AME

AME2056

1A Single Cell Li-ion Battery Linear Charger

■ General Description

The AME2056 is constant-current/constant-voltage linear charger IC for single cell lithium-ion batteries. The battery charge termination voltage is fixed at 4.2V, the charge current can be programmed an external resistor up to 1000mA(Max.). In the trickle charge mode, the trickle charge voltage is 2.9V that automatically terminates the charge cycle when the charge current drops to 1/10 the programmed value after the final float voltage is reached. Other features includes Thermal Shutdown, Soft-start Function, Battery temperature detector, under-voltage lockout, automatic recharge and two Status indication for Charge Status, no battery and battery failure indicators.

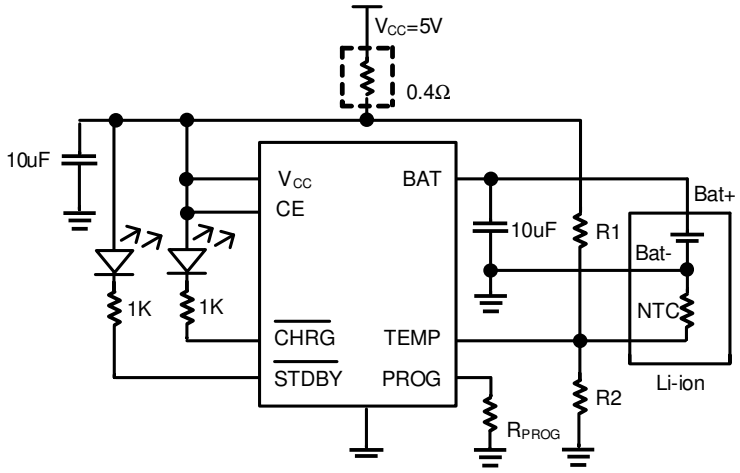
■ Applications

- Charging docks, charging cradles
- Low Cost and Small Size Chargers
- Cellular phones

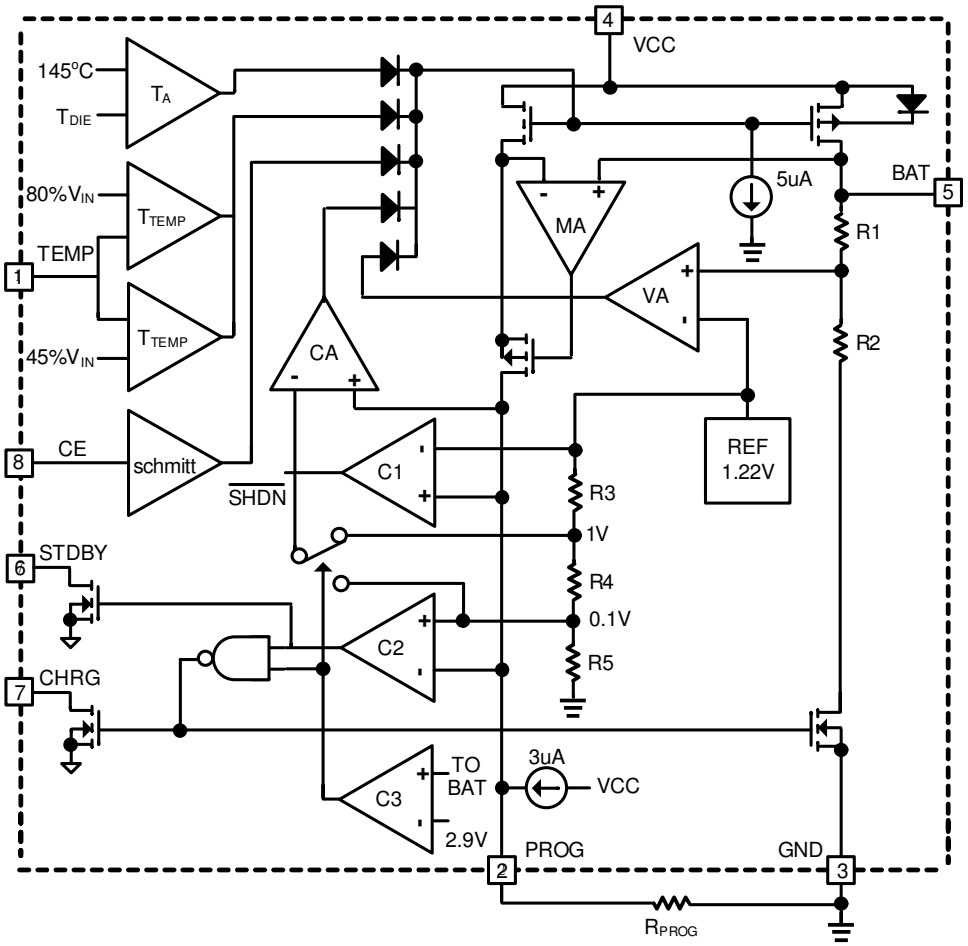
■ Features

- Standalone Li-Ion Battery Charging
- Programmable Charge Current
- Charge Termination Voltage: 4.2V(Typ.)
- Trickle Charge Voltage: 2.9V(Typ.)
- Standby Current: 55μA(Typ.)
- No Sense Resistor or Blocking Diode Required
- Constant-current/constant-voltage Operation
- Automatic Recharge
- Battery temperature Detector
- C/10 Charge Termination
- Two Status indication for Charge Status, no battery and battery failure indicators
- Soft-start Function
- Thermal Shutdown
- Available in SOP-8/PP, MSOP-8, SOT-25 and DFN-8D(2x2x0.75mm) Package
- Green Products Meet RoHS Standards

■ Typical Application

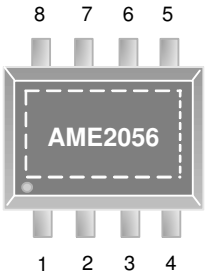


■ Functional Block Diagram



■ Pin Configuration

SOP-8/PP
Top View

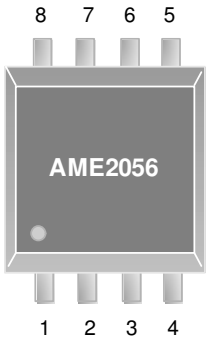


AME2056-AZA

1. TEMP
2. PROG
3. GND
4. VCC
5. BAT
6. $\overline{\text{STDBY}}$
7. $\overline{\text{CHRG}}$
8. CE

*** Die Attach:**
Conductive Epoxy

MSOP-8
Top View

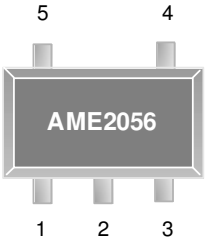


AME2056-AQA

1. TEMP
2. PROG
3. GND
4. VCC
5. BAT
6. $\overline{\text{STDBY}}$
7. $\overline{\text{CHRG}}$
8. CE

*** Die Attach:**
Conductive Epoxy

SOT-25
Top View

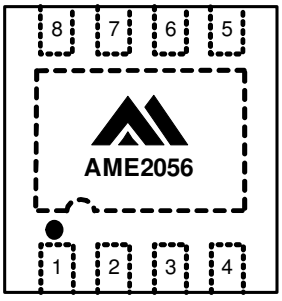


AME2056-AEV

1. $\overline{\text{CHRG}}$
2. GND
3. BAT
4. VCC
5. PROG

*** Die Attach:**
Conductive Epoxy

DFN-8D
Top View
(2x2x0.75mm)



AME2056-AVA

1. TEMP
2. PROG
3. GND
4. VCC
5. BAT
6. $\overline{\text{STDBY}}$
7. $\overline{\text{CHRG}}$
8. CE

*** Die Attach:**
Conductive Epoxy

■ Pin Description

8 Pin SOP-8/PP, MSOP-8, DFN-8D

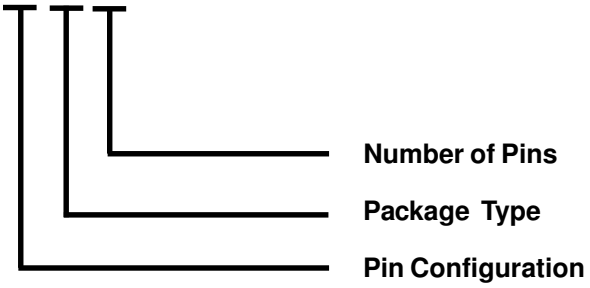
Pin Number	Pin Name	Pin Description
1	TEMP	Temperature sense Input.
2	PROG	Charge Current Setting and Charge Current Monitor Pin.
3	GND	Ground.
4	VCC	Input Supply Voltage
5	BAT	Battery connection Pin.
6	$\overline{\text{STDBY}}$	Charge terminatel Status Output.
7	$\overline{\text{CHRG}}$	Open-Drain Charge Status Output.
8	CE	Chip Enable Input.

5 Pin SOT-25

Pin Number	Pin Name	Pin Description
1	$\overline{\text{CHRG}}$	Open-Drain Charge Status Output.
2	GND	Ground.
3	BAT	Battery connection Pin.
4	VCC	Input Supply Voltage
5	PROG	Charge Current Setting and Charge Current Monitor Pin.

■ Ordering Information

AME2056 x x x



Pin Configuration		Package Type	Number of Pins
A (SOP-8/PP) (MSOP-8) (DFN-8D)	1. TEMP 2. PROG 3. GND 4. VCC 5. BAT 6. $\overline{\text{STDBY}}$ 7. $\overline{\text{CHRG}}$ 8. CE	E: SOT-2X Q: MSOP V: DFN Z: SOP/PP	A: 8 V: 5
A (SOT-25)	1. $\overline{\text{CHRG}}$ 2. GND 3. BAT 4. VCC 5. PROG		

■ Absolute Maximum Ratings

Parameter	Maximum	Unit
Input Voltage	-0.3 to +6	V
PROG Pin Voltage	-0.3 to (V_{CC}+0.3V)	V
BAT Pin Voltage	-0.3 to +6	V
All Other Pins	0.3 to +6	V
BAT Pin Current	1.2	A
Short-Circuit Duration	Continuous	
Electrostatic Discharge (HBM)	2	KV
Electrostatic Discharge (MM)	200	V
Electrostatic Discharge (CDM)	1000	V
Junction Temperature	150	°C
Storage Temperature Range	-65 to +150	

■ Recommended Operating Conditions

Parameter	Symbol	Rating	Unit
Ambient Temperature Range	T_A	-40 to +85	°C
Junction Temperature Range	T_J	-40 to +125	
Input Supply Voltage	V_{CC}	4.5~5.5	V

■ Thermal Information

Parameter	Package	Die Attach	Symbol	Maximum	Unit
Thermal Resistance* (Junction to Case)	SOP-8/PP	Conductive Epoxy	θ_{JC}	19	°C / W
Thermal Resistance (Junction to Ambient)			θ_{JA}	84	
Internal Power Dissipation			P_D	1450	mW
Thermal Resistance* (Junction to Case)	MSOP-8	Conductive Epoxy	θ_{JC}	80	°C / W
Thermal Resistance (Junction to Ambient)			θ_{JA}	206	
Internal Power Dissipation			P_D	625	mW
Thermal Resistance* (Junction to Case)	SOT-25	Conductive Epoxy	θ_{JC}	81	°C / W
Thermal Resistance (Junction to Ambient)			θ_{JA}	260	
Internal Power Dissipation			P_D	400	mW
Thermal Resistance* (Junction to Case)	DFN-8D	Conductive Epoxy	θ_{JC}	22.8	°C / W
Thermal Resistance (Junction to Ambient)			θ_{JA}	114	
Internal Power Dissipation			P_D	880	mW
Lead Temperature (Soldering, 10 sec)*				350	°C

■ Electrical Specifications

Typical values V_{CC}=5V with typical T_A = 25°C, Unless otherwise specified.

Parameter	Symbol	Test Condition	Min	Typ	Max	Units
VCC Operating Range	V_{CC}		4.5		5.5	V
Supply Current	I_{CC}	Charge mode, R_{PROG}=1.2K			500.0	uA
Standby Current	I_{STBY}	Standby mode(charge end)		55	100	uA
Shutdown Current	I_{SHUT}	Shutdown mode (R_{PROG}=NC, V_{CC}<V_{BAT} or V_{CC}<$V_{UVLO)}$		55	100	uA
Float Voltage	V_{FLOAT}	T_A=25°C, I_{BAT}=40mA	4.158	4.2	4.242	V
Maximum Battery Current	$I_{BAT(MAX)}$	SOT-25 / DFN-6D / DFN-8L			800.0	mA
		SOP-8/PP / MSOP-8			1000	mA
BAT Pin Current	I_{BAT1}	R_{PROG}=2.4KΩ, CC mode V_{BAT}=4V	450	500	550	mA
	I_{BAT2}	R_{PROG}=1.2KΩ, CC mode V_{BAT}=4V	900	1000	1100	mA
	I_{BAT3}	Standby mode, V_{BAT}=4.2V			-6	uA
	I_{BAT4}	Shutdown mode (R_{PROG}=NC)			±2	uA
	I_{BAT5}	Sleep mode, V_{CC}=0V			-2	uA
Trickle Charge Current	I_{TRIKL}	V_{BAT}<V_{TRIKL},R_{PROG}=1.2KΩ		130		mA
Trickle Voltage	V_{TRIKL}	R_{PROG}=1.2KΩ, V_{BAT} Rising	2.8	2.9	3	V
Trickle Voltage Hysteresis	V_{TRILK_HYS}		60	80	100	mV
VCC UVLO Rising Threshold Voltage	V_{UVLO}	V_{CC}:Low to High	3.5	3.7	3.9	V
VCC UVLO Hysteresis	V_{UVLO_HYS}		150	200	300.0	mV
VCC-VBAT lockout Threshold Voltage	V_{ASD}	V_{CC}:Low to High	60	100	140	mV
		V_{CC}:High to Low	5	30	50	mV
C/10 Charge Termination Current Threshold	I_{TERM}	R_{PROG}=2.4KΩ		70		mA
		R_{PROG}=1.2KΩ		130		mA

■ Electrical Specifications (Contd.)

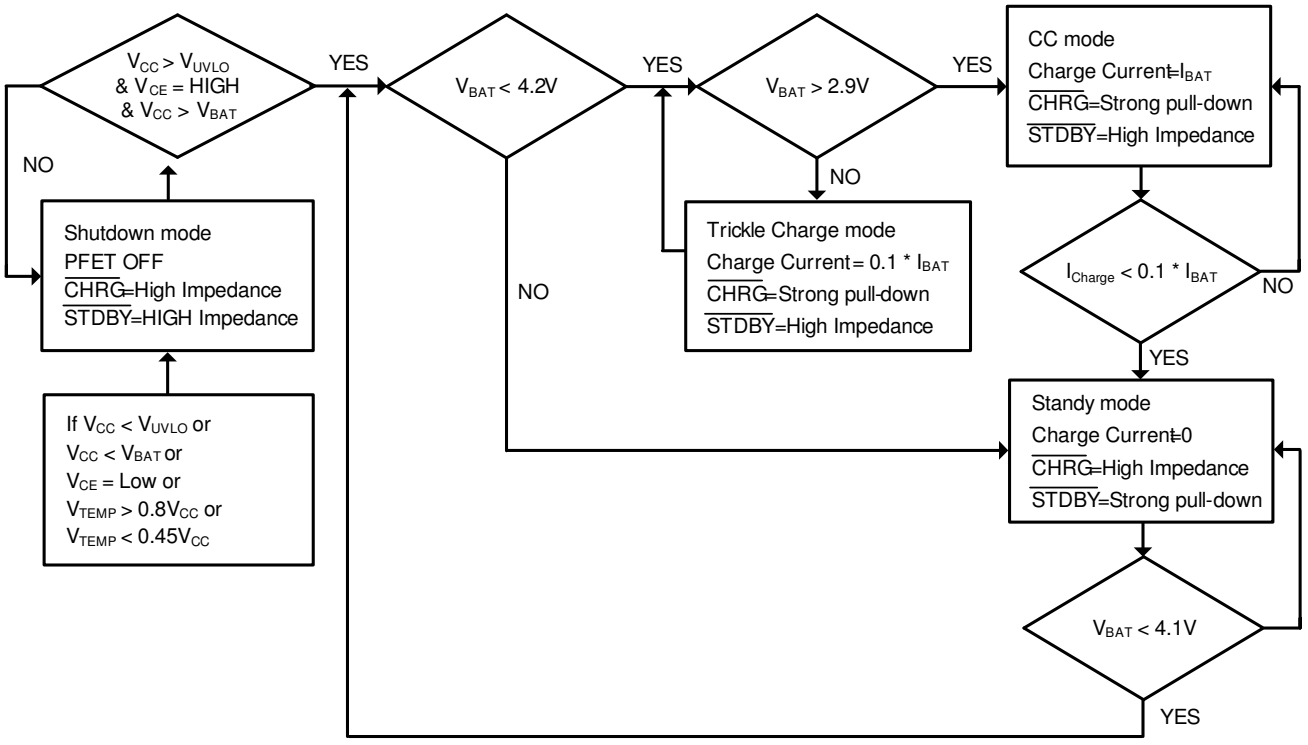
Parameter	Symbol	Test Condition	Min	Typ	Max	Units
PROG Pin Voltage	V_{PROG}	R_{PROG}=1.2KΩ, CC mode	0.9	1	1.1	V
$\overline{CHRG}$ Pin Output Low Voltage	$V_{\overline{CHRG}}$	$I_{\overline{CHRG}}$=5mA		0.3	0.6	V
$\overline{STDBY}$ Pin Output Low Voltage	$V_{\overline{STANBY}}$	$I_{\overline{STDBY}}$=5mA		0.3	0.6	V
Temp Pin High Threshold Voltage	V_{TEMP-H}			80	82	$\%V_{CC}$
Temp Pin Low Threshold Voltage	V_{TEMP-L}		43	45		$\%V_{CC}$
Recharge Threshold Voltage	ΔR_{ECHRG}	V_{FLOAT}-V_{RECHRG}	60	150	200	mV
Temperature Limit	T_{LIMT}			145		°C
ON Resistance	R_{ON}			650		mΩ
Soft Start Time	t_{SS}			400		uS
Recharge Battery Time	t_{RECHRG}	V_{BAT}:High to Low	0.8	1.8	4	ms
Battery Termination Detect Time	t_{TERM}	I_{BAT} falling (less than I_{CHRG} /10)	0.8	1.8	4	ms
I_{PROG} Pin Pull-up Current	$I_{PROG_pull_up}$			2		uA

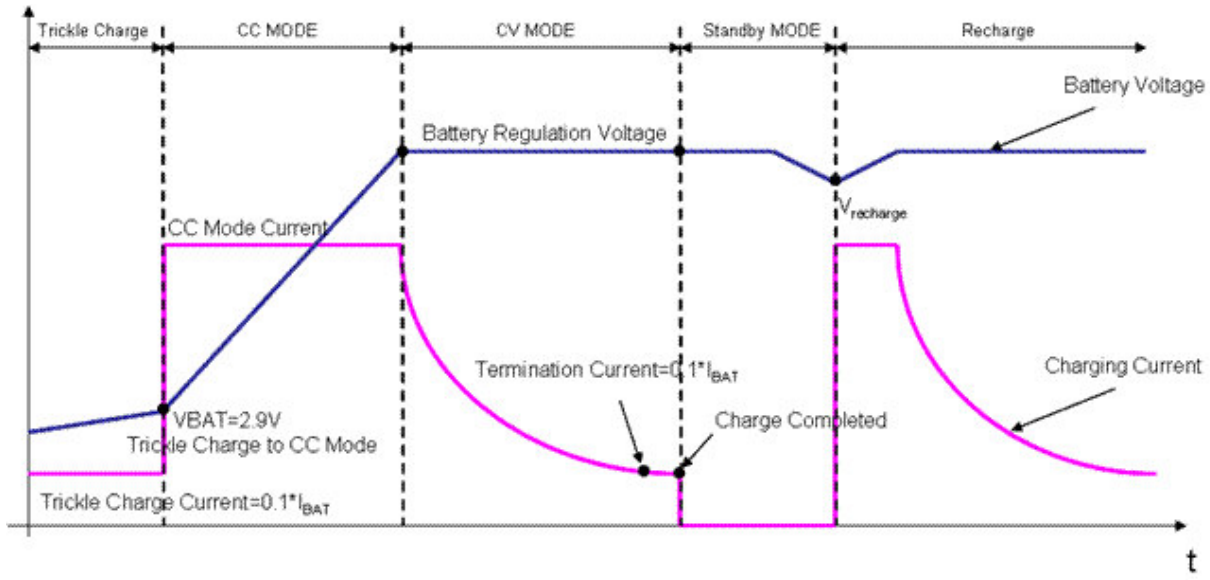
■ Detailed Description

The AME2056 is a linear battery charger designed for single cell lithium-ion batteries. The charger has CC/CV modes with programmable charging current. Charging current is programmed by an external resistor. No blocking diode or external sense resistor are required.

State Diagram of A Typical Charge Cycle

A charge cycle starts when the V_{CC} pin voltage rises above the UVLO threshold. If the voltage at BAT pin is smaller than 2.9V, the charger is operating in trickle mode. AME2056 supplies 1/10 programmed current to the battery. When the BAT pin voltage is greater than 2.9V, the charger enters constant-current mode. The charger supplies the programmed current to the battery. When the voltage at BAT pin approaches the float voltage (4.2V), the charger operates in constant-voltage mode and the charging current is decreased. A charge cycle is terminated when the charging current drops below 1/10 programmed current after the float voltage is reached. When the charging current falls below 1/10 programmed charging current for longer than T_{TERM} (1.8ms), charging is terminated. The AME2056 enters in standby mode.





Setting Charge Current

The charging current can be programmed by a resistor connected from the PROG pin to ground. The battery charging current is 1200 times the PROG pin flowing out current. The value of required resistor can be calculated by the following equation:

$$R_{PROG} = \frac{1200}{I_{CHG(MAX)}}$$

The instantaneous charging current provided to the battery can be determined by monitoring the PROG pin voltage with the following equation:

$$I_{CHG} = \frac{1200}{R_{PROG}}$$

Charge status indicator

AME2056 has two status indicators $\overline{\text{CHRG}}$ and $\overline{\text{STDBY}}$. When the charger is operating in charging status, the $\overline{\text{CHRG}}$ and $\overline{\text{STDBY}}$ outputs enter strong pull-down and high impedance status, respectively. If the battery is in full status, the $\overline{\text{CHRG}}$ and $\overline{\text{STDBY}}$ outputs enter high impedance and strong pull-down, respectively. When the TEMP pin voltage is greater than V_{TEMP-H} or lower than V_{TEMP-L}, the $\overline{\text{CHRG}}$ and $\overline{\text{STDBY}}$ outputs enter high impedance.

When the TEMP pin is short to ground for disable the temperature protection and the battery is not to connect BAT pin, the light of $\overline{\text{CHRG}}$ and $\overline{\text{STDBY}}$ are flicker and bright, respectively.

Charger's Status	Red led $\overline{\text{CHRG}}$	Green led $\overline{\text{STDBY}}$
Charging	light	dark
Battery in full state	dark	light
Under-voltage, battery's temperature is to high or too low, or not connect to battery(use TEMP)	dark	dark
BAT pin is connected to 10uF capacitor, No battery mode (TEMP=GND)	Green LED bright, Red LED flicker	

Thermal Protection

The internal thermal feedback loop of AME2056 reduces the charging current when the die temperature rises above approximately 145°C. The function protects the AME2056 from excessive temperature and allow user to push the limits of the power handing capability without risk of damaging AME2056.

Battery Temperature Fault Monitoring

In the battery over-temperature condition, the charger will turn off the internal pass device. Two internal compared voltage references V_{TEMP-H} and V_{TEMP-L} are 80%*V_{CC} and 45%*V_{CC}, respectively. When the voltage at TEMP pin rises above V_{TEMP-H} or falls below V_{TEMP-L}, AME2056 stops charging. After the system recover from a temperature fault, the charger will resume operation. If applications do not need the function, short the TEMP pin to ground.

The resistance of R1 and R2 are set according to the battery temperature range and the value of thermal sensitive resistor. Assume the battery is equipped with NTC thermistor and the temperature range is T_L to T_H (T_L<T_H). The thermistor resistance R_T decreases as temperature increases from T_L to T_H.

The TEMP pin voltage can be calculated as:

$$V_{TEMP} = \frac{R2 // R_T}{R1 + R2 // R_T} \times V_{CC}$$

The V_{TEMP} decreases as the temperature increase from T_L to T_H.

R1 and R2 resistance are set for temperature:

$$0.8 \times V_{CC} = V_{TEMP-H} = \frac{R2 // R_{TL}}{R1 + R2 // R_{TL}} \times V_{CC} \quad \text{at } T_L$$

$$0.45 \times V_{CC} = V_{TEMP-L} = \frac{R2 // R_{TH}}{R1 + R2 // R_{TH}} \times V_{CC} \quad \text{at } T_H$$

Where R_{TL} and R_{TH} are the thermistor resistances at T_L and T_H, respectively.

The R1 and R2 can be derived as following:

$$R1 = \frac{R_{TL} \times R_{TH} \times (V_{TEMP-H} - T_{TEMP-L})}{(R_{TL} - R_{TH}) \times V_{TEMP-H} \times T_{TEMP-L}}$$

$$R2 = \frac{R_{TL} \times R_{TH} \times (V_{TEMP-H} - T_{TEMP-L})}{R_{TL} \times (T_{TEMP-L} - T_{TEMP-H} \times T_{TEMP-L}) - R_{TH} \times (T_{TEMP-L} - T_{TEMP-H} \times T_{TEMP-L})}$$

Under Voltage Lockout (UVLO)

The AME2056 incorporates an under voltage lockout circuit to keep the device disabled when V_{CC} is below the UVLO rising threshold voltage. Once the UVLO rising threshold voltage is reached, the device start-up begins. The device operates until V_{CC} falls below the UVLO falling threshold voltage. The typical hysteresis in the UVLO comparator is 200mV.

Manual Shutdown

The AME2056 can be shutdown by removing RPROG or pull the CE pin to the low-level voltage. A new charge cycle is restarted by reconnecting the program resistor or pulling the CE pin to high-level voltage.

Automatic Recharge

After the charge cycle is terminated, the AME2056 monitors the BAT pin voltage by a comparator with a 1.8ms filter time ($T_{RECHARGE}$). When the BAT pin voltage drops below 4.1V, a charge cycle restarts. The function can keep the battery near a fully charged condition.

Stability Considerations

In constant-current mode, the feedback loop includes the PROG pin. Because of the additional pole created by the PROG pin capacitor and resistor. The equivalent capacitance on this pin must be kept to minimum for the maximum allowed program resistor. The pole frequency created by the PROG pin should be kept above 100kHz. When the PROG pin is loaded with a capacitor, CPROG, the following equation can be used to calculate the maximum resistance.

$$R_{PROG} \leq \frac{1}{2 \times \pi \times 10^5 \times C_{PROG}}$$

Generally, the average battery current may be of interest to the user rather than instantaneous current. A simple RC filter can be used on the PROG pin to measure the average battery current as shown in Figure 1. A 10K resistor has been added between the PROG pin and the filter capacitor to ensure stability.

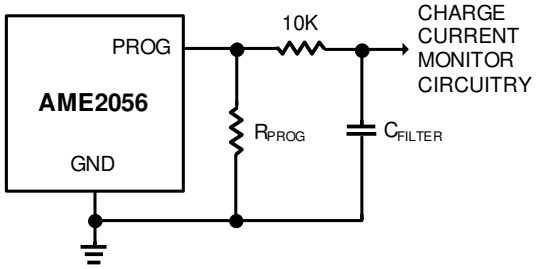


Figure 1

Power Dissipation

AME2056 has thermal feedback protection to reduce the charging current in overload condition, so the power dissipation is required to consider. The power dissipation definition is:

$$P_D = (V_{CC} - V_{BAT}) \times I_{BAT}$$

Where P_D is power dissipated, V_{CC} is the input supply current, V_{BAT} is the battery voltage and I_{BAT} is the charge current.

AME2056 will automatically reduce the charging current to maintain the die temperature under 145°C approximately, so it is not necessary to check maximum power dissipation. The ambient temperature of thermal feedback protection is:

$$T_A = 145^o C - P_D \times \theta_{JA} = 145^o C - (V_{CC} - V_{BA}) \times \theta_{JA}$$

For example: AME2056 operating from a 5V power providing 0.8A to a 3.75V Li-Ion battery. The maximum ambient temperature which the AME2056 operates in 0.8A condition can be calculated:

$$T_A = 145^o C - (5V - 3.75V) \times 0.8A \times 84^o C / W = 57^o C$$

The AME2056 can be used above 57°C, but the charging current will be reduced below 0.8A. The charging current can be calculated:

$$I_{BAT} = \frac{145^o C - T_A}{(V_{CC} - V_{BAT}) \times \theta_{JA}}$$

According to the previous example with ambient temperature of 90°C, the charging current is reduced to:

$$I_{BAT} = \frac{145^o C - 90^o C}{(5 - 3.75) \times 84} = 524mA$$

Layout Consideratons

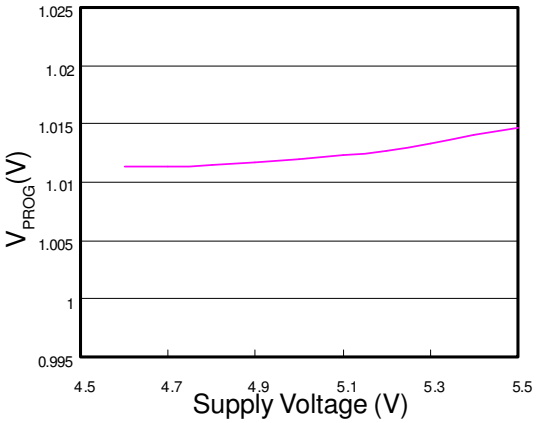
The good thermal conduction PCB layout is very important to apply to maximize the available charging current. The thermal path is from the die to the PCB. The PCB is the heat sink. The copper pads footprint should be as large as possible and expand out to large copper areas to spread and dissipate the heat to the ambient. Other heat source must be considered when designing a PCB layout because they will affect overall temperature rise and maximum charging current.

V_{cc} Bypass Capacitor

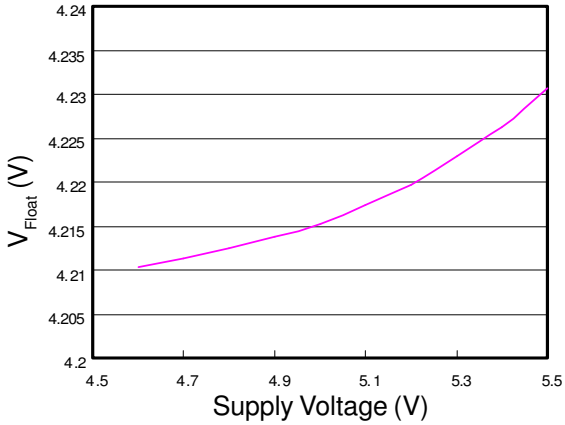
Many types of capacitors can be used as input bypass capacitor. However, the high voltage transients can be generated under some start-up conditions when using the self-resonant and high Q characteristics of ceramic capacitors. Adding a 0.4Ω resistor in series with an X5R ceramic capacitors will minimize start-up voltage transients.

■ Characterization Curve

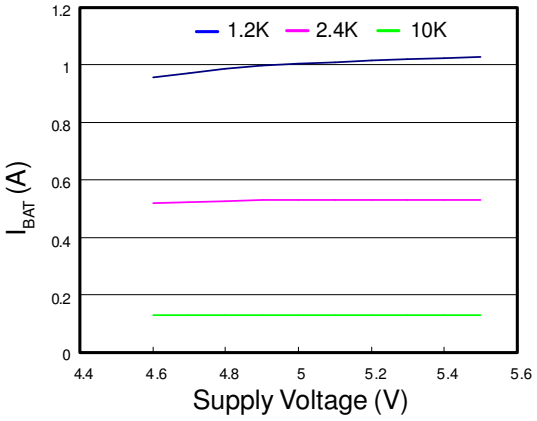
PROG Pin Voltage vs. Supply Voltage
(Constant Current Mode)



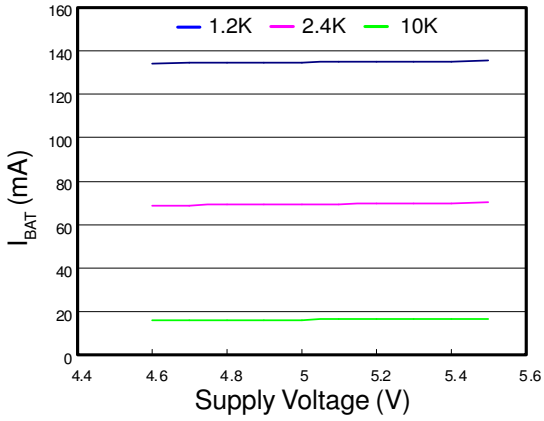
Battery Regulation (Float) Voltage
vs. Supply Voltage



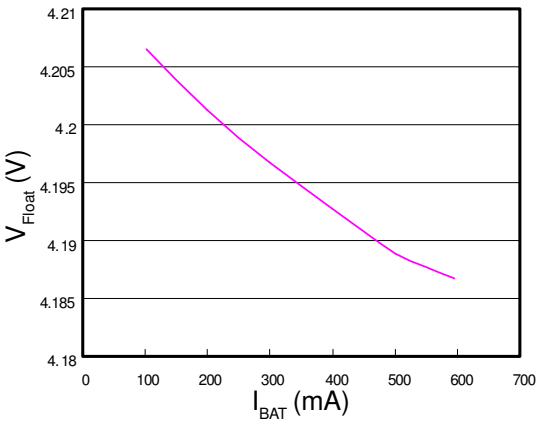
Charge Current vs. Supply Voltage



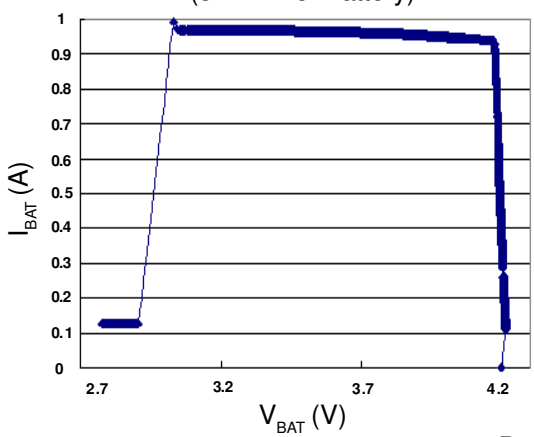
Trickle Charge Current
vs. Supply Voltage



Battery Regulation (Float)
Charge Current

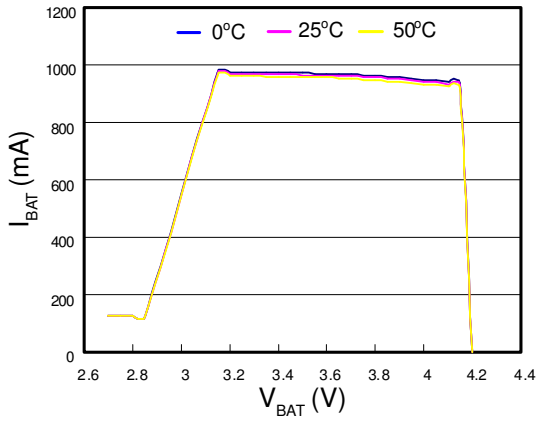


Charge Current vs. Battery Voltage
(3.7V Li-Ior Battery)

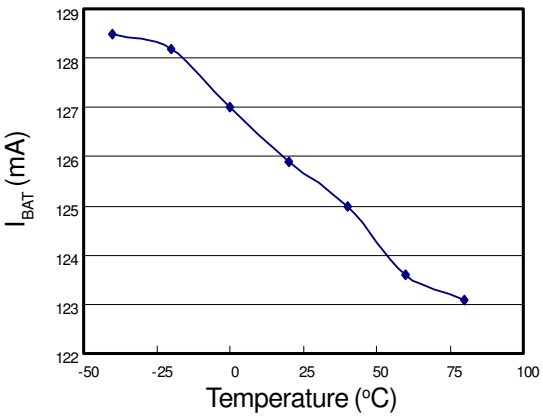


■ Characterization Curve

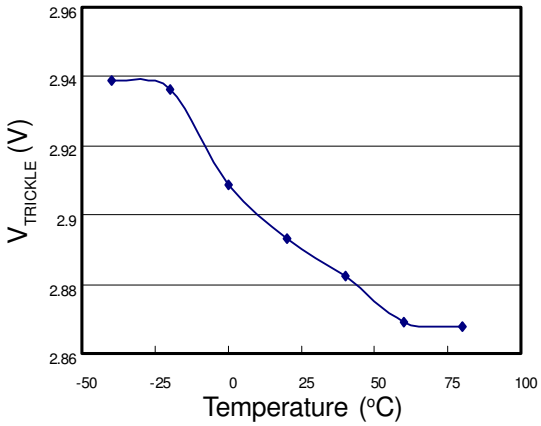
Charge Current vs. Battery Voltage



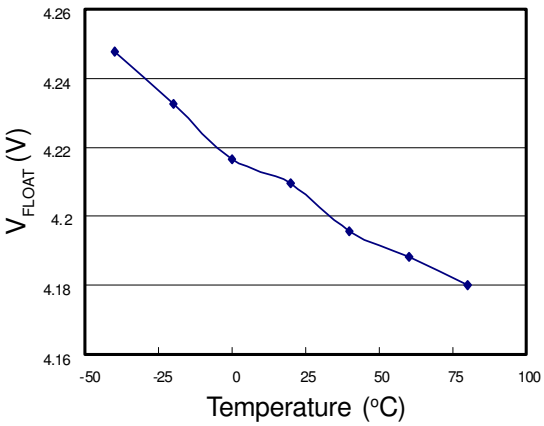
Trickle Charge Current vs. Temperature



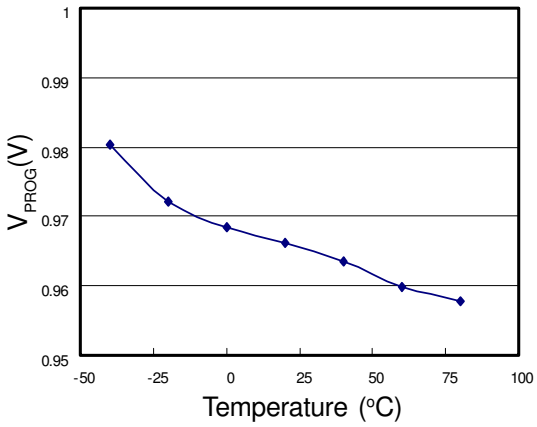
Trickle Charge Threshold vs. Temperature



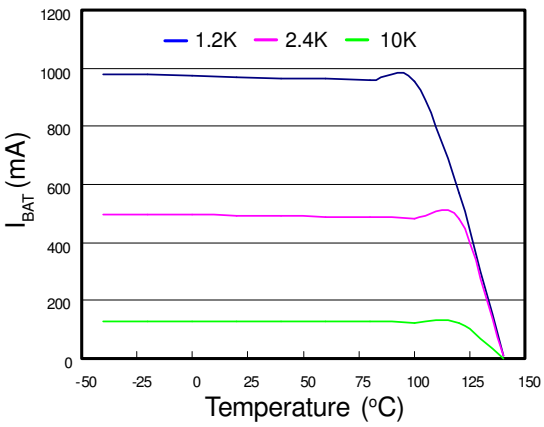
Battery Regulation (Float) Voltage vs. Temperature



PROG Pin Voltage vs. Temperature

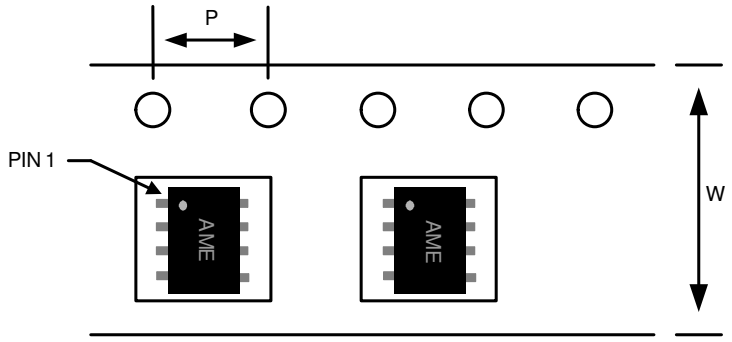


Charge Current vs. Temperature



■ Tape and Reel Dimension

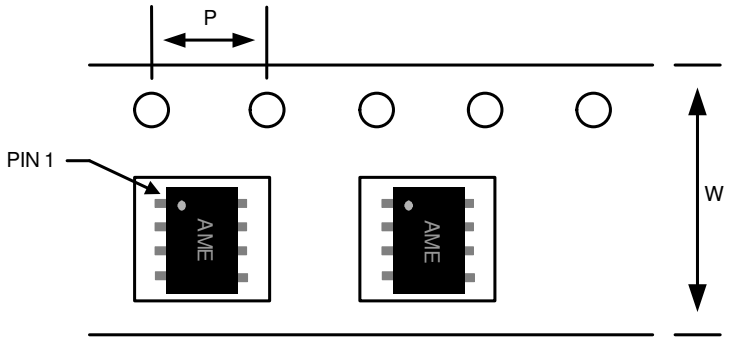
SOP-8/PP



Carrier Tape, Number of Components Per Reel and Reel Size

Package	Carrier Width (W)	Pitch (P)	Part Per Full Reel	Reel Size
SOP-8/PP	12.0±0.1 mm	4.0±0.1 mm	2500pcs	330±1 mm

MSOP-8

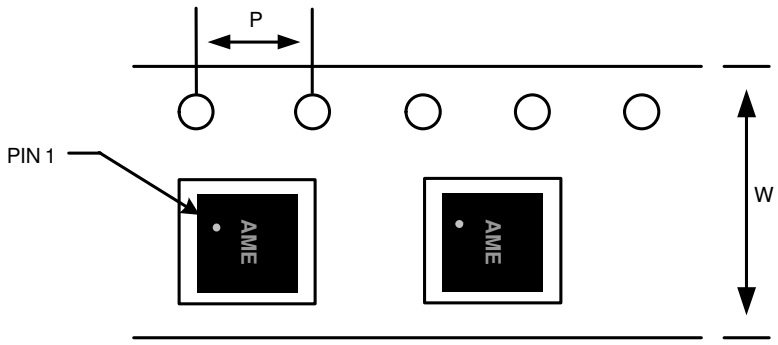


Carrier Tape, Number of Components Per Reel and Reel Size

Package	Carrier Width (W)	Pitch (P)	Part Per Full Reel	Reel Size
MSOP-8	12.0±0.1 mm	4.0±0.1 mm	4000pcs	330±1 mm

■ Tape and Reel Dimension (Contd.)

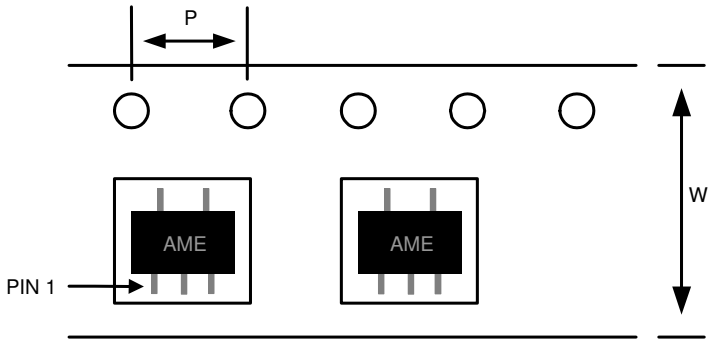
DFN-8D
(2mmx2mmx0.75mm)



Carrier Tape, Number of Components Per Reel and Reel Size

Package	Carrier Width (W)	Pitch (P)	Part Per Full Reel	Reel Size
DFN-8D (2x2x0.75mm)	8.0±0.1 mm	4.0±0.1 mm	3000pcs	180±1 mm

SOT-25

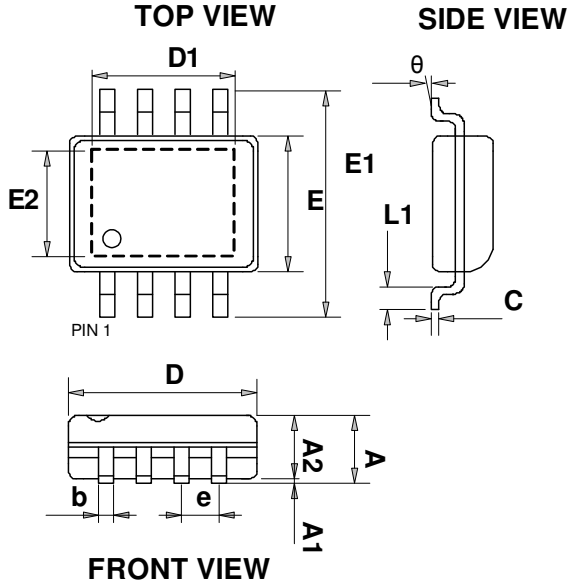


Carrier Tape, Number of Components Per Reel and Reel Size

Package	Carrier Width (W)	Pitch (P)	Part Per Full Reel	Reel Size
SOT-25	8.0±0.1 mm	4.0±0.1 mm	3000pcs	180±1 mm

■ Package Dimension

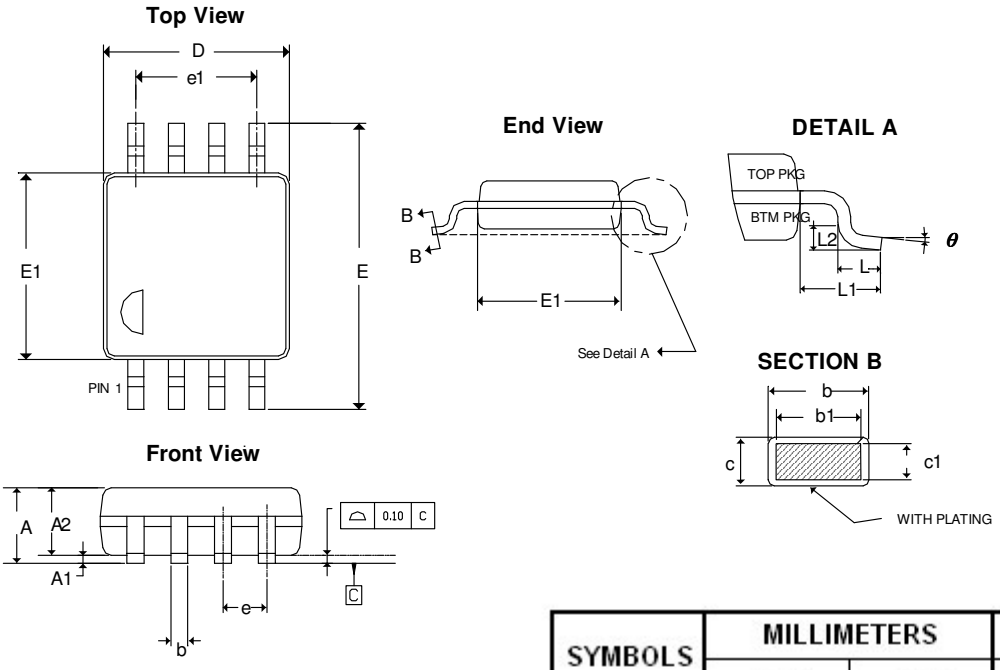
SOP-8/PP



SYMBOLS	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	1.350	1.750	0.053	0.069
A1	0.000	0.250	0.000	0.010
A2	1.250	1.650	0.049	0.065
C	0.100	0.250	0.004	0.010
E	3.750	4.150	0.148	0.163
E1	5.700	6.300	0.224	0.248
L1	0.300	1.270	0.012	0.050
b	0.310	0.510	0.012	0.020
D	4.720	5.120	0.186	0.202
e	1.270 BSC		0.050 BSC	
θ	0^o	8^o	0^o	8^o
E2	2.050	2.513	0.081	0.099
D1	2.150	3.402	0.085	0.134

■ Package Dimension (Contd.)

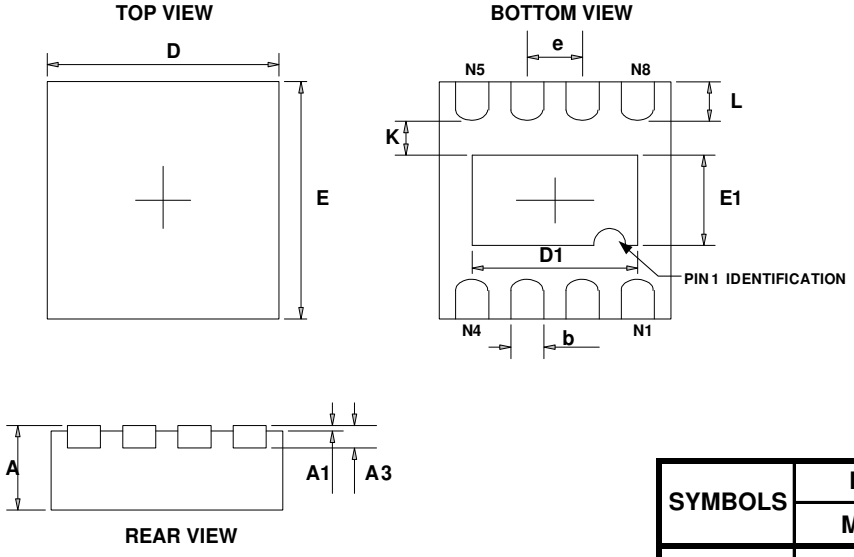
MSOP-8



SYMBOLS	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	-	1.10	-	0.043
A_1	0.00	0.20	0.000	0.008
A2	0.75	0.95	0.029	0.037
b	0.25	0.38	0.010	0.015
b1	0.28	0.33	0.011	0.013
c	0.08	0.23	0.003	0.009
c1	0.13	0.17	0.005	0.007
D	2.90	3.10	0.114	0.122
E	4.75	5.05	0.187	0.199
E1	2.90	3.10	0.114	0.122
e	0.65 TYP		0.026 TYP	
e1	1.95 TYP		0.077 TYP	
L	0.40	0.80	0.016	0.031
L1	0.94 REF		0.037 REF	
L2	0.254 TYP		0.010 TYP	
θ	0°	8°	0°	8°

■ Package Dimension (Contd.)

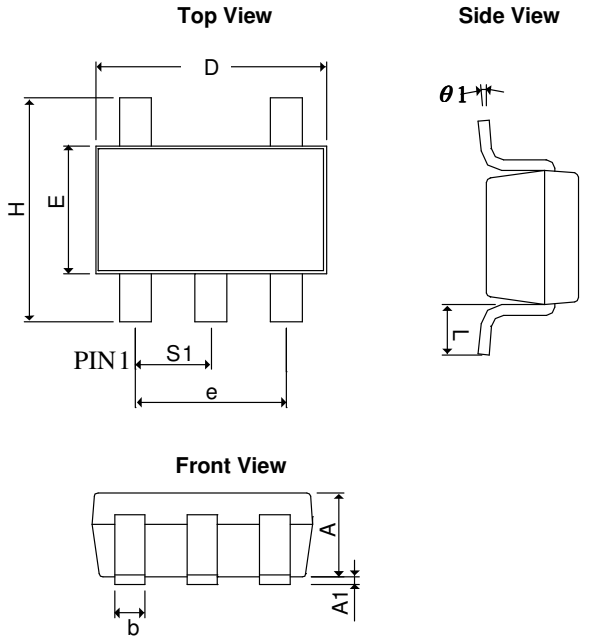
DFN-8D
(2mmx2mmx0.75mm)



SYMBOLS	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	0.700	0.800	0.028	0.031
A1	0.000	0.050	0.000	0.002
A3	0.203 REF		0.008 REF	
D	1.900	2.100	0.075	0.083
E	1.900	2.100	0.075	0.083
D1	1.100	1.650	0.043	0.065
E1	0.500	0.950	0.020	0.037
K	0.200 MIN		0.008 MIN	
b	0.180	0.300	0.007	0.012
e	0.500 TYP		0.020 TYP	
L	0.200	0.450	0.008	0.018

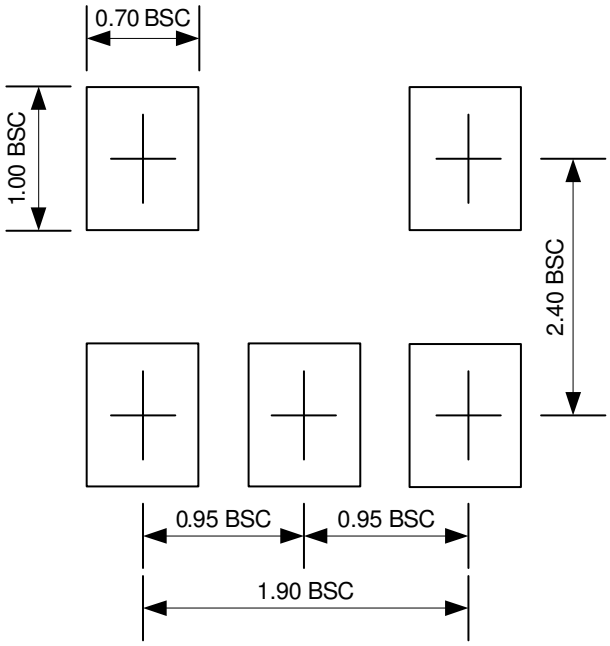
■ Package Dimension (Contd.)

SOT-25



SYMBOLS	MILLIMETERS		INCHES	
	MIN	MAX	MIN	MAX
A	0.90	1.30	0.0354	0.0512
A_1	0.00	0.15	0.0000	0.0059
b	0.30	0.55	0.0118	0.0217
D	2.70	3.10	0.1063	0.1220
E	1.40	1.80	0.0551	0.0709
e	1.90 BSC		0.0748 BSC	
H	2.60	3.00	0.1024	0.1181
L	0.37 BSC		0.0146 BSC	
θ1	0°	10°	0°	10°
S_1	0.95 BSC		0.0374 BSC	

Lead Pattern Drawing



Note:

1. Lead pattern unit description:
   BSC: Basic. Represents theoretical exact dimension or dimension target.
2. Dimensions in Millimeters.
3. General tolerance ±0.05mm unless otherwise specified.



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Document: A022A-DS2056-A.04

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