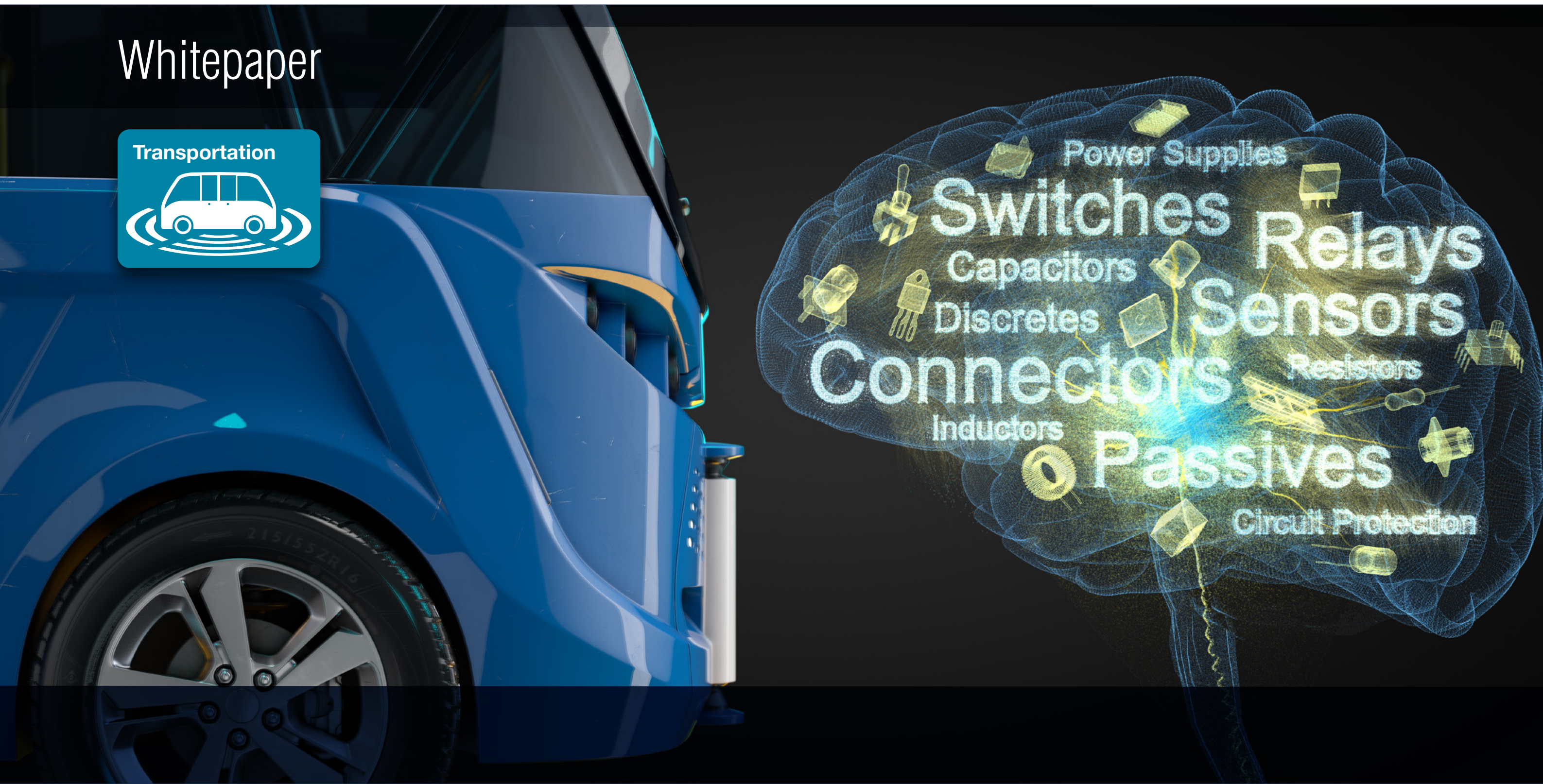
Whitepaper



Specifications and standards for electronic components used in PHEV/EVs

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Executive Summary

Designing electronic components into automotive applications requires the parts and the supplier to hold qualifications. For parts, there are many standards relating to stress testing and safety, generated by automotive organisations and international agencies. For suppliers, quality management systems are mandatory. This whitepaper explores the standards and quality systems and how they relate to particular components.

Introduction

Manufacturing and delivering electronic components into the automotive industry requires a commitment to quality and value at the highest levels. Standards exist for the stress testing of products, defined by organisations such as the Society of Automotive Engineers (SAE) and the Automotive Electronics Council (AEC) along with international agencies such as IEC and ISO. AEC standards in the AEC-Q series for passive and some active components and modules are seen as the minimum requirements for component stress testing but have several grades depending on the application within the vehicle. Some components such as charging connectors have established functional specifications defined by IEC standards. Additionally, all components may be subject to EMC testing, typically at least ESD, with IEC standards often used, along with automotive-specific requirements such as those defined by ISO 11452. Components such as opto-isolators and transformers are sometimes used for isolation to prevent electric shock and need to comply with standard ISO 6469 in this application. An additional 'qualification' is for the supplier to hold certification to the automotive quality management system IATF 16949:2016. With these hurdles overcome, the quality and reliability of modern vehicles is assured with world leaders in component supply successfully competing for business direct and through distribution.

BMW say that their suppliers must have 'Benzin im Blut' or 'Petrol in the blood'. This sums up the dedication expected from automotive market suppliers, delivering components and modules which are innovative, premium quality and competitive while upholding their environmental and social responsibilities. It's a tough challenge but OEMs like BMW increasingly cooperate with suppliers, sharing risks, and partnering to achieve optimum solutions through established standards.

Identifying automotive specifications and standards

The Society of Automotive Engineers (SAE) [1], around for more than 100 years, has a large set of standards covering all aspects of car component design and test, with some reaching down to electronic component level. These relate mainly to testing methods but include guidelines on subjects like EMC, derating and even precautions against the introduction of counterfeit parts. The SAE documents interlock with IEC/ISO standards: for example, in the area of EV safety, IEC EN 62660-1&2 and IEC EN 61982-2&3 for Lithium-ion cell testing; IEC 61851 for conductive charging systems; ISO 6469 for general EV safety and IEC 62196 for plugs and sockets.

Of course, electronic components are an increasing feature of car design. We are a long way from the first 'solid state' ignition timing and gear shifting of the 1970s with modern EVs said to have a more than $1000 value of just semiconductors built in [2]. The number of passive components, when you consider all the infotainment and connectivity functions, runs into many tens of thousands with just Multi-Layer Ceramic Capacitors (MLCCs) topping 18,000 in an EV [3].

Ironically, the automotive manufacturing industry in the '90s felt they were not getting sufficient attention from electronic component suppliers due to their relatively small demand, so OEMs Chrysler, Ford Motors and Delco Electronics set up the Automotive Electronics Council (AEC) [4] to establish a common series of standards for the quality and qualification of automotive electronics. Initially, the AEC also involved itself in quality system specifications, but later this was ceded to the International Automotive Task Force (IATF) and the International Standards Organisation who now manage the process-oriented quality standard IATF 16949:2016, based on enhancements to the general industry standard ISO 9001:2015.

AEC-Q standards are for stress testing

In the case of electronic components and some modules, the AEC has generated the familiar AEC-Q series of standards which, however, define methods of stress testing rather than functionality. Stresses considered are not just environmental though: electrical and mechanical tests are included, along with the requirement to consider EMC effects as necessary. A common feature to all of the standards is the temperature grading for different automotive environments (Table 1).

Table 1: AEC temperature grades for automotive environments

Grade	Ambient Operating Temperature Range	Typical Application
0	-40°C to +150°C	All automotive
1	-40°C to +125°C	Mostly under-hood
2	-40°C to +105°C	Passenger area hotspots
3	-40°C to +85°C	Passenger area general

The current AEC-Q standards are:

AEC-Q100: a base standard covering stress test qualification of integrated circuits and giving the general principles. Sub documents AEC-Q100-001 to 012 deal with specific tests including wire bond and solder ball shearing to ESD and short circuit performance of smart power devices.

AEC-Q101: a base standard and sub-documents 001 to 006 dealing with testing of discrete semiconductors with a similar range of content, again including ESD and wire bond shear testing.

AEC-Q102: exclusively for opto-electronics. High temperature operation of these devices is a particular emphasis in tests due to the inherent limitation of opto-electronics in this respect. The common environmental, mechanical and ESD tests also apply.

A new standard released in September 2017, **AEC-Q104**, covers 'multi-chip' modules with active and passive components combined into a single package for reflow solder attachment to a printed circuit board. Power modules are still deemed to be outside the scope of the standard, typically requiring agreed, extra test procedures.

AEC-Q200 and sub-documents 001 to 007 for passive components covers a wide range of parts and their tests. Again, the application is graded according to temperature (Table 2). Note that grade '0' parts are specified to +150°C, 10 degrees higher than for integrated circuits.

Table 2: AEC qualified component temperature grades

Grade	Ambient Operating Temperature Range	Passive Component Type	Typical Application
0	-50°C to +150°C	Flat chip ceramic resistors, X8R ceramic capacitors	All automotive
1	-40°C to +125°C	Capacitor Networks, Resistors, Inductors, Transformers, Thermistors, Resonators, Crystals and Varistors, all other ceramic and tantalum capacitors	Mostly Underhood
2	-40°C to +105°C	Aluminum Electrolytic capacitors	Passenger area hotspots
3	-50°C to +85°C	Film capacitors, Ferrites, R/R-C Networks and Trimmer capacitors	Passenger area general

It should be noted that the AEC-Q standards are not used by test agencies to qualify components; they are for 'self-certification' by suppliers to prove compliance. Also, the standards are 'base level' with individual automotive customers at any tier possibly imposing further component qualification requirements for their particular application. While there are many tests specific to automotive, the AEC-Q standards also refer to documents from other sources for general testing such as MIL-STD-883, JEDEC, JESD, IPC and UL. The AEC-Q standards themselves are free to download [5].

Components qualified to the appropriate AEC-Q standard are not necessarily different in construction to 'commercial' parts. Parts rated to 85°C maximum would be commonly used in non-automotive applications, but the AEC-Q qualification at grade 3, in table 3, ensures a higher level of quality from an enhanced screening and testing process at the manufacturer. The extra steps might include increased test sample size at temperature, humidity and voltage bias, 100% vision inspection and enhanced physical testing and lot sizes.

Mindful of the overhead of comprehensive testing, AEC allows the use of manufacturers' generic qualification data for families of components, accumulated from field data and internal qualification testing. Definitions of 'family' and lot and sample sizes are carefully defined though, so that risk is minimised. As AEC-Q qualification testing need only be performed once, there is a strict requirement that the manufacturing process is adequately controlled to maintain quality and stress tolerance of components. Evaluation parts must be manufactured using production tooling and operatives, with samples from non-consecutive lots. Production changes inevitably occur though, and depending on the scale, different requalification levels are required according to the Product Part Approval Process (PPAP) [6], developed by the Automotive Industry Action Group (IAG) [7]. Table 3 summarises the five levels of part and data submission requirements for increasing severity of changes.

Table 3: Product Part Approval Process levels

PPAP Levels	PPAP Submission Requirements
1	Product Submission Warrant only (and for designated appearance items, an Appearance Approval Report) submitted to customer
2	Product Submission Warrant with product samples and limited supporting data submitted to customer
3	Product Submission Warrant with product samples and complete supporting data submitted to customer
4	Product Submission Warrant and other requirements as defined by customer
5	Product Submission Warrant with product samples and complete supporting data reviewed at organization's manufacturing location

Some components have functional automotive specifications

While general purpose components such as resistors, capacitors and discrete semiconductors have AEC-Q standards controlling qualification testing, their functionality is not defined and it is up to the automotive equipment designer to choose the correct part for the application. Some components though, such as connectors, have specific standards relating to their practical performance and form factor. The connection to an external charger in an EV is an example, where a 'Combined Charging System' or CCS was proposed in 2011 for a standardised single connector pattern to be used worldwide. The standard is now formalised under IEC 62196 'Plugs, socket-outlets, vehicle connectors and vehicle inlets – conductive charging of electric vehicles'. The connectors are of four variants: Type 1, Type 2, Combo 1 and Combo 2 which together cover all options for AC single-phase, AC three-phase and high voltage DC fast charging. CCS is being promoted by an association of car makers, suppliers and interested parties 'CharIn' but there are rival connector standards: CHAdeMO in Japan and GB/T in China. Connectors also need to conform to the standards for 'ingress protection' or IP, typically IP44 (mated) for external charging and IP67 for connectors internal to the vehicle. IEC 61851 also applies with requirements for 'conductive connection to charging supplies for electric vehicles'.

Another grouping of car manufacturers; Audi, BMW, Daimler, Porsche and VW have cooperated to produce 'LV' standards for connectors in automotive applications. LV-214 is an example, which includes the definition of performance of cable crimps in harnesses such that crimp force monitors and other tests can differentiate between 'good' and 'bad' connections. Faults which must be detectable include 'empty' crimps, missing wire strands and insulation in the conductor crimp area. LV 215 addresses the requirements for automotive high voltage connectors in different power categories with specifications for functionality, safety and reliability.

ZVEI, the German Electrical and Electronic Manufacturers' Association, has an automotive action group which is closely involved in the standards with committees in various working areas (Arbeitskreiss – AK) including connector contact validation and processing.

Automotive EMC standards

Electromagnetic compatibility in vehicles is of prime importance and there are many standards generated by SAE, ISO and CISPR which are relevant, along with specific OEM requirements. Each standard cross-refers to others and will often be based on international norms such as the IEC 61000 series covering all types of immunity and emissions. An important standard is also ISO 11452: 'Component Test Methods for Electrical Disturbances In Road Vehicles', a collection of sub-standards covering immunity to radiated and conducted interference, specifically for vehicles. EMC requirements for EV charging systems are also referred to in IEC 61851. EMC standards generally relate to complete products although sometimes they can be applied to sub systems or modules. Tests can also be relevant to electronic components, for example ESD immunity where high voltage contact and air discharges are applied, even to humble resistors, to ensure there is no degradation.

Safety

Many electronic components will play a role in electrical safety in EVs; high voltages are present and insulation systems must be suitable to prevent electric shock. Some components such as opto-isolators and transformers have the prime function of electrical isolation and must be rated appropriately. Standard ISO 6469: 'Electrically propelled Road Vehicles' is a collection of 4 documents addressing electrical safety of the energy storage system and protection against electric shock generally in normal and crash conditions. Part 1 relates to batteries, Part 2 to vehicle operational safety, Part 3 to protection against electric shock and Part 4 to post-crash safety.

QA systems

Part of the 'qualification' for a component to be accepted into an automotive application is the QA management system of the supplier. Generally, the industry standard ISO 9001 is insufficient for all but the non-critical functions such as infotainment, and otherwise IATF 16949:2016 is mandatory. This standard is an extension to ISO 9001 and is process-orientated with applicability right through the organisation from management leadership through manufacturing processes to after-sales support. Certification is a lengthy process involving extensive documentation, internal audits then external assessment. Unlike ISO 9001, the quality management system must be run for a period to actually demonstrate compliance before full certification is granted. Even when successful, automotive OEMs are likely to want to see a history of manufacturing of non-critical parts controlled by the quality system before considering contracts for more general supply.

Qualified automotive suppliers are supported by distribution

Procurement of electronic components with AEC-Q certification from suppliers with IATF 16949:2016 quality management systems is easy through distribution. TTI Europe (Figure 1) stocks automotive grade passive and suppression components from Vishay, Kemet, AVX, Nichicon and Littelfuse among others. Connectors available include those from Amphenol, Aptiv, Molex, Phoenix Contact, ITT Cannon and TE Connectivity for charging and in-vehicle applications while relay and contactors are featured from TE Connectivity and TDK. Pulse Electronics and Standex-Meder add to the line-up with standard and custom automotive-grade magnetic components.

Figure 1: A selection of automotive grade connectors from Aptiv and relays/ contactors from TE Connectivity, available from TTI Europe

Automotive electronic component quality ‘in the blood’ of suppliers

Over the 100+ years of work on standards for vehicle components, robust qualification methods have evolved for suppliers and their products to the extent that sufficiently safe ‘autonomous driving’ is a reality. Commitment to standards such as those from AEC along with automotive quality management systems ensures that quality and value is ‘in the blood’ of the supply chain from manufacturer to distribution.

[1] *Society of Automotive Engineers www.sae.org*
[2] *Mobility trends: what’s ahead for automotive semiconductors: McKinsey and Company: https://www.mckinsey.com/industries/semiconductors/our-insights/mobility-trends-whats-ahead-for-automotive-semiconductors*
[3] *MLCCs by the numbers: https://www.smithweb.com/market-blog/mlccs-by-the-numbers/*
[4] *Automotive Electronics Council www.aecouncil.com*
[5] *AEC Documents: http://www.aecouncil.com/AECDocuments.html*
[6] *https://en.wikipedia.org/wiki/Production_part_approval_process*
[7] *Automotive Industry Action Group https://www.aiag.org/*

About TTI

TTI, Inc. is the world's leading authorized distributor specialist offering passive, connector, electromechanical, discrete, power supplies and sensor components. TTI's extensive product line and supply chain solutions have made the company the distributor of choice for industrial, defense, aerospace and consumer electronic manufacturers worldwide.

TTI's extensive product line includes: resistors, capacitors, connectors, discretes, potentiometers, trimmers, magnetic and circuit protection components, wire and cable, wire management, identification products, application tools, power supplies, sensors and electromechanical devices. These products are distributed from a broad line of leading manufacturers. TTI strives to be the industry's preferred information source by offering the latest IP&E technology and market information through the online MarketEye Research Center. MarketEye includes articles, technical seminars, RoHS, seminars, industry research reports and much more.

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