Designing Multiple Load System Power Supplies

Design tools have been developed over the past ten years to help power supply designers create single DC to DC power supplies. These tools feature parts selection, material cost calculation, simulation and prototype procurement. This has simplified the design process and reduced time-to-market. But with design complexity increasing, the need for ten or more power supplies on a PC board has increased the challenge. Now, a new breed of design tool has emerged that allows the configuration and design of multiple-load power supply systems at one time. Performance goals such as small footprint, high efficiency and low overall system cost can be applied to an entire system at once. **Jeff Perry, Senior Manager WEBENCH Tools, National Semiconductor Corp., USA**

To begin the power supply design process, the engineer needs to first determine the voltage and current specifications including minimum and maximum input voltage, output voltage and load current. The user must also decide the overall design goals for component footprint, efficiency and cost. Then the designer can use a tool such as National Semiconductor's WEBENCH® Designer to visualise the options to determine which solution is best for the design requirements.

Designing a single power supply

Figure 1 shows a graph of different solutions for a typical buck power supply that has 14-22V input, and 3.3V/1A output. The y axis shows the component footprint, the x axis shows the efficiency and the bubble size shows the total bill of material (BOM) cost. In this case, there are 50 different design possibilities shown for the given set of inputs and there is considerable variation in performance of the different designs. This is due to a) differences in switching frequency, b) devices having synchronous versus asynchronous switching, and c) controller devices with external FETs versus integrated FET devices. The graphical approach makes it easy to determine which solution fits the designer's goals and what the trade-offs are.

System level design

If one takes this single supply design approach and applies it to an entire system, then the number of possibilities increases dramatically. For example, Figure 2 shows a system board which has an FPGA, memory, communications and motor control elements.

This system has an input of 48V and nine loads. The first task in creating the system level power supply is to group the voltages together, which gives us a total of five outputs. Next the designer needs to

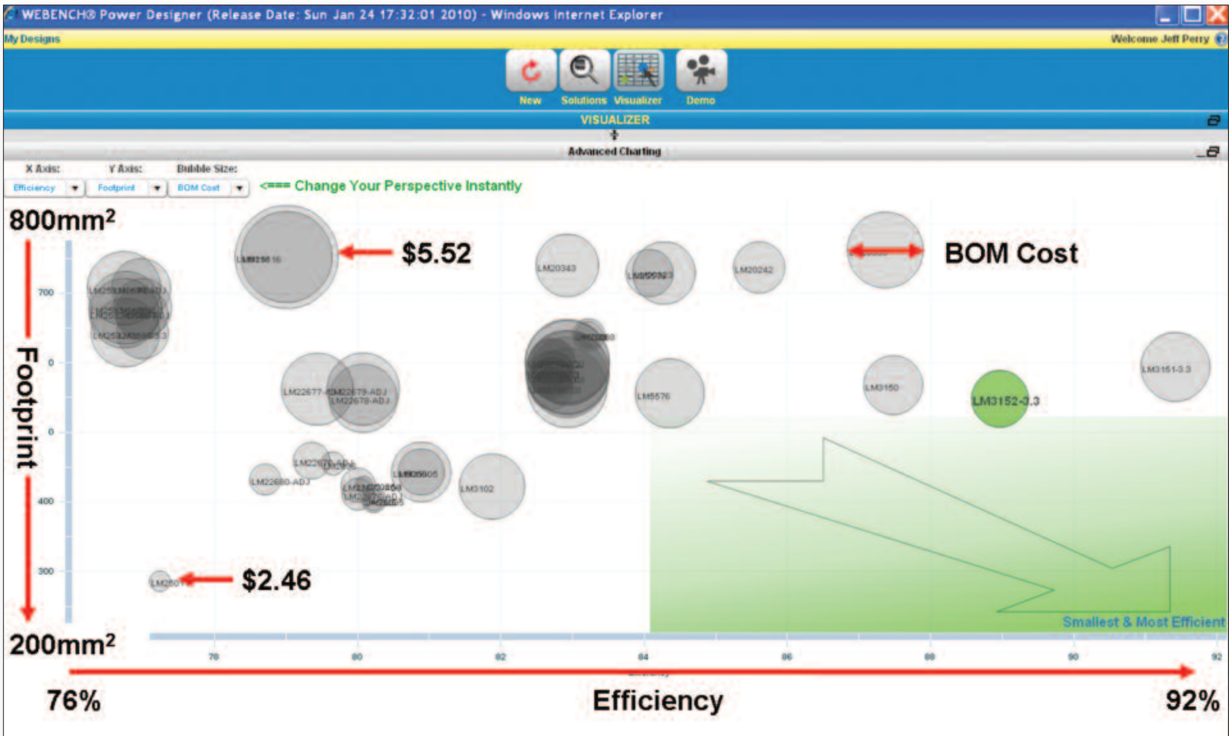
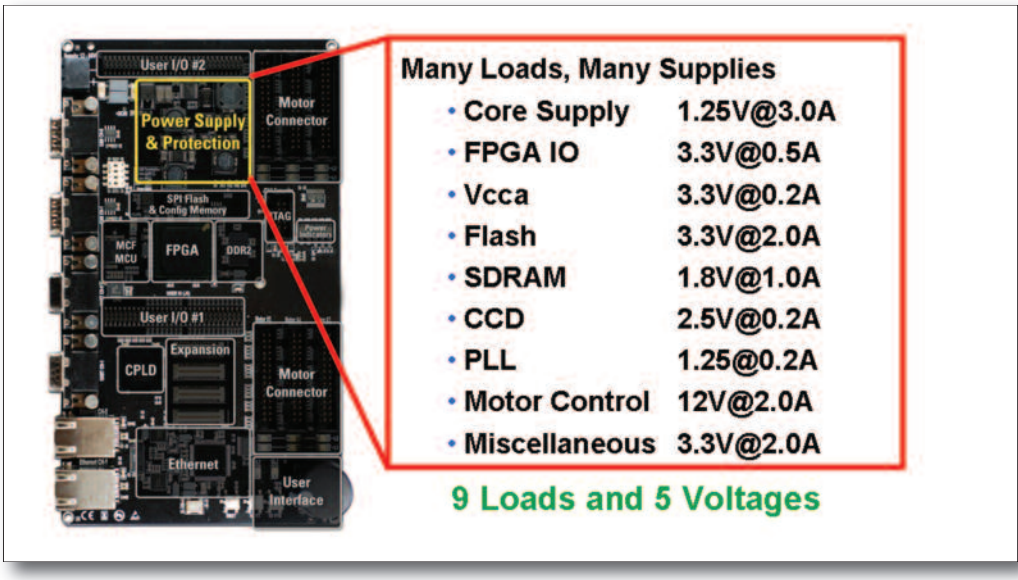


Figure 1: **Graph of 50 different power supply solutions for a given set of inputs showing trade-offs between footprint, efficiency and BOM cost**



Example of multiple DC loads within a single system board requiring multiple power supply solutions

determine the architecture required including the need for one or more intermediate voltage rails which are placed between the source supply and the point of load supplies. An example of this is shown in Figure 3.

An intermediate rail can often improve the performance of the system by restricting the duty cycles of the various supplies to optimal regimes to improve efficiency. It can also reduce cost and footprint by limiting higher voltage components to the intermediate supply and allowing the downstream supplies to use lower voltage components which tend to be less expensive and smaller, particularly in the case of ceramic capacitors. After determining the voltage rail architecture, the designer needs to optimise the supplies for small footprint, high efficiency and/or low cost.

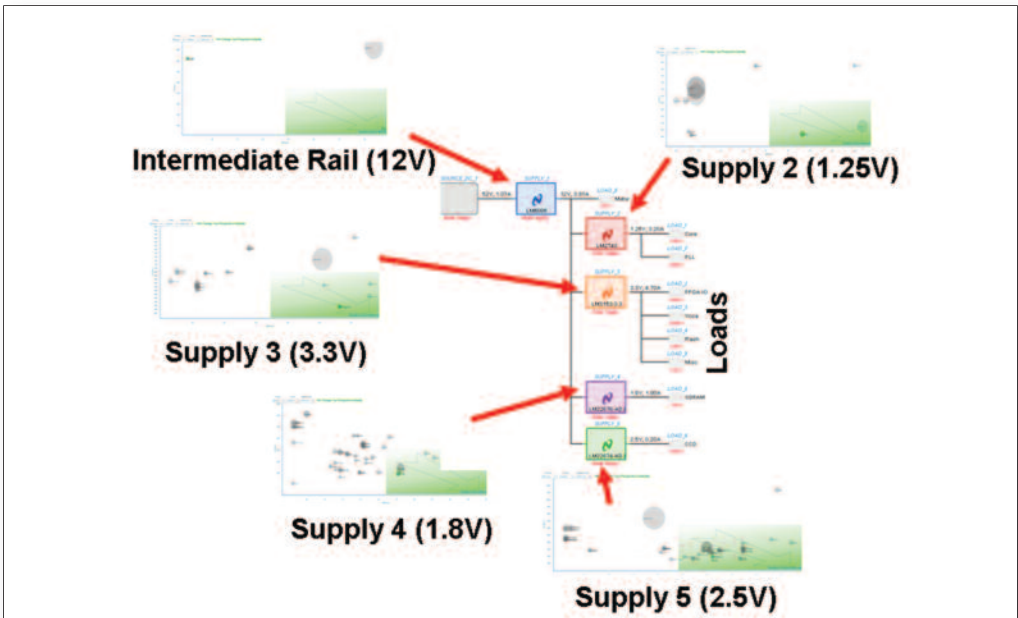
The problem with this approach is that possibilities multiply rapidly. For example, if there are five different voltage rail architectures, five different power supplies and fifty possible power supply solutions for each supply, the designer now has 1,250 options to be considered. Add in five different optimisations for efficiency, footprint and cost and the total grows to 6,250 solutions to review.

The key is to narrow the choices down and use visualisation tools to drive to the best solution for the design goals. Figure 4 shows a plot of different system level designs produced from the WEBENCH Power Architect tool. Each bubble in the chart represents a different architecture/rail configuration and different optimisation for footprint, BOM cost or efficiency. As can be seen, there is a significant variation in the results.

System design optimisation

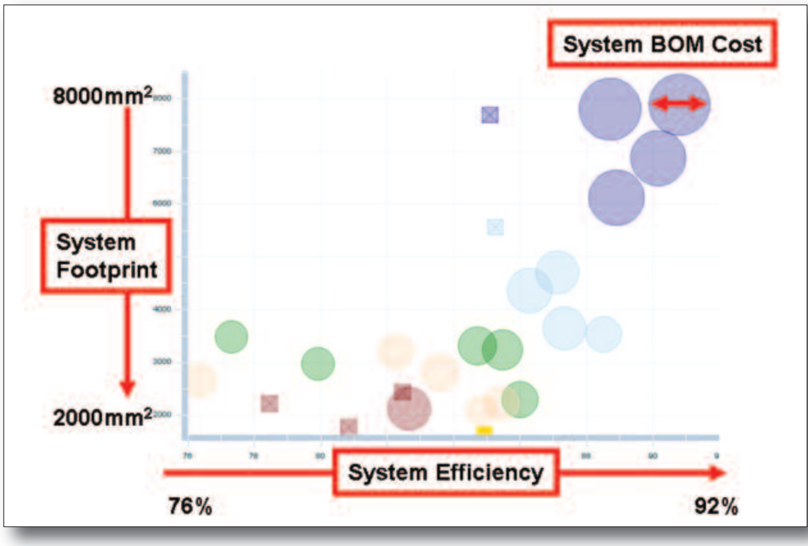
Within Figure 4, the different colours represent the various design optimisations. For the designs optimised for high efficiency, the switching frequency was lowered to reduce AC switching power losses and improve system efficiency. However, in order to keep the inductor ripple current constant at the lower frequency, the inductance was increased, which then increased the footprint of the inductor and led to a larger overall system footprint. Also, the BOM cost has been increased which is typical of larger components.

These designs are shown in the upper right corner of the graph in dark blue colour. On the other hand, for designs optimised for small system footprint, the frequency was decreased which allowed the inductance, and inductor size, to be reduced while maintaining the same inductor ripple current. The smaller parts tend to be less expensive so the overall BOM costs have been lowered. The trade-off is that the AC switching power losses have increased and the efficiency has gone down. These results are shown in the lower left portion of the graph in red colour. Other colours shown on the graph are compromises between the



Typical power supply system architecture using one intermediate rail supply at 12V and four point of load power supplies. Also shown are the trade-off graphs for each supply showing the large number of options to be considered

Graph of 25 system solutions for a nine load power supply system. The colors represent different optimisations emphasising small system footprint, low system BOM cost or high system efficiency



two extremes.

The extreme values of the array of power supply solutions are shown in Figure 5 and the trade-offs to be made are evident. To achieve the highest system efficiency of 91%, the system BOM cost and component footprint are 2.8 and 4.3 times higher than the other extreme options. On the other hand, to get the lowest BOM cost or smallest footprint, the efficiency drops to 85%. But the designer can also choose options in between the extremes.

Thus we see that using tools which allow the user to narrow down and visualise large numbers of multiple load system-level power supply solutions can save a great deal of time during the design phase and lead to an outcome that is optimised for the designers specific needs.

Literature

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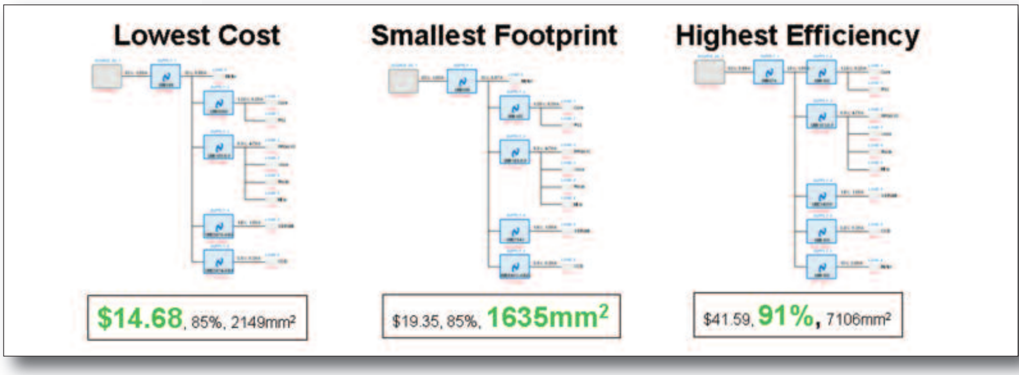

LEFT: Summary of system solutions for a nine load power supply system showing lowest BOM cost, lowest component footprint and highest efficiency options