Telecom Power Systems: Why be Discrete?

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Power supply modules have been very popular in telecom systems for their ease of use, design robustness, and multiple sources. The system designer just determines the maximum load requirements, consults a favorite vendor's catalog, and the power system design is done as shown in **Figure 1**. However, in so doing, the designer loses an excellent chance at putting money on his company's bottom line and gives it to the vendor. The designer also gives competitors who are willing to invest in the power supply engineering a chance to undercut his prices. The traditional option of going with power modules not only has a high cost, but also leaves the board designer with little flexibility to adapt to changing power needs across different boards. The result is typically an over-design and a less than optimal performance-to-cost trade-off. On the other hand, the option of going with a discrete solution requires significant engineering resources for power design, qualification and transfer to manufacturing. Also, some designers are concerned that the system may be less reliable if they put power components on the same PCB as the high value digital circuits.

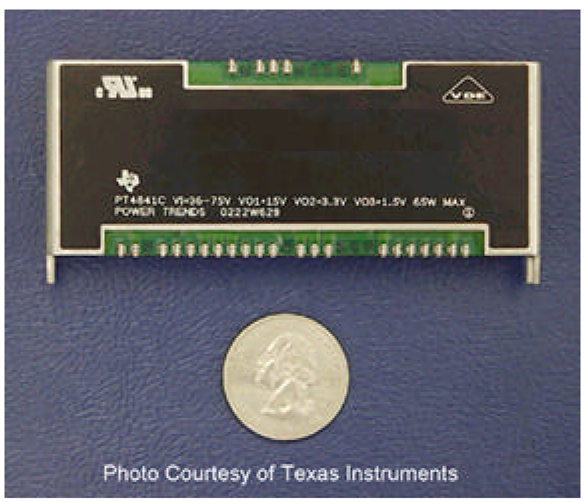

Figure 1: Power Modules Offer Quick Time to Market But Cost More

Figure 2 shows a typical telecom power subsystem. An EMI filter conditions and filters the input power as it first enters the rack. Then a motherboard or wiring harness distributes power to boards within the rack. Power enters the circuit card assembly through an in-rush limit circuit, which supplies it to the power supply modules. Typically, these modules are single output modules whose output currents are available in discrete steps. This approach has several cost inefficiencies. First, several single-output power supplies will cost more than one multiple-output power supply because the design duplicates some of the components such as transformers, and control and power semiconductors.

Secondly, since output currents are only available in discrete steps, the power supplies are always over capacity and consequently over-priced. Thirdly, this approach creates a cost burden of an assembly within an assembly -- someone has to kit, build, test and deliver the power supply module before the telecom board can be built. So there are duplications of effort: the power supply goes through two solder processes, two inventory and kitting processes, and at least two levels of testing. On the other hand the designer can eliminate many of these costs by placing the power supply components directly on the telecom board. These cost challenges force OEM board designers to make tough choices for their power solutions.

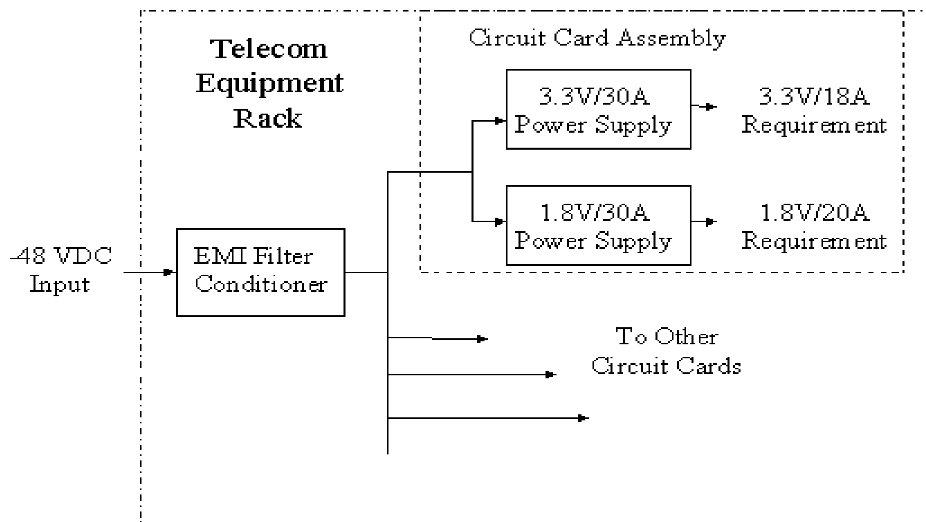

Figure 2: Telecom Power System Has Excess Cost Due to Excess Capacity.

Alternative Architectures

There are several very viable alternatives to using single output modules. In some cases; multiple output modules can easily cut power system cost by 30%. However, the real cost savings occur when the manufacturer eliminates the assembly-within-assembly approach and makes the power supply part of the board as shown in **Figure 3**. The designer has a couple of options: leverage a reference design from an IC vendor or start with a blank sheet of paper to create a design optimized to the system's exact requirements. Unfortunately, the reference design option may have some of the shortcomings of the module approach. Manufacturers will have a limited number of reference designs available so the power supply may have excess capacity. Also, most reference designs focus on single outputs and may not offer the total cost savings of a custom approach. However, they can offer a low risk approach to eliminating a substantial portion of the power system cost.

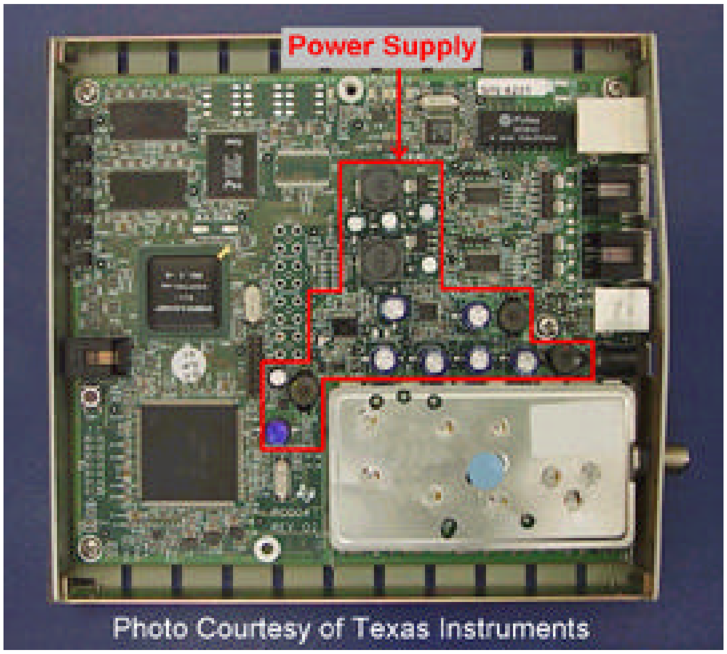

Figure 3: Integrating the Power Supply Provides a Significant Cost Savings

The Trade-Offs

Picking the optimal power supply architecture for a given project requires a careful evaluation of the time and resources available for designing, producing, and sustaining the power supply. **Figure 4** shows a typical decision tree for selecting the power system approach. After establishing the requirements, the designer must first decide whether to make or buy. On the buy path, the next step is to choose between a full custom design or configuring the power system from single or multiple output modules. While not very popular in the telecom market, procuring full custom designs is very popular in consumer electronics such as set top boxes. On the make side of the decision tree, the next step is to choose between preparing a design from scratch or using references design available from industry. Modules, reference designs, and custom designs each have their own set of advantages and disadvantages. When deciding which route to take, it helps to consider factors such as the time to market window, engineering resources, production costs, and acceptable risk level.

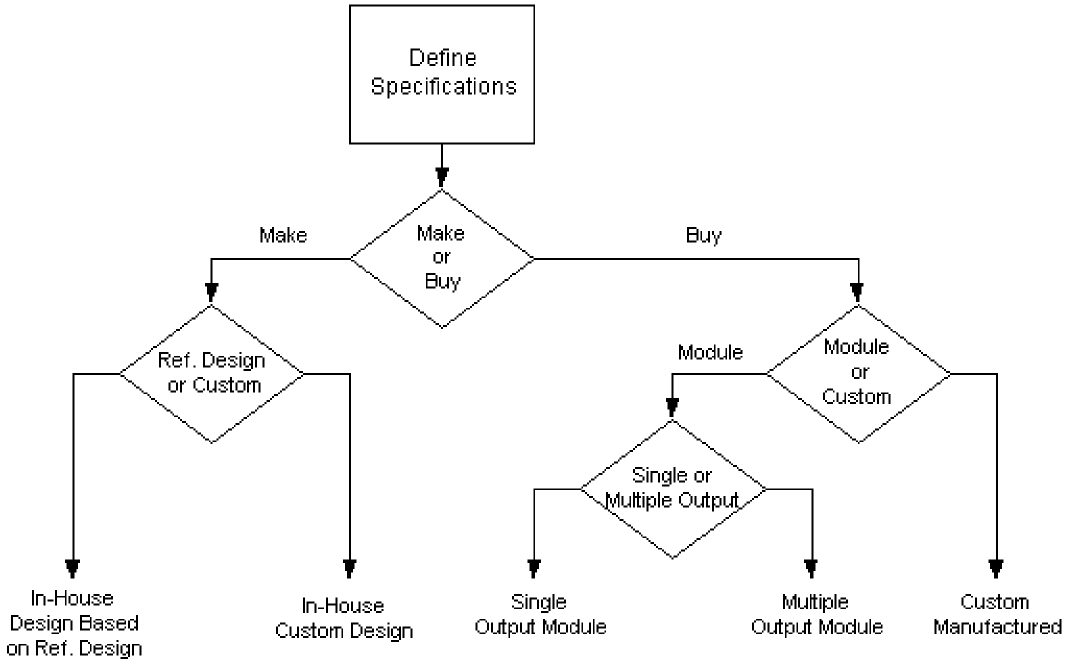

Figure 4: OEM Board Designers Make Tough Choices for their Power Solutions.

Time to Market

Often, the designer doesn't know the exact power requirements for a board until the last minute and has limited engineering time and resources available to meet the power needs. Power modules, by far, offer the most attractive solution in these situations. The major factors that determine time to market are engineering development time, safety approval, component lead-time, and test time.

With power modules, the engineering development effort is usually limited to layout, thermal management, and selecting a few external components. In addition, power modules nearly always carry safety agency approval, which can speed the approval time for the entire system. The limited number of components in a modular solution reduces the likelihood of long lead times for purchasing. Also, since the manufacturer already tests power modules, the system power supply test time can be significantly reduced.

In situations where time to market is less critical, a reference design may offer an attractive solution. A semiconductor manufacturer completes the majority of the engineering development effort and makes that information available to the public in hope of selling an IC. An example is shown in **Figure 5**. While the design resembles a power module, the intent is to integrate the power electronics onto the board with the remainder of the electronics. In most cases, development time is limited to layout, thermal management, identifying alternative parts, and trouble shooting the inevitable snags along the away. Usually, the reference design provider also supplies Gerber files and some level of support, both of which can reduce development time. Some reference designs already have safety approval, and most others are designed with a good knowledge of the safety guidelines. As a result, acquiring safety approval for a reference design is typically much easier than for a custom design, and slightly more difficult than for a modular solution. The larger bill of materials for reference designs increases the odds of long component lead times, compared to a modular solution. The added degree of complexity also translates into more time spent on testing the power supply.

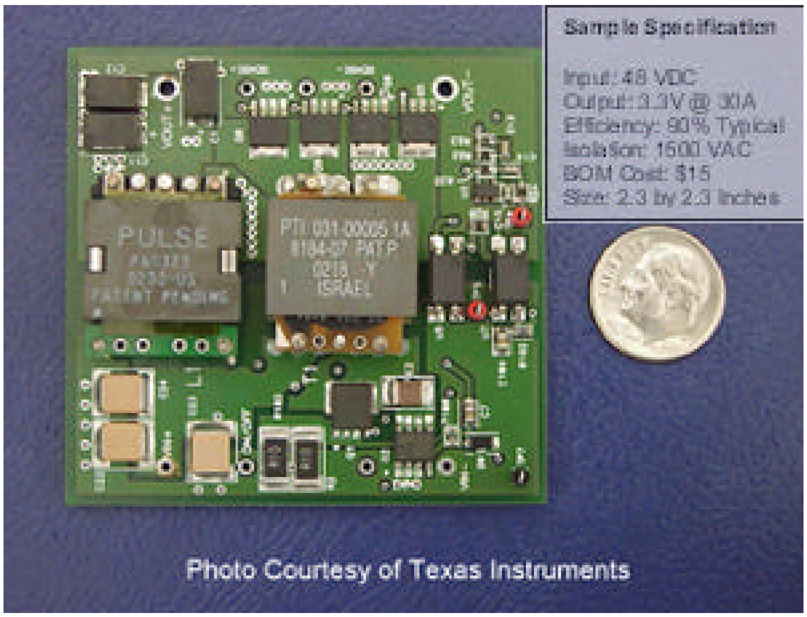

Figure 5: Semiconductor Makers Offer Reference Designs to Cut Development Time

Custom power supply solutions can significantly impair the time to market of a product. The engineering development effort can be quite intense, as the power supply must be designed from scratch. Snags and multiple revisions are virtually guaranteed. In addition, the safety approval process can add to delays in getting the product to market. Since the size and complexity of custom designs are similar to reference designs, the component lead times and test times can be expected to be about the same. In general, custom power supply designs should not be considered if a product needs to be marketed quickly. However, a staged approach could be considered with the first offering using a module, followed by a cost-reduced custom design.

Engineering Resources
Power modules also offer a distinct advantage when it comes to dedicating engineering sources to the power supply. Typically, an engineer with little power

supply design knowledge can successfully implement a modular solution. The most daunting tasks for incorporating a power module into a system are selecting the correct module, EMI filter design/selection, layout, and managing the power losses.

With reference designs, the design provider has already completed most of the development effort. As a result, the engineer incorporating the reference design need not be a power supply guru. Still, some level of expertise with power supplies is required. Unforeseen problems can and usually will arise that require non-trivial solutions. Tailoring a reference design for a specific application may require making minor adjustments to the circuit. This also requires the engineer to have a fundamental understanding of power supply design. Documentation and support from the reference design provider can assist the power supply engineer in solving most problems. **Table 1** provides a checklist of items that should be available for a thoroughly documented reference design.

Table 1: A Good Reference Design Should Provide More Than Just a Schematic

- ✓ Schematic
- ✓ Evaluation Board
- ✓ Bill Of Materials
- ✓ Detailed Specifications
- ✓ Theory of Operation
- ✓ Performance Curves
- ✓ Typical Waveforms
- ✓ List Of Alternate Parts for Key Components
- ✓ Safety Approval
- ✓ Reliability Analysis
- ✓ EMI Measurements

Designing a custom power supply obviously requires an experienced engineer with a thorough understanding of power supplies. Custom power supply designers are basically on their own, and must rely heavily on their abilities. Acquiring help to solve major design problems can prove costly and time consuming. However, going the custom route provides a solution that is finely tuned to the needs of the system.

Production Cost

The non-recurring costs of time to market and engineering development must be weighed against the long-term costs. The length of the bill of materials will impact the cost. Certainly, the larger component count of discrete solutions puts increased strain on the purchasing department, compared to a modular solution. In addition, a larger bill of materials means more assembly time and cost.

However, the downside of power modules is easy to see by looking at the price tag. The module costs include mark-ups over the actual manufacturing cost to account for all other costs and desired profit margins. As a result, the component costs of discrete solutions can easily be less than one-half the cost of a power module. In addition, power modules are only available in discrete power (output voltage and current) steps, and are designed for the full feature set. The customer pays for the total power capacity and all features, even when they are not required. With discrete designs, there is a flexibility to scale the design and omit features to save costs and/or board space.

Risk

Some of the risks that influence the decision to choose include the robustness of the design, the ability to modify the design, the skill level needed to sustain and test the product, and thermal management. The common perception is that the modules are more reliable than the discrete designs. In reality, the reliability is subject to the number of components and connections. With higher levels of integration available in power management ICs, the number of external components is minimized. In many cases, board designers can take advantage of the latest, higher performance components quicker with a discrete design than with modules. This is due to the fact that modules have significant development cycles. For example, it is easier to get improved efficiency with a discrete solution by replacing a new generation MOSFET with lower RDS-on in the circuit. With modules, you have to wait for the newer product introduction and may also have to pay a higher price for the newer product. The main concern with the discrete solutions is when a failure occurs. It is easier to throw away a power module after failure than the whole board. With discrete implementation, field or even factory technicians may not have the ability to debug the component level failures in the power circuit and the only solution may be to replace the entire board.

Module developers spend considerable amounts of time on the electrical design to achieve high efficiency levels. In addition, they invest heavily in the packaging technology and design effort to reach acceptable thermal management levels. Clearly, that is the value added with the modules. However, modular solutions are also constrained by the fact that they cannot use any of the main board area to spread/dissipate heat. They also end up as tall components blocking the airflow and making it harder for the heat removal process. In that sense, the discrete solutions offer additional latitude for getting the heat out and also provide better channels for the airflow. In addition, the discrete solution allows easy drop-in of a newer component that can improve the efficiency significantly.

The reference design may be riskier in that it may not be as robust as a module. The module may have many units functioning in a number of different environments that help to detect latent design flaws. In a reference design, there may not be this history. So a potential user will need to try to gauge the maturity of the reference design and look for examples of good engineering practice like the safe-operating area (SOA) curves shown in **Figure 6**. This figure presents the output current rating of the power supply reference design at various ambient temperatures and air flow. This provides the needed thermal data to determine if a particular design is suitable in the needed ambient.

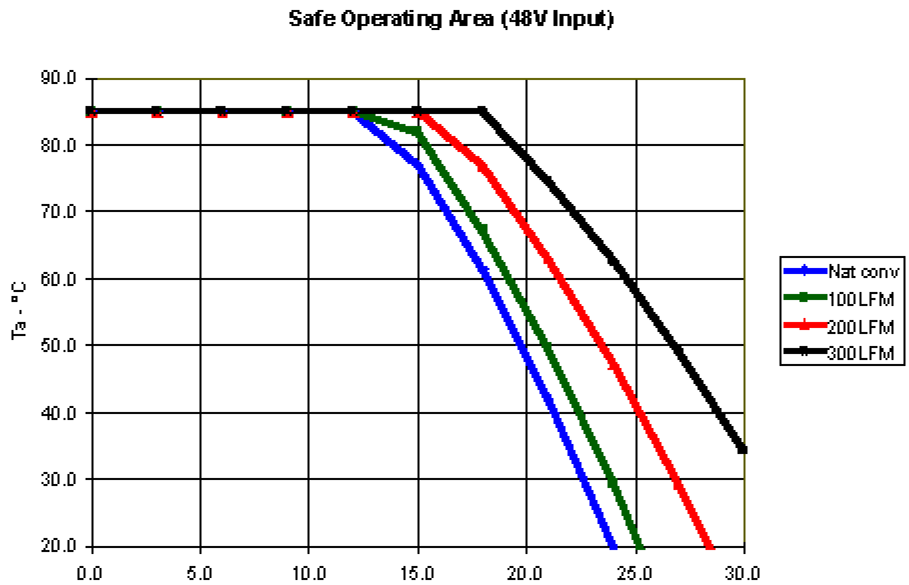

Figure 6: Design Documentation Provides Indication of Good Design Practices.

So how do you decide?

Power system architecture, like all engineering challenges, is a complex trade of cost, risk and time-to-market as shown in **Table 2**. If time-to-market, engineering cost or risk is the overwhelming issue in a product's development, modules make the most sense. They will require comparatively little engineering effort to get them through the design and agency approval process to the final product. However, they cost more and won't be suitable for high volume applications. A full custom design will be the most cost competitive for this situation. However, there will need to be a great deal of power supply expertise available to support the design effort, which will impact engineering cost, time to market, and risk. The reference design provides a compromise between the two. It will not provide the total cost savings of a custom design but will save some of the development time and mitigate some of the risk as the reference design provider's experienced engineers will have completed much of the effort.

Table 2: A Custom Power Supply Offers the Lowest Production Cost But Highest Risk

	Module	Reference Design	Custom
Power Supply Development Time (Months)	1	2-3	4-6
Engineering Development Effort (Man-months)	1	4	12
Production Cost ($)	100	40	25
Risk	Lowest	Medium	Highest

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