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Content Level	BASIC		INTERMEDIATE		ADVANCED	Y	Confidentiality	Public	Y	Private	

Hardware Compatibility	Product Line	IoT Modules	Series	EM9190	
				EM9191	
				EM7690	

Software Compatibility	F/W SWIX55C_03.XX or higher	Document Type	App Note	Y	Tech Note	

1 Version

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2 Introduction

This document is provided to Semtech distributors and clients to aid more rapid development of embedded applications using the Semtech portfolio of cellular solutions. To request a new application/technical note, contact your regional Semtech Product Marketing Manager.

3 Glossary

Term	Definition
5G	5G New Radio
CC	Carrier Components
DL	Downlink
FR1	5G NR Sub-6 GHz
FR2	5G NR mmW
LPM	Low Power Mode
MMW	5G NR millimeter Wave
MTPL	Maximum Transmit Power Limit
NSA	Non-Standalone
PA	Power Amplifier
PCell	Primary Cell
QTM	Qualcomm mmWave transceiver module
RAT	Radio Access Technology
SA	Standalone
SCell	Secondary Cell

Term	Definition
TJ	Junction temperature (internal temperature of SDX55 chip)
TMD	Thermal Mitigation Device
TS	Thermal Sensor
Tx	Transmit
UL	Uplink
vRLF	Virtual Radio Link Feature

4 Scope

Note: In this document EM91 refers to the EM919x / EM7690 module series (EM9190, EM9191 and EM7690).
Note that RAT support varies by module variants:

- *EM9190 modules support 5G NR mmW (FR2), 5G NR Sub-6 GHz (FR1), LTE and WCDMA.*
- *EM9191 modules support 5G NR Sub-6 GHz (FR1) LTE and WCDMA.*
- *EM7690 modules support LTE and WCDMA.*

This document describes preconfigured thermal mitigation techniques that EM91 modules use to reduce their operating temperature when active and passive thermal dissipation methods (such as heatsinks, airflow over the module, etc.) are insufficient. (For cooling method details, refer to *[1] EM9190 Thermal Application Note (Doc# 2174257).*)

Note: EM91 thermal mitigation techniques are not user-configurable.

5 Thermal Mitigation Overview

When a host platform's passive and active cooling methods cannot keep the EM91 module's operating temperature within Class A range (-30°C to +70°C), the module automatically uses thermal mitigation techniques to reduce the temperature.

The module's operating temperature is monitored via thermal sensors (TS) that are attached to specific thermal mitigation devices (TMD) as listed in Table 1. Each TMD initiates specific actions to mitigate overheating (see 6 Supported Thermal Mitigation Actions) based on preconfigured thermal policies in the TMD.

Table 1: Thermal Mitigation Summary

TMDs	Monitored TS[a]	Thermal Mitigations				
		Level[b]	Temperature Threshold (°C) to Enter		Temperature Threshold (°C) to Exit	
▪ PA[c] ▪ PA_FR1[d]	PA + PA1	1	100		85	
		2	105		90	
		3	115		85	
▪ MODEM[e]	MODEM_TSENS + MODEM_TSENS1	1	99		96	
		2	101		98	
		3	105		100	
▪ MMW0[f] ▪ MMW1[f] ▪ MMW2[f] ▪ MMW3[f]	QFE_MMW0 QFE_MMW1 QFE_MMW2 QFE_MMW3		QTM527[g]	QTM525[h]	QTM527[g]	QTM525[h]
		1	95	75	93	73
		2	100	80	98	78
		3	105	85	93	73

a. For document example purposes. Actual configured TSs can be identified through **!TMCONFIG** responses.
b. No thermal mitigation for level 0.
c. The 'PA' TMD monitors both sensors (PA, PA1) for WCDMA/LTE thermal mitigation actions. The highest sensor value is used compare with the Enter/Exit temperature thresholds.
d. The 'PA_FR1' TMD monitors both sensors (PA, PA1) for 5G Sub6 thermal mitigation actions. The highest sensor value is used compare with the Enter/Exit temperature thresholds.
e. The 'MODEM' TMD monitors to both sensors (MODEM_TSENS, MODEM_TSENS1).
f. Each 'MMWx' TMD monitors its corresponding sensor (QFE_MMWx).
g. Because the high-power mmW antennas (QTM527) are collocated, the modem reports only mmW0, using the value of the sensor with the maximum temperature.
h. Low-power mmW antenna (QTM525) reports all four sensors (MMW0–MMW3).

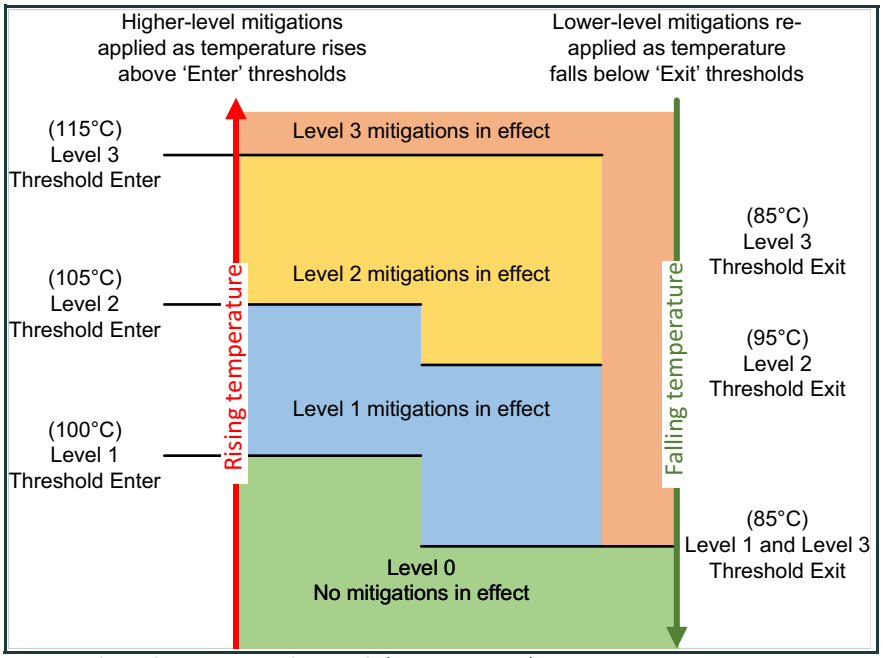

Figure 1: Thermal Mitigation Levels example (PA / PA1 sensors)

Important: *Thermal mitigation components (TSs, TMDs) are subject to change. This document describes the thermal mitigation process using a representative sample of TSs and TMDs. For the specific mitigation configuration on your module, use the AT command* ***!TMCONFIG****.*

6 Supported Thermal Mitigation Actions

This section summarizes the thermal mitigation actions supported by EM91 modules:

- 6.1 2Rx Fallback
- 6.2 Drop SCells
- 6.3 UL Throttling
- 6.4 MTPL Backoff Duty-cycling
- 6.5 QTM Element Reduction
- 6.6 WCDMA Data Throttling
- 6.7 Limited Service Mode

Table 2: Supported Thermal Mitigations by RAT and Mitigation Level

Level	Mitigations						
	RAT: WCDMA	RAT: LTE		RAT: 5G NR FR1		RAT: 5G NR FR2	
		Modem	PA	Modem	PA	Modem	PA
1	6.6 WCDMA Data Throttling	—	6.3 UL Throttling	▪ 6.1 2Rx Fallback ▪ 6.2 Drop SCells	6.3 UL Throttling	6.2 Drop SCells	▪ 6.5 QTM Element Reduction ▪ 6.3 UL Throttling
2	6.4 MTPL Backoff Duty-cycling	▪ 6.1 2Rx Fallback ▪ 6.2 Drop SCells	6.4 MTPL Backoff Duty-cycling	LTE Fallback (NSA)	▪ 6.4 MTPL Backoff Duty-cycling ▪ LTE Fallback (NSA)	LTE Fallback (NSA)	QTM Module Switching
3	6.7 Limited Service Mode	6.7 Limited Service Mode	6.7 Limited Service Mode	6.7 Limited Service Mode	6.7 Limited Service Mode	6.7 Limited Service Mode	▪ LTE Fallback (NSA) ▪ 6.7 Limited Service Mode (SA)

Note: The working frequency of the EM91 module's Cortex-A7 application processor may also downgrade as the temperature increases.

6.1 2Rx Fallback

The 2Rx fallback mitigation reduces any 4Rx-capable CC to 2Rx, to reduce power on the RF transceiver and modem baseband. The mitigation triggers one CC at a time starting with SCells and ending with the PCell.

6.2 Drop SCells

The Drop SCells mitigation reduces the carrier aggregation envelope when applied to an activated SCell. The mitigation drops the least-used SCell to start data throttling and save baseband and RF power.

6.3 UL Throttling

The uplink throttling mitigation action reduces PA power consumption by automatically stepping down (decreasing) the RAT's UL throughput in 10% steps, to a minimum rate of 1 Mbps, as shown in Table 3.

Table 3: UL Data Throttling Example

UL Data Throttling Sublevels[a]	Reduction (%)	Target UL Throughput (Mbps)
No throttling	0	150
Sublevel 1	10	135
Sublevel 2	20	120
Sublevel 3	30	105
Sublevel 4	40	90
Sublevel 5	50	75
Sublevel 6	60	60
Sublevel 7	70	45
Sublevel 8	80	30
Sublevel 9	90	15
Sublevel 10	Maximum	1

a. The current throttling sublevel is not available through software interfaces (AT Commands or API). If logs are accessible, read 0xB89C→current throttle.

6.4 MTPL Backoff Duty-cycling

The Maximum Transmit Power Level (MTPL) backoff duty-cycling mitigation action applies a periodic 'backoff' amount to reduce PA Tx power consumption. The backoff magnitude depends on the MTPL backoff stage — stage 1 or stage 2. The stage 2 backoff amount is double the stage 1 backoff amount.

Figure 2 and Table 4 illustrate the behavior of the MTPL backoff action.

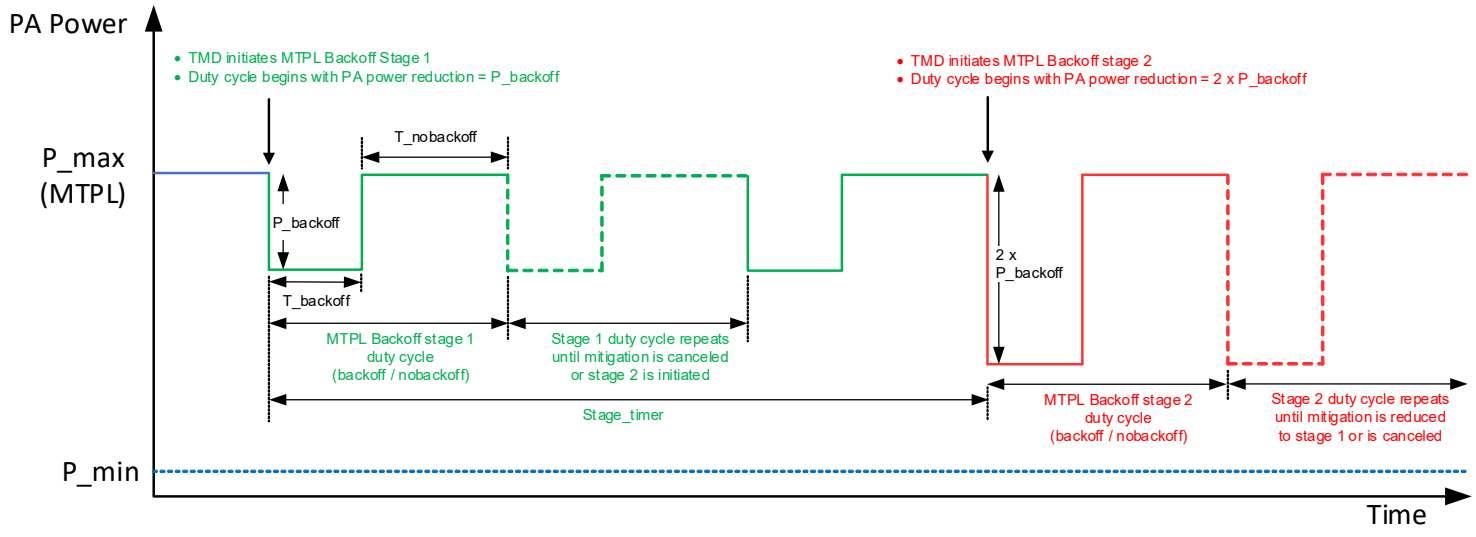

Figure 2: MTPL Backoff Behavior

Table 4: MTPL Backoff Parameters[a]

Parameter	Description	Notes
P_backoff	Initial MTPL backoff value, in dB At MTPL backoff stage n, the power backoff amount is (n * P_backoff).	Actual MTPL backoff amount is minimum{P_backoff, P_backoff_max}
P_backoff_max	Maximum MTPL backoff value, in dB	
T_backoff	Length of time that the MTPL backoff is applied	
T_nobackoff	Length of time that no MTPL backoff is applied	
Stage_timer	Time spent in stage 1	

a. Backoff parameter values are not configurable.

6.5 QTM Element Reduction

The QTM element reduction mitigation reduces the allowed number of antenna elements in one or more steps.

For example, if the number of antenna elements is 4 and the module reaches the Level 1 entry thermal threshold, the first stage is to reduce the number of elements to 2. If the module temperature does not drop to the Level 1 exit threshold before the stage_timer expires, the second stage is to reduce the number of elements to 1.

6.6 WCDMA Data Throttling

The WCDMA data throttling mitigation reduces the PDU size to throttle the UL data and reduce the DL flow by sending WIN_SIZE SUFI to the network.

6.7 Limited Service Mode

When the module enters limited service mode:

- The module drops the current call if one is in progress. Only emergency calls will be allowed.
- The module remains connected with the network but only provides limited service.

Note: To ensure level 3 mitigations are removed when the operating temperature drops to the exit threshold, the module periodically checks the thermal sensors.

7 Low Power Mode

As shown in Figure 3, the module automatically enters low power mode when the SDX55 chip's internal temperature (JT) exceeds a critical temperature threshold (i.e., the temperature rises to High Critical or drops to Low Critical). When the temperature re-enters the normal zone (i.e., the temperature drops below High Warning or rises above Low Warning), the module re-enters normal power mode.

Note: If the internal temperature reaches 120 °C, the module automatically resets — see 8 Automatic Module Reset for details.

To display the module's defined internal temperature limits, use the AT command **!PCTEMPLIMITS?**.

For example:

```
at!pctemplimits?
!PCTEMPLIMITS: 118,100,70,-30,-45
  ← format: <high_critical>,<high_warning>,<normal>,<low_warning>,<low_critical>
```

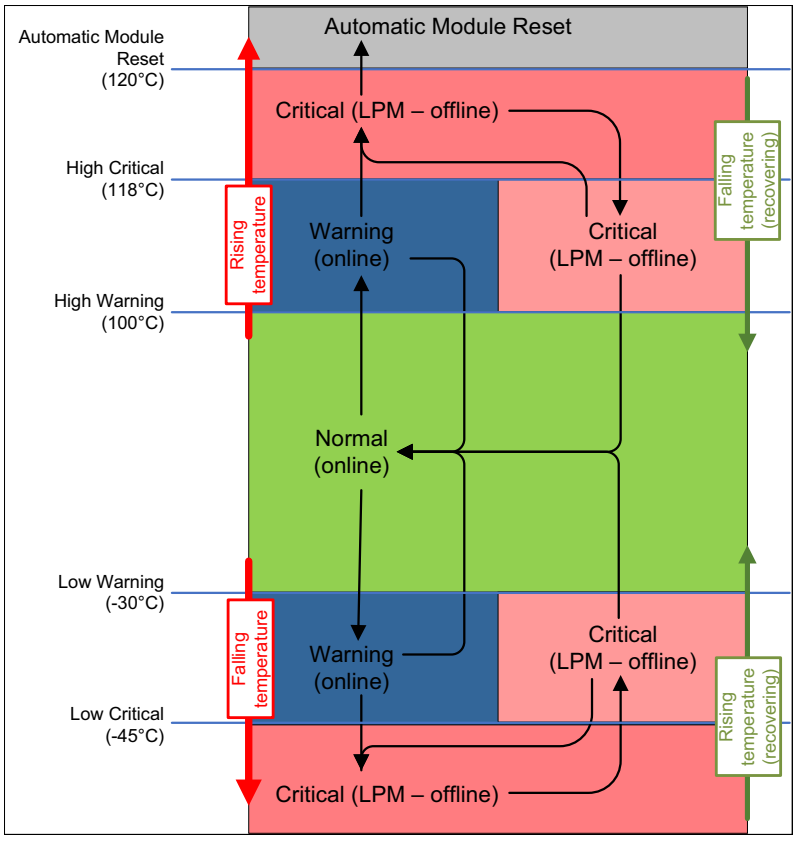

Figure 3: Low Power Mode Protection

8 Automatic Module Reset

If the module's internal temperature (TJ) reaches 120°C (TJ_{max}), the module automatically resets.

However, the module's chipset protection feature may cause the module to crash or fail to enumerate until TJ and/or the ambient temperature decrease sufficiently (Note: This is not a fixed recovery threshold.) If this occurs, the host should wait until the combination of TJ and ambient temperatures decreases, then power cycle the module to attempt to boot and enumerate.

Note also that the module may boot into LPM if the temperature is low enough to enable the module to boot, but still too high to attach.

A Appendix — Thermal Mitigation Software Interfaces

Semtech provides the following thermal mitigation-related software interfaces:

- A.1 Appendix — Thermal Mitigation AT Commands
- A.2 Appendix — Thermal Mitigation API Functions

A.1 Appendix — Thermal Mitigation AT Commands

The proprietary Semtech AT commands listed below are used to manage thermal mitigation. For command details, refer to *[2] EM9 Series AT Command Reference (Doc# 41113480)*.

Table 5: Thermal Mitigation-related AT Commands

AT Command		
!PCTEMP	Name	Return current temperature information
	Description	Return the module's internal temperature and its temperature state.
	Syntax	!PCTEMP?
!PCTEMPLIMITS	Name	Report temperature state limit values
	Description	Report temperature state limit values. Note — Certain modem functionality is affected by the module's internal temperature state. The possible temperature states are high critical, high warning, normal, low warning, and low critical.
	Syntax	!PCTEMPLIMITS?
!TMCONFIG	Name	Configure EM92 thermal mitigation thresholds
	Description	This command can be used to display the preconfigured thermal mitigation thresholds for sensors that are monitored by specific thermal mitigation devices.
	Syntax	!TMCONFIG?
!TMSTATUS	Name	Report EM92 thermal mitigation status
	Description	Report the thermal mitigation status of all available thermal mitigation devices in the module.
	Syntax	!TMSTATUS?

Table 5: Thermal Mitigation-related AT Commands (Continued)

AT Command		
!TMURC	Name	Enable / disable thermal mitigation indications (URC)
	Description	Enable/disable thermal mitigation indications (URC).
	Syntax	!TMURC=<status>

A.2 Appendix — Thermal Mitigation API Functions

The API functions listed below are used to manage thermal mitigation. For details, refer to *[3] Sierra Wireless Linux SDK API Reference Guide (Included in the MBPL package).*

Table 6: Thermal Mitigation-related API Functions

API Functions	Related QMI Object
Get thermal mitigation status for specific colling device	
pack_tmd_SLQSTmdGetMitigationLvl(pCtx, pReqBuf, pLen, reqArg)	QMI_TMD_GET_MITIGATION_LEVEL (0x22)
unpack_tmd_SLQSTmdGetMitigationLvl(pResp, respLen, pOutput)	
Get module's temperature value and status	
unpack_dms_SwiEventReportCallBack_ind(pResp, respLen, pOutput)	QMI_DMS_SWI_EVENT_IND (0x5557)

B References

The following documents are available at source.sierrawireless.com:

[1] EM9190 Thermal Application Note (Doc# 2174257)

[2] EM9 Series AT Command Reference (Doc# 41113480)

[3] Sierra Wireless Linux SDK API Reference Guide (Included in the MBPL package)

C Support

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D Document History

Rev #	Release date	Description
1.0	March 9, 2020	Creation
1.1	June 12, 2020	Updated thermal mitigation actions
1.2	August 25, 2020	Added SDK API information

Rev #	Release date	Description
2	October 29, 2021	Updated Table 1 threshold values
3	May 23, 2025	General Update

5 Legal Notice