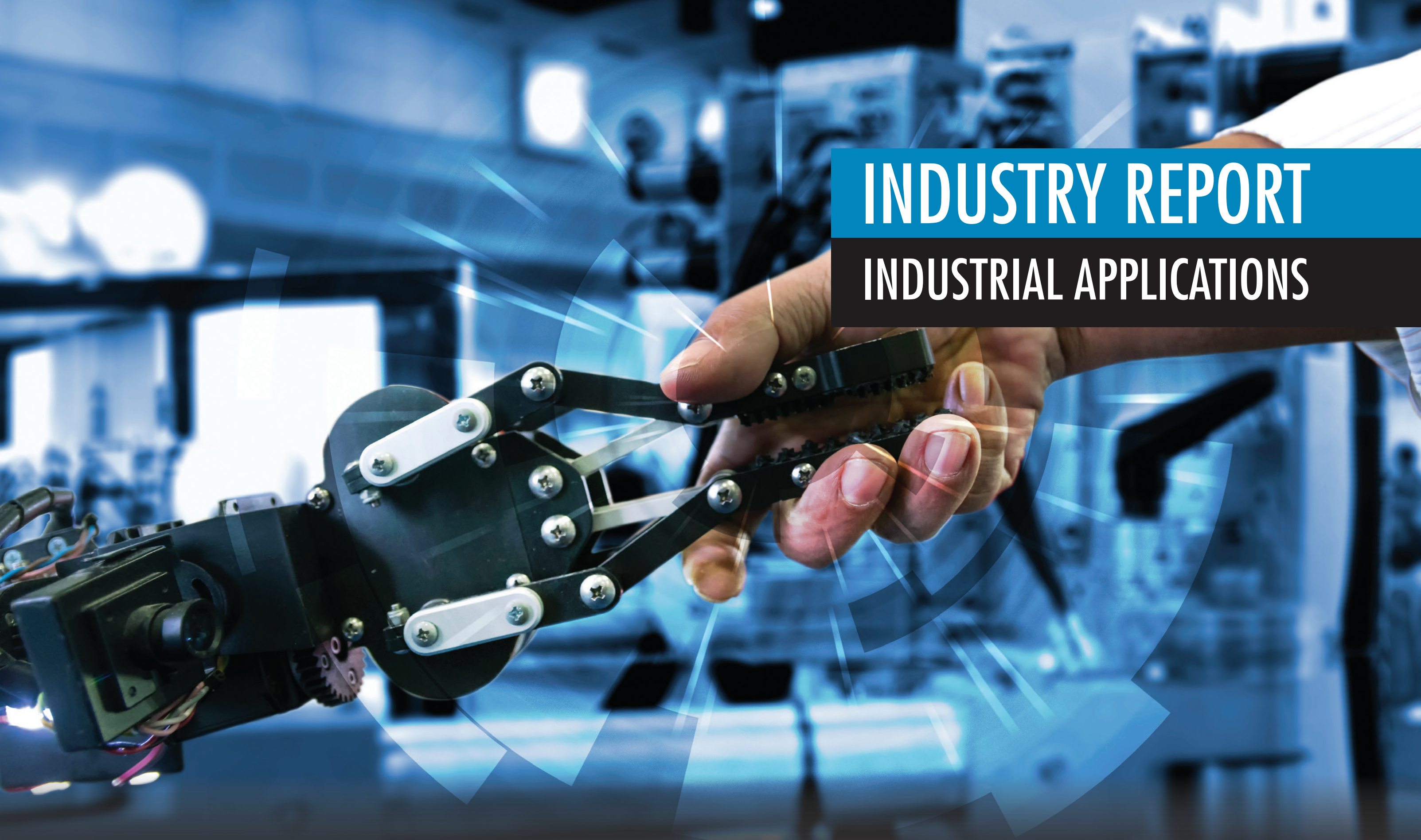


INDUSTRY REPORT

INDUSTRIAL APPLICATIONS

Power supplies for industrial applications

Powering industrial applications and meeting; industry compliance, emerging legislation and ever improving efficiency targets

Understanding increasing demands on new age industrial machinery and robotics is a complicated business, especially when powering such applications with remote control, monitoring and automation. As industry specialists we strive in researching and developing solutions for leading technology and with this report we aim to deliver a small portion of our knowledge and research to you.

Report covers: Efficiency | Regulatory compliance | Ruggedisation | Reliability | Redundancy | Environmental impact | Size and scalability | Battery charging

SUNPOWER® ELECTRONICS LTD

Power supplies for industrial applications

An industrial power supply may be built into a machine on a factory floor, as the name implies. Equally though, the term is used to specify products intended for a myriad of other markets; CCTV, lighting, battery chargers, medical equipment, marine, EPOS, servers and PCs are just some examples. While widely diverse, these applications share a common need for products that are resilient to the environments they will face, while providing a reliable and cost-effective solution.

This is a guide for equipment and system designers seeking to source such power supplies – products that will deliver the industrial performance they need, while giving a competitive edge to their own solutions. Often, these components are seen as simple building blocks that can be dropped in as the last part of a design; however, this approach can lead to disappointment or worse. In fact, the power supply is critical to not only the reliability and performance quality of any electronics assembly, but also its safety, electrical efficiency, size, ruggedness, environmental impact, ease of use and overall competitiveness.

It's possible to source power supplies that address these issues and enhance the host equipment's saleability by contributing to flawless, reliable performance. That being said however, the supply's electronic and environmental excellence alone doesn't qualify it as a solution; It must also be compliant with all relevant legislation. Legislation itself has become a moving target for manufacturers, as IEC, CSA/UL and EN safety standards 60950-1 (Information & Communication Technology Equipment) and 60065 (AV Equipment) are currently being replaced by 62368-1 (Safety Requirements for Audio/Video, Information and Communications Technology Equipment). This is not a minor upgrade, but instead a major shift in the approach to achieving compliance; designers must adjust accordingly and develop effective strategies to handle the changeover.

Medical equipment is a special case, because of the safety implications for operators and especially patients. Such equipment must comply with harmonised standards, particularly EN 60601; moving to these standards also calls for a new approach to safety design.

In addition to safety requirements, all power supplies are subject to increasingly stringent legislation regarding power efficiency, during both normal operation and standby mode. This is encapsulated in the US's EISA standard and Europe's Ecodesign Directive.

Sunpower has extensive experience in designing and supplying power solutions to equipment designers and manufacturers, and understands that this is just one demand on hard-pressed engineers' time. In this industry focus, we explain the issues around the changing legislation, together with the other factors critical to operational reliability and product success. This helps designers use our experience to save time and remove uncertainty in their power supply selection, freeing them to grow their products' value through their own core expertise.

Please note that the report document includes notes regarding battery chargers, as improving technologies mean that batteries find ever more uses within traction, mobile power, and electronic system back-up applications.

The following contents page shows the topics covered. Legislation is ever-present, but this should be viewed as a positive influence; products designed to be compliant will be equipped to survive in their target environments.

Contents

Safety, efficiency and regulatory compliance

As electronic products and equipment have steadily grown in complexity, maintaining uncompromised safety standards has become increasingly challenging, yet as essential as ever. Equipment users must remain protected from injury, whilst manufacturers should minimise exposure to litigation. Standards bodies around the world are recognising these realities and have responded with new-generation safety legislation that has shifted significantly from prescriptive rules to a new hazards-based concept, with more performance-based options. Safety should be built into the fabric of the equipment design, rather than added as an attempt to tick legislative boxes.

60065 and 60950-1 to be replaced by 62368-1

For equipment manufacturers, this shift means that the currently applicable standards - IEC 60065 (audio, video and similar electronic apparatus), and IEC 60950-1 (information and communication technology equipment) - are being replaced by IEC 62368-1 (Safety Requirements for Audio/Video, Information and Communications Technology Equipment). For an OEM product to achieve compliance, all its internal components, including power supplies, must be fully compliant.

For Europe, EN 60065, EN 60950-1 and EN 62368-1 versions of the above standards apply, while North America has adopted CSA/UL 60065, CSA/UL 60950-1 and CSA/UL 62368-1. Both the EN and the CSA/UL standards come fully into force on June 20, 2019, as recommended by the IEC TC108 Technical Committee.

62368-1 is not just a merger of the two previous somewhat overlapping standards but instead a shift to the new hazards-based safety concept and its arrival brings both challenges and opportunities for equipment manufacturers. The challenges lie in understanding the new concepts and applying them in practice to manufactured products and the opportunities arise because the inadequacies of earlier approaches that can now be eliminated. The traditional tactic of designing in safety compliance just before finalising a product for manufacturing has become inefficient; with immense pressure to reduce time to market. Redesigns due to safety concerns can slow product introduction and vastly increase costs at that particular point in the product development journey.

Protection from liability is another concern. A plaintiff in a product liability suite would assert that a manufacturer should have foreseen a hazard, regardless of whether the relevant standard's language addresses it.

62368-1 and Hazards-Based Safety Engineering [i, ii]

The 62368-1 solution has been facilitated by an expansion in the safety engineer's role and the appearance of an approach known as Hazards-Based Safety Engineering, or HBSE. An HBSE analysis of any product starts with a basic premise: Any product that causes injury does so through transfer of energy of sufficient magnitude and duration to a body part. If the energy source, the transfer mechanism and effect – the human body's susceptibility – can be quantified, the likelihood or otherwise of injury can be predicted.

Fig.1: The HBSE three-block energy transfer model for injury.

Power supplies for industrial applications

HBSE extends to defining a two-step process of confirming the existence of hazardous energy sources, then tests to determine the effectiveness of protective safeguards. This process, along with the rest of the HBSE 'Back to basics' methodology, is built into standards such as 62368-1 providing a philosophy and toolset for designing safety into products.

Accordingly but subject to the comments below, 62368-1 is a performance-based standard, where compliance is demonstrated by testing and simulation of all possible fault conditions. While this allows for greater design flexibility, it can be time-consuming and costly for complex products. Additionally engineers will have different opinions about what 'all possible fault conditions' includes, so this approach can become very subjective often delaying product certification.

By contrast, 60065 and 60950-1 use a prescriptive approach, meaning that they are recipes with a set of rules that closely define product design. 62368-1 retains many of these prescriptive design rules along with its hazard-based safety concept and performance options, this may allow greater design flexibility in some cases. The IEC Technical Committee responsible for publishing the standard, TC108, predicts that IEC 62368-1 will be technology-independent, allowing for greater design adaptability and minimizing the need for regional and national differences to the standard.

With these considerations in mind, manufacturers may choose to apply the prescriptive route to compliance, continuing to use known safeguards such as energy limiting circuits. Performance options should be carefully considered before implementation in the product design and discussed with certification body engineers or organisations such as Intertek Group PLC or TUV Rheinland.

Acceptability of previously certified components

OEM equipment manufacturers will be relieved to know that implementation need not be as onerous as it may first appear, if their products contain power supplies that are already certified to the 60950-1 or 60065 standards.

IEC 62368-1:2014 recognises that requiring all existing certified components within a product to transition to the new standard, would impose a tremendous burden on manufacturers and certification bodies alike. In clause 4.1.1 the new standard states that, "Components and subassemblies that comply with IEC 60950-1 or IEC 60065 are acceptable as part of equipment covered by this standard without further evaluation other than to give consideration to the appropriate use of the component or sub-assembly in the end product."

Low Voltage Directive

Electrical equipment including power supplies designed for use within certain voltage limits, must comply with the Low Voltage Directive for legal sale into the European Union. This can currently be achieved by certification to safety standard EN 60950-1 (Information & Communication Technology Equipment) or EN 60065 (AV Equipment). With that mentioned however EN 62368-1 has now been formally documented as a suitable standard for establishing presumption of conformity of AV & ICT equipment with the EU LVD.

Issues related to EN 60950-1, EN 60065 and EN 62368-1 have been discussed in the previous section.

National equivalents for IEC 62368-1

The IEC System Of Conformity Assessment Schemes for Electrotechnical Equipment and Components (IECEE) has published a cross-refence list showing national equivalents to IEC 62368-1:2014. This list is shown below:

Country/Group	Reference
Norway	IEC 62368-1(ed.2)
United Kingdom	EN 62368-1:2014
Denmark	DS/EN 62368-1:2014
Canada	CAN/CSA C22.2 No. 62368-1-14
USA	UL/IEC 62368
CENELEC	EN 62368-1:2014/A11
Finland	N/A
Italy	CEI EN 62368-1:2016
Sweden	SS-EN 62368-1:2014+AC1:2015+AC2:2017+A11:2017

Fig.2: National equivalents for IEC 62368-1

A special case for safety standards - medical electrical equipment

Manufacturers who wish to place medical electrical equipment on the European market must apply CE marking to their device, to indicate compliance with applicable European Medical Device Directives. These directives contain essential requirements that must be in compliance with harmonised standards, particularly EN 60601, of which offers a 'Presumption of Conformity'. This makes understanding and meeting the requirements of EN 60601 fundamental for all manufacturers of Medical Electrical Equipment.

The third edition of EN 60601-1 contains the latest changes to the standard, including the introduction of extensive Risk Management requirements that must be addressed. The standard is harmonised with IEC 60601-1 third edition, which has been adopted globally.

Another major impact of the third edition is the distinction made between the operator and the patient relating to means of protection from electric shock. As a result, the concept of Means of Protection (MOP) has been introduced. A MOP can be in the form of; safety insulation, a protective earth, a defined creepage distance, or an air gap or other protective impedance. These solutions can and often are used in various combinations. Basic insulation for example, is one MOP while double insulation counts as two MOPs. MOPs break down into two further classifications; Means of Patient Protection (MOPP) and for operators not needing the same level of protection as patients, Means of Operator Protection (MOOP).

Examples of equipment requiring MOPP include dialysis machines, electro surgery units, ventricular assistance devices and electrocardiography systems. MOOP is suitable for air flow measurement equipment, nurse call systems and patient information centre screens.

It is the medical product manufacturer's responsibility to determine the likelihood of a patient coming into contact with their device through a formal risk assessment process (ISO14871). The manufacturer must then decide whether patient protection (MOPP) or operator protection (MOOP) is necessary. For power supplies where there is deemed to be no significant risk of this contact happening, IEC/EN 60601-1 norms do not apply and a power supply conforming to IEC/EN 60950 can often be used.

For both MOPP and MOOP, as Fig. 3 shows, the insulation between the primary and secondary of the input transformer must meet at least 2 x MOP, while the insulation between the primary and protective earth (FG) must be at least 1 x MOP under normal conditions.

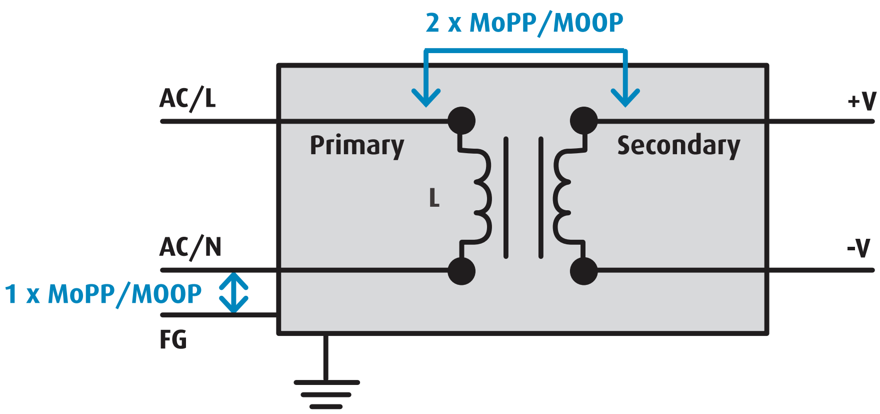


Fig. 3: MOP insulation requirements.

The isolation, creepage and insulation requirement for MOPP and MOOP are different, as shown in Fig.4.

Isolation, creepage and insulation requirements

Classifications	Isolation	Creepage/clearance	Insulation
1 x MOOP	1500 Vac	2.5/2mm	Basic
2 x MOOP	3000 Vac	5/4mm	Double
1 x MOOP	1500 Vac	4/2.5mm	Basic
2 x MOOP	4000 Vac	8/5mm	Double

Fig.4: table showing isolation, creepage and insulation requirement for MOPP and MOOP.

Creepage is the shortest path between two conductive parts measured along the surface of the insulation, while clearance is the shortest distance through air between two conductive parts.

Generally speaking, MOOP follows the requirement guidelines of IEC 60950 while MOPP follows those of IEC 60601-1 second edition. This did not categorise devices according to patient or operator contact and the new concept was introduced in the third edition.

For equipment used within a laboratory environment without contacting patients, a power supply that meets 2 x MOOP is usually sufficient. A power supply that meets 2 x MOPP standards provides the highest level of protection. It can be advantageous to specify to this level as it covers most medical applications.

Ecodesign Directive

Since the Nineties curbing excessive power consumption in external power supplies (EPSs) has been a matter of international concern. This was with good reason since the predominantly linear products of the time had efficiencies sometimes as low as 50% with excessive drain, even on no-load.

Since then voluntary and then mandatory regulations have grown to ensure higher average energy efficiencies within EPSs, both during operation and on no-load. Currently EPSs in the US must comply with the DoE's Energy Independent Security Act (EISA) Level VI.

The European Union enacted ErP (Energy Related Products) Ecodesign Directive 2009/125/EC in 2009, planned to harmonise with EISA by April 2011. The Directive is now at Phase 2 which applies to any product placed on the market after 27 April 2011. Phase 2 is in harmony with EISA Level V and it is expected to be upgraded to Stage 3 to meet US levels in 2017.

By comparison to Level V, the Level VI standard tightens performance thresholds not only for adaptors in active mode but also during no-load conditions. Additionally it expands the range of products covered, so regulated products now include:

- Multiple-voltage external power supplies
- Products with power levels >250 watts

The Tables below summarise Level VI performance thresholds.

Single-voltage external AC-DC power supply[1], basic-voltage

Nameplate Output Power (P-out)	**Minimum Average Efficiency in Active Mode** (expressed as decimal)	**Maximum Power in No-Load Mode** (W)
P-out ≤1W	0.5 x P-out +0.16	0.100
1W < P-out ≤ 49W	0.071 x In (P-out) - 0.0014 x P-out +0.67	0.100
49W < P-out ≤ 250W	0.880	0.210
P-out > 250W	0.875	0.500

Single-voltage external AC-DC power supply, low-voltage[2]

Nameplate Output Power (P-out)	**Minimum Average Efficiency in Active Mode** (expressed as decimal)	**Maximum Power in No-Load Mode** (W)
P-out ≤1W	0.517 x P-out +0.087	0.100
1W < P-out ≤ 49W	0.0834 x In (P-out) - 0.0014 x P-out +0.609	0.100
49W < P-out ≤ 250W	0.870	0.210
P-out > 250W	0.875	0.500

Single-voltage external AC-AC power supply[3], basic-voltage

Nameplate Output Power (P-out)	**Minimum Average Efficiency in Active Mode** (expressed as decimal)	**Maximum Power in No-Load Mode** (W)
P-out ≤1W	0.5 x P-out +0.16	0.210
1W < P-out ≤ 49W	0.071 x In (P-out) - 0.0014 x P-out +0.67	0.210
49W < P-out ≤ 250W	0.880	0.210
P-out > 250W	0.875	0.500

Fig.5: Tables showing EISA Level VI performance thresholds.

The following Notes apply to the tables in Fig.5:

1 Single-Voltage External Ac-Dc Power Supply

An external power supply that is designed to convert line voltage ac into lower-voltage dc output and can convert to only one dc output voltage at a time.

2 Low-Voltage External Power Supply

An external power supply with a nameplate output voltage less than 6 volts and nameplate output current greater than or equal to 550 milliamps. Basic-voltage external power supply means an external power supply that is not a low-voltage power supply.

3 Single-Voltage External Ac-Ac Power Supply

An external power supply that is designed to convert line voltage ac into lower-voltage ac output and can convert to only one ac output voltage at a time.

4 Multiple-Voltage External Power Supply

An external power supply that is designed to convert line voltage ac input into more than one simultaneous lower-voltage output.

Unsure about your power supply's compliance?

If you're unsure on how your chosen power supply will affect your entire equipment's regulatory compliance, you can consult with Sunpower's technical support department. We will be able to advise on not only our power supply's certification but also how integrating it will affect your product's compliance.

Ruggedisation

Previously, we saw that the term 'industrial' covers widely diverse applications, each imposing their own demands on the power supplies they use. Railway rolling stock equipment for example, constantly endures shock and vibration and sometimes temperature extremes or sudden changes. Marine hardware can suffer all of this with the addition of salt spray. Any outdoor equipment is liable to be exposed to temperature extremes, water and possibly dust ingress depending on its location in the world. Even apparently benign environments such as offices may be close to a manufacturing plant creating troublesome levels of shock and vibration for example.

So how can a power supply manufacturer design a product that's resilient to the application-specific challenges it will face? The answer comes from considering two factors:

- The environmental challenges that the product could face

- Legislation relevant to these challenges

Accommodating the legislation is important and not only to simply achieve compliance but also because compliance ensures that the product will survive in its target environment.

The United States Military Standard MIL-STD-810 provides an excellent starting-point as it addresses a broad range of environmental conditions. Now up to Version G, it comprises a series of performance and manufacturing guidelines established by the US Department of Defence for military and commercial equipment and its applications.

One interesting aspect of the standard is the exhaustive list of environmental challenges it has recognised and defined laboratory test methods for as shown in Fig. 6 below:

Test Method 500.5 Low Pressure (Altitude)	Test Method 515.6 Acoustic Noise
Test Method 501.5 High Temperature	Test Method 516.6 Shock
Test Method 502.5 Low Temperature	Test Method 517.1 Pyroshock
Test Method 503.5 Temperature Shock	Test Method 518.1 Acidic Atmosphere
Test Method 504.1 Contamination by Fluids	Test Method 519.6 Gunfire Shock
Test Method 505.5 Solar Radiation (Sunshine)	Test Method 520.3 Temperature, Humidity, Vibration and Altitude
Test Method 506.5 Rain	Test Method 521.3 Icing/Freezing Rain
Test Method 507.5 Humidity	Test Method 522.1 Ballistic Shock
Test Method 508.6 Fungus	Test Method 523.3 Vibro-Acoustic/Temperature
Test Method 509.5 Salt fog	Test Method 524 Freeze/Thaw
Test Method 510.5 Sand and Dust	Test Method 525 Time Waveform replication
Test Method 511.5 Explosive Atmosphere	Test Method 526 Rail Impact
Test Method 512.5 Immersion	Test Method 527 Multi-Exciter
Test Method 513.6 Acceleration	Test Method 528 Mechanical Vibrations of Shipboard Equipment (Type I – Environmental and Type II – Internally Excited)
Test Method 514.6 Vibration	

Fig.6: table showing MIL-STD-810G environmental conditions and tests definitions.

It is beyond the scope of this article as well as the needs of most power supply users to discuss all of these conditions. Instead we focus on the most frequently occurring types and standards – in addition to 810G – applicable to them. Note that some standards relate to specific environmental conditions (for example, IP ratings refer to dust and liquid ingress) while others relate to equipment types, or industries (for example Standard IEC 61347 refers to LED and lighting systems).

Common environmental challenges

Temperature: Industrial and military products must work to environmental variability including wider temperature ranges, than commercial devices. Accordingly three broadly accepted operating temperature grades have been defined:

- Commercial: 0 ° to 70 °C
- Industrial: -40 ° to 85 °C
- Military: -55 ° to 125 °C

However individual manufacturers may define their own temperature grades, including ‘extended’ and ‘automotive’ definitions for example. Military Standard MIL-STD-810 addresses exposure to high and low temperatures plus temperature shock under both operating and storage conditions.

Components within subassemblies such as power supplies can potentially overheat due to the combined effect of elevated ambient temperatures and heat generated by the components themselves. To prevent this either active or passive cooling methods will be used within the subassembly.

Passive cooling (typically in the form of heatsinks mounted on thermally-generating components), relies solely on the thermo-dynamics of conduction, radiation and convection. The technique is commonly used and is relatively easy and inexpensive to implement. More efficient passive thermal management can be achieved by using heat spreaders which distribute heat over a wide area and heat pipes that use liquid to conduct thermal energy away from the heat source.

Active cooling by contrast applies energy to a device such as a fan or pumped liquid cooling system to remove heat from a hot component at a faster rate. Whilst efficient its drawbacks include the need to use electricity to operate, possible audible noise, and increased cost and complexity compared with passive designs, plus the introduction of another potential point of failure.

Solid, liquid and gas ingress: Power supplies are installed in both indoor or outdoor locations and potentially exposed to ingress of elements generated by natural environmental conditions or industrial processes. Possibilities include water, dust and fibres, as well as corrosive agents and various gases and atmospheres. These hazards and degrees of protection against them are defined by two major standards:

- The IP (Ingress Protection) code, formulated by the International Electrotechnical Commission under the IEC 60529 standard. It designates the various types and degrees of protection afforded to electrical equipment by its enclosure.

- NEMA 250, defined by the National Electrical Manufacturers Association. The standard covers a broader set of harsh conditions than the IP code and includes ratings for indoor and outdoor locations, both hazardous and non-hazardous.

The IP code has the form ‘IPXY’ where X and Y denote the level of protection from particle ingress and water respectively. The first digit also represents the amount of protection provided to external objects from contact with parts within the enclosure. The requirements for each degree of protection are specified in the standard, as well as the procedures to test and confirm them. Fig.7 below shows some common IP ratings.

Rating	Water Protection	Dust Protection
IP65	Water at 12.5 litres per minute through 6.3mm nozzle from any direction	Total dust ingress protection
IP66	Water at 100 litres per minute through 12.5mm nozzle from any direction	Total dust ingress protection
IP67	Submersion into water up to 1 meter deep for amount of time specified by manufacturer	Total dust ingress protection
IP68	Permanent submersion beyond 1 meter into water of depth stated by manufacturer	Total dust ingress protection
IP689K*	Water at 80-100MPa (mega-pascal) and 14-16 litres per minute from four angles while the device is rotated at 5RPM.	Total dust ingress protection
*IP69K is a German standard and not congruent with other IP standards. It should not be assumed that it meets the requirements of lower IP standards.		

Fig.7: IP Rating examples.

The NEMA standard is similar to the IP code and provides a popular standard for protective enclosures. It covers ingress of water and foreign objects such as dust and fibres as well as corrosive agents and various gases and atmospheres. Fig.8 below provides a brief description of each level of protection, which NEMA specifies with a NEMA Enclosure Type Number.

Rating	Uses	Description
4 & 4X	General Purpose weather-proof	Intended for use indoors or outdoors with protection from wash down environment and corrosion resistance.
6 & 6P	General Purpose weather-proof	Intended for use indoors or outdoors with protection from occasional submersion.
7	Hazardous	Intended for indoor use in Class I, Groups A, B, C, and D environments per NFPA rating system.
8	Hazardous	Intended for indoor or outdoor use in Class I, Groups A, B, C, and D environments per NFPA rating system.
9	Industrial	Intended for indoor or outdoor use in Class II, Groups E, F and G environments per NFPA rating system.
12 & 12K	Industrial	Intended for use in industrial application with protection from dust and non corrosive liquid drip.
13	Industrial	Intended for use in industrial application with protection from dust spraying water, oil and non corrosive liquid drip.

Fig.8: NEMA ratings.

Note that, because NEMA Enclosure Types are tested over a wider set of environmental conditions, it is not possible to obtain an equivalent NEMA Type from an IP code – although the opposite (converting a NEMA Type to an IP code) may provide a good guideline.

Shock and vibration: Vibration can be a major source of failure in many systems. It can appear in applications ranging from automobile, train and aerospace to oil drilling, power stations and manufacturing plant but can also manifest itself in milder environments through shipping, transportation and everyday use.

Vibration is measured in metres per second squared (m/s^2). It can also be expressed in gravitational units ('g') where 1 g equals 9.81 m/sec^2 approximately.

PCBs have become increasingly susceptible to vibration as their component population levels grow steadily. Chip miniaturisation requires solder joints and electrical connections in lower numbers and reduced sizes, increasing vulnerability. Potting or supporting the ICs can offer very effective reinforcement to solder joints but often presents trade-offs with cost and thermal specifications.

Vibration may also cause mechanical failure in the equipment's housing. This is equally undesirable for example a loosened screw, pin, or clip can lead to cascading failures that damage and even destroy the system. Elastomers and thermoplastic mounts can effectively reduce the likelihood of such an event by dampening instead of transmitting the vibrations.

Although modelling and analysis can be helpful testing is often necessary to prove product reliability under harsh conditions, yet this can be difficult and expensive. One solution is to use accelerated product reliability test methods such as HALT (Highly Accelerated Life Test) and HASS (Highly Accelerated Stress Screen) of which subjects a product to random vibration on multiple axes while inspecting it for signs of failure. Done properly such testing can increase product reliability while also reducing time-to-market. The techniques are effective even for military standards and are specified by MIL-STD-202.

Industry and equipment-related environmental standards

While the standards above relate to specific environmental challenges (for example IP ratings are concerned entirely with ingress protection), other standards as below are referred to industry or equipment types (such as EN 50155:2007, which is an international standard covering electronic equipment used on rolling stock for railway applications).

Standard IEC 60950 is applicable to mains-powered or battery-powered information technology equipment, including electrical business equipment and associated equipment with a rated voltage not exceeding 600 V. This standard specifies requirements intended to reduce risks of fire, electric shock or injury for the operator and layman who may come into contact with the equipment and where specifically stated for a service person.

Equipment covered by IEC 60950 includes but is not restricted to; industrial battery chargers, banking equipment, office machines, IT, networking and telecommunications equipment.

Please refer to the section '60065 and 60950-1 replaced by 62368-1' above to see how 62368-1 is replacing the earlier standards, including 60950-1.

Standard IEC 61347 has special significance for designers and installers of LED and other lighting systems. The standard specifies general and safety requirements for lamp control gear for use on DC supplies up to 250V and/or AC supplies up to 1000V at 50Hz or 60Hz.

IEC 61347-2-13:2014+AMD1:2016 CSV specifies particular safety requirements for electronic control gear for use on DC or AC supplies up to 1000 V (AC at 50 Hz or 60 Hz) and at an output frequency which can deviate from the supply frequency, associated with LED modules. Control gear for LED modules specified in this standard are designed to provide constant voltage or current at SELV or higher voltages.

Some standards apply specifically to rail applications. These include:

EN 55015:2013 – covers limits and methods of measurement of radio disturbance characteristics of electrical lighting and similar equipment. It includes all lighting equipment intended to be used for light generation and illumination purposes and intended to be used with batteries or connected to low voltage mains network, such as lighting equipment for buses and trains.

EN 50155:2007 - an international standard covering electronic equipment used on rolling stock for railway applications. The standard covers aspects of this electronic equipment including; temperature, humidity, shock, vibration, and other parameters.

IEC 60571:2012 - covers the conditions of operation, design, construction, and testing of electronic equipment, as well as basic hardware and software requirements considered necessary for competent reliable equipment. Applies to all electronic equipment for control, regulation, protection, supply, installed on rail vehicles and associated with: either the accumulator battery of the vehicle, or a low voltage power supply source with or without a direct connection to the contact system.

IEC 61373 - This International Standard specifies the requirements for testing items of equipment intended for use on railway vehicles which are subjected to vibrations and shock owing to the nature of railway operational environment. To gain assurance that the quality of the equipment is acceptable, it must withstand tests of reasonable duration that simulate the service conditions seen throughout its expected life.

BS EN 50121-3-2:2006 - This European Standard applies to emission and immunity aspects of electromagnetic compatibility for electrical and electronic apparatus intended for use on railway rolling stock.

The frequency range considered is from DC to 400 GHz. Testing is not defined for frequencies above 1 GHz.

The standard considers the internal environment of the railway rolling stock and the external environment of the railway and interference to the apparatus from equipment such as hand-held radio transmitters.

EN 55022:2010 applies to information technology equipment. Procedures are given for the measurement of the levels of spurious signals generated by the ITE and limits are specified for the frequency range 9 kHz to 400 GHz.

Despite these challenges power supplies such as Sunpower's Harsh Environment series are available, which are well-protected enough for use as bolt-on devices rather than as delicate electronics that require external protection, with all its implications for design, testing and manufacturing. Fig.9 below shows some typical harsh environments that Sunpower products are designed into.

"The IEC develops International Standards for all electrical, electronic and related technologies. Adoption is voluntary, although they are often referenced in national laws or regulations around the world. Experts from all over the world develop IEC International Standards."

Visit the IEC website - http://www.iec.ch/index.htm

"BSI is the business standards company that helps organizations make excellence a habit – all over the world. Our business is enabling others to perform better."

Visit the BSI website - https://www.bsigroup.com/en-GB/

Application	Environmental challenges
Telecoms cabinets/base stations	Wide range of weather conditions and temperatures
Railways / transport	Shock & vibration
Battery charging	Shock & vibration/temp ranges
Outdoor signage	Extreme temp ranges/environmental conditions
Marine environment	Corrosive environment/salt-air moisture
Street lights/floodlight/spot lights/ down lights/warehouse & car park lighting	- Dirty/Dusty environment – roof space etc - Damp/wet environment for lighting - Marine lighting
Pro-Audio	Shock & vibration (portable kit), temp ranges
Domestic shower application	Temperature, humidity, ingress

Fig 9: Table showing harsh applications and their environmental challenges.

These Sunpower harsh environment supplies have several features that facilitate their enhanced performance. These include recent developments in potting compounds, which are used to 'encapsulate' the power supply's electronics.

The potting compound provides insulation during use in particularly cold conditions; conversely, it conducts heat away efficiently when high temperatures are the challenge. With no fans to fail reliability is improved significantly.

Without fans to draw moisture or dust into the PSUs, providing a good IP rating with high resilience to these threats becomes possible –fan-less means no audible mechanical noise.

Potting the PCB and components also protects them from shock and vibration that occurs during transport and handling; Sunpower's products have vibration test ratings up to 5G.

These power supplies have electrical as well as environmental safeguards, with short circuit, overcurrent, overvoltage and over temperature protections.

Reliability

Reliability is influenced by design, specification (or over-specification), components used and construction. Paying attention to the points below will help to optimise the power supply's performance as a reliable component within its host equipment:

- Ensure adequate heat sinking, convection and/or forced cooling to avoid hot-spots
- Allow for inrush current limiting circuits and their heating effects
- Careful cable routing
- Care in selection of components, particularly capacitors.
- Are fuses slow-blow type? Are they adequately rated for repeated turn on cycles?
- Can the power supply cope with the high currents associated with the lower mains voltages found in some countries?
- Does the power supply have short circuit, over current, over voltage and over temperature protections?
- If the power supply uses fan forced-air cooling, does it have a fan fail alarm?

Availability and redundancy

Although high reliability is an essential attribute, it's not in itself the ultimate guarantor of uninterrupted operation. It's just one contributor to what users really need from their equipment: very high availability.

For example, if an operator has 100 hours' production run booked for some equipment, he needs it to be available i.e. capable of fully performing its role (for 100 hours – in other words, 100% availability). If in fact the power supply suffers a breakdown during that period (of which takes one hour to repair), then the equipment has only been available for 99 hours; 99% availability.

Availability (A) is formally defined as $\frac{MTBF}{(MTBF+MTTR)}$ (where MTBF = Mean Time Between Failures and MTTR = Mean Time To Repair). From this we can see that while reliability contributes to improving availability by increasing MTBF, it isn't the only factor. Conversely it is particularly important to note that availability can be significantly improved by reducing MTTR.

The simplest way to reduce MTTR is to implement a power solution with 'hot swap/redundancy' capability. If the power supply comprises a chassis with one or more modules that can simply be pulled out and replaced on failure, MTTR reduces to just a few seconds or minutes - compared with the considerably longer time that would be needed for a supply that must be more painstakingly accessed, dismounted and disconnected from the power wiring, and then replaced with similar effort.

Yet MTTR can be reduced even further through using a redundant power configuration. Suppose for example, that the production equipment needs 300 W to operate and it's fed from a power chassis containing two 330 W modules. During normal operation the modules share the load equally, however if one module fails the other has sufficient capacity to support the load by itself, which accordingly suffers no loss of power at all. The faulty module can then be safely pulled out and replaced without disconnecting power from the load. This arrangement is generically known as N+1 redundancy, where N is the number of modules needed to support the load.

Sunpower's power supply lineup includes Hot Swap power supplies that offer this high availability benefit. Their hot swap operation is facilitated by active current sharing outputs, remote sensors, alarms and TTL status signals, and protective covering plates.

For larger systems, Sunpower offers 1U high 19" racking units, which can accommodate up to three 2000W power modules for a total capacity of 6000W (or 4000W N+1 redundant capacity). Up to three such rack units can be stacked and paralleled for a total 18000W capacity or 16000W N+1 redundant capacity. The modules can be remotely monitored and controlled via serial, USB or Ethernet connections using Windows-based communications software.

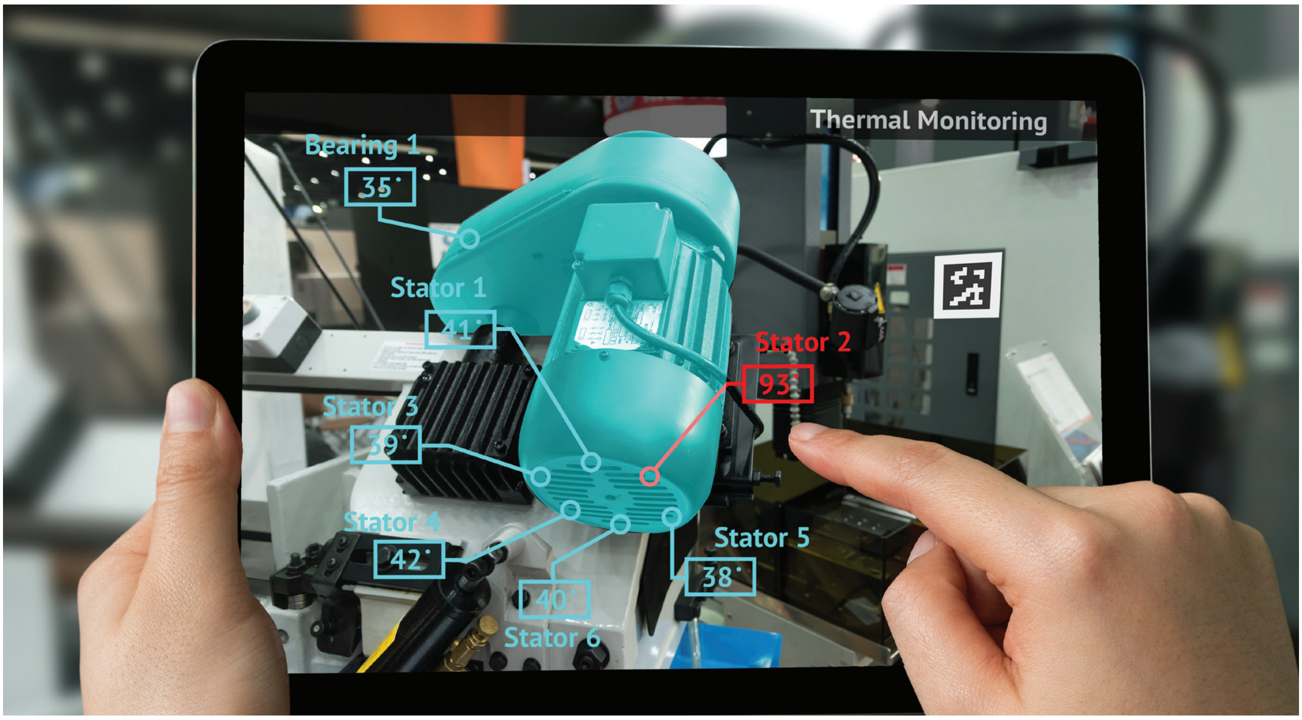
If even higher power capacity is required, Sunpower's Mean Well RCP-1600 1.6 kW 1U rack mountable modules can be used. With power density up to 25W/inch3, power capacities to 24000W are achievable by populating up to three Mean Well RHP-1U 19" rack shelves with these units and using their active current sharing feature. The RCP-1600 series offers great design flexibility through built-in functions including I2C and PMB bus communications, output programming, remote control, auxiliary power, alarm signalling and other facilities.

Communications, monitoring and control

Whether power supplies are powering a non-stop production process, or a remote CCTV system, users must have visibility of their status at all times, so that they can be aware of and act on any problem such as a fan failure before it becomes a system shutdown. They must also be able to control the equipment, either locally or remotely with a degree of simplicity or sophistication appropriate to the needs of the application.

For small simple systems that do not merit the overhead of network communications, power supplies can provide status information and control simply through relay contacts and TTL logic signals. More advanced communications over a serial RS-232 connection or bus such as the Power Management Bus (PMBus) or I2C-Bus, USB port or Ethernet network allow remote users to monitor and control a number of power supplies in parallel and gain access to time- and date-stamped alarm and event logs.

Sunpower's 19" racking power supply modules can be remotely controlled and have PMBus serial communications capability. Individual signals for AC OK, DC OK, fan fail and OTP (Over temperature protection) alarms are provided. For larger configurations a 1U high Rack Control and Monitoring Unit can control and monitor up to thirty-two 2000W power modules.



Efficiency and environmental impact

The power supply's impact on its electrical and physical environment can be minimised through the right choice of product:

Audible: Use power supplies that do not need fans, such as Sunpower's Harsh Environment range. Fan-less operation not only eliminates mechanical audible noise, but also improves reliability without an electromechanical device to fail.

Electrical efficiency: Use power supplies that offer good operating efficiency with a near-unity power factor. As well as reducing energy costs and meeting compliance requirements, higher-efficiency power supplies run cooler keeping equipment within acceptable operating temperatures becomes correspondingly easier.

Higher power factors reduce the unnecessary expense of oversizing supply cables and switchgear to handle non-productive reactive currents.

ZVS (Zero Voltage Switching) can also be used to reduce power dissipation and improve efficiency.

Sunpower offers power supplies in a range of formats, including 19" rack-mounting, modular, open-frame and encapsulated, that variously operate with high efficiencies, use ZVS, and have active power factor correction with power factors up to 0.98 or better.

Low harmonics: Choose power supplies that do not impose excessive harmonics, as these can interfere with or damage nearby equipment sharing the same mains supply.

Green performance: Another point for consideration is that further energy savings can be made by designing power supplies with low standby power consumption; Sunpower's IRM-60 single-output encapsulated PCB-mount PSU for example, has a no-load power consumption of less than 0.1W at 240VAC input.

The majority of Sunpower's power supplies conform to Low No-Load power consumption standards such as DOE Level VI this is especially useful for systems that remain in an 'idle' state for extended times during normal operation.

Size reduction and scalability

Small size can provide a competitive edge whether it's to improve portability in mobile equipment or reduce footprint in permanent installations. That being said engineers must often achieve a power setup comprising multiple voltage levels and power requirements along with designing in any size reduction. Additionally the power solution may need scaling to drive a range of variously-rated OEM products.

Sunpower's modular PSU range offers practical answers to this problem. With 35 different modules to choose from and a wide range of voltage rails, from 1.6 to 53VDC, can be set up to efficiently match individual equipment requirements. 75W, 150W and 300W modules are available to populate 450W, 650W and 1000W chassis as appropriate to the power levels required.

Many Sunpower PSUs offer a high power density to help reduce power supply real estate. Sunpower's Mean Well RCP-1600 19" rackmounting series, for example features a power density of up to 25W/in3, together with power capacities of up to 24000W using multiple modules with active current sharing.

Most Sunpower PSUs have universal AC inputs, so they are ready for international use without modification.

Battery chargers

With improved technologies facilitating lower-cost, more power-dense solutions, batteries are increasingly attractive for traction, mobile and power back-up applications. Batteries do also depend on the best available charger designs however to assure good, reliable performance. Accordingly we have provided some information and case studies here about our battery chargers, as power system designers increasingly seek such products for their projects. We've also provided an introduction to BS EN 60335-2-29, a safety standard applicable to battery chargers.

Traction and mobile power environments include trucks, motorcycles, electric scooters, motorhomes and caravans, golf buggies, aviation, cleaning equipment and even standard appliances. IT and communications back-up applications include UPS systems, radio systems, surveillance installations and scoreboards.

Sunpower's range extends to 8000W with active current share and parallel functionality throughout. All products come with a universal input and up to 5G vibration rating for stable solutions in demanding applications. Other ruggedisation features include good temperature operating ranges with built-in temperature compensation and conformal coating options.

Float 2, 3 and 8 Stage charging solutions are available, with fully-programmable charging curves and coverage of Lead-Acid, Gel, Flooded, AGM, Lithium-Ion and Lithium-Manganese technologies.

Safety standards are in line with other power supply products with short circuit, over voltage, overload, over temperature and reverse polarity protection functions on all models. Built-in power factor correction is provided and communication over I2C and PMBus is supported.

The case studies below highlight how battery chargers can be modified for highly diverse applications in various markets.

- **Floor cleaner charging:** The customer needed a 5G rated unit with control and feedback. We modified a charger to support a beacon mounted on the cleaner, to show battery status and report it back to a central hub.

- **Caravans and motor homes:** We corrected a competitor's faulty design to allow users to monitor their battery systems and charging curve status and prevent battery over-charging.

- **Racing vehicle battery charging:** We modified a charger design to support AGM battery charging - a smart design which does not discharge quickly while changing from bulk to float charge.

- **Portable jumpstart pack for light aircraft and vehicles:** This charger, developed to support a customer-specific battery design, can be set to different profiles using DIP switches. The customer can select two alternative charging curves for their different battery configurations.

- **Racecourse data for bookmakers:** A small, compact charger that facilitates portability in a bookmakers' system, featuring a locking DC connector that simplifies plug'n'play operation.

- **Boat-charging system:** These products were chosen because they were compact, ruggedised and fit for purpose while being smaller than the chargers they replaced.

EN 60335-2-29: a safety standard for battery chargers

BS EN 60335-2-29 deals with the safety of electric battery chargers for household and similar use having an output at safety extra-low voltage, their rated voltage being not more than 250 V.

BS EN 60335-2-29 also covers battery chargers not intended for normal household use but which nevertheless may be a source of danger to the public, such as products intended for use in garages, shops, light industry and on farms.

As far as is practical BS EN 60335-2-29 deals with the common hazards presented by appliances that are encountered by all persons in and around the home. In general however it does not consider:

- the use of appliances by young children or infirm persons without supervision;

- playing with the appliance by young children.

There are further design criteria that apply to installation type and location. These can be summarised as below:

- Clearance requirements at high altitude: As air pressure changes with altitude, physical clearance distance for power supplies (including battery chargers) that should be allowed for accordingly. IEC 60664 defines a multiplication factor for calculating high altitude clearances. For example a power supply for use at 5000 metres should have a clearance 1.48 times greater than a unit designed for the default height of 2000 metres.

- Safety distances for pollution levels: IEC 60664-1 (Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests) refers to degrees of pollution level – From Pollution degree 1, no pollution, to Pollution Degree 4, which causes persistent conductivity - as defined in 60335-1 Annex M. The golden rule for selecting 60335 power supplies and battery chargers is to select one that complies with Pollution degree 3.

Conclusion

This report has shown how the current move to the 62368-1 standard – and for medical equipment, EN 60601-1 - is making equipment manufacturers fundamentally rethink how they design safety into their products, moving from applying prescriptive rules to following a hazards- or risk-based approach. Additionally manufacturers must accommodate increasingly stringent standards relating to energy efficiency and resilience to environmental stresses.

While highlighting the demands that standards make on manufacturers, the report also emphasises the benefits they offer. Apart from protecting users from injury and manufacturers from litigation, standards have information quantifying the parameters that designers should expect from their target applications, so that they can accommodate them successfully.

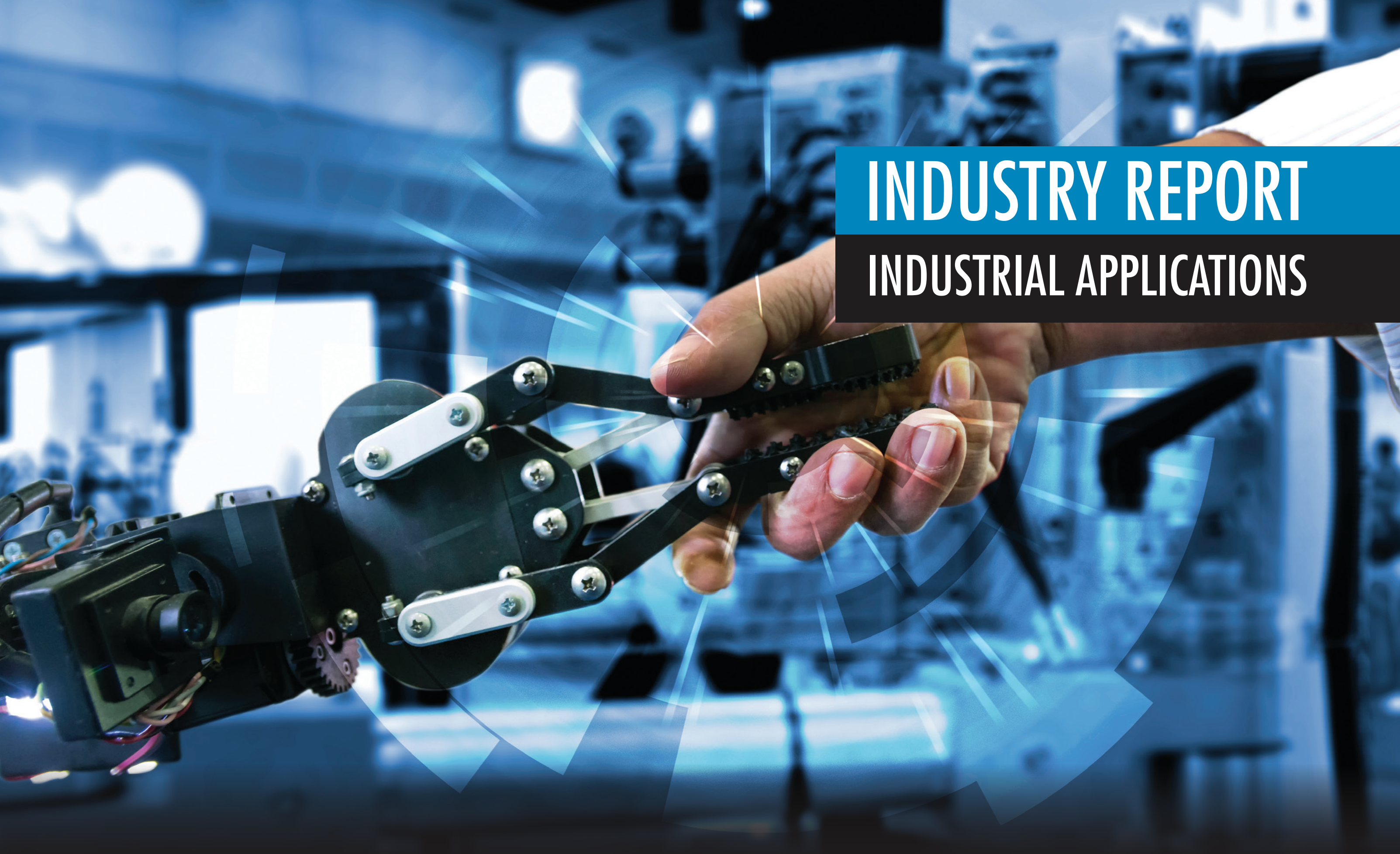
The report includes some notes on battery chargers, as the choice of charger is essential to realising the maximum possible benefits of improving battery technology.

The above factors make the power supply selection task both critical and demanding. Accordingly it makes sense to discuss your particular application's requirements with a well-established, knowledgeable PSU supplier. This will pay dividends with both a more competitive end-product and protection from the threats described above.

References:

[i] HBSE information based on article: 'Hazard-Based Safety Engineering', Gary Weidner, Conformity, May 2004.

[ii] Information about 62368-1 and its impact on manufacturers taken from article 'IEC 62368-1:2014 is here – Time to panic?' by Doug Massey, published on the ACS website on August 5, 2014.



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Sunpower Electronics Ltd
Orion House, Calleva Park,
Aldermaston, Berkshire,
RG7 8SN UK

www.sunpower-uk.com
email enquiries@sunpower-uk.com
+44 (0) 118 9408739

SUNPOWER® ELECTRONICS LTD