Technical Article

Tech innovations shaping next-generation medical devices: balancing power, efficiency, and reliability

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Abstract: *Reliable, efficient power supplies are essential to the safe operation of modern medical devices, particularly as healthcare shifts towards distributed and home-based environments. This article explores how innovations in power design address challenges such as thermal performance, noise, safety standards, and power stability to support next-generation medical technologies.*

Figure 1: A continuous positive airway pressure (CPAP) machine to prevent sleep apnoea and snoring (Source: stock.adobe.com/VictorMulero)

The role of power supplies in ensuring the safe and reliable operation of medical devices has never been more critical. They are vital in providing stable power for various devices, from sophisticated imaging equipment, such as MRI and CT scanners, to patient monitors, breathing apparatus, and dialysis machines. They are designed to meet the strict medical safety standards that protect both patients and healthcare professionals.

Although distributed healthcare has been a longstanding component of medical services, the trend has shifted from centralised facilities towards out-of-hospital healthcare in lower-cost settings, such as ambulances, homes, and community clinics. Home healthcare, particularly with the recent advancements in the internet of medical things (IoMT) technology, enables devices to monitor vital signs and other health indicators in real-time and automatically alert medical practitioners should an anomaly or emergency event occur. This capability helps address people's health issues at an earlier stage. In addition, these devices are more cost-effective and labour-efficient as well as more convenient for the patient.

Considering larger design margins

Medical standards have strict EMC and leakage current limits. Choosing a power supply with large design margins gives engineers plenty of headroom, making it easier to integrate the power supply into their system design and minimising testing and trials.

With lives at stake, medical technology cannot fail and must remain reliable, especially in home or remote healthcare settings where immediate maintenance or replacement isn't feasible. In such deployments, a critical indicator of power supply reliability is the lifetime of the electrolytic capacitor (e-cap), which directly impacts how long a device can operate reliably at elevated temperatures. Selecting a power supply that uses a high-quality e-cap with an optimum design margin is advised, not only to improve reliability and robustness, but to ensure longer deployments, reducing maintenance needs and supporting the continuity of care in distributed healthcare environments.

Handling different voltage rails

A common requirement for large, fixed medical devices, such as imaging equipment, is having three to four different supply voltages – powering electronics (monitor, display, interface), moving parts (motors), cooling equipment (Peltier cells, cooling fluid) and, if required, the applied parts to the patient. Here, options include using a modular power supply, which can cover up to all four voltage rails, or a distributed architecture using a single output AC-DC converter and, for each voltage rail, separate point-of-load (PoL) non-isolated DC-DC converters.

For portable and home healthcare devices that require compact and lightweight designs, the trend is to use lower-power, single-output power supplies from which additional voltages can be generated, if needed, directly on the board or by using PoL non-isolated DC-DC converters.

High performance over a wide temperature range

It is indisputable that a high-efficiency power supply will dissipate less energy as heat, and therefore requires less cooling. Power supplies must deliver high performance over a wide temperature range. However, there is little point in selecting a very compact power supply that requires an external fan to achieve its nominal output power at temperatures above +30 °C. Choosing a power supply that can operate efficiently and reliably at temperatures ranging from +50 °C to +60 °C, and sometimes even +70 °C, is essential.

In portable medical equipment, which tends to be more compact compared to fixed installations, the power supply is typically not the only source of heat. With the limited space inside for effective thermal dissipation, the surrounding electronics, including FPGAs, MCUs, and displays, start to become the primary sources of heat.

Choosing a supply with the right ratings and reliable operating thermals is therefore necessary. Consider a new-generation, 200 W power supply with a long e-cap lifetime, for example, that can deliver at least 100 W or 80 W at 70 °C.

Fan or fanless?

Low audible noise is crucial in many healthcare scenarios. For instance, audible noise from devices near a convalescing patient can delay or complicate recovery. Prolonged exposure to audible noise can cause stress-related or fatigue-related health issues for the operator. Moreover, in the home healthcare environment, where human-centric care is a must, audible noise can be intrusive, interfering with the patient’s comfort, rest, or ability to communicate or engage with others. To minimise the amount of audible noise generated by their products, look for a power supply with silent or quiet operation.

A typical application for silent operation, when no fan is allowed, would be for a patient monitor. New-generation power supplies with outputs of 250 W or 400 W, are available that require no fan, and instead dissipate waste heat via natural convection or conduction cooling.

For quiet operation, consider using new-generation power supplies that feature high-quality, low-noise fans with a temperature-controlled rotation speed. A typical application scenario would be to support pulsed loads, such as for hospital beds, dentist chairs or medical aesthetic devices.

Figure 2: Dentist chair and surrounding apparatus (source: stock.adobe.com/NejronPhoto)

Handling peak power requirements

The newest generations of power supplies need to handle peak power, typically under two different application scenarios.

This first scenario is when the peak power is required for a short amount of time, in the region of some seconds to a few minutes, like hospital beds, dentist chairs and medical aesthetic devices. Here, a power supply with peak power capabilities for a certain duty cycle is recommended.

In the second scenario, peak power is only required for a minor part of the entire working time, but longer than a few minutes. An example would be when the device needs to operate at – or close to – full load for 1 or 2 hours, and then for 10 hours at a lower load. Here, it is important to choose a power supply that maintains consistently high efficiency across high and low loads.

Figure 3: Breathing apparatus for home oxygen therapy (source: stock.adobe.com/vera)

Additional safety considerations in the home

Despite the significant medical care and cost benefits home healthcare brings, the home introduces a number of risks that are typically absent in the clinical setting, including untrained users, poor power quality and infrastructure, and a less controlled environment. To address the concerns, a stricter medical standard – IEC 60601-1-11 – for home healthcare devices defines additional requirements for certain aspects of safety and performance.

Concerning power supply selection, the main risk is that homes may not have the same reliable power supply and infrastructure as medical facilities, which can affect the performance and reliability of medical devices. Specifically, the standard mandates a wider input voltage range for home healthcare devices, aiming to ensure they continue functioning reliably even when the mains voltage drops.

Handling power fluctuations

If, for example, the device needs to maintain functionality when the mains voltage drops below 85 % (or 80 % for life-support equipment), the power supply must be designed with that in mind. Therefore, it is prudent to choose a power supply with an input voltage range covering at least 85 Vac to 264 Vac and consult directly with the power supply manufacturer for life-support equipment.

Class II construction

Globally, the standard of local electrical infrastructure and specifications can differ significantly. Consequently, it is not assured that all power sockets will possess a protective earth connection, or even if present, that it has been correctly fitted. Class II construction of equipment unlocks access to home healthcare by protecting non-professional users from electrical shocks. It assumes that not all homes have protective earth ground wiring. A key enabler is a Class II medical power supply that has no earth connection and, instead, uses double or reinforced insulation as its means of protection.

Higher EMC requirements

The home is also a less controlled environment compared to hospitals – there could be electromagnetic interference from various nearby electronic devices, such as smart phones and laptops. Therefore, stricter electromagnetic compatibility (EMC) requirements and immunity standards ensure that devices function properly. Equipment is commonly categorised as EMC Class A or Class B. Class B is the more rigorous classification, and all home healthcare devices must meet this requirement. Targeting a power supply that meets the requirements for Class B conducted and radiated emissions will help simplify end-equipment testing.

Extending hold-up times

Concern around hold-up time has intensified for designers of home healthcare devices following the introduction of stricter immunity standards defined in the IEC 60601-1-11 standard. They mandate resilience to a range of AC voltage dips and short-term brownouts lasting from 20 ms to 5 seconds. These brief interruptions can compromise critical device functions, resulting in system resets, data loss, or other undesirable outcomes.

Innovations in hold-up technology play a vital role in ensuring that the power supply continues to deliver power to the load. In the event of AC input absence, it is also essential to ensure the medical device can complete specific processes, such as returning to a ‘safe’ or ‘home’ position or automatically saving valuable patient data, before the DC output is lost. Ensuring these essential processes are completed safely, even before battery backup systems engage, safeguards patients during blackouts and maintains care.

The power supply’s hold-up time relies on the energy stored in its capacitors to maintain operation. There are a couple of methods to extend power supply hold-up time: one option is to use a modified power supply; the other is to use a higher-rated power supply and operate it at a reduced load. The second option is especially advantageous when the manufacturer has two power rating options with the exact form, fit, and function (FFF). Both options require a thorough technical assessment of the end equipment with the power supply manufacturer.

Future developments for healthcare

The selection of a power supply is a critical decision that impacts the overall design, safety, and functionality of medical equipment. Engineers must navigate a complex landscape of requirements, including strict medical safety standards, EMC and leakage current limits, and the need for high performance across diverse operating temperatures.

The trend towards home healthcare and portable medical devices further complicates the power supply landscape, necessitating compact, lightweight, and highly efficient solutions that can operate reliably in less controlled environments. Moreover, the silent or quiet operation of medical devices is becoming increasingly important, leading to a preference for fanless power supplies or those with temperature-controlled, low-noise fans.

As the healthcare industry continues to evolve, with a growing emphasis on distributed healthcare, the role of power supplies will only become more central. TDK-Lambda’s ongoing development of its AC-DC power supply ranges, coupled with its robust support structure and localised manufacturing capabilities, positions the company as a key player in enabling the future of medical technology.

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https://www.emea.lambda.tdk.com/uk/products/acdc-power-supplies/

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