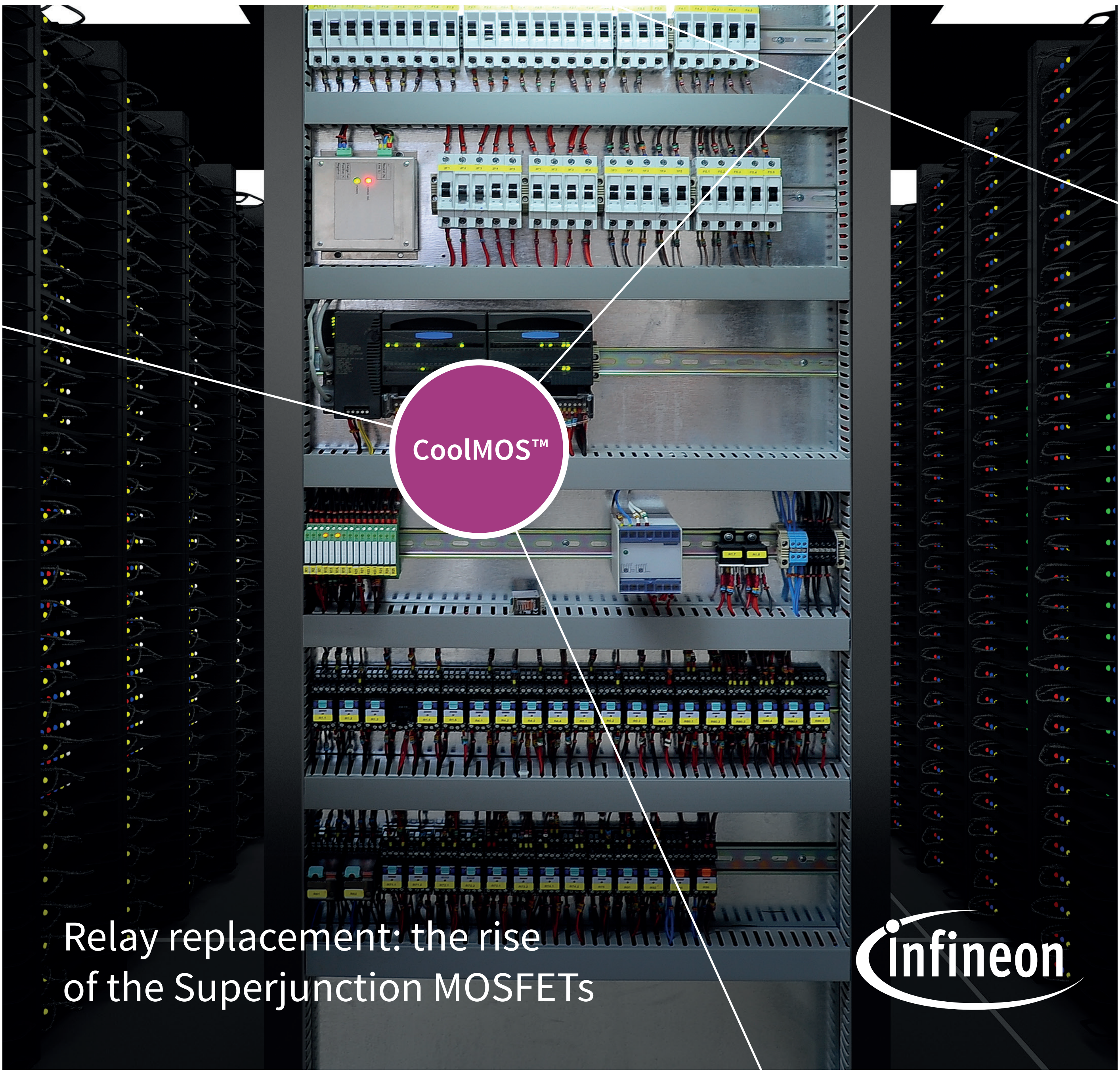
PSD EUROPE

Information to Power Your Designs

November 2019




Special Report: IoT + Wearables (pg #)

# Moving from Electromechanical to Solid-State in Relays and Circuit Breakers

## As a mature technology, however they continue to suffer from some inherent weaknesses

By: Giovanbattista Mattiussi, Product Marketing Manager, Infineon Technologies

As a mature technology, electromechanical relays and circuit breakers are well established, however they continue to suffer from some inherent weaknesses. Moving to solid-state technology can address these but introduces its own challenges. So, what is the right solution?

**Contacts conditions after 3 interruptions of 10 kA current**

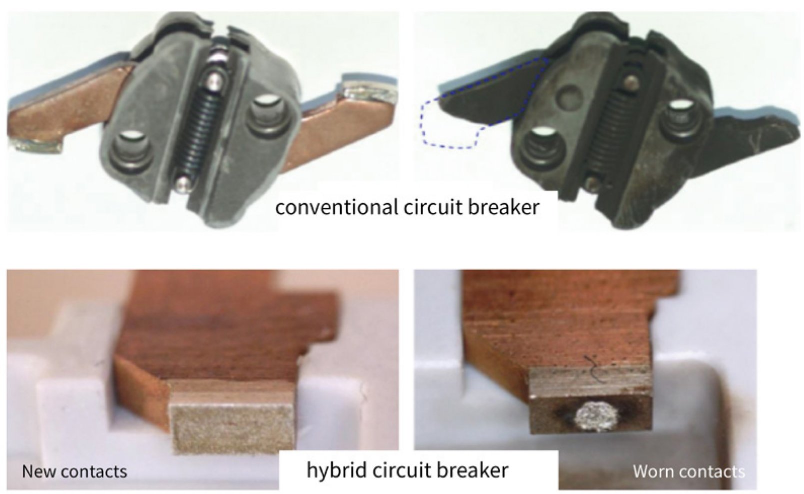



*Figure 1: Contact wear in an electromechanical relay (courtesy of Eaton Corporation)*

In the movies, whenever the lights go out or power is lost in a dramatic way, it is normally accompanied by a loud and helpful 'clunk' on the soundtrack, just so the viewer understands exactly what's happened. In general, that is an accurate representation because high-voltage relays and circuit breakers are still largely electromechanical in nature. Apart from the legacy associated with using electromechanical solutions, the prevailing opinion in the engineering domain is that semiconductor technology is inappropriate for high-voltage switching applications. However, recent technological developments are helping to change the facts that influence this impression, as we explain here.

**Electromechanical versus solid-state**

As a foundation for that explanation, it is worth reviewing what an electromechanical relay or circuit breaker is and how its solid-state counterpart is developing. The noise associated with an electromechanical solution comes from the physical nature of the relay; using electromagnetism to attract/repel metal contacts which move at speed.

The amount of mechanical movement involved could be seen as a point of failure and, in practice, it is, but the main point of fatigue will likely be the surfaces of the contacts, as the high voltages they pass can arc as they come into close proximity, jumping the airgap before full contact is made.

The same phenomenon is present when the contacts are forced open. The main point to appreciate here is that the voltage, whether AC or DC, is present at the contacts during actuation. If no provision for zero voltage switching (in the case of an AC voltage) is made, there will likely be arching every time the relay is activated. This can rapidly degrade the contacts and even cause them to fuse together. Even in less extreme cases, the resistance between the contacts is likely to increase over time and with use, causing their behaviour to become unpredictable.

Ultimately, the fatigue endured due to wear and usage is likely to lead to failure. This results in the manufacturer giving a finite lifetime for the device.

Similarly, an electromechanical relay can suffer from contact bounce, in the same way a low-voltage switch might. However, when switching high voltages, debounce is less easily implemented.

Solid-state switches, on the other hand, will often implement zero voltage switching to ensure the device starts conducting when the voltage (or current, which is likely to be out of phase with the voltage) is at its lowest. Even when working on DC voltages and currents, the switch-on time is more easily controlled with a solid-state switch. The aim here is to avoid inrush currents that may cause other systemic issues, but

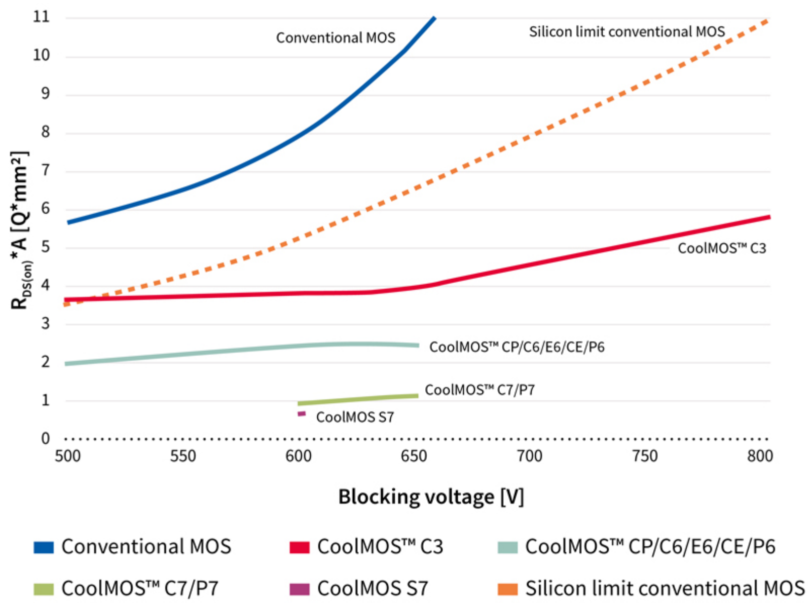



*Figure 2: $R_{DSon}$ x A improvement in Superjunction MOSFETs over time*

the net effect is the relay or circuit breaker is much more reliable over its entire lifetime which, incidentally, is likely to be much longer than an electromechanical alternative.

There are good reasons why engineers still favour an electromechanical option and they are mainly related to cost, performance and functionality. In the case of cost, it is fair to say that a solid-state option will command a higher price than an electromechanical relay or circuit breaker, however when considered over the lifetime of the application and the Maintenance, Repair and Operations (MRO) cost associated with the function, an argument can be made for using solid-state. This is largely based on total system cost, weighed against the expected lifetime; an electromechanical relay may have an operational lifetime measured in the low hundreds of thousands of operations, while a solid-state relay's lifetime would be measured in the tens of millions.

Furthermore, the industry is approaching a point where it could offer price parity between the two technologies. While there is some innovation taking place with electromechanical designs, this is only helping to maintain the average selling price or, more realistically, increase it. Meanwhile, the average selling price of a solid-state solution is on a downward curve.

In terms of performance, the parameter that is most often cited is power loss due to the resistance of the conduction path. For an electromechanical device, this resistance will initially be low but inevitably increase over time, due to the reasons outlined above. For

present, thereby extending its useful lifetime.

Of course, there are many applications that do not require galvanic insulation. Also, existing regulations applicable to circuit breakers still assume an electromechanical device is being used and so do not fully consider the superior performance that solid-state offers. Once the regulations catch up with technology, they may well become less stringent in terms of the galvanic insulation requirements, depending on the application

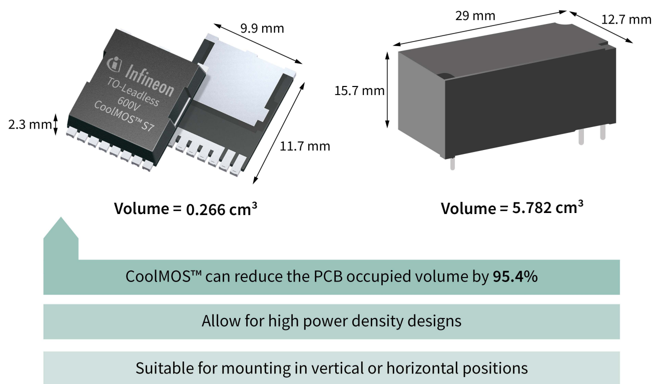



*Figure 3: Solid-state relays provide significant reductions in volume*

a solid-state solution, the power losses experienced are directly related to the on-resistance, which is defined by the type of semiconductor used and the size of the power transistor's channel; both these features influence the cost. While the on-resistance isn't subject to change over the lifetime of the device, it is finite and subject to the design requirements. Ideally, the conductions losses and the semiconductor cost should both be low, and can be summarised by the figure of merit, referred to as the on-resistance by area, or Rds(on) x A. This is a major focus for semiconductor manufacturers, and something Infineon has addressed through its CoolMOS™ technology platform, as explained in more detail in the next section.

An additional concern is safety. Solid-state solutions switch significantly faster than an electromechanical device, as there are no moving parts. While faster response times are clearly advantageous, this comes with the disadvantage of not having any physical disconnection between the input and output. In many applications where human contact with the machine is possible, safety regulations will specify galvanic insulation between the high-voltage input and the output.

Galvanic insulation is most frequently implemented as an airgap, or a physical space between conducting elements. This remains one area where solid-state technology is at a disadvantage, however it has given rise to the concept of the hybrid circuit breaker or relay, which uses a solid-state device to switch the high voltage and a smaller, lower cost electromechanical relay to provide the galvanic insulation at the output, which can be switched when no voltage is

### The rise of Superjunction MOSFETs

Solid-state switches are implemented using transistors realised using a semiconducting substrate. To date the most widely used substrate is silicon, but the transistor configurations vary. For AC switching, particularly when implementing zero voltage switching, the Triac (or silicon-controlled rectifier, SCR) is the favoured device. MOSFETs constructed in a planar topology are commonly used for switching DC voltages, while IGBTs can and are used for both AC and DC switches.

However, all of these approaches incur losses due to the on-resistance of the channel, as explained earlier. These losses manifest as unwanted heat which must be dissipated, and that invariably leads to the use

of a heatsink, requiring more space and an increase to the Bill of Materials.

A Superjunction MOSFET goes beyond the planar – or 'flat – manufacturing process based on a single p-n junction, to a structure that features multiple, vertical p-n junctions. As a result, the on-resistance is 'shared' across multiple parallel paths, which has the effect of lowering the overall on-resistance. Infineon has been a pioneer of the Superjunction MOSFET since the 1990s and has continued to develop the technology over all that time. It offers significant benefits when compared to other transistor topologies, specifically in the area of on-resistance by area. This leads to commensurately lower losses, which means it not only becomes more affordable but also allows it to be used in applications that are switching higher voltages and current, without the need for heat dissipation.

With its CoolMOS™ 7 technology, Infineon is leading the $R_{DSon}$ x A race. Infineon is also about to release a new technology – the CoolMOS™ S7* – which promises to deliver even lower $R_{DSon}$ x A and to successfully trade off switching losses for lower on resistance. In solid-state relay and circuit breaker applications, this perfectly matches the performance to the requirements, as relays and circuit breakers are not required to switch at high frequencies.

**Conclusion**

Using a solid-state device in a relay or hybrid circuit breaker has many benefits; it offers significantly faster switching times, eliminates arching and the noise associated with electromechanical devices, it is inherently more reliable and predictable, while delivering much longer lifetimes. Developments such as the CoolMOS™ 7 solution from Infineon are addressing the disadvantages that have traditionally limited its use.

The latest Superjunction MOSFET platform from Infineon is providing a breakthrough in solid-state relay and smart circuit breaker design. It offers an unprecedentedly low $R_{DSon}$ x A figure of merit at a price point that will meet the needs of designers and their end markets. What's more, a solid-state relay will be far smaller than an electromechanical alternative, leading to a reduction in volume of over 95%.

Superjunction MOSFETs are just one example of the broad range of products Infineon offers, addressing the need for more innovation in the power domain. Solid-state relays and solid-state circuit breakers are becoming increasingly viable thanks to developments like CoolMOS ™ 7. Infineon has a long heritage of innovation and will continue to develop and deliver solutions that provide more for less.

Infineon Technologies
www.infineon.com/coolmos