

Low-Power Liquid Detection

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1. Abstract

The need to detect the presence of liquid is increasingly widespread in today's landscape of smart home appliances, connected devices, and deployment of sensitive electronics at the edge in harsh environments.

The ability to detect the presence of liquid, whether from a leaking pipe or from moisture ingress, in a sensitive Internet of Things (IoT) node - and raise an early alert, provides systems with an additional level of robustness, and extra peace of mind to end customers.

Microchip Technology Incorporated has developed an innovative, low-power way to detect liquids with capacitive and conductive sensing.

2. Applications for Liquid Detection

There are many scenarios for which liquid detection may be useful. The focus of this paper is on the detection of water, since this is the liquid most commonly affecting many aspects of day-to-day life, both from the perspective of people and electronics.

2.1. For the Home

One of the more common use cases is the detection of a water leak in a pipe or household appliance. Looking specifically at household appliances, there are multiple potential sources of a leak.

Figure 2-1. Typical Household Kitchen with Multiple Potential Sources of Water Leaks



Sinks, dishwashers, washing machines, and even some high-end coffee machines can be plumbed into a mains water source, meaning that a large amount of water could quickly accumulate on the floor if unnoticed. In the best case, such a leak would require considerable time and effort to remove the excess water and dry the affected area. In the worst case, this type of leak could require expensive repairs, especially in the context of an apartment block where the leak could permeate into adjacent flats.

For freezers and refrigerators, the drain channels used to dispel meltwater and condensation can become blocked. The resulting water leakage could damage flooring or create conditions conducive to mould growth due to the moisture.

Elsewhere in the home, hot water tanks, immersion heaters, air conditioning systems, central heating installations, and bathrooms are all susceptible to water or - even worse - wastewater leaks.

2.2. For Insurance

Another source of liquid-induced damage for homeowners is from natural disasters such as floods. These can occur due to heavy rainfall causing rivers to burst their banks, or from more violent weather events such as hurricanes and tsunamis. As a result of this, many insurance companies are beginning to issue standalone devices for detecting the presence of water.

2.3. For Water Infrastructure

Faults in large-scale water infrastructure can have significant impacts, both economically and environmentally. Aside from the damage caused to surrounding property and infrastructure (e.g. building foundations, roads, etc.), wasting water in the supply network costs water companies vast amounts of money.

It is estimated that, in the UK alone, up to 2.4 billion litres of water are wasted each day [2, 3], water which could be stored and preserved to help buffer supply during periods of drought. Early detection of pipe ruptures minimises disruption while repairs are carried out, and helps utility companies to save money, and meet their sustainability targets.

Figure 2-2. Smart Agriculture Applications



2.4. For Preventative Maintenance

Detecting liquid does not have to be limited to detecting when a liquid escapes from a container, it can also be used to detect water ingress. With the rise of electronic devices being deployed in outdoor, harsh environments, failure due to moisture exposure is an increasing concern, particularly if the system is in a physically remote location that would make service or replacement costly and time-consuming.

Moisture can enter a product in multiple ways, the most common being a direct leak of liquid through a crack or joint in the enclosure. If a product utilizes a dedicated watertight seal as a serviceable item, then this could be replaced at the first sign of moisture ingress, negating the need for replacement of an entire mainboard due to corrosion, breach of specification, or component damage. This translates into direct cost savings for the end user and helps prevent the creation of needless electronic waste.

In addition to direct liquid ingress, products can also be exposed to large variations in humidity and temperature, leading to the formation of condensation within an enclosure. If condensation is detected within a product, countermeasures can be taken, including enabling a small heater or solid-state dehumidifier to reduce the relative humidity within the enclosure.

In battery-powered systems, the ability to dynamically enable and disable a power-hungry feature, such as a heating element, based upon real-time ambient conditions will help extend the run time of the system resulting in increased availability.

3. Legacy Liquid Detection Solutions: Mechanical and Electrical

Reliable liquid detection is critical in a wide range of applications, from industrial automation and medical devices to consumer appliances and automotive systems. Legacy implementations often require custom sensing algorithms, analog front-end circuitry, and complex firmware development.

3.1. Legacy Mechanical Solution

Mechanical solutions typically utilize a float which changes position due to rising water levels. As the float changes position, it actuates a resistive wiper which triggers a signal at a pre-set level. While mechanical float-based liquid detection solutions are simple and cost-effective, they have several limitations that reduce their suitability in modern applications.

Even when operating properly, mechanical solutions do not offer the same precision as electrical solutions, do not offer any progressive information to the monitoring system, and do not provide any self-monitoring capability. Mechanical solutions are susceptible to physical wear and tear, obstructions due to debris or sediment, and they can provide false signals due to liquid movements. Finally, mechanical float solutions simply may not fit into space constrained applications, which are becoming ubiquitous in areas such as IoT and smart agriculture.

Figure 3-1. Legacy Mechanical Solution



3.2. Legacy Electrical Solution

Electrical resistance-based liquid detection solutions operate by placing two or more probes in the target environment and measuring the electrical resistance or conductivity across the liquid. While electrical resistance-based solutions have been used due to their straightforward implementation and low component count, they also have several limitations that reduce their suitability in modern applications.

Resistance-based solutions utilize contacts that must physically touch the liquid, making them susceptible to corrosion and eventual failure. Detection accuracy may be negatively impacted by changes in the conductivity of the liquid, which may be caused by sediment or saline; compensating may require calibration, increasing system complexity. Resistance-based solutions are typically 'always on', and will therefore consume more power than allowed for by many power budgets.

4. Simplifying Liquid Detection with a Comprehensive Solution for Embedded Systems

Microchip Technology has introduced a solution that makes liquid detection easier with:

- Dual-mode sensing: Capacitive and conductive detection integrated into a single device.
- Turnkey functionality: No firmware development or signal processing required.
- Versatile communication: Digital I/O for basic use, UART for advanced applications.
- Power efficiency: Optimized for low-power operation in always-on systems.
- Operating Voltage Range: 1.8 - 5.5 V.
- Ultra-Low Power: Uses less than 1 μA in lowest power mode.
- Compact & Robust: 3x3 mm VQFN; -40°C to $+125^{\circ}\text{C}$ operation.
- Ease of use: Plug-and-play deployment minimizes development time and system complexity; supports a wide range of sensor shapes and sizes.

The MTCH9010 Liquid Detection Turnkey Device detects a wide variety of liquids—including water, saline, and other conductive or dielectric fluids - without requiring additional external components. It consolidates capacitive and conductive sensing capabilities, enabling designers to detect the presence of liquids across diverse use cases.

Unlike discrete sensing solutions that depend heavily on host-side signal processing, the MTCH9010 performs all detection and signal analysis internally, delivering a streamlined and power-efficient approach.

It is ready-to-use and pre-programmed: there is no need for code development and it can be used entirely standalone.

Figure 4-1. Liquid Detection Turnkey Device



4.1. Two Sensing Modes, One Device

Traditional liquid sensors force engineers to choose between different detection methods. The MTCH9010 removes that limitation by offering two sensing modes in a single device:

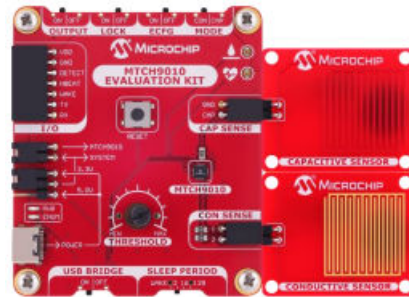
- Capacitive Mode: Ideal for detecting water, oils, fuels and alcohol-based liquids by sensing changes in dielectric properties. This method for liquid detection relies on the principle that the presence of a liquid changes the dielectric constant of the medium between two conductive plates, which in turn affects the system capacitance.
- Conductive Mode: Detecting liquid using the conductive method involves measuring the electrical conductivity of the liquid. This method is based on the principle that liquids, especially those containing ions (such as water with dissolved salts), can conduct electricity.

A simple pin selection allows seamless switching between the two, eliminating the need for multiple sensors and streamlining product design. This selectable sensing mode makes the MTCH9010 ideal for applications where different liquids may be present in different use cases or where a system needs the flexibility to detect various fluids without requiring hardware changes.

4.2. Evaluation Kit Enables Quick and Easy Prototyping

Microchip Technology has also introduced an Evaluation Kit that makes it easier for designers to familiarize themselves with the capabilities of the Liquid Detection Turnkey Device. The MTCH9010 Evaluation Kit includes two sensor boards - one capacitive and one conductive - that enable system designers to easily interface and test their sensor configurations. Users can connect their own sensor to the board, so they can test and validate the device using a sensor with the exact size and shape as will be used in the final design. This versatile platform supports rapid development and experimentation of standalone testing and more complex system-level prototyping.

Figure 4-2. Evaluation Kit



5. Applications

The Liquid Detection Turnkey Device is ideal for use in:

- Smart appliances (e.g., leak detection in dishwashers or washing machines)
- Battery-operated consumer electronics
- HVAC and automotive systems requiring environmental sensing
- Industrial fluid systems:
 - Pipework
 - Storage containers
 - Agriculture
- Medical devices with fluid monitoring:
 - Dialysis Machines
 - Pharma Refrigerators
 - Autoclaves & Sterilizers
 - IV Pumps and Drug Infusion Systems
 - CPAP/BiPAP Ventilator Humidifiers
 - Dental Equipment and more

Figure 5-1. Medical IV Pumps/Drug Infusion Devices



Figure 5-2. Automotive Applications



6. Conclusion

For engineers looking to implement liquid detection without the burden of custom analog design or firmware development, the MTCH9010 offers a compact, reliable, and efficient solution.

For battery-powered and remote sensing applications, power efficiency is everything. Many traditional sensors constantly draw power, draining batteries quickly and making long-term operation difficult. The MTCH9010 is designed with ultra-low-power operation, allowing devices to run for years without frequent battery replacements.

Its integrated sensing capabilities and turnkey operation allow for rapid deployment, making it well-suited for both new designs and retrofits in existing systems.

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