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Power Management Issues in High Frequency Circuits and Systems

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This tutorial reviews the primary areas where power management is essential to achieve the best system-wide performance in high frequency products

Power management is often the responsibility of engineers other than the high frequency specialists in a product's design team. But since it is such an important part of the overall design—especially in portable wireless devices—every member of the team should understand the issues involved. There will be specific requirements for each engineer's piece of the overall design, but it is also important that the team understands the overall power-related set of objectives.

The major areas of power management include the following:

- Power supply
- Internal power distribution
- Power quality (noise, transients, etc.)
- Power consumption
- Thermal power dissipation

There may be other issues, depending on the application, but these are the most important. Although I'll look at each area individually, remember that there are many ways that they overlap.

Power Supplies

Power supply options are widely varied: internal or external power supply modules, batteries using several different chemistries, and perhaps a central power bus, such as a battery bank at a remote communications site. Each type of power source has a different set of design requirements. For example:

Internal power supplies bring AC mains power into the unit, creating the potential for 50/60 Hz energy (and harmonics) getting into the signal path. External power supplies, especially pre-packaged OEM assemblies, may result in an engineer taking for granted the issues of supply regulation, noise and protection circuitry. External supplies also add the issue of connection method. Maintenance and reliability requirements will determine whether an external power supply uses such connections as screw terminals, specialized power connectors, or simpler common power plug-and-jack combinations.

Battery power adds the requirement for charging circuitry as well as battery condition monitoring. Each battery chemistry (lead-acid, NiCd, NiMH, Li-ion, etc.) has unique characteristics regarding charge and discharge rate, temperature (both environmental and internally-generated), and number of charging cycles.

Central power sources, which were once standard in all remote telephone and microwave repeater facilities, are again receiving attention, particularly in remote sites with alternative-energy power (mainly solar). A key issue is the high current capability of the battery or AC power supply, which requires mechanical protection of the distribution buses.

Internal Power Distribution

After the power supply is established, DC power must be routed to the various portion of the system. This may be as simple as the wires that carry ±12 VDC and +5 VDC to all the components inside a personal computer, or as complicated as power-over coax to tower-top mounted electronics.

Within an enclosure or across a large printed circuit board, choices may include single-voltage power, multiple voltage distribution, or a system of sub-regulators and DC-DC converters to deliver the required power to each local portion of the system.

The physical method of distribution is another design choice and can affect other aspects of performance. Cables and connectors are simple to implement and have the advantage of separating power distribution and signal paths. But they require that the enclosure have sufficient volume. In more restricted spaces, power may be distributed via the PCB, most commonly as a separate copper layer, isolated from adjacent signal layers by ground planes.

In addition to delivering power to the operating circuitry, there are often external accessories to consider. Standard plug-in connectors are easily implemented, but the more flexible Power-over-Ethernet (PoE) and USB must include consideration of the effects of cable length, voltage drop and the issues discussed in the next section.

Power Quality (Noise, Transients, etc.)

This part of power management is squarely in the high frequency designers realm. Preventing the power supply circuitry from degrading the signal path is a major issue at high frequencies. At short wavelengths, coupling is much stronger between PCB traces and components than it is at longer, lower frequency wavelengths. Reducing that coupling to and from power distribution requires good high frequency practices that are more closely related to signals than power supplies.

Since the purpose of this tutorial is to identify the issues, not to solve all of them, we'll just list the major areas of concern:

- Proper bypassing/decoupling of power to IC pins
- Routing of power traces in isolated PCB layers
- Avoiding transients caused by high-current on/off transitions in other parts of the system
- Coupling/crosstalk from signal lines into power lines, which may then be propagated to undesirable portions of the circuit
- Minimizing DC shifts due to digital transitions, then preventing coupling of any remaining energy into other parts of the system
- Separation of analog and digital power (and ground)
- Special attention to primary and bias power connections to RF/microwave devices
- Proper regulation to avoid secondary modulation of the DC as RF power output fluctuates with signal modulation
- Troubleshooting power circuitry along with all other portions of a system during regulatory EMC compliance testing

Overall, power quality should be viewed as involving separation between sections of a larger system.

Power Consumption

In portable electronics, battery lifetime is paramount. Consumers must be happy with the performance of the device, which will not be the case if they must recharge the batteries too often. As a result, power consumption management requires a combination of techniques and design choices.

The first is simply using components that consume less power. Changing from a standard of 5 volts to 3.3 volts was a major step. Now we have lower voltage devices, which generally consume less power. Mainly, these are small-signal and digital baseband devices. Also, voltage regulators and DC-DC converters should operate as efficiently as possible, both in their conversion efficiency and control circuit power consumption.

Unfortunately, many wireless devices are modulated with complex signals that require high linearity. Power amplifier efficiency is much less when operated in the linear region. Since PAs are among the highest power portions of a wireless system, much attention has been given to design methods that improve efficiency by allowing a PA to operate closer to its saturation power, where it is more efficient. To compensate for the increasing non-linearity, designers may choose from various feedback and feed-forward schemes, as well as digital predistortion methods. More complex architectures such as Doherty amplifiers and polar modulation are additional options.

A key technique is a power-down or "sleep" mode for portions of the circuit, nearly eliminating their power consumption during times they are not used. In some cases, these times may be very short, such as the pauses in speech or during transmit/receive modes in a TDMA system. These small savings can accumulate, becoming a significant savings.

Thermal Power Dissipation

Thermal power is closely related to DC power consumption. Any greater efficiency will result in less generated heat. In handsets and other portable devices, total power is low, but excess heat must be managed carefully. Even low power devices create heat, and within a very small area, power density can create an unwanted temperature rise.

Finally, the biggest thermal power problem area is high power equipment, including base stations and switching centers. For these systems, there is usually a set of tradeoffs among reduced power consumption, heat flow management, and active cooling, either by ventilation or air conditioning. Designers must balance equipment performance, available space, local environmental conditions and other factors to get the best results.