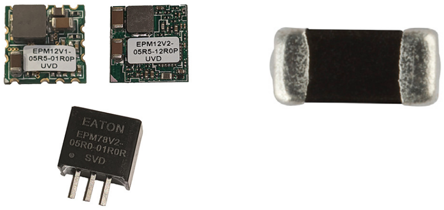
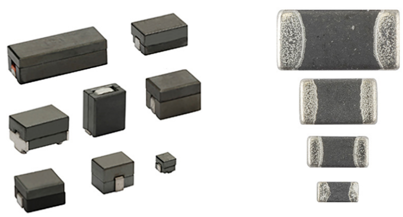
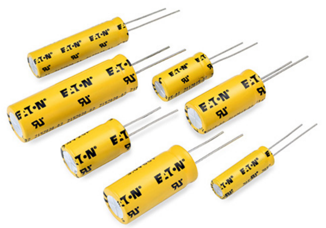
High reliability electronics enhance 5G communications







Introduction

The advent of 5G connectivity for vehicles, robotics, and drones is creating new markets and applications previously only seen in science fiction movies. Something these movies rarely succeed in capturing is the engineering effort needed to ensure reliable connectivity and operation of communication links. The latest 5G systems will need telecommunication units and boosters, or 5G Repeater Box units, distributed throughout environments and even onboard vehicles (in cases where the communication link to 5G base stations isn't reliable due to interference or the inability to place 5G base stations in closer proximity). Given the rugged environments these 5G telecommunication units will be placed in, continuous uptime requirements for their operation and reliability of the internal electronics and systems is of the utmost importance.

This whitepaper discusses several of the engineering challenges associated with ensuring the reliability of a 5G radio link for automotive and industrial applications, as well as available electronic components and devices useful in achieving these new stringent reliability requirements.

5G Radio link vulnerabilities and failure

5G radio communications hardware is a mix of analog, digital, RF, and power hardware and is usually an assembly of a variety of boards, packaged components, and interfaces. The main components are the power supply unit, digital board(s), RF transceiver board, and network interface (which is more commonly an optical interface). Each of the boards connect through an interconnect interface with each other, and they often have expansion boards, daughter boards, or other auxiliary/accessory components interfacing with the primary boards.

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Each of these boards and accessories are subject to faults and electromagnetic interference (EMI). ESD is typically only a concern for parts of the assembly that interface with external components, but static charge may also build up within an assembly housing given the right conditions. The primary hardware segments of 5G systems also typically require several voltage rails, from 48 volts down to around 1 volt, depending on the requirements of the field programmable gate arrays (FPGAs), CPUs, or application-specific integrated circuits (ASICs). Any faults or irregularities in the main power supply, often AC from the electrical grid or off-grid power inverters, can result in surges or low voltage/current conditions, which can empare communication link operation or even damage hardware components.

Typically, the digital boards are the most sensitive to power faults and fluctuations. These boards often have DC/DC converters internally to handle input voltage rails and to supply the multitude of voltage supplies to the various digital subcircuits. Hence, PSU faults that result in voltage rail destabilization can lead to fault conditions within the DC/DC converter if not properly protected. Moreover, any outdoor 5G system is in threat of EMI from lightning strikes or electromagnetic pulse (EMP) from natural sources (solar flares) or intentional EMI from malicious actors. EMI and EMPs can result in overvoltage or overcurrent conditions, which may damage the PSU or even penetrate within the 5G subsystem circuits themselves. The sensitive electronics within the digital boards at the input of the RF transceiver boards are generally the most susceptible to external EMI, and benefit from additional protections at their ports.

Reliability of 5G communication systems

Fortunately, there are a variety of components, often passives, that can be readily added in key locations within a 5G communications system to enhance its reliability and mitigate sensitive subcircuits susceptibility to ESD, EMI, and EMP.

Supercapacitors help eliminate power faults and provide ride-through power for telecom systems

Supercapacitors can store electrons in an extremely dense electric field. This allows supercapacitors to charge and discharge extremely quickly compared to conventional battery technologies, including lithium-ion chemistries. Though supercapacitors aren't as energy dense as the latest battery technologies, they respond in milliseconds or less to changes in supply voltage conditions. The result is that a supercapacitor sized for the application can respond quickly enough to mitigate voltage drops in even fast transient voltage conditions. Given a large enough rated supercapacitor, such a protection device can also provide ride-through power for the seconds needed to engage backup power supply systems, which prevents a low voltage condition or abrupt shutoff that could result in damaging voltage/current surges within a 5G communications system.

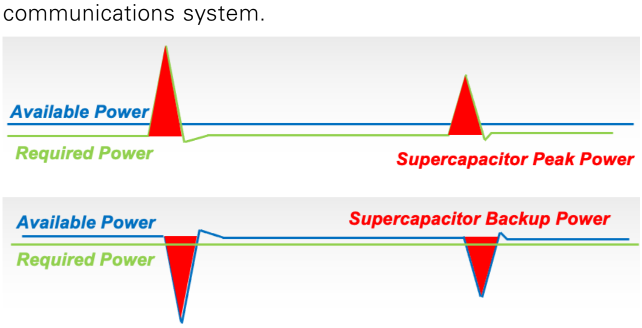

Figure 1: Eaton supercapacitors provide peak and backup power.

Rugged power modules reduce power system failure

Not all PSU or power modules are designed with the same reliability and ruggedness in mind. Some power modules are designed to be rugged without the need for additional external parts or modifications by the user. Most require circuit protection additions to prevent faults to achieve a desirable level of reliability for 5G applications. With 5G vehicle-to-everything (V2X) and autonomous vehicle technology on the horizon, it is becoming increasingly crucial to have rugged PSUs and power modules that can ensure a stable power supply to diverse 5G systems.

Eaton offers DC-DC converter power modules, which have built-in short circuit protection to protect the module during overcurrent events.

Figure 2: Eaton Power Module (EPM) DC-DC converters.

Overcurrent and overvoltage protection devices mitigate power supply issues and battery system surges

Even the best PSU/power module may be subjected to voltage/current conditions at the grid connection that result in overvoltage or overcurrent conditions. These surges may even be carried on to the 5G subsystem boards through conductive enclosures or result in EMI that is conducted to subcircuits within the system. Hence, using circuit protection devices to protect the most susceptible parts of the 5G communication link circuitry is critical in ensuring 100% uptime and minimal system maintenance.

Overvoltage protection devices are commonly either surface mount components or through hole components for high power systems, that are directly designed into the subsystem printed circuit boards (PCBs), interface boards, or interconnect. For example, multilayer varistors (MLVs) can be designed into a circuit board as a reliable form of overvoltage protection. Other surface mount circuitry protection include MLV-based ESD protection, other low capacitance polymer voltage variable material ESD suppressors, and transient voltage suppression TSV diodes for ESD protection. These circuit protection devices are key in providing targeted protection to susceptible digital circuits and sensor/control subcircuits.

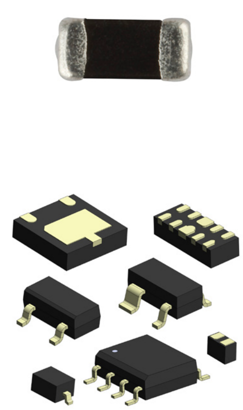

Figure 3: Top - Eaton Multilayer Varistors (MLV); Bottom - TVS diode ESD suppressors

Power inductors ensure smooth operation of DC/DC conversion circuitry

Flat-pac (FP) power inductors are ideally suited to providing voltage regulation, filtering, and energy storage in close proximity to the electronics they support. FP power inductors are compact surface mount components, and hence can be placed near leads or terminals to sensitive components, such as FPGAs, ASICs, CPUs, and RF/analog components. Of particular use in 5G systems, is the use of FP power inductors to provide voltage regulation and filtering of DC/DC conversion circuitry providing voltage rails for various digital, analog, and RF circuits.

Figure 4: Eaton FP inductors.

These DC/DC converters are most likely switching converter typologies, which intrinsically introduce switching transients and noise into the voltage rails they provide. With power inductors placed near the DC/DC converter voltage rail terminals, these transients can be suppressed before there is a chance for them to be electrically or magnetically conducted into sensitive circuits. Another option for Point-of-load (POL) converters are EXL inductors, as these inductors exhibit high power density and low DCR. Hence, EXL inductors can be used to improve reliability and efficiency of POL converters.

Ferrite beads minimize high-frequency electrical noise in EMI-sensitive 5G devices

Along similar lines as surface mount power inductors, ferrite chip beads in very close proximity to the sensitive 5G transceiver circuitry, such as the low-noise amplifiers (LNAs), can help to ensure threats from EMI are mitigated. As EMI can enter along any unshielded conductor, using a larger footprint throughhole or connectorized ferrite beads may allow for EMI to have a viable path of entry into a sensitive circuit that the designers may think is protected. With ferrite chip beads, the EMI circuit protection can be applied right at the terminals to the most sensitive components, minimizing the threat.

Figure 5: Eaton ferrite chip beads.

Conclusion

For 5G systems to be reliable, additional steps are needed to ensure the power rail to the 5G unit is prevented from dropping low, the power supply unit is protected, onboard DC/DC converters within the unit are protected, and that the 5G transceiver is resilient to ESD and EMI. There are several varieties of surge protection/suppression and circuit protection, as well as supercapacitors that are ideal for providing enhanced protection and reliability to 5G systems even in remote and extreme environments.

Resources

- Eaton circuit protection
- Eaton DC-DC converters
- Eaton magnetics (inductors & transformers
- Eaton overvoltage protection
- Eaton supercapacitors

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