WHITE PAPER

EFFECTIVE FOG PREVENTION STRATEGIES FOR MODERN VEHICLES

H2TD Series Humidity Sensor

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INTRODUCTION

From the early days of wiping condensation with a rag to developing windshield wipers and HVAC systems, the transportation industry has always looked for new ways to maintain a clear field of vision for drivers. Today's vehicles have evolved with sophisticated systems that aim to automatically maintain clear windshields and, more recently, camera lenses. Instead of the driver having to adjust settings at every sign of fog manually, advanced HVAC systems now rely on sensors to automatically activate only when necessary. These systems aim to deliver just the right amount of intervention needed for a seamless, energy-efficient and distraction-free driving experience.

Safety Benefits

Ensuring clear visibility is essential for safe driving, particularly in changing weather conditions. This need has been enforced globally through government regulations, such as the Commission Regulation (EU) No 672/2010, which mandates that all vehicles include a system to remove mist from the interior glazed surface of the windscreen. An effective fog prevention strategy allows automotive manufacturers to help reduce the risk of fog build-up, minimize potential distractions, meet global regulations and improve overall driver awareness.

Energy Efficiency Benefits

Maintaining efficiency is a significant challenge in battery electric vehicles (BEVs) and other energy-conscious designs. The ability to predict and prevent fogging conditions reduces the need for energy-intensive, reactive defogging. Accurate fog condition detection allows systems to activate only when necessary, preemptively adjusting surface temperatures to prevent condensation from forming. This approach requires less energy than converting existing condensation back to vapor, which helps conserve battery power and can help improve the vehicle's overall efficiency and range.

Strategies for Predictive Fog Prevention

At the center of a fog prevention strategy are humidity sensors. By providing a dew point measurement—the temperature at which condensation occurs—humidity sensors enable systems to predict fog and activate countermeasures such as heating camera lenses or automatic adjustment of the HVAC system.

Predicting a fogging condition relies on three main measurements:

- Relative Humidity
- Temperature Measurement of Ambient Environment
- Surface Temperature of the Target Surface (typically the windshield or camera lens)

Condensation forms when the windshield surface temperature falls below the dew point. The dew point (°C) is a function of relative humidity and ambient temperature, expressed as Dew Point(°C) = f(RH, T), and can be estimated using various algorithms. By analyzing these inputs, the system can assess the likelihood of condensation by comparing the dew point temperature to the windshield surface temperature.

Setting the Ideal Threshold

Establishing an optimal threshold between the windshield temperature and dew point is critical, as a small, precisely calibrated threshold enables efficient HVAC system performance. If the threshold is set too large, the HVAC system may activate too soon, leading to unnecessary energy consumption. Conversely, fog may appear on the windshield if the threshold is too small, leading to manual intervention and increased energy consumption to convert the condensation back to a vapor.

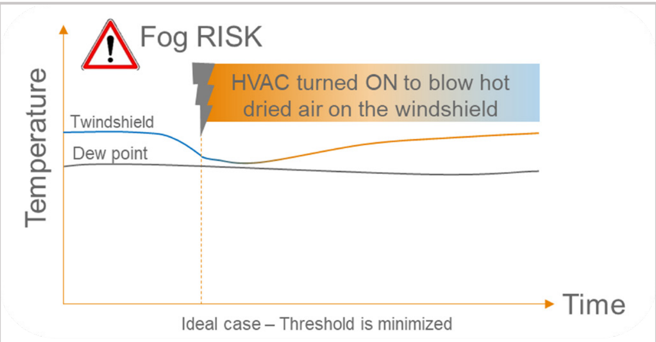


Figure 1. Illustrates the relationship between windshield temperature and dew point threshold.

Figure 1. illustrates an ideal scenario where the HVAC is set to activate just before the windshield temperature meets the dew point. Minimizing this threshold while accounting for potential errors is important to help improve the driver experience and extend the possible range of electric motors.

Setting an ideal threshold and delivering accurate fog detection depends on:

- High-precision dew point measurements
- Fast response time for windshield temperature
- Long-term measurement stability
- Minimal thermal interference from the environment

Importance of Sensor Placement

Location, location, location. Just as in real estate, location is critical for sensor placement. For windshield fog prevention, the ideal location is the center top of the windshield—commonly used for rearview mirrors, cameras, and antennas. This position is furthest from boundary conditions and minimizes the influence of external factors such as sunload and HVAC system thermal interference.

Placing sensors in less optimal locations can result in measurements being affected by hot or cold spots and other thermal interference, compromising the sensor's accuracy and the effectiveness of the fog prevention strategy.

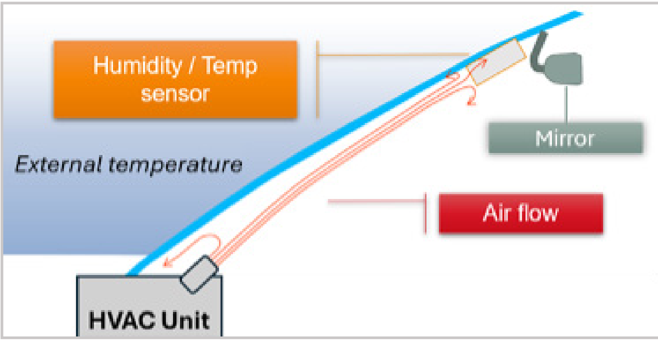


Figure 2. Illustrates the ideal placement of humidity sensor placement for fog prevention applications.

Standalone vs. Combo Sensors

A popular strategy at many OEMs is to use a combination sensor that includes rain, sunlight, and humidity in a single module. This approach aims to reduce costs by eliminating multiple PCB assemblies and packaging. The mounting location is typically at the top center of the windshield, near or within the rearview mirror area.

While this strategy offers benefits for sunload measurement, there are notable drawbacks and considerations for fog prevention applications:

- Heat Generation: Combination sensors typically contain several active components that support the rain and sunlight functionality and generate heat, which can affect measurement accuracy .
- Size: Combination sensors are typically around 60% larger than standalone humidity sensors .
- Consolidation of RLS: Vision-based camera sensing is rapidly evolving to meet the requirements for Rain, Light, and Solar detection, signaling a shift in the need for traditional combination sensors and their role in vehicle architectures.

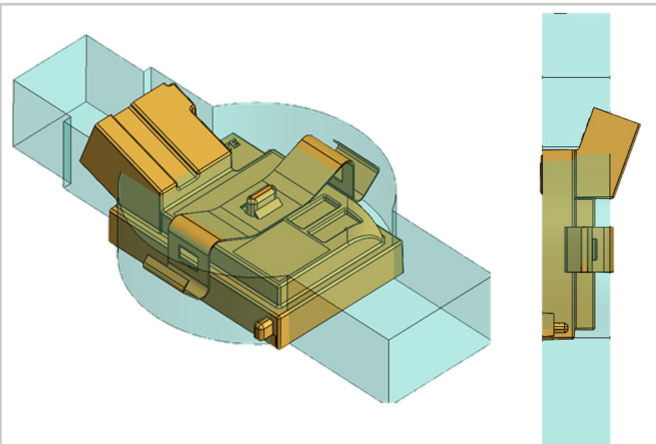
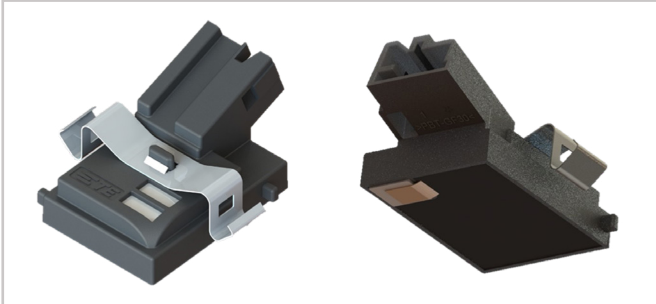


Figure 3. Illustrates size difference between industry-leading combination sensor and TE's Defogging Sensor.

TE Connectivity's Anti-Fog/Defogging Sensor: Features, Advantages and Benefits



TE Connectivity's Anti-Fog/Defogging Sensor, housed in a compact and customizable package, features relative humidity sensing and negative temperature coefficient elements that enable dewpoint calculation and windshield temperature measurement.

Compact Size

The sensor boasts a compact form factor (29.5 mm * 21.6 mm * 17.4mm), allowing precise placement. Its customizable housing and small size make it easy to integrate into modern vehicle designs, particularly within the center top of the windshield.

High Accuracy and Performance

The sensor provides accurate dew point measurements (±1.5°C) isolated from the windshield, enabling reliable data unaffected by environmental influences. By isolating the windshield temperature measurement from ambient interference, the sensor provides precise readings, helping enhance the predictive capability of the system and helping allow for optimized activation of the HVAC.

Technical Features			
Measurement range and accuracy	Operating	Storage	Humidity
	-40/+90°c	-40/+105°c	0/100%RH
	+/-2°C, on full scale		+/-1,5°C dewpoint
Supply Voltage	12V	Current consumption	10mA max.
Communication	Digital LIN 2.2		
Connector	Automotive grade, inclination possible		
Fixation	Metallic clip		

Potential for Camera Lens Defogging

Forwarding-facing cameras installed near the windshield may utilize the standalone anti-fog sensor from the rearview mirror area to support anti-fog measures. However, cameras installed in alternate locations must have a separate strategy to maintain a clear line of sight. TE also offers chip-level solutions which can be integrated into the camera system to support predictive condensation countermeasures.

Conclusion

The modernization of fog prevention strategies, aimed at preventing condensation from forming on the windshield, provides automotive OEMs with the tools required to improve safety, enhance energy efficiency, and elevate the driving experience. By integrating precise humidity sensing, accurate dew point measurement, strategic sensor placement, and optimized threshold calculations, these systems can now reliably activate countermeasures to help prevent fogging on both windshields and camera lenses.

To learn how TE Connectivity can work with you to bring your fog prevention strategies to life and explore our broader portfolio of automotive sensor solutions, visit **te.com/AutomotiveSensors** or **contact your local account representative today.**

About TE Connectivity

TE Connectivity is a global industrial technology leader creating a safer, sustainable, productive, and connected future. Our broad range of connectivity and sensor solutions enable the distribution of power, signal and data to advance next-generation transportation, renewable energy, automated factories, data centers, medical technology and more. With more than 85,000 employees, including 9,000 engineers, working alongside customers in approximately 130 countries, TE ensures that EVERY CONNECTION COUNTS. Learn more at **www.te.com** and on **LinkedIn**, **Facebook**, **WeChat**, **Instagram** and **X (formerly Twitter)**.

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