SGM40565
High Input Voltage Charger for Loosely Coupled Charging

GENERAL DESCRIPTION

The SGM40565 is a fully integrated high input voltage single-cell Li-Ion battery charger. The charger deploys the CC/CV charging profile optimized for Li-Ion battery. It charges at wide input voltage range (up to 26.5V), and adjusts charging current adaptively based on the die junction temperature.

The charge current and the full-of-charge (FOC) current are programmable with external resistors. It safely precharges an over-discharged battery or a new battery with reduced charging current. The device also has LDO mode in which SGM40565 powers load with no battery installed, or maintains loading when battery is fully charged.

4.05V, 4.2V and 4.35V charging voltage options are available.

Its open-drain indication output(s) ($\overline{\text{PPR}}$ and $\overline{\text{CHG}}$ for TDFN-2×2-8L package, and $\overline{\text{CHG}}$ only for WLCSP-1.3×0.7-6B package) together with an $\overline{\text{EN}}$ input provide simple interface for various applications. When no adapter is attached or when it is disabled, the charger only draws less than 1μA leakage current from the battery.

The SGM40565 is available in Green WLCSP-1.3×0.7-6B and TDFN-2×2-8L packages and is rated over the -40℃ to +85℃ temperature range.

FEATURES

- **Integrated Pass Element and Current Sensor**
- **No External Blocking Diode Required**
- **Low Component Count and Cost**
- **Programmable Charge Current**
- **Programmable Full-of-Charge Current**
- **Charge Current Thermal Fold-Back for Thermal Protection**
- **2.48V/2.55V/2.65V Trickle Charge Threshold**
- **26.5V Maximum Voltage for the Power Input**
- **Power Presence and Charge Indications**
- **Less than 1μA Leakage Current off the Battery When No Input Power Attached or Charger Disabled**
- **Available in Green WLCSP-1.3×0.7-6B and TDFN-2×2-8L Packages**

APPLICATIONS

Activation Keys
Battery Powered Appliances
IOT Gadgets
Battery Powered Instruments
Toothbrush Shaver Thermometer

PACKAGE/ORDERING INFORMATION

MODEL	V_{CH} (V)	PACKAGE DESCRIPTION	SPECIFIED TEMPERATURE RANGE	ORDERING NUMBER	PACKAGE MARKING	PACKING OPTION
SGM40565	4.05	TDFN-2×2-8L	-40℃ to +85℃	SGM40565YTDE8G/TR	SXA XXXX	Tape and Reel, 3000
		WLCSP-1.3×0.7-6B	-40℃ to +85℃	SGM40565YG/TR	4BXX	Tape and Reel, 3000
	4.2	TDFN-2×2-8L	-40℃ to +85℃	SGM40565-4.2YTDE8G/TR	G6A XXXX	Tape and Reel, 3000
		WLCSP-1.3×0.7-6B	-40℃ to +85℃	SGM40565-4.2YG/TR	6BXX	Tape and Reel, 3000
	4.35	TDFN-2×2-8L	-40℃ to +85℃	SGM40565-4.35YTDE8G/TR	G6C XXXX	Tape and Reel, 3000
		WLCSP-1.3×0.7-6B	-40℃ to +85℃	SGM40565-4.35YG/TR	6DXX	Tape and Reel, 3000

NOTE: XX = Date Code. XXXX = Date Code.

Green (RoHS & HSF): SG Micro Corp defines "Green" to mean Pb-Free (RoHS compatible) and free of halogen substances. If you have additional comments or questions, please contact your SGMICRO representative directly.

MARKING INFORMATION

YY X X

- Date code - Month ("A" = Jan. "B" = Feb. ··· "L" = Dec.)
- Date code - Year ("A" = 2010, "B" = 2011 ···)
- Chip I.D.

For example: 4BGJ (2016, October)

ABSOLUTE MAXIMUM RATINGS

VIN to GND.. -0.3V to 28V
$\overline{PPR}$, $\overline{CHG}$, $\overline{EN}$, IMIN, IREF, BAT to GND........ -0.3V to 6V
Package Thermal Resistance
TDFN-2×2-8L, θ_{JA}.. 118℃/W
Junction Temperature...+150℃
Storage Temperature Range ....-65℃ to +150℃
Lead Temperature (Soldering 10 sec)........................+260℃
ESD Susceptibility
HBM...4000V
MM...200V
CDM 1000V

RECOMMENDED OPERATING CONDITIONS

Supply Voltage Range ....4.55V to 26.5V
Maximum Supply Voltage 26.5V
Programmed Charge Current ....5mA to 400mA
Operating Temperature Range ....-40℃ to +85℃

OVERSTRESS CAUTION

Stresses beyond those listed may cause permanent damage to the device. Functional operation of the device at these or any other conditions beyond those indicated in the operational section of the specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect reliability.

ESD SENSITIVITY CAUTION

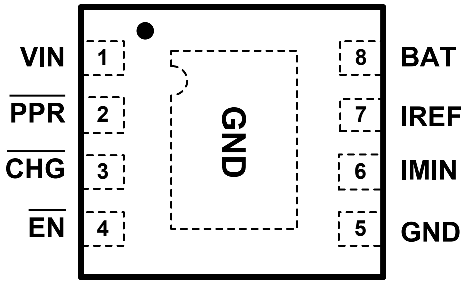
This integrated circuit can be damaged by ESD if you don't pay attention to ESD protection. SGMICRO recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

DISCLAIMER

SG Micro Corp reserves the right to make any change in circuit design, specification or other related things if necessary without notice at any time.

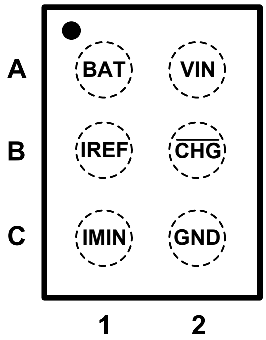
PIN CONFIGURATIONS

(TOP VIEW)



TDFN-2×2-8L

(TOP VIEW)



WLCSP-1.3×0.7-6B

PIN DESCRIPTION

PIN		NAME	FUNCTION
TDFN-2×2-8L	WLCSP-1.3×0.7-6B		
1	A2	VIN	Power Input. The absolute maximum input voltage is 26.5V. A 1μF X5R ceramic capacitor is recommended to be placed very close to the input pin for decoupling purpose. Additional capacitance may be required to provide a stable input voltage.
2	—	$\overline{PPR}$	Open-drain Power Presence Indication. The open-drain MOSFET turns on when the input voltage is above the POR threshold and off otherwise. This pin is capable to sink 15mA current to drive an LED. The maximum voltage rating for this pin is 5.5V. This pin is independent on the $\overline{EN}$ pin input.
3	B2	$\overline{CHG}$	Open-drain Charge Indication. This pin outputs a logic low when a charge cycle starts and turns to high impedance when the full-of-charge (FOC) condition is qualified. This pin is capable to sink 15mA current to drive an LED. When the charger is disabled, the $\overline{CHG}$ pin outputs high impedance.
4	—	$\overline{EN}$	Enable Input. This is a logic input pin to disable or enable the charger. Drive to high to disable the charger. When this pin is driven to low or left floating, the charger is enabled. This pin has an internal 200kΩ pull-down resistor.
5	C2	GND	System Ground.
6	C1	IMIN	Full-of-Charge (FOC) Current Programming Pin. Connect a resistor between this pin and the GND pin to set the FOC current. The FOC current I_{MIN} can be programmed by the following equation: $$I_{MIN} = \frac{8450}{R_{IMIN}} \text{ (mA)}$$ where R_{IMIN} is in kΩ.
7	B1	IREF	Charge-Current Programming and Monitoring Pin. Connect a resistor between this pin and the GND pin to set the charge current limit determined by the following equation: $$I_{REF} = \frac{9170}{R_{IREF}} + 1 \text{ (mA)}$$ where R_{IREF} is in kΩ. The resistor should be located very close to this pin. The IREF pin voltage also monitors the actual charge current during the entire charge cycle, including the trickle, constant-current, and constant-voltage phases. When disabled, V_{IREF} = 0V.
8	A1	BAT	Charger Output Pin. Connect this pin to the battery. A 1μF X5R ceramic capacitor is recommended for decoupling and stability purposes. When the $\overline{EN}$ pin is pulled to logic high, the BAT output is disabled.
Exposed Pad	—	GND	Exposed Pad is Internally Connected to GND. Connect it to a large ground plane to maximize thermal performance; not intended as an electrical connection point.

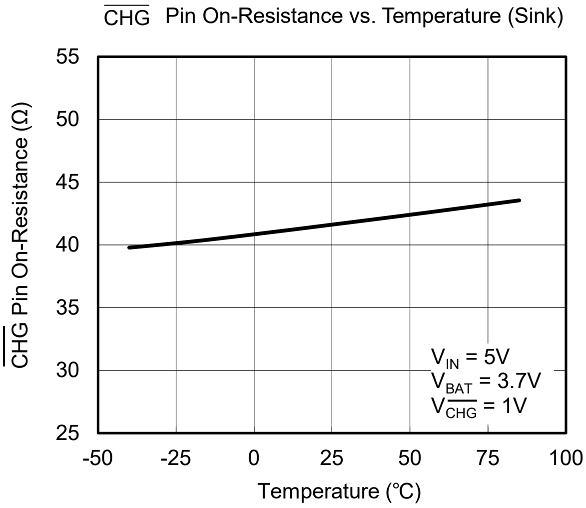
ELECTRICAL CHARACTERISTICS

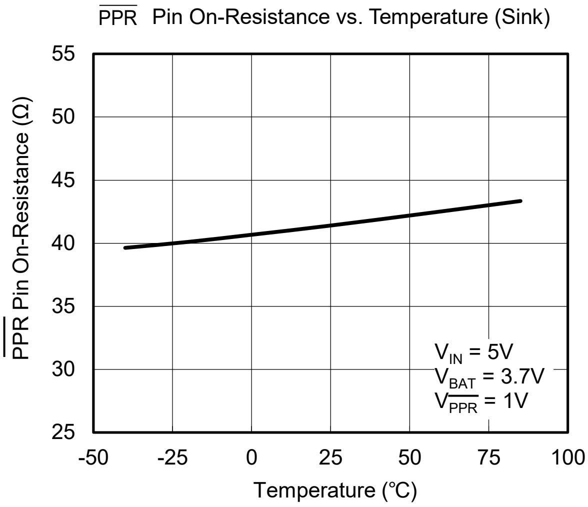
(V_{IN} = 5V, R_{IMIN} = 909kΩ, T_A = +25℃, unless otherwise noted.)

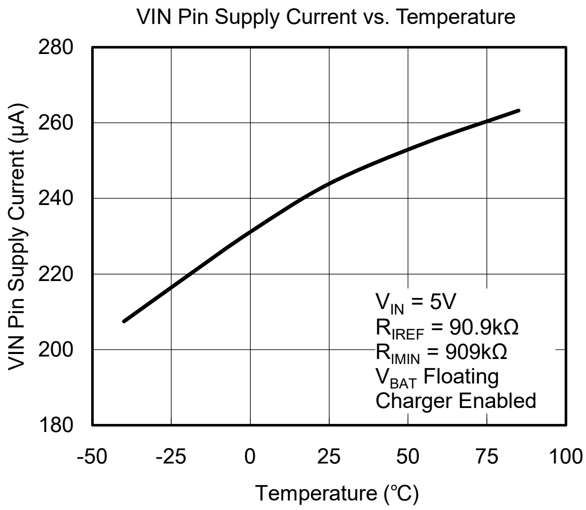
PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
POWER-ON RESET						
Rising POR Threshold	V_{POR}	V_{BAT} = 2V, R_{IREF} = 226kΩ	3.10	3.80	4.54	V
Falling POR Threshold	V_{POR}	V_{BAT} = 2V, R_{IREF} = 226kΩ	2.26	2.95	3.62	V
VIN-BAT OFFSET VOLTAGE						
Rising Edge	V_{OS}	V_{BAT} forced to 4.5V, R_{IREF} = 226kΩ		110	200	mV
Falling Edge	V_{OS}	V_{BAT} forced to 4.5V, R_{IREF} = 226kΩ	5	60		mV
STANDBY CURRENT						
BAT Pin Sink Current	$I_{STANDBY}$	Charger disabled (2)		0.1	1	μA
BAT Pin Sink Current	$I_{STANDBY}$	Input floating		0.01	1	μA
VIN Pin Supply Current	I_{VIN}	V_{BAT} floating, R_{IREF} = 90.9kΩ, Charger disabled (2)		175	245	μA
VIN Pin Supply Current	I_{VIN}	V_{BAT} floating, R_{IREF} = 90.9kΩ, Charger enabled		245	325	μA
VOLTAGE REGULATION						
Output Voltage, SGM40565-4.05	V_{CH}	R_{IREF} = 90.9kΩ, V_{IN} = 10V, charge current = 1mA	4.00	4.05	4.10	V
Output Voltage, SGM40565-4.2	V_{CH}	R_{IREF} = 90.9kΩ, V_{IN} = 10V, charge current = 1mA	4.15	4.20	4.25	V
Output Voltage, SGM40565-4.35	V_{CH}	R_{IREF} = 90.9kΩ, V_{IN} = 10V, charge current = 1mA	4.30	4.35	4.40	V
CHARGE CURRENT (1)						
IREF Pin Output Voltage	V_{IREF}	V_{BAT} = 3.7V, R_{IREF} = 226kΩ	1.15	1.2	1.27	V
Constant Charge Current	I_{REF}	R_{IREF} = 90.9kΩ, V_{BAT} = 3.7V	88	100	112	mA
Trickle Charge Current	I_{TRK}	R_{IREF} = 90.9kΩ, V_{BAT} = 2.3V	12	19	28	mA
Full-of-Charge Current	I_{MIN}	R_{IREF} = 90.9kΩ	2	9	21	mA
FOC Rising Threshold		R_{IREF} = 90.9kΩ	57	76	96	mA
PRECONDITIONING CHARGE THRESHOLD						
Preconditioning Charge Threshold Voltage, SGM40565-4.05	V_{MIN}	R_{IREF} = 90.9kΩ		2.48		V
Preconditioning Charge Threshold Voltage, SGM40565-4.2	V_{MIN}	R_{IREF} = 90.9kΩ		2.55		V
Preconditioning Charge Threshold Voltage, SGM40565-4.35	V_{MIN}	R_{IREF} = 90.9kΩ		2.65		V
Preconditioning Voltage Hysteresis	V_{MINHYS}	R_{IREF} = 90.9kΩ		100		mV
INTERNAL TEMPERATURE MONITORING						
Charge Current Fold-Back Threshold	T_{FOLD}			115		℃
LOGIC INPUT AND OUTPUTS						
$\overline{EN}$ Pin Logic Input High (2)			1.6			V
$\overline{EN}$ Pin Logic Input Low (2)					0.8	V
$\overline{EN}$ Pin Internal Pull-Down Resistance (2)			150	200	255	kΩ
$\overline{CHG}$ Pin On-Resistance when LOW		Pin voltage = 1V		42	72	Ω
$\overline{CHG}$ Leakage Current when High Impedance		$V_{\overline{CHG}}$ = 5.5V		0.01	4.5	μA
$\overline{PPR}$ Pin On-Resistance when LOW (2)		Pin voltage = 1V		42	72	Ω
$\overline{PPR}$ Leakage Current when High Impedance (2)		$V_{\overline{PPR}}$ = 5.5V		0.01	4.5	μA

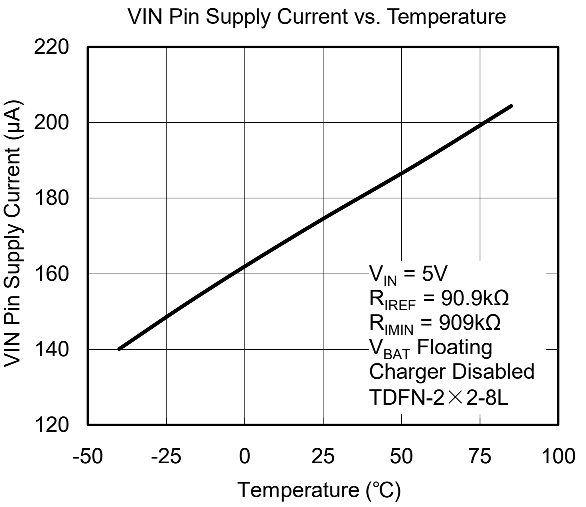
NOTES:
1. The charge current can be affected by the thermal fold-back function if the IC under the test setup cannot dissipate the heat.
2. The parameters of $\overline{EN}$ / $\overline{PPR}$ pins are for TDFN-2×2-8L package.

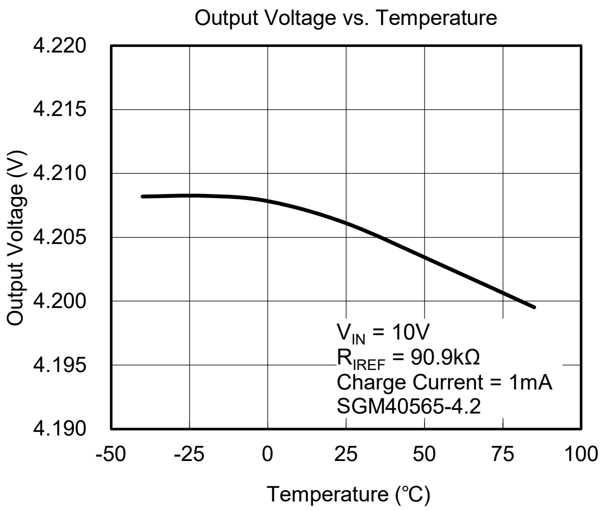
TYPICAL PERFORMANCE CHARACTERISTICS

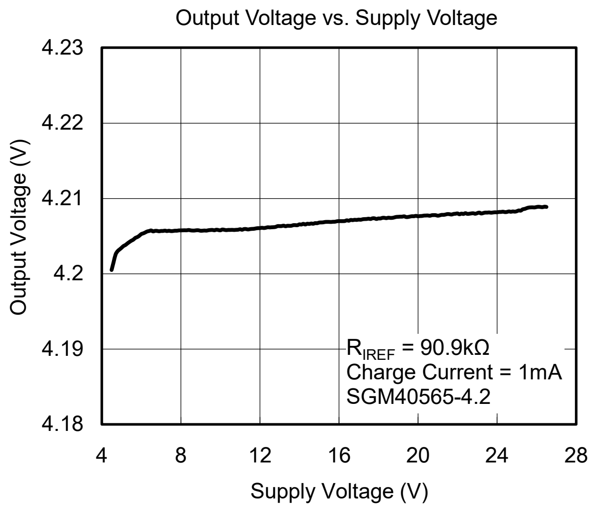






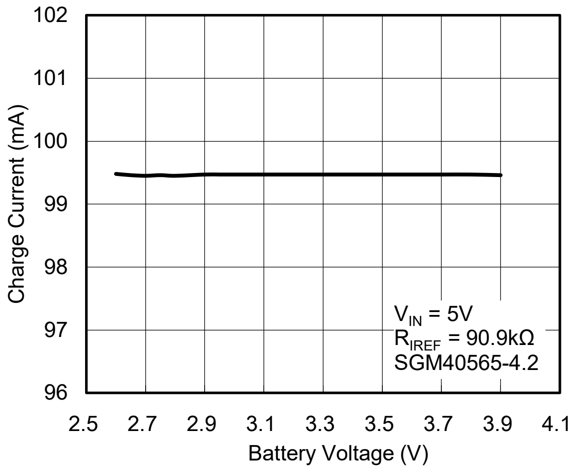




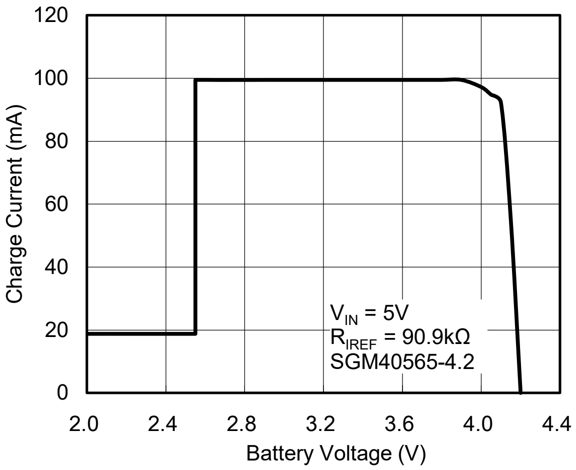


TYPICAL PERFORMANCE CHARACTERISTICS (continued)

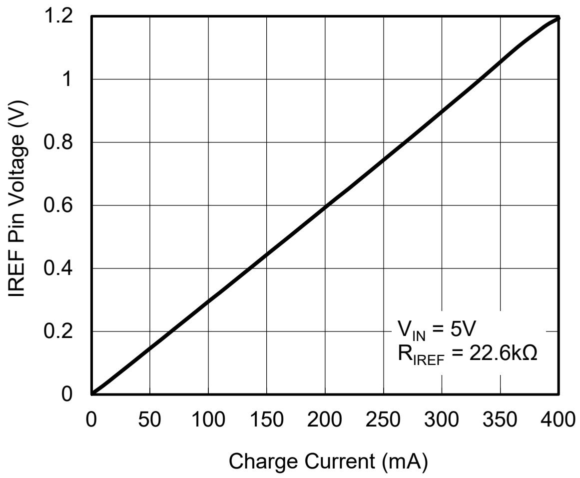
Charge Current vs. Battery Voltage



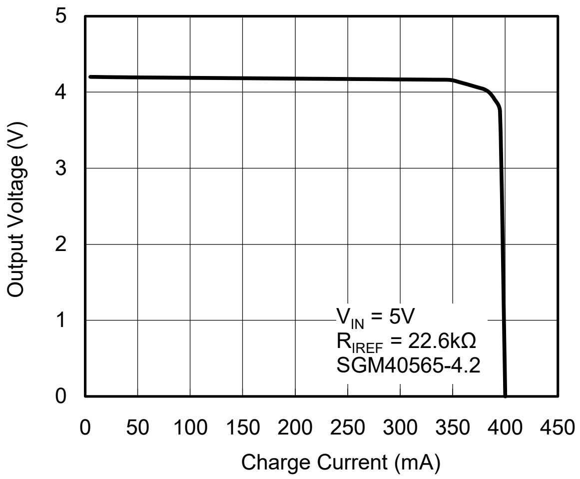
Charge Current vs. Battery Voltage



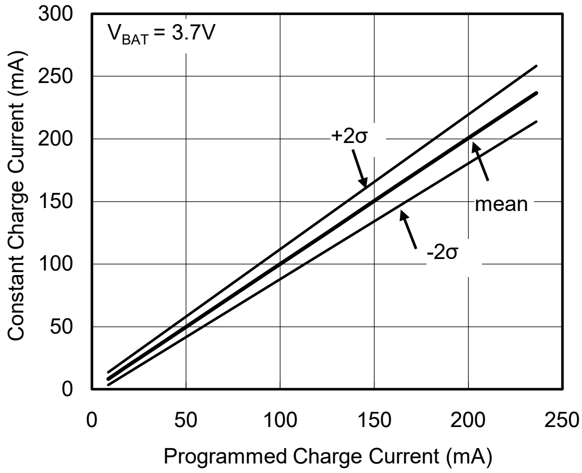
IREF Pin Voltage vs. Charge Current



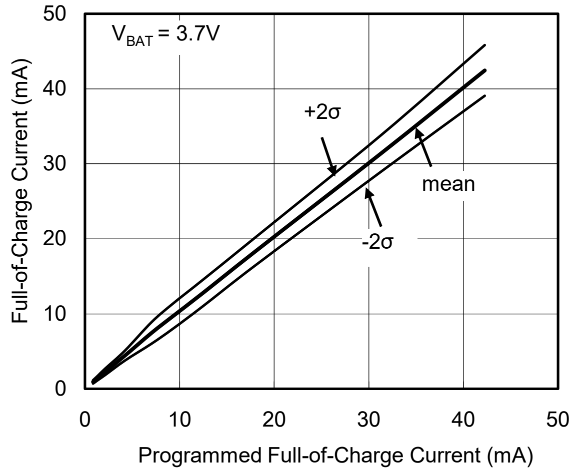
Output Voltage vs. Charge Current



Charge Current Programming ±2σ Tolerance Guide



Full-of-Charge Current Programming ±2σ Tolerance Guide



TYPICAL APPLICATIONS

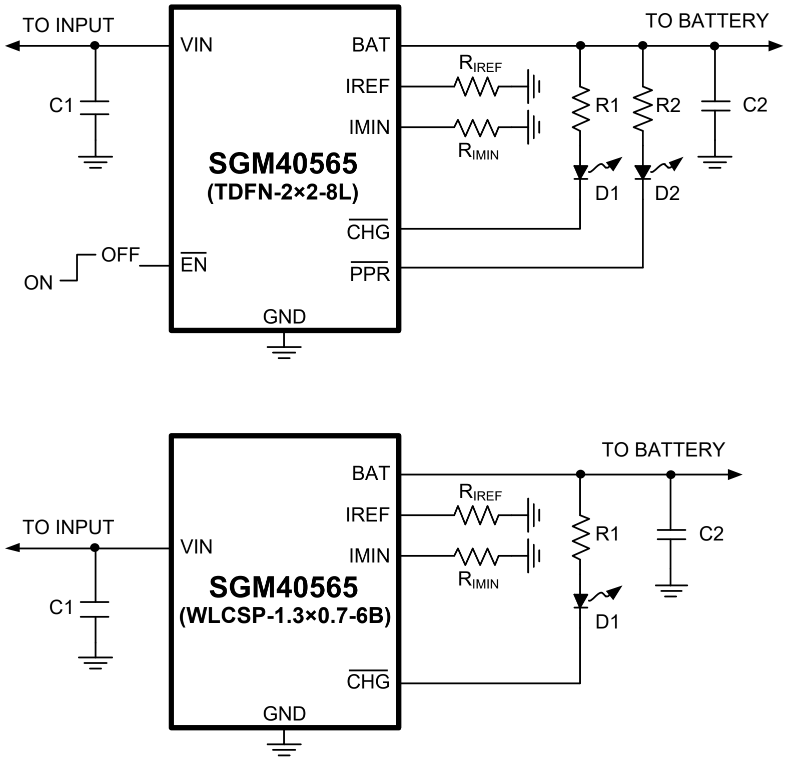


Figure 1. Typical Application Circuits Interfacing to Indication LEDs

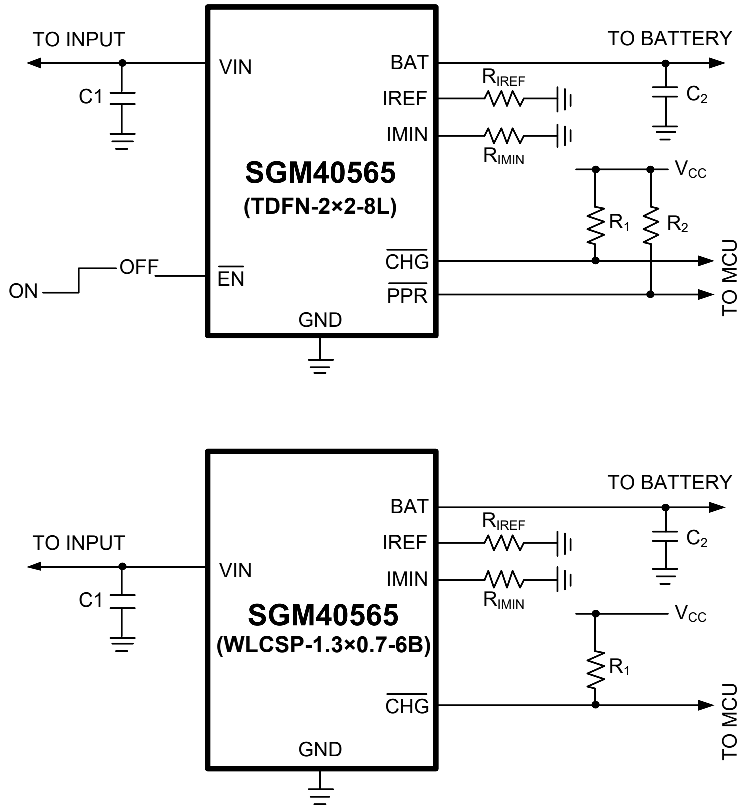


Figure 2. Typical Application Circuit with the Indication Signals Interfacing to an MCU

TYPICAL APPLICATIONS (continued)

COMPONENT DESCRIPTION FOR FIGURE 1

PART	DESCRIPTION
C_1	1μF X5R ceramic cap
C_2	1μF X5R ceramic cap
R_{IREF}	90.9kΩ, 1%, for 100mA charge current
R_{IMIN}	909kΩ, 1%, for 9mA FOC current
R_1, R_2	300Ω, 5%
D_1, D_2	LEDs for indication

COMPONENT DESCRIPTION FOR FIGURE 2

PART	DESCRIPTION
C_1	1μF X5R ceramic cap
C_2	1μF X5R ceramic cap
R_{IREF}	90.9kΩ, 1%, for 100mA charge current
R_{IMIN}	909kΩ, 1%, for 9mA FOC current
R_1, R_2	100kΩ, 5%

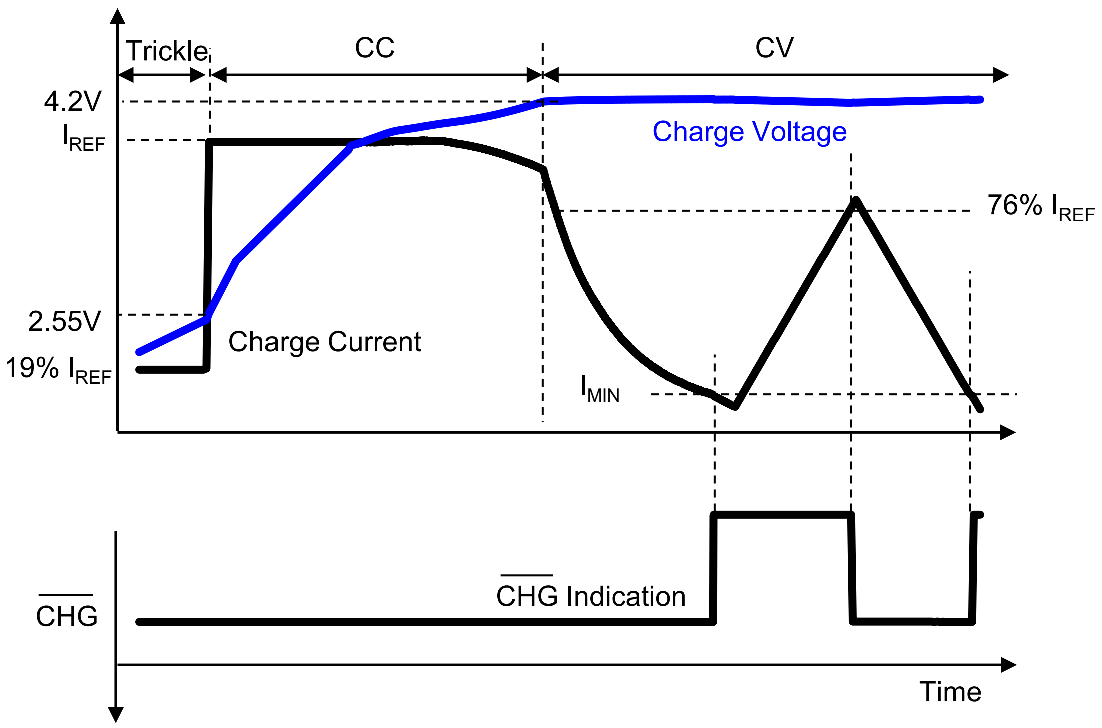


Figure 3. Typical Charge Profile

OPERATION

The SGM40565 charges a Li-Ion battery using a CC/CV profile. The constant current I_{REF} is set with an external resistor R_{IREF} (see Figure 1) and the constant voltage is fixed at 4.05V/4.2V/4.35V. If the battery voltage is below the typical 2.48V/2.55V/2.65V trickle charge threshold, the SGM40565 charges the battery with a trickle current of 19% of I_{REF} until the battery voltage rises above the trickle charge threshold. The CC mode is maintained at the rate determined by programming I_{REF} until the cell voltage rises to 4.05V/4.2V/4.35V. When the battery voltage reaches 4.05V/4.2V/4.35V, the charger enters a CV mode and regulates the battery voltage at 4.05V/4.2V/4.35V to fully charge the battery without the risk of over charge. Upon reaching an full-of-charge (FOC) current, the charger indicates the charge completion with the $\overline{CHG}$ pin, but the charger maintains an output voltage of 4.05V/4.2V/4.35V. Figure 3 shows the typical charge waveforms after the power is on.

The FOC current level I_{MIN} is programmable with the external resistor R_{IMIN} (see Figure 1). The $\overline{CHG}$ pin turns to low when the trickle charge starts and rises to high impedance at the FOC. After the FOC is reached, the charge current has to rise to typically 76% of I_{REF} for the $\overline{CHG}$ pin to turn on again, as shown in Figure 3. The current surge after FOC can be caused by a load connected to the battery.

A thermal fold-back 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 SGM40565 accepts an input voltage up to 26.5V.

$\overline{PPR}$ Indication

The $\overline{PPR}$ pin is an open-drain output to indicate the presence of the AC adapter. Whenever the input voltage is higher than the POR threshold, the $\overline{PPR}$ pin turns on the internal open-drain MOSFET to indicate a logic low signal, independent on the $\overline{EN}$ pin input. When the internal open-drain FET is turned off, the $\overline{PPR}$ pin leaks less than 4.5μA current. When turned on, the $\overline{PPR}$ pin is able to sink at least 15mA current under all operating conditions. The $\overline{PPR}$ pin can be used to drive an LED (see Figure 1) or to interface with a micro-processor.

Power Good Range

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

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

where the V_{OS} is the offset voltage for the input and output voltage comparator, discussed shortly. Both V_{POR} and V_{OS}, 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.

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.

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.

$\overline{CHG}$ Indication

The $\overline{CHG}$ is an open-drain output capable of sinking at least 15mA current when the charger starts to charge, and turns off when the FOC current is reached. The $\overline{CHG}$ signal is interfaced either with a microprocessor GPIO or an LED for indication.

OPERATION (continued)

$\overline{EN}$ Input

$\overline{EN}$ is an active-low logic input to enable the charger. Drive the $\overline{EN}$ pin to low or leave it floating to enable the charger. This pin has a 200kΩ internal pull-down resistor so when left floating, the input is equivalent to logic low. Drive this pin to high to disable the charger. The threshold for high is given in the Electrical Characteristics table.

IREF Pin

The IREF pin has the two functions as described in the Pin Description section. When setting the fast charge current, the charge current has high accuracy with the charge current set over the range of 5mA to 400mA. When monitoring the charge current, the accuracy of the IREF pin voltage vs. the actual charge current has the same accuracy as the gain from the IREF pin current to the actual charge current.

Operation without the Battery

The SGM40565 relies on a battery for stability. It works under LDO mode and the stability is not guaranteed 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_{REF} and the thermal fold-back.

Thermal Fold-Back

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

APPLICATION INFORMATION

Design of I_{REF}, I_{MIN} and $\overline{\text{CHG}}$ Indication

A higher I_{REF} could charge faster, but may suffer the penalty of reduced battery life. The maximum I_{REF} should be designed to follow battery vendor's instruction for a given battery life expectation.

I_{MIN} is the end of charge current when $\overline{\text{CHG}}$ indicates a full of charge condition. All current out of the SGM40565 BAT pin should be counted into I_{MIN}, including load current and the indication LED currents. As illustrated in Figure 3, the SGM40565 continues to supply current unless it is disabled by $\overline{\text{EN}}$ pulled high, regardless of the status of $\overline{\text{CHG}}$ pin. When charge current ever goes lower than I_{MIN}, $\overline{\text{CHG}}$ pin stays high impendence until the charge current goes higher than 76% of I_{REF}, which is another factor to consider in design of I_{REF}, I_{REF} should be high enough to so that 76% of I_{REF} is higher than the current that is designed not to initiate $\overline{\text{CHG}}$ indication, while is low enough to assure the power source could deliver higher than 76% of I_{REF} to initiate $\overline{\text{CHG}}$ indication.

Input Capacitor Selection

The input capacitor is required to suppress the power supply transient response during transitions. Mainly this capacitor is selected to avoid oscillation during the start up when the input supply is passing the POR threshold and the VIN-BAT comparator offset voltage. When the battery voltage is above the POR threshold, the V_{IN} - V_{BAT} offset voltage dominates the hysteresis value. Typically, a 1μF X5R ceramic capacitor should be sufficient to suppress the power supply noise.

Output Capacitor Selection

The criterion for selecting the output capacitor is to maintain the stability of the charger as well as to bypass any transient load current. The minimum capacitance is a 1μF X5R ceramic capacitor. The actual capacitance connected to the output is dependent on the actual application requirement.

Input Power Sources

Any input power source in power-good range could be used with this device for charging. However, charging with a high voltage source causes excessive heating for an appliance to compensate, though the SGM40565 might keep charging at a fold-back current. A 5V wall cube or a USB power port is a commonly preferred source. With its 26.5V maximum input voltage, the SGM40565 is flexible to be powered from a loosely regulated magnetic coupling source, which outputs a rated low voltage at designed load and output goes high when load current is low.

REVISION HISTORY

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

APRIL 2018 – REV.A.2 to REV.A.3

Added SGM40565-4.05 test data in the Electrical Characteristics section.......... 4

MARCH 2018 – REV.A.1 to REV.A.2

Updated Electrical Characteristics section.......... 4

OCTOBER 2017 – REV.A to REV.A.1

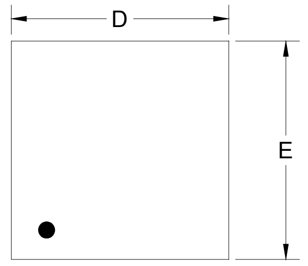
Changed Electrical Characteristics section.......... 4

Changes from Original (JUNE 2017) to REV.A

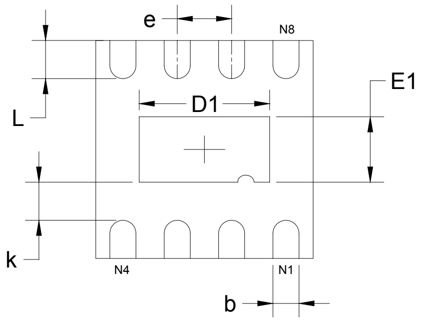
Changed from product preview to production data.......... All

PACKAGE OUTLINE DIMENSIONS

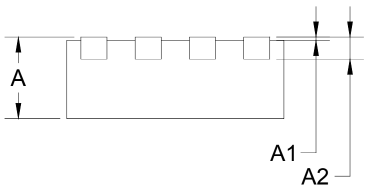
TDFN-2×2-8L



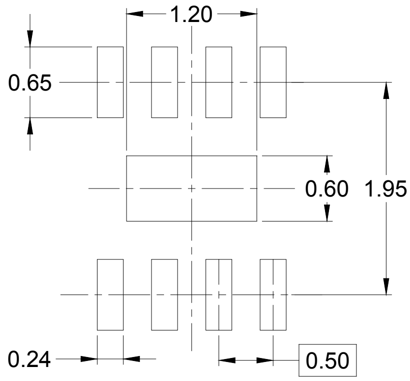
TOP VIEW



BOTTOM VIEW



SIDE VIEW

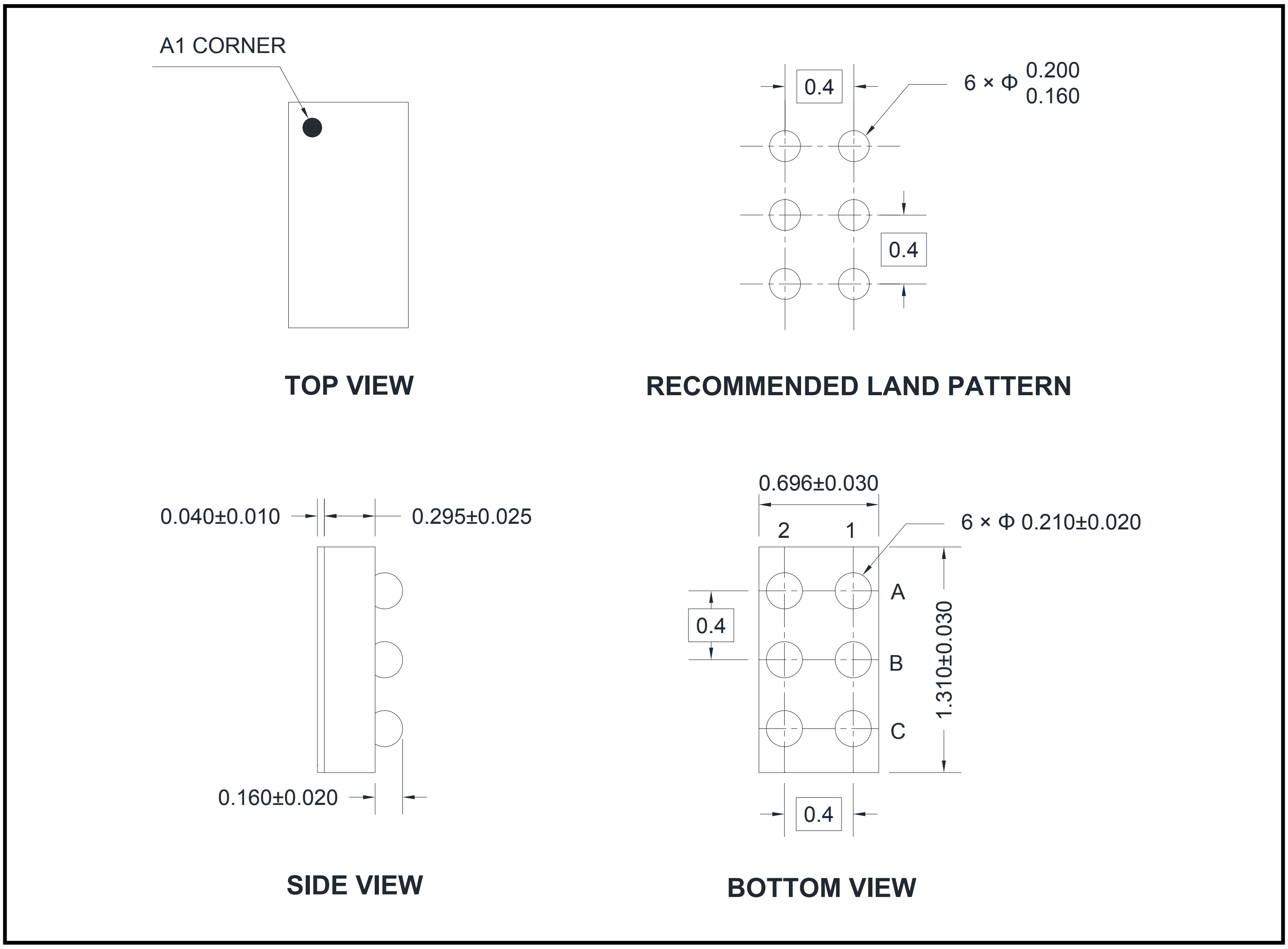


RECOMMENDED LAND PATTERN (Unit: mm)

Symbol	Dimensions In Millimeters		Dimensions In Inches	
	MIN	MAX	MIN	MAX
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A2	0.203 REF		0.008 REF	
D	1.900	2.100	0.075	0.083
D1	1.100	1.300	0.043	0.051
E	1.900	2.100	0.075	0.083
E1	0.500	0.700	0.020	0.028
k	0.200 MIN		0.008 MIN	
b	0.180	0.300	0.007	0.012
e	0.500 TYP		0.020 TYP	
L	0.250	0.450	0.010	0.018

PACKAGE OUTLINE DIMENSIONS

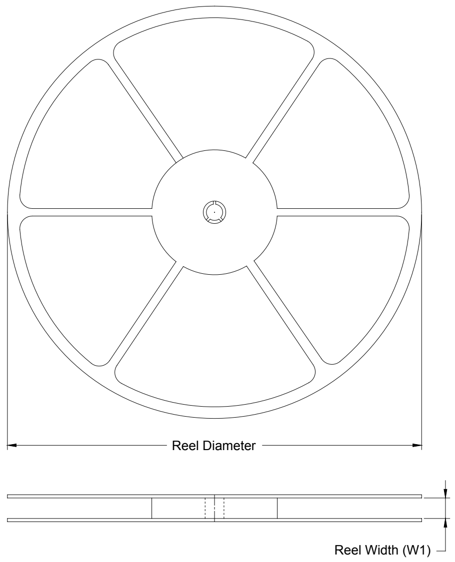
WLCSP-1.3×0.7-6B



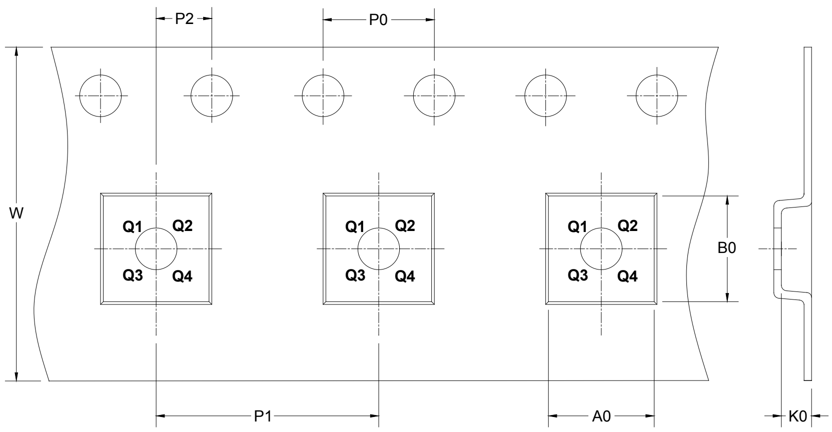
NOTE: All linear dimensions are in millimeters.

TAPE AND REEL INFORMATION

REEL DIMENSIONS



TAPE DIMENSIONS



DIRECTION OF FEED

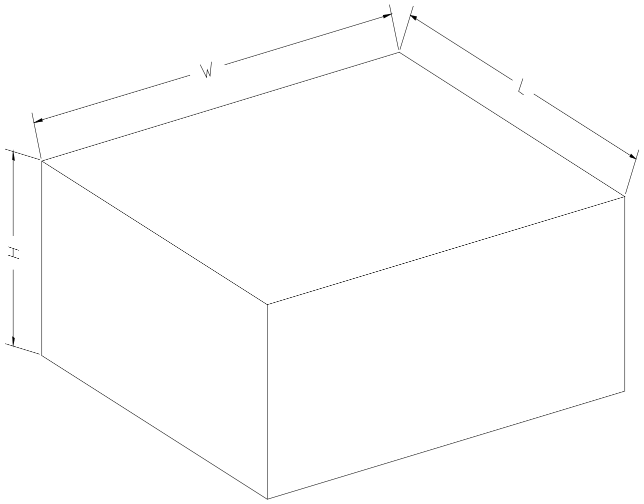
NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF TAPE AND REEL

Package Type	Reel Diameter	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
TDFN-2×2-8L	7″	9.5	2.30	2.30	1.10	4.0	4.0	2.0	8.0	Q1
WLCSP-1.3×0.7-6B	7″	9.2	0.80	1.41	0.59	4.0	4.0	2.0	8.0	Q1

DD0001

CARTON BOX DIMENSIONS



NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF CARTON BOX

Reel Type	Length (mm)	Width (mm)	Height (mm)	Pizza/Carton
7″ (Option)	368	227	224	8
7″	442	410	224	18

DD0002