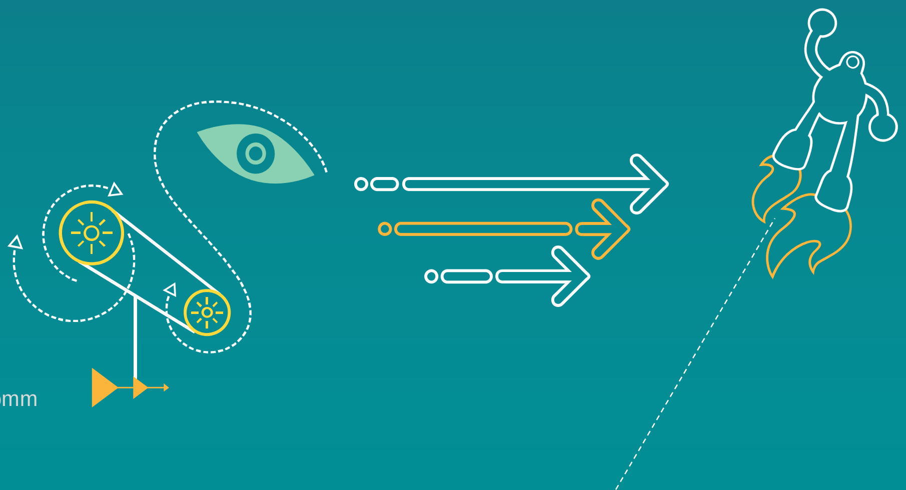
Why, What, Where, When, and How

Design For Thermal: Key Requirements

Qualcomm Technologies, Inc.



80-VU794-24 Rev. F

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Revision History

Revision	Date	Description
A	October 2012	Initial release
B	April 2013	Slide 5: Added definition of AVS, PDN, PVS, & Thermal Tuning Slide 7: Added that CFD SW companies will provide training for their tools. Added the option to copy QRD instead of purchase CFD software for thermal design Slide 12: Emphasized PDN routing must be routed first Slide 13: Added important thermal cautions for ES devices Slide 13 & 14: Added reference to thermal tuning document number Slide 16: Emphasized that air is a thermal insulator Slide 18: Added touch temperature limits
C	March 2014	Added “How” to the document title Introduced CTS (Coefficient of Thermal Spreading) and Thermal Design Reviews throughout the slides Slide 7: Removed references to copying QRD MD/ID as a thermal solution. Slide 10: Added multiple other document references related to thermal design, PDN, etc. Added slides 11-12 Slide 15: Clarified that PCB Layout Database is needed for to achieve best layout review Slide 14-18: Added items to the design timeline including hardware and software thermal design reviews, references to key application notes, and underlined required design reviews.
D	July 2014 (not published to Docs & Downloads)	Slide 4: Clarified the AVS definition, added a heat pipe definition, and clarified the heat spreader definition Slide 5: Added key components, added a thermal interface material (TIM) definition and distinguished it from heat spreader Slide 8: Added boot thermal management and a low temperature restriction to the examples list Slide 10: Updated the images of the MSM8974 folder structure in Docs & Downloads Slide 18: Clarified TIM usage vs. other heat spreaders and placed items in priority order Slide 19: Added a list of key global thermal suppliers Slide 20: Added a list of key Asia thermal suppliers
E	July 2014	Changed formatting to emphasize important concepts. **Note:** See the revision history description for Rev. D for information about the latest technical changes.
F	December 2014	Slide 17: Updated the flowchart showing the steps to thermally optimize a design Slide 18 and 19: Separated “How to Design for Thermal: Mechanical Techniques” and “How to Design for Thermal: System Techniques”

Definitions (1 of 2)

- **Adaptive voltage scaling (AVS):** AVS sets the minimum but adequate operating voltage on a power rail. It is composed of an open loop (i.e., fuses are blown during silicon production to identify optimum initial voltage settings) and a closed loop (i.e., algorithm dynamically optimizes the operating voltage during operation). The open loop portion is also referred to as PVS. See *Application Note: Adaptive Voltage Scaling* (80-N8715-14) for details.
- **Computational fluid dynamics (CFD) software:** Third-party CFD software used to design for thermal management. It solves energy, continuity, and momentum equations. (Examples are Icepak by ANSYS and FloTHERM from Mentor Graphics.)
- **Device:** Any type of wireless terminal, smartphone, or data card.
- **Device skin:** The outside material on a device that is typically in contact with a user.
- **Heat:** Thermal energy (J) typically transferred by conduction, convection, or radiation as a result of a temperature difference. The term "heat" can also be used interchangeably with thermal power. (W).
- **Heat capacity:** The amount of heat required to increase the temperature of a device by one degree. (J/°C).
- **Heat density:** Heat (thermal power) per unit area. (W/m^2).
- **Heat pipe:** A thin sealed metal tube containing a fluid that vaporizes at the hot end and condenses at the cooler end. The fluid returns to the hot end by capillary action through a wick or tiny grooves in the wall. It is much more effective in transferring heat than a metallic conductor.
- **Heat spreader:** Material with high thermal conductivity (k) used to reduce peak temperatures through heat dissipation or spreading. Examples are PCB copper ground planes, metal shields, metal device skins, and thin graphite based sheets. Graphite has very high thermal conductivity (~500–600 W/m°K) in the x and y planes but much less in the z plane (~3–10 W/m°K). This makes it ideal for x–y heat spreading in smartphones.
- When used properly, will effectively increase the overall heat capacity of a design.
- **Industry design/mechanical design (ID/MD):** IM/ID is the most significant factor in designing for thermal. Refers to the entire form factor of a device including total surface area, skin material type and finish, all dimensions and relative placement of ICs, shields, battery, sockets, peripherals, LCD panels, PCB stack-up via type, amount of copper, etc.
- **Isotherms:** Temperature profiles of a device generated by thermal CFD software. Each line in an isotherm represents a constant temperature.

Definitions (2 of 2)

- **Key components:** The highest heat generating ICs (MSM™, PAs, battery charger/PMIC, WLAN, and camera).
- **KPI:** Key performance indicators.
- **Power delivery network (PDN):** The PCB PDN refers to the power rail connections between the PMIC and the baseband IC, including all associated passive components and their connections to the power rails. See *Training: Power Delivery Network Design* (80-VT310-13) for details.
- **Process voltage setting (PVS):** PVS sets the minimum but adequate operating voltage on a power rail. It is an open loop technique (fuses are blown during silicon production to identify optimum voltage settings). See *Processor Voltage Setting (PVS) Application Note* (80-N8715-13) for details.
- **Thermal conductivity**: The measure of a material's ability to conduct heat. (W/m°K).
- **Thermal interface material (TIM):** TIM replaces air gaps above key components. It provides a thermally conductive path to another heat spreader or a heat sink helping to control the peak IC junction temperatures. TIM is typically thicker than heat spreaders such as graphite sheets or metal shields. It has thermal conductivities of ~3–17 W/m°K in all directions (isotropic). This is similar to the thermal conductivity of graphite sheets in the z direction and up to 700 times higher than air.
- **Thermal power:** The amount of heat energy per unit time. (W).
- **Thermal equilibrium:** A steady state where there is no longer any change in temperature over time.
- **Thermal tuning:** The procedure documented in *Presentation: Thermal Tuning Procedure* (80-N9649-1). It explains how to optimize the parameters in the thermal configuration file for each unique ID/MD. When done correctly, this process ensures that each device operates with maximum performance without exceeding the temperature limits for the device skin or exceeding the maximum operating temperatures of the ICs in the device.

Design For Thermal: Why Is This Needed?

- Heat generation is increasing and device form factors are shrinking
  - **Higher performance** (more heat generated)
    - Increase in CPU, graphics, and memory clock frequencies
    - Product performance exceeding laptop performance of a few years ago
    - Leakage current increases exponentially with temperature (leakage current also generates heat)
  - **Smaller form factors** (less heat capacity)
    - The industrial & mechanical design (ID/MD) determines the overall heat capacity of a device
    - Thinner form factors make it more difficult to incorporate heat spreader material
  - **Smaller process nodes** (more heat generated)
    - Supply voltages no longer scale down linearly with process node
    - Increase in leakage currents
- Increased heat creates potential issues.
  - Uncomfortable or unusable device skin temperatures
  - Increased probability of thermally induced failure in ICs
- Thermal mitigation algorithms decrease performance and user experience

Key message: *Proper thermal design greatly extends the time of operation at maximum performance levels without adversely affecting user experience or increasing the probability of device failure.*

Design For Thermal: What Is Needed? (1 of 2)

- Thermal models for key components; supplied by Qualcomm Technologies, Inc. (QTI)
  - Theoretically validated through JEDEC standards
  - Includes material property characteristics and basic geometry
  - Includes relevant heat sources (**Note**: Customers can modify the models to suite their use-case scenarios)
- Thermal use-case examples; supplied by QTI
  - Thermal power concurrency per device for the most challenging use-cases
- Thermal CFD software – purchased by the customer
  - Icepak from ANSYS or FloTHERM from Mentor Graphics
    - Schedule tool training with these companies
  - Solves energy, continuity, and momentum equations
  - Provides temperature profiles for each component of the design including ICs and skin
  - Enables "what if" scenarios allowing the designer to select the proper materials, components, geometries, and overall industrial/mechanical design to achieve goals in performance, user experience, and cost

Key message: *Thermal CFD software must be purchased by the customer and used with models from QTI in order to properly design for thermal.*

Design For Thermal: What Is Needed? (2 of 2)

- Chipset hardware requirements; supplied by QTI
  - Design guidelines contain chipset thermal design information (e.g., thermistor placement)
  - *Thermal Design Checklist* (80-VU794-21) contains important PCB design information
  - Device specifications contain chipset max. case temperature and PDN specifications
- Thermal mitigation software; supplied by QTI
  - Controls thermal power in passively cooled devices by limiting performance
- Key performance indicators; defined by the customer
  - For the thermal use-case scenarios provided by QTI, the customer should define maximum run time before impacting user experience (fps/data rate degradation or device skin/IC case temperature issue)
- Software parameters for each device or device subsystem to control overall thermal power – defined (tuned) by the customer
  - Examples: WLAN, LCD backlight, CPU, GPU, modem (WCDMA, 1X EVDO, LTE, GSM, and TD-SCDMA), battery charging, kernel, camcorder, core control, threshold control, dynamic control algorithm, battery current limiting, speaker coil calibration (for speaker protection algorithm), boot thermal management (BTM), low temperature voltage restriction (Cx, Gfx), and low temperature restriction (Mx)

Key message: *The customer must define thermal KPIs, design ID/MD using CFD thermal software, and edit thermal configuration files during thermal tuning.*

Design For Thermal: What Does QTI Thermal Mitigation Software Do?

- Compensates for inadequate ID/MD design (not enough heat capacity)
- Manages IC temperature limits (e.g., 80–90°C logic/85°C POP memory case)
- Manages device skin temperature limits (OEM/carrier typically 42–45°C; depends on material and finish)
- How it works
  - Passive cooling by reducing performance
  - Thermal daemon controls thermal management device performance levels
  - Thermal management devices communicate with kernel space drivers, user space daemons, and other remote subsystems
  - Provides coverage from boot up to power down
  - Customer must configure thermal management devices and thresholds for each unique ID/MD. The goal is to optimize the tradeoff between maximum system performance and device temperature.
- Hardware sensor inputs
  - Temperature sensors are on the MSM die (**Note**: MSM7x25A, MSM8x25, and MSM8x25Q are exceptions)
  - Customer must add PCB thermistors PA and XO (see chipset design guidelines for details)

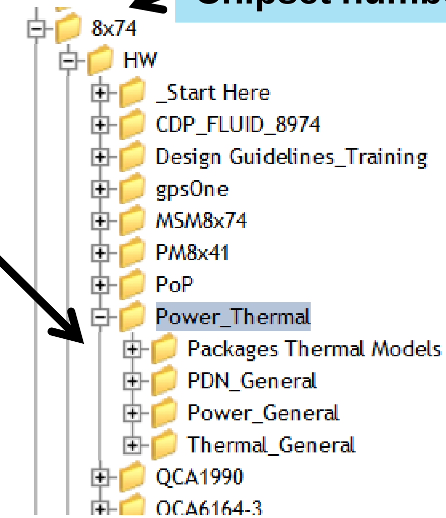
Key message: *Thermal mitigation software cools devices by limiting performance (e.g., reduces fps, data throughput, effective maps, clock rates, etc.).*

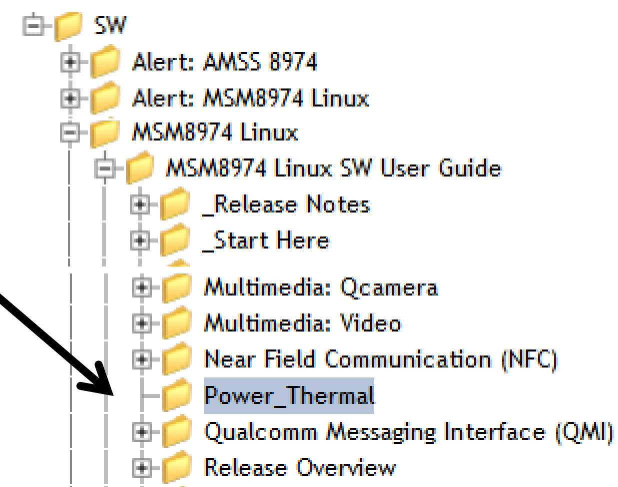
Design For Thermal: Where to Get Thermal Models, Use-Cases, & Training

HW: Power_Thermal Folder
- ❑ Package thermal models
- ❑ Thermal power concurrency use-cases (-12 doc)
- ❑ *Design For Thermal (80-VU794-24)*
- ❑ *Thermal Design Checklist* (80-VU794-21)
- ❑ *Coefficient of Thermal Spreading (80-VU794-14)*
- ❑ *Skin Temp. Measurement Using IR Camera (80-VU794-15)*
- ❑ *Thermal Sim Example (HB11-NJ902-6HW)*
- ❑ *Simplified Thermal Sim Example (HB11-NJ903-6HW)*
- ❑ *PDN Design Training (80-VT310-13)*
- ❑ *PDN Layout Requirement (80-VT310-16)*
- ❑ *Automated Voltage Scaling (80-N8715-14)*
- ❑ *Process Voltage Scaling (80-N8715-13)*
- ❑ Other HW Thermal training docs

SW: Power_Thermal Folder
- ❑ Thermal mitigation docs
- ❑ OS-specific SW dos
- ❑ *Power Consumption App Note (80-family-7)*
- ❑ *Thermal Tuning Procedure* (80-N9649-1)
- ❑ *SW Thermal Debugging (80-NM998-1)*
- ❑ *MSMxxx Linux Android Power & Thermal Management*
- ❑ Other SW Thermal Training docs

Chipset number





Key message: *QTI's customer portal, Docs & Downloads, contains thermal models, thermal use-cases, and thermal training for each chipset.*

Design For Thermal: When Are These Items Needed?

- Thermal CFD software; purchased by customer
  - At least three months before engineering samples (ES) (allow time for training by third-party software vendors)
- Thermal models for key components; supplied by QTI
  - During ID/MD definition
  - Typically two months before QTI ES
- Thermal use-case examples; supplied by QTI
  - Two months before ES

Key message: *Plan to start thermal simulations approximately 2–3 months before QTI chipset ES are available. See timeline slides for details.*

Design For Thermal: Timeline (1 of 5)

~8–12 weeks before QTI ES (and/or customer first SMT)

- QTI publishes device specifications, chipset thermal models, thermal use-cases with CS thermal power range projections, and current consumptions with CS current consumption range projections
- Customer defines product tier, power (DoU), and thermal budget
- Customer defines ID/MD including battery size and chipset placement on PCB
- Customer starts thermal simulations using CFD software (e.g., Icepak or FloTHERM)
  - See *Thermal Design Checklist* (80-VU794-21) and pages 12–13 of this document
- Customer optimizes design to achieve high CTS and submits review via **Thermal Design Review** case (hardware simulation)
  - See *Coefficient of Thermal Spreading (CTS) Figure of Merit for Mobile Thermal Management* (80-VU794-14)

~6–8 weeks before ES (and/or customer first SMT)

- QTI reference schematic, schematic review checklist, and design guidelines are published
- Customer creates schematic and requests a **Schematic Design Review** in Salesforce
  - Refer to the QTI *Reference Schematic* and *Schematic Review Checklist* (80-family-91)
- Customer finalizes parts placement and re-simulates thermal use-cases and CTS
- Customer requests a **Thermal Design Review** (hardware simulation) in Salesforce
  - Submit the CTS score from the simulation and overall device surface area for review

Design For Thermal: Timeline (2 of 5)

- **~4–6 weeks before ES (and/or customer first SMT)**
  - QTI reference layout for PDN, PDN specifications, and layout review checklist is published
  - Customer routes PDN before any other nets
    - Achieve the PDN specification published in the *Device Specification*, Ch. 3 (80-family-1)
  - Customer requests a **PDN Design Review** through Salesforce
    - See *PDN Reference Layout* (DP25-family-x), *Training: Power Delivery Network Design* (80-VT310-13), and *PDN Layout Requirements for PCB Designers and CAD Engineers* (80-VT310-16)
  - Only after meeting the PDN specification, route other critical signals
    - See *Chipset Design Guidelines* (80-family-5) and *Layout Review Checklist* (80-family-92)
  - Customer requests a **Layout Design Review** in Salesforce and uploads PCB database
    - Submitting the PCB database ensures faster turnaround with more coverage and accuracy
- QTI hardware and software ES (and/or customer first SMT)
  - **Note**: PVS and/or AVS open loop is not mature in ES parts
  - Customer may need external thermal mitigation (e.g., heat sink, heat spreader, or small fan) during initial board bring-up and software development to avoid thermal-related issues
  - Do not enable thermal stress testing or benchmark testing during this time period
    - Thermal mitigation algorithm is not mature; ICs can be damaged and test results invalid if any device operating temperature range is exceeded (e.g., PoP memory, baseband IC, or PMIC > 85°C case temperature)

Design For Thermal: Timeline (3 of 5)

- **~3+ months after ES**
  - QTI completes PVS and/or AVS open loop characterization and blows fuses; basic thermal mitigation algorithm is enabled
  - Customer installs shields, heat spreaders, and button-up phones for initial thermal testing or use external mitigation techniques (small fan/heat sink)
    - Thermal mitigation algorithms must be enabled to keep from exceeding recommended device operating temperature ranges
  - Customer runs high-power use-cases (as software is available) to confirm assumptions about hot spots and power dissipation; begin to validate KPIs on thermal
- **QTI feature complete (FC) software**
  - QTI includes AVS closed loop and thermal mitigation algorithms in the software build
  - QTI updates the power consumption application note with measurements
  - Customer begins to tune software to minimize power consumption
  - Customer begins to test thermal mitigation
    - Set thermal mitigation trigger points to effectively manage both junction temperature and device skin temperature; see *Presentation: Thermal Tuning Procedure* (80-N9649-1) for thermal tuning steps
    - **Important**: Do not change QTI's first mitigation temperature set point, as this is required to protect silicon reliability
    - it is required to make use of the on-die MSM temperature sensors according to QTI's thermal mitigation algorithm implementation. These temperature sensors protect the silicon by triggering unmaskable interrupts that occur within milliseconds of overtemperature detection

QTI CS (hardware + software)

- QTI includes any final updates to PVS and/or AVS and thermal software
- QTI updates the power consumption application note measurements with breakdowns
- QTI updates the device specification with maximum power specifications
  - Maximum Dhrystone power/core @ 85°C (scripts provided)
  - Maximum sleep power (Mx+Cx) @ 30°C (airplane mode)
- Customer completes SMT and begins CS hardware bring-up
- Customer requests a **Thermal Design Review** (software) through Salesforce and uploads the following files for review:
  - Boot thermal monitor (BTM) in SBL
  - Kernel thermal monitor (KTM) in DTSI
  - Thermal-engine configuration file (user space)

Design For Thermal: Timeline (5 of 5)

QTI CS (hardware and software) cont.

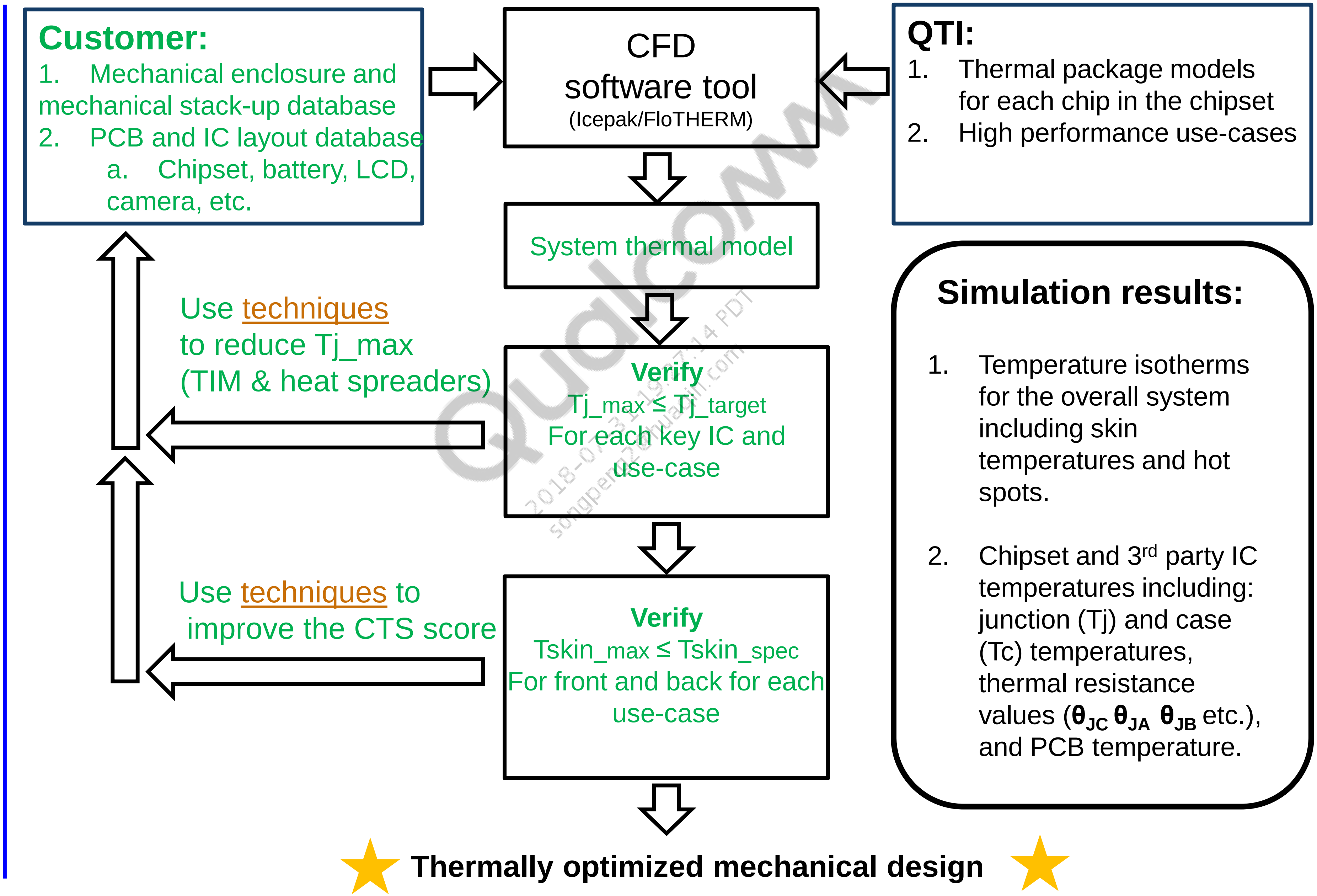
- Customer verifies overall KPIs on performance, power, and thermal are acceptable
  - Perform final updates to ID/MD, if required
  - Optimize current consumption vs. use-cases; verify DoU targets are met
    - See *Configuration of Input Pins During Device Sleep* (80-VN499-7)
    - Ensure software contains all of the latest CRs from QTI affecting power
  - Verify use-case performance vs. time and temperature KPIs
  - Finalize thermal mitigation algorithm tuning
    - See *Presentation: Thermal Tuning Procedure* (80-N9649-1) for thermal tuning steps; this must be performed on the customer platform to achieve the best overall performance
    - See *Skin Temperature Measurement Procedure Using IR Camera* (80-VU794-15); this is very important to improve the accuracy and precision of IR camera measurements
- Customer requests a **thermal design review** (hardware measurement) in Salesforce for final CTS verification

Customer lab entry

- Customer software including thermal configuration files should be frozen at this time

Product launch

How to Design For Thermal: Flowchart



How to Design For Thermal: Mechanical Techniques

Spread the heat

- Optimize the ground plane and connections
  - Use larger copper weight for a solid ground plane layer
  - Connect each ground pin of key ICs directly to this layer (MSM, PMIC, PAs, WLAN, and camera)
- Separate hottest ICs
  - Do not allow overlap on opposite sides of the PCB
  - Place connectors on opposite sides of key ICs where possible (e.g., SIM and SD card)
- Use Thermal Interface Material (TIM)
  - Eliminate air gaps between the top of key ICs and heat spreaders; use TIM under compression and thermal grease for better thermal conduction (supplier links)
- Use heat spreaders
  - Connect TIM to graphite sheets, metal shields, and metal battery case (supplier links)
  - Use large surface areas with high thermal conductivity
- Use air gaps
  - Balance the heat flow between front and back of the PCB
  - Insulate hot spots on the device skin from hot areas below

Absorb the heat

- Use surface roughness or plastic skin to allow higher touch temperatures
- Use battery mass and surface area
  - Requires good thermal conductivity between metal battery case and heat sources
- Use phase change material or heat pipes (supplier links)

Simulate

- Perform system thermal simulations using FloTHERM/Mentor Graphics or Icepak/ANSYS
- Use QTI-supplied thermal package models and thermal use-cases
- Send CTS results for both sides of the device, total device surface area, and device skin temperature limits to QTI for a thermal design review

How to Design For Thermal: System Techniques (Hw + Sw)

Reduce the heat

- Ensure minimum but adequate power rail voltages
  - Meet the PDN specification, enable DCVS, AVS, etc.
- Implement all power-related CRs
- Ensure high performance use case power is aligned with QTI power dashboard.
- Use MSM/APQ internal TSENS (temperature sensors on die)
  - Control Tj max
- Use thermistors on the PCB to control Tskin_max
  - Place thermistors close to XO, PAs, WLAN, camera and the charger to better control IC temperatures
  - Use dedicated thermistors to better control maximum skin temperature.
  - Keep some distance away from hot components.
- Enable QTI thermal mitigation software
- Perform thermal tuning using *Presentation: Thermal Tuning Procedure* (80-N9649-1)

Design Review

- Open Thermal Design Review Case for Hw: QTI to review thermal system simulation results
  - Send CTS results for both sides of the device
  - Total device surface area
  - Device skin temperature limits
- Open Thermal Design Review Case for Sw: QTI to review thermal configuration file
- Open Thermal Design Review Case for Hw: QTI to review thermal system measurement results

How to Design For Thermal: Example Thermal Suppliers – Global

Supplier name	Thermal management type
GrafTech http://www.graftech.com	Manufactures thin (~0.1–0.3 mm thick) graphite heat spreader sheets used in handsets
Panasonic http://www.panasonic.com/industrial	Provides thin (~10 µm) impregnated and no fill type graphite heat spreader sheets
Laird Technologies http://www.lairdtech.com	Supplies TIM/gap filler
Fuji Poly http://www.fujipoly.com	Manufactures thin sheets of silicon with high conductivity and aluminum-based thermal interface material
Parker Hannifin Chomerics http://www.chomerics.com	Thin custom made copper foils that can be bent and shaped to fit any size IC package, widely used in the small form factor electronic systems. Also manufactures TIM/gap fillers
Bergquist Company http://www.bergquistcompany.com	Provides phase change materials, TIM/gap fillers, and other interface material
CoolerMaster http://www.coolermaster.com	Manufactures very thin heat pipes, vapor chambers, and other special purpose heat sinking products
Shin-Etsu http://www.shinetsu.co.jp/en/	Used as a paste for making good contact between rough surfaces; product names: X-23-7868-2D and X-23-7772-4 (**Note**: not necessary if a flexible TIM pad is used)
Dow Corning http://www.dowcorning.com	Manufactures thermal PADs (TIMs), thermally conductive adhesives, etc.
Murata http://www.murata.com	Manufactures thermistors for temperature detection of XO, PA, camera, charger, WLAN, and device skin

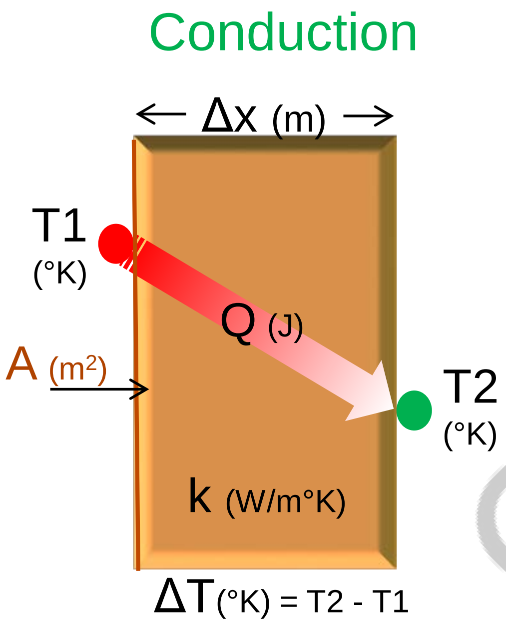
How to Design For Thermal: Example Thermal Suppliers – Asia

Supplier name	Thermal management type
Beijing Jones Co., Ltd www.jones-corp.com	Manufactures thermal grease, thermal pad, and graphite sheets
Suzhou Tianmai Thermal Technology Co., Ltd http://www.sz-tianmai.com	Manufactures very thin heat pipes
Wha-Yueb Technology Co., Ltd http://www.whayueb.com.tw/	Manufactures thermal interface material and copper foil
AVC http://www.avc.com.cn	Manufactures very thin heat pipes, vapor chambers, and other special-purpose heat sinking products

Thermal Concepts Backup

Thermal Concepts: Conductive Heat Transfer

(Back)



Q' = heat transfer rate (W)

$$\frac{\Delta Q}{\Delta t} = -kA\frac{\Delta T}{\Delta x}$$

Key message: Conduction is **the** primary heat transfer mechanism in mobile devices. Material type and area are key variables to increase conductive heat transfer.

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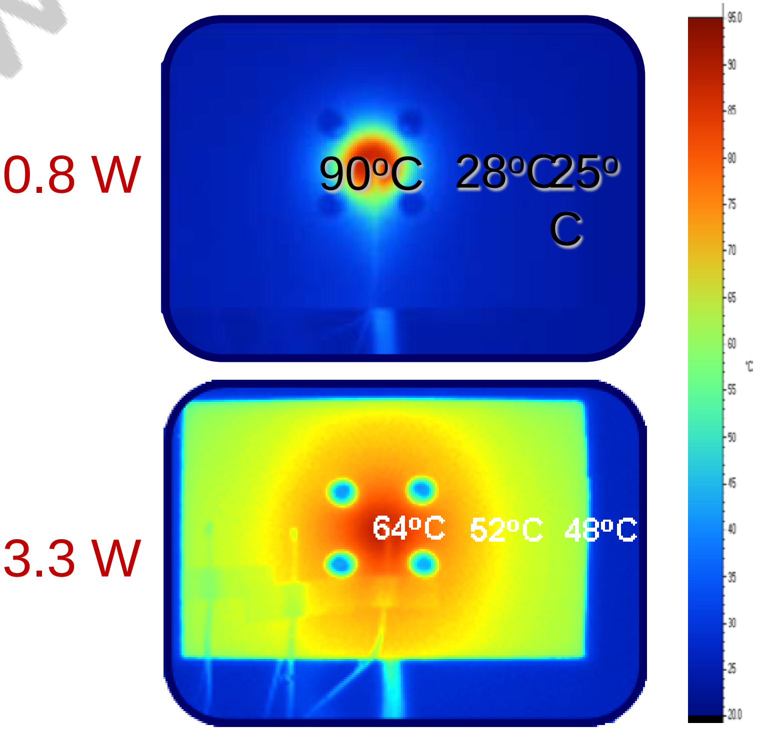
- A larger thermal conductivity (k) material conducts heat better.
  - Metal shields, PCB ground planes, graphite sheets, and device skins made of higher k materials help lower peak temperatures in devices by transferring larger amounts of heat energy away from hot spots (e.g., heat spreaders)
    - Graphite (in-plane): k > 370 W/m°K
    - Copper: k = 360 W/m°K
    - Aluminum: k = 205 W/m°K
    - Magnesium: k = 156 W/m°K
    - Plastic: k = 0.2 W/m°K
    - Air: k = 0.024 W/m°K **(air has 15,000 times the thermal resistance of copper)**
- A larger heat transfer surface area (A) conducts heat better.
  - Heat spreaders extend heat-transfer surface area of ICs when attached to the IC through a high k material. (e.g., PCB GND plane connected to IC by solder balls).
  - A PCB ground plane's thickness and width (cross-sectional surface area), number of layers, and vias are critical items in reducing IC peak temperatures by spreading heat energy.
- A larger temperature differential (ΔT) across a smaller distance (Δx) conducts heat better.
  - In the device skin, ΔT is constrained by maximum allowed skin touch temperature (T2).

Thermal Concepts: Heat Spreaders Using Conductive Heat Transfer

Back

Graphite-based heat spreader example:

- A 0.8 W heat source generated a 90°C hot spot within seconds in the top image
- SPREADERSHIELD flexible graphite (SS400-0.127-P1GP1A1) was applied in the bottom image
- Peak temperature reduced by 26°C (90°C to 64°C) while allowing a 400% increase in power (~3.3 W)



Thermal images from a bare 0.8 W heat source vs. a 3.3 W heat source with SPREADERSHIELD

Key message: A graphite heat spreader material uses conductive heat transfer to improve the overall heat capacity of a device.

Touch Temperature Limits for Device Surface (Back)

IEC and Underwriters Lab have similar specifications (table below)

- UL 60950-1 in the United States (same as Europe, Canada, Australia, etc.)

OEMs/carriers typically:

- Have operating temperature specifications of 45°C (25°C ambient case)
- Limit external rise over ambient to ~20°C
- Maximum operating temperature of 40°C (ambient) → total temperature = 60°C < limit (nonmetal)

EN60950-1:2005 Max Temperature	External surface of equipment which may be touched	Knobs touched for a short period (10 s)	Handles or grips continuously held in normal use
Metal	70°C	60°C	55°C
Ceramic and glass	80°C	70°C	65°C
Plastic and rubber	95°C	85°C	75°C

Questions?

Submit technical questions to https://support.cdmatech.com.