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HL78xx Low Power Modes

APPLICATION NOTE

Introduction

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- Terms and Abbreviations
- Legal Notice

Overview

The HL78xx supports 3GPP power saving features (PSM, eDRX), implements low power modes, and provides configuration settings to optimize power consumption.

Note: *Throughout this document "HL78xx" refers to all modules in the HL78 series, unless otherwise specified.*

This document supplements the "3GPP Power Saving Features" section of the HL78xx Product Technical Specification. It provides detailed descriptions, usage instructions and use cases for the following features and low power modes:

- 3GPP Power Saving Features:
  - eDRX— Low power consumption DRX extension for host applications that must be reachable but can tolerate extended sleep cycles (e.g. long receive latency periods).
  - PSM — Low power consumption feature for host applications that send mobile originated (MO) data at extended intervals (e.g. several hours, days, or weeks) and do not need to be reachable during those intervals.
- Low Power Modes:
  - Sleep Mode — Basic low power mode.
  - Lite Hibernate Mode — Intermediate low power mode.
  - Hibernate Mode — Lowest power mode.

3GPP Power Saving Features

HL78xx modules support 3GPP advanced power saving features — eDRX (extended DRX) and PSM (Power Saving Mode).

eDRX

Extended Idle DRX (I-eDRX) is a 3GPP-specified extension of the Discontinuous Reception (DRX) low power consumption feature. This extension reduces the number of paging messages the module must monitor while remaining in idle state, resulting in a corresponding decrease in power consumption at the cost of increasing receive latency.

In eDRX, the module monitors only the paging opportunities that occur in a Paging Time Window (PTW) and then enters eDRX Sleep before the next PTW. During eDRX Sleep, the module may enter a very low power state for power savings. This sequence (eDRX PTW followed by eDRX Sleep) comprises a single eDRX cycle.

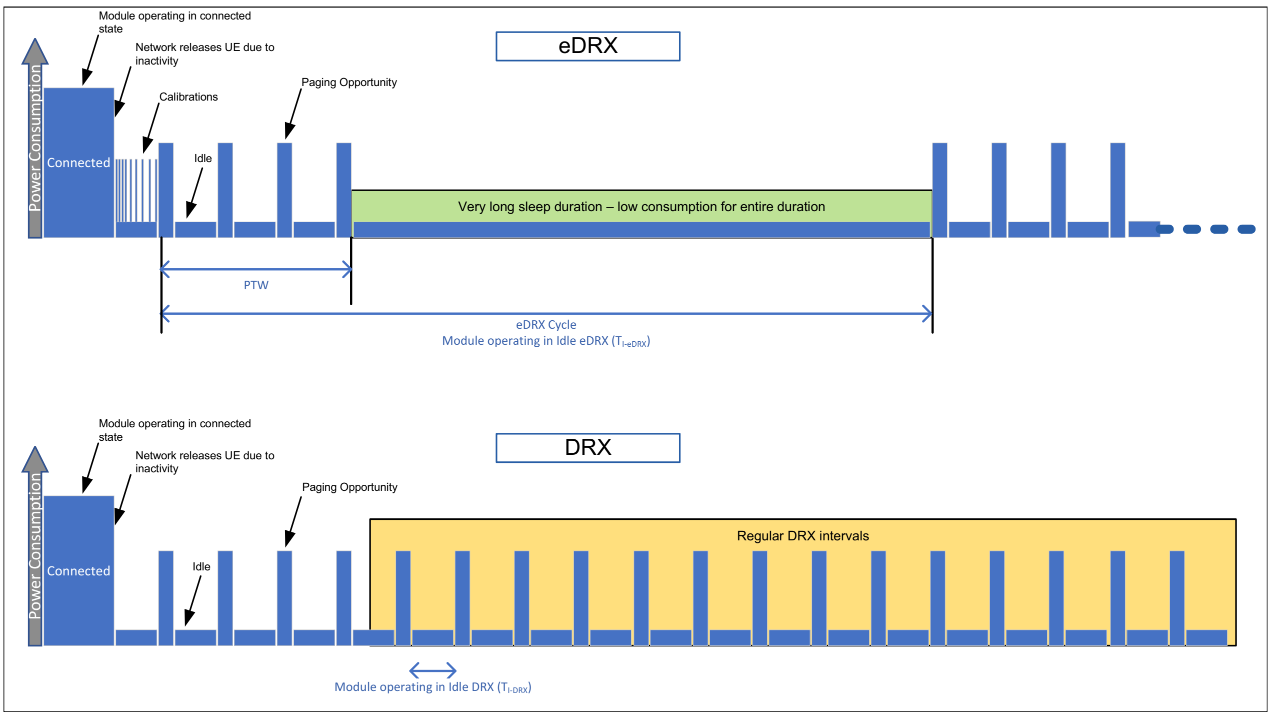


Figure 1: eDRX vs DRX comparison

The eDRX cycle length ($T_{I\text{-}eDRX}$) is negotiated between the module and the network during Attach and TAU procedures. The module requests a preferred cycle when enabling eDRX, and the network replies with two parameters:

- $T_{I\text{-}eDRX}$ – Actual eDRX cycle length to be used

$T_{I\text{-}eDRX}$ can be set from 5.12–2621.44 seconds (~44 minutes) in LTE M and from 20.48-10485.76 seconds (~175 minutes) in NB IoT. The requested value is configured by the customer using the +CEDRXS command, and the negotiated eDRX values (TI-eDRX and TPTW) are read using the +CEDRXRDP command.

(The +KEDRXCFG command also can configure and read eDRX cycle length and PTW length. Important – only one of +CEDRXS and +KEDRXCFG can be used. Do not use a combination of both commands.)

Note: *HL78xx modules are optimized to provide the best eDRX performance with an 81.92 s cycle. With cycles longer than 81.92 s, additional (but diminishing) current consumption savings may be attained at the expense of increased receive latency.*

While the module is in I eDRX, it periodically wakes very briefly to calibrate its internal clock with the network. These calibrations are much shorter than a regular paging opportunity and the module is not reachable during the calibration. After RRC is released, calibrations initially occur at ~10 s intervals, increasing slowly up to 81.92 s or $T_{I\text{-}eDRX}$, whichever is shorter. See Calibration Procedure *for details.*

The length of time a network holds data for the module is network-dependent. If it is determined that the network is not holding some data for the module, use AT+CEDRXS to set a shorter $T_{I\text{-}eDRX}$ value.

- T_{PTW} – Paging time window length

The module remains in I-eDRX until it detects a paging message from the network during a paging opportunity, or needs to access the network (to make a data connection, send a mobility TAU or periodic TAU, etc.), at which time it returns to the connected state.

Note: *Low power modes (i.e. Sleep, Lite Hibernate, Hibernate) do not affect eDRX settings and functionality.*

PSM

PSM (Power Save Mode) is a 3GPP feature that allows the module to minimize power consumption by entering a very low power state while remaining registered with an LTE network. This mode is useful for applications that do not need to be reachable by the network, or can tolerate extremely high receive latency.

PSM behavior depends on two timers – the PSM Timer (Extended T3412 – extended periodic TAU timer) and the PSM Active Timer (T3324). The module requests PSM (with its preferred Extended T3412 and T3324 values) in an ATTACH or TAU (Tracking Area Update) procedure to the network, and the network eithers accepts the request (using the module's preferred values or network-specified ('negotiated') values) or rejects it (in which case PSM is not enabled).

If the network accepts the PSM request:

1. The network saves module state information and the module remains attached (registered) to the network.
2. The network releases the RRC session, which starts the Extended T3412 and T3324 timers.
3. The module enters the PSM active state. In this state, it can receive/send packets from/to the network. The module stays in PSM Active State until T3324 expires.

Note: *If T3324 is long enough, enabling eDRX may result in additional power savings during Active time.*

4. The module enters the PSM dormant state. In this state:
   - The module is not reachable by the network.
   - The module can enter a very low power state mode (e.g. Lite Hibernate, Hibernate) for improved power savings.
   - The host application can wake the module to send mobile-originated data. If this happens:
     - **i.** The host application must wait until it receives a +KCELLMEASURE URC before attempting data transmission. For details, see Using the +KCELLMEAS URC.
     - **ii.** The module enters the connected state to send the data. After the data session finishes, the module moves back to step 2.

- The module can disable PSM or change PSM parameters , which triggers a TAU procedure. If this happens, the module enters the connected state, does the TAU procedure, and then:
  - If PSM is disabled, the PSM operation is terminated.
  - If PSM is still enabled, the module moves back to step 2.

Note: *While in dormant state, the network does not hold any data packets being sent to the module (i.e. mobile-terminated packets).*

5. If the host application does not send data or perform any network activity before Extended T3412 expires, the module automatically sends a periodic TAU to the network:
- If the network receives the TAU, the module enters the connected state. After the TAU procedure completes, the module moves back to step 2.
- If the network does not receive the TAU, it detaches the module (the module's state information is removed) and the module must reattach to the network before sending data.

A host application enables and configures PSM using the AT+CPSMS command (see +CPSMS (Power Saving Mode Setting) AT Command). This configuration is persistent on the module. The module requests the PSM configuration in its ATTACH or TAU request. The host application only needs to configure once (or to change the configuration).

Table 1 describes characteristics of the PSM timers.

Table 1: PSM Timer Characteristics

Timer/ Characteristics	Details
T3324 (Active Timer)	Duration the module must be idle (eDRX or DRX mode with no Rx/Tx activity) before it enters PSM dormant state.
Timer starts (at 0)	The timer (re)starts at 0 s each time the module enters idle state (after the network releases the RRC session).
Timer stops	The timer stops in the following ways: ▪ Before it expires, when any data transfer (Rx/Tx) interrupts the idle state. The RRC session begins. ▪ When it expires. The module enters PSM dormant state.
Selecting appropriate timer value	Considerations: ▪ The requested timer value should be long enough to allow the module to send a packet to a server and receive a reply before entering PSM dormant state. If the timer is too short, the module will enter PSM dormant state before receiving the reply and the packet will be lost (since networks typically do not hold mobile-terminated packets for later transmission). ▪ Select the shortest suitable timer to reduce current consumption.
Extended-T3412 (Extended Periodic TAU Timer)	Maximum duration the module can remain attached to the network without transmitting (i.e. in a data session or TAU procedure). *Note: For DRX and eDRX, the network typically specifies the basic periodic TAU timer (T3412) value to use. However, if the network instead provides the extended-T3412, the module will use that value.* When enabling PSM, the module specifies the preferred extended-T3412 value and the network replies with both the negotiated extended-T3412 and the basic network-specified T3412. The module will always use the extended-T3412 for PSM.
Timer starts (at 0)	The timer (re)starts at 0 s each time the module enters idle state (after the network releases the RRC session).

Table 1: PSM Timer Characteristics

Timer stops	The timer stops in the following ways: ▪ Before the timer expires, if the host application wakes the module to request that it send mobile-originated data to the network. ▪ Before the timer expires, if the host application uses the +**CPSMS** AT command to update the configuration with new preferred values. The module sends the new preferred values to the network to negotiate the new values and update the timers. ▪ When the timer expires, the module automatically wakes and sends a periodic TAU message to the network. In each case, the timer restarts at 0 when the module re-enters idle state.
Selecting appropriate timer value	Considerations: ▪ Requested timer value should typically be **much** longer than the expected interval for sending mobile-originated data to the network. This ensures the module does not waste current by waking to send a periodic TAU and then waiting in RRC idle mode before returning to PSM dormant state. ▪ There is no problem with requesting a very long (or maximum) duration. If the network does not support the requested value, it may use a shorter 'negotiated' value. ▪ Networks may not support abnormally short requested timer values. If the network does not support the requested value, it may use a longer 'negotiated' value or not enable PSM.

Typical PSM Operations

A typical PSM use case is a host application that infrequently sends mobile-originated data to the network and does not need to be reachable for long periods. One example would be a battery-powered device that collects data from a remote sensor and then transmits it to the network.

In PSM mode, the host application must wait until it receives a +KCELLMEAS URC before attempting data transmission after waking from hibernation. This ensures the module is camped on a cell and is ready to transmit data. The +KCELLMEAS URC also provides signal quality information that the host application can optionally use to make an informed decision about whether to transmit data. Refer to the HL78xx AT Commands Reference Guide for configuration details for this URC, and the Signal Quality URC on Wakeup Application Note for more detailed usage information.

For the purpose of this use case, assume:

- Maximum time expected between remote sensor data reports — 34 hours
- Maximum idle time (the longest period the module should remain reachable from the network (after RRC is released) without being contacted) — 20 seconds

Based on those parameters, the module must set appropriate preferred PSM values:

- Active Timer (T3324) — Set to 20 seconds. A longer timer would increase power consumption by remaining in idle mode longer than necessary to receive a possible data transmission from the network.
- Periodic TAU cycle timer (Extended T3412) — Set to maximum allowed value and the network will return the negotiated value. Setting a shorter timer (close to expected sensor reporting period) could result in the timer expiring, forcing a TAU transmission. Setting a longer timer results in the host application waking up and transmitting only when sensor data is received.

Note: *In a typical PSM use case, the extended T3412 should be configured much longer than the data transaction interval so that no TAU procedure is needed (since each TAU increases total power consumption).*

Figure 2 illustrates this use case:

Time T0 — Module boots and attaches to network.

Time T1 — Module drops to Idle state, T3324 and Extended T3412 start at 0.

Time T2 — Nothing received from network, T3324 expires, module drops to PSM dormant state.

(Note – WAKEUP is low.)

Time T3 — Host application receives sensor data that is to be sent to the network server.

Time T4 — Host application asserts WAKEUP (High). Module wakes and Extended T3412 stops. After UART1_CTS signal is active and +KCELLMEAS URC is received, module issues AT commands (e.g. +KTCPSND, +KUDPSND) to send data to network. (Refer to the HL78xx AT Command Reference Guide for examples.)

Time T5 — Module drops to Idle state, T3324 and Extended T3412 restart at 0.

Time T6 — Nothing received from network, T3324 expires, module drops to PSM dormant state.

(Note – WAKEUP is deasserted (low) after AT commands are complete.)

Time T7 — Remote sensor had no data to send, no data received. Extended T3412 expires, module boots and sends TAU to network.

Time T8 — Module drops to Idle state, T3324 and Extended T3412 restart at 0.

For signal state details of this use case, see PSM Use Cases.

For a detailed description of the wakeup handshaking process, see Module—Host Application Handshake on Wakeup from Low Power Modes.

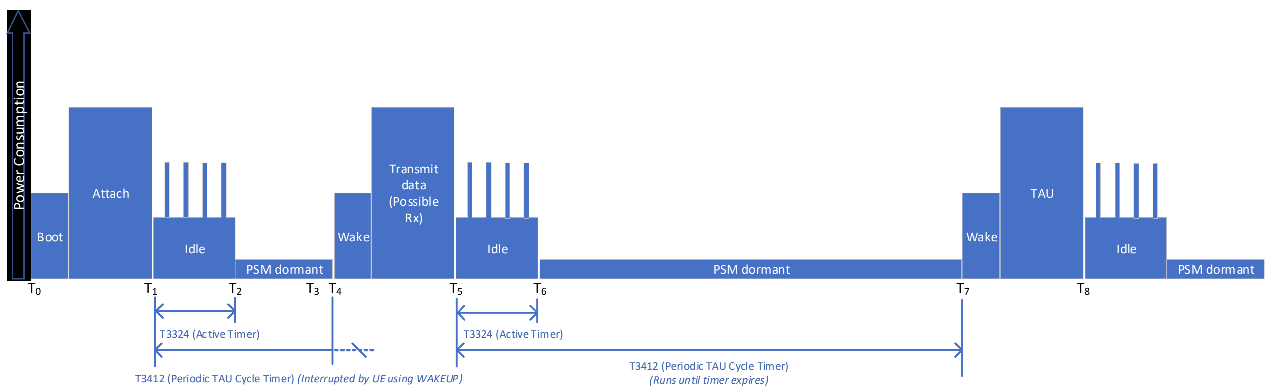


Figure 2: Power Saving Mode – Typical Use Case Example

A variation of this use case is to have the host application periodically wake the module (before the Extended T3412 timer expires) to send a polling packet to the network to check if the network requires the module to be accessible. (The packet could contain sensor data, host application and/or module diagnostic information, or other useful information.) If the network responds that it needs the module to leave PSM mode and remain accessible, the module can then switch to eDRX mode, which provides low-power benefits but remains accessible (unlike PSM).

Using the +KCELLMEAS URC

In PSM mode, the host application must wait until it receives a +KCELLMEAS URC before attempting data transmission after waking from hibernation. This ensures the module is camped on a cell and is ready to transmit data.

The +KCELLMEAS URC also provides signal quality information that the host application can optionally use to make an informed decision about whether to transmit data. For URC configuration details, refer to the HL78xx AT Command Reference Guide, and for detailed usage information, refer to the Signal Quality URC on Wakeup Application Note.

If the module is hibernating in PSM dormant phase and WAKEUP is asserted (High), the module wakes and initiates an attempt to camp on a cell.

If the camp attempt:

- Succeeds – A +KCELLMEAS URC will be sent with signal quality information. After this URC, the module is ready to transmit data.
- Fails (unsuccessful before the user-specified timeout) – A +KCELLMEAS URC will be sent with no signal quality information.

The signal quality information included in the +KCELLMEAS URC for a successful camp attempt can be used by the host application to determine if it is worthwhile to attempt data transmission, or to retry at a later time when less energy may be required. The URC includes many signal quality metrics – one easy-to-use metric is the current CE level. As the CE level increases (indicating decreasing signal quality), more repetitions are required to transmit data. The CE level corresponds to approximate signal quality as follows:

Technology	+KCELLMEAS CE Level	Approximate Signal Quality
LTE-M	1	Good
	2	Poor
NB-IOT	1	Good
	2	Poor
	3	Very poor
Note: CE Level uses the format defined for the AT+CRCES command. For details, refer to +CRCES and +KCELLMEAS in the HL78xx AT Command Reference Guide. For additional +KCELLMEAS details, refer to the Signal Quality URC on Wakeup Application Note.		

Concurrent PSM and eDRX

eDRX and PSM can be concurrently enabled to further decrease the module's current consumption, as compared with the current consumption of the module operating with only PSM enabled. In this configuration, when the module transitions from the connected state to the idle state, it enters eDRX for the duration of the Active Timer (T3324) window of PSM.

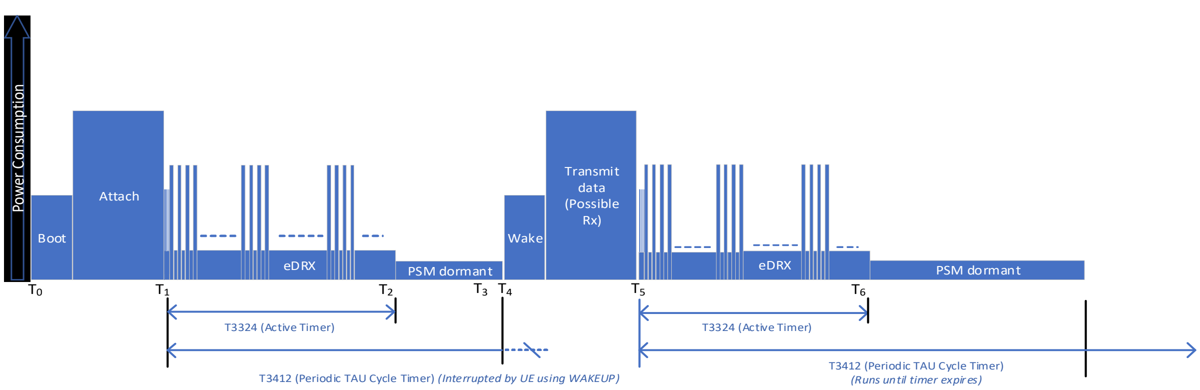


Figure 3: Concurrent PSM and eDRX

For example, if PSM and eDRX are configured with the following settings:

- PSM:
  - T3412 (PSM Timer) — 86400s (24 hours)
  - T3324 (Active Timer) — 327.68s (~5.5 minutes)
- eDRX:
  - eDRX cycle time — 81.92s

Assuming the network does not attempt to contact the module after the module leaves the connected state and enters PSM idle state:

- The module will stay in the idle state for 327.68 seconds (the Active Timer).
- While in the idle state, the module will:
  - **a.** Remain in eDRX power saving mode for 4 cycles of 81.92 seconds each.
  - **b.** Go to PSM dormant state for ~23h55m until the T3412 timer expires.
  - **c.** Wake and send a periodic TAU, and then the PSM process repeats.

RAI

In 3GPP R14 and after, Release Assistance Indication (RAI) is a 3GPP feature to indicate network release in the RRC connection. The RAI feature can improve module power consumption.

In the default settings, the RAI feature is disabled. The host can enable RAI feature by AT command AT+KRAICFG. When enabling RAI, the module provides RAI capability to the network. The module sends RAI to the network, when module has no data to send or receive, by setting BSR=0 (AT command AT+CNMPSD). The network might send RRC release to the module after receiving RAI and the module can go to sleep immediately.

When enabling RAI, some networks expect the module to notify the network when module has no data to send or receive. Therefore, if the module does not send RAI, some networks do not send “RRCConnectionRelese” to module and cause module not to sleep. Therefore, it is highly recommended to enable the RAI feature only when applications can control this feature.

RAI support table on HL7810, HL7812 and HL7845 is as below:

		CAT-M1	NB-IOT
UDP	Control plan	X	Support
	User plan	Support	X
TCP	Control plan	X	X
	User plan	Support	X

Power Modes

The HL78xx module operates in the following power modes – Running (i.e. active), and low power modes (Sleep, Lite Hibernate, Hibernate, OFF), as described in 6.1 Power Mode Descriptions. Power consumption is greatly reduced by integration of the 3GPP power saving features (PSM and eDRX) with the low power modes.

Power Mode Descriptions

The HL78xx module supports operation in the following power modes:

- Running (Running Mode
- Low power modes
  - Sleep (Sleep Mode
  - Lite Hibernate (Lite Hibernate Mode)
  - Hibernate (Hibernate Mode)
  - OFF (OFF Mode)

  The AT+KSLEEP command is used to enable the lowest possible power mode that the module can enter– for example:
  - If Lite Hibernate is enabled, the module could go to Sleep or Lite Hibernate, but never Hibernate.
  - If Hibernate is enabled, the module could go to any low power mode (Sleep, Lite Hibernate, Hibernate).

  For details, refer to the HL78xx AT Command Reference Guide.

Module Subsystems

The HL78xx is composed of two main subsystems:

- Modem (LTE M, NB IoT, GSM (HL7802, HL7812 only))
- Application processor

Note: *It is possible for the two subsystems to be in different power modes. The detailed topics for the power modes indicated in Power Mode Descriptions describe instances where this may occur.*

Modem Subsystem

The modem subsystem runs the LTE M/NB IoT protocol stack, GSM protocol stack (HL7802, HL7812 only), physical layer and RF.

The subsystem will be in one of the following states, as defined by the 3GPP specification:

- OFF — Modem is turned off, SIM is not powered (AT+CFUN=0)
- Flight mode — Modem is turned off, SIM is powered (AT+CFUN=4)
- Connected — Modem has an active connection with the network for signaling or data exchanges.
- C-DRX/C-eDRX — Modem maintains active connection while entering short sleep cycles to reduce power consumption.
- DRX sleep — Modem is registered to the network but with no active connection and periodically listens to the network for paging.
- eDRX sleep — Same as DRX sleep state but modem listens less frequently to the network for paging.
- PSM dormant state — Module is registered to the network with a successful PSM negotiation and is in a dormant state.
- Out of coverage — Modem is not registered to the network due to lack of coverage.

- Searching mode — Modem performs periodic scans to find a suitable network after power on or after network coverage is lost.

Application Subsystem

The application subsystem runs services such as TCP/IP stack, AirVantage connector, AT commands service and controls the host interfaces such as UART1 and GPIOs. The application subsystem will be in one of the following states:

- Active — Data or AT commands are being processed.
- Sleep — No more data or AT commands to process, waiting for interrupts like UART1_DTR, internal timer or modem subsystem events such as SMS reception, IP data reception, modem state change notifications, etc.
- OFF — Application subsystem is turned off. When the application subsystem exits from this state, it performs a full boot if it is on stateless hibernation. It will perform system wake up from retention if it is on stateful hibernation.

Stateful vs. Stateless

Stateless (HL7800, HL7802)

The application layer must perform warm boot upon wakeup and re-initialize contexts to the default state. Warm boot draws power since application layer contexts are all initialized.

Modem settings are saved in flash so that they can be re-used after wakeup.

Stateful (HL7810, HL7812, HL7845)

In stateful hibernation (upon entry into hibernation) necessary memory context is saved to retention memory and to a specific partition of flash memory. Upon exit from hibernation, the saved memory context is restored to allow cores in the modem subsystem to continue to run.

Since necessary memory context is restored, system wake up from hibernation avoids the reboot process and significantly reduces power consumption.

Power Management Subsystem

The power management subsystem manages all the power saving activities. It also controls which power domain is powered or unpowered (see Modem Power Domains for power domain list).

Flash Wearing Protection

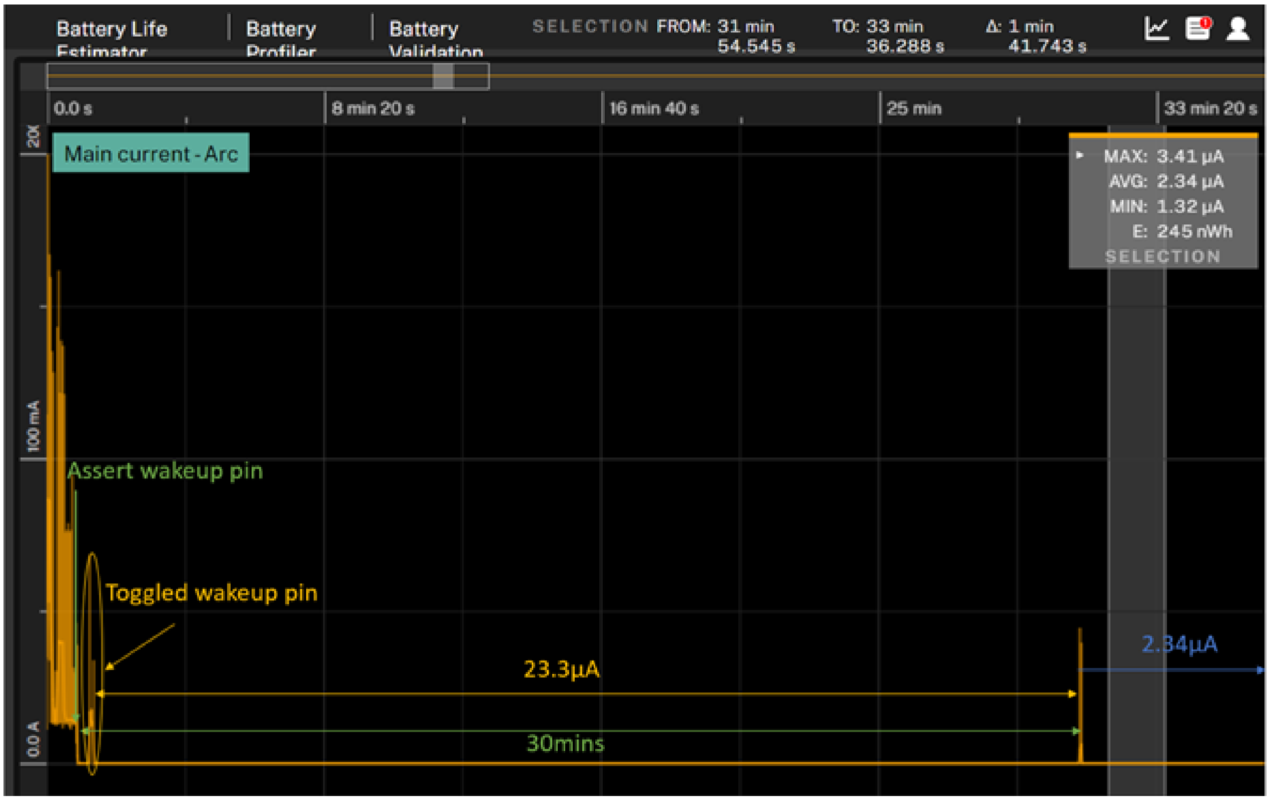
In stateful hibernation, the memory context will be saved to retention memory or flash. If memory context is retained into flash, the module's floor current can go to approximately 2 µA. But if the memory context is retained into retention memory, the module's floor current can only go to more than 10 microampere due to the retention memory needs to be powered. However, flash is only guaranteed about 100'000 erase/write operations in 10 years of operation. Therefore, the module have to prevent frequently erasing and writing to flash.

To prevent flash wear out, if the module tries to go into hibernate mode in less than 30 minutes, the module only retains the memory context into retention memory. Also, after 30 minutes from its last hibernate entry, the module wakes up and retains all the memory context into flash and re-enters hibernation. The module's floor current eventually reaches 2 µA as the retention memory is unpowered.

The following sample scenarios indicate how flash wearing protection functions.

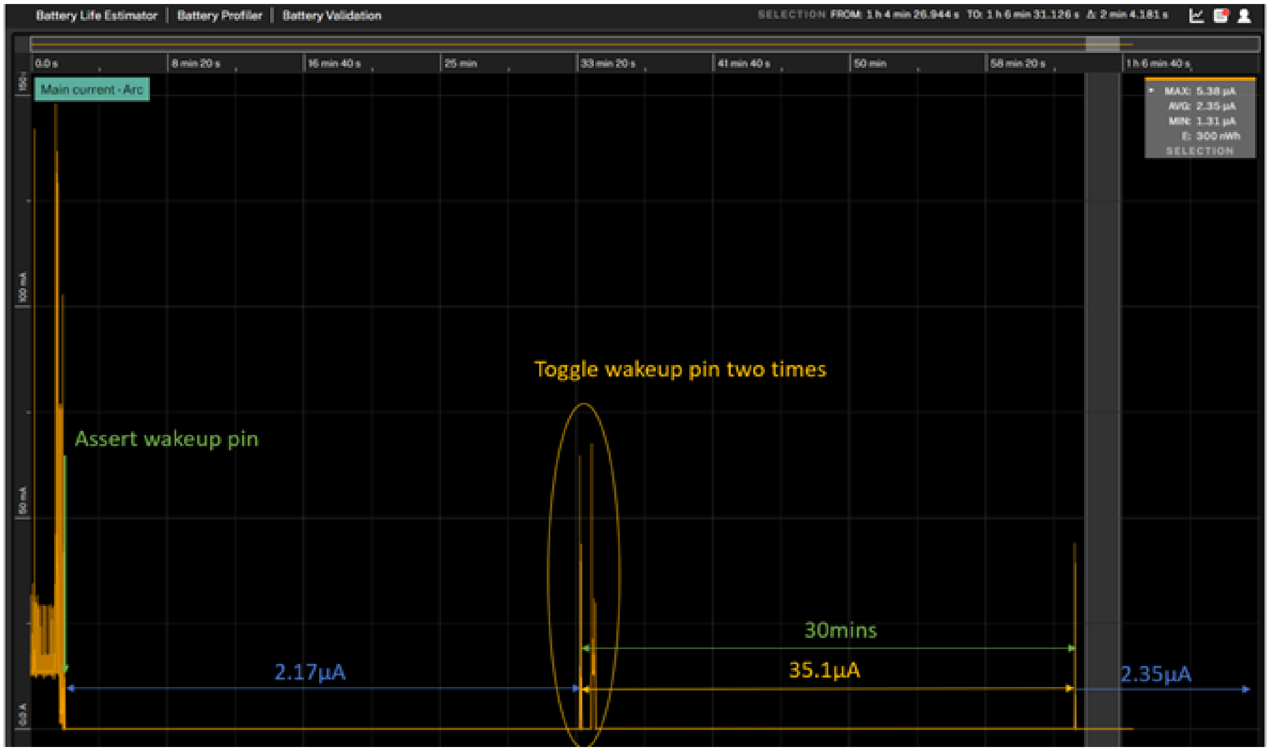
Scenario 1: Under PSM, host toggled module's wakeup pin while entering hibernate mode.

The module retains the data into retention memory for the first 30 minutes after entering hibernate mode. Since the host toggled the wakeup pin, the module waits for 30 minutes before retaining into flash.



Scenario 2: Host toggled wakeup pin after 30 minutes.

If the module has no further actions 30 minutes after being toggled, the module will wait for 30 minutes and then retain into flash.



Modem Power Domains

The HL78xx has several power domains that are supplied independently via VBATT. This allows the module to operate with some domains unpowered in supported low power modes. For HL78xx hardware architecture details, refer to the HL78xx Product Technical Specification.

The HL78xx's power domains include:

- Low Power — This domain is ON in all power modes. It includes the RTC (32 KHz clock), a RAM retention memory (not available in Hibernate during PSM dormant state) and the following I/Os:
  - RESET_IN_N — (Active state – Low) Resets the module
  - WAKEUP — (Active state – High) Wakes the module up from low power modes
- I/O — This domain is ON in all power modes except Hibernate and OFF . When this d omain is powered, VGPIO output is available.
- Core — This domain is ON in Running and Sleep power modes. It includes the main system.
- Fast Clock — This domain is ON in Running mode only. It includes the main (26 MHz) system clock.
- RF — This domain is ON in Running mode only, during RX/TX activity.

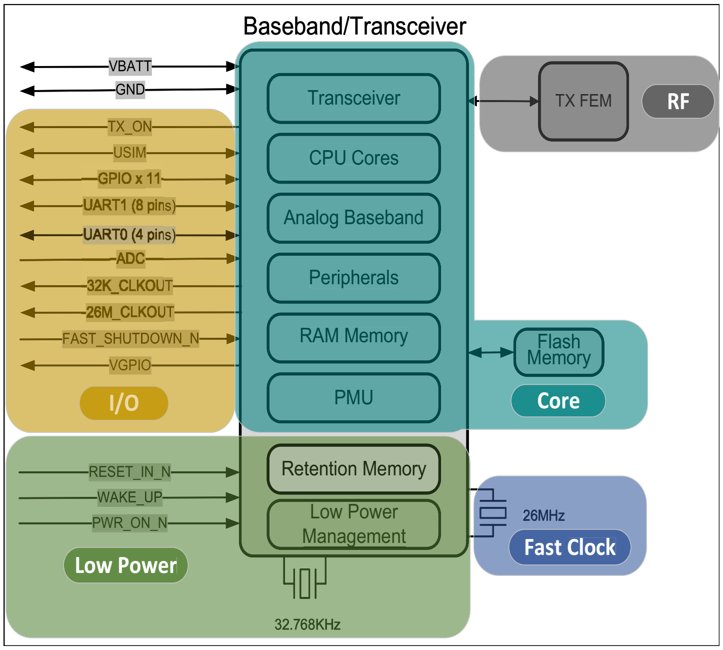
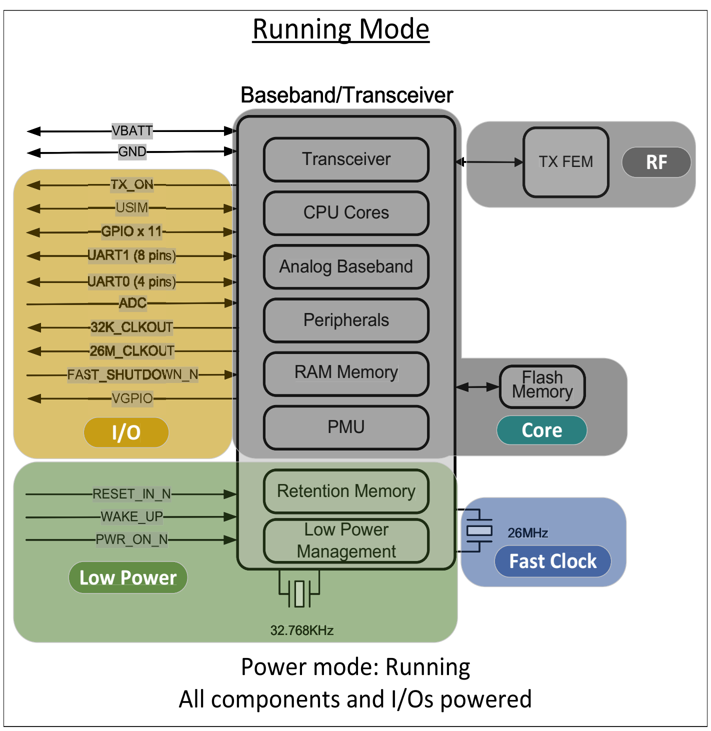


Figure 4: Modem Power Domains

Running Mode

In running mode, all module power domains are powered. Note that RF power is only on during Rx/Tx activity.



Sleep Mode

In Sleep mode (+KSLEEP <level> = 0), the Fast Clock and RF power domains are unpowered. All other domains are powered.

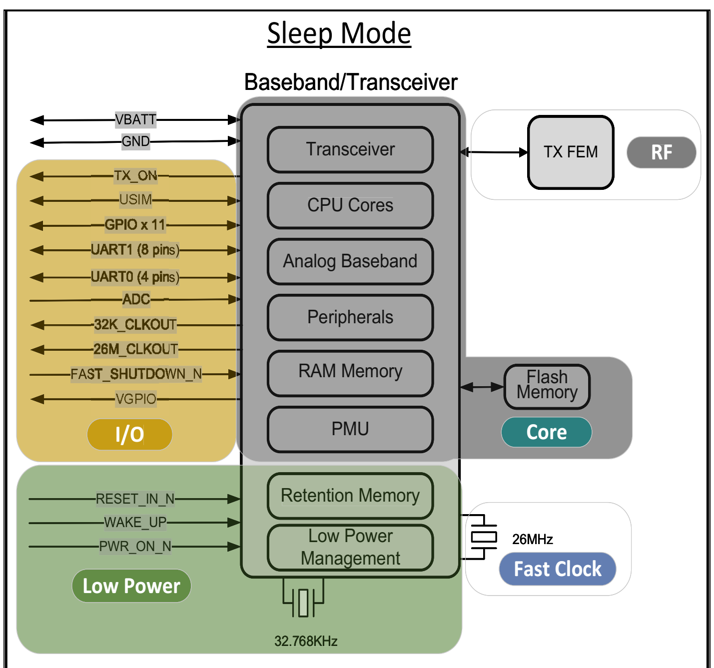
The module enters this mode if all the following conditions are met:

Sleep mode is allowed (+KSLEEP <level> is set to 0 – Sleep, 1 – Lite Hibernate or 2 – Hibernate).

- +KLSLEEP <delay> timer is not running.
- The application subsystem is in sleep state.
- The modem subsystem is in DRX or in eDRX sleep, OFF , in PSM dormant state, or in out of coverage mode.
- UART1_DTR is not active (only if +KSLEEP <mngt> parameter is set to 0).
- WAKEUP pin is set to inactive (Low).
- RESET_IN_N pin is set to inactive (High).

The module's subsystems (one or both) can be woken by any of the following:

- WAKEUP signal transition to active (High) – Wakes both subsystems.
- UART1_DTR signal transition to active (Low) – Wakes both subsystems (only if +KSLEEP <mngt> is set to 0, and <level> is set to 0 – Sleep or 1 – Lite Hibernate).
- Module events such as SMS or IP data reception – Wakes both subsystems. (Note - IP wakes the application layer to check for a socket, and SMS wakes the application layer to save the message in NV memory.)
- All unsolicited result codes that are activated by the customer application (as module state changes (+CREG, +CEREG, etc.) – Wakes the application layer. (The modem subsystem is already on – the +CEREG URC is created by the modem subsystem.)
- Internal processing needs such as internal timer expiration, interrupts, etc. – One or both subsystems will wake, depending on the processing requirements. (e.g. [a] only the modem subsystem wakes in receive mode during PTW in eDRX mode, or upon TAU timer expiry; [b] when a flash write is required, the modem subsystem is already on and wakes the application subsystem)



Power mode: Sleep
App processor sleeping; Modem out-of-coverage, sleeping, or off

Lite Hibernate Mode

In Lite Hibernate mode (+KSLEEP <level> = 1), only the I/O and Low Power domains are powered – the Core, Fast Clock, and RF domains are unpowered. Applications that require I/Os to be retained must use either Lite Hibernate mode (recommended) or Sleep mode. In this mode, the application subsystem is OFF. The modem subsystem may wake up periodically to listen to paging or to perform a periodic Tracking Area Update procedure while in eDRX, but the application subsystem stays OFF.

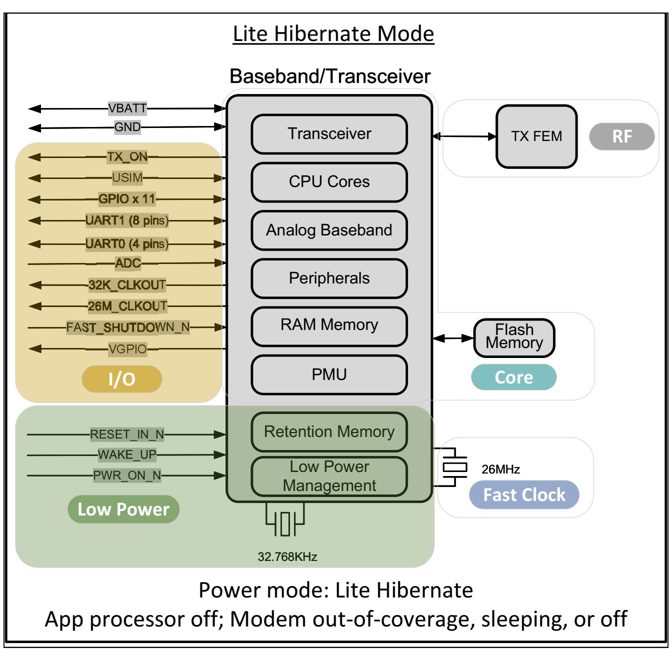
The module enters this mode if all the following conditions are met:

- Lite Hibernate mode is allowed (+KSLEEP <level> is set to 1 – Lite Hibernate or 2 – Hibernate).
- UART1_DTR is not active (only if +KSLEEP <Mngt> parameter is set to 0).
- +KLSLEEP <delay> timer is not running.
- The application subsystem is in sleep state (note that once the module enters Lite Hibernate mode, the application subsystem state changes to OFF).
- The modem subsystem is in one of the following states: DRX sleep, eDRX sleep, OFF , PSM dormant, or out of coverage.
- WAKEUP pin is set to inactive (Low).
- RESET_IN_N pin is set to inactive (High).

The module's subsystems (one or both) can be woken by any of the following:

- WAKEUP signal transition to active (High) – Wakes both subsystems.
- Performing a TAU procedure (triggered by T3412 expiration in eDRX mode or extended T3412 expiration in PSM dormant state) – Wakes the modem subsystem. In some cases (e.g. when LWM2M is enabled), the application subsystem also wakes.
- Enabling receiver during PTW in eDRX mode – Wakes the modem subsystem.
- Receiving data during PTW in eDRX mode – Wakes the application subsystem.
- Modem subsystem state change as network coverage is lost or recovered – May wake the application subsystem (e.g. if +CEREG URCs are enabled, if the recovered service requires an MRU (Most Recently Used cell) table update, etc.).

For a detailed description of the wakeup handshaking process, see Module—Host Application Handshake on Wakeup from Low Power Modes.



Hibernate Mode

Hibernate mode (+KSLEEP <level> = 2) is recommended for applications targeting the lowest power consumption.

With this mode enabled, the module can achieve its minimal power consumption :

- eDRX sleep – approximately 12 µA
- PSM dormant – approximately 2 µA (if Extended T3412 ? 30 mins) or approximately 12 µA (if Extended T3412 < 30 mins)

In Hibernate mode, only the Low Power power domain is powered, all other domains are unpowered. Note that in the lowest power PSM dormant state, the Retention memory contexts are backed up to flash and then the Retention memory is unpowered. In this mode, the application subsystem is OFF . The modem subsystem may wake up periodically to listen to paging or to perform a periodic Tracking Area Update procedure while in eDRX, but the application subsystem stays OFF.

- The module enters this mode if all the following conditions are met:
- Hibernate mode is allowed (+KSLEEP <level> is set to 2 – Hibernate).
- UART1_DTR is not active (only if +KSLEEP <Mngt> parameter is set to 0).
- (Note – This method (+KSLEEP=0,2) is not recommended.)
- +KLSLEEP <delay> timer is not running.
- The application subsystem is in sleep state (note that once the module enters Hibernate mode, the application subsystem state changes to OFF).
- The modem subsystem is in PSM dormant state, or is in eDRX sleep state and the UICC deactivation feature is enabled for eDRX.

  Note that UICC deactivation mechanism is a release 13 feature (refer to ETSI TS 131 102 V13.4.0 clause 5.1.10 and 5.1 11):

  - In PSM, UICC deactivation can be done if PIN code is disabled.
  - In eDRX, UICC deactivation can be done if PIN code is disabled and deactivation of UICC is authorized in EFAD.

  Note that if the modem subsystem is in eDRX and UICC deactivation is not enabled, then the lowest power mode the module can enter is Lite Hibernate.

  Support of this feature by the UICC may be retrieved by reading the SIM's EFAD file using AT+CRSM=176,28589,0,0,4 and checking the response. The feature is supported if the first bit of Byte 1 and the fourth bit of Byte 3 are '1' in the <response> parameter.

  e.g. +CRSM: 145,15,01000802

  The <response> is "01000802" (B4B3B2B1). Byte 1 ("01") = 0001 and byte 3 ("08") = 1000.
- WAKEUP pin is set to inactive (Low).
- RESET_IN_N pin is set to inactive (High).

The module's subsystems (one or both) can be woken by any of the following:

- WAKEUP signal transition to active (High) – Wakes both subsystems.
- Performing a TAU procedure (triggered by T3412 expiration in eDRX mode or extended T3412 expiration in PSM dormant state) – Wakes the modem subsystem. In some cases (e.g. to send URCs due to changes in RF conditions), the application subsystem also wakes.
- Enabling receiver during PTW in eDRX mode – Wakes the modem subsystem.
- Receiving data during PTW in eDRX mode – Wakes the application subsystem.
- Modem subsystem state change as network coverage is lost or recovered – May wake the application subsystem (e.g. if +CEREG URCs are enabled, if the recovered service requires an MRU table update, etc.).

Note: *In eDRX mode, the module enters Hibernate mode between paging opportunities whether in a paging time window or between paging time windows.*

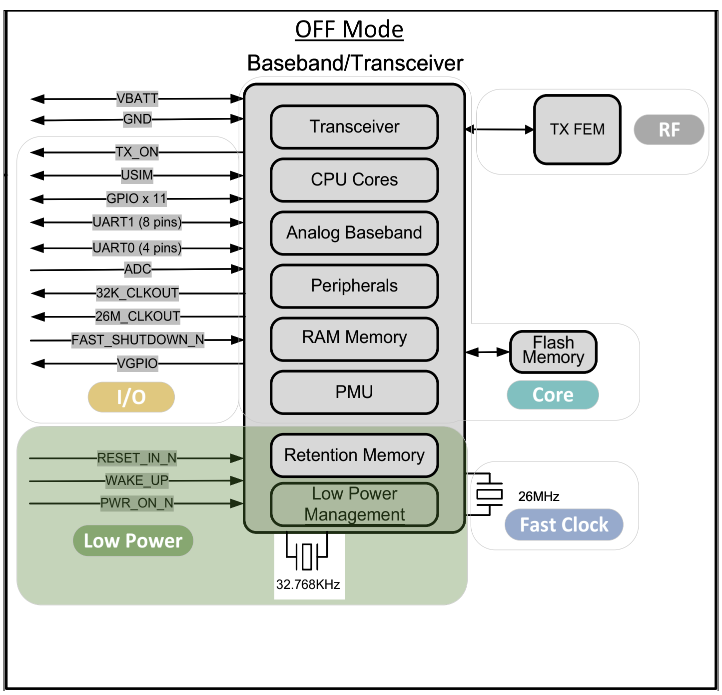
In both eDRX and PSM modes, when the module enters Hibernate, I/Os are not retained. If the module is in eDRX, the modem subsystem periodically partially wakes to listen to the paging. During this short wake-up, certain I/Os are configured with reset values as described in the PTS, so some I/O toggling will occur (and can be ignored).

For a detailed description of the wakeup handshaking process, see 7Module—Host Application Handshake on Wakeup from Low Power Modes.

OFF Mode

In OFF mode, most of the Low Power domain is powered (the 32 kHz clock and retention memory are unpowered). All other domains are unpowered.

In this mode, the application subsystem is OFF and the modem subsystem is OFF. The module enters this mode if it is switched off by the +CPWROFF command. The module can be woken by the WAKEUP signal (high).



Low Power Mode Operation

The lowest power mode that the module can possibly enter is configured using the +KSLEEP command. Then, when operating, the module automatically selects the best power mode based on the +KSLEEP configuration and the current module state as shown in Table 2.

Table 2: Module Power Mode Details

+KSLEEP configuration		Module state	Best achievable power mode	Signal states to enter power mode (All required)	Hardware wakeup sources (Any)[a]	Modem Subsystem-Related Wakeup Sources from Lite Hibernate or Hibernate
<mngt>	<level>[b]					
Sleep disabled (<mngt>=2)	N/A	Connected	No power save mode	N/A	N/A	-

Table 2: Module Power Mode Details (Continued)

+KSLEEP configuration		Module state	Best achievable power mode	Signal states to enter power mode (All required)	Hardware wakeup sources (Any)[a]	Modem Subsystem-Related Wakeup Sources from Lite Hibernate or Hibernate
<mngt>	<level>[b]					
Sleep enabled (<mngt>=0 or <mngt>=1)	Sleep (<level>=0)	DRX, eDRX, Flight Mode, PSM, out of coverage	Sleep	WAKEUP: inactive UART1_DTR: inactive3[c]	WAKEUP: active RTC timer timeout event UART1_DTR: active**	-
	Lite Hibernate (<level>=1)	DRX	Lite Hibernate	WAKEUP: inactive UART1_DTR: inactive3[c]	WAKEUP: active RTC timer timeout event UART1_DTR: active**	-
		Flight Mode	Lite Hibernate			-
		Back-off period during network coverage recovery	Lite Hibernate			Expiry of back-off period
		eDRX	Lite Hibernate			SMS or IP reception Network coverage lost
		PSM	Lite Hibernate			Extended T3412 (Periodic TAU timer)
	Hibernate (<level>=2)	DRX	Lite Hibernate	WAKEUP: inactive UART1_DTR: inactive3[c]	WAKEUP: active RTC timer timeout event	-
		Flight Mode	Lite Hibernate			-
		Back-off period during network coverage recovery	Lite Hibernate			Expiry of back-off period
		eDRX (UICC deactivation disabled)	Lite Hibernate			SMS or IP reception Network coverage lost
		eDRX (UICC deactivation enabled)	Hibernate			SMS or IP reception Network coverage lost
		PSM	Hibernate			Extended T3412 (Periodic TAU timer)
		+CFUN=0	Hibernate		WAKEUP: active	

a. UART1 data reception by the module does not trigger a module wake up from any low power mode.
b. Lowest possible power saving mode that module can enter.
c. Only if configured with +KSLEEP <mngt> parameter set to 0.

The figure below is an example of the module's low power mode state transition graph with the following configuration:

- +KSLEEP <level> parameter is set to 2 – Hibernate mode,
- +KSLEEP <Mngt> parameter is set to 1 – Standalone sleep mode, and
- UICC deactivation feature is supported by the SIM card.

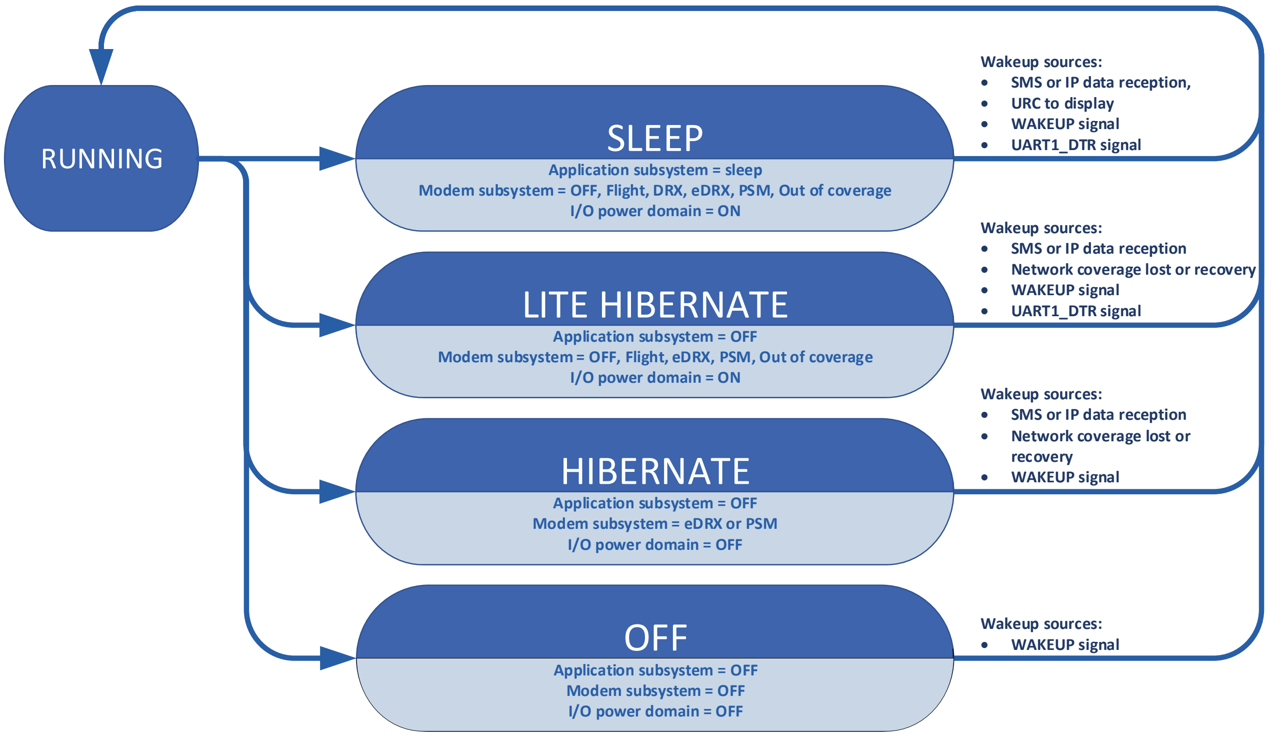


Figure 5: Low Power Mode Transition Graph Example

Host Application Interface

Monitoring Low Power Modes

The host application can detect when the module enters/exits lite hibernate and hibernate modes by monitoring the following signals:

- GPIO6 – The host application can use AT+KHWIOCFG=3,1,6 to enable monitoring (via GPIO6) of lite hibernate mode entry/exit. GPIO6 is pulled low when the module enters eDRX sleep state, and set high when the module wakes.
- VGPIO – The host application can use VGPIO as an indirect indicator of hibernate mode entry/exit. When the module enters hibernate mode, most I/Os (including VGPIO) are indeterminate and cannot be driven by the host application.

  Since VGPIO is not powered in Hibernate mode, its output voltage may be used to monitor Hibernate mode entry/exit – when the voltage is low, the module has entered Hibernate; when the voltage is high (1.8 V), the module is awake (not in Hibernate).

  Note – While in Hibernate mode, external I/O input may affect the actual voltage of VGPIO as VGPIO is not powered internally. For additional details, refer to the HL78xx Product Technical Specification.

Host Application Wake Up Signal (Ring Indicator)

If a host application is designed to enter a low power mode by itself and needs to be woken only when the module receives data for the host application to process (SMS or IP packets), the module must send a ring indicator signal to wake the host application.

The HL78xx module provides UART1_RI (a standard active-low ring indicator tied to VGPIO), and an option (+KRIC command) to configure an active-high GPIO as an alternative ring indicator that is driven high only for specific types of incoming data (the signal is always kept low otherwise). Refer to [2] HL78xx Product Technical Specification for details.

If the module's lowest power mode is configured as:

- Lite Hibernate or Sleep – UART1_RI can be used to wake the host application from its low power mode.
- Hibernate – UART1_RI cannot be used because VGPIO is not powered in Hibernate mode. When the module enters Hibernate mode, UART1_RI becomes low (its active state), which would incorrectly wake the host application.

  Therefore, the alternative ring indicator must be used. To configure GPIO2 to function as a ring indicator, use the +KRIC command (refer to the HL78xx AT Command Reference Guide for details).

IP Server Mode

As mentioned previously, when the module enters Lite Hibernate or Hibernate mode, the application subsystem is put in OFF state, which closes TCP server sockets or UDP sockets.

The module offers a configuration option for +KTCPCFG and +KUDPCFG (<restore_on_boot>) that automatically reopens a TCP server socket or a UDP socket at boot/wake time. With this option enabled (<restore_on_boot>=1), an incoming TCP connection request or UDP packet received during eDRX mode may be processed and notified to the host application. If not enabled, or if the module receives another IP frame, the IP frame will wake the module but be discarded.

To allow time for IP packet reception and processing after the module exits from Lite Hibernate or Hibernate mode, the +KSLEEP <delay> parameter should be configured to satisfy the host application's performance requirements. This delay prevents the module from immediately re-entering Lite Hibernate or Hibernate mode, and lets the host application processor wake up and raise the WAKEUP pin (High) or UART1_DTR. (Note — UART1_DTR is available only in Lite Hibernate mode, not Hibernate, and only if configured with +KSLEEP <mngt> parameter set to 0.)

When the module receives data in Lite Hibernate or Hibernate mode:

1. The modem subsystem wakes the application subsystem to process the data. The TCP server socket or UDP socket that was closed when the module entered Lite Hibernate/Hibernate mode will reopen automatically if the +KTCPCFG / +KUDPCFG <restore_on_boot> configuration option was enabled (<restore_on_boot>=1).
2. The application subsystem asserts the ring indicator to wake the host application to process the data. If <restore_on_boot> was enabled, an incoming TCP connection request or UDP packet received during eDRX mode may be processed and notified to the host application. If not enabled, the IP frame will wake the module but be discarded.

When the host application wakes in response to the ring indicator signal:

1. The host application immediately asserts WAKEUP (High) keep the module awake.

   However, if the host application does not wake quickly enough, the module may re-enter Lite Hibernate/Hibernate before WAKEUP is asserted. To prevent this, configure the +KSLEEP <delay> parameter with a duration long enough to allow the host application to wake and assert WAKEUP (High).

   Note: *If the +KSLEEP <mngt> parameter was set to 0 and the module is in Lite Hibernate, the host application can assert UART1_DTR instead of WAKEUP. (UART1_DTR is not available in Hibernate mode.)*

2. The host application receives the incoming data and communicates with the back-end server as needed.

   If the application is aware that no more data will be transferred, AT+KNMPSD can be used to shorten the RRC connected state.
3. The host application deasserts WAKEUP (Low) when communication with the back-end server is finished. This enables the module to enter Lite Hibernate/Hibernate state when all module subsystems allow it.
4. The module resumes eDRX operations with maximum power savings.

   Note: *If the host application does not deassert WAKEUP (Low) when communication is finished, the module resumes eDRX operation in active state with high current consumption.*

For a more detailed description of the wakeup handshaking process, see Module—Host Application Handshake on Wakeup from Low Power Modes below.

Module—Host Application Handshake on Wakeup from Low Power Modes

This section describes the handshake sequences between the module and host application when the module wakes from Lite Hibernate or Hibernate mode, for both host-initiated and module-initiated wakeup.

Host-initiated Module Wakeup

Host-initiated wakeup is required when the host application needs the module to send data (i.e. mobile-originated (MO)), or needs to execute an AT command on the module.

(Note – In these sequences, the host application asserts either WAKEUP or UART1_DTR, depending on +KSLEEP configuration.)

- Handshake sequence to send MO data in PSM or eDRX:
  a. The host application asserts WAKEUP or UART1_DTR.
  b. The host application asserts UART1_RTS and waits for the module to either assert UART1_CTS or send a +KSUP URC (if enabled via +KSREP).
  c. If the module is in PSM, it waits to receive a +KCELLMEAS URC and optionally process signal quality data. (Note - +KCELLMEAS URCs mut be enabled by the host application.)
  d. If the +KTCPCFG/+KUDPCFG <restore_on_boot> option is:
  - Enabled (i.e. used for IP data) – The module sends the data as follows:
    - UDP – Send UDP data immediately
    - TCP – Bring up TCP connection and then send data
  - Disabled (i.e. not used) – Create a TCP or UDP socket, and then send data
  - Handshake sequence to process a non-data AT command:
    i. The host application asserts WAKEUP or UART1_DTR.
    ii. The host application asserts UART1_RTS and waits for the module to either assert UART1_CTS or send a +KSUP URC (if enabled via +KSREP).
    iii. The host application sends the AT command and the module processes it.

Module-initiated Host Wakeup

Module-initiated host wakeup is required when the module wakes autonomously due to received data (e.g. mobile-terminated (MT) SMS or IP data in eDRX), a network state change, etc.)

(Note – In this sequence, the signal(s) used by the module depend on its configured lowest power mode, and on +KRIC configuration. If the lowest power mode is Hibernate, the module uses the alternative ring indicator (GPIO2, configured via +KRIC). If the lowest power mode is Lite Hibernate or Sleep, the module can use UART1_RI or the alternative ring indicator (if configured).)

- Handshake sequence:
  a. The module toggles GPIO2 or UART1_RI, and asserts UART1_CTS.
  b. The host application asserts WAKEUP before the GPIO2/UART1_RI pulse ends, to keep the module awake while the host communicates with the backend server.
  c. The host application assert RTS.
  d. The module sends all URCs, and the host application reads and processes incoming data.

(Note – MT data in PSM mode is not a recommended/supported use case.)

Low Power Mode Use Cases

This section describes typical PSM and eDRX use cases.

UDP vs. TCP – Considerations for Low Power Operation

The HL78xx supports both TCP and UDP transmission protocols.

While TCP provides for higher-reliability data transmission than UDP, the messaging overhead associated with establishing / terminating TCP connections and optimizing data transfer can result in greater power consumption than UDP.

Under good network conditions, both TCP and UDP work well as latency is short and consistent, similar to wired networks. However, as conditions worsen, LPWA networks (LTE-M and NB-IOT) use mitigation methods / reliability mechanisms (repetitions and slower peak data rates) to deal with wireless communication uncertainty, allowing the module to continue to operate. These mitigations / mechanisms add latencies and jitter to packet transfers, which impact TCP protocol operations to a point that might make TCP unusable. For battery powered devices, the extra packets used by TCP for connection establishment/disconnection and TCP retransmissions will consume more power.

LPWA applications typically send or receive small data packets (up to ~10kB). For these smaller packets, the additional overhead from TCP for connection establishment/disconnection has a relatively larger impact. Given that LPWA has its own reliability mechanisms to deal with uncertainty, the TCP messaging overhead is essentially 'pure overhead'. The additional reliability provided by TCP should not be needed for smaller data transmissions. Applications can use UDP and include a UDP reply (ACK) packet for simple reliability and, if necessary, resend packets.

In summary,

- Low-latency (good conditions) – Both TCP and UDP are suitable.
- High-latency (poor conditions) – UDP is suitable. TCP is not suitable, since LPWA networks use mitigation techniques that make TCP less effective or unusable (the techniques make TCP's messaging overhead unmanageable).
- Battery-powered devices – UDP is suitable. TCP is not suitable, since TCP overhead (extra packets for connect/ transmit/disconnect), especially with correspondingly small packets for LPWA, consumes more power.

Therefore, UDP (with the application using reply packets) is recommended.

PSM Use Cases

The recommended Low Power mode for PSM is Hibernate mode. When configured for PSM, the module enters PSM dormant state (in Hibernate mode) once the Active Timer (T3324) expires. It is then woken by the host application to send host-initiated data packets (see PSM Typical Use Case – Data Transmission Initiated by Host).

In Hibernate mode, the I/Os are not retained and the module can be only be woken up from the WAKEUP pin (High).

Table 3 describes the AT commands used to configure a module (that expects to send mobile-originated data every 24 hours) for PSM with a 20 second Active Timer and 320 hour (~2 weeks) Periodic TAU Timer.

Table 3: PSM Use Case – Related AT Command Configurations

Description	Command
PSM configuration: ▪ Extended-T3412 = 320 hours ▪ T3324 = 20 seconds	AT+CPSMS=1,,,"11000001","00001010" OK
Sleep Mode configuration ▪ Hibernate Mode ▪ Managed via WAKEUP pin	AT+KSLEEP=1,2 OK
Signal Quality on Wakeup URC configuration ▪ Configures URC to be sent (indicating current signal quality details) after wakeup when camp on cell attempt is successful ▪ If the module cannot camp on cell and get signal quality details, URC is sent after user-configured timeout (e.g. 35 s)	AT+KCELLMEAS=1,35

PSM Typical Use Case – Data Transmission Initiated by Host

The host application may want to send data over the network while the module is in PSM mode and Hibernate Low Power mode. Before sending data, the host application will first wake the module up using the WAKEUP signal (High). Once the UART1_CTS signal is active and the +KCELLMEAS URC is received, the host application will reopen a TCP/UDP socket or reinitiate PPP connection over UART1.

As PDN/PDP context is saved in PSM mode, these procedures are executed rapidly. Once data is sent, Extended T3412 and T3324 timers are rearmed with their initial values.

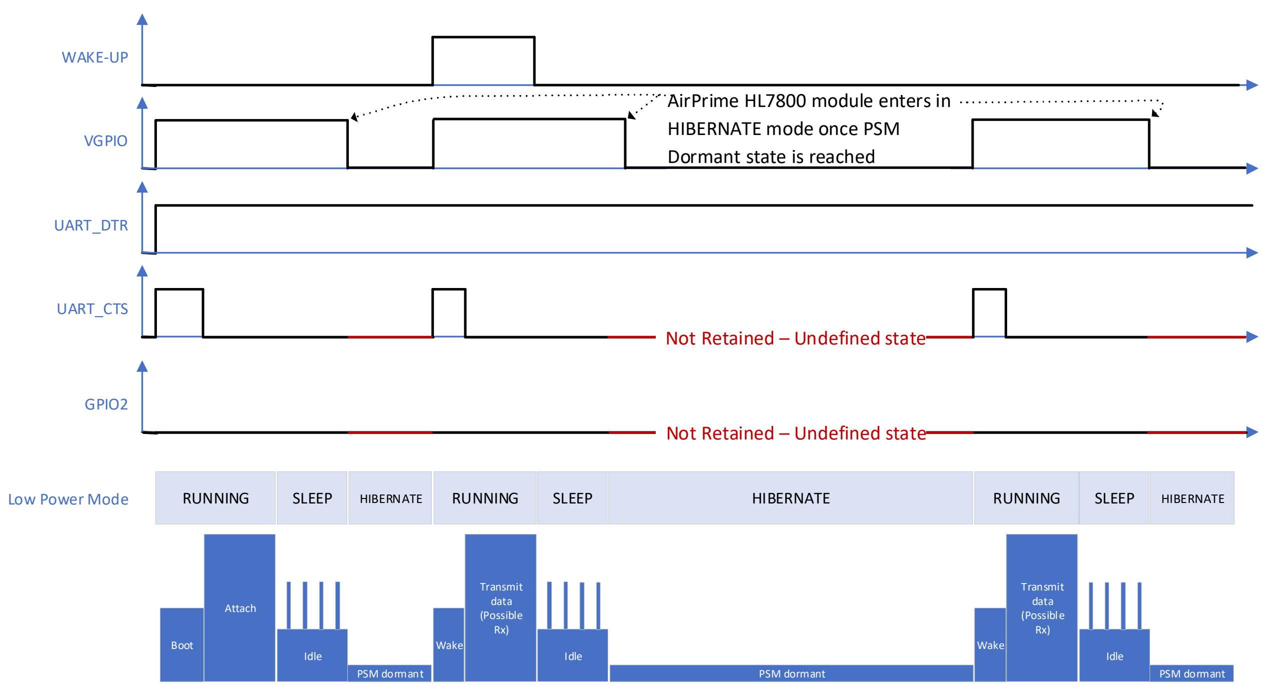


Figure 6: PSM Mode – Typical Use Case

eDRX Use Case

The recommended Low Power state to achieve the best power consumption saving while the module is in eDRX mode is Hibernate mode. When configured in eDRX mode, the module enters the lowest power consumption mode during eDRX sleep period. In particular, this mode depends on the UICC configuration as explained previously:

- If the UICC does not allow UICC deactivation in eDRX mode, the module enters Lite Hibernate mode during eDRX sleep period.
- If the UICC allows UICC deactivation in eDRX mode, the module enters Hibernate mode during eDRX sleep period.

The module periodically wakes up to listen to the paging as described previously. This wake up is a partial wake up meaning that only the modem subsystem of the module is awake.

Calibration Procedure

For the first few minutes after entering Lite Hibernate or Hibernate mode (note – not the lowest power PSM dormant state), the module repeatedly wakes to calibrate the internal clock and maintain synchronization with the network.

The calibration for eDRX begins when transitioning from CONNECTED to IDLE state. It starts with a 1.28-second initial wakeup cycle, then gradually extends the wakeup interval until reaching the requested eDRX cycle or the limit. HL781x has a limit of 163.84 seconds while HL780x is limited to 81.92 seconds at room temperature. Outside the 15-35°C range, All HL78 series limit will be 81.92 seconds.

The calibration procedure relaunches after each RRC connection (TAU or Data) or if network synchronization is lost.

Note: *For an 81.92 s eDRX period or greater, the entire calibration procedure can take approximately 10 minutes.*

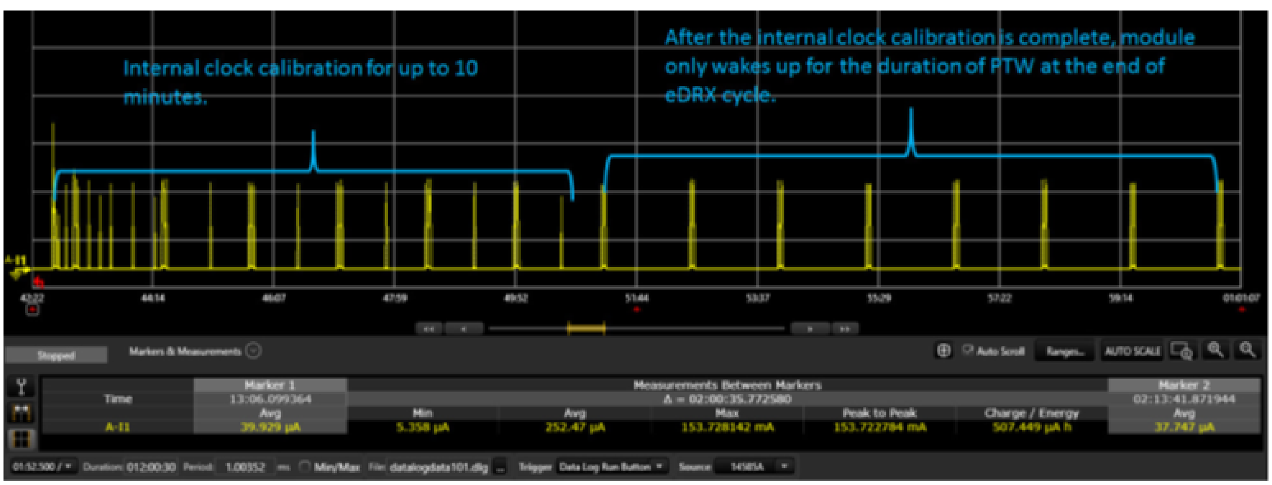


Figure 7: eDRX Mode – Calibration Procedure

eDRX/Hibernate Mobile-Terminated Use Case

When the HL78xx enters eDRX idle in Hibernate mode, the module's application subsystem is put in OFF state, which stops its embedded TCP/IP stack. If the host application must be woken when an IP frame is received and requires the frame to be properly routed, the module offers a configuration option (<restore_on_boot> for

+KTCPCFG and +KUDPCFG) that automatically reopens a TCP server socket or a UDP socket at boot/wake time. With this option enabled (<restore_on_boot>=1), the received IP frame is not lost and an associated URC notification is triggered on the UART1 port.

Table 4 describes the AT commands used to configure a module for eDRX, and setting it to use UDP server socket (with <restore_on_boot> enabled). The example following the table describes how an incoming UDP packet is managed in this configuration.

Table 4: eDRX Use Case – Related AT Command Configurations

Description	Command
eDRX configuration: eDRX cycle = 81.92 seconds	AT+CEDRXS=1,4,"0101" OK *Note: The second parameter is the RAT (<AcT-Type>). Use '4' for LTE-M (as shown), or '5' for NB-IoT.*
Sleep Mode configuration ▪ Standalone Hibernate mode ▪ 10 seconds delay	AT+KSLEEP=1,2,10 OK
RING indicator configuration: ▪ Active on incoming UDP data ▪ Pulse = 1 second ▪ GPIO2	AT+KRIC=128,0,1,2 OK
UDP socket configuration: UDP Server listening	AT+KUDPCFG=1,1,5000,,,,,1
Hardware Flow Control: Active	AT&K3

When the module is in eDRX/Hibernate mode:

1. The modem subsystem listens periodically to the network paging channel.
2. If the backend server sends an incoming UDP packet, the network first buffers this packet until the next paging opportunity of the module.
3. At the paging opportunity, network sends a paging message to request the establishment of an RRC connection.
4. The modem subsystem receives the paging message and:
   - initiates an RRC connection to receive and buffer the UDP packet, and
   - wakes up the application subsystem, which perfoms a boot sequence, restores the UDP server socket (listening mode) and sends back a "ready" notification to the modem subsystem.
5. The modem subsystem sends the buffered UDP packet to the application subsystem for processing.
6. The application subsystem wakes the host application to receive and process the UDP packet (and additional packets, if necessary). For a detailed description of the wakeup handshaking process, see Module-initiated Host Wakeup.
7. When the host application finishes communicating with the backend server, the host application de-asserts WAKEUP (low) to signal the module that it can go to eDRX/hibernation mode.
8. The network releases the RRC connection after it has idled (no data transfer) for the required time period (RRC_INACTIVITY_TIMER).
9. The module goes to eDRX/hibernation mode, and this process repeats (i.e. go back to Step 1).

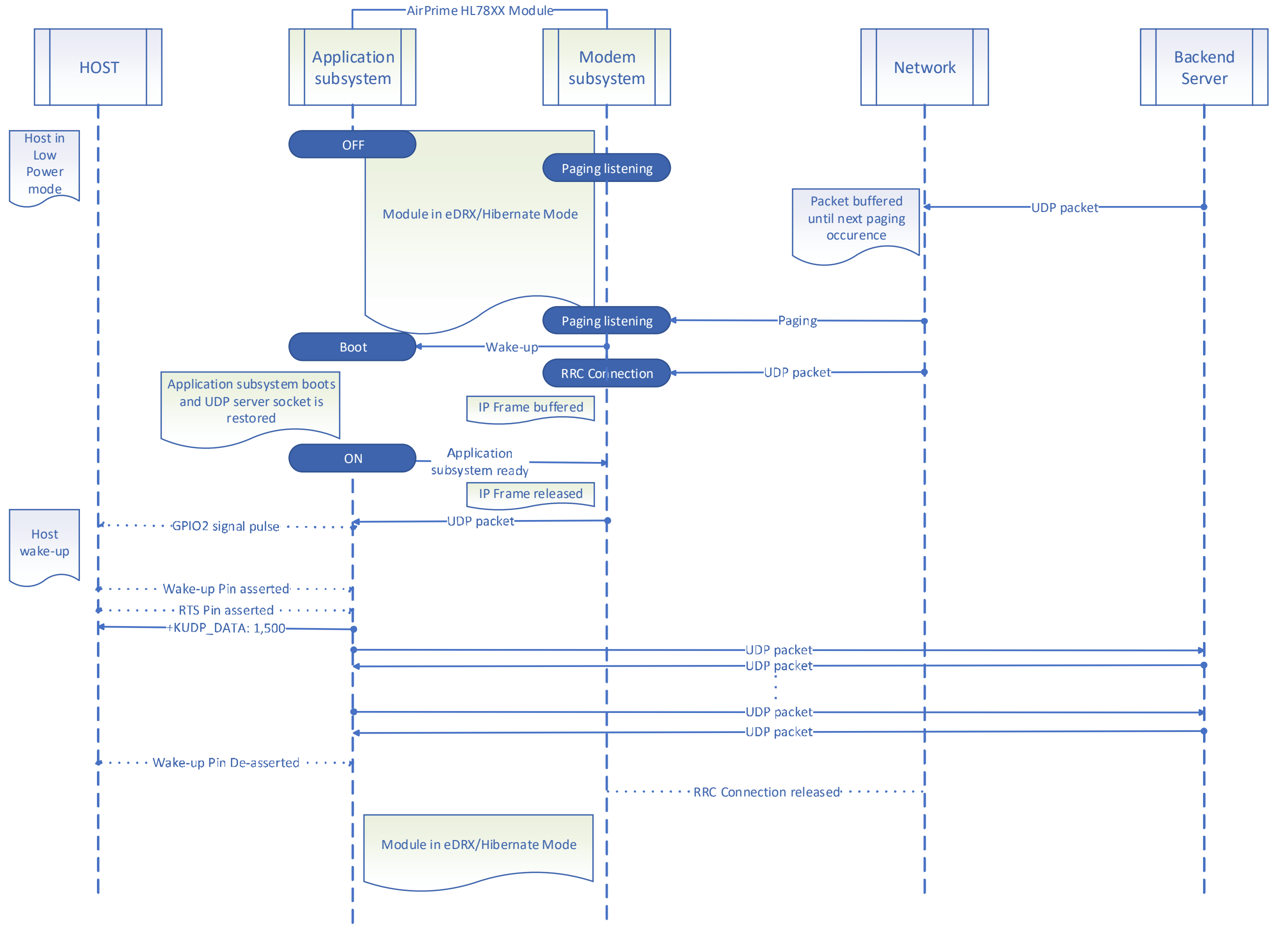


Figure 8: eDRX/Hibernate Mobile-Terminated Use Case Flow Chart

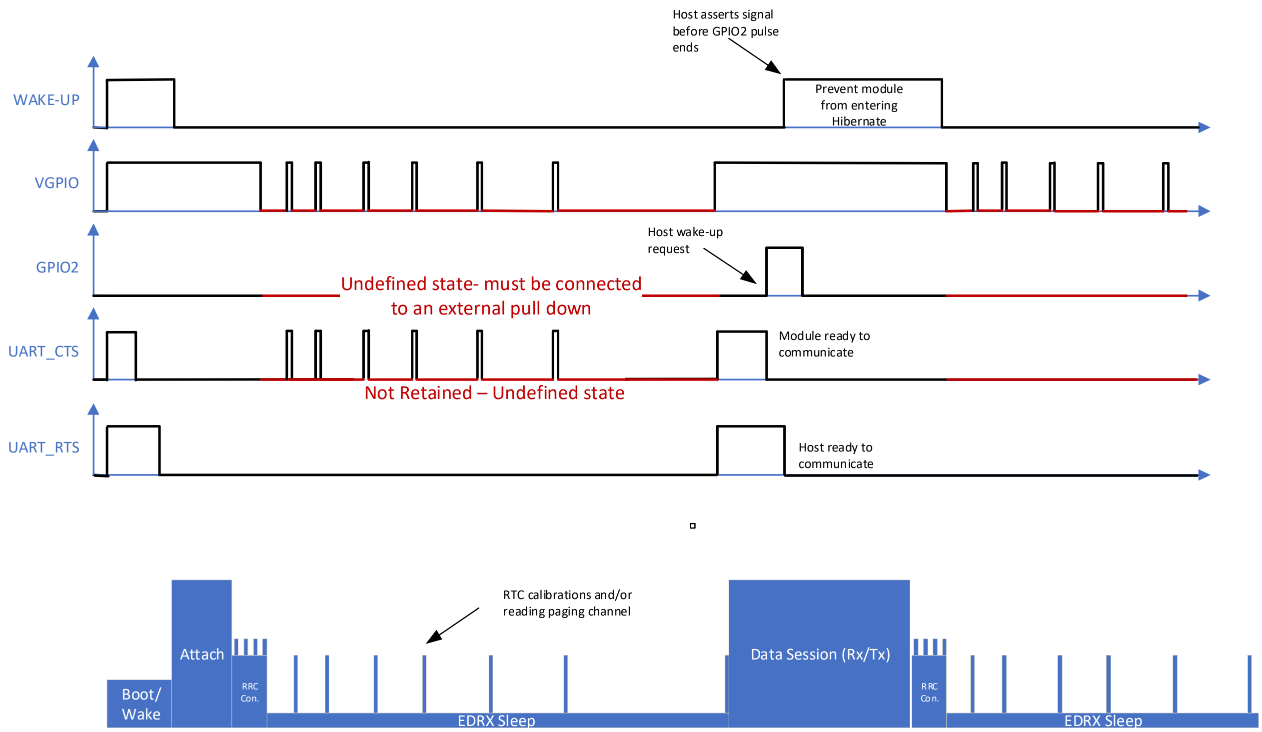
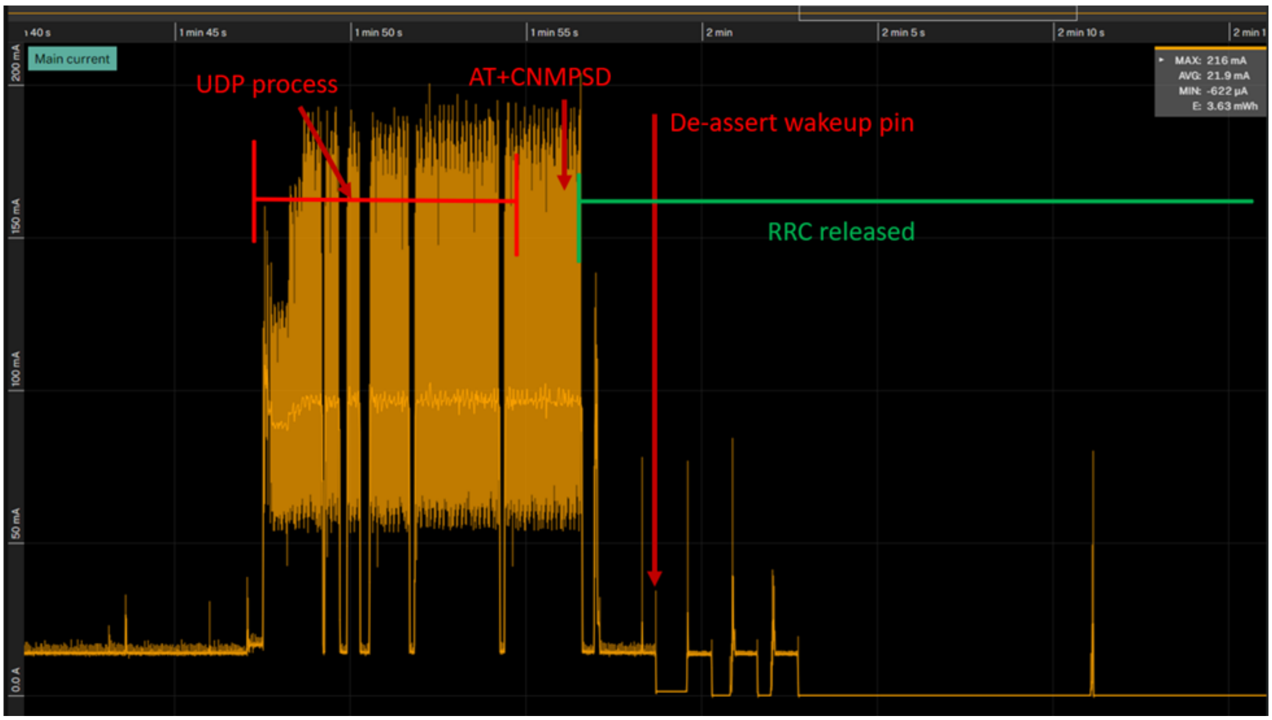


Figure 9: eDRX/Hibernate Mobile-Terminated Use Case Sequence Diagram

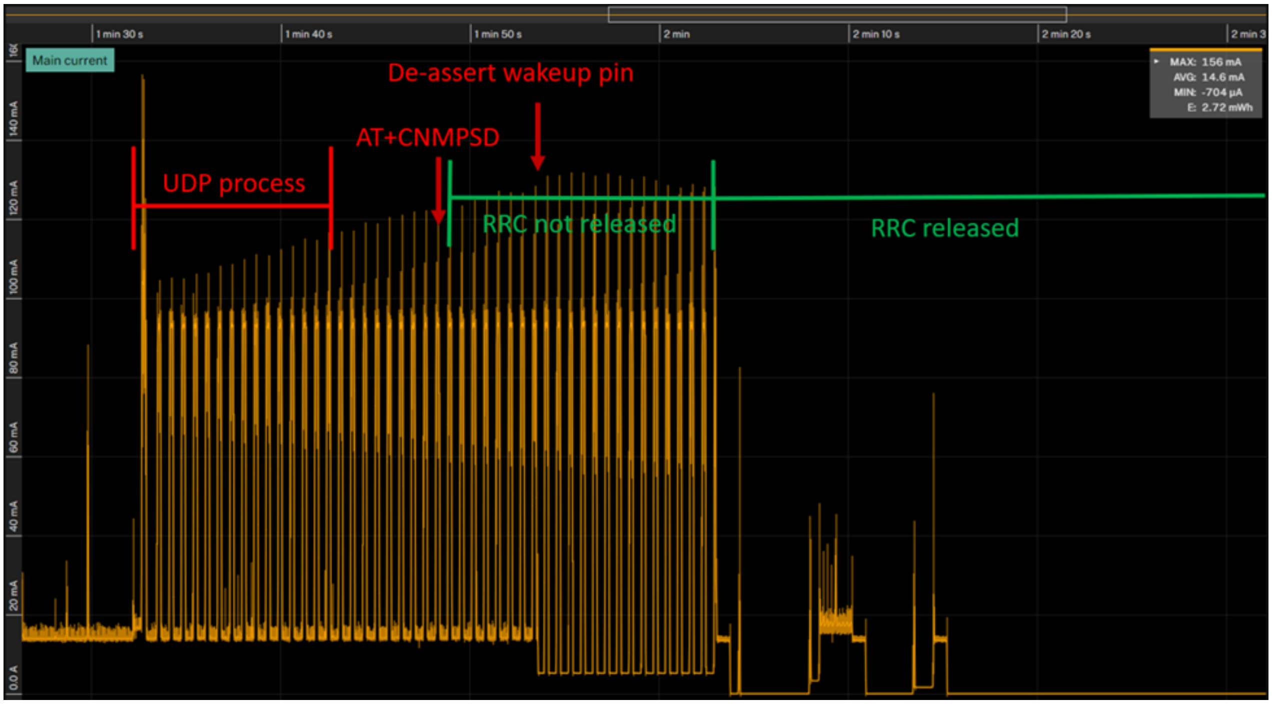
RAI Use Case

RAI Use Case Under eDRX

The following is a RAI enabled test under eDRX. After the host do the UDP upload process, RRC is released immediately after the host executes AT+CNMPSD. Then the module will go to sleep immediately after de-asserting the wakeup pin (module still needs to wait for memory context saving to retain memory or flash memory).



The following is a RAI disabled test under eDRX. After the host do the UDP upload process, RRC is not released immediately because the RRC inactivity timer is not timed out yet and because RAI is not enabled, the AT+CNMPSD will not make RRC released. Therefore, the module is still under CDRX and does not go to sleep until RRC inactivity timer timeout.



RAI Use Case Under PSM

The following is a RAI enabled test under PSM, which is the same as eDRX. Note that after RRC release was triggered by AT+CNMPSD, module still need to wait for the T3324 timer and then the module can go to sleep.

Current Consumption

For typical current consumption measurements, refer to the HL78xx Product Technical Specification.

For current consumption measurements under other conditions, contact your regional Semtech Product Marketing Manager.

AT Commands

Commands in this section are presented in alphabetical order.

+CEDRXRDP (eDRX Read Dynamic Parameters) AT Command

Refer to the HL78xx AT Command Reference Guide for detailed command descriptions.

Syntax

AT+CEDRXRDP

+CEDRXRDP: <AcT-type>[,<Requested_eDRX_value>[,<NW-provided_eDRX_value>

[,<Paging_time_window>]]]

OK

Description

The execute command returns <AcT-Type> and <Requested_eDRX_value>, <NW-provided_eDRX_value> and <Paging_time_window> if eDRX is used for the cell that the module is currently registered to.

Defined Values

Table 5: Parameters

Parameter	Value	Description
<AcT-type>		Access technology type as defined in the **+CEDRXS** command (see Table 7)
<Requested_eDRX_value>		Requested eDRX cycle time as defined in the **+CEDRXS** command (see Table 7)
<Paging_time_window>	See table below	Paging Time Window size

Table 6: <Paging_time_window> Values

<Act-type>=5 – NB-IoT						<Act-type>=4 – LTE-M				
Bit				**Paging Time Window Length**		**Bit**				**Paging Time Window Length**
8	7	6	5			4	3	2	1	
0	0	0	0	2.56 seconds		0	0	0	0	1.28 seconds
0	0	0	1	5.12 seconds		0	0	0	1	2.56 seconds
0	0	1	0	7.68 seconds		0	0	1	0	3.84 seconds
0	0	1	1	10.24 seconds		0	0	1	1	5.12 seconds
0	1	0	0	12.8 seconds		0	1	0	0	6.4 seconds
0	1	0	1	15.36 seconds		0	1	0	1	7.68 seconds
0	1	1	0	17.92 seconds		0	1	1	0	8.96 seconds
0	1	1	1	20.48 seconds		0	1	1	1	10.24 seconds
1	0	0	0	23.04 seconds		1	0	0	0	11.52 seconds
1	0	0	1	25.6 seconds		1	0	0	1	12.8 seconds
1	0	1	0	28.16 seconds		1	0	1	0	14.08 seconds
1	0	1	1	30.72 seconds		1	0	1	1	15.36 seconds
1	1	0	0	33.28 seconds		1	1	0	0	16.64 seconds
1	1	0	1	35.84 seconds		1	1	0	1	17.92 seconds
1	1	1	0	38.4 seconds		1	1	1	0	19.20 seconds
1	1	1	1	40.96 seconds		1	1	1	1	20.48 seconds

Examples

Send the following command to request an eDRX cycle of 81.92 s.

AT+CEDRXS=1,4,5

OK

AT+CEDRXRDP

+CEDRXRDP: 4,5,5,0

OK

In this example, the network accepted the 81.92 s eDRX cycle and provided a PTW of 1.28 seconds.

+CEDRXS (eDRX Setting) AT Command

Refer to the HL78xx AT Command Reference Guide for detailed command descriptions.

Syntax

AT+CEDRXS=[<mode>,[,<AcT-type>[,<Requested_eDRX_value>]]]

Description

The set command controls the setting of the module's eDRX parameters. The command controls whether the module wants to apply eDRX or not, as well as the requested eDRX value for each specified type of access technology.

Defined Values

Table 7: Parameters

Parameter	Value	Description
<mode>	Integer type	Indication to disable or enable the use of eRDX in the module
	0	Disable the use of eDRX (default value)
	1	Enable the use of eDRX
	2	Enable the use of eDRX and enable unsolicited result code: **+CEDRXRDP: <AcT-type>[,<Requested_eDRX_value> [,<NW-provided_eDRX_value>[,<Paging_time_window>]]]**
	3	Disable the use of eDRX and discard all parameters for eDRX or, if available, reset to the manufacturer specific default values
<AcT-type>	Integer type	Access technology type
	4	E-UTRAN (WB-S1 mode) = LTE-M
	5	E-UTRAN (NB-S1 mode) = NB-IoT
<Requested_eDRX_value>	String type "b4b3b2b1"	Requested eDRX cycle time 3GPP specification defines this parameter as a string type using the indicated format. HL78xx extends the parameter definition to allow values to be entered as the integer equivalent. See table below for values.
	Integer type 0-15	

Table 8: <Requested_eDRX_value> Values

Integer	String (bits: "b4b3b2b1")				T_{eDRX}	Description
	b4	**b3**	**b2**	**b1**		
0	0	0	0	0	5.12 seconds	For LTE-M only
1	0	0	0	1	10.24 seconds	For LTE-M only
2	0	0	1	0	20.48 seconds	For LTE-M AND NB-IoT
3	0	0	1	1	40.96 seconds	For LTE-M AND NB-IoT
4	0	1	0	0	61.44 seconds	For LTE-M only
5	0	1	0	1	81.92 seconds	For LTE-M AND NB-IoT
6	0	1	1	0	102.4 seconds	For LTE-M only
7	0	1	1	1	122.88 seconds	For LTE-M only
8	1	0	0	0	143.36 seconds	For LTE-M only
9	1	0	0	1	163.84 seconds	For LTE-M AND NB-IoT
10	1	0	1	0	327.68 seconds	For LTE-M AND NB-IoT
11	1	0	1	1	655.36 seconds	For LTE-M AND NB-IoT
12	1	1	0	0	1310.72 seconds	For LTE-M AND NB-IoT
13	1	1	0	1	2621.44 seconds	For LTE-M AND NB-IoT
14	1	1	1	0	5242.88 seconds	For NB-IoT only
15	1	1	1	1	10485.76 seconds	For NB-IoT only

+CEREG (EPS Network Registration Status) AT Command

Refer to the HL78xx AT Command Reference Guide for detailed command descriptions.

Syntax

AT+CEREG=<n>

OK

AT+CEREG?

+CEREG: <n>,<stat>[,[<tac>],[<ci>],[<AcT>][,[<cause_type>],[<reject_cause>][,[<Active-Time>],

[<Periodic-TAU>]]]]

OK

Description

The execute format of this command enables unsolicited result codes.

Both the query format of this command and the unsolicited result codes return the negotiated values for the PSM Active Timer (T3324) and Periodic TAU PSM cycle timer (Extended T3412).

When <n>=4, the unsolicited result code will provide the module with the Active Timer value and optionally the extended periodic TAU value if there is a change of the network cell in E-UTRAN.

If the Active Timer value is returned, it means the network allows the use of PSM.

Defined Values

Table 9: Parameters

Parameter	Value	Description
<Active-Time>		Negotiated Active Timer as defined in the **+CPSMS** command (see Table 12).
<Periodic-TAU>		Negotiated Periodic TAU cycle timer as defined in the **+CPSMS** command (see Table 11).

+CPSMS (Power Saving Mode Setting) AT Command

Refer to the HL78xx AT Commands Interface Guide for detailed command descriptions.

Syntax

AT+CPSMS=[<mode>[,<Requested_Periodic-RAU>[,<Requested_GPRS-READY-timer>

[,<Requested_Periodic-TAU>[,<Requested_Active-Time>]]]]]

Description

The set command controls the setting of the module's PSM parameters. It controls whether the module wants to apply PSM or not, as well as the requested extended periodic TAU value in E-UTRAN and the requested Active Timer value.

See the unsolicited result codes provided by +CEREG for the Active Timer value and the extended periodic TAU value that are allocated to the module by the network in E-UTRAN.

Defined Values

Table 10: Parameters

Parameter	Value	Description
<mode>	Integer type	Indication to disable or enable the use of PSM in the module
	0	Disable the use of PSM
	1	Enable the use of PSM
<Requested_Periodic-RAU>		Not used
<Requested_GPRS-READY-timer>		Not used
<Requested_Periodic-TAU>		Requested extended periodic TAU (Extended-T3412) value (see Table 11)
<Requested_Active-Time>		Requested Active Timer (T3324) value (see Table 12)

Table 11: <Extended_Periodic-TAU> Values

Bit								Description
8	7	6	5	4	3	2	1	
0	0	0	Timer Value					Value is incremented in multiples of 10 minutes Periodic TAU = Timer Value × 10 minutes
0	0	1						Value is incremented in multiples of 1 hour Periodic TAU = Timer Value × 1 hour
0	1	0						Value is incremented in multiples of 10 hours Periodic TAU = Timer Value × 10 hours
0	1	1						Value is incremented in multiples of 2 seconds Periodic TAU = Timer Value × 2 seconds
1	0	0						Value is incremented in multiples of 30 seconds Periodic TAU = Timer Value × 30 seconds
1	0	1						Value is incremented in multiples of 1 minute Periodic TAU = Timer Value × 1 minute
1	1	0						Value is incremented in multiples of 320 hours Periodic TAU = Timer Value × 320 hours
1	1	1						Value indicates that the timer is deactivated Periodic TAU timer deactivated

Table 12: <Requested_Active-Time> Values

Bit								Description
8	7	6	5	4	3	2	1	
0	0	0	Timer Value					Value is incremented in multiples of 2 seconds Active Timer = Timer Value × 2 seconds
0	0	1						Value is incremented in multiples of 1 minute Active Timer = Timer Value × 1 minute
0	1	0						Value is incremented in multiples of decihours Active Timer = Timer Value × 6 minutes *(decihours)*
1	1	1						Value indicates that the timer is deactivated Active Timer deactivated

+CRSM (Restricted SIM Access) AT Command

Refer to document the HL78xx AT Command Reference Guide for detailed command descriptions.

Syntax

AT+CRSM=176,28589,0,0,4

+CRSM: <sw1>,<sw2>[,<response>]

Description

This command (with the specific indicated parameter values) reads the SIM's EFAD file.

+CNMPSD (No More PS Data) AT Command (for HL7810, HL7812, and HL7845 only)

Refer to the HL78xx AT Command Reference Guide for detailed command descriptions.

Syntax

AT+CNMPSD

OK

Description

This command indicates to the module that there is no more data to transmit or receive and brings the LTE RRC layer to the Idle state immediately, rather than waiting for a network-controlled timeout (typically 10 – 20 seconds).

Reference Documents

	Filename	Reference number
[1]	HL78xx AT Commands Interface Guide	41111821
[2]	HL78xx Product Technical Specification	41113770
[3]	Signal Quality URC on Wakeup Application Note	2174298

Software Compatibility

Firmware
Release 4.6.9.4

Terms and Abbreviations

Term/Initials	Definition
CE Level	The Coverage Enhancement Level is the number (1-4) assigned to the module by the network to indicate signal coverage level at the module's position. Higher numbers indicate a higher UL repetition factor will be used in communications. For details, refer to AT+CRCES in [1]the HL78xx AT Command Reference GuideHL78xx AT Commands Interface Guide
C-DRX / C-eDRX	Connected mode DRX
Connected mode	Modem state when a connection is established with the network for data or signaling exchange.
Domain	See Modem Power Domains
eDRX	See eDRX
E-UTRAN modes	WB-S1 mode — LTE-M (Cat-M1); NB-S1 mode — NB-IoT (NB1)
Flight mode	Modem subsystem is OFF, and SIM is powered. Synonyms: Airplane mode, offline mode, standalone mode
Host application	Device incorporating the HL78xx module
I-eDRX	Extended Idle DRX
Idle mode	Modem state when it has no dedicated channel allocated and it listens periodically to the paging channel according to its DRX or eDRX cycle.
MO	Mobile Originated – Data transfer initiated by the module (i.e. "IP pull")
MT	Mobile Terminated – Data transfer initiated by the network-side server (i.e. "IP push")
MRU	Most Recently Used cell
Power Domain	A set of hardware modules that share the same power source.
PSM	Power Saving Mode
PSM dormant	Modem state when it is registered to the network and not listening to the paging channel.
PTW	Paging Time Window
Receive latency	The length of time required for the module to receive a message sent from the network
RRC	Radio Resource Control protocol
TAU	Tracking Area Update
UE	User Equipment (i.e. the HL78xx module)
URC	Unsolicited Result Code

Document History

Revision number	Release date	Changes
1.0	November 08, 2018	Document creation, preliminary release
2.0	February 28, 2019	General document update
3.0	May 9, 2019	Updated Hibernate Mode section
4.0	July 24, 2019	Added eDRX Maximum limits at 25°C
4.1	Sept 4, 2019	Updated eDRX maximum limits at 25°C
5.0	August 24, 2021	General document update
6.0	July 21, 2023	Added HL7810, HL7812, HL7845 Added information on Stateful vs. Stateless hibernation Added AT Command information for + CNMPSD
7	July 2024	Updated Flash Wearing Protection
8	June 2025	Updated Calibration Procedure

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