AXPM44056

1A Li-ion Battery Linear Charger with Comms Mux

Preliminary Datasheet — Sep 2021

Description

The AXPM44056 is a cost-effective, fully integrated single-cell Li-Ion battery charger with integration of Communication Mux using the Vin pin. The charger uses a CC/CV charge profile required by Li-Ion battery. The charge current and the end-of-charge (EOC) current are programmable with external resistor. When the battery voltage is lower than typically 2.55V, the charger preconditions the battery with typically 18% of the programmed charge current. When the charge current reduces to the programmable EOC current level during the CV charge phase, an EOC indication is provided by the LED pin, which is an open-drain output. An internal thermal foldback function protects the charger from any thermal failure. One indication pin allows simple interface to a microprocessor or LED. When no adapter is attached or when disabled, the charger draws less than 1μA leakage current from the battery.

Features

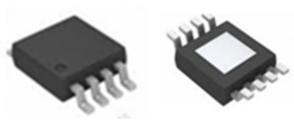
- Communication Mux at Vin for communication between Earpiece SOC and Cradle HOST MCU
- Complete Charger for Single-Cell Li-Ion or Polymer Batteries
- 4.5V ~ 7V Operating input range
- Charge Current Thermal Foldback for Thermal Protection
- 2.55V Trickle Charge Threshold
- Less than 1μA Leakage Current off the Battery When No Input Power Attached
- Programmable Charge Current with external resistor
- Internally set current limit without a current sensing resistor. Internally set at 1/10X I_{CHG}

Applications

- Battery powered systems
- TWS earpiece

Table 1 Device Summary

Order code	Package	Packing
AXPM44056	SOIC8E	Tube



SOIC8E

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Figure 1 Block Diagram

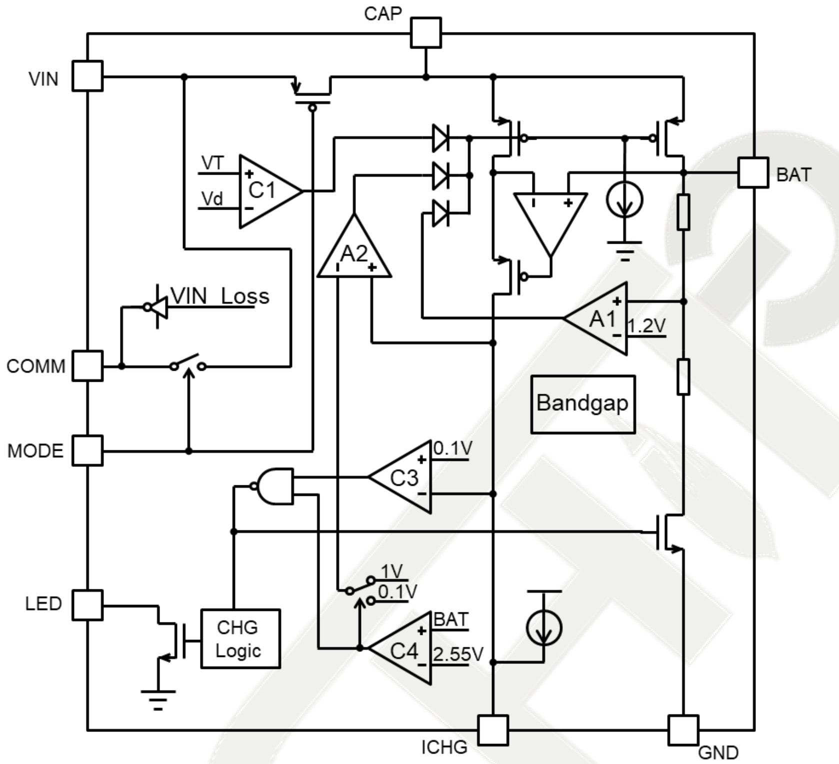
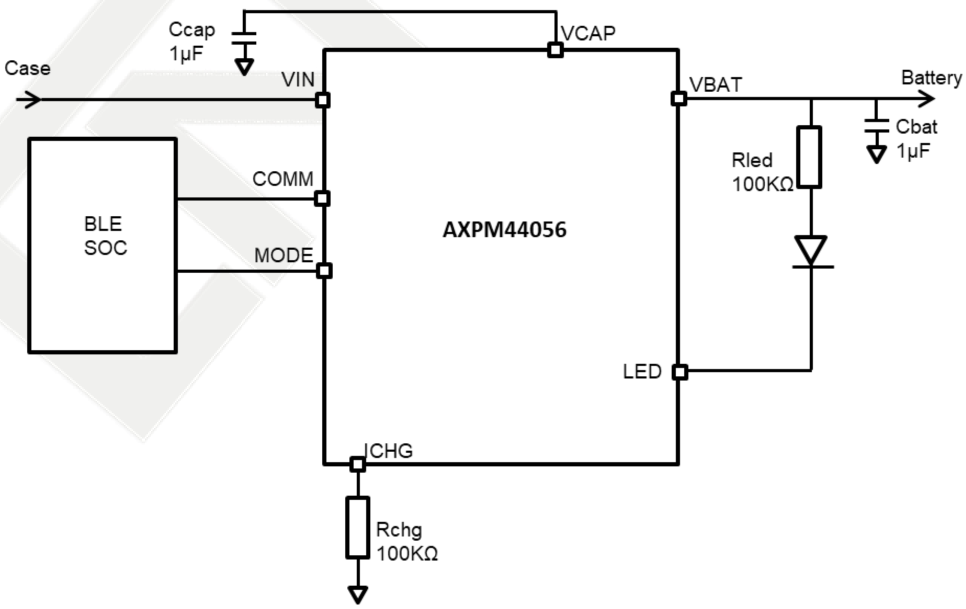


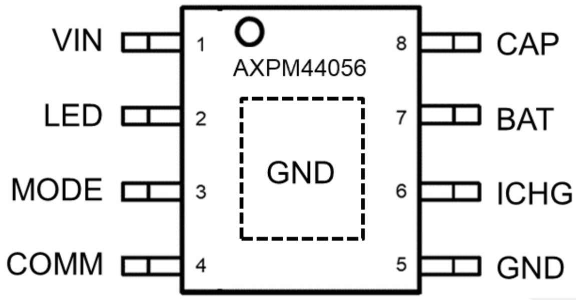
Figure 2 Application Circuit (typical)



2 Pin Description

2.1 Pin Names

Figure 3 Pin Connection



2.2 Pin Functions

Table 2 Pin Functions

Pin number	Pin name	Description
1	VIN	Power Input. No decoupling capacitor is recommended as it will impede the communication when used in Communication Mode
2	LED	Open-drain Charge Indication. This pin outputs a logic such that LED is off when not charging, flashing when charging and ON when full charged This pin is capable to sink 15mA (MIN) current to drive an LED.
3	MODE	Control pin for Charge and Comms mode. A logic 1 input will set it into Comms Mode and 0 logic will set it as Charge mode
4	COMM	Communication input pin from SOC for mux into VIN during Comms mode. This enables the system SOC to communicate with the Host charger through the VIN pin.
5	GND	Ground pin
6	ICHG	Charge-Current Programming Pin. Connect a resistor between this pin and the GND pin to set the charge current limit determined by the following equation: $I_{CHG} \geq 100mA$, $I_{CHG} = \left(\frac{10000}{RCHG}\right)$ A Termination current I_{EOC} = 1/10x of I_{CHG} The ICHG pin voltage also monitors the actual charge current during the entire charge cycle, including the trickle, constant-current, and constant-voltage phases.
7	BAT	Charger Output Pin. Connect this pin to the battery. A 1μF or larger X5R ceramic capacitor is recommended for decoupling and stability purposes.
8	CAP	Decoupling pin for VIN. A 1μF or larger value X5R ceramic capacitor is recommended for decoupling purpose. CAP pin is connected to VIN when in Charge Mode and isolated from VIN when in Comms Mode.

3. Electrical Specifications

3.1 Absolute Maximum Ratings

Table 3 Absolute Maximum Ratings

Symbol	Parameter	Value	Unit
VIN, CAP, BAT	Supply voltage	-0.3 to +7	V
MODE, COMM, ICHG, LED	Voltage	-0.3 to 7	V
Tj	Junction temperature	150	°C
Tstg	Storage temperature	-55 to +150	°C

3.2 Thermal Data

Table 4 Thermal Data

Symbol	Parameter	Value	Unit
Rth j-ambient	Thermal resistance junction-to-ambient Max.	58	°C/W

3.3 Electrical Characteristics

VIN = 5V Tamb = +25°C; unless otherwise specified.

Table 5 Electrical Characteristics

Symbol	Parameter	Test conditions	Min	Typ	Max	Unit
V_{opmax}	Maximum Supply Voltage				7	V
V_{OP}	Operating Supply Voltage		4.55		6.10	
I_{CHG}	Programmed Charge Current		100		1000	mA
V_{POR}	Rising POR Threshold	V_{BAT} = 3.0V, R_{ICHG} = 120kΩ,		3.55		V
V_{POR}	Falling POR Threshold			3.33		V
	VIN-BAT Offset Voltage Rising Edge	V_{BAT} = 4.5V, R_{ICHG} = 120kΩ		110	200	mV
	VIN-BAT Offset Voltage Falling Edge		5	60		mV
V_{OVP}	Over-Voltage Protection Threshold	V_{BAT} = 4.3V, R_{ICHG} = 120kΩ,		6.17		V
$V_{OVPHYTS}$	OVP Threshold Hysteresis			400		mV
I_{STABY}	BAT Pin Sink Current	V_{IN} input is floating			1	μA
I_{VIN}	VIN Pin Supply Current	V_{BAT} = 4.3V, R_{ICHG} = 24.3kΩ		200	320	μA
V_{CH}	Output Voltage	R_{ICHG} = 24.3kΩ, 4.55V < V_{IN} < 6.10V, charge current = 20mA	4.152	4.2	4.248	V
Rdson	PMOS On Resistance	V_{BAT} = 3.8V, charge current = 500mA, R_{ICHG} = 10kΩ		0.7		Ω
V_{ICHG}	ICHG Pin Output Voltage	V_{BAT} = 3.8V, R_{ICHG} = 120kΩ		1.00		V
I_{CHG}	Constant Charge Current	R_{ICHG} = 20.0kΩ, V_{BAT} = 2.8V to 3.8V	440	500	560	mA
I_{TRK}	Trickle Charge Current	R_{ICHG} = 20.0kΩ, V_{BAT} = 2.4V	55	90	135	mA
I_{MIN}	End-of-Charge Current	R_{ICHG} = 20.0kΩ	44	50	56	mA
	EOC Rising Threshold	R_{ICHG} = 20.0kΩ	315	370	435	mA
V_{MIN}	Preconditioning Charge Threshold Voltage	R_{ICHG} = 20.0kΩ	2.46	2.55	2.65	V
V_{MINHYS}	Preconditioning Voltage Hysteresis	R_{ICHG} = 20.0kΩ	20	100	190	mV

T_{FOLD}	Charge Current Foldback Threshold			115	℃	℃
I_{LED}	LED Sink Current when LOW	V_{LED} = 1.0V	15	24		mA
F_{LED}	LED Pulse frequency when charging			1		Hz
I_{LED}	LED Leakage Current when High Impedance	V_{LED} = 5.5V			4.5	µA

4 Functional Description

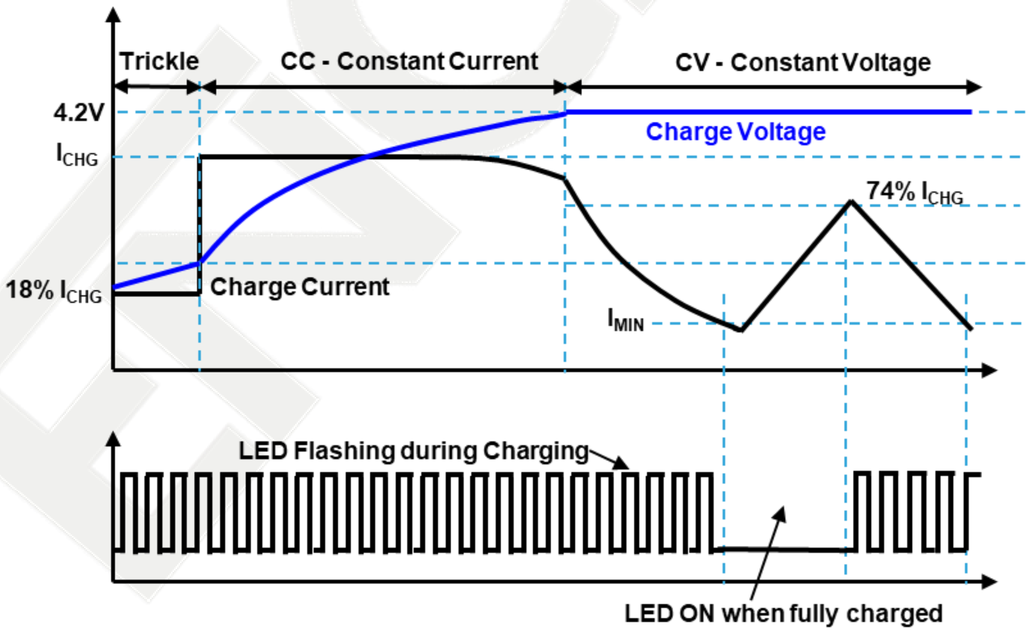
4.1 Overview

The AXPM44056 charges a Li-Ion battery using a CC/CV profile. The constant current I_{CHG} is set with the external resistor R_{CHG} (see Figure 2) and the constant voltage is fixed at 4.2V. If the battery voltage is below a typical 2.55V trickle charge threshold, the AXPM44056 charges the battery with a trickle current of 18% of I_{CHG} until the battery voltage rises above the trickle charge threshold. Fast charge CC mode is maintained at the rate determined by programming I_{CHG} until the cell voltage rises to 4.2V. When the battery voltage reaches 4.2V, the charger enters a CV mode and regulates the battery voltage at 4.2V to fully charge the battery without the risk of over charge. Upon reaching an end-of-charge (EOC) current, the charger indicates the charge completion with the LED pin, but the charger continues to output the 4.2V voltage. Figure 4 shows the typical charge waveforms after the power is on.

The EOC current level I_{MIN} is set as 1/10X of I_{CHG}. The LED indicates the charging status of the device. This pin outputs a logic such that LED is off when not charging(VIN < V_{POR}), flashing when charging and ON when full charged. This pin is capable to sink 15mA current to drive an LED. After the EOC is reached, the charge current has to rise to typically 74% I_{CHG} for the LED pin to indicate pulse charging again, as shown in Figure 4. The current surge after EOC can be caused by a load connected to the battery.

A thermal foldback function reduces the charge current anytime when the die temperature reaches typically 115℃. This function guarantees safe operation when the printed circuit board (PCB) is not capable of dissipating the heat generated by the linear charger. The AXPM44056 accepts an input voltage up to 7V but disables charging when the input voltage exceeds the OVP threshold, typically 6.17V, to protect against unqualified or faulty AC adapters.

Figure 4 Typical Charge Profile



4.2 Power Good Range

The power good range is defined by the following three conditions:

1. $V_{IN} > V_{POR}$
2. $V_{IN} - V_{BAT} > V_{OS}$
3. $V_{IN} < V_{OVP}$

where the V_{OS} is the offset voltage for the input and output voltage comparator, discussed shortly, and the V_{OVP} is the over-voltage protection threshold given in the Electrical Characteristics table. All V_{POR}, V_{OS}, and V_{OVP} have hysteresis, as given in the Electrical Characteristics table. The charger will not charge the battery if the input voltage is not in the power good range.

4.3 Input and Output Comparator

The charger will not be enabled unless the input voltage is higher than the battery voltage by an offset voltage V_{OS}. The purpose of this comparator is to ensure that the charger is turned off when the input power is removed from the charger. Without this comparator, it is possible that the charger will fail to power down when the input is removed, and the current can leak through the PFET pass element to continue biasing the POR and the Pre-Regulator blocks.

4.4 Dropout Voltage

The constant current may not be maintained due to the $R_{DS(ON)}$ limit at a low input voltage. The worst case $R_{DS(ON)}$ is at the maximum allowable operating temperature.

4.5 Indication LED

The is an open-drain output capable of sinking at least 15mA current in pulse mode when the charger starts to charge and turns fully ON when the EOC current is reached. The signal is interfaced either with a microprocessor GPIO or an LED for indication.

4.6 ICHG Pin

The ICHG pin has the two functions as described in the Pin Description section. When setting the fast charge current, the charge current is guaranteed to have 12% accuracy with the charge current set at 500mA. When monitoring the charge current, the accuracy of the ICHG pin voltage vs. the actual charge current has the same accuracy as the gain from the ICHG pin current to the actual charge current.

4.7 Operation without the Battery

The AXPM44056 relies on a battery for stability and works under LDO mode if the battery is not connected. With a battery, the charger will be stable with an output ceramic decoupling capacitor in the range of 1μF to 200μF. In LDO mode, its stability depends on load current, C_{OUT}, etc. The maximum load current is limited by the dropout voltage, the programmed I_{CHG} and the thermal foldback.

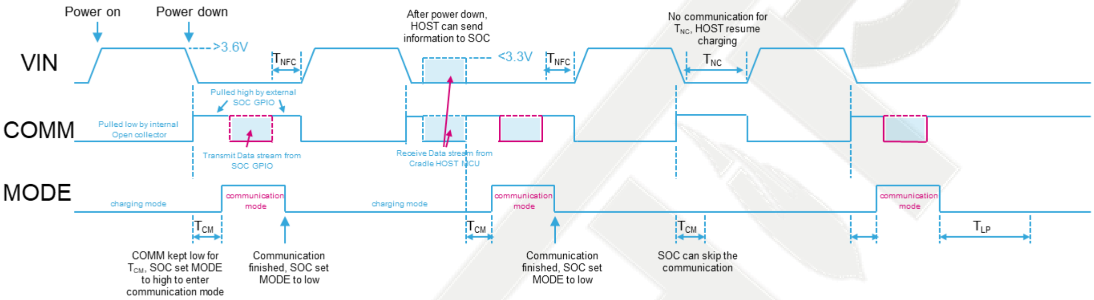
4.8 Thermal Foldback

The thermal foldback function starts to reduce the charge current when the internal temperature reaches a typical value of +115℃.

4.9 Communication Mode

AXPM44056 has a function that enables a Communication Mode between the Cradle HOST and Earpiece through the VIN pin. This enables communication without incurring extra connections between earpiece and charging cradle. The Communication Mode is first initiated by the Cradle HOST asserting VIN pin < 3.3V. When VIN>3.6V, VIN input switch turns on, this sets the device in the normal Charging Mode. When VIN<3.3V, VIN input switch turns off, isolating the VIN pin from the BAT and also the decoupling capacitor at CAP. The device enters into communication mode. COMM pin which is usually pulled low is released and will be pulled up high by the SOC GPIO. This signals to the SOC that VIN is low and Cradle HOST has initiated a communication mode.

Figure 5 Communication Mode Profile



A typical communication session as in Figure 5 will proceed as follows:

1. Transmit : Earpiece SOC data transmit to cradle HOST MCU
   - HOST pull down VIN, MCU switches communication port to input mode, ready to accept UART signals through VIN from the earpiece SOC.
   - When SOC detects COMM at High level for more than TCM, SOC recognizes the HOST has initiated Communication Mode and it can response by setting MODE pin to High to start the communication mode.
   - Once MODE is set to high, the SOC GPIO can start streaming UART input signals to be transmitted to the Cradle MCU. The UART protocol can be a pre-determined protocol between earpiece SOC and Cradle HOST MCU.
   - On completion of transmission, SOC set MODE to Low to go back to charging mode
   - HOST wait for new data, if no new data received for more than T_{NFC}, HOST would exit communication mode, switch on power again to charge earpiece

2. Receive: Earpiece SOC receive data from Cradle HOST MCU
   - HOST pull down VIN and start to send data to SOC before T_{CM} times out. UART data is received direct to the COMM pin and input into SOC.
   - HOST wait for new data, if no new data received for more than TNFC, HOST would exit communication mode, switch on power again to charge earpiece.

3. Its possible to have consecutive Transmit and Receive cycles as shown in Figure 5.

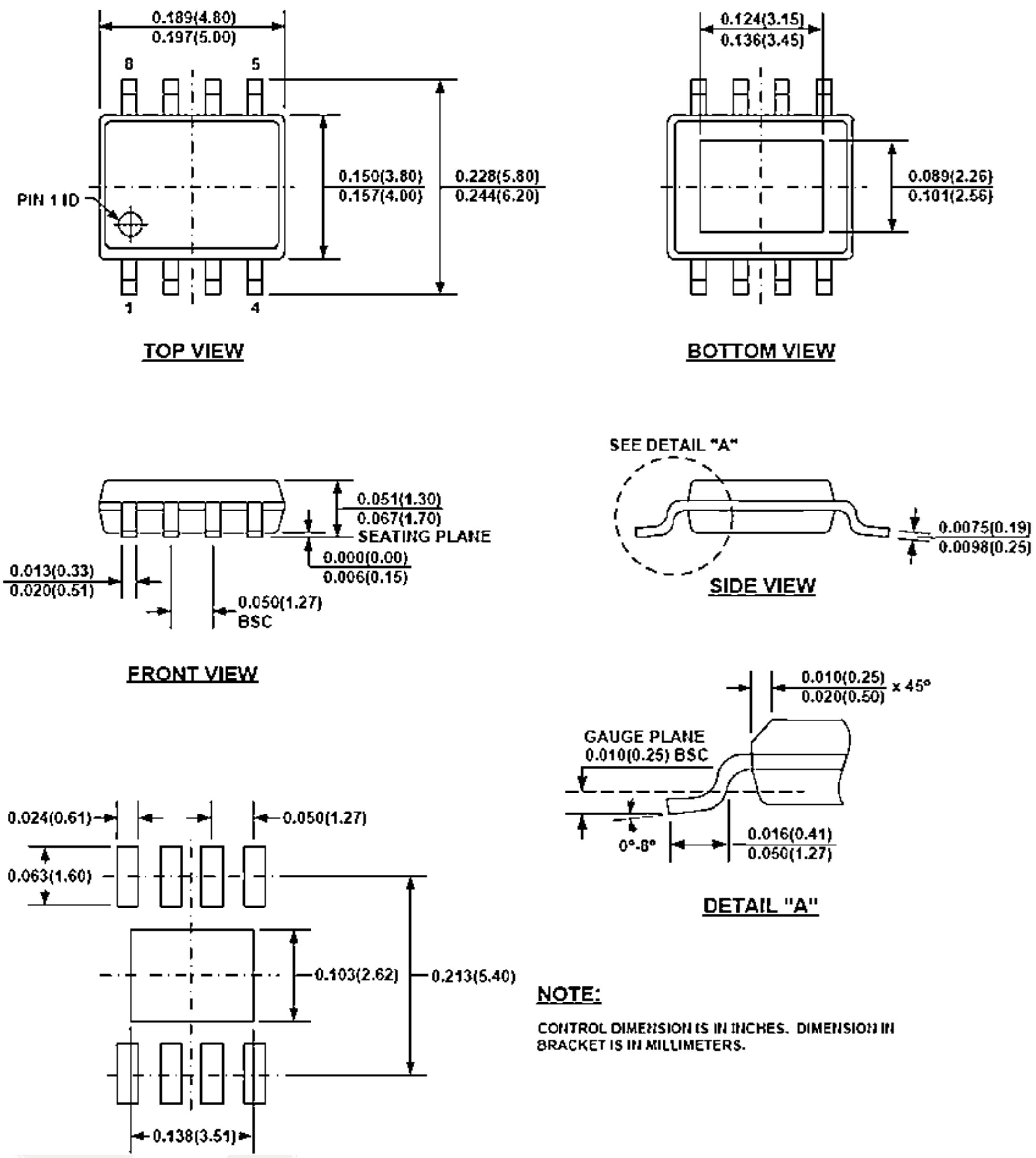
4. If HOST wait more than TNC without receiving/transmitting any data, it will go back to charge mode

5. When SOC exit communication MODE=Low, if power does not resume after T_{LP}, it means that power loss or earpiece was taken out of the case (charger go into low power mode)

6. T_{CM}, T_{NFC}, T_{NC} and T_{LP} are pre-determined protocol timings by SOC and MCU. AXPM44056 does not impose any restrictions.

5 Package Information

Figure 4 SOIC8E Mechanical Data and Package Dimensions



6 Revision History

Table 6 Document Revision History

Date	Version	Description
Sep 2021	Draft	Preliminary Version