



Simplified Thermal Model

AirPrime HL8548 and HL8549



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4115879
1.1
September 08, 2015

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Contact Information

Sales Desk:	Phone:	1-604-232-1488
	Hours:	8:00 AM to 5:00 PM Pacific Time
	Contact:	http://www.sierrawireless.com/sales
Post:	Sierra Wireless 13811 Wireless Way Richmond, BC Canada V6V 3A4	
Technical Support:	support@sierrawireless.com	
RMA Support:	repairs@sierrawireless.com	
Fax:	1-604-231-1109	
Web:	http://www.sierrawireless.com/	

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Document History

Version	Date	Updates
1.0	September 04, 2015	Creation
1.1	September 08, 2015	Updated section 3.2 Upper Operating Temperature Limit



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1. Overview

This document provides a thermal model for the AirPrime HL8548 and HL8549 which can be used by customers in carrying out their product thermal simulation and design.

2. Thermal Model Overview

2.1. Description

The AirPrime HL8548 and HL8549 modules can dissipate thermal energy through two different paths:

- through the molding material or shielding on the module's top side, or
- through the bottom copper side

These two paths are respectively referred as to T and B in the following chapters.

The module is considered as a single component with one internal temperature, T_J , which is the internal temperature as reported by the `AT+KADC` command.

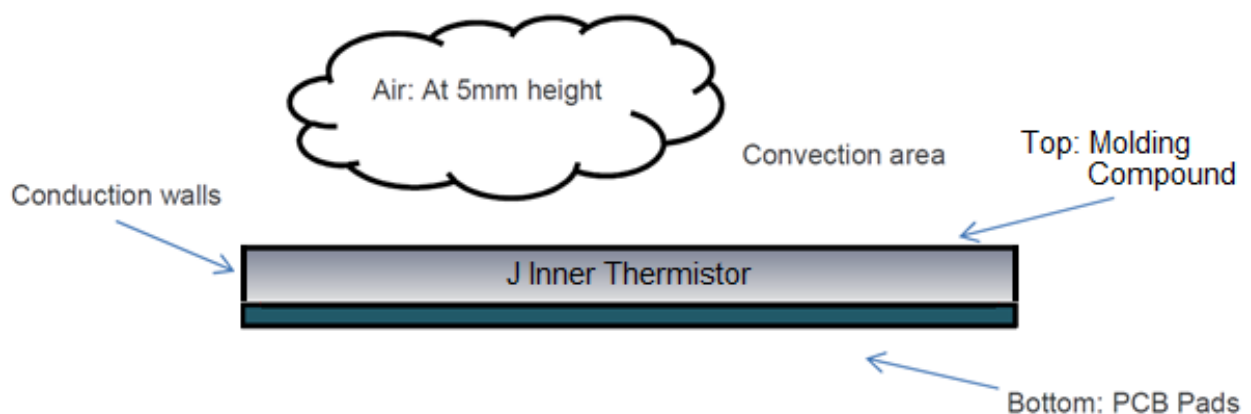


Figure 1. Thermal Areas with the Top and Bottom of the Module Surrounded by Still Air

The following assumptions are made with respect to the thermal model presented in this document:

- The top side of the module is filled with Molding Compound or shielding. It exchanges heat with air by convection. This is usually the higher thermal resistive path. Its model characteristics depend on the thermal conductivity of the Molding Compound or shielding and in the way is linked to the PCB. It acts as a heat sink.
- The bottom side of the module is mainly populated with thermal ground pads that drain out the heat to the customer application PCB which acts as a heat sink. The exchange with the application PCB is done through conduction, while the PCB exchange with air is done through convection and radiation. This is the dominant thermal low resistive path.

Measurements were done in worst-case working conditions. Considering the module alone (meaning not soldered on a board), both top and bottom thermal resistances have been evaluated through these measurements and calculations.

Thermal resistance model from module to still air

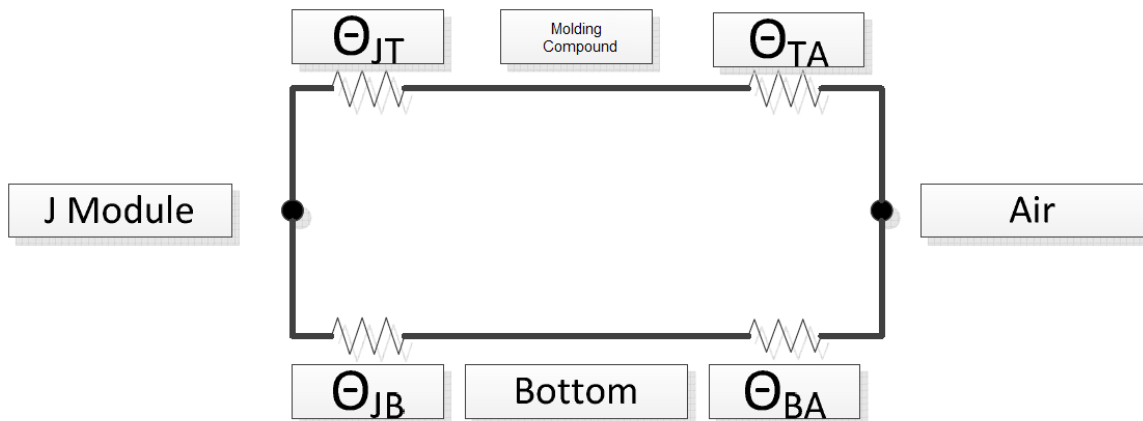


Figure 2. Thermal Model

Where:

J Module is the internal temperature sensor location (used by the **AT+KADC** command).

Θ_{JT} is the thermal resistance from J Module to the top side.

Θ_{TA} is the thermal resistance from the module's top side area to the air.

Θ_{JB} is the thermal resistance from J Module to the bottom PCB side.

Θ_{BA} is the thermal resistance from the module's bottom PCB side area to the air. This is the intrinsic bottom side to air thermal resistance. With a practical application, as this bottom side is soldered on a PCB, the thermal resistance with air of the application PCB will substitute for the Θ_{BA} model value and will be the main thermal dissipation contributor.

Air is the ambient temperature measured 5 mm above the module, with still air conditions.

2.2. Parameters

$$\Theta_{JT} = 49^{\circ}\text{C/W}$$

$$\Theta_{TA} = 21^{\circ}\text{C/W}$$

$$\Theta_{JB} = 3^{\circ}\text{C/W}$$

$$\Theta_{BA} = 53^{\circ}\text{C/W}$$



3. Module Temperature Mapping

3.1. Internal Thermistor

The HL8548 and HL8549 have two internal thermistors that allows the monitoring of the internal temperature reading by AT command.

- Thermistor (NTC200), located close to the VCTCXO
- RF Transceiver (embedded Intel PMB5712)

The following figure shows the thermistor locations inside the module.

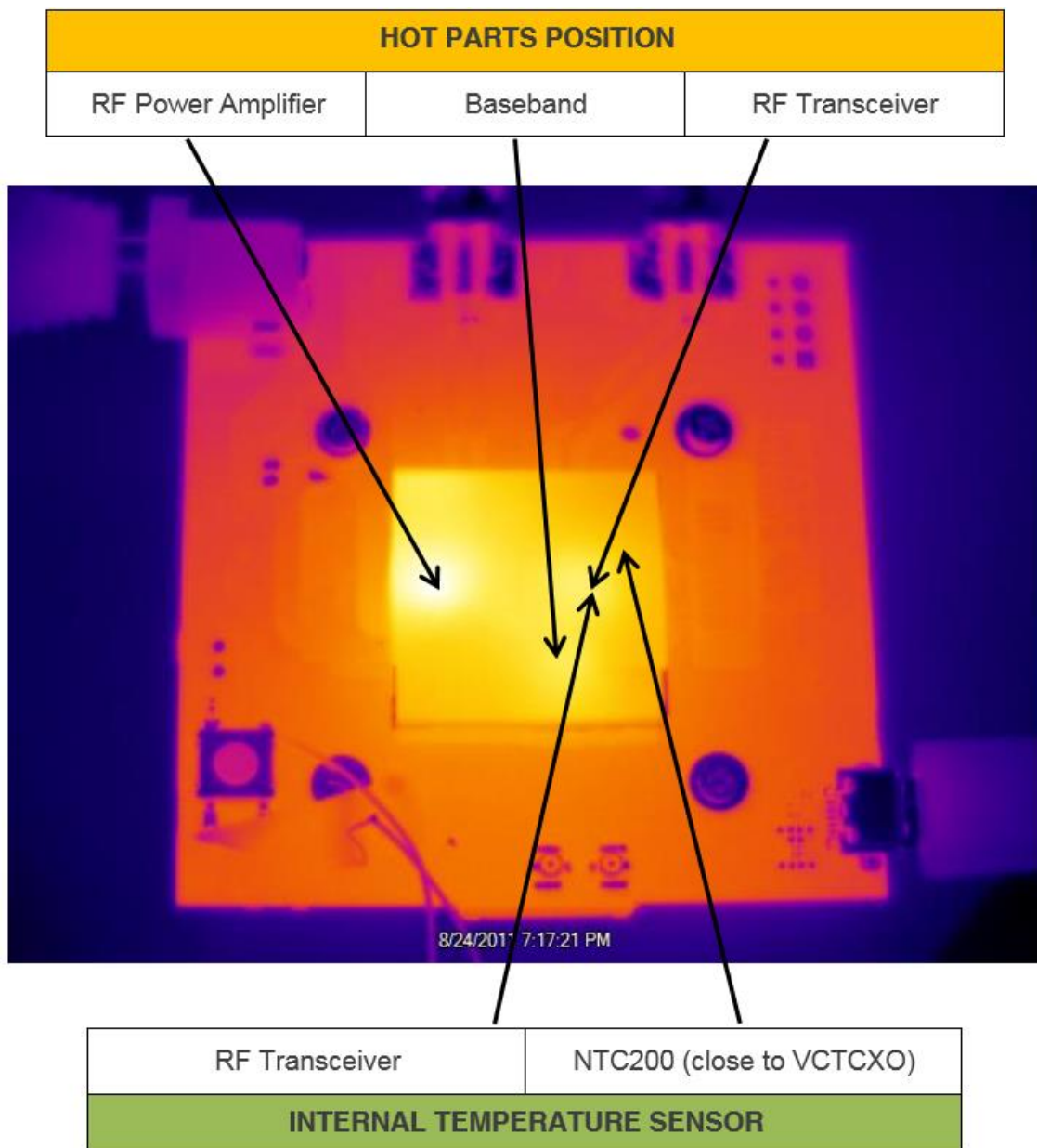


Figure 3. Hot Part Position and Internal Temperature Sensor

3.2. Upper Operating Temperature Limit

The module has reached its maximum operating temperature when the RF transceiver embedded temperature sensor reaches +107°C. Note that it is not recommended to operate the module above this maximum internal operating temperature.

The temperature can be read by the AT command **+KADC**. The firmware monitors the temperature to manage unsolicited messages and actions as specified by the AT command. Refer to the tables below for details regarding this AT command.

3.2.1. Module Temperature Reading

Table 1. Module Temperature Reading

Corresponding AT Command	Description
AT+KADC=3,1	For the RF transceiver's internal temperature reading
AT+KADC=2,1	For the NTC200's internal temperature reading

The **AT+KADC** command will return the real time internal thermistor reading, regardless of whether the module is in communication mode or idle mode.

Table 2. +KADC Command Syntax

Command Form	Response and Parameter Description
<i>Test command</i>	
<u>Syntax</u> AT+KADC=?	<u>Response</u> +KADC: (list of supported <Meas id> s),(list of supported <Meas time> s) OK
<i>Read command</i>	
<u>Syntax</u> AT+KADC=<Meas id>,<Meas time>	<u>Response</u> +KADC: <Meas result> , <Meas id> , <Meas time> [,<Temperature>]
	<u>Parameters</u> <Meas id> Measurement ID 0 VBATT – “VBATT” voltage 1 VCOIN – “BAT RTC” backup battery voltage 2 THERM – connected to NTC200 (the thermistor on board which is located close to the 26MHz VCTCXO) 3 Reserved 4 ADC0 5 Reserved 6 Reserved 7 ADC1
	<Meas time> Measurement time 1 During TX 2 Far from TX 3 No constraint

Command Form	Response and Parameter Description
	<p><Meas result> Measurement result is in μV</p> <p><Temperature> Temperature for VCOIN in degrees Celsius.</p>

3.2.2. Temperature Monitoring

The firmware supports the internal temperature monitoring function and performs the following actions when the temperature reaches either the upper or lower temperature limit via the **AT+KTEMPMON** command:

- Prompts with an unsolicited message
- Other selective actions (note that these actions are disabled by default)
 - Shuts the module down automatically
 - Triggers the selected GPIO

Table 3. +KTEMPMON Command Syntax

Command Form	Response and Parameter Description
<p><i>Test command</i></p> <p><u>Syntax</u> AT+KTEMPMON=?</p>	<p><u>Response</u> +KTEMPMON: (list of supported <mod>s),(list of supported <temperature>s), (list of supported <urcMode>s),(list of supported <action>s), (list of supported <hystTime>s),(list of supported <repGPIO>s) OK</p>
<p><i>Read command</i></p> <p><u>Syntax</u> AT+KTEMPMON?</p>	<p><u>Response</u> +KTEMPMON: <mod>,<temperature>,<urcMode>,<action>,<hystTime>,<repGPIO> OK</p>
<p><i>Write command</i></p> <p><u>Syntax</u> AT+KTEMPMON= <mod>, [<temperature>],[<urcMode>],[<action>],[<hystTime>],[<repGPIO>]]]]]</p>	<p><u>Response</u> +KTEMPMON: <level>,<value> OK</p> <p><u>Parameters</u></p> <p><mod> <u>0</u> Disable the module's internal temperature monitor <u>1</u> Enable the module's internal temperature monitor</p> <p><temperature> Temperature limit before the module acts as defined by <action>. Range = 0 – 150; default value = 0</p> <p><urcMode> <u>0</u> Disables the presentation of the temperature monitor URC <u>1</u> Enables the presentation of the temperature monitor URC</p>

Command Form	Response and Parameter Description
	<p><action> 0 No action 1 Automatic shut-down when the temperature is beyond <temperature> 2 The output pin <repGPIO> is tied HIGH when <temperature> is reached; when the temperature is normal the output pin <repGPIO> is tied LOW. Note that if this parameter is required, it is mandatory to set the <repGPIO> parameter.</p> <p><hyst_time> [0,255] Hysteresis time in seconds. All action will only happen if <temperature> is maintained for at least as long as this period. This parameter is mandatory if <action> is not zero. Default value: 30.</p> <p><repGPIO> 1 – 8, 10 – 12, 15 Defines which GPIO is used as output pin. This parameter is mandatory only if <action>=2 is required. Default value: 12.</p>
Reference	<p><u>Notes</u></p> <ul style="list-style-type: none"> • When the module's internal temperature reaches either operating or extreme levels; the unsolicited message is in the format: +KTEMPMEAS: <level>,<value> where: <level> is the threshold level (see note below): -2 extreme temperature lower bound -1 operating temperature lower bound 0 normal temperature 1 operating temperature upper bound 2 extreme temperature upper bound <value> is the actual temperature expressed in degrees Celsius • Typical temperature bounds are represented as follows: Extreme Temperature Lower Bound -40°C Operating Temperature Lower Bound -20°C Operating Temperature Upper Bound +90°C Extreme Temperature Upper Bound +107°C • Due to temperature measurement uncertainty there is a tolerance of +/- 2°C • Check available GPIOs with +KGPIOCFG when using this command • This command will return ERROR if the selected GPIO is already being used by another feature. Check GPIO availability with other related commands +KSIMDET, +KSIMSEL, +KSYNC, +KJAM, +GSMAD, +GNSSAD, and +KTEMPMON when using this command.



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