PCI-SIG ENGINEERING CHANGE NOTICE

TITLE:	Mini Card Thermal Guidelines Changes
DATE:	October 28, 2005
AFFECTED DOCUMENT:	PCIe Mini CEM Specification, Revision 1.1
SPONSOR:	Jim Panian, QUALCOMM

Part I

2 1. Summary of the Functional Changes

Changes are proposed to the Thermal Guidelines. The section is restructured as follows:

2.4.2. Thermal Guidelines for PCI Express Mini Card add-in card designers – provides guidelines for PCI Express Mini Card add-in card designers to follow to assure compatibility with host systems.

2.4.3. Thermal Guidelines for system board designers – provides guidelines for host system board designers to follow to assure compatibility with PCI Express Mini Card add-in card technologies such as Wireless Wide Area Network (WWAN).

2.4.1. Thermal Design Definitions – aligned with the WFF CEM specification.

3 2. Benefits as a Result of the Changes

Providing complete thermal guidelines will increase awareness of the thermal requirements by both host system board designers and PCI Express Mini Card add-in card designers.

4 3. Assessment of the Impact

In cases where either the system board or PCI Express Mini Card add-in card does not strictly follow the guidelines a coordinated solution between the card and the host platform vendor is dictated. The update to the Thermal Guidelines should hasten a coordinated solution.

5 4. Analysis of the Hardware Implications

The Thermal Guidelines are non-normative. As a result, no hardware implications are identified.

6 5. Analysis of the Software Implications

The Thermal Guidelines are non-normative. As a result, no software implications are identified.

Part II

Detailed Description of the change

Change Section 2.4 on page 23:

2.4 Thermal Guidelines

The following thermal guidelines are meant to provide guidance to both system board designers and PCI Express Mini Card add-in card designers.

2.4.1. Thermal Design Definitions

The *Thermal Design Power (TDP)* is the steady state electrical power that is converted to heat and dissipated by a card or any heat source. The TDP is less than the electrical power and as an example could be the electrical power minus the radiated power in a wireless radio.

Steady state is defined as the operational application profile that represents the normal use scenario for the product being specified. This might include a series of radio transmissions and receptions occurring at a regular interval that is representative of actual use within normal bounds for the network being used. A maximum TDP would be based on a steady state condition associated with the scenario that dissipates the maximum average power.

A *thermal guideline* is a non-normative technical discussion or objective that could be used to describe the design or the conditions in which it operates.

In cases where either the system board or PCI Express Mini Card add-in card does not strictly follow the guidelines a coordinated solution between the card and the host platform vendor is dictated. Solutions might be able to manage higher thermals by implementing features that may include passive (e.g. thermal insulation, thermal spreading) and active (e.g. thermal-based throttling) techniques. Such techniques are not comprehended by this specification.

2.4.2. Thermal Guidelines for PCI Express Mini Card add-in card designers

This section provides guidelines for PCI Express Mini Card add-in card designers to follow to assure compatibility with host systems.

For purposes of this specification, power consumption is not necessarily directly related to the thermal dissipation limitations within the system; e.g., additional power may be consumed via the system interface, yet the thermal energy may be dissipated in circuits located off the card (most likely in a remote media interface circuit such as an antenna). Power consumption limits for PCI Express Mini Card are included in Chapter 3.

System Board Requirements:

- System board designers should ensure that the board can dissipate 28.1 °C/W in the region of the add-in card. The method in which this is dissipated depends on the OEM standards, but natural convection/radiation is unlikely. Most applications will require some air flow over the add-in card.
- Direct attach thermal solutions are not allowed.

Add-In Card Requirements:

- The maximum thermal dissipation directly from any PCI Express Mini Card add-in card is 2.3 W at a component temperature of 90 °C and 65 °C ambient temperature inside the host and around the add-in card.
- De-rate maximum card power 0.046 W for every 1 °C component T_{CASE} is rated below 90 °C.
- Example: T_{CASE} = 85 °C, then de-rate power 0.23 W to P = 2.07 W.
- The total thermal energy dissipated must be spread out relatively uniformly over the PCI Express Mini Card add-in card in order to avoid hot spots. Figure 2-11Figure 6-1 provides guidance on power density. The top side of the card can generally tolerate as much as twice the density as the bottom side of the card, with the components on the bottom side being trapped between the add-in card PCB and the system board PCB.

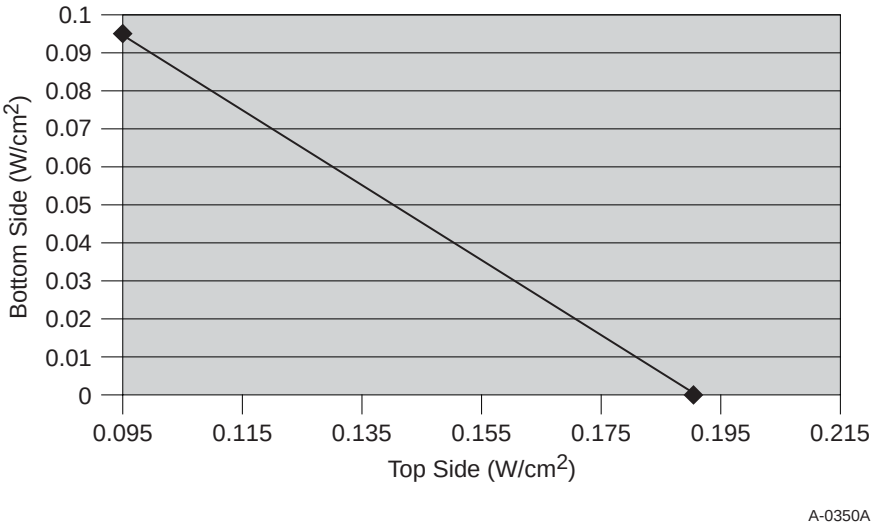


Figure 6-1: Power Density Uniform Loading at 80 Percent Coverage

Example: If side one of the card is loaded to 0.12 W/cm², the other side of the card (side two) can only be loaded to 0.07 W/cm². In all cases, the sum of power densities for both sides of the card should not exceed 0.19 W/cm².

Note: Additional heat beyond the maximum 2.3 W of thermal dissipation, listed on page 3 as a requirement for an add-in card, may be generated by the PCI Express Mini Card add-in card's I/O circuitry. For example, for certain modem line conditions in the approved countries, TBR21 states a modem may dissipate as much as an additional 2.4 W (40-V drop at 60 mA). If the add-in card requires additional thermal management in order to stay within

the aforementioned criteria, the add-in card manufacturer must coordinate with the system board manufacturer to achieve a final solution.

2.4.2.1. Implementation Notes

The following points should be considered when developing a PCI Express Mini Card add-in card's thermal design.

- It is accepted that some host platform designs may be designed to support higher TDP limits and, if so, this should be noted by the vendor as a capability beyond the basic assumptions made in establishing the guidelines in this specification.

- The component temperature of 90 °C is an ergonomic requirement so that the customer is not discomforted by the temperature of the PCI Express Mini Card add-in card when using the computer. The 90 °C component temperature is meant to assure that no greater than a 65°C skin temperature is experienced when touching the exterior of the host device. UL 60950-1 temperature limits could also be considered.

- The card's TDP should be spread out relatively uniformly over the assembly. Higher TDP components should not be co-located.

- The host platform encloses the card thermally with no forced convection and no predictable or well-defined natural convection air buoyancy path.

- Thermal impact of card materials should be considered for temperature rise and for allowable touch temperature.

- The card PCB may need thermal vias to help conduction and heat spreading for high TDP components.

- The maximum ambient rating for the card may be determined by measuring the card surface temperature when installed in the host un-powered.

2.4.3. Thermal Guidelines for Integrating Wireless Wide Area Network Mini Card add-in cards

This section provides guidelines for host system board designers to follow to assure compatibility with Wireless Wide Area Network (WWAN) PCI Express Mini Card add-in cards.

It is recommended that system board designers meet the following requirements:

- For WWAN add-in cards, Thermal Dissipation = Electrical Input Power – Antenna Output Power. For WWAN, thermal dissipation can be inferred by measuring

electrical input power and antenna output power. Another technique is to add up the maximum thermal dissipation from all components from spec sheets or through measurements.

- Design for the maximum TDP based upon the technology. The worst case WWAN add-in card can dissipate up to 3.1W of thermal energy.

WWAN Technology	Max TDP
W-CDMA HSDPA 1900 @ 22 dBm	2.9 W – 3.1 W
W-CDMA HSDPA 850 @ 22 dBm	2.8 W – 3.0 W
W-CDMA HSDPA 2100 @ 22 dBm	2.7 W – 2.7 W
CDMA 2000 1xEVDO @ 24 dBm	2.7 W – 2.9 W
GPRS Class 10 @ 32 dBm	1.8 W

- Design to a maximum component surface temperature of 85 °C. Components in a WWAN add-in card typically have a maximum surface temperature of 85 °C.
- WWAN add-in cards must operate within their product specification. Power Amplifiers are the main heat generators.

  Temperature delta from host to WWAN device at reference PCB area
  - 0 –20C (WWAN Idle)
  - 20 –40C (WWAN active, still air)

  Temperature delta between PA and reference PCB area:
  - 20 -30 C (WWAN active)
- The WWAN add-in card temperature profile depends on host cooling approach including
  - Natural convection
  - Forced air
  - Direct attach
- Location of "heat sources" near the WWAN add-in card can negatively impact the thermal design. Do not place the add-in card near other host heat sources or "down wind" from such heat sources.
  - Host CPU's and graphics cards are both heat (and noise) sources
- Inadequate cooling may cause the WWAN add-in card to overheat

    - WWAN devices monitor internal temperature to ensure RF performance will be met over target temperature range
    - Required for FCC compliance on Transmitter
    - Overheated modules may have shortened lifespan (field returns)

- To be conservative the thermal design of the system board must consider the TDP of the worst-case operating mode of the WWAN add-in card. The worst case mode is when a WWAN add-in card is sitting on the edge of a cell and continuously transmitting data. For example, this may occur if a camera is attached to the host.
- The WWAN add-in card typically does not operate in the worst-case operating mode. For example, consider CDMA 2000 1xEVDO. The Maximum Thermal Dissipation varies based upon the distance from the base station:
    - Max Thermal Dissipation = 1.0 W (close to the base station)
    - Max Thermal Dissipation = 1.8 W (middle of the cell)
    - Max Thermal Dissipation = 2.7 W (edge of the cell)

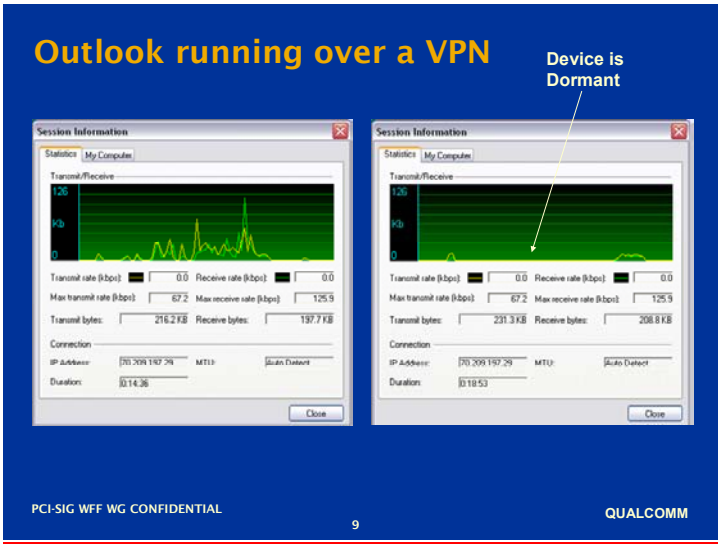
  These values are representative. Max input voltage is assumed.

  The CDMA 2000 1xEVDO network is constantly sending power control bits to the WWAN add-in card to control the output power. CDMA requires devices to transmit power at the lowest possible level to provide reliable service across the cell.

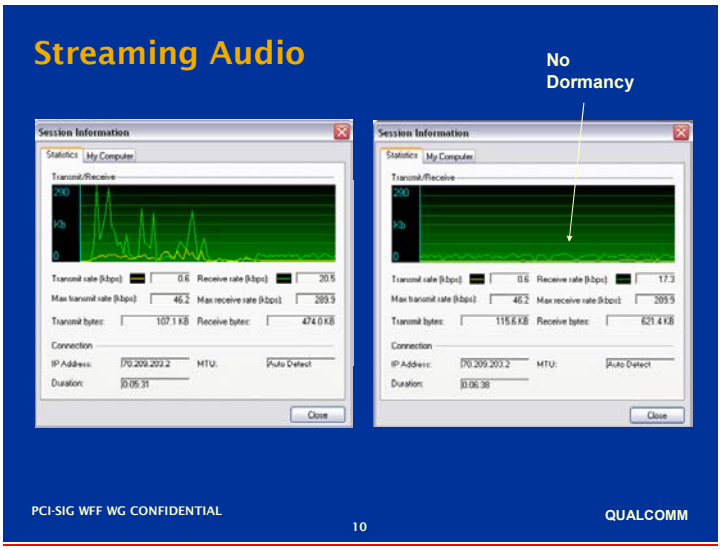
  CDMA 2000 1xEVDO devices go into a power save mode called dormancy on their own after at least 20 seconds of data inactivity.

  Dormant state:
    - Average Thermal Dissipation: << 1 W
    - Maximum Thermal Dissipation: < 1 W

- The Average Thermal Dissipation is function of the user-level application that is running and the distance from the base station. Most business applications enable the device to go dormant thereby lowering the average thermal dissipation
    - Average Thermal Dissipation < Max Thermal Dissipation



- Applications that perform data streaming such as VOIP, video streaming from an attached camera or streaming audio prevent the device from going dormant
    - Average Thermal Dissipation = Max Thermal Dissipation



- The host should support the USB Selective Suspend feature to reduce electrical power consumption and thermal dissipation by the WWAN add-in card.
- System board designers must consider WWAN in their platform thermal design from the beginning. It is difficult to retrofit WWAN in existing platforms.