Voltage Regulator Trade-Offs in Portable Devices

Voltage regulators and converters are extensively used in many electronic systems ranging from kitchen appliances to electronics for space exploration, and sophisticated military/spy equipment. They are most often placed between the main power source, such as a battery, and a load, such as an ASIC chip, to produce specific and accurate voltages. Typical electronic systems will need multiple regulators in order to create and maintain various required voltages within it.

Portable devices operate from batteries which are most often Alkaline, NiMH, Lithium or Zinc based. The voltage range of these batteries varies widely dependent on the type and quantity of batteries in each device. It can be from less than 1.0V for a single AA/AAA battery to around 8V for dual Lithium-Polymer batteries. Power delivery systems must therefore be optimized for each application.

Some of the main challenges in the design of power delivery in a portable device that must be considered are the efficiency, which affects operating time, the board area, the reliability, the solution cost, the noise, and the time to market. Figure 1, shows a block diagram of a portable device operating from a single Lithium-Polymer battery. It is clear that many solutions can satisfy different design specifications, even here in this simple system.

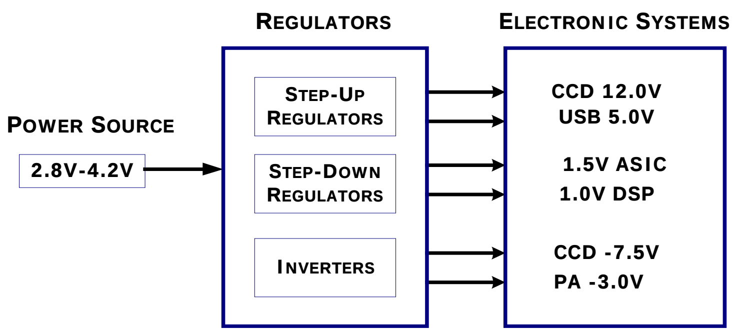

FIGURE 1. BLOCK DIAGRAM OF A POWER SYSTEM IN A PORTABLE DEVICE.

To illustrate this point, a simple example can be used to demonstrate numerous architectures and their advantages with respect to each other. Figure 2, shows a portable electronic device that consumes 464mW of total power and is operated from a Lithium-Polymer battery with 3.5 Watt-Hours of energy. The simplest approach to deliver power to all of the sections in this device is to use 4 linear or LDO regulators and two step-up or boost converters. Assuming the boost converters have 85% efficiency, then the device would operate for approximately 324 minutes. Here, a constant energy level is implied for the battery and it is also assumed that all of the blocks are constantly operating at all times.

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Now, if the cost for each LDO regulator solution is assumed to be $0.25 and the cost for each DC/DC converter solution is estimated to be $0.75. In both cases this cost would include the cost of IC and passives. The total solution cost for the power delivery design shown in Figure 2 is $2.50. (The cost of monitoring or charging circuits is not included in this example.)

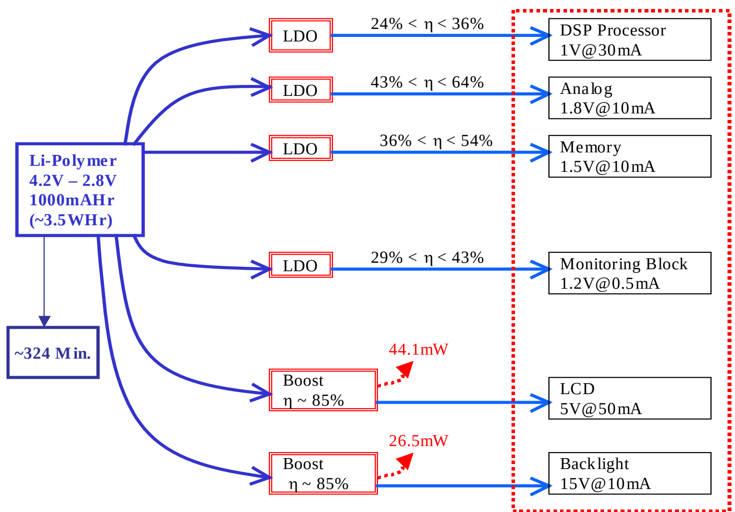

FIGURE 2. POWER DELIVERY SOLUTION FOR A 460MW PORTABLE DEVICE.

The power delivery system price tag in the device can be reduced if the boost converter used for the LCD is replaced by a linear or an LDO regulator. Figure 3 shows the new design where only one boost converter and 5 LDO regulators are used. The total cost is lowered to $2.00 (based upon previous assumptions) at the expense of lowering the efficiency and reducing the operating time to 170 minutes. The 25% reduction in cost has had a net effect of a ~47% drop in operating time. (Again, the cost of monitoring and charging circuits are excluded.)

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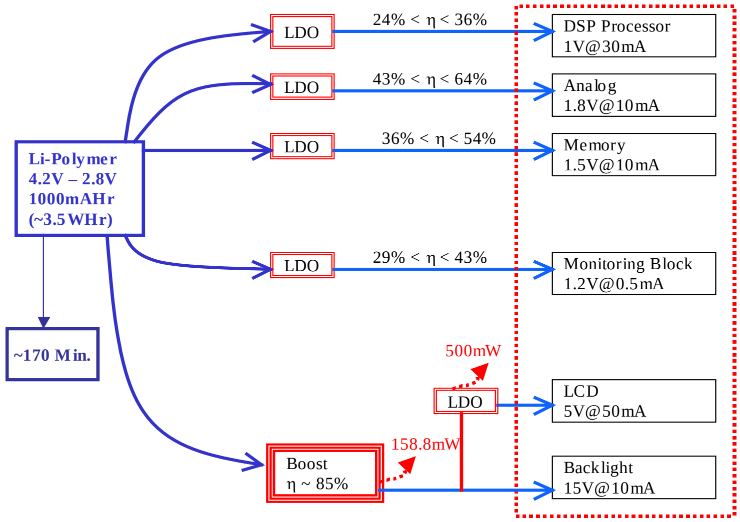

FIGURE 3. REGULATOR DESIGN FOR THE PORTABLE DEVICE WITH LOWER BOM.

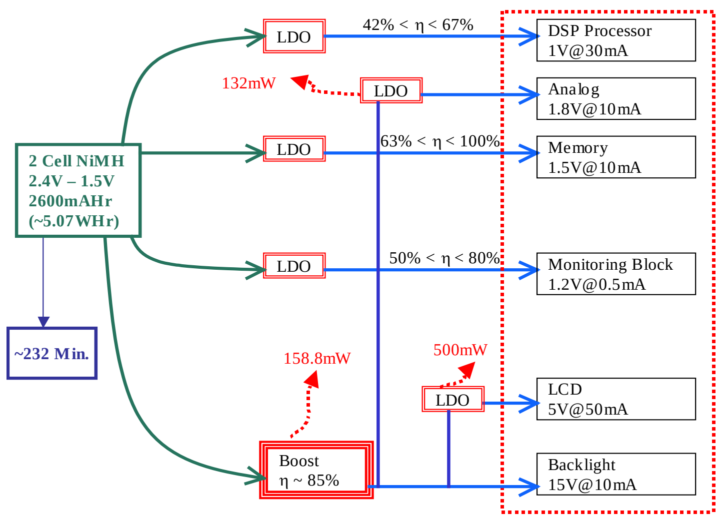

FIGURE 4. THE SAME PORTABLE DEVICE OPERATING WITH 2 NIMH BATTERIES.

Figure 4 shows the same device operating from two NiMH batteries instead of a single Lithium Polymer battery. Using NiMH batteries would reduce the overall cost by removing the expense associated with Li-Polymer battery and its related charging and monitoring circuits. However, since NiMH batteries have less power per mass, the overall size and/or weight of the battery can increase. The power delivery system shown in Figure 4 would cost $2.00 (based on previous assumptions) while the device would operate for 232 minutes. Figure 5 shows another design variation for the same device that is operating from two NiMH batteries. This solution shown in Figure 5 would cost around $2.40, with operating time of around 480 minutes for the device.

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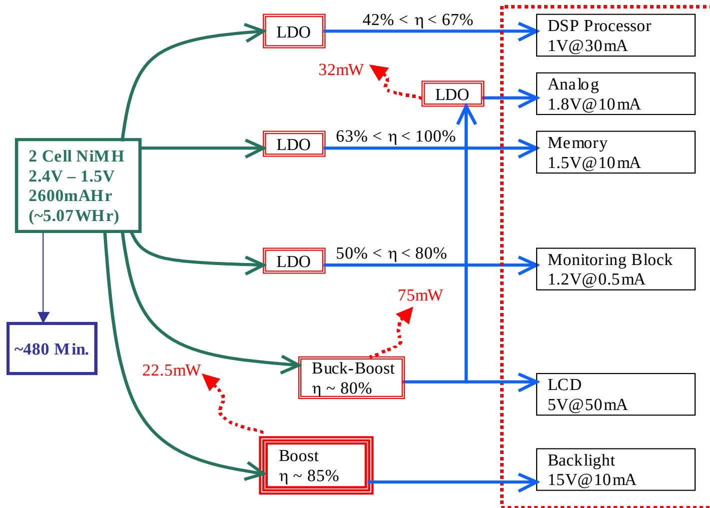

Figure 5. Another power system design for the device.

Moving or replacing one component in the power delivery design can effect operating time, while the cost variations can be relatively small. Selecting the optimum solution in a portable device can be a very important item that will shape the overall performance and cost of the portable system. Table 1 summarizes the cost and operating times of the four depicted design examples. These examples illustrate that the power delivery and regulation system can be heavily influenced by the main power source, budget and available space.

TABLE 1. SUMMARY OF COST AND OPERATING TIMES FOR ILLUSTRATED EXAMPLES.

	FIGURE 2	FIGURE 3	FIGURE 4	FIGURE 5
BATTERY	1 Cell Li-Polymer	1 Cell Li-Polymer	2 NiMH	2 NiMH
BOM (USD)	$2.50	$2.00	$2.00	$2.50
OPERATING TIME	324 Minutes	170 Minutes	232 Minutes	480 Minutes
% CHANGE	1 (Normalized)	47% ↓	29% ↓	48% ↑

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