A Case Against Discretes

Nitin Kalje
Market Segment Manager
PMIC-Consumer/Industrial

Abstract

Power conversion and its management are critical parts of a system design. Power is one of the most vulnerable parts of a system as it is exposes that system to the outside world and handles high-power electrical signals. Complex hardware designs based on applications processors and communications processors require multiple numbers of power rails. Accuracy of stabilized voltage levels and their timing is critical for reliable system boot-up. Most of the time the power designs are not given enough attention, and project managers tend to cut corners with this critical function. For example, a discrete power solution implementation may actually end up costing more than a specialized power solution using power management integrated circuits (PMICs). This paper will discuss the hidden cost of discrete power solution implementations and how robust and reliable NXP® PMICs effectively reduce project costs.

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Complex power map for multiple applications

A typical multimedia system consists of a high-performance i.MX 6Dual or i.MX 6Quad processor with 2D, 3D graphic processing unit, 3D 1080p video processing block, multiple interfaces including DDR, WLAN, Bluetooth®, GPS, audio amplifier, various sensors, flash and camera control and drive units, SD, eMMC memory control and various communication interfaces like USB, HDMI, SATA, LVDS and mPCIe. Similarly, IoT gateway networking equipment typically includes a power-efficient, high-performance dual-core LS1021x processor, audio block, integrated flash, DDR memory, display control and multiple SerDes lanes for high-speed peripheral interfaces such as PCI Express, SATA and SGMI-II. All these interface circuits within the processors and the peripherals need various voltage levels and currents. Moreover, they all need to be powered up in a proper sequence for successful system boot up, and must be monitored for faults during the normal operation. This kind of complex power system design with discrete power devices is impractical without sacrificing the product quality. For example, the glitches associated with improper boot up or unexpected system failure can have huge negative impacts on customer experience and may even trigger an equipment recall event. The situation gets even worse when input blackout or brownout occurs. Turning off rails due to sudden power loss may not be as big of a concern as recovering the rails in a disciplined manner.

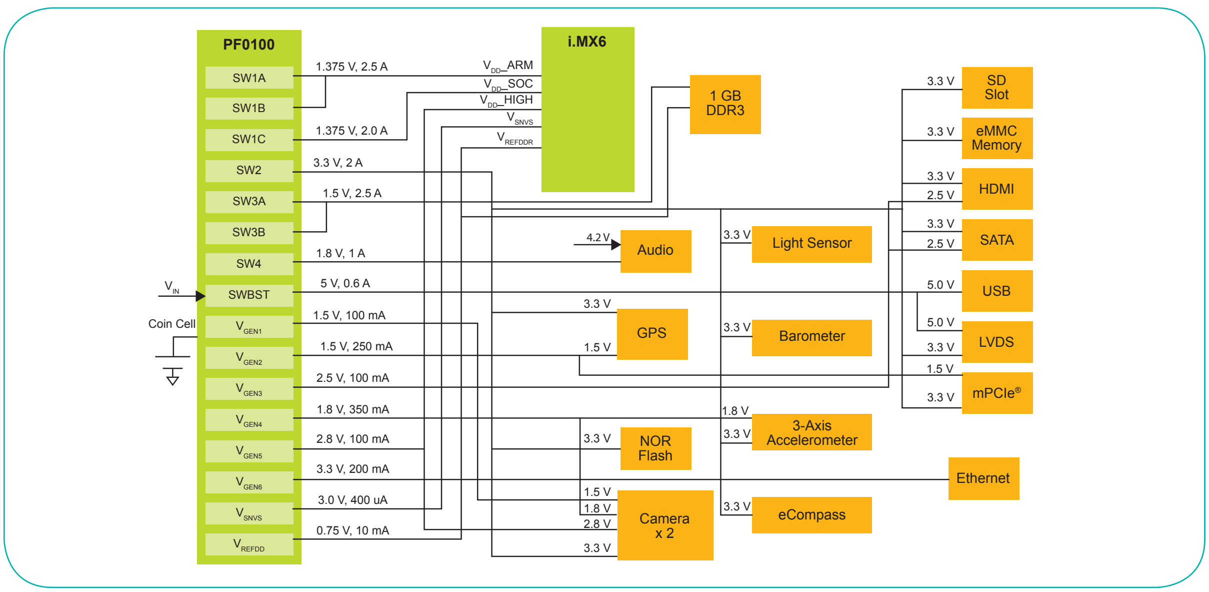

Figure 1: Complex power map for applications processors—i.MX 6 and MMPF0100

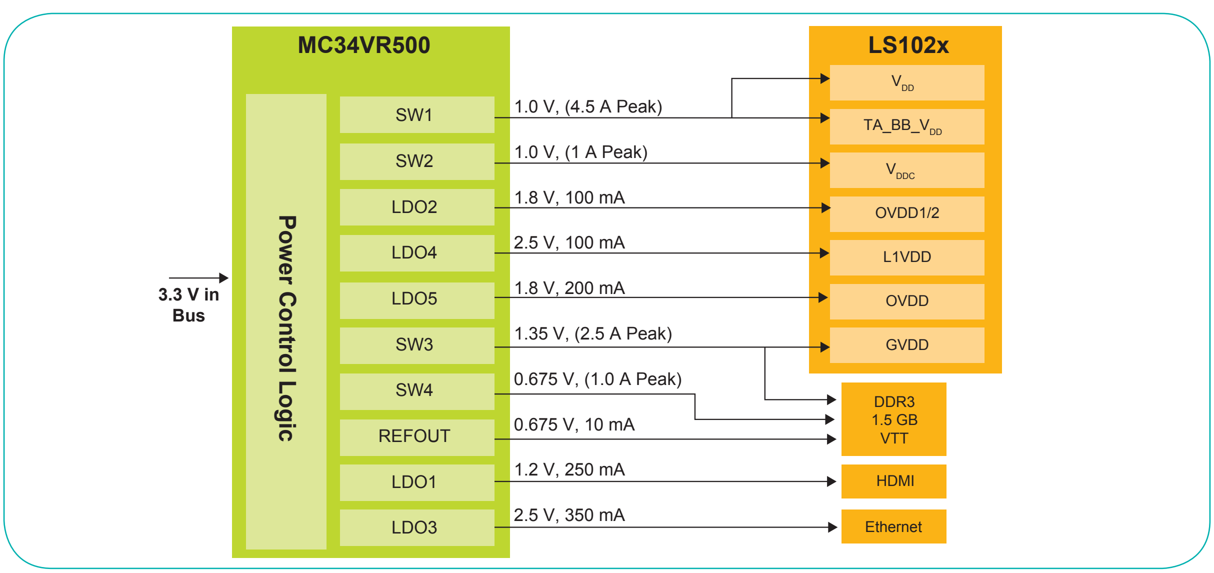

Figure 2: Complex power map for communication processors—LS1021x and MC34VR500

The PMIC's ability to centrally monitor all the LDOs, DDR and switching regulator blocks for overvoltage, overcurrent and overtemperature fault conditions, along with its ability to control the operation of these rails, allows smooth power down of the system. When used, NXP's PF0100, PF3000 and VR500 PMICs resolve the uncertainty of the power recycling behavior.

The MMPF0100 is a highly efficient, quick-turn programmable 14-channel, 11.7 A system power management solution targeting the i.MX 6 applications processor family. The MC34PF3000 is a high-performance, quick turn programmable, 12-channel, 7.2 A power solution targeting i.MX 6 UltraLite and i.MX 7 processors. The MC34VR500 is a quad buck regulator with a 4.5 A peak current and five user-programmable LDOs targeting low-power communications processors like LS1 and T1.

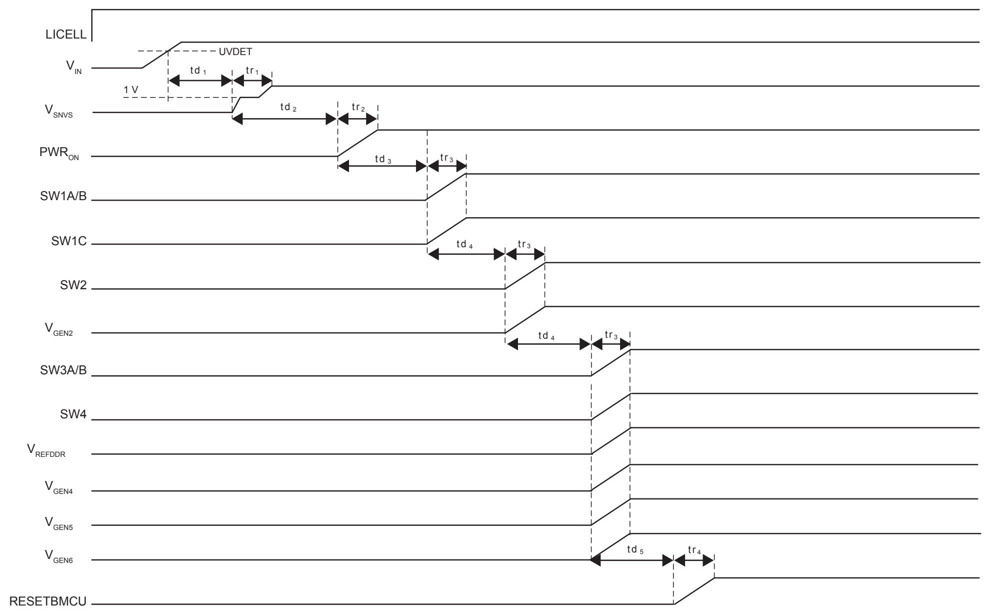

Figure 3: Complex power sequence (default)—MMPF0100

Hidden costs of discrete solutions

There are many apparent and hidden costs associated with discrete solutions. The cost of individual components is usually very low because they're usually purchased at volume discounts for use across multiple platforms. However, using generic components comes with inherent drawbacks.

- Generic components may not be a perfect fit for a given application and they may not be proven to work with target processors. For example, some discrete regulators' output voltage accuracy and settling time do not meet the processor tolerance requirements.
- Using a less-than-perfect power solution impacts device quality and the manufacturer's reputation.
- The solution size is another important factor to consider when designing the hardware.

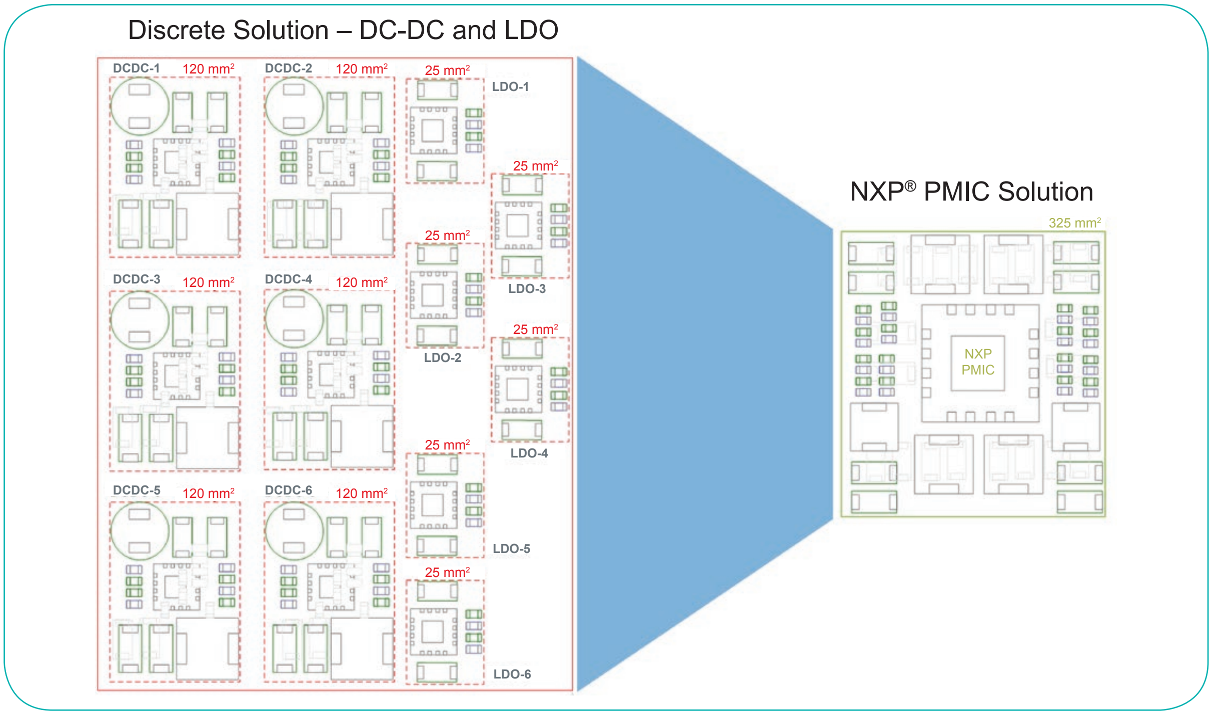

Figure 4: Typical component placement—discrete vs. equivalent NXP PMIC Solution

A typical discrete DC-DC switching regulator uses up to twenty discrete passives (resistors and capacitors). They're used for programming various parameters like V_{OUT}, soft-start, frequency, input/output filtering, sequencing delays, closed loop compensation and synchronization. And each LDO regulator uses up to four components including input/output capacitors, soft-start and start-up delays. The number of components quickly adds up to four to six buck regulators and six LDOs—and they become expensive to manage. Other hidden costs of using discrete solutions include:

a. Assembly and PCB cost—The placement cost per component may be insignificant but with the addition of hundreds of components, they become a significant portion of assembly. Many times, the cost of insertion exceeds the component cost itself.

b. Cost of carrying inventory—Keeping and managing hundreds of part numbers becomes a logistical nightmare. Additional resources for managing the inventory to ensure uninterrupted production line is not free.

c. Solution size—Any discrete implementation inherently increases the solution size. Depending on the frequency of operation and type of passive filter components, the discrete implementation could take three to five times larger PCB real estate in comparison with that of the PMIC implementation. Larger equipment size means packaging and high storage, shipping and installation costs.

d. Failure rate (MTBF)—Part counts and the number of joints seriously impacts equipment failure rate. According to the part count reliability prediction method, equipment failure rate depends on part complexity, equipment quality levels, equipment environment and the total number of parts. Adding hundreds of components to the bill of materials when using discrete solutions affects MTBF significantly. Refer to MIL-HDBK-217F Appendix A.

Apparent advantages of PMIC solutions

The combined requirement of multiple voltage rails, multiple functions and smaller equipment size demands extreme integration. High-power processor systems such as high-end networking switches and routers require distributed power architecture to ensure that the point-of-load (POL) regulators are physically located near the electronic loads. However, in the case of low-power, compact devices like wireless access points or e-book readers, a small PCB size mandates a highly integrated solution. The typical 2–3 A buck regulator needs about 100–150 mm^2 PCB area depending on the operating frequency and selection of passive components type. The most size optimized (up to 120 mm^2) solution uses relatively higher frequency operation, small ceramic capacitors and a high-density inductor. The typical 200–300 mA LDO needs about 25 mm^2 PCB area. Therefore, the MMPF0100 type of PMIC (4–6 DC-DC, 6 LDOs) equivalent discrete solution would need about 800 mm^2 of PCB real estate. In comparison, the MMPF0100 based solution can fit in 350 mm^2 PCB area, for a significant space saving of 60 percent (6–8 PCB layers).

NXP PMICs offer size optimization by design. State-of-the-art 130 nm BCD process technology along with clever architecture makes the NXP power solution exceptionally small. The PF0100/PF3000 series PMICs operate multiple DC-DC converters at the same frequency but in an out-of-phase manner. Out-of-phase operation effectively increases the switching frequency seen by the input capacitor. As illustrated in Figure 5, for example, the PF0100's four DC-DC regulators switching at 2 MHz and operating at 90 degrees out of phase, effectively increase the input capacitor ripple frequency to 8 MHz. Higher ripple frequency significantly reduces the input capacitor need and shrinks the solution size further. Note that the ripple phase operation is not feasible when using a discrete solution without adding significant cost as well as clock generator and synchronization complexity.

The I^2C-based central control and monitoring operation is an essential feature when powering the complex systems using high-performance processors like i.MX applications processors and Layerscape® communications processors. Highly integrated power regulators and PMICs with I^2C capability make the control and monitoring operation ubiquitous with the system. I^2C works seamlessly between numerous internal blocks including all DC-DCs, LDOs, the thermal sensor, the UV/OV detection circuit and the main processor load. Again, the discrete implementation makes it very difficult to monitor and control major functions from individual DC-DC and LDO regulators.

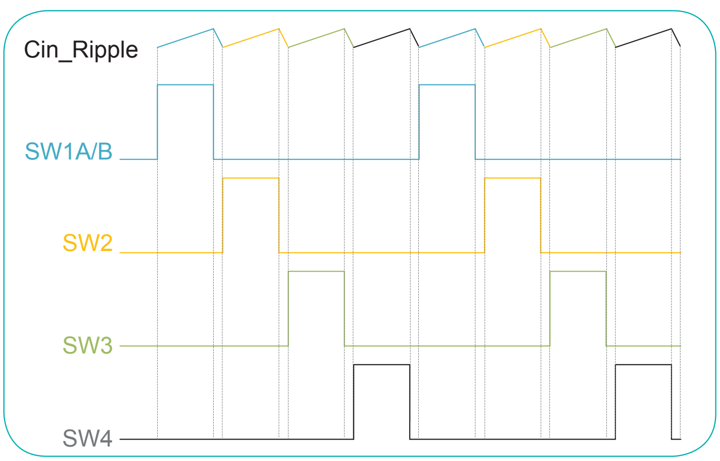

Figure 5: Ripple phase operation reduces required input capacitor

Conclusion

There is a good reason why the rise of PMICs coincided with the popularity of small hand-held gadgets like flip phones, smart phones and tablets with cramped processing power and connectivity. Adoption of PMICs has become necessary for equipment manufacturers to keep up with the customer demand of reliable yet highly portable devices while staying within their own budgets and logistical restraints. NXP's line of robust, reliable PMICs, such as the PF0100, PF0200, PF3000 and VR500, replaces discretes and provides a quick time-to-market solution without sacrificing performance.

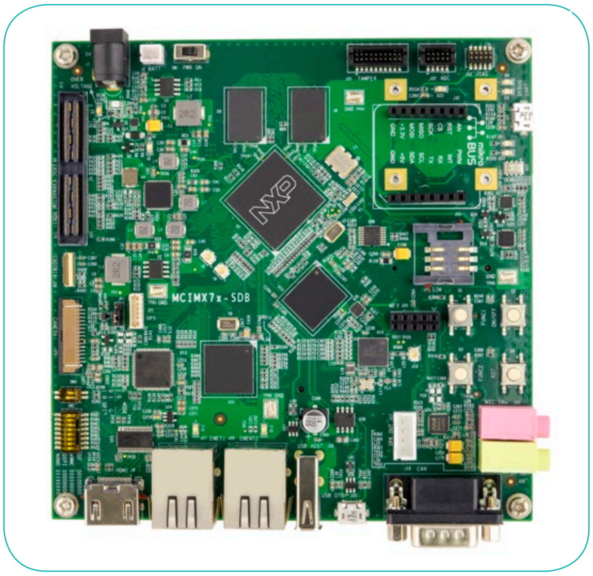

Figure 6: i.MX 7-PF3000 SABRE board

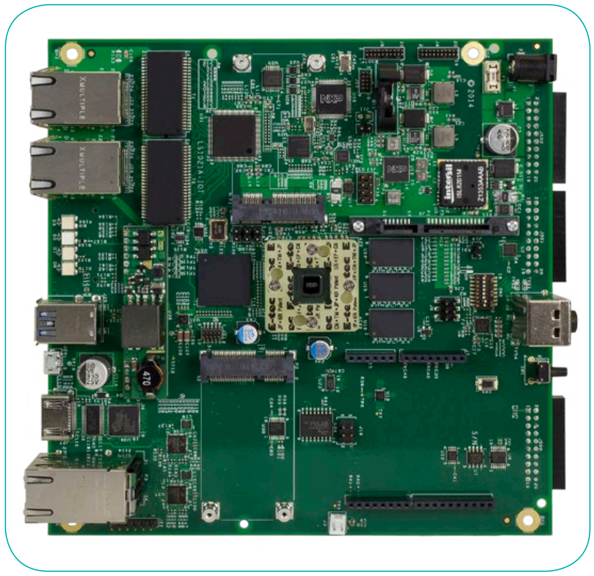

Figure 7: LS1021-VR500 IoT gateway module

Contributor

Nitin Kalje
Market Segment Manager
PMIC-Consumer/Industrial

How to Reach Us:

Home Page: **www.nxp.com**
Web Support: **www.nxp.com/support**

USA/Europe or Locations Not Listed:
NXP Semiconductors
Technical Information Center, EL516
2100 East Elliot Road
Tempe, Arizona 85284
+1-800-521-6274 or +1-480-768-2130
www.nxp.com/support

Europe, Middle East, and Africa:
NXP Halbleiter Deutschland GmbH
Technical Information Center
Schatzbogen 7
81829 Muenchen, Germany
+44 1296 380 456 (English)
+46 8 52200080 (English)
+49 89 92103 559 (German)
+33 1 69 35 48 48 (French)
www.nxp.com/support

Japan:
NXP Semiconductors
ARCO Tower 15F
1-8-1, Shimo-Meguro, Meguro-ku,
Tokyo 153-0064, Japan
0120 191014 or +81 3 5437 9125
support.japan@nxp.com

Asia/Pacific:
NXP Semiconductors Hong Kong Ltd.
Technical Information Center
2 Dai King Street
Tai Po Industrial Estate
Tai Po, N.T., Hong Kong
+800 2666 8080
support.asia@nxp.com

Document Number: PMICWP REV 1