Uncovering flaws in capacitive level sensors

To improve their dialysis machine, Baxter wanted to implement capacitive level sensors. Two sensor models were suggested and a deep dive revealed some major flaws in one of them.

Whenever it comes to medical engineering, the equipment needs to be reliable and work when the condition changes without compromising the patient. When Baxter in the next generation dialysis machine wanted to implement capacitive level sensors, an extensive evaluation of two sensor models began. The sensors function was to measure the liquid level in chambers where dialysis fluid is mixed and where air bubbles removed.

The two sensor models tested are *type A*, an in-house developed sensor, and *type B*, a sensor developed by a third party. A capacitive level sensor uses that air and liquid are able store different amounts of energy. The total difference of energy stored in a chamber can then be measured using various methods. The method used in type A is known, while type B is a so called *black box problem*, meaning only the output is known. There is however a key difference between the sensors that makes type B more suitable for implementation than type A.

One way of revealing the difference between the sensors is to measure different liquids, where the different liquids are able to store varying amount of energy. Type A sensors uses a method that measures the stored energy straight off and will therefore have different results for different liquids, even if the chamber is filled with the same amount. Much like if you have 1 kg cotton and 1 kg lead, and try to measure the volume of the object only by the weight.

Another method to uncover the difference between the sensor models is to see how they handle changes in temperature. A liquid that is heated will expand causing the liquid level to rise. In the same time is the ability to store energy reduced, causing type A sensors to believe there are lesser liquid in the chamber than before. The type A sensors will thus not only show the wrong measurement, the error will increase as the temperature rises!

Type B doesn't show problems with the measurements in the same way as type A, but the absence of knowledge about the model gives an unsettling feeling that problems may rise in the future. Problems that can't be anticipated and without solution. Type B is however build on a more stable foundation and is definitely worth the time spend on more tests to look at the durability and respond to change in climate.

The sensors used in the dialysis machine today are optical and magnetic sensors that can determine if the liquid level is high or low. Capacitive level sensors are able to measure everything in between, and if it the model can sustain 10 consecutive years of work, it will open up new control possibilities in the future.