LIQUID LEVEL SENSING USING REED SWITCH TECHNOLOGY

When measuring discrete levels of liquids such as automobile brake fluid, reed switch technology is simple, inexpensive and reliable. The principle involves a magnet mounted on a float that closes an adjacent magnetic reed switch as the magnet approaches the switch. Typically, the reed switch is mounted and sealed in a plastic or non-magnetic metal tube, and a ring magnet mounted on a float rides up and down the tube depending on the liquid level. Since the tube is non-ferrous, it does not impede the magnetic field, so the switch operates when the field intensity reaches a threshold level. Thus the reed switch is protected from the fluid being monitored. The tube should be designed so that the point of entry of the sensor leads is above the highest liquid level. Typically, a magnet made with inexpensive plastic bonded ferrite with an energy product of about 16 KJ/m^3 can be used. Such magnets only cost a few cents. The principle is shown here.

Using a ring magnet is a good solution since as the magnet sweeps by the reed switch, only one closure occurs as the plane of the magnet lines up with the contact gap of the switch. Other types of magnets and polar angles can cause two or even three closures, causing potential problems in the software used to monitor the level sensor.

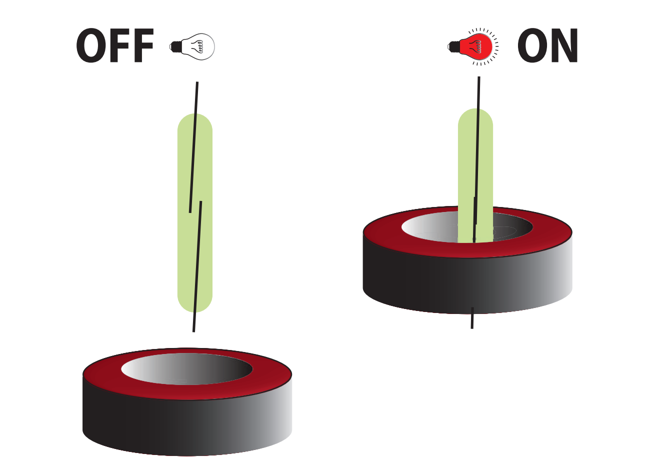

Fig. 1 LEFT – liquid level low, reed switch open. **RIGHT** – liquid level high, switch closed.

The system shown in Figure 1 is typical configuration used for brake fluid level monitoring in automobiles, to test that the reservoir is FULL. Note that if the wires to the sensor are severed, the reed switch appears to be open and the sensor registers low. It is therefore fail-safe in this application. Other applications such as monitoring that a tank, sump or overflow vessel is EMPTY require that the reed switch is mounted lower, so it is closed when the magnet is low. If the vessel fills, the float magnet rises and the reed switch opens. Severed sensor wires then register as a vessel overflow condition – a false positive signal, but one which ensures that vessel overflow cannot be missed.

Simulation tools developed by Coto and used for customer support allow magnet-switch system designs to be rapidly prototyped.

The method described so far frequently implemented in automobiles for monitoring brake fluid levels. It can be modified to register multiple levels by incorporating a chain of reed switches and a resistor ladder that provides a varying resistance or voltage depending on the liquid level. For example, using three reed switches instead of one, the reed switch level sensor can register a **RED** alert - "stop and check brake fluid immediately," **ORANGE** – "check brake fluid level soon," and **GREEN** – "brake fluid level OK."

Discrete voltage levels corresponding to each switch closure can be developed using a resistor ladder. A typical configuration for a 4-switch system is shown in Figure 2. The resistor network can be extended to any number of levels within the resolution range of the A/D converter that is being used. Thus deep tanks can be monitored with many discrete levels. Variable switch spacing schemes can also be devised to suit tanks with spherical or other varying cross sections.

In the case of a three-level sensor, the vehicle's computer can monitor V_{OUT} and unambiguously determine the three different liquid alert levels. With this scheme, the sensor designer should space the reed switches so that only one is closed at

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any given time. The required spacing can be determined by experimentation, or by magnetic field simulation. Simulation tools developed by Coto and used for customer support allow magnet-switch system designs to be rapidly prototyped. For example, Figure 3 shows a simulation of a three switch level sensor using a 6 mm internal diameter ring magnet. The simulation calculates the expected magnetic flux density in each switch and the forces in the contact gap as the magnet traverses up and down the switch array. Animations of the changing field are developed;

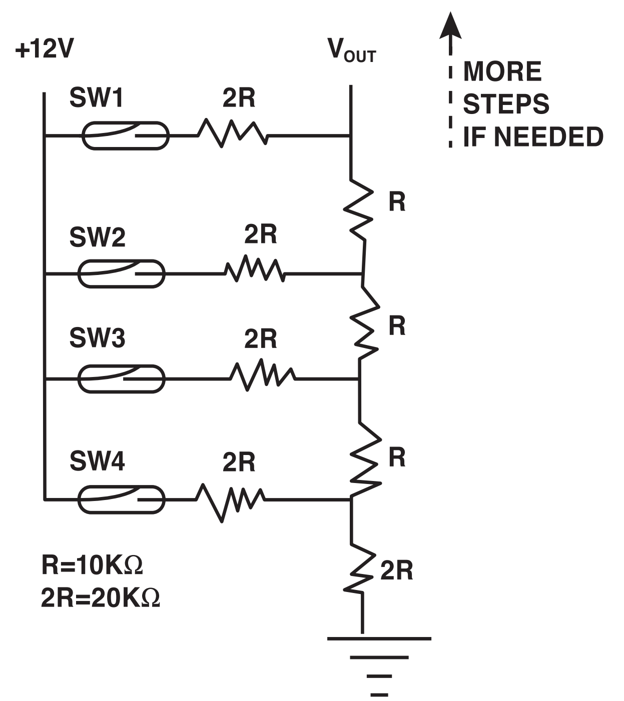

Fig. 2 Reed switch - R 2R resistor ladder diagram.

Figure 3 shows a still from such an animation. Since the flux density required to operate a switch of a given closure sensitivity is known for every switch leaving the Coto factory, it is possible to predict the minimum distance the switches should be spaced in order to ensure that only one switch is turned on at any given time.

Choice of reed switch

Figure 1 shows a bare glass reed switch in order to visualize the reed switch blades. However, bare glass reed switches are fragile, and a better choice is a plastic encapsulated reed switch such as Coto Technology's CT05 or CT10 series. They consist of a high-quality reed switch encapsulated in a hard epoxy resin, which effectively "splints" the reed switch, protecting it from shock, vibration and environmental damage. As such, they are ideal for under-hood automobile operation.

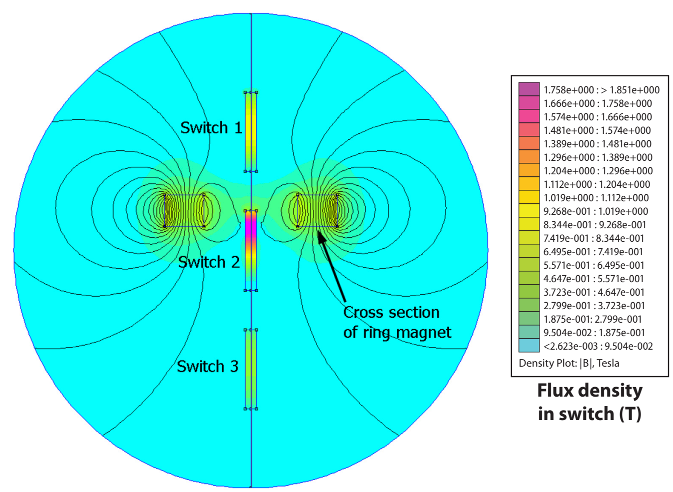

Fig. 3 Magnetic field simulation of three reed switch level sensor. Plastic foam float supporting the magnet is non-magnetic, and is omitted for clarity.

The CT05 series switches are surface mount devices 6.4 mm long (9.55 mm including leads), and are also available in a slightly short J-bend format. The CT10 series is 12.8 mm long (16.4 mm with leads). Apart from the advantages of increased ruggedness, the surface mount format makes it simple to attach the switches to printed circuit boards or flex circuits using pick-and-place equipment. While designing the CT05 or CT10 switches into a sensor, it's useful to note that every switch that leaves the Coto factory is tested for operate and release sensitivity AFTER lead cropping and encapsulation, ensuring that these sensitivities are known accurately. In contrast, other reed switch manufacturers test the operate and release sensitivity before lead cropping and molding, and can only make a rough estimate of the sensitivity of the shipped product.

Relationship between Amp-Turn (AT) operate and release sensitivity, and required operate and release field.

The CT05 and CT10 series reed switches are specified in terms of the range of operate AT. For example, the CT10-1030-G1 switch has a range from 10 to 30 AT. In other words, Coto warrants that the operate sensitivity of a switch randomly selected from a batch of CT10-1030-G1 switches will operate in a field of between 10 amp-turns and 30 amp-turns measured in Coto's factory test coil. (The specification for this coil is available on request.) However, most CT series switch users expect to use a permanent magnet to operate the switch. What magnetic field strength is needed to operate a 10 AT switch? There is a simple rule of thumb to figure this. It is:

4 AT = 1 mT

In other words, divide the switch AT by 4 to get the required field strength in milliTeslas (mT). So the 10 AT switch will operate when immersed in a field of approximately 10/4 = 2.5 mT (25 Gauss in the older CGS units.) Correspondingly, a 30 AT switch will close at 7.5 mT.

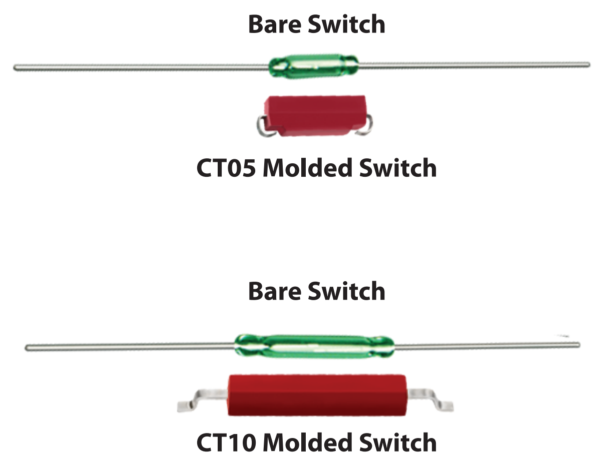

Fig. 4 bare glass reed switches are fragile, and a better choice is a plastic encapsulated reed switch such as Coto Technology's CT05 or CT10 series. They consist of a high-quality reed switch encapsulated in a hard epoxy resin, which effectively "splints" the reed switch, protecting it from shock, vibration and environmental damage.

Other level sensor design considerations

Considerations for designing reed switch level sensors include the following:

1. **What is the nature of the fluid being monitored?** Though the switch will be installed inside a protective tube of plastic or non-magnetic metal, the float and possibly the magnet will be directly exposed to the fluid, so highly corrosive or flammable fluids are probably not suitable.
2. **Design the system so it is fail safe.** Consider what condition will be registered if the leads to the sensor are severed, and place the reed switch in the appropriate position relative to the float position of the magnet.
3. **Is continuous or discrete level monitoring needed?** Reed float sensors can't provide continuous (step-free) monitoring, though as we have shown, multiple reed switches can be used to provide a series of discrete levels.)
4. **Consider reliability.** The CT05 and CT10 series switches have contact life expectancy between 100 million and 5 billion contact closure cycles while switching a signal level load. They are also highly shock and vibration resistant. It's likely the equipment they are installed in will wear out long before the switches do.
5. **Consider the space available.** Space (and weight) cost money, especially in automobile applications. The smaller and slightly more expensive CT05 switch may be the best choice compared to the CT10, after taking into account the smaller reservoir volume that can be used, and the reduced space needed in the engine compartment. Plus of course, the lower weight and volume of brake fluid needed, and the resultant reduction in the carbon footprint of the vehicle.
6. **What are the environmental conditions?** When looking at alternative fluid level sensing technologies (and there are many, as a quick Google search will show), consider shock, vibration, high temperatures and even G-forces. Reed float sensors using ring magnets make great brake fluid sensors even during high-G cornering, since the float movement is constrained by the tube containing the reed switch or switch ladder.
7. **Consider the cost.** Reed float sensors are simple, reliable, inexpensive and consume no power. Exotic technologies such as radar, ultrasonic and magnetostrictive level sensors may be overkill for a simple level sensing application. Look at all the positives and negatives before starting your sensor design, and lean on Coto if you need the best applications support in the industry!

For further information contact **classic@cotorelay.com**
For detailed data sheets on the CT05 and CT10 series switches, visit **www.cotorelay.com**

