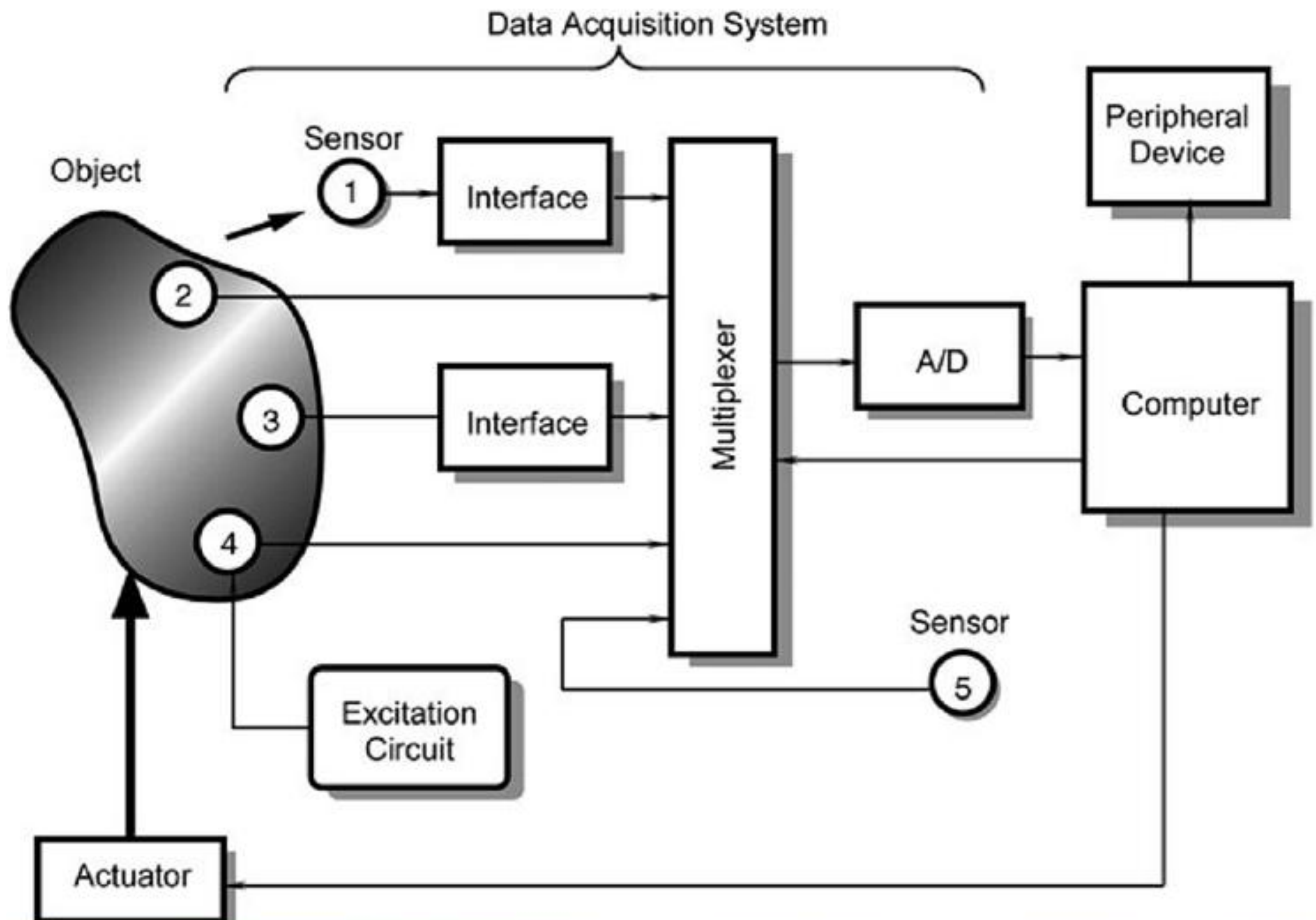
Sensors to monitoring the bacteria growth

- In our project to monitoring the bacteria growth we decided to determine the soil temperature and CO_2 level.



Positions of sensors in a data acquisition system

To illustrate the place of sensors in a larger system, Fig. 1 shows a block diagram of a data acquisition and control device. Sensor 1 is noncontact, sensors 2 and 3 are passive, sensor 4 is active, and sensor 5 is internal to a data acquisition system



Selecting temperature sensors

- How to select the best temperature sensor? In general, all sensor types are useful temperature measurement options, but each has its advantages and disadvantages. For example:
  - Thermistors provide high resolution, have the widest range of applications, are the most sensitive, and are low cost, but are nonlinear and have limited temperature range and poor repeatability.
  - Thermocouples have the highest temperature region and are durable for high vibration and high-shock applications, but require special extension wire and the signal is very low.
  - RTDs are linear and are highly accurate and stable, but they are very expensive and required complex circuits in order to be excited.
  - Silicon types are low cost and very linear, good precision, high signal, but have a limited temperature range.
- When we want to select a sensor we have to answer to the following questions:

1. Does the application require contact or non-contact sensing?
2. What temperature range is the sensor required to control or monitor?
3. What is the rate of temperature change of the application?
4. How tightly do you need to control or monitor the temperature?
5. How important is total system cost in the selection of the sensor?

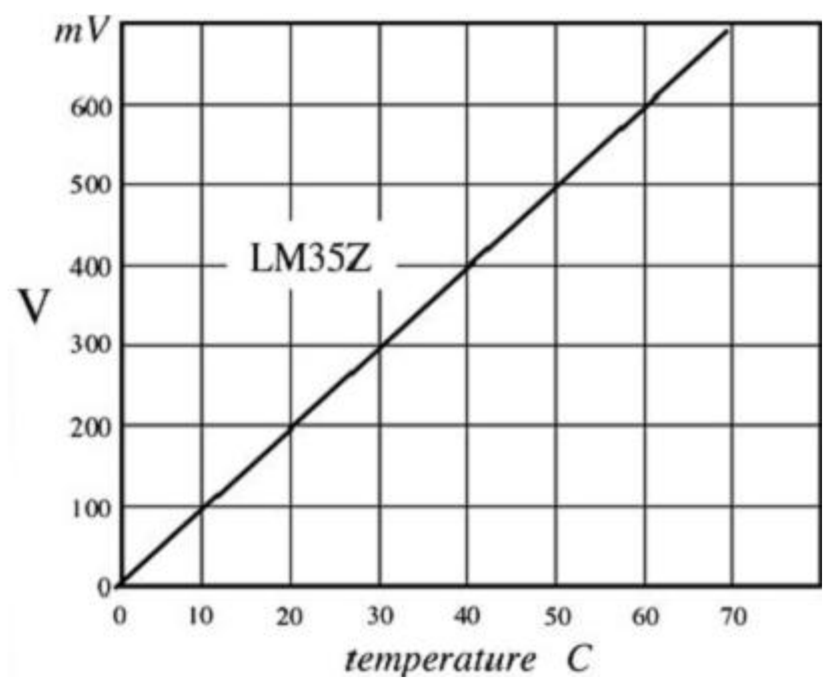
- The selected temperature sensor for our application is LM35 from Texas Instruments.

Semiconductor pn-Junction Sensors

- A semiconductor pn-junction in a diode and a bipolar transistor exhibits quite a strong thermal dependence.
- Figure shows a transfer function of a LM35Z temperature sensor, which has a linear output internally trimmed for the Celsius scale with a sensitivity of 10 mV per °C. The function is quite linear where the nonlinearity error is confined within ±0.1°. The function can be modeled by

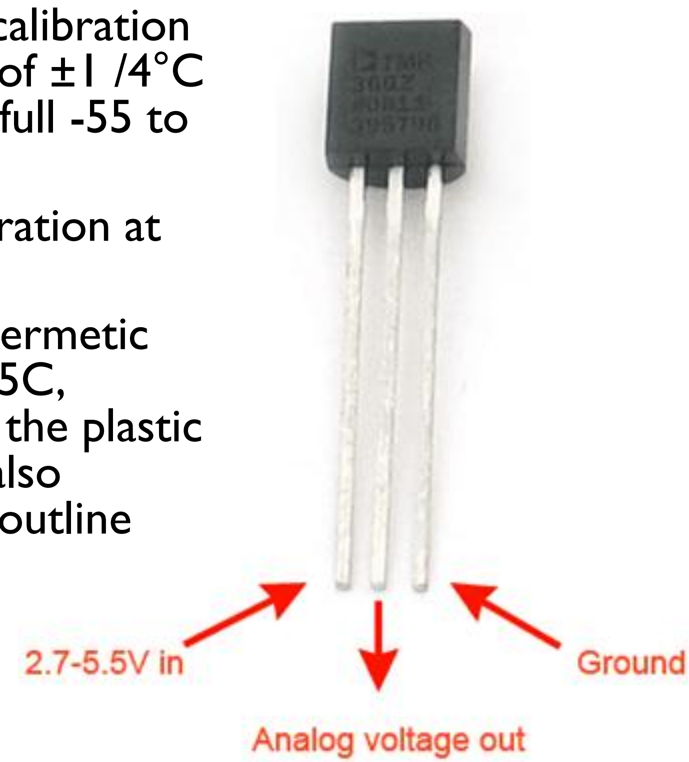
$$V_{out} = V_0 + a \cdot t$$

where t is the temperature in degrees C.



LM35 precision centigrade temperature sensors

- The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius temperature.
- The LM35 thus has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling.
- The LM35 does not require any external calibration or trimming to provide typical accuracies of ±1 /4°C at room temperature and ±3 /4°C over a full -55 to +150°C temperature range.
- Low cost is assured by trimming and calibration at the wafer level.
- The LM35 series is available packaged in hermetic TO-46 transistor packages, while the LM35C, LM35CA, and LM35D are also available in the plastic TO-92 transistor package. The LM35D is also available in an 8-lead surface mount small outline package and a plastic TO-220 package.



Features

- Calibrated directly in ° Celsius (Centigrade)
- Linear + 10.0 mV/°C scale factor
- 0.5°C accuracy guaranteeable (at +25°C)
- Rated for full −55° to +150°C range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 4 to 30 volts
- Less than 60 µA current drain
- Low self-heating, 0.08°C in still air
- Nonlinearity only ±1⁄4°C typical
- Low impedance output, 0.1 W for 1 mA load

IR 15TT Miniature Infrared Twin-Gas Sensors for Hazardous Areas and Intrinsic Safety in Mining

- The IR15T Series are suitable for reliable monitoring of gas levels in general industrial safety applications, where the infrared sensor size is restricted and requires flameproof/ explosion-proof certification. The IR15TT is filtered to sense a broad range of hydrocarbons, and carbon dioxide, but has a slight cross-sensitivity to water vapour when the RH is high.

Features

- Two active gas channels for simultaneous detection of carbon dioxide, methane and hydrocarbons
- IR15TT and IR25TT sensing ranges: carbon dioxide for 0 – 2% vol. conc. (optional 0 – 5% vol.) and hydrocarbons to LFL levels (optional 0 – 100% vol.)
- IR15TT-M and IR25TT-M sensing ranges: carbon dioxide for 0 – 2% vol. conc. (optional 0 – 5% vol.) and methane to LFL levels (optional 0 – 100% vol.)
- Diffused gas sampling
- Low power
- Reference channel for self-compensation
- Special gold-plated optical/gas cavity for stable signal levels
- Embedded thermistor temperature sensor
- Operational in varying ambients of temperature, pressure and humidity
- Fast response
- Rugged stainless steel construction
- No moving parts
- Resistance to corrosion
- Series 4 size to complement miniature catalytic and electrochemical gas sensors
- Immunity from ‘poisoning’
- Reliable fail-safe operation
- Low maintenance

Conclusions

- We decided to choose LM35 sensor because it is best suited for our type of application which required the measurement of temperatures in may points and the transmission of the sensor signals relatively over a large distance.
- This sensor has a relatively high output voltage, a good linearity a good precision and good repeatability.
- From the LM 35 sensor range we choose the best characteristics sensor type LM35 CA.
- It is best suited to be utilized with our National Instrument PXI system which can measured high accuracy analog voltage inputs.
- Finally, we decided to choose IR 15 TT sensor to measure CO2 level because it is suite for our type of application.

Thank you for your attention!