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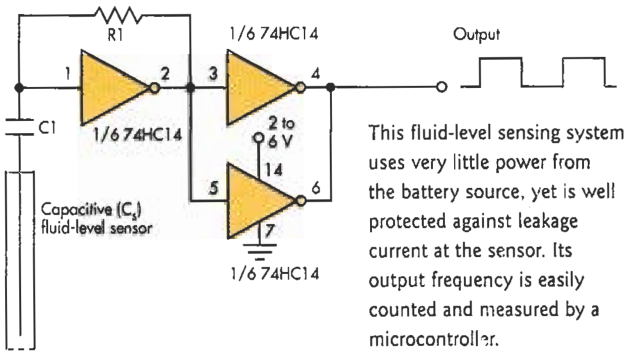
Low-Power Logic Gate Protects Fluid Sensor From Leakage Current

Fluid-level sensing is very common in industrial applications and now is being used in domestic applications to sense water levels in overhead tanks. The greatest challenge for designers is to make these sensors operate with ultra-low power using battery voltages between 2 and 6 V, while making the device insensitive to potential damage from leakage current coming from mains power running pumps and valves.

The design described here uses three sections of a 74HC14 CMOS logic-gate-type hex Schmitt trigger that draws less than 10 pA *(see the figure)*. A large feedback resistance on the order of 1 MΩ limits the charging and discharging current to less than 5 μA.

While sensor capacitance C_S is in the 100-pF to 100-nF range, it doesn't leak the charge into the fluid dielectric because the center electrode is made of steel insulated with Teflon. Series capacitor C1 is 100 times greater than C_S and doesn't affect the measurement since the effective capacitance of the two in combination is closer to the much smaller C_S. Even if C_S shorts to an electrical current or voltage source, the sensor oscillator remains isolated through capacitor C1.

The sensor is essentially a pair of parallel capacitors with fluid and air dielectrics. Consequently, C_S varies when the fluid level (and, therefore, the air level) in the sensor changes. The dielectric constant of water is 80 times greater than that of air, so the effective capacitance depends on the water and its changing level in the sensor column.



This fluid-level sensing system uses very little power from the battery source, yet is well protected against leakage current at the sensor. Its output frequency is easily counted and measured by a microcontroller.

The sensor's output is a signal in the 0- to 10-kHz range, which can be easily counted and measured by a microcontroller. The fluid level is measured as reciprocal of the frequency:

$$\text{Fluid level} = k/f$$

where k is a constant for a given fluid type. If the fluid type changes, a new constant must be utilized. Users can exploit this fact to detect contamination in the fluid by comparing the signal from same-height fluid levels. This can be effectively used for sensing fat content in milk and adulterated petroleum products or food oils.

C1 must be a high-voltage NPO or X7R capacitor. A 2-kV X7R type was used in this application because NPO capacitors rated that high are very expensive. The device was tested and found to be safe even with such a high voltage leaking at the sensor end. The test current was limited to 1 μA at 1 kV. This fluid measurement technique was less expensive than dc-dc converter isolation and optical isolation methods.

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