DIODES INCORPORATED

White Paper

July 2020

Alternative Power Sources in the IoT

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The Internet of Things (IoT) is one of the global megatrends and billions of new devices are being added to IoT systems each year. These are often low-cost sensors or other small endpoints using wired or wireless connectivity.

Of course, every "thing" that is connected needs power, often for 24/7 operation – for example, a smart meter. With so many devices to connect, power components and cabling can make up a significant portion of an IoT system's overall cost. In particular, IoT applications will often include remote monitoring and controlling devices, where power can be difficult, or expensive, to provide. The IoT device may itself be inaccessible once deployed, such as a flow meter buried under the ground.

In these cases, taking power from an existing AC supply, known as "offline power," may be impractical. An obvious alternative is batteries, but this means there is the cost and inconvenience of replacing primary, non-rechargeable cells, or of recharging secondary cells. For most use cases, we want our IoT devices to last many years, if not decades, without attention or maintenance. Therefore, replacing batteries every few years is not practical – and recharging can be difficult and costly.

So, where offline power and batteries are not practical, what other ways are there to power IoT endpoints?

In this article, we'll look at the options available for alternative power sources in the IoT, and how these technologies can be used in practice.

Power Demands of IoT Endpoints

The good news is that the power requirements of today's IoT devices can often be reduced to extremely low levels.

A typical IoT endpoint might include a sensor, microcontroller or processor, some memory, and the wireless or wired communications interface. There have been huge advances recently in cutting the overall system power consumption, for example with sensors that can handle much of the processing themselves, so the main processor can stay in a low-power sleep mode for as long as possible. Highly efficient power management and conversion components have also reduced energy demands.

Wireless protocols such as Sigfox, Bluetooth Low Energy (BLE), and LoRaWAN now have minimal power consumption demands. Standby current for many components has been cut dramatically.

These advances in reduced energy demands can be important for IoT devices that spend most of their time in an idle state and only transmit information occasionally.

Well-established technologies have also been optimized to bring power usage down to very low levels.

Power Demands of IoT Endpoints (CON'T)

For example, Hall-effect sensors are based on an invention from 1879, but still play a vital role in motion detection for the IoT, such as determining whether a window is open or closed. Very low-power Hall-effect switches, such as the AH1911/AH1921 switches from Diodes Incorporated, can meet this need in a compact, robust package

For IoT devices with space constraints, Hall-effect switches in smaller chip-scale packages, such as the AH1892/AH1898, can provide the perfect fit.

However, low-power IoT devices also come with the expectation of having high processing capabilities, with processing being shifted in many applications from the cloud to the "edge," or the IoT device itself – thus benefiting from lower latency and reduced bandwidth costs.

This means that, for many applications, there is an increasing demand for power to the IoT endpoint even though efficiency is improving.

In relation to powering IoT chipset with the highest possible efficiency and lowest power consumption, low quiescent current LDOs, such as the AP7354/AP7351/AP2205/AP7370, can address the needs of applications with high and low supply voltage requirements.

Alternative Power Sources

Energy is all around us, and the power requirements of many IoT devices are nowadays so low that harvesting this ambient energy as their main power supply is a practical choice. This means that renewable sources such as solar and wireless energy harvesting are becoming possible options. Another alternative is to deliver power through wired data connections, such as Universal Serial Bus (USB) and Power over Ethernet (PoE).

Electrical power can be generated from many sources, including sunlight, motion or temperature differences, taking advantage of the surroundings of the IoT endpoint. For example, the pushing of a switch by a person can generate electrical energy using a tiny dynamo, or small solar modules can generate enough electricity to power sensors. Temperature differences can also be exploited to generate electricity, as can power harvested from RF energy in wireless networks. To ensure the IoT device still functions in periods of darkness or when no power can be generated by energy harvesting, energy can be stored in a small battery, a supercapacitor or a capacitor.

In fact, a supercapacitor or capacitor may be the best option, because it can go through many more discharge/charge cycles than a battery, without a decline in capacity – thus extending the service-free life of the IoT device.

While renewables and harvesting provide one solution, and are particularly suitable for wirelessly connected devices, there are still many devices that will deliver their data or receive their instructions via a wired connection. For these endpoints, a simple, cost-effective option can be to deliver power over this data connection, thus avoiding the cost and complexity of a separate dedicated power line. There are now many products available for this purpose that are capable of supplying low-voltage DC power, such as the AP61100 (5V/1A) buck converter for USB applications, or the AP62200 (18V/2A) /AP63200 (32V/2A) family, which is suited to PoE secondary DC bus applications. Using devices such as these can avoid the necessity of including power converters in endpoints, which would otherwise be required to convert the AC supply to a DC bus voltage.

FIGURE 1.

Wired in Focus

Let us look in more detail at how IoT devices can be powered over wired data connections.

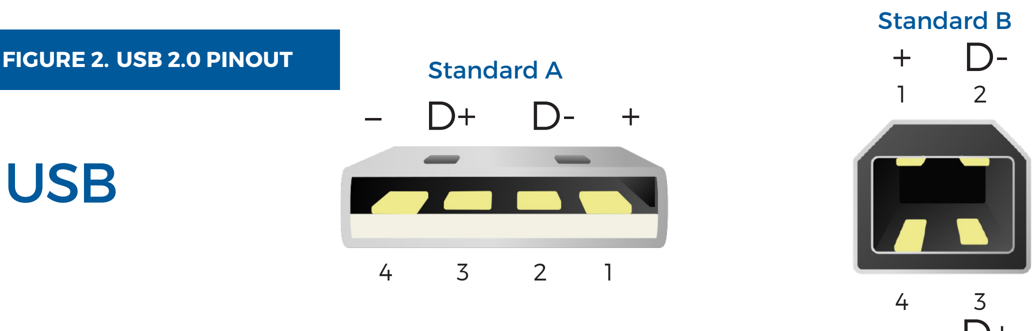
One of the most common options is the USB standard, which has become near ubiquitous in billions of devices all around us. This popularity has meant there is a huge range of USB options available to designers, and economies of scale have driven component costs down.

Figure 2 shows the pinout for USB 2.0, where there are two connections for data (D+ and D-), a 5V DC supply, and ground.

In USB 2.0, the charging current supplied is normally 500mA, although the minimum required is defined by the standard at 100mA, while USB 3.0 can provide 900mA.

For many of today's low-power IoT applications, this level of power is more than sufficient with most mobile devices needing 10W or less. For high-power devices such as monitor screens, the latest USB 3.1 (USB Type-C®) can support up to 100W, if needed. The specifics of power profiles and supply levels are negotiated between devices by sending and receiving pulses on the two data lines.

FIGURE 2. USB 2.0 PINOUT



(Courtesy: Wikipedia and Wiki Commons; by Simon Eugster)

Wired in Focus (CON'T)

Another common wired interface is, of course, Ethernet, which has become the dominant networking standard today. Being able to supply Power over Ethernet (PoE) means there is one fewer cable needed, and this has become a popular option for relatively low-power connected devices, such as IP phones. For the IoT, Ethernet may well be a good option to provide connectivity, and can be more robust than wireless.

There are multiple techniques for transmitting power on the twisted-pair Ethernet cables, with several of them defined by the IEEE 802.3 standard, which was originally ratified in 2003. These alternatives can transport power over the Ethernet data lines, by adding a common voltage to each data line, or can keep power and data on separate connections.

The latest version of the IEEE 802.3 standard defines multiple options for power transmission and supports the supply of up to 100W. This means that devices such as LED lights, high-performance security cameras and wireless access points can be supported, as well as IoT endpoints that require high power.

USB in Practice

USB as a power supply technology is familiar from the world of consumer gadgets, where it has mostly enabled us to replace the previous muddle of multiple different chargers and cables.

For IoT applications, USB provides simplicity of use, with enough sophisticated features to handle system management where needed – for example, to ensure each device takes only the power that it requires. Although there are only four USB wires, the standard defines negotiation protocols and power profiles, enabling communication between power sources and endpoints to optimize the supply.

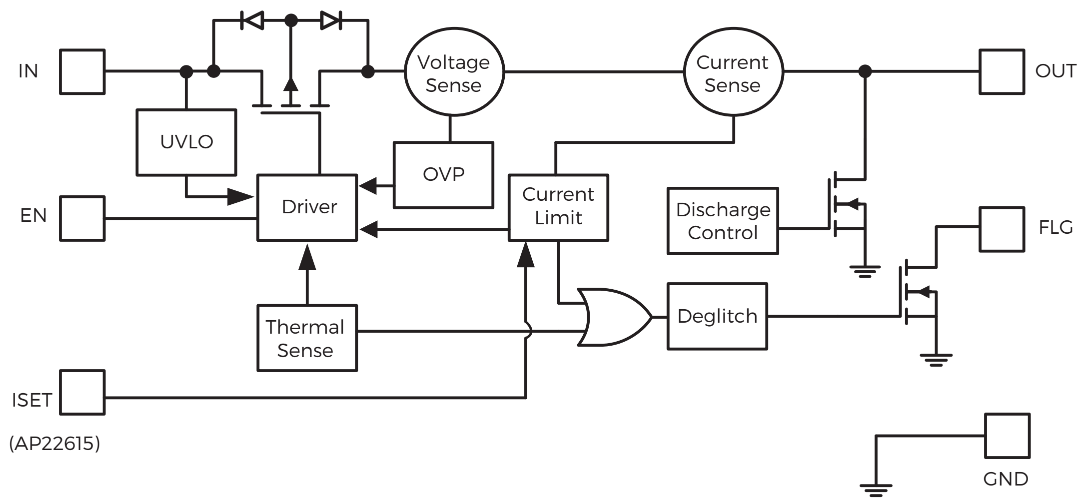
One important design feature of USB is that it does not require a handshake or data exchange *before* power is applied to a device. This keeps everything simple and plug-and-play and means that costs are low (with no need for a secondary power source in the device being powered). But it does mean there is a risk of faults, for example if a device tries to demand too much power or introduces a short-circuit.

To protect against these risks, designers can use a power switch (such as the AP22811/AP22804/AP22814 family), which offers over-current, short-circuit and over-temperature protection with auto-recovery, as well as protection against reverse current and voltage.

These devices provide high efficiency as well as protection for the USB ports, and can deliver up to 3A, with an extremely low on-resistance of 50mΩ to minimize power losses. For applications that require adjustable current, the AP22652/AP22653 can deliver up to 2.1A with 65mΩ $R_{ds(on)}$. Diodes also offers the AP22615/AP22815, which adds an over-voltage-protection function able to withstand 28V, with both a fixed and adjustable current limit.

The USB switches also provide a soft-start function, which ensures the output voltage has a reasonable rise-time to protect both the source and load. False fault conditions are minimized with a feature that provides protection against any current surges.

FIGURE 3: FUNCTIONAL BLOCK DIAGRAM OF AP22615 USB SWITCH



POE in Practice

If we look now at an example of a PoE system in practice, one use case is in smart homes or offices to power devices such as LED smart light bulbs. Each bulb is connected to a PoE switch over a standard Cat5 Ethernet cable, and is allocated an IP address by the switch.

This arrangement means the light bulbs can be controlled by an app on the user's computer or phone, for example to turn the lights on and off at a specific time, or even in response to a voice instruction. The system could also include other devices, such as ambient light sensors, which allow for more sophisticated control, such as brightness adjustment in response to daylight levels.

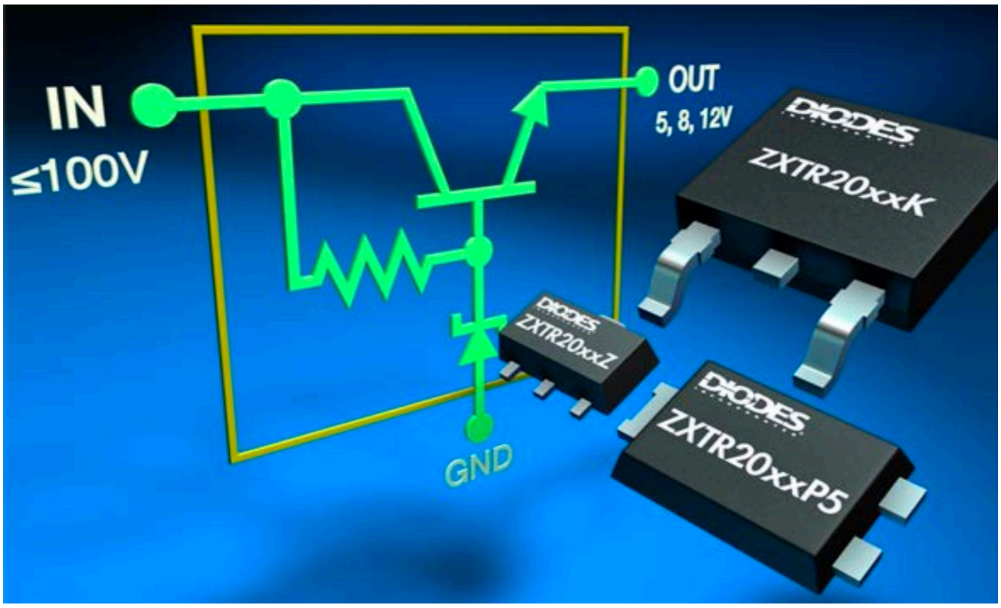
Similarly, security cameras can be powered using PoE, which means they only require a single data/power cable, rather than two separate wires. This ability makes installation simpler and more convenient, and reduces costs.

The high power available in recent versions of PoE is sufficient for more demanding camera features, such as high-resolution video capture, zooming and panning.

For these kinds of higher-power IoT applications, power efficiency is still essential to ensure multiple devices can run optimally, and designers will always be looking to reduce costs and save space. This requires efficient devices at each stage of the power system, with high density and integration where possible.

For example, the ZXTR2000 family of linear regulators is designed for 48V DC power systems, such as for telecoms, networking and PoE. By monolithically integrating a transistor, Zener diode and resistor into a single package, the regulators help to reduce component count and board space requirements.

FIGURE 4. ZXTR2000 HIGH-VOLTAGE LINEAR REGULATORS



Conclusion

As discussed, the IoT brings new requirements for efficient, low-cost power supplies. While offline AC power may be suitable for some applications, there are many situations where this is too costly, inconvenient or simply unavailable.

Batteries provide one alternative for powering IoT endpoints, but they require maintenance, charging or replacement at relatively frequent intervals, with lifetimes often being quoted at somewhere between three and ten years. For many IoT applications, this is not long enough, and the cost of service visits would be too high – if they are even possible.

Consequently, increasing attention is being paid to alternative ways to power IoT endpoints and new possibilities are opening up as the endpoints become more efficient and often have ultra-low power requirements. For some use cases, this means energy harvesting is an option – generating electrical energy from light, motion, temperature or RF energy.

For many IoT applications, however, energy harvesting is impractical. This may be because the endpoint has higher power requirements than can be supplied by harvesting, or there may be no convenient source of energy.

Therefore, providing power via a wired data connection, where it already exists, is a good solution for IoT endpoints in many applications. Both the USB and Ethernet standards support sophisticated power delivery modes, while maintaining simplicity of use, and there is a huge range of cost-effective, proven components available from multiple vendors.

It is vital that power is not an afterthought in an IoT design. By working with an expert in power management, such as Diodes Incorporated, system designers can ensure they choose USB or PoE components that are best suited to their requirements – and will provide an efficient, high-quality power supply for the lifetime of the IoT device.

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