Application Note

Power Rails Design for Battery Powered Camera and Video Doorbell

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ABSTRACT

Battery powered camera and video doorbell have a great growth in these years. In this type of product, all engineers have a common problem – how to extend battery working lifetime. This application note provides a power rails design based on high-efficiency and low-power consumption.

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1 Introduction

Battery powered camera products have had great growth in recent years, including wireless camera, video doorbell, e-locker and so on. Not only because battery power camera is easy to install anywhere, but also video performance and battery working time are improved. Correspondingly, the growth also pushes engineers to try to find extremely energy saving designs and energy supply designs. Basically, there are several approaches to extend battery working lifetime. Find ultra-low shutdown current power components which do not normally work, find ultra-low quiescent current power components for always working parts, design high-efficiency power rail to increase power utilization, install auxiliary power supply such as solar panel, optimize firmware to reduce run up time, and working modes.

2 Battery Powered Camera Functions

For battery powered camera, the most important functions are recording and uploading video stream to remote cloud or transferring video stream to remote PC or mobile phone. Beside the functionality, there are some other additional functions to highlight different camera products, such as PTZ function, remotely talking, night vision, auto recording when someone enters monitoring area, or can be powered by solar panel so easily install anywhere.

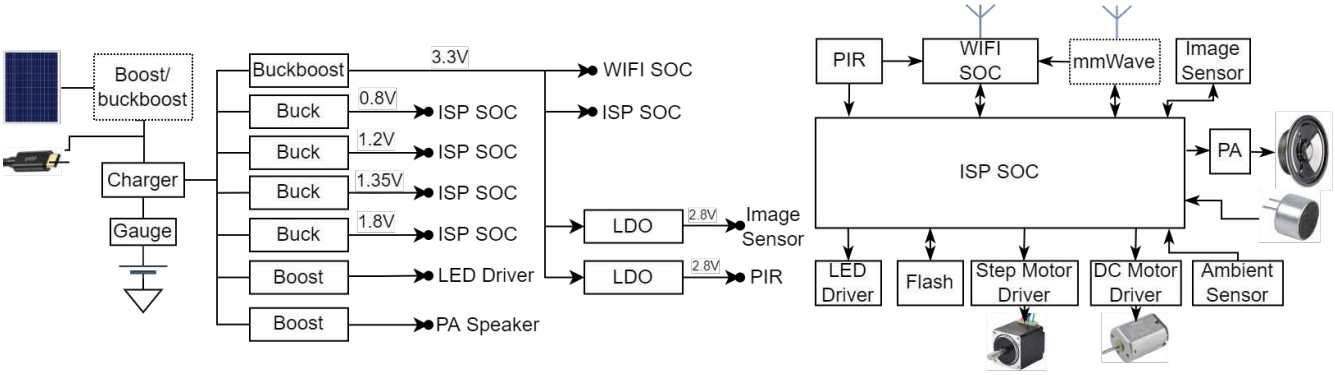

Figure 2-1. Function Block of Battery Powered Camera

There are several good functions in battery powered cameras, but customer experience is not good if the battery only works for a short time. So, for power rails design, the design not only implements all of the needed various power rails, but also to have a reasonable power design topology structure and firmware running processing, how to charge battery, save every micro energy from shutdown or sleep components to extend working lifetime as long as possible.

3 Power Supply

In most instances, the power supply has a USB charge port. With the increasing popularity of the USB Type-C® port, more and more battery powered cameras have USB Type-C charge ports instead of old Micro USB port in new design. Besides USB Type-C charge port, some battery powered cameras also supports solar panel energy input, the USB port allows the device to be installed anywhere with maintenance-free.

3.1 USB Type-C Charge Port

USB Type-C is more and more popular in many electrical devices such as mobile phone, laptop, hand-held power tools, and cameras. The USB Type-C has some very powerful functions, for example, higher-power input and output based on PD protocol, support USB3.1, support Display port protocol, ear phone connection, and so on. Recently, European Union (EU) lawmakers have reached an agreement on legislation to force all future smart phones sold to support USB Type-C port in the EU. Most of the battery powered cameras only need power input, and some integrate power output features. For most battery powered cameras, where the battery is only charged by adapter, quickly charging and high efficiency is necessary because end customers do not like waiting very long for battery charging.

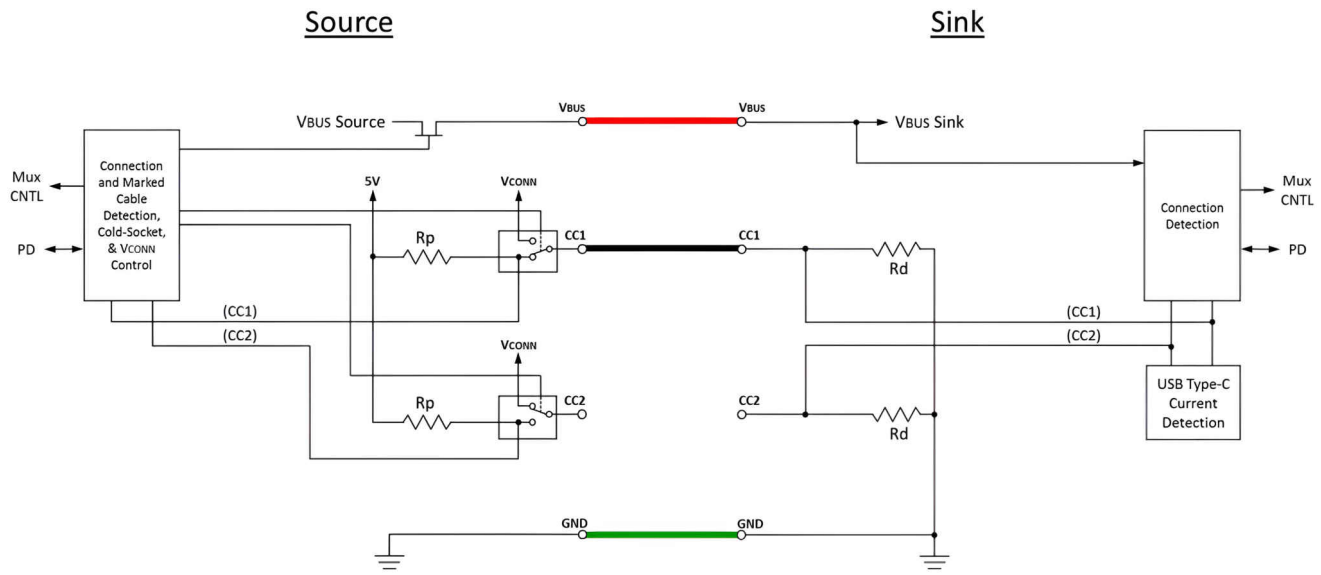

Figure 3-1. USB Type-C Connection Between Source and Sink

USB Type-C power can be output only after finishing negotiation between two devices by CC line.

If only needing 5-V input, a simple approach is to directly connect 5.1 KΩ resistor on CC pin, Sink receives max 5 V/3 A if the source supports.

If implementing a high-power input or with power input or output feature, a PD controller is needed.

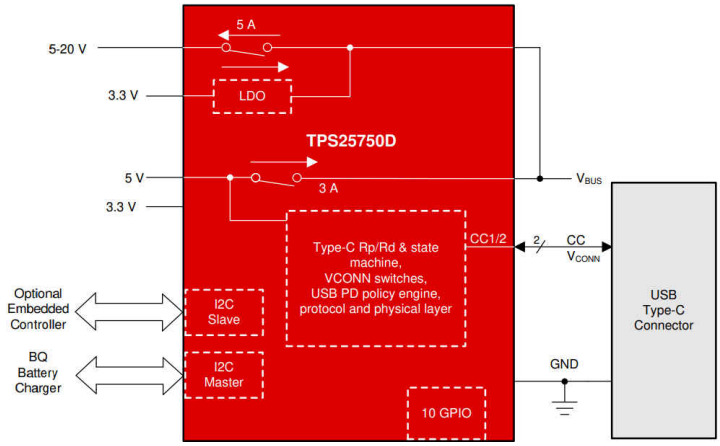

Figure 3-2. TPS25750D Function Block

TI offers most USB Type-C application chips of fully functional USB Type-C or only power path management. TPS25750D is integrated FET and PD controller, and has capability to handle up to 20 V/5 A input and 5 V/3 A output protocol. The TPS25750D has many power protecting features, for example, dead battery startup, current or voltage protection, and so on. By simple GUI configuration, TPS25750D can not only implement most PD power management, but also configure TI battery charger IC through primary I2C port.

3.2 Solar Charging

The equivalent circuit of the solar cell is shown as Figure 3-3. The solar cell is actually a power source which includes a somewhat larger internal resistance and has primary features of diode. The solar cell P-V and I-V curve is shown as Figure 3-4

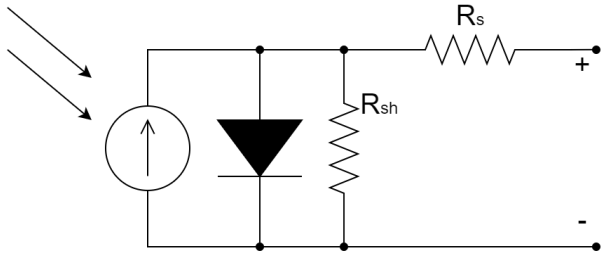

Figure 3-3. Solar Cell Equivalent Circuit

Under certain light and temperature conditions, solar cell I-V and P-V curve is shown as Figure 3-4. There is a max power point which is changing along with voltage rising.

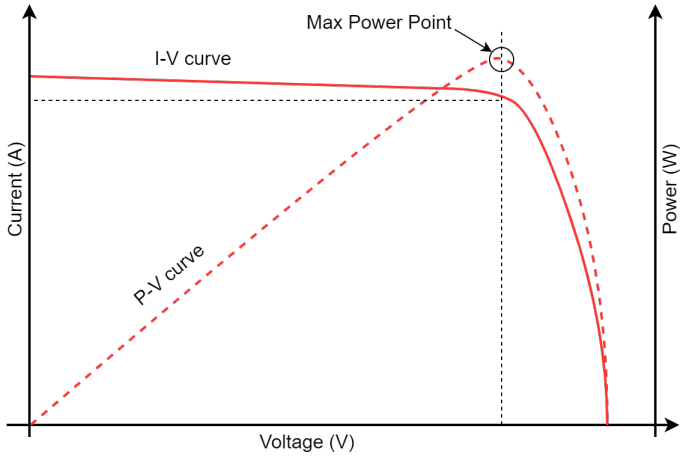

Figure 3-4. Solar Cell PV/IV Curve

Solar cell battery is not the same as normal battery such as Li-ion battery, the solar cell battery is most similar to a constant current source with a somewhat larger internal resistance. The output current and voltage is small on a cloudy day and night. Temperature is also a factor affecting current and max voltage of solar cell battery. so MPPT (Max Power Point Tracking) is an important feature in solar energy system, especially for power grid or high-power energy harvest system. But as a power supply for battery powered camera, instead of care about Max power point of solar cell battery, several designers mostly care about how to continuously and high-efficiency achieve energy both in day and night.

TLV61070A is 2.5-A boost component with pass-through feature. Quiescent current is 20 uA. If output voltage of connected USB adapter or solar panel is larger than configured voltage of boost, power can pass through TLV6170 and directly reach rear charger. And when solar panel output voltage is low in cloudy day or night light, TLV6170 start to convert input voltage to configured voltage such as 4.3 V. This process makes the charger continuously charge the battery even when voltage or current of solar panel becomes low.

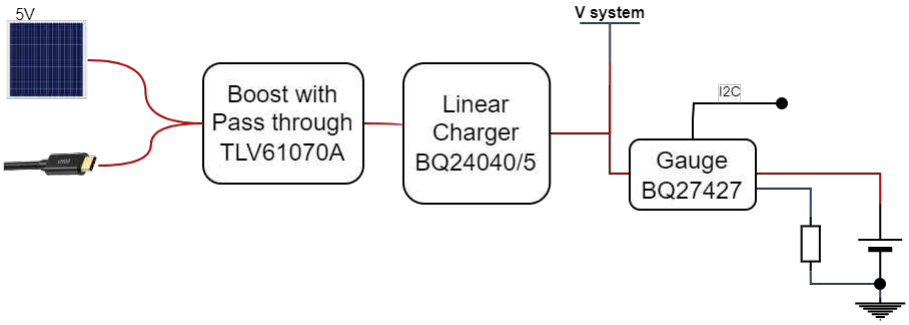

Figure 3-5. Solar Charger Design Function Block

BQ21040/5 is very low cost and max 1-A 1-cell linear Li battery charger without power path management and ship mode feature. Mostly, video processing circuit stays in sleep mode, and total average current is less than 1 mA. When the battery is charged to full status, the charger automatically terminates charging and damage battery not due to continuously charging.

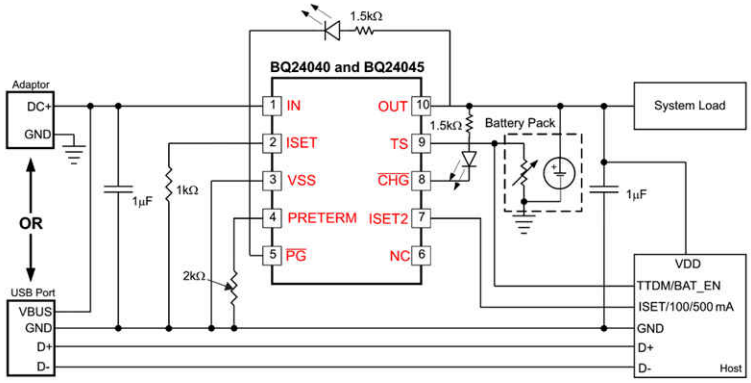

Figure 3-6. BQ21040/5 Charger Function Block

BQ21040/5 is a standalone charger with only a few external resistor configurations. Fast charging current and termination current can be separately configured, this makes it possible to input relatively big charging current in sunny day as well as input small charging current in darker days.

If using BQ21080 charger, the BQ21080 power path management function can provides shutdown charging when battery is full and video recording is continuously working. Ship mode can maintain that the battery has energy after finishing charging is delivered to end customer.

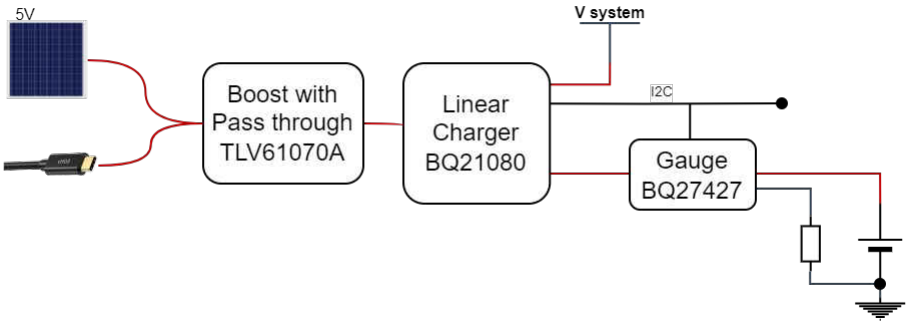

Figure 3-7. Solar Charger Design Function Block

BQ21080 is 800-mA, 1-cell linear Li battery charger with power path management and ship mode feature. With ship mode feature, the battery in camera can be designed nondetachable to save cost.

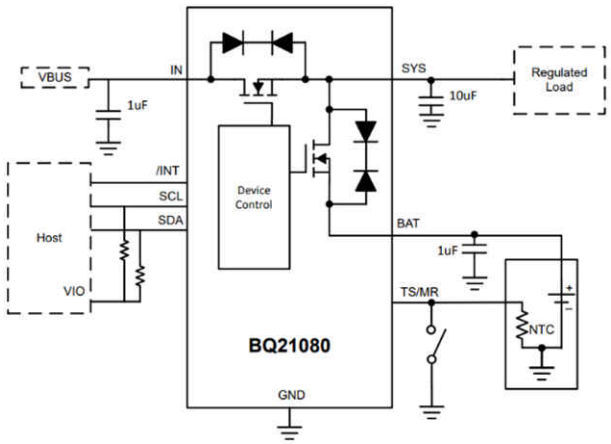

Figure 3-8. BQ21080 Charger Function Block

BQ21080 can also be easily configured through I2C such as charging current, termination current, enable or disable VINDPM, charging time, and so on. BQ21080 can configure battery regulation voltage with 0.5% accuracy from 3.6 V to 4.65 V in 10-mV steps, to support 4.35 V, 4.4 V , 4.45 V, high voltage Li battery charging. BQ21080 charging current range is from 5 mA to 800 mA.

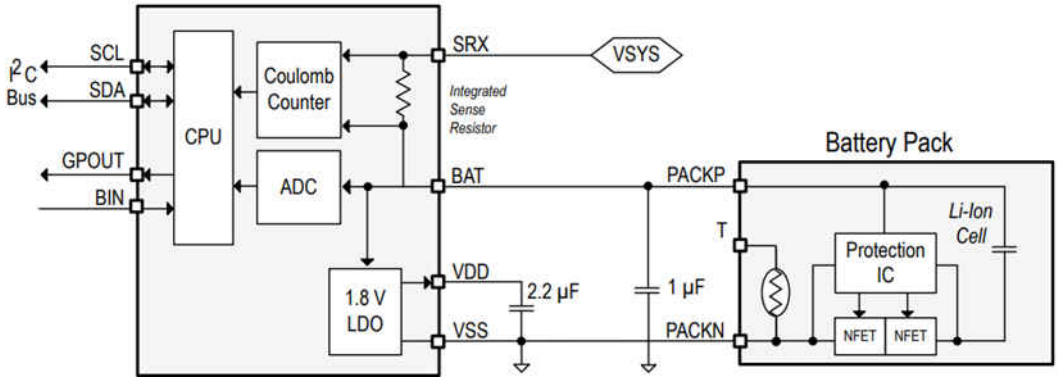

Figure 3-9. BQ27427 Gauge Function Block

BQ27427 is system side, 1-cell and low cost Li battery gauge, integrated sensing resistor, and supports 4.2 V, 4.35 V and 4.4 V charging strategy battery, and automatically adjust battery aging, self-discharge, temperature, and rate changes.

4 Power Structure Design

A good power structure is very important for low-power consumption design. The power structure not only implements high-power efficiency, but also must be a reasonable power management logic such as which power rail is always-on, which power rail can be asleep and also woken up. The reason why is the power structure needs to sort power rails to always-on power and power that can be shutdown if power consumption of video processing is too high, the current is not small even when video SOC stays in sleep mode. WIFI needs to continuously connect to the internet so that the power structure can respond to the remote request on time.

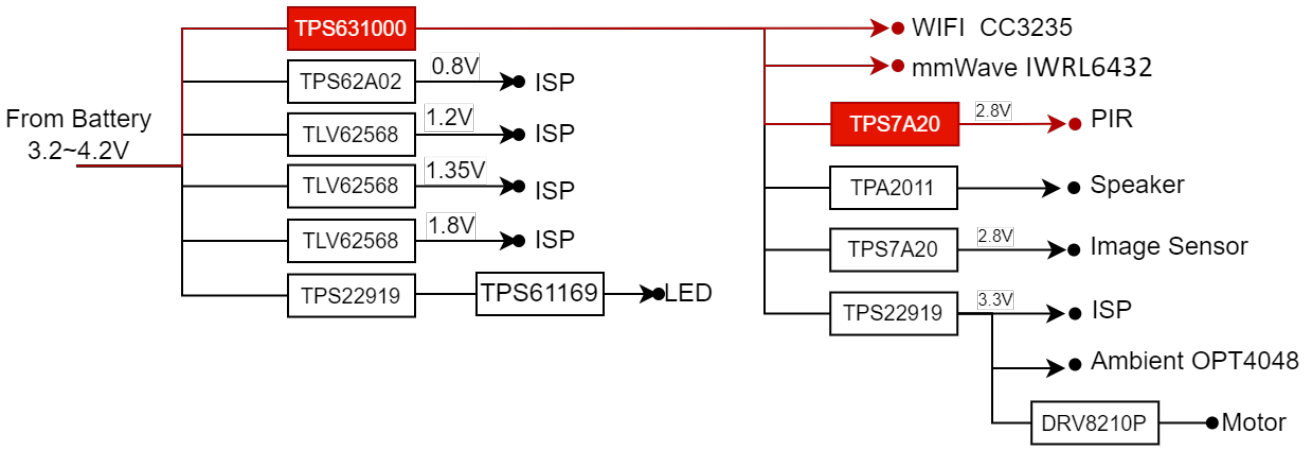

Figure 4-1. Battery Powered Camera Power Tree

4.1 Always Working Power Rails

The trigger event always needs to be powered on so the event can respond on time. PIR is mostly applied in battery powered camera to detect if there is a human approaching. At times, PIR is not suitable for some location that is easily exposed to sunlight due to causing several false alarms to wake up the entire system. A low-cost mmWave (IWRL6432) detector has no such concerns. The detector only detects movement through Doppler way and immunity temperature and light. Wi-Fi is not only the main transferring video stream, Wi-Fi also need receive remote command such as starting recording command. But power consumption of Wi-Fi connection is not very small, so there are some approaches to improve it, such as using TWT of Wi-Fi6, using Wi-Fi SOC which Intermittently working and sleep, using Sub-1GHz private protocol to connect a special remote station, something like this. TI Wi-Fi SOC CC3235 is specially designed for low power consumption which is just 4.5 uA in hibernate mode and 120 uA in deep sleep mode.

Figure 4-2 is a common power structure design. Some low voltage power rails are a little different because of using different ISP SOC.

Li battery output voltage changing is respective with temperature and discharging time as shown Figure 4-3. To achieve most energy from battery and get a stable voltage for sensing and RF performance, buckboost component is a good option.

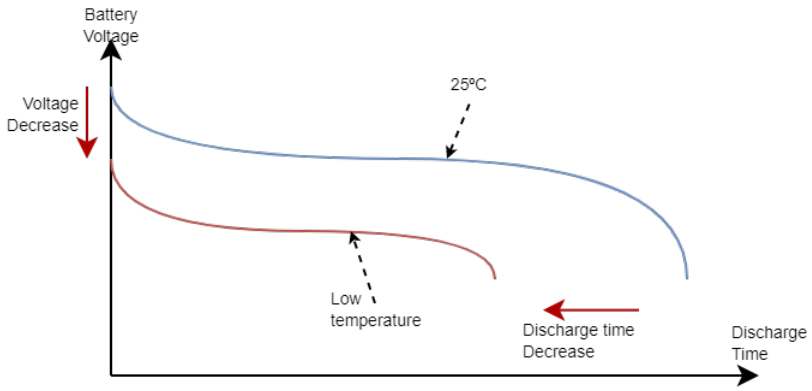

Figure 4-2. Battery Output Voltage and Discharge Time vs Temperature

TPS631000 is TI's latest and low-cost buck-boost component. TPS631000 SOT package and very few external components reduce total design cost.

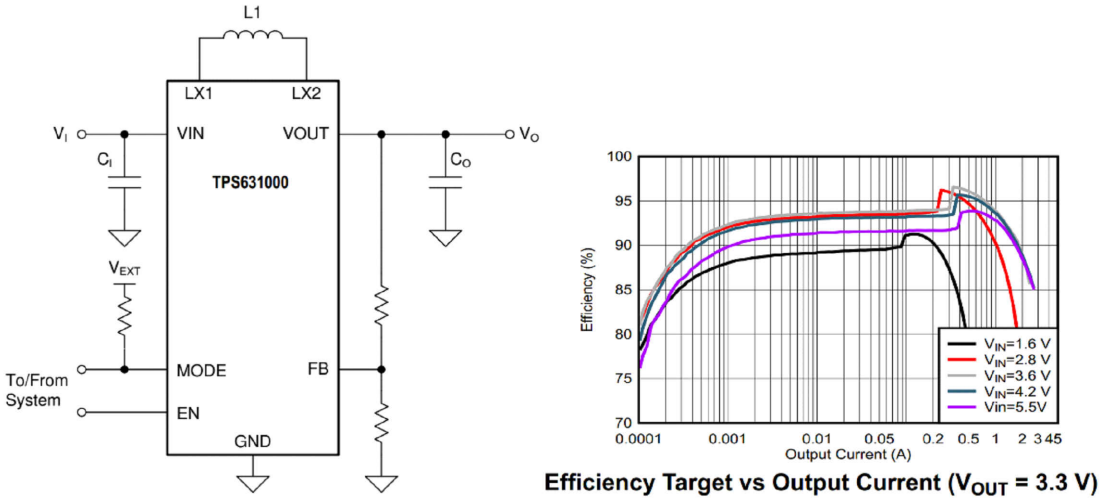

Figure 4-3. TPS631000 Efficiency

TPS631000 is specially optimized design for battery power supply to make its efficiency mostly over 90%, even over 95%. It has 8uA typical quiescent current and 2MHz switching frequency. All of these make it very suitable applied for battery power system to save energy in always working mode.

TPS7A20 is 300-mA low cost LDO with 7 uVrms noise, 6.5 uA quiescent current and 95dB/1KHz high PSRR LDO. These features make it ideal for always working to power sensor in low power consumption system. its shutdown current is less than 5nA under Li battery power input. so it can be also used in system which need to be shutdown.

Although Wi-Fi components is always powered by TPS631000, power consumption of Wi-Fi connection is relevant big. In most instance, Wi-Fi SOC is working in interval working mode. CC3235's SDK can support easily configured entering in deep sleep or hibernate mode and automatically be woken up by RTC or GPIO or remote network request.

Generally, always working power rails are major source of energy consumption, need give more consideration about power efficiency, quiescent current no matter in power converter, PIR LDO, PIR circuit, mmWave power rail, or Wi-Fi working mode.

4.2 Intermittent Power Supply

To increase battery working lifetime, video processing circuit is in shutdown mode most time and woken up and start to work when there is a trigger event such as PIR trigger, or regular task, or remote network request. Video processing circuit is consisted of ISP SOC, image sensor, Flash, ambient sensing, IR/White flash LED, IR cut and so on. Due to the fact that the video processing circuit are working in shutdown mode most of the time, more attention is shown to shutdown current and power efficiency. Actually, although video processing circuit working time is not too much,the video processing circuit are also a major source of energy consumption.

Efficiency of low voltage output is easily overlooked, especially since there are some similar voltage output efficiency. For example, 0.8 V efficiency is needed in design but only given 1.2 V voltage output efficiency in SPEC. Mostly, the lower voltage output, the worse the efficiency is. So, reference power efficiency is only needed when voltage output is larger than the SPEC given.

TPS62A02 is a 2-A buck with very good efficiency in low-voltage output.

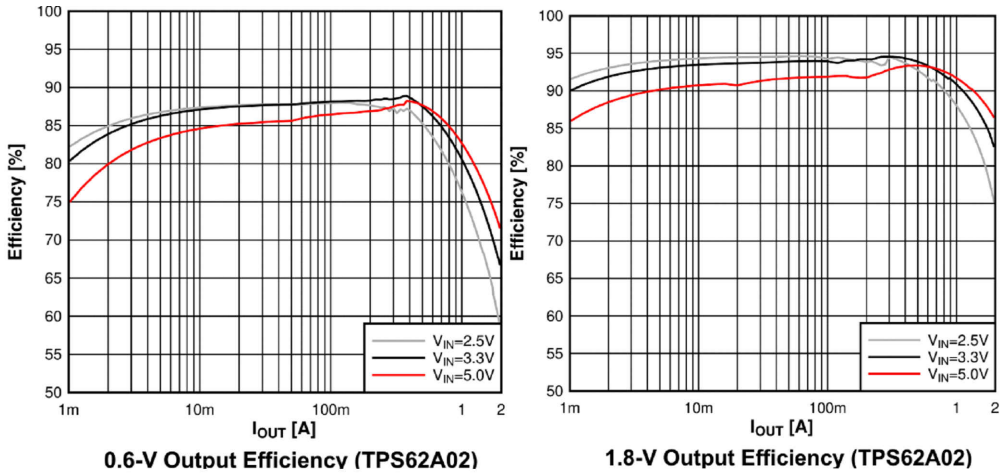

Figure 4-4. TPS62A02 Efficiency

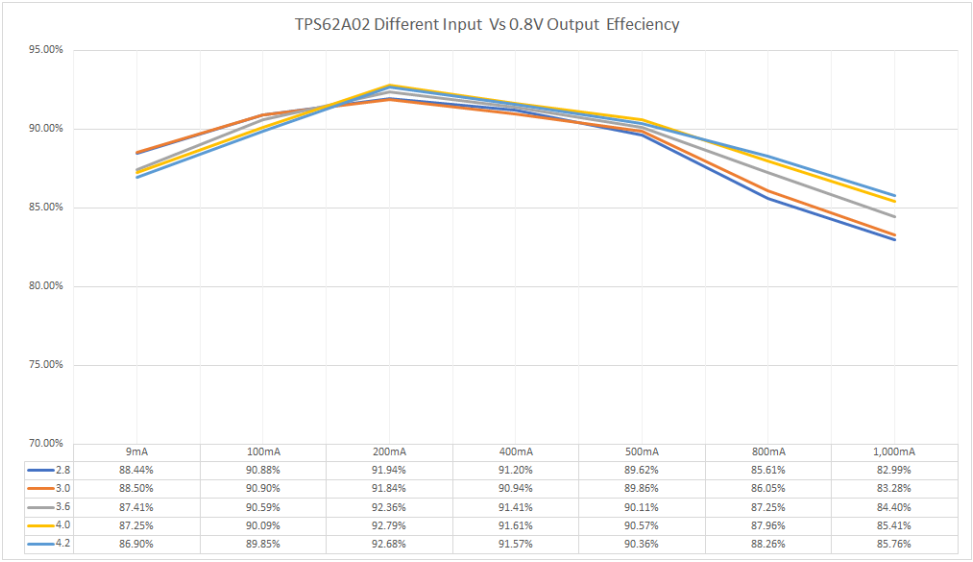

Figure 4-5. TPS62A02 Output 0.8 V Efficiency

TPS62A02 shutdown current is typical 10 nA. TPS62A02 is also a very good feature for shutdown mode.

TLV62568 is a very low-cost 1-A buck component with a good power efficiency. Shutdown current is typical 100 nA

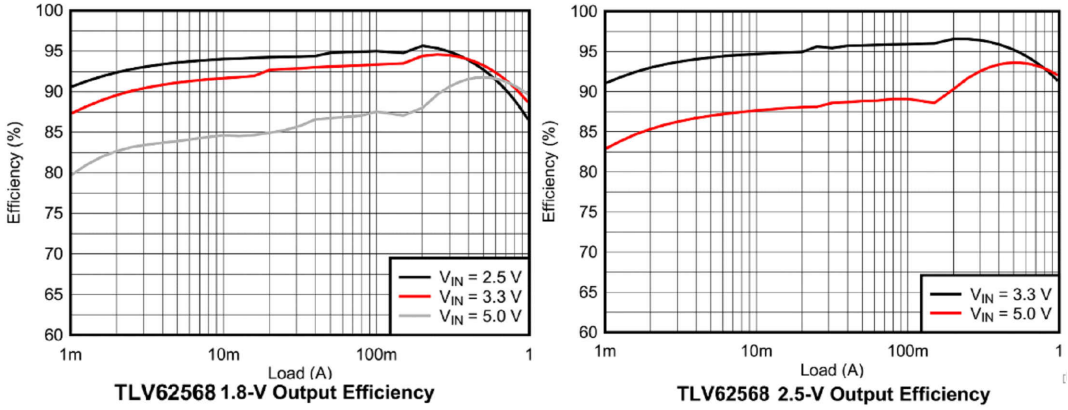

Figure 4-6. TLV62568 Efficiency

Sometimes, a load switch is a good option for shutting down some non working circuit in most time. TPS22919 is a low cost 1.5-A load switch. The load switch quiescent current is 8 uA, and shutdown current is 2 nA.

4.3 High Efficiency Power Rails

Based on the prior video working mode, a reasonable high-efficiency power rails increases battery working lifetime. From Figure 4-7, the most energy is used by LED lighting, video processing, always-on Wi-Fi and Audio. Except always-on power rails, others mostly take a big current when the power rails are awake and fully running. Especially for low voltage output rails, the efficiency is very low if not carefully selecting the correct component. Although cost is a critical factor in the product, total equivalent power efficiency is also a key feature which have a big influence for battery lifetime.

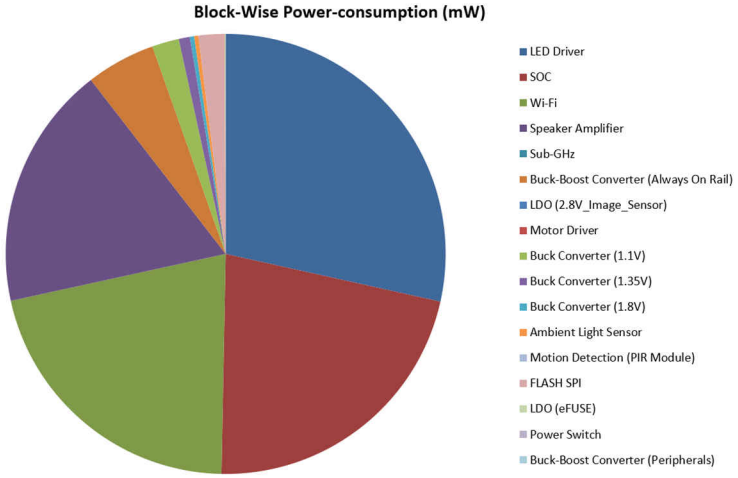

Figure 4-7. An Example of Battery Powered Camera Energy Consumption Pie Chart

For example, assume designed total efficiency is 70%, energy consumption without always-on power rails assumes taking 80% in total energy, real battery working lifetime is 100 days. If increasing total power efficiency to 88%, battery lifetime:

$$100 \times ((1 - 80\%) + 80\% \times \frac{88\%}{70\%}) \approx 120.5(day) \quad (1)$$

Total battery working lifetime increases over 20%. Although this is just a rough calculation because by not adding some sleep, quiescent, shutdown current changing, but the calculator also shares that the total power efficiency is very important in battery powered camera.

Besides using high-power efficiency and low shutdown current components in video processing circuits and using high-power efficiency and low-quiescent current components in an always working circuit. A good power structure can help improve efficiency, for example, in Figure 4-1, if PIR LDO and Image sensor LDO is placed before buckboost and directly connected with the battery, the power structure can provide good noise rejection, but efficiency is a little worse at times.

A good power management strategy can improve battery lifetime based on a designed for power consumption structure. In addition, Wi-Fi SOC low power consumption feature and working mode also have big impact for battery lifetime.

5 Conclusion

In power design of battery powered camera, a good power structure is very important for low power consumption design, as well as power efficiency, sleep/quiescent/shutdown current. Need pay more attention to design always working power rails, reasonable working scenes of video processing and trigger, and LED using strategy.

6 References

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