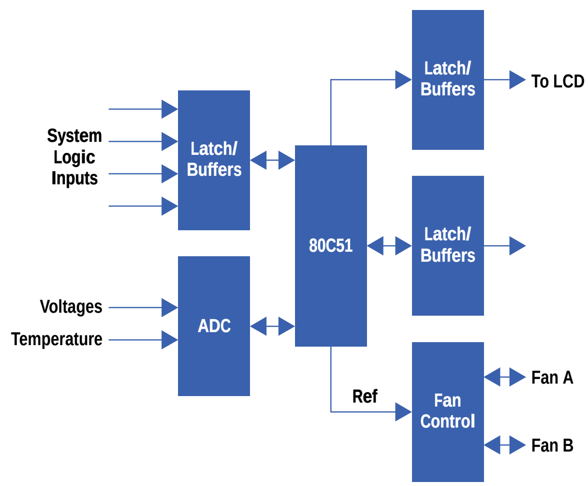
K Class Power System

The power system in the HP 9000 K-class servers uses a number of new and emerging technologies to achieve excellent platform performance without compromising cost, reliability, and quality metrics. Combined in the power system are the system power monitor, the system power supply, and an optional uninterruptible power supply (UPS). Key contributions of the system power monitor include: system turn-on and initialization including error reporting via a front-panel LCD display, temperature monitoring and cooling, fan speed control based on ambient temperature, fan synchronization and fault detection, continuous power supply output voltage monitoring, special manufacturing modes of operation, overtemperature detection and warning, overtemperature shutdown, and other features. The system power supply uses power factor correction to achieve low power-line distortion while maximizing the available VA capacity of the input ac circuit. A standard dc-to-dc forward converter follows the regulated power factor corrected output. Remote sensing is used on all output rails to achieve tight regulation specifications. The power system is optimized for use with several HP UPSs employing both offline and online technologies. The UPSs use an autoranging technology allowing worldwide use. Worldwide regulatory and safety approvals apply to these UPSs. The hardware provides power-line filtering and conditioning while the firmware provides many useful status and control capabilities, both real-time and programmed for later execution.

System Power Monitor

The system power monitor (Fig. 1) is where the power system gets its HP personality. It was intended that most if not all nonstandard features of the power system would be concentrated in this assembly, as opposed to having them in the power supply itself.

Fig. 1. *System power monitor block diagram.*



The power monitor is designed around a microprocessor, so that most of its features are determined by firmware. This made it convenient to modify these features as required during the system development phase, without changing hardware. The power monitor is powered by a dedicated +15Vdc supply which is turned on at all times if the system has ac power. The functions of the power monitor are:

- Check the CPU modules in the system to see that they are all compatible with each other.
- Check the power supply in the system to see that it is compatible with the CPUs present.
- Respond to system keyswitch position and turn power supply on and off as required.
- Monitor all power supply output voltages for valid range.
- Monitor ambient temperature and initiate operator warnings.
- Control fan speed as a function of ambient temperature.
- Synchronize the two fans to avoid acoustic beating.
- Check for fan failure.Monitor internal system temperature for valid range.
- Initiate system reset signals.
- Issue ac powerfail warning signal.

- In case of any system malfunction, shut down the system and write a message to the front-panel liquid crystal display indicating why the system was shut down.

The notable contributions of the power monitor are its fan control scheme, which makes the system remarkably quiet for its power level, and its contribution to system maintainability through diagnostic display messages.

System Power Supply

The system power supply is rated for 925W of continuous dc output. Five output rails are provided: +3.30Vdc (V_{DL}), +4.4Vdc (V_{DH}), +5.1Vdc (V_{DD}), +12Vdc, and –12Vdc. The +3.3Vdc and +5.1Vdc rails are used for standard logic circuits while the +4.4Vdc is used exclusively for the CPUs. The +12Vdc is used primarily for disk drives and I/O with the remaining –12Vdc rail being used strictly for I/O. All rails have ±1.5% regulation windows. Additionally, a +15Vdc, 300-mA rail is provided for use by the system power monitor. This rail is electrically isolated from the computer rails. Its single point of ground is provided by the power monitor, which eliminates the potential for ground loops. The system power supply implementation is done entirely in discrete devices with one hybrid, four daughter cards, and a 2.6-mm-thick, HP FR4 motherboard. The density is 1.8 watts per cubic inch. Both a discrete version and a dc-to-dc module approach were initially investigated, but cost, cooling, and reliability concerns ultimately resulted in the discrete version being chosen.

The K-class power requirements required the maximum allowable VA capacity of a 100/120Vac, 15A branch circuit. To fully utilize the 15A circuit and not require customer installation of a 20A branch circuit it was decided early in the development cycle that the system power supply would use power factor correction. This means that the input voltage and current waveforms are in phase, so the power supply appears to be a resistive load on the ac line. By comparison, traditional offline switchers appear to the ac line as peak detectors and thus there are very large “spikes” of input current at the peaks of the input voltage waveform. With the system power supply appearing resistive, power is drawn out of the ac line continuously rather than just at voltage peaks. Without power factor correction, typical offline switchers are limited to approximately 600W given 100Vac input lines. Power factor correction also allows the supply to operate over a wide range of input voltages without requiring any additional circuitry such as autoranging circuitry or line select switches. The regulated output voltage of the power factor correction circuit is +400Vdc. The supply is rated to operate with input voltages from 90Vac to 140Vac for its lower operating range and from 180Vac to 264Vac in its higher operating range. The frequency range of operation in either voltage range is 50 to 60 Hz. There is a minimum guaranteed carryover time of 20 ms before a powerfail warning is issued and an additional 5 ms of carryover time after a powerfail is issued. Another benefit of using power factor correction is that European norms for line distortion are already met when they become mandated in the European Community.

Two forward dc-to-dc converters are employed in the power supply. Both converters take the regulated +400Vdc output of the power factor correction stage and convert it to the desired regulated output voltage. With the V_{DD} rail exceeding 500W it made sense, considering component selection and cost, to have V_{DD} generated by one converter and the remaining rails by a second converter which is rated at about 425 watts. The use of two converters also allows sequencing of the V_{DD} rail with respect to the V_{DH} rail, which was a semiconductor requirement.

Two output connectors are required for busing power between the power supply and the system board. The footprint of the connectors measures only six square inches, so the impact of the power system on the system board layout was minimal.

Uninterruptible Power Supplies

Unlike many previous HP systems which used battery backup of only main memory during short duration ac power failures, thus halting any processes in progress, the K-class power supply uses uninterruptible power supplies (UPSs) for backup. This allows uninterrupted operation during an ac line failure for some predetermined period of time after which the computer can be automatically and controllably shut down. Should the power be restored before shutdown is required, processing will have continued uninterrupted. Should shutdown be required because of an extended power loss then the computer can do a controlled shutdown programmatically, after which the UPS can be shut down. This controllable turn-off of the UPS and host computer is well-suited for applications in which customers want to reduce their energy consumption by shutting down equipment programmatically overnight or over the weekend.

Two UPS technologies are available from HP. The lower-power units—600VA (425W) standalone, 1300VA (1300W) standalone, 1.3-kVA (1300W) rackmount, and 1.8-kVA (1800W) rackmount—all employ offline technology. The UPS directs the incoming ac directly to the load being supported unless the input falls outside of a defined set of voltage and frequency limits. Once this occurs the UPS then switches to inverter mode and outputs regulated ac using its internal batteries and a dc-to-ac upconverter. This technology is very effective, reliable, cost-competitive, and efficient for many applications in which a defined loss of ac input for the load can be supported. The time period during which there is no ac input is defined as transfer time. The offline units have a transfer time of 10 ms maximum and this maps well into HP’s computer products which have a guaranteed carryover time of 20 ms minimum. The offline topology is very energy efficient; when the ac input is within tolerance the UPS is just maintaining its internal batteries. Unless the batteries have been run down because of an earlier power failure the batteries are in a “float” state and require very little input power.

The topology employed by the high-power 3-kVA UPS is online interactive. In this technology the UPS monitors the incoming ac waveform and adjusts it on a cycle-by-cycle basis, interactively regulating the output ac to the host computer system. Should the line deviate substantially outside of its normal range the UPS transfers from online to inverter mode and continues to provide the load with regulated ac derived from the UPS's internal batteries. This technology provides excellent regulation of the ac output supplied to the load under all line conditions and is suitable for mission-critical applications where even slight losses of ac input are disruptive. The 3-kVA UPS also provides isolation from line for ground-loop-sensitive products by means of an isolation transformer. This topology is also very energy efficient because the majority of the losses during normal running are localized in the isolation transformer. With proper choice and design these losses can be greatly reduced resulting in a very efficient design.

HP's offline units are autoranging in both voltage and frequency and have world-wide safety and regulatory recognition. This feature allows worldwide coverage with just one model per power range. These units have 15 minutes of run time at rated load rather than the industry standard of 7 to 8 minutes. The software feature set includes programmable on and off times, input voltage, input frequency, output voltage, and battery voltage, UPS internal temperature monitoring, self-test mode, and numerous other status and warning codes.

HP's online 3-kVA unit provides regulated 230Vac output at either 50 or 60 Hz. It provides 3 kVA or 3 kW of output, allowing full utilization with power factor corrected loads.

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