T zinc (AgZn), and lithium−ion (Li−Ion). HPM10 also detects zinc−air (Zn−Air) and nickel−metal hydride (Ni−MH) batteries but doesn't charge them.

HPM10 includes a Charger Communication Interface (CCIF) to inform the hearing aid charger about the charging progress. Other battery information such as voltage levels, current levels, temperature, and different types of battery failures can also be communicated.

HPM10 has the flexibility that allows easy integration into various types of hearing aids. It can be used without any connection to the main hearing aid digital signal processing (DSP), and manage the switch on and off operation, as well as the battery EOL control by−itself. Closer integration and communication with the main hearing aid DSP can also be obtained.

KEY FEATURES

Supports Multiple Battery Types: Can charge and manage the power of multiple battery chemistries, including rechargeable Li−ion and AgZn batteries. Ni−MH batteries and disposable Zn−Air batteries can be detected as well. An automatic chemistry detection system recognizes the battery type.

Flexibility to Support Multiple Battery Sizes: The charging parameters should be updated depending on the battery size. Parameters corresponding to one battery size can be stored in an One−Time Programmable (OTP) memory at customer site.

Power Supply: Provides a clean supply to the hearing aid DSP. When a Li−ion battery is used, a step−down capacitive divider or Charge Pump is used, providing a voltage between ~1.4 V and ~0.95 V. When a AgZn battery is used, a linear regulator can be used, providing a 1.5 V max. HPM10 can also directly provide the battery voltage to the hearing aid DSP. Eg., when a Zn−Air battery is used or if the DSP can handle the voltage of a AgZn battery.

Charger Communication Interface: Communicates the status of the charging process and battery voltage to the hearing aid charger and allows user interaction with HPM10.

Information sent in this mode includes:

- Battery voltage level and charge current
- Charge Mode phase
- Battery chemistry type
- Fault conditions

Battery Life Optimization: High−precision current and voltage sources are used to manage the battery charge curves with the precision required to optimize battery life duration.

Battery Supervision: Ensures that the battery doesn’t fall below critical levels. This helps to maximize battery life.

Non−Volatile Memory (OTP): Stores charging parameters, trim codes, and general product specific settings.

Power On and Off Management: Based on a smart method between HPM10 and the hearing aid DSP.

SPECIFICATION

Table 1. ABSOLUTE MAXIMUM RATING

Symbol	Parameter	Min	Max	Unit
VDDP	DC Supply Voltage for charging	−0.5	5.7	V
VDDIO	Digital I/O supply	−0.5	5.5	V
VDD_OTP	OTP Supply	−0.5	6.0	V
DVREG	Regulated supply for HPM10	−0.5	2.0	V
VBAT	DC supply voltage, battery connection	−0.5	5.5	V
VSSA	Analog ground	−0.5		V
VSS	Digital Ground	−0.5		V
VDDIO I/O pins	SCL, SDA, CCIF	−0.5	VDDIO+0.3	V

Table 3. ELECTRICAL SPECIFICATIONS

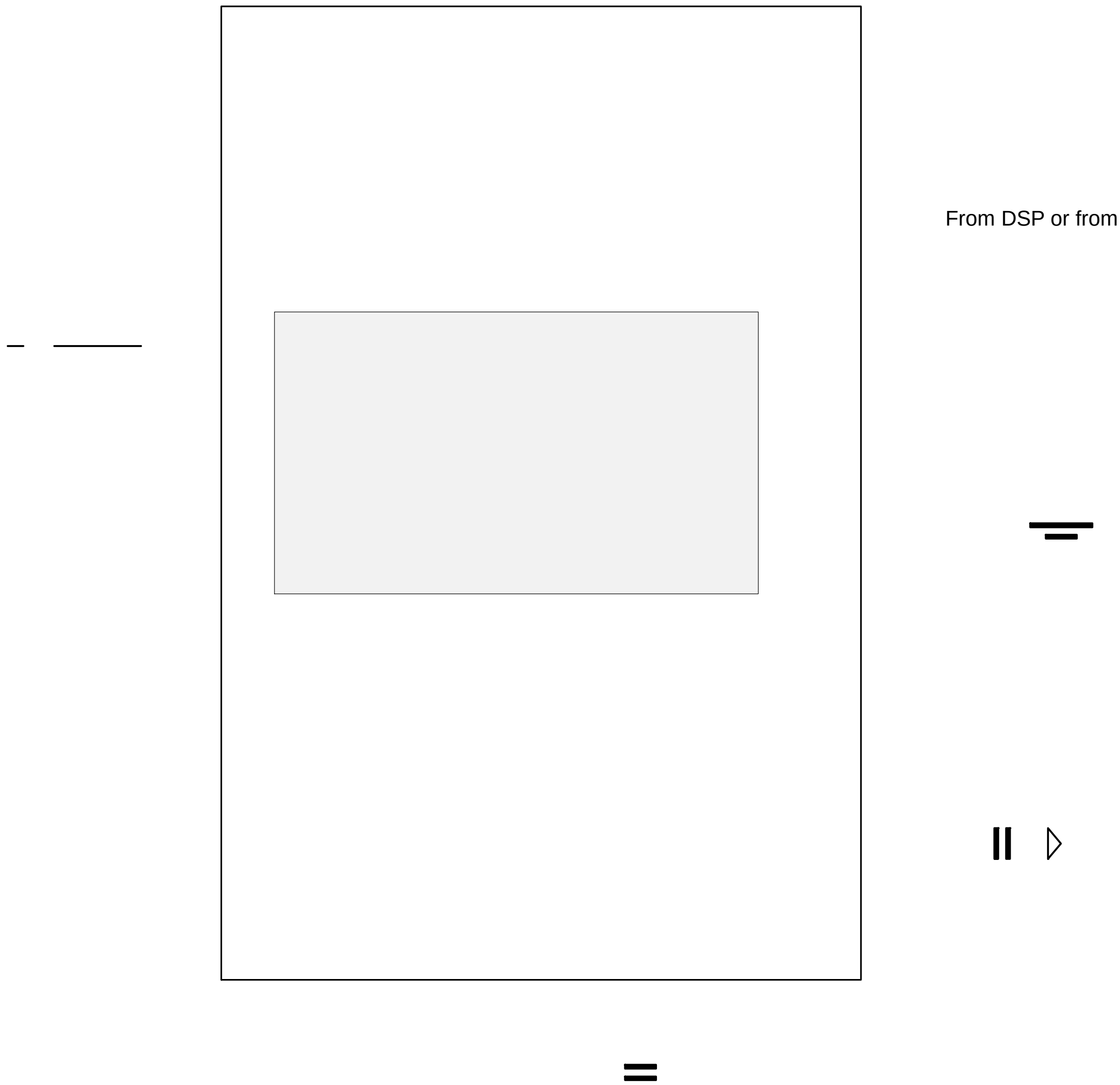
Description	Symbol	Conditions	Min	Typ	Max	Units	Screened
HEARING AID MODE OSCILLATOR							
Clock frequency	HA_Fclk	T = 25°C, Vbat = 1.3 V	66	95	124	kHz	✓
Clock frequency temperature deviation		T = 0°C to 50°C	−10	−1	10	%fclk	
Clock frequency supply deviation		Vbat = 1 V to 4.3 V	−10	0.2	10	%fclk	
CRADLE MODE OSCILLATOR							
Clock frequency	Fclk	T = 25°C	250.88	256	261.12	kHz	✓
Clock frequency temperature deviation		T = 0°C to 50°C	−2	−	2	%fclk	
Clock frequency supply deviation		VDDP = 5.0 to 5.2 V	−1	−	1	%fclk	
DVREG Linear Regulator for the Digital Blocks							
Linear Regulator	DVREG		1.71	1.8	1.89	V	✓
Regulator PSRR	$DVREG_{PSRR}$	I_{LOAD}=200 μA		30		dB	✓
Load Current	I_{LOAD}				200	μA	✓
Load Regulation	$LOAD_{REG}$						

Table 3. ELECTRICAL SPECIFICATIONS

Description	Max	Units	Screened

HPM10 INTERNAL ARCHITECTURE

The architecture of the HPM10 chip is shown in Figure 1.



EXTERNAL COMPONENTS

HPM10 requires six external components listed in Table 4. Depending which type of rechargeable battery is used, some of the decoupling caps are not needed.

Table 5. EXTERNAL COMPONENTS

Component	Function

HPM10 USAGE IN A HEARING AID

HPM10 has the built−in flexibility to allow integration within various sorts of hearing instruments. The battery door can be sealed or unsealed. The hearing aid may have a pushbutton or may not. HPM10 can be integrated with the hearing aid DSP though dedicated communication lines, or it can work independently from the hearing aid DSP. The following list gives a few possible scenarios of integration:

Hearing Aid with a Push Button and Sealed Battery Door:

Cradle Charging

- When the hearing aid is inserted to the cradle, it will charge. While charging, the hearing aid will turn off.
- When the hearing aid is taken out from the cradle, it will go into Deep Sleep Mode (HPM10 in Deep Sleep Mode).

Power On/Off

- To turn on the hearing aid, use the pushbutton.
  - Logic high at SWIN signal is detected and turns on HPM10
  - HPM10 supplies the main DSP with VHA
- To turn off the hearing aid, use the pushbutton.
  -

Cradle Charging

- When the hearing aid is inserted to the cradle, it will charge. While charging, the hearing aid will turn off.
- When the hearing aid is taken out from the cradle, it will turn on.

Power On/Off

- When the battery is removed, the hearing aid will shut down
- When the battery is inserted, the hearing aid will turn on

Battery

- When the battery goes EOL, the hearing aid will automatically turn off (HPM10 in Deep Sleep Mode) through two possible mechanisms:
  - HPM10 goes into Deep Sleep Mode to protect the battery from over discharge
  - DSP detects low battery voltage and puts HPM10 in Deep Sleep Mode through the DS_EN pin

In all modes, when the device is removed from the cradle, it will either immediately turn on or wait until the pushbutton is pushed. This means that for the first and second use cases (Hearing Aid with a Pushbutton and Sealed Battery Door and Hearing Aid with a Pushbutton and Unsealed Battery Door), the hearing aid manufacturer will be able to configure HPM10 to directly switch on or wait for the pushbutton.

In case the hearing aid doesn't have a pushbutton, once the battery is fully charged and the hearing aid remains on the cradle, HPM10 includes a system that compensates

HPM10 WORKING MODES

HPM10 has three working modes represented in the state machine below.

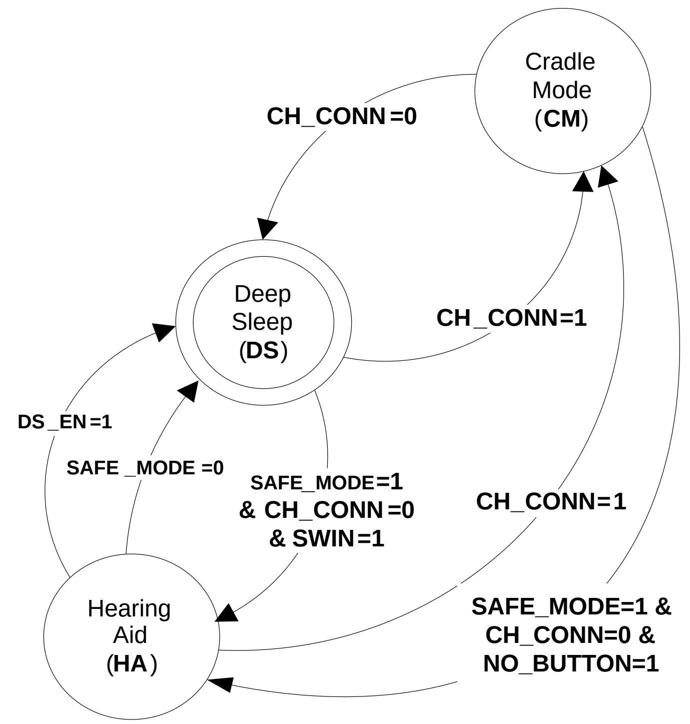


Figure 3. HPM10 State Machine

Deep Sleep Mode: A low power mode with all blocks turned off. HPM10 can enter Deep Sleep Mode in one of three ways:

- From Hearing Aid Mode when the host DSP toggles the DS_EN pin high. An example use−case for this transition is when a program is running on the host DSP, that determines that the hearing aid is not being worn or the measured battery voltage is below a specified value and puts the system into Deep Sleep Mode to save power.
- From Hearing Aid Mode when the battery voltage drops below the EOL set point (**VEOL** level), for the battery chemistry actively being used to avoid irreversible battery damage. This is when VBAT<1.0 V (for AgZN) or 2.2 V<VBAT<3.0 V (for Lithium−Ion). This will draw the *SAFE_MODE* status bit to 0.
- From Cradle Mode when the hearing aid charger is removed, in case the OTP bit “no_button” is not set.

Cradle Mode: The hearing aid will enter in Cradle Mode when the hearing Aid is physically connected to Cradle (*CH_CONN*=1). In this mode, the hearing aid battery is being charged.

Once in this state, the following sequence of processes will occur:

- The OTP is enabled and its contents are copied to internal latches.
- After the OTP contents have been read, a Cyclic Redundancy Check (CRC) is made by the controller. If it fails, the system transitions to completion phase in Cradle Mode and an error flag is set.
- If the CRC passes, the controller starts the charging process.

The charging process is controlled by a controller and firmware in ROM.

Hearing Aid Mode: The hearing aid DSP power is supplied by HPM10 and there is no digital logic running on HPM10. In this mode, the hearing aid is in normal operation mode and receives its supply voltage from HPM10. HPM10 can enter Hearing Aid Mode in two ways:

- From Deep Sleep after SWIN goes high from a button press. The battery voltage must be in a valid range.
- From Cradle Mode after removed from Cradle with OTP bit NO_BUTTON=1. The battery voltage must be in a valid range.HPM10 is either clocked with the Hearing Aid Mode Oscillator, or with the divided EXT_CLK.

The recommended tasks for the host DSP in Hearing Aid Mode are as follows:

- Set the external clock division ratio (if desired) by driving the 3 CLKDIV pins (*)
- Apply a valid clock to EXT_CLK pin

- Periodically monitor pin VHA using its on−board ADC
- Monitor SWOUT to determine button press events
- Monitor the WARN to determine if the hearing aid has been placed in cradle, in which case the DSP should shut itself down gracefully before HPM10 cuts the power to VHA.
- Toggle pin DS_EN to logical high (VHA level), if it needs to put HPM10 into Deep Sleep Mode

(*): CLKDIV can be configured by the DSP (through GPIO for example) or through physical connection.

In Hearing Aid Mode, voltage monitoring is used to prevent turn−on if battery voltage is not acceptable, and to control the output mode of the VHA supply.

The voltage levels and modes are as follows:

- 1.0 V to 1.5 V The battery type could be AgZn, Zn−Air, or NiMH. A low impedance switch connects VBAT to VHA to power the DSP.
- 1.5 to 2.2 V The battery type is likely AgZn. If pin AGZN_REG_EN=floating, then the VHA voltage is powered by a 1.5 V regulator. This is to protect those DSPs that are not able to handle the unregulated AgZn voltage. For those DSP that can handle maximum AgZn battery voltages, the pin AGZN_REG_EN=0V will enable the low impedance switch between VBAT and VHA.
- 3.0 V and above. The battery type is Li_Ion. VHA is powered by a divide by 3 step down converter.

VBAT voltages outside of these ranges will not enable the VHA, and the DSP will not be powered. Note that each of these thresholds have hysteresis to ensure stable operation.

The following figure indicates how HPM10 monitors voltage in Hearing Aid Mode.

Interfaces to Host DSP

In Hearing Aid Mode, the SWOUT pin provides a level shifted version of the SWIN pin. The SWOUT pin would typically be connected to the host DSP’s GPIO pin so that the button on the hearing aid connected to SWIN can also be load on the VDDP wired supply. This current modulation is superimposed on the existing current that is used to charge the battery. State transitions will cause short current transient steps that need to be ignored by the Primary Charger data detector. To support the HPM10 usage in a wireless recharging device, an alternate interface has been provided. It is composed of pad “CCIF” that is a digital output duplicating the raw UART signal (i.e. not the differential encoded data).

The CCIF pin can be configured in the OTP to provide a static signal that can be used by the system to provide information on the battery charge as follow:

CCIF Pin State	Corresponding Information
HI	Charge Complete
LO	Fault
HI−Z	Neither

In OTP Burn mode (ATST_EN=HIGH), the CCIF pin is used as an external reset input active LOW. This reset is necessary during the OTP READ procedure and it is to ensure that digital is in a known good state and the OTP contents have been loaded before doing the read. The CCIF pin, when in input mode, does not have a pull−up or pull−down resistor so it should not be left floating.

Primary Charger to HPM10 (Receive): The Primary Charger can use voltage modulation of VDDP to transmit data to the HPM10. HPM10 uses edge detection and AC coupling to extract the data easily without a precise amplitude requirement. This helps relax the requirements on the drive signal and the loading of the VDDP line by the Charge Control block. For robust pulse detection, the rise/fall time of the 200 mV modulation should be less than 100 μs.

Battery Monitoring

HPM10 employs two methods of battery monitoring:

1. In Cradle Mode, the high−precision 10 bit ADC continuously measures voltage and current to the battery.
2. In Hearing Aid Mode, the system uses instantaneous voltage to analog comparators to perform simple detection of battery chemistry. Refer to the Hearing Aid Mode section on page 19 for more information.

Figure 5 illustrates how the battery monitoring is done in a hearing aid system using HPM10.

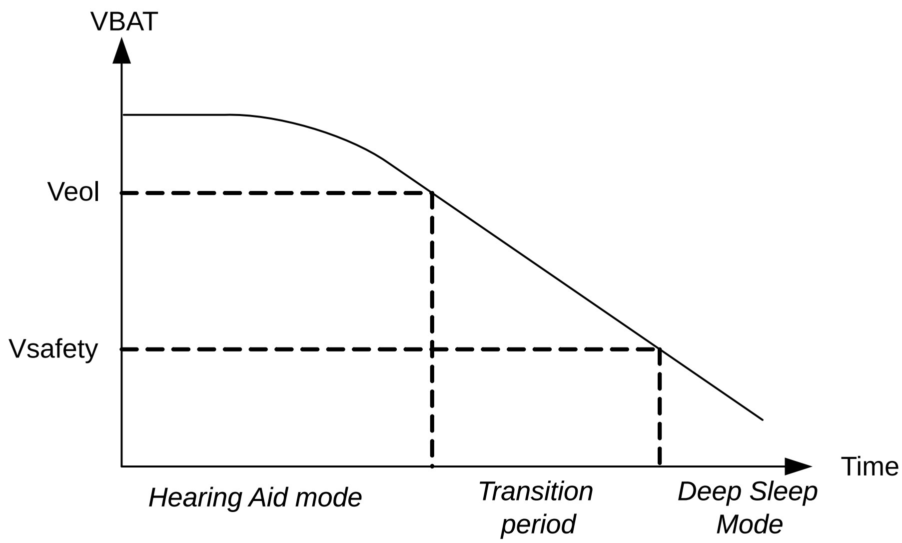


Figure 5. Battery Monitoring for Battery End of Life (EOL)

The hearing aid DSP will have to determine its Veol threshold, and detect when the VBAT reaches this level. From this point, the hearing aid DSP will have to manage its battery EOL procedure (playing a beep users hear, managing datalogging, etc.) before its toggles the DS_EN pin.

If the DS_EN pin hasn’t been toggled by the hearing aid DSP and if the hearing aid DSP keeps on drawing power from the battery, HPM10 will preserve the rechargeable battery from over−discharging by forcing Deep Sleep Mode when VBAT reaches Vsafety. In this mode, the VHA supply is stopped (*SAFE_MODE* status bit = 0). Vsafety is 2.8 V for Li−Ion and 1.0 V for AgZn.

Battery Charging Control

While in Cradle Mode, HPM10 controls the charging of the attached battery. The charging cycle is different for each battery type, with the charging phase transition points for each chemistry (voltage, current temperature and time) stored in OTP and available to the micro−controller in Cradle mode.

The chemistries that are supported by HPM10 are Silver−Zinc (AgZn) and Lithium−Ion (Li−ion). While Zinc−Air (ZnAir) and Nickel−Metal Hydride (Ni−MH) batteries are detected, they are not charged.

As shown in Figure 6, a charger state machine operates in five phases to manage the charging process:

- Start−up (**SU**):
  - Battery type detection
  - OTP boot and CRC checking
- Initialization (**INIT**):
  - Li−ion pre−charge (trickle)
  - Li−ion advanced charging algorithms
  - Over−discharge recovery for AgZn.
- Phase 1 (**PH1**):
  - Li−Ion: Maintain a constant current and monitor the voltage.
  - AgZn: Lower plateau (Ag_2O) and transition zone

Table 8. HPM10 Pin Arrangement

	1	2	3	4	5
A	SDA	RESERVED	VDDIO	CCIF	VDDP
B	SCL	RESERVED	DS_EN	VSS	DVREG
C		VDD_OTP	CLKDIV[2]	ATST_EN	WARN
D	EXT_CLK	SWOUT	CLKDIV[1]	RESERVED	AGZN_REG_EN
E	VSSA	CLKDIV[0]	CP2B	SWIN	CP1B
F	VHA	VSSCP	CP2A	VBAT	CP1A

Table 9. MISC DIE SPECIFICATION

Subject	Specification
Bump metallization	Lead Free (Sn/Ag/Cu)
Backside coating specification	Adwill LC2850
Backside coating thickness	40 µm ± 3 µm

LQFP 32 Pin List

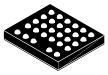
The HPM10 version used on development boards is packaged in a LQFP package of 32 pins. The following table shows the allocation of the IOs:

Table 10. LQFP PIN LIST

Pin #	Pin Name	I/O	Pin #	Pin Name	I/O
1	SDA	I/O	17	CP1A	O
2	RESERVED	I	18	CP1B	O
3	CCIF	I/O	19	VBAT	

[redacted]

[redacted]



SCALE 4:1

WLCSP29 2.05x1.74x0.417

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PACKAGE
OUT

29X