IMPROVING A SIMPLE 3-WIRE LEVEL SENSOR ASSEMBLY BY USING THE REDROCK™ RR131 TMR DIGITAL SWITCH

Background

Level sensors are traditionally produced using a reed switch ladder. As a floating magnet sweeps past a series of reed switches, the sequential closing of each switch shorts out a chain of resistors, producing a varying resistance that can be converted to a varying voltage corresponding to the fluid level. Though widely used, there are several disadvantages to such a scheme. First, reed switches are relatively large, limiting the resolution of a reed-based level sensor to about 15mm when using 5mm molded reed switches. Second, reed switches are prone to multiple closures as a magnet passes by, complicating the algorithms needed to decode the switch closures. Third, reed switches are mechanical devices that have a limited lifetime before the contacts fail. It is therefore desirable to provide a solid state solution that has higher spatial resolution and reliability.

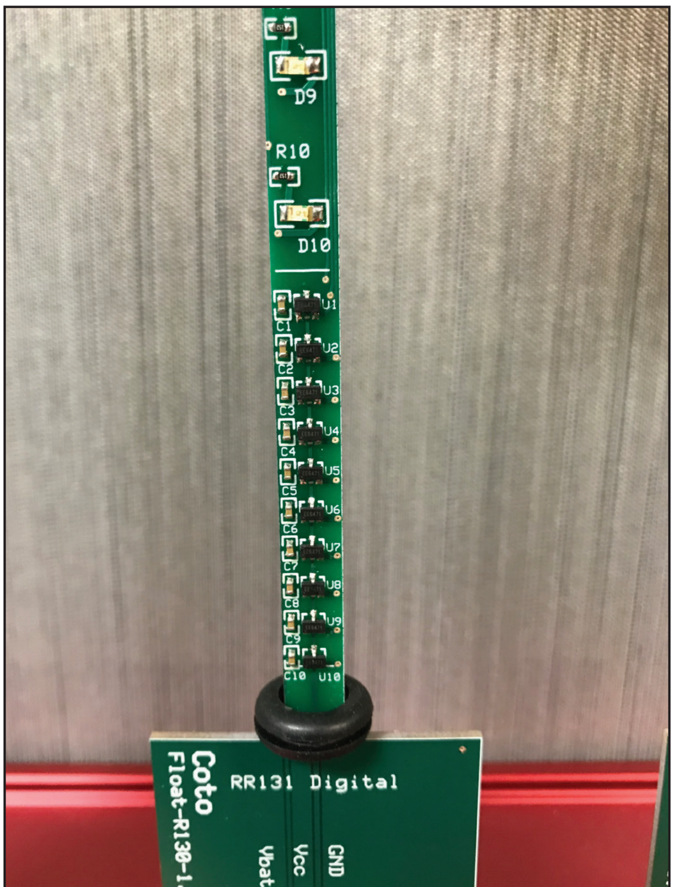

Fig. 1 Level Sensor Demonstration Model

Using the RedRock™ RR131 to Improve the Level Sensor Design

To provide a better level sensor design, a prototype level sensor was fabricated using RedRock RR131 TMR digital switches. The RR131 is an integrated digital magnetic switch based on Tunneling MagnetoResistance (TMR) technology, with integrated CMOS circuitry and an open-drain MOSFET switch.

Close spacing of the ten sensors results in a resolution of approximately 4mm, though this could be reduced further in future designs. Furthermore, with correct selection of the magnet, the response pattern of the sensors results in only one sensor operating at a time, simplifying the task of decoding the output from the resistor chain. Production versions would be built with surface-mount resistors, allowing a ring magnet to slide up and down the assembly.

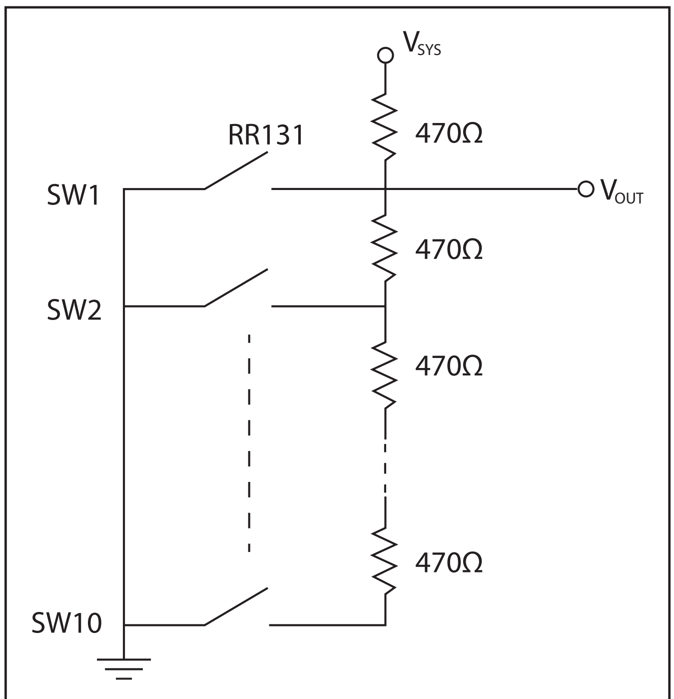

Fig. 2 Level sensor circuit schematic

The circuit schematic for the sensor assembly is shown in Figure 2.

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There are ten individual RR131 sensors whose open drain MOSFETs are sequentially shorted to ground through a chain of 470 ohm resistors as a magnet sweeps by each sensor in turn. Setting V_{SYS} to 3.0V results in the following values for V_{OUT} as each switch is successively turned on:

0.2810	1
1.6094	2
2.0625	3
2.3125	4
2.4513	5
2.5469	6
2.6094	7
2.6719	8
2.7188	9
2.7344	10

Fig. 3a Sensor assembly V_{OUT} vs. switch closed

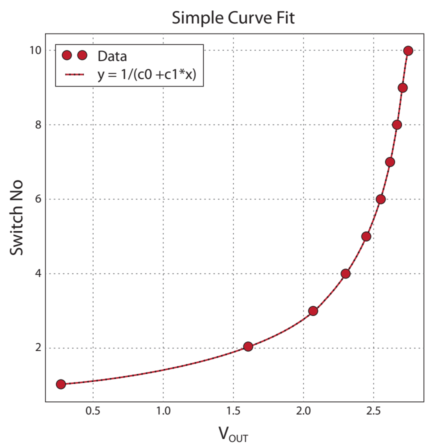

Fig. 3b Graph of data on the left

Since the curve can be fitted very accurately by a function of the form:

$$\text{Switch Number} = 1/(c0 + c1.V_{OUT})$$

the number of the switch that is closed (and therefore the level) can be predicted from the curve fit equation by inserting the value of V_{OUT}. The results are shown in Figure 4. After rounding to one significant figure, there is an exact one-to-one correspondence between the known and the predicted closed switch numbers.

0.2810	1	1.0501	1.0
1.6094	2	2.0322	2.0
2.0625	3	2.9842	3.0
2.3125	4	4.0244	4.0
2.4513	5	4.9900	5.0
2.5469	6	5.9776	6.0
2.6094	7	6.8663	7.0
2.6719	8	8.0654	8.0
2.7188	9	9.2808	9.0
2.7344	10	9.7719	10.0

Fig. 4 Prediction of switched closed from measured V_{OUT}

Note that, because of the significant ON resistance of the MOSFET switches, the values for V_{OUT} vs. switch number deviate slightly from what values would be expected if R_{ON} = 0 ohms. For example, V_{OUT} with switch #1 closed was measured at 0.2810 V corresponding to R_{ON} = 50 ohms. (The theoretical value is V_{OUT} = zero V for R_{ON} = 0 ohms.) The offset, which is due to finite values for R_{ON}, does not affect the utility or accuracy of the measurements, since the curve fitting compensates for finite R_{ON}.

Conclusions

1. A prototype method has been developed to sense level or distance using a chain of RR131 sensors.
2. With V_{SYS} and V_{DD} connected to the same source, this is a three wire solution (V_{SYS}/V_{DD}, ground and V_{OUT})

