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by Matthew Prentice

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Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David



ACDA6002 - Electronic Systems
Design

14 Day Weather and Air Quality
measurement and logging system

Matthew Prentice (2116359)

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Introduction

Review of Product Space

There's a wide range of variety when it comes to commercial Weather Monitoring Stations, depending on the budget and sensor requirements of the customer. On one end of the scale budget-stations can be purchased from online marketplaces such as amazon for sub-£100 or mid-range stations for ~£200. On the other end of the scale, professional installations can cost upwards of £4000.

				
	<i>Ecowitt Wireless Weather Station [1]</i>	<i>WMS-25 [2]</i>	<i>QUESTemp° 36 [3]</i>	<i>KestrelMet 6000 [4]</i>
	Amazon.co.uk	Omega.co.uk	tsi.com	kestrelmet.com
Cost	£120.81	£2,678.15	£3,456	£838.76
Temperature	✓ -40°C to 60°C	✓ -26 to 70°C	✓ 0 to 120°C	✓ -40° to 60° C
Humidity	✓ 10% to 99%	✓ 3% to 100%	✓ 20% - 95%	✓ 0 to 100%
Wind Speed	✓ 0 to 50 m/s	✓ 0 to 57 m/s	✓ 0 to 20 m/s	✓ 1 to 64.8 m/s
Wind Direction	✓	✓ 0 to 360°		✓ 1° to 360°
Rainfall	✓ 0 – 6000 mm	✓		✓ up to 198mm / hr
Air-Borne Particle Count				
Sun Brightness	✓ 0 – 200 kLux			✓ 0 to 1750 W/m2
UV Exposure Levels	✓ 0 to 15			
VOC Levels				
GPS Location				
Data storage	Wi-Fi with Cloud Service	SD Card	Internal	Cellular/Wi-Fi Data Cloud Service

Table 1 - Feature comparison from a selection of Weather Monitoring Stations

Review of Sensor Technologies

Temperature

There are several options for the accurate measurement of air temperature, all of which have a high level of accuracy. Thermistors are the most common and cost effective solution, typically costing as little as a couple of pound for a bare sensor, or up to £30 when packaged. Their resistance changes non-linearly, resulting in higher resolution at lower temperatures. Resistance based thermometers are another excellent option for highly accurate and stable temperature measurement. These are typically based on the resistance of a wire made out of platinum, but can also use Nickle or Copper, for a well understood resistance vs temperature characteristic which changes nearly linearly. Finally solid state sensors can be used to measure the temperature, operating with a linear voltage response from temperature sensitive diodes. Solid state sensors are widely used within electronic devices for their small size, high performance and low cost.

<i>Technology</i>	<i>Accuracy</i>	<i>Response Time</i>	<i>Stability</i>	<i>Cost</i>	<i>Typical Applications</i>
<i>Resistance Temperature Thermistors</i>	High	Moderate	Excellent	High	Meteorological stations, Laboratory measurements, industrial use
	High	Fast	Moderate	Low	Consumer electronics, HVAC systems
<i>Semiconductor-Based Sensors</i>	Moderate	Fast	Moderate	Low	Consumer electronics, automotive

Humidity

The Humidity of the air can be measured using a variety of different sensors. With the temperature and humidity level known, the Dew Point can be calculated, which is a useful data point for gardeners, farmers, and athletes among others. Sensors to measure humidity can utilise a change in capacitance, resistance, refractive index, mechanical stresses or temperature of a material that absorbs moisture from the air, aka is hygroscopic. Capacitive sensors are accurate and stable over a wide range of humidity, while resistive sensors are cheaper but also less accurate. Thermal sensors are typically used in conjunction with other sensors but measure humidity by detecting changes in the temperature of a hygroscopic material. Optical sensors detect changes in the refractive index of a material to calculate the humidity, they are far less common but can offer high accuracy and fast response times. Piezo-resistive sensors detect changes in the mechanical stress of a hygroscopic material to calculate humidity. They are often used in specialized applications where high sensitivity is required.

<i>Technology</i>	<i>Accuracy</i>	<i>Response Time</i>	<i>Stability</i>	<i>Cost</i>	<i>Typical Applications</i>
<i>Capacitive</i>	High	Fast	Excellent	Moderate	HVAC systems, weather stations, consumer electronics
<i>Resistive</i>	Moderate	Moderate	Good	Low	Consumer electronics, industrial controls
<i>Thermal</i>	High	Moderate to Fast	Good	High	Specialized industrial applications
<i>Optical</i>	High	Very Fast	Excellent	High	Scientific research, specialized equipment
<i>Piezo-resistive</i>	High	Fast	Excellent	High	High-sensitivity applications

Wind Speed

Wind speed sensors (aka anemometers) are basically synonymous with weather stations, typically using cup or vane. These feature three or four cups, vane or propeller spinning a central shaft with the rotation proportional to the wind speed. These anemometers are widely used in weather stations due to their simplicity and robustness. However, their mechanical nature means they require regular maintenance, and their accuracy can be affected by wear and environmental factors. A higher accuracy sensor uses an electrically heated wire which is cooled, and as air flows over it. The wind speed can then be calculated based on the change in resistance of the wire as it cools or heats. Hot-wire anemometers offer high accuracy and fast response times, making them suitable for research and industrial applications. However, they are delicate and require careful handling and maintenance. Other methods of measuring Wind Speed include the use of Ultrasonic or Sonic transducers to measure the amount of time it takes for pulses to travel between the transducers, which is affected by the wind. This allows the sensor to calculate wind speed and direction. Ultrasonic and Sonic anemometers are highly accurate and due to having no moving parts, require minimal maintenance, making them ideal for meteorology, aviation and wind energy applications. Finally wind speed can also be measured by use of a laser and the measurement of the Doppler shift of that laser beam to calculate wind speed. Laser Doppler Anemometer are known for their exceptional accuracy and stability, often used in advanced research and fluid dynamics studies. However, their high cost and complexity limit their widespread use.

<i>Sensor Type</i>	<i>Accuracy</i>	<i>Response Time</i>	<i>Stability</i>	<i>Cost</i>	<i>Typical Applications</i>
<i>Cup</i>	Moderate	Moderate (50-100ms)	Moderate	Low	Weather stations, Wind farms
<i>Vane</i>	Moderate	Moderate (50-100ms)	Moderate	Low	Meteorology, HVAC systems

<i>Hot-Wire</i>	High	Fast (10-50ms)	Moderate	Moderate	Research, Industrial processes
<i>Ultrasonic</i>	High	Very Fast (1-5ms)	Good	High	Aviation, Wind energy
<i>Laser Doppler</i>	Very High	Very Fast (1-5ms)	Excellent	Very High	Advanced research, Fluid dynamics
<i>Sonic</i>	High	Fast (1-10ms)	Good	High	Meteorology, Wind energy

Wind Direction

Similar to Anemometers, the measuring wind direction has a long history of wind vanes mounted up high to visually indicate the direction the wind is blowing. Wind vanes are commonly used in weather stations and aviation to provide a visual indication of wind direction. They are simple, reliable, and relatively low-cost, though they require regular maintenance to ensure accuracy. Where an electrical output is required, wind vanes tend to use a magnetic rotary encoder or magnetometer to determine the direction [5]. A GPS-based wind direction sensor uses signals from satellites to determine wind direction with high precision. By tracking the movement and position of a GPS-enabled device, it can accurately calculate wind direction [6]. These sensors offer very high accuracy and stability, with fast response times; typically used in advanced navigation systems and research applications where precise and reliable data is essential. However, GPS Wind Sensors come at a higher cost compared to traditional mechanical sensors. An ultrasonic wind direction sensor measures wind direction by using sound waves. It has multiple ultrasonic transducers that emit and receive sound pulses. The time it takes for the sound to travel between the transducers is affected by wind, allowing the sensor to determine wind direction [7]. Similarly, laser-based sensors analyse the Doppler shift from multiple laser transducers to accurately determine the wind direction. Ultrasonic and Laser sensors provide high accuracy and fast response times, with no moving parts, resulting in low maintenance requirements. They are commonly used in wind energy and aviation applications, although laser sensors are limited in use due to their high cost and complexity.

<i>Sensor Type</i>	<i>Accuracy</i>	<i>Response Time</i>	<i>Stability</i>	<i>Cost</i>	<i>Typical Applications</i>
<i>Vane</i>	Moderate	Moderate (50-100ms)	Moderate	Low	Weather stations, Aviation
<i>Magnetic Compass</i>	High	Fast (10-50ms)	High	Low	Navigation, Aviation
<i>GPS</i>	Very High	Fast (1-10ms)	Very High (Satellite dependant)	High	Advanced navigation, Research
<i>Ultrasonic</i>	High	Fast (1-10ms)	High	High	Wind energy, Aviation
<i>Laser</i>	Very High	Very Fast (1-5ms)	Very High	Very High	Advanced research, Fluid dynamics

Air borne particle count

Airborne particle counters are typically found as part of clean-room systems to monitor the particulate levels in the air handling systems of the clean-room. They operate using a few different technologies including Optical via a laser or other light source which is disrupted by particles and the disruption is detected by photodetectors. Using this technique the size of the particles can also be identified. Optical sensors have a fast response time while being very accurate. To enable smaller particles to be identified a condensation process can be applied to the frontend of an optical sensor, this causes particles to grow in size as they absorb vapour and makes smaller particles significantly easier to identify. For highly accurate particle count and size distribution then a Scanning Mobility Particle Sizer would be used, classifying and sorting particles by size based on their induced electrical charge then counted via optical or condensation process to finish with a highly accurate distribution measurement. Finally an Electric Low Pressure Impactor (ELPI) could be used which collects particles on impactor stages at different pressure levels, separating them by aerodynamic size [1]. The collected particles are then counted and sized using the same technique as the Scanning Mobility Particle Sizer.

<i>Sensor Type</i>	<i>Accuracy</i>	<i>Response Time</i>	<i>Stability</i>	<i>Cost</i>	<i>Typical Applications</i>
<i>Optical Particle Counter</i>	High	Moderate (10-50ms)	Moderate	Low	Weather stations, Aviation
<i>Condensation Particle Counter</i>	Very High	Fast (1-10ms)	High	Low	Navigation, Aviation
<i>Scanning Mobility Particle Sizer</i>	Very High	Moderate (10-50ms)	Very High (Satellite dependant)	High	Advanced navigation, Research
<i>Electric Low Pressure Impactor</i>	Moderate	Moderate (50-100ms)	High	High	Wind energy, Aviation

Sunlight brightness

Measurement of light levels can be accomplished a few different ways. Most commonly a Light Dependent Resistor (LDR) would be used which is a resistor whose resistance varies with light intensity. As the light intensity increases, the resistance decreases, and vice versa. LDRs are commonly used in smart lighting systems, where they detect ambient light levels and adjust the lighting accordingly. Where higher accuracy is needed a Photodiode can be used; this is a semiconductor device that proportionally converts light into an electrical current. Photodiodes are widely used in display brightness control and automatic lighting systems. If higher gain is required then a Phototransistor could be used. A Phototransistor is similar to a photodiode but with higher sensitivity and gain. It amplifies the electrical signal generated by the incident light, providing a stronger output. Where only a digital output is required an Integrated Circuit Ambient Light Sensor can be used as a compact sensor that measures ambient light levels and provides digital output. These are commonly used in smartphones, laptops, and monitors to automatically adjust screen brightness based on the surrounding light conditions as they offer high accuracy and stability, with a fast response time of 1-10 milliseconds. Finally for high precision applications a Charge-Coupled Device (CCD) should be used, which is a highly sensitive sensor that converts light into electrical signals. CCDs are used in advanced research and high-precision applications where accurate light measurement is crucial. They offer very high accuracy and stability, with a fast response time of 1-10 milliseconds. CCDs are more expensive compared to other sensors but are essential for applications requiring precise light measurement.

<i>Sensor Type</i>	<i>Accuracy</i>	<i>Response Time</i>	<i>Stability</i>	<i>Cost</i>	<i>Typical Applications</i>
<i>Light Dependant Resistor</i>	Moderate	Moderate (50-100ms)	Moderate	Low	Smart lighting systems, Display brightness control
<i>Photodiode</i>	High	Moderate (10-50ms)	High	Low	Display brightness control, Automatic lighting systems
<i>Phototransistor</i>	High	Moderate (10-50ms)	High	Low	Display brightness control, Smart lighting systems
<i>Integrated Circuit Ambient Light Sensor</i>	High	Fast (1-10ms)	High	Moderate	Smartphones, Laptops, Monitors
<i>Charge Coupled Device</i>	Very High	Fast (1-10ms)	Very High	High	Advanced research, High-precision applications

UV levels

Measurement of Ultraviolet (UV) levels is important to a weather station due to its impact on developing skin conditions. A UV Photodiode is a semiconductor device that proportionally converts UV light into an electrical current. These sensors are highly accurate, with response times typically between 1-10 milliseconds, and offer high stability [9]. Photodiode UV sensors are commonly used in environmental monitoring and display brightness control due to their compact size and low cost. Similar to standard light, where higher gain is required a UV Phototransistor can be and offer high accuracy and stability, with response times typically between 1-10 milliseconds. For a simpler approach a UV Photoresistor (LDR) can be used just the same as a normal LDR. In scenarios where heat is a factor, Pyroelectric UV Sensor should be used, detecting a change in temperature caused by the absorption of UV radiation. It uses materials that exhibit a change in their electrical properties when exposed to UV light [9]. Alternatively a Spectrometer UV Sensor measures the intensity of UV radiation at specific wavelengths using a

sophisticated optical system. These sensors provide very high accuracy and stability, with response times typically between 1-10 milliseconds. Spectrometer UV sensors are used in scientific research and advanced industrial applications that require precise UV measurements.

Sensor Type	Accuracy	Response Time	Stability	Cost	Typical Applications
Photodiode	High	Fast (1-10ms)	High	Low	Environmental monitoring, Display brightness control
Phototransistor	High	Fast (1-10ms)	High	Low	Industrial process control, UV curing systems
Photoresistor	Moderate	Moderate (50-100ms)	Moderate	Low	Simple UV detection, Educational purposes
Pyroelectric	High	Fast (1-10ms)	High	Moderate	Flame detection, Gas analysis
Spectrometer	Very High	Fast (1-10ms)	Very High	High	Scientific research, Advanced industrial applications

GPS position

Standard GPS Module

A Standard GPS Module is a basic GPS receiver that provides accurate positioning information by communicating with satellites. These modules are widely used in navigation systems, tracking devices, and various consumer electronics. They offer high accuracy and stability, with response times typically between 1-10 milliseconds. Standard GPS modules are cost-effective and suitable for general-purpose applications.

High-Sensitivity GPS Module

A High-Sensitivity GPS Module is designed to provide better performance in challenging environments, such as urban canyons or dense forests. These modules use advanced signal processing techniques to improve sensitivity and accuracy. They are commonly used in automotive navigation systems, surveying equipment, and other applications requiring reliable positioning in difficult conditions. High-sensitivity GPS modules offer very high accuracy and stability, with response times similar to standard modules.

RTK GPS Module

An RTK GPS Module (Real-Time Kinematic) provides centimeter-level accuracy by using a fixed base station and a mobile receiver. This technique corrects for errors in satellite signals, resulting in highly precise positioning data. RTK GPS modules are used in precision agriculture, construction, and other applications where exact location information is critical. They offer very high accuracy and stability, with response times typically between 1-10 milliseconds. However, RTK GPS modules are more expensive due to their advanced technology.

GPS Data Logger

A GPS Data Logger is a device that records GPS data over time, which can be downloaded and analyzed later. These loggers are used in research, environmental monitoring, and asset tracking. They provide high accuracy and stability, with response times similar to other GPS modules. GPS data loggers are moderately priced and offer a convenient way to collect and store location data.

GPS Receiver

A GPS Receiver is a device that receives signals from GPS satellites and calculates the user's position. These receivers are commonly found in smartphones, tablets, and other consumer electronics. They offer high accuracy and stability, with response times typically between 1-10 milliseconds. GPS receivers are cost-effective and widely used in various applications requiring location awareness.

Sensor Type	Accuracy	Response Time	Stability	Cost	Typical Applications
Standard GPS Module	High	Fast (1-10ms)	High	Low	Navigation, Tracking
High-Sensitivity GPS Module	Very High	Fast (1-10ms)	High	Moderate	Automotive, Surveying
RTK GPS Module	Very High	Fast (1-10ms)	Very High	High	Precision Agriculture, Construction
GPS Data Logger	High	Fast (1-10ms)	High	Moderate	Data Logging, Research
GPS Receiver	High	Fast (1-10ms)	High	Moderate	Consumer Electronics

VOC level

Photoionization Detector (PID)

A Photoionization Detector (PID) uses ultraviolet light to ionize volatile organic compounds (VOCs) in the air, producing an electrical current proportional to the concentration of VOCs. PIDs offer high accuracy and stability, with response times typically between 1-10 milliseconds¹. They are widely used in industrial safety, environmental monitoring, and hazardous material detection due to their sensitivity and reliability.

Metal Oxide Semiconductor (MOS)

A Metal Oxide Semiconductor (MOS) sensor detects VOCs by measuring changes in the resistance of a metal oxide material when exposed to gases. These sensors are cost-effective and commonly used in indoor air quality monitoring and consumer electronics². However, they have moderate accuracy and stability, with response times typically between 50-100 milliseconds.

Electrochemical Sensor

An Electrochemical Sensor measures VOC levels through a chemical reaction that generates an electrical current. These sensors offer high accuracy and stability, with response times typically between 1-10 milliseconds². Electrochemical sensors are widely used in industrial safety, medical devices, and environmental monitoring due to their sensitivity and reliability.

Optical Sensor

An Optical Sensor uses light absorption or scattering to detect VOCs. These sensors provide very high accuracy and stability, with response times typically between 1-10 milliseconds². Optical sensors are used in advanced research and environmental monitoring, where precise and reliable measurements are essential.

MEMS-grade Sensor

A MEMS-grade Sensor employs Micro-Electro-Mechanical Systems (MEMS) technology to detect VOCs. These sensors are compact, cost-effective, and offer high accuracy and stability, with response times typically between 1-10 milliseconds². MEMS-grade sensors are commonly used in indoor air quality monitoring, automotive applications, and personal gas detection.

Sensor Type	Accuracy	Response Time	Stability	Cost	Typical Applications

<i>Photoionization Detector</i>	High	Fast (1-10ms)	High	Moderate	Industrial safety, Environmental monitoring
<i>Metal Oxide Semiconductor</i>	Moderate	Moderate (50-100ms)	Moderate	Low	Indoor air quality, Consumer electronics
<i>Electromechanical</i>	High	Fast (1-10ms)	High	Moderate	Industrial safety, Medical devices
<i>Optical</i>	Very High	Fast (1-10ms)	Very High	High	Advanced research, Environmental monitoring
<i>MEMS</i>	High	Fast (1-10ms)	High	Low	Indoor air quality, Automotive

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System Design

System Design – Component Selection

Processing

Sensors – Temperature

Temperature can be detected using a range of different methods; thermistors can be used to IR sensor, thermocouple, thermometer & camera

Sensors – Humidity

Sensors – Wind Speed

Sensors – Wind Direction

Sensors – Air Borne Particles

Sensors – VOC Levels

Sensors – Sunlight Brightness

Sensors – UV Index

Sensors – Location

Connectivity

System Design – Circuit Design

System Design - Software

System Design – Bill of Materials

Specification Review

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FINAL GRADE

GENERAL COMMENTS

22/100

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MATTHEW PRENTICE

21.80

RESEARCH-INFORMED LITERATURE

 Reasonable literature review of a number of available systems with a good comparison table of relevant information but more detail would have improved it. 65% **6.5**

KNOWLEDGE AND UNDERSTANDING

 No schematic design or PCB were submitted. 0% **0**

ANALYSIS

 Very few components were identified 30% **10.5**

PRACTICAL APPLICATION AND DEP.

 no costings or future enhancements were submitted 0% **0**

SKILLS FOR PROFESSIONAL PRAC.



The report is poorly presented and incomplete, with a selection of references. This is a very poor submission not commensurate with the students ability. Better time management would have seen a much better submission.48%

4.8