mVOC – A lightweight environmental data and air samples acquisition system to install in captive balloons

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The Problem

- Research project to study the impact of Volatile Organic Compounds (VOCs) generated in coastal regions (Environment Department).
- VOC samples and meteorological parameters must be measured in a vertical plan to a correct pollution characterization.
- Measure requires specific systems to be mounted in a small helium balloon with low weight capacity.
- No commercial system available with the adequate characteristics.

μVOC System Requirements

- Lightweight
  - The Helium balloon used (Vaisala TSB-5, similar to a Zeppelin) has 5m3 capacity and is able to carry a 2.7kg load.
  - Captive balloon, so the weight of the cable must also be taken into consideration (at least 1Kg for 1.000 meters).
  - Ozone meter must also be mounted in the balloon.
  - 3 μVOC systems at different heights, each with its own power module.

The TSB-5 balloon

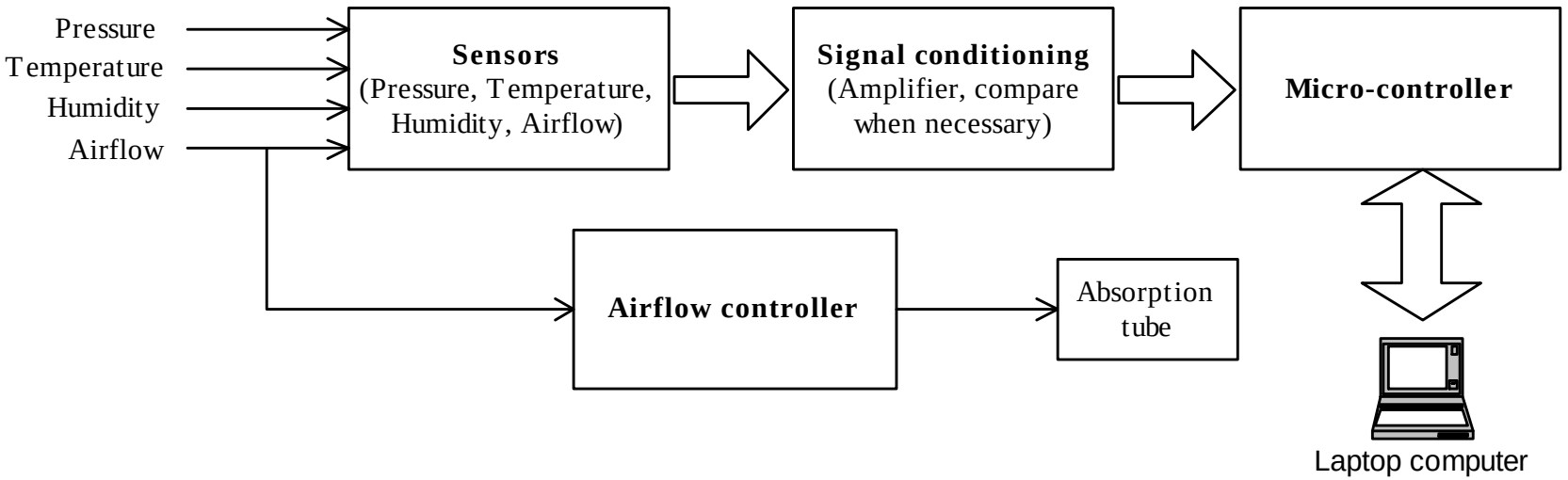
mVOC System Requirements

- Low cost
  - Just half a dozen of units.
- Robust – failures must not occur
  - Harsh operating environment.
  - Field experiments expensive (hellium fill) and time consuming.
- User friendly interface
  - Configuration (depends on meteorological conditions) and verification of acquired data must be done in the field.

mVOC Functionalities

- Measurements to take:
  - Temperature (-20ºC to 40ºC)
  - Humidity (10 to 100%)
  - Pressure (1050 to 850 hPa)
  - Maximum duration: 2 hours.
  - Maximum data acquisition rate: 1 sample/sec (user selectable).
- Acquisition of VOC samples:
  - Circulating air at a 100ml/sec flow during a pre-defined time interval through a tube containing an absorption material.

System Architecture

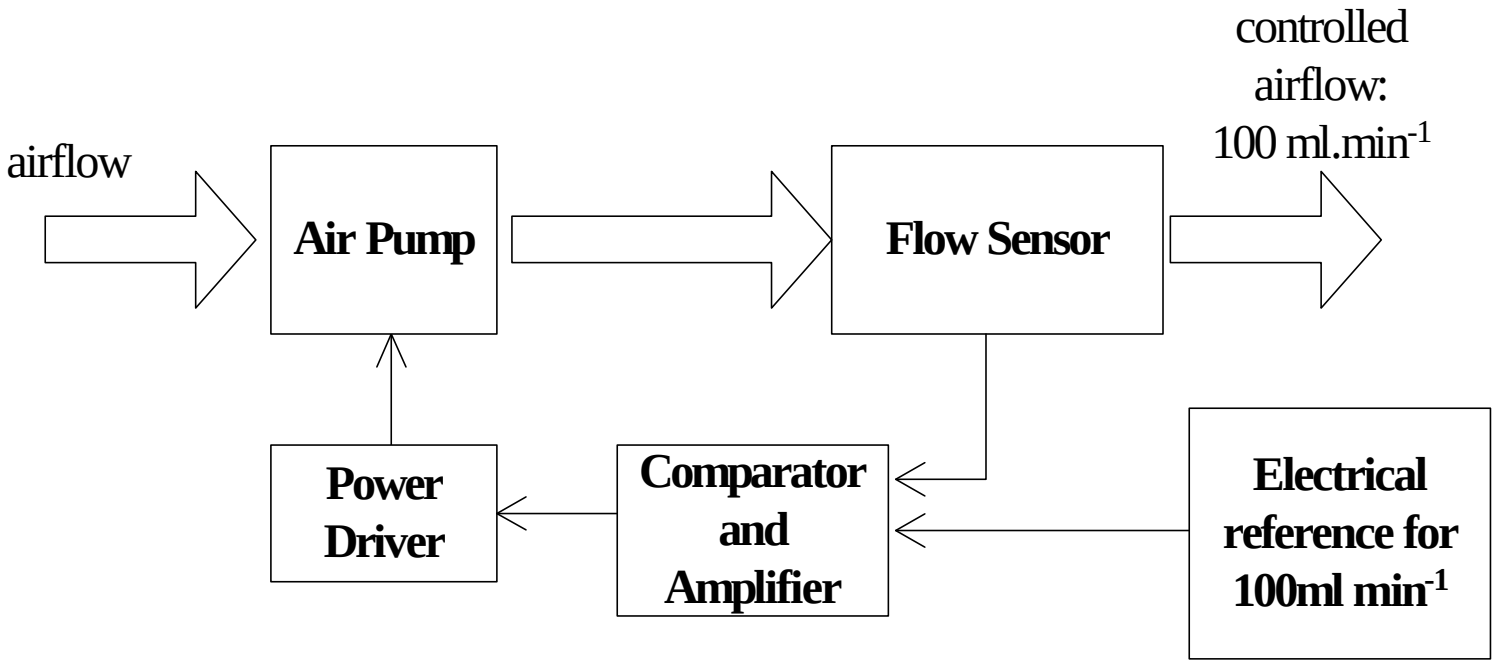


System elements

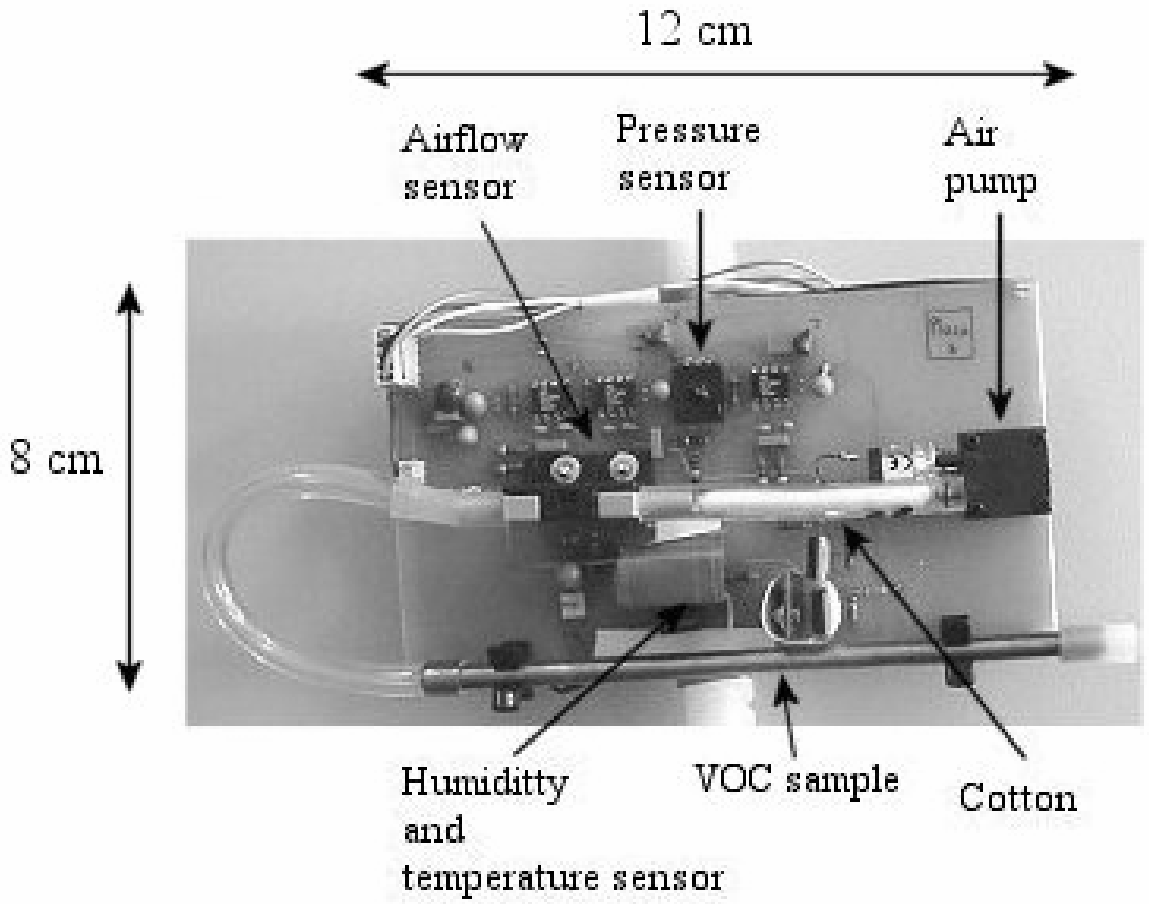
- Analog acquisition unit
  - Platinum resistor temperature sensor mounted in a Wheatstone bridge (Honeywell HIH-3602-C)
  - Sensitive humidity polymer sensor used to measure the humidity (Honeywell HIH-3602-C)
  - Internal vacuum reference sensor is used for pressure (Sensym SX15AD)
- Air flow controller:
  - Heat transfer air flow sensor (Honeywell AWM3100V)
  - Membrane air pump (NMP09L from the KNF company)
  - Analog controller.
- Microcontroller unit (Single Chip PIC 16F876)

Air flow controller

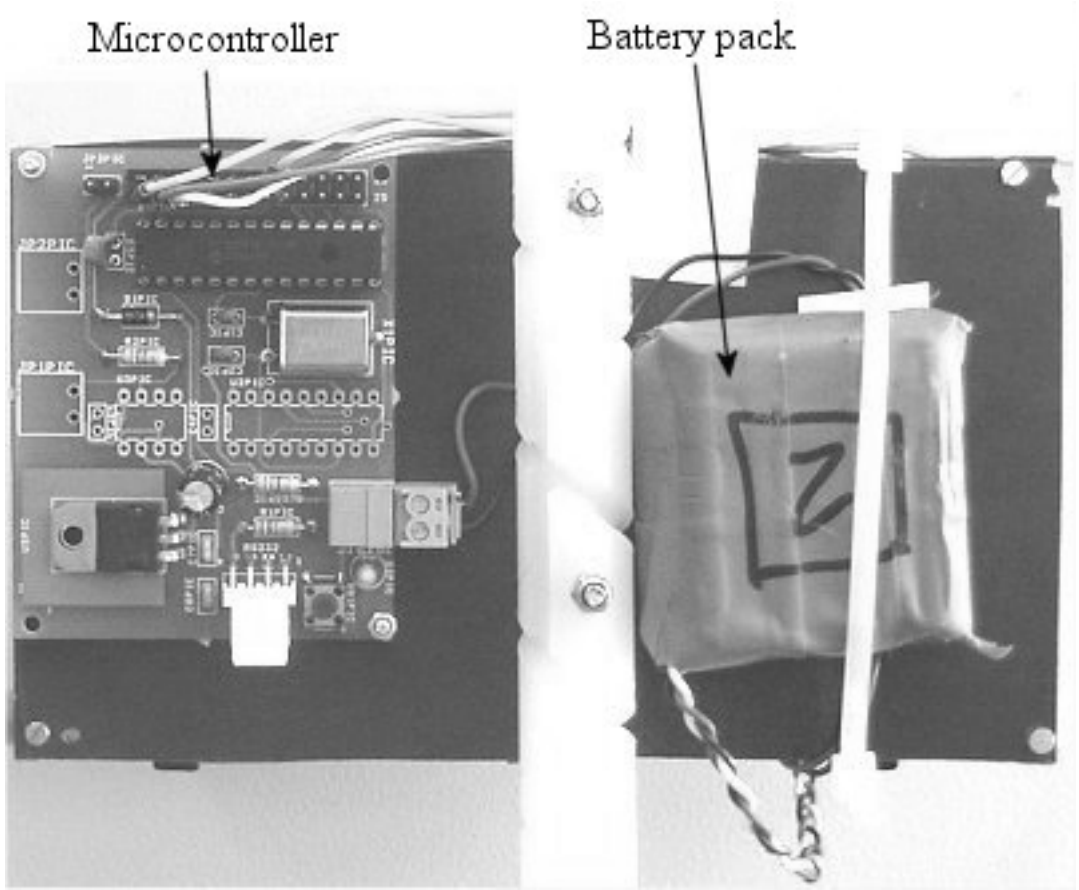
- Analog air flow controller required due to the high non-linearity of the NMP09L air pump and low-processing power of the microcontroller.



Acquisition unit and air flow controller



Microcontroller unit and power module



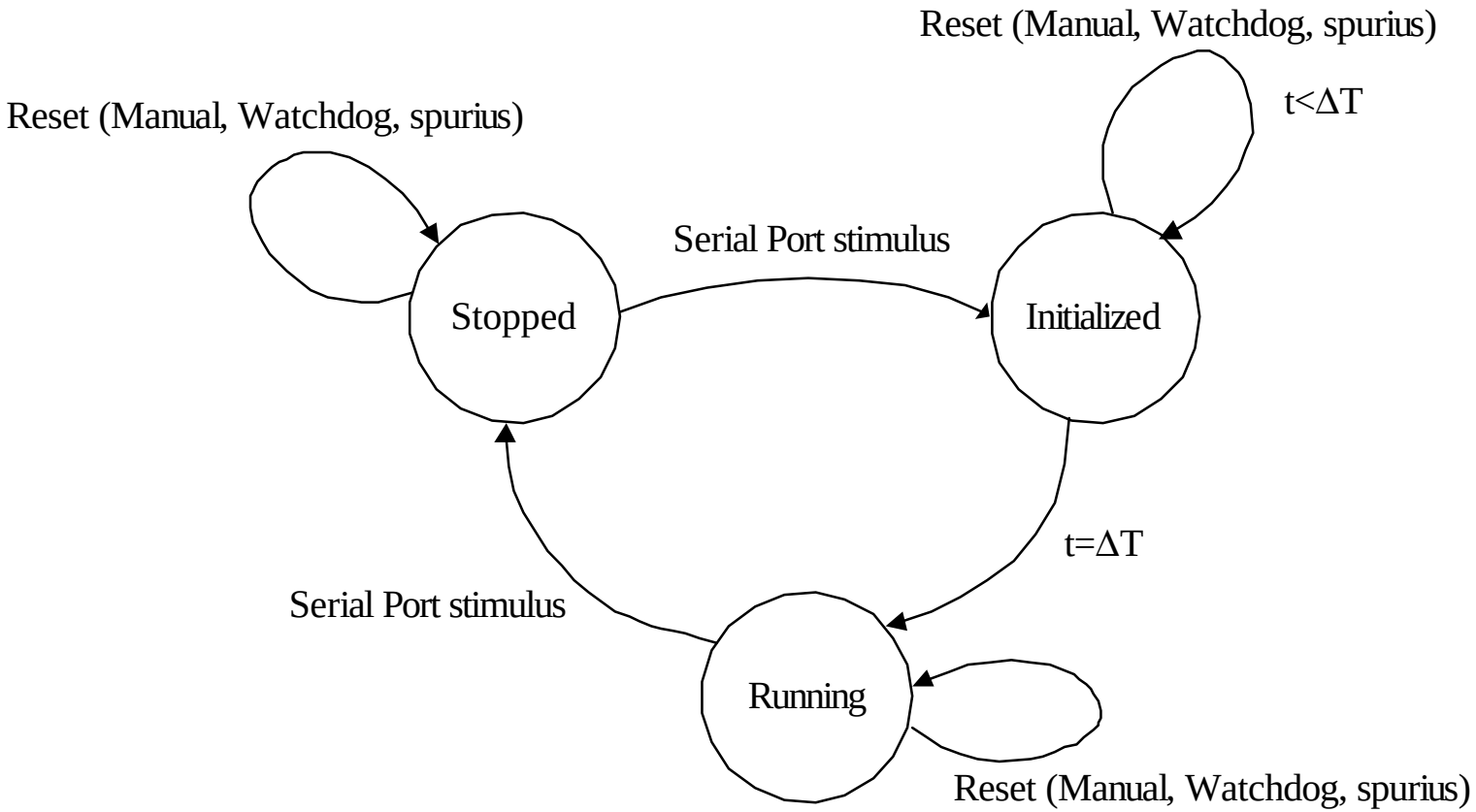
Microcontroller unit - requirements

- Sampling period of the physical parameters derived from a 1 second clock tick signal.
- Sampling periods programmed in the field, prior to the launching of the system.
- Data, stored in the flash memory, must include:
  - The physical quantity code (e.g. T - temperature).
  - The sample value.
  - An offset in seconds measured from the start of the system operation.
- State of operation also stored in flash
  - System can recover the last state of operation

Microcontroller unit – Operation states

- System has three states:
  - Stopped
  - Initialized
  - Operating
- Stopped – Starts operating or has successfully finished (ready for configuration).
- Initialized – all parameters (offsets and sampling rates) are defined and the system is waiting for the adequate time to start the operation.
- Operating – Normal acquisition of parameters

State diagram of operation

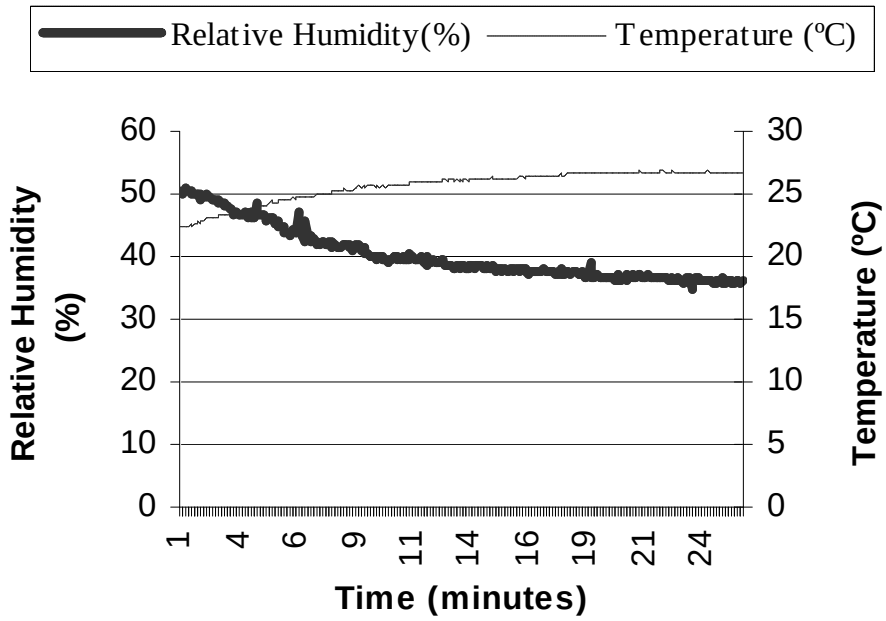


Configuration program

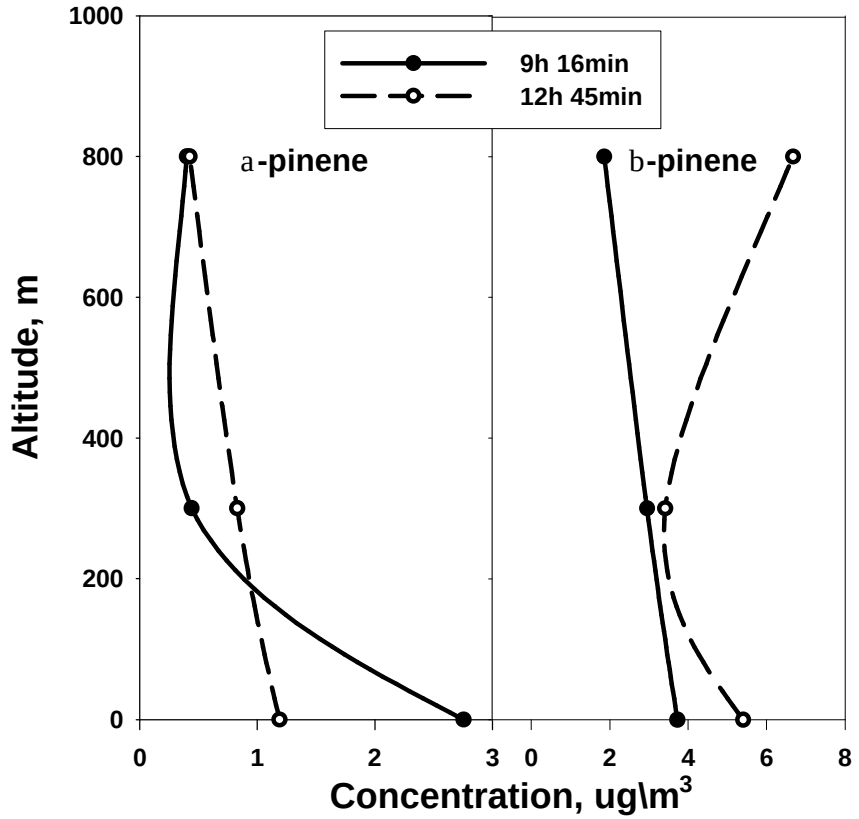
- Field configuration uses a user interface program running in a portable PC computer.
- Communication with system is made through serial port.

Field Trials

- Tests made 1 week long
- Environment variables acquired with success
- Environment Department is at the moment analyzing the obtained results
- The figure, shows an acquisition made in 25 September 2002, starting at 10AM in Aveiro, Portugal.



Field Trials



Vertical profile of two volatile organic compounds

Conclusions

- Current off-the-shelf microcontrollers offer a good solution to develop specialized environment data acquisition systems:
  - Adequate for harsh environments.
  - Lightweight, low power and cheap.
- We presented an example of such a system intended to:
  - Be installed in a captive balloon.
  - Collect air samples to determine pollution caused by volatile organic compounds (VOCs).
  - Perform other environmental measures.

Future improvements

- To integrate a very lightweight and low power wireless interface.
- To adapt the software for online data acquisition.
- To increase the robustness of the electronic system to adverse meteorological conditions such as the sun incidence.
- To proceed with more field trials to reinforce the system validation.