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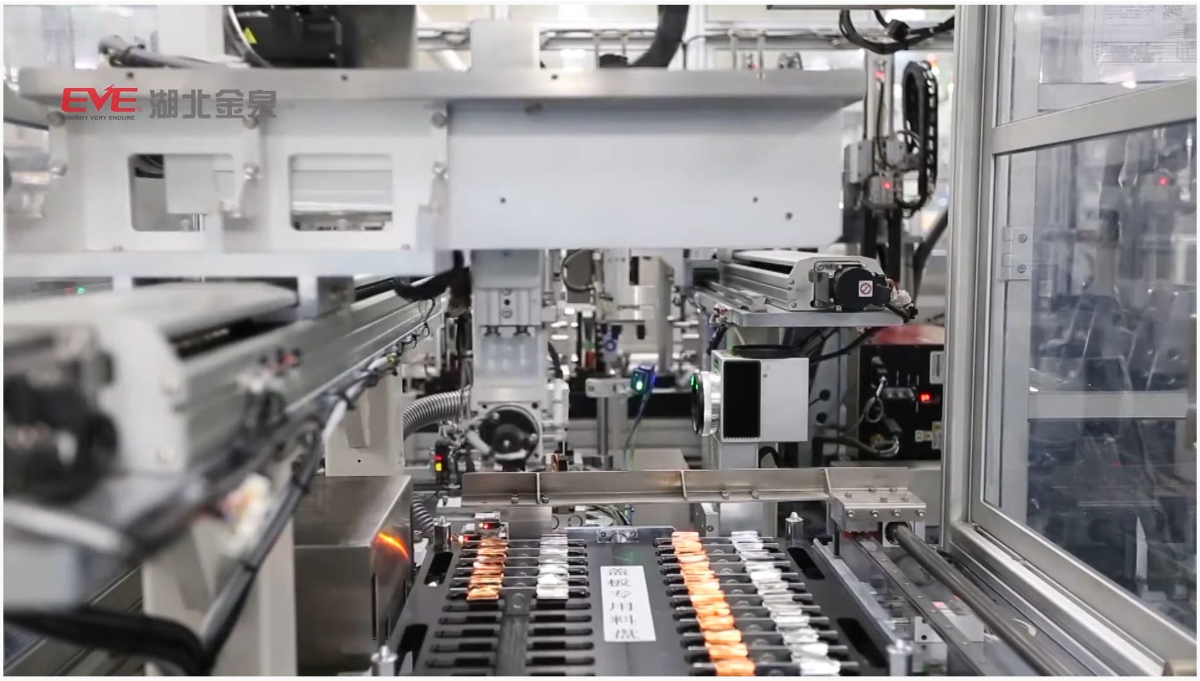
That's how the Contact Check function of HIOKI's DM7275 Voltmeter and SM711x Super Megohm series works

Working as an Application Engineer at HIOKI Europe I got asked by our Sales guys how the Contact Check function of the DM7275 voltmeter works, which by the way is used in production and characterization of lithium ion batteries. Here is what I found when I took a closer look in to feature.

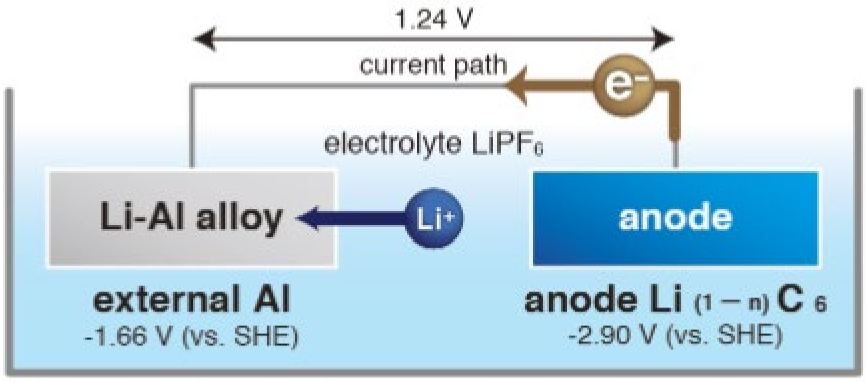
Apparently, there are not many devices available on the market for this particular application: During production of lithium ion batteries the cells need to get tested in rather high frequency at the end of an assembling line. To get started, check out this video on how a lithium ion production looks like:



https://www.youtube.com/watch?v=EV4cc889qcA&feature=emb_logo

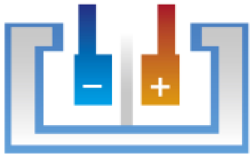
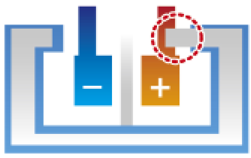
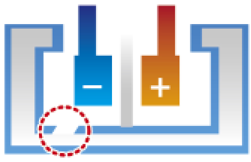
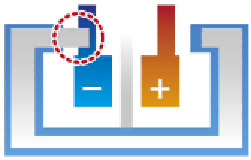
You might have noticed the high throughput on this video and it's quite obvious that testing the quality of the batteries needs to be done within a fairly short time. The 18650 type cells shown in the second part of the video are usually tested with normal insulation testers before filling in the electrolyte. However, especially the so called flat pouch cells in the first part have special quality requirements since they're commonly used in big battery packs in the automotive industry. Here the Contact Check function comes into play. But first lets elaborate on the background of this quality check in more detail...

For the preservation of the battery as well as safety of the cells, the insulation of the negative electrode towards the aluminium encapsulation is the most crucial. This is due to the difference in electrochemical potential which leads to corrosion of the aluminium in case there's both a short cut from the electrode to aluminium and at the same time a breakage of the aluminium coating which isolates it from the electrolyte:



[insulation defect between the negative electrode and the enclosure aluminum]
aluminum reduced and Li-Al alloy generated

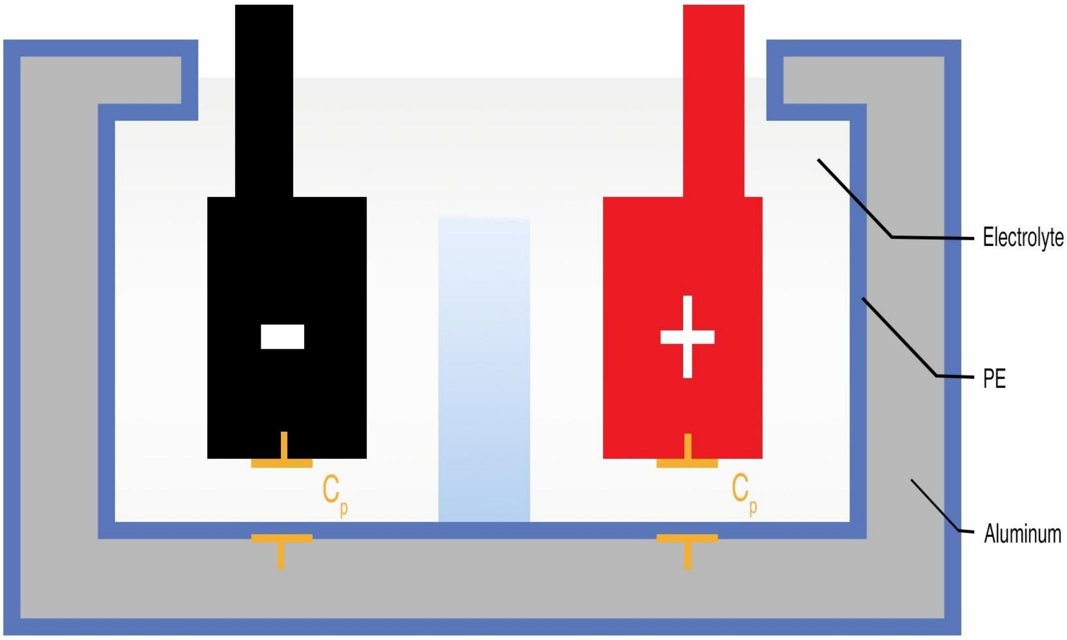
As the electrolyte has a substantial part, this test can only be done after the filling process. However, using a common insulation tester with high voltages might cause decomposition of the electrolyte and thus, damage the battery. Therefore, measuring the electrical potential from positive electrode to pouch is the only way to effectively identify this error. This potential should usually be around 0V for a battery which can get considered non defective. If an insulation as described above occurs it will rise to a higher value which you can see in this table:

	Defect location	Cause	Phenomenon	Pass/ Fail	Enclosure potential	Test method
(1)	non-defective 	-	-	Pass	unsettled (0V)	-
(2)	between positive and negative electrode 	Puncture of separator by dendrite Contamination with metallic particles Winding defect	Increase in self-discharge Abnormal heating	Fail	unsettled (0V)	Insulation resistance
(3)	Between positive electrode and enclosure aluminum 	Contamination with metallic particles Enclosure seal defect	No impact on battery characteristics	Pass	0V	Enclosure potential
(4)	Between electrolyte and enclosure aluminum 	Cracks in insulating coating	No impact on battery characteristics	Pass	~2.6V (= +0.9 - (-1.7))	Enclosure potential
(5)	Between negative electrode and enclosure aluminum 	Contamination with metallic particles Enclosure seal defect	Degradation progresses (if cracks develop in the enclosure aluminum's insulation coating)	Fail	~3.8V (= +0.9 - (-2.9))	Enclosure potential

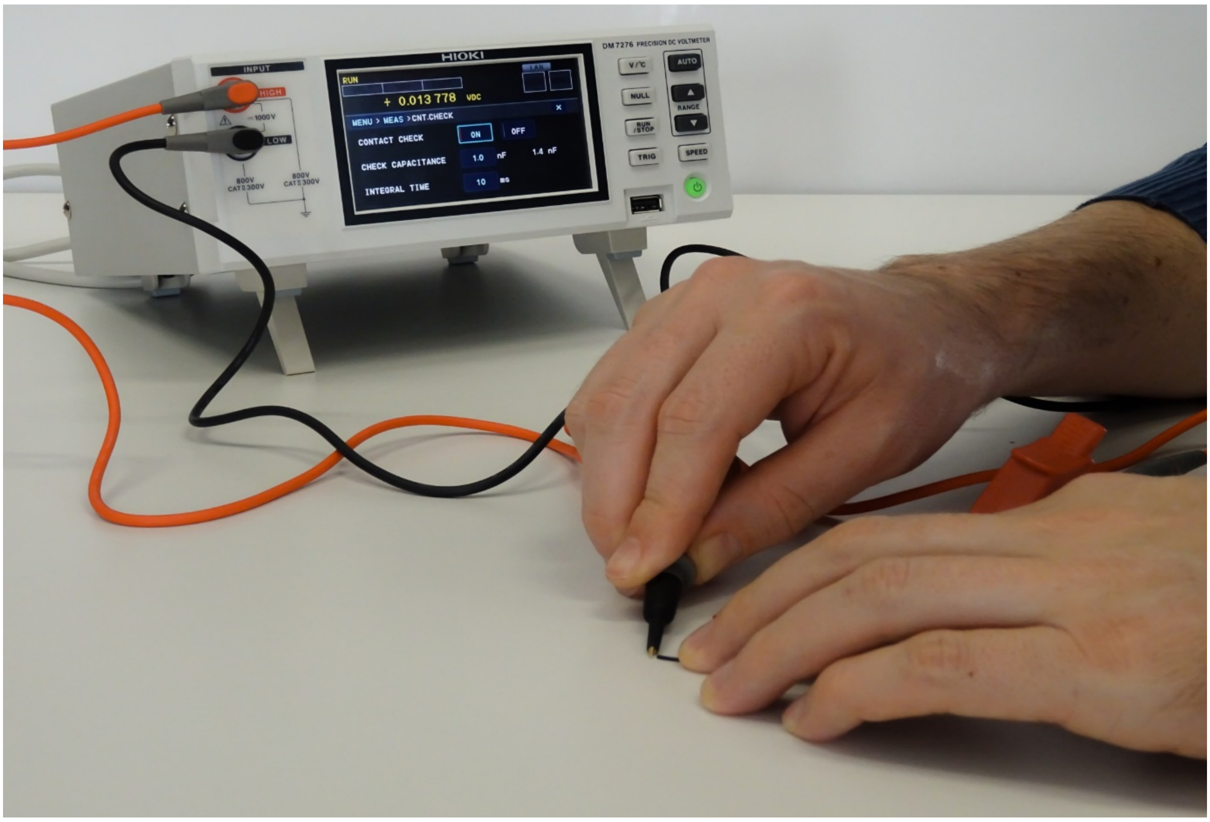
(Actually, the potential for a non defective battery is undetermined from each of the electrodes to aluminium since there's no electrical connection. As this is quite unpractical during testing usually an input resistance is used with a resistance in the range of several MΩ to GΩ. By doing that the measured voltage becomes 0V)

So far, so good! During the quality check the situation now gets a bit more complicated: As mentioned before, you need to establish the electrical contact from the probes to the respective metal part within a fairly short amount of time. Additionally, the aluminium encapsulation is coated with a non-conductive protection layer. If that connection can't get established properly the reading of the voltmeter will be 0V as well. Consequently, in that case a possibly bad battery might get rated as good simply because the electrical contact wasn't established.

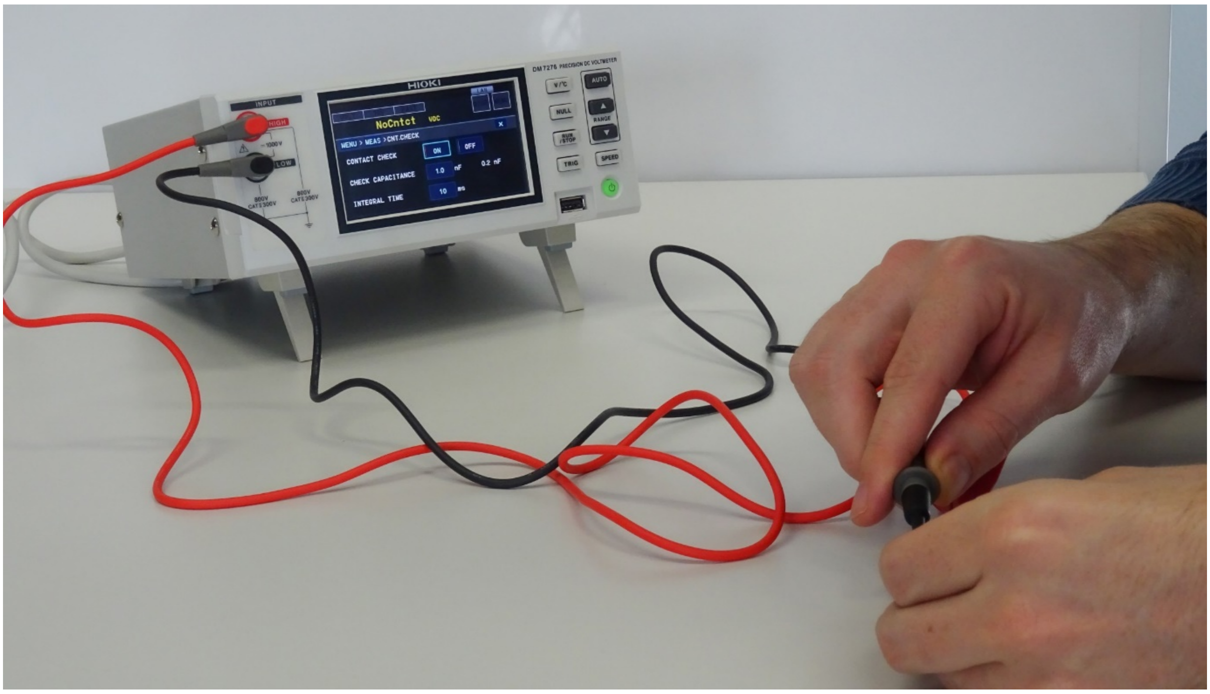
And here the Contact Check function becomes important: Lucky for us the rather big area of the aluminium pouch which is isolated from the active parts inside the cell forms a small capacity. During contacting of the cell this capacity is charged (actually, as I understood it the capacity is rather a result from some kind of an equalizing current).



That capacity - usually in a range of a few nF - is measured and displayed by the DM7275. If not contacted well, the capacity readings would be somewhere around 0 nF. If an electrical contact is established it would be noticeably increased. On the pictures below you can see what that looks like on the display of the DM7275. Here the voltage from pouch to negative electrode is close to 0V and the measured capacity is 1.4 nF. As a result the cell is contacted well (here I set 1.0 nF as a threshold):



Without a proper contact I only got 0.2 nF and therefore "NoCntct":



In a production some experience is needed to identify the right threshold but once it's done the reliability of a quality check can be highly improved using that function.

I just found this video made by my colleagues at HIOKI headquarters in Japan at which they assemble a battery using only aluminium and copper foil, a separator, and salt water measuring the contact check capacity of that. If you're not scared off by the background music I recommend watching it - even if just to appreciate the lovely test setup my colleagues created:

https://www.youtube.com/watch?v=JX4IabEQK1Y&feature=emb_logo

While writing this article I've been thinking of possible further use of measuring this capacity and came to those:

- Testing the electrolyte filling process: If the electrolyte doesn't moisten the whole electrode I would expect to find effects on the capacity. In general, issues affecting the dielectrical strength in between the aluminium pouch and outer electrodes should be somehow affect the capacity readings. That could e.g. be a blister in the electrolyte or other inhomogeneities.
- Average "thickness" of the capacitor: Since the capacity is dependent on the distance of the dielectric separator. I wonder if this can be used to detect issues in the homogenity of the base material received from the suppliers.
- In general it would be interesting to track the measured capacity and do a statistical evaluation on those values. However, I'm not sure what to expect from that. But in any case it's going to be interesting...

You're most welcome to share your opinion on the three points above and send me further suggestions. As I'm not working in the lithium ion battery production, if you have better insight I appreciate any feedback. Feedback on the article is also highly appreciated. Thank you for reading.