Continuous Level Float Sensors

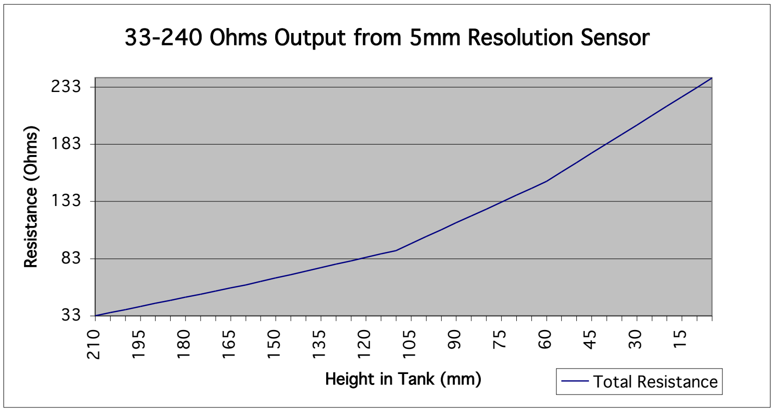
The principles and practical applications behind the standard, reliable sensor for accurate and continuous tank level measurement.

by Frank J. Smith
Madison Company

Like many modern industries, the field of liquid measurement and control has been significantly transformed over the past couple of decades with the introduction of digital technology and the proliferation of PLC and microprocessor instrumentation. Solid state, radar, capacitance and frequency-based sensors have often replaced more traditional pressure and buoyancy devices to monitor and transmit critical fluid level data in many industrial applications. Moreover, the pervasiveness of more sophisticated "smart" controllers and recorders have made continuous output sensors more the norm when compared to simple single-point, "high/low" level switching. One long-established level measurement technology that has enjoyed continued popularity is the Continuous Level Float Sensor (CLFS), a simple, directly installed electromechanical device that produces a variable resistance or a continuous current or voltage output corresponding to the relative position of a vertically moving magnetic float.

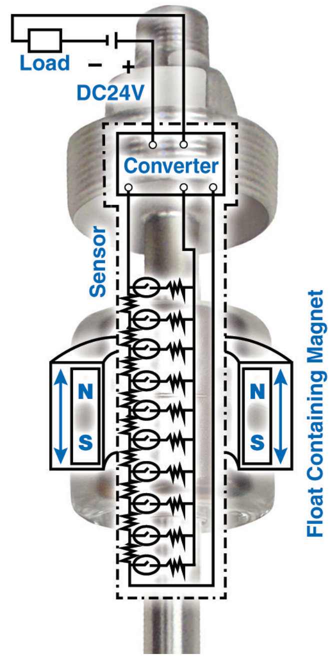
I. Electrical

The industrial versions of CLFS are modeled on mechanical float-activated “senders” long used in automotive and marine fuel tanks as potentiometric transmitters to coil-based panel gauges. A potentiometer-type wiper arm connected to a float in the fuel tank moves across a series of resistors as the float moves up and down, thereby regulating the battery-generated voltage to the gauge movement. A common automotive resistance range is 33 to 240 ohms. Other ranges include 0 to 30 ohms and 0 to 90 ohms, plus special resistance/level curves that have been offered by specific manufacturers. These frequently have nonlinear outputs owing to the comparative fluid volume in an asymmetrical tank and the nonlinearity of the typical panel gauge scale (see Figure 1).



(Figure 1) Nonlinear tank level/electrical resistance curve.

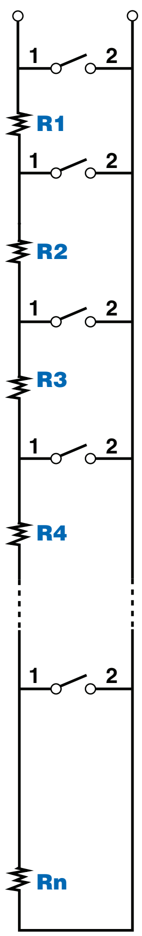
The industrial versions typically employ a float containing an internal bar or ring magnet that moves over a sealed stem, magnetically activating a vertical ladder of reed switches and resistors contained within. As the liquid level changes, the float follows and its internal permanent magnet sequentially opens and closes the reed switches across their integral resistors. This increases or decreases the cumulative series resistance at each position (R = R1 + R2 + RN). The reed switch/resistor track is usually integrated into a vertical printed circuit board (PCB), and the resolution of the associated output is determined by the spacing of the individual reed switches – often at ¼-inch or ½-inch increments. The sealed tube (typically stainless steel, brass or PVC) isolates the switch/resistor array from both the fluid it is in and the float itself, which magnetically trips the reed switches through the tube and float shell wall (see Figure 2).

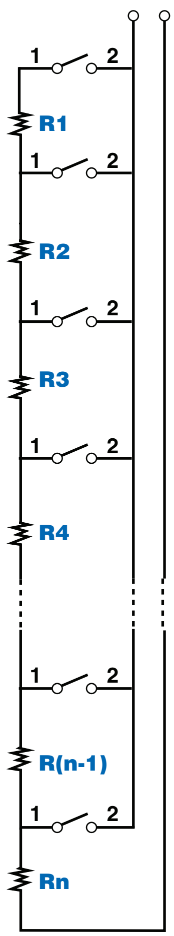


(Figure 2) Magnetic reed switch and resistor chain with magnetic float.

Prefabricated reed switch/resistor PCBs will often include repeating resistor levels of equal value (i.e. 100Ω) to follow linear level and liquid volume changes in cubical, rectangular or vertically mounted cylindrical tanks. Some will feature custom resistance ranges with nonlinear and varying resistor values to monitor liquid levels in tanks with nonparallel sides. Horizontally mounted tank cylinders, for instance, will have the highest resistor values at the mid-point of the PCB, with equally decreasing values above and below center to best reflect the proportional cross-sectional volume of a circular tank.

Some applications require that the full and empty range limit correspond to either high or low resistance, which can be accomplished by wiring the circuit through the bottom or top of the resistor chain (see Fig. 3a & 3b).





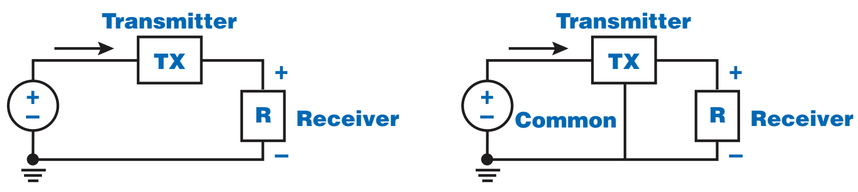
(Figure 3a, left) Circuit layout with least resistance at "full" and highest resistance at "empty".

(Figure 3b, right) Circuit layout with highest resistance at "full" and least resistance at "empty."

While a variable resistance is useful in transmitting a proportional electrical signal to electromagnetic gauges, most instruments now rely on computer-readable formats such as current loops or digital outputs. A 4-20 mA analog current loop is the most common industrial process output used today. Current loops are simple two-wire devices powered from the system to which they are connected that can carry signals over long distances with little degradation or noise interference.

The Magnetic Float Transmitter reed switch/resistor chain described above is often used to divide the introduced voltage to a signal-conditioning module that then converts the signal to a proportionate 4-20 mA output. Taken together, the signal conditioner and the variable resistor board make up the transmitter. This identifies the liquid level as the relative position of the magnetic float by its resistance/voltage at that point and converts to a corresponding current output.

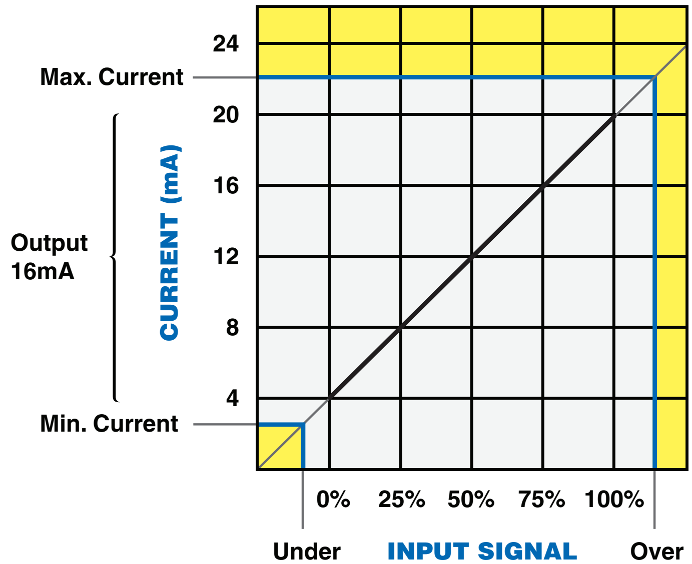
The comparison between the process measurement and the resulting current output value is determined by the calibration of the signal conditioner over the 16 mA span. That relationship tends to be linear since the linear or nonlinear mapping to the level position is already established in the resistance curve. 20 mA typically corresponds to the maximum level and 4 mA to the minimum level, although that can be inverted either in the calibration of the signal conditioner or the resistor board wiring as described above. Setting 4 mA to represent a “live zero” also helps differentiate a true power loss to the receiving instrument.



(Figure 4) Two- and three-wire transmitter connections.

The two-wire current loop discussed here is the simplest and most common arrangement, although there are several ANSI/ISA-standard connection types that fall into the loop circuit category. These include a three-wire configuration where the transmitter shares a common wire with the receiver and a separate DC power connection (see Figure 4).

The 4-20 mA, two-wire loop power system uses DC current because it affords a single signal level, unlike AC power where the alternating signal makes it difficult to ascertain a stable transmission level. Today most current loops use 24 VDC, which is the most common supply voltage for process controls (although some higher voltages are used in older systems). The two-wire 4 to 20 mA loop circuit consists of the transmitter/sensor itself, the power supply and a receiver – typically a PLC or panel meter, though it could be a valve actuator, motor speed controller or even a wireless transmitter. While there can be only one transmitter in a loop, there can be several receiver devices in the same circuit, supplied by the same source current. It is important that the power supply produces sufficient voltage to operate the transmitter and that it exceeds the voltage drop at the receiver(s) and any significant resistance in long transmission lengths. Since the loop circuit transmitter draws its power directly from the power source with a 4 mA low-level reference, it needs to operate at less than 4 mA so that minimum and maximum transmitter voltage limits are prescribed (see Figure 5).



(Figure 5) Sensor input vs. transmitter output.

Besides its obvious simplicity of wiring and its relatively long transmission capability, the loop power circuit's low sensitivity to electrical noise is another advantage in busy industrial installations. Its maximum 20 mA output current is low enough to qualify it for "intrinsically safe" classification when used with appropriate barrier components in hazardous locations.

The 4-20 mA format is so widely used and supported by new and existing compatible devices that its place as the leading analog industrial standard seems fairly secure for the foreseeable future. New digital communication platforms such as HART protocol also use frequency variations based on the 4-20 mA scale that permit simultaneous communication with these analog devices.

II. Mechanical

The Continuous Level Float Sensor is, after all, an electromechanical device with a moving magnetic float immersed in the fluid it is measuring. Therefore, attention must be paid to several important mechanical and environmental factors to ensure proper specification and installation. Liquid characteristics such as turbulence, specific gravity, temperature, viscosity and chemical compatibility are important considerations when selecting a CLFS. Common stem and mount materials for a CLFS include 316 stainless steel, brass and polypropylene. The floats are typically stainless steel, Buna-N or polypropylene.

Material Examples and Ideal Applications for Mount, Stem and Float

Mount and Stem Material

316 Stainless Steel	Good for high-temperature and corrosive liquids and applications with high clean or clean-in-place requirements. Commonly used in food processing, medical and potable water applications.
Brass	Best used with petroleum-based liquids like lubricants and diesel. Commonly used in fuel tanks and processing equipment.
Polypropylene	Good resistance to acidic solutions. Available in FDA grade. Used in chemical systems and medical and food processing applications.

Float Material

316 Stainless Steel	Good for high temperature and pressure (300 PSIG).
Buna-N (Nitrile)	Good for oil-based liquids. Very low density and ideal for fluids with low specific gravity. Often used with brass stem and mount.
Polypropylene	Resistant to acidic liquids. Used in electroplating, etching and metal cleaning.

Buoyancy of the float in a particular liquid is determined by its relative density or ”specific gravity” – the ratio of the material’s density to the density of water. As a general rule, most floats need to have a specific gravity difference 20% to 25% less than the specific gravity of the liquid they will be placed in. Most sensor floats are designed for buoyancy in water and have specific gravities of no greater than 0.75 to 0.80. In oils or other liquids with typical specific gravities of 0.75 to 0.90, floats must have a minimum specific gravity of between 0.55 and 0.70.

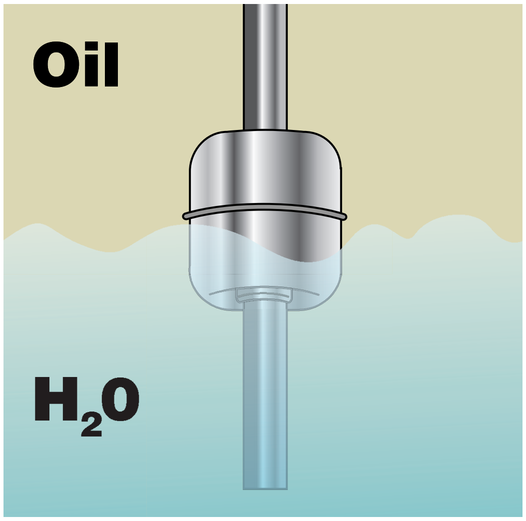
Tank temperature is also an important consideration, not only for its effects on the specific gravity and viscosity of the liquid but also in its effect on the selected material of the float, stem and internal electronic components. Stainless steel, for example, is a widely used material for CLFSs because of its higher temperature resistance and good chemical compatibility. Plastic materials such as polypropylene may offer good chemical resistance, but they cannot be exposed to higher temperatures (above 100°C / 212°F). In both cases, the sensitivity of the circuit boards inside the stem dictate the maximum temperature – typically no greater than 85°C (185°F).

Mobile tanks or tanks with strong pumping action can often create turbulence that will cause the float to move suddenly and result in unstable output readings. This can be minimized by installing the sensor away from the inlet/outlet of the tank or by installing the sensor in a “slosh shield”, a baffled vertical tube that surrounds the float movement and dampens any extraneous fluid motion.

Free movement of the float is, of course, critical to the proper performance and accurate output of any CLFS. As with any moving part, the float must be allowed to go up and down, unimpeded by any solids in the fluid that may jam the movement or any highly viscous or sticky liquids that might adhere to the float. It is also important to keep in mind that CLFSs have floats with internal magnets surrounding their center tubes, making them vulnerable to collecting ferrous particles that can jam or weigh down the movement.

III. Liquid Interface Detection

One of the unique applications for CLFSs is the detection and position measurement of the level interface of two dissimilar liquids – typically oil and water. By using a float weighted to sink through the lower-density oil but float on the higher-density water, the CLFS can differentiate the two by simply floating at the water level (see Figure 6). This direct detection of liquid interface has no counterpart in other electronic technologies that measure level indirectly by utilizing pressure or ultrasonic signal echo.



(Figure 6) Liquid interface float.

These differ from a standard CLFS only in their use of a heavier float, specially made with shot or other weight welded into it. Where a standard stainless float may be made to a specific gravity of 0.70 to be buoyant in water, the interface float may be weighted to a specific gravity of 0.90 that is still lighter than water but heavier than the oil layer above it.

Multiple liquid interface sensors can be connected together into a common gauging system to monitor three or more varying fluid density layers in a single tank. Typical applications include emulsion tanks, oil-water separators, waste oil containers and filtration systems.

IV. Summary

As with any comparison between two common-purpose technologies, the chief advantage of Continuous Level Float Sensors is their low cost relative to newer electronic or high-accuracy sensors. Float sensors, particularly those with pre-fabricated resistor boards, are comparatively less expensive than radar, ultrasonic or capacitance sensors for similar applications.

The CLFS is a primary position measuring device that monitors the level position directly without resorting to ”secondary indicators” such as system pressure, signal response time or the conductive or capacitive properties of the liquid. Provided the float is free to move, the sensor is unaffected by changes in temperature, fluid dielectric, tank pressure, foam or emitted gas. The float sensor can be designed for most any size tank or process fluid and, as we have seen, can be modified to detect dissimilar fluids such as oil-water interface. The current loop design is useful for simple installation and long signal transmission with little noise interference.

As an “immersed” device, a CLFS can sometimes be made to incorporate a secondary sensor such as a thermostatic switch, resistive temperature probe (RTD) or separate high or low reed switch contacts actuated by the same transmitter float to power discrete alarm circuits. Where space permits, these secondary sensors can be built directly into the float sensor tube.

Typical Applications for Continuous Level Float Sensors Include:

Water Storage

Food Processing

Cooling Towers

Generator Fuel Tanks

Fuel Storage

Off-Highway Vehicles

Oil/Water Separators

HVAC Refrigerant Tanks

Condensate Water Tanks

Conversely, as an immersed sensor the CLFS is not recommended for monitoring solids and should not be used in highly contaminated processes that might jam or hinder the float movement. The rigid stem sensor is usually manufactured and shipped in its full length and may obstruct practical installation, especially where overhead clearance is limited.

About Madison Company

Madison Company, established in 1959, is a world leader in the field of liquid level sensing technology, manufacturing rugged and reliable level controls at its ISO-certified factory in Branford, Connecticut.

In addition to its wide selection of float switches and sensors, Madison now offers both radar and ultrasonic transmitters, as well as pressure, proximity and optical controls designed and built for the most demanding OEM applications.

www.madisonco.com • 1-800-466-5383 • 203-488-4477