

1A Linear Lithium Battery Charger With Thermal Regulation MX4036

1 Features

- ◆ Constant-Current/Constant-Voltage Operation with Thermal Regulation to Maximize Charge Rate Without Risk of Overheating
- ◆ Continuous Programmable Charge Current Up to 1A
- ◆ No MOSFET, Sense Resistor or Blocking Diode Required
- ◆ Preset 4.2V/4.35V/4.05V/4.4V/4.1V Charge Voltage with $\pm 1\%$ Accuracy
- ◆ Charge Status Output Pin
- ◆ Battery Temperature Sensing
- ◆ C/10 Charge Termination
- ◆ 2.9V Trickle Charge Threshold
- ◆ 100 μ A Supply Current in Shutdown mode
- ◆ Automatic Recharge

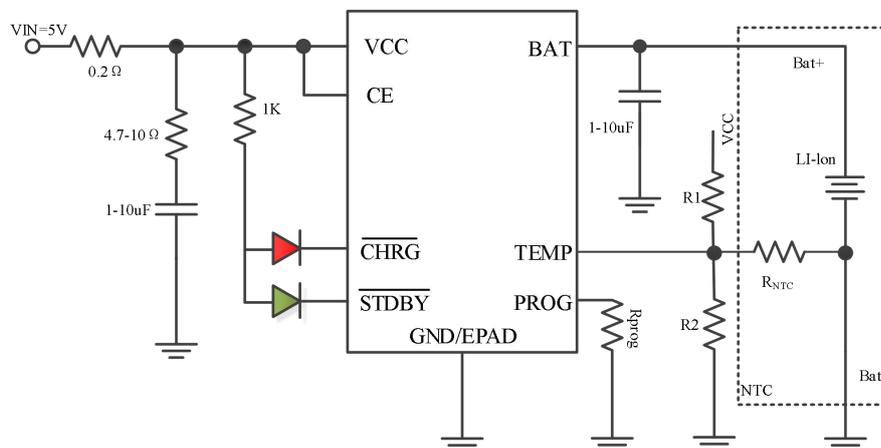
2 Applications

- ◆ MP3 /MP4 Players
- ◆ Wireless handsets
- ◆ USB charge applications
- ◆ Charging docks, charging cradles

3 Description

The MX4036 is a complete constant-current /constant-voltage linear charger for single cell lithium rechargeable battery. No external sense resistor is needed, and no blocking diode is required due to the internal P-MOSFET architecture. Furthermore, the MX4036 is specifically designed to work within USB power specifications. It's package and low external component count make the MX4036 ideally suited for portable applications. An internal block regulates the current when the junction temperature increases, in order to protect the device when it operates in high power or high ambient temperature. The charge voltage is fixed at 4.2V/4.35V/4.05V/4.4V/4.1V, and the charge current can be programmed externally with a single resistor. The MX4036 automatically terminates the charge cycle when the charge current drops to 1/10th the programmed value after the final float voltage is reached. When the input supply (wall adapter or USB supply) is removed, the MX4036 automatically enters a low power sleep mode, dropping the battery drain current to less than 2 μ A.

Simplified Schematic



Device Information

ORDERABLE DEVICE	VOLTAGE (V)	DEVICE MARKING ⁽¹⁾	PACKAGE TYPE	PACKAGE SIZE (mm)	PACKAGE QTY.(Reel&Tape)
MX4036AE8	4.2	MX4036A E8xyz	ESOP8	4.9 x 3.9 x 1.5	4000
MX4036AD8	4.2	MX4036A D8xyz	DFN2*2-8	2.0 x 2.0x 0.75	3000
MX4036ADA	4.2	MX4036A DAxyz	DFN3*3-8	3.0 x 3.0x 0.75	3000
MX4036BE8	4.35	MX4036B E8xyz	ESOP8	4.9 x 3.9 x 1.5	4000
MX4036BD8	4.35	MX4036B D8xyz	DFN2*2-8	2.0 x 2.0x 0.75	3000
MX4036BDA	4.35	MX4036B DAxyz	DFN3*3-8	2.0 x 2.0x 0.75	3000
MX4036CE8	4.05	MX4036C E8xyz	ESOP8	4.9 x 3.9 x 1.5	4000
MX4036CD8	4.05	MX4036C D8xyz	DFN2*2-8	2.0 x 2.0x 0.75	3000
MX4036CDA	4.05	MX4036C DAxyz	DFN3*3-8	3.0 x 3.0x 0.75	3000
MX4036DE8B	4.4	MX4036D E8Bxyz	ESOP8	4.9 x 3.9 x 1.5	4000
MX4036DD8B	4.4	MX4036D D8Bxyz	DFN2*2-8	2.0 x 2.0x 0.75	3000
MX4036DDAB	4.4	MX4036D DABxyz	DFN3*3-8	3.0 x 3.0x 0.75	3000
MX4036EE8	4.1	MX4036E E8xyz	ESOP8	4.9 x 3.9 x 1.5	4000
MX4036ED8	4.1	MX4036E D8xyz	DFN2*2-8	2.0 x 2.0x 0.75	3000
MX4036EDA	4.1	MX4036E DAxyz	DFN3*3-8	3.0 x 3.0x 0.75	3000

(1) "MX4036A/B/C/D/E" is device code, "E8/D8/DA" is package code, "x" is year code, "y" is month code, "z" is lot number code.

4 Pin Configuration and Functions

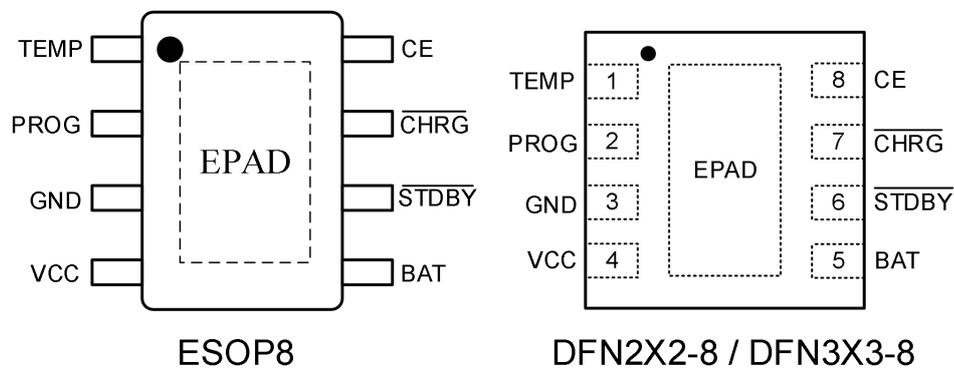


Figure 1.Pin Configuration

PIN NO.	NAME	DESCRIPTION
1	TEMP	Battery temperature detection Pin. When external temperature detection is not required Function, the TEMP can be connected directly to GND.
2	PROG	Charge Current Program, Charge Current Monitor and Shutdown Pin.
3	GND	Ground pin.
4	VCC	Positive Input Supply Voltage.
5	BAT	Charge Current Output. Provides charge current to the battery and regulates the final float voltage to 4.2V/4.35V/4.05V/4.4V/4.1V.
6	$\overline{\text{STDBY}}$	Open-Drain Output for Charge Finished flag. The STDBY pin outputs low when the battery is finished charging. When in the status of charging, it becomes high impedance.
7	$\overline{\text{CHRG}}$	Open-Drain Charge Status Output Pin.
8	CE	Enable the IC charge or not. Drive this pin high or floating to enable charger, low to disable.

5 Specifications

5.1 Absolute Maximum Ratings

Over operating temperature range(25°C) (unless otherwise noted)⁽¹⁾

ITEM		MIN	MAX	UNIT
Voltage (²)	VCC	-0.3	30	V
	PROG	-0.3	10	V
	TEMP、CHRG、STDBY	-0.3	30	V
	CE	-6.5	30	V
	BAT	-4.35	13	V
BAT Pin Output Current			1200	mA
PROG Pin Output Current			1200	μA
Maximum junction temperature, T _J		-40	145	°C
Storage temperature, T _{stg}		-65	125	°C
Junction-to-ambient thermal resistance, R _{θJA} (ESOT8)			63	°C/W
Junction-to-ambient thermal resistance, R _{θJA} (DFN2*2-8)			98	°C/W
Junction-to-ambient thermal resistance, R _{θJA} (DFN3*3-8)			80	°C/W

(1) Stresses beyond those listed under absolute maximum ratings may cause permanent damage to the device. These are stress ratings only and the device is not switching. Functional operation of the device at these or any other conditions beyond those indicated under recommended perating conditions is not implied. Exposure to absolute– maximum– rated conditions for extended periods may affect device reliability.

(2) All voltage values are with respect to network ground terminal .

5.2 Recommended Operating Conditions

ITEM	MIN	MAX	UNIT
Operating junction temperature ⁽¹⁾	-40	125	°C/W
Operating ambient temperature	-40	85	°C/W

(1) All limits specified at room temperature (TA = 25°C) unless otherwise specified. All room temperature limits are 100% production tested. All limits at temperature extremes are ensured through correlation using standard Statistical Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).

5.3 Electrical Characteristics

$V_{CC}=5V$, $T_A=25^{\circ}C$, unless otherwise specified.

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{CC}	Input Voltage Range		4.5	5	6.5	V
V_{OVP}	Over-Voltage Protection Threshold			6.8		V
I_{CC}	Input Supply Current	Charge Mode, $R_{PROG}=1K$		150	500	μA
		Standby Mode (Charge Terminated)		100	200	μA
		Shutdown Mode (R_{PROG} Not Connected, $V_{CC}<V_{BAT}$, or $V_{CC}<V_{UV}$)		50	200	μA
V_{FLOAL}	Regulated Output (Float) Voltage	$0^{\circ}C \leq T_A \leq 85^{\circ}C$	4.158	4.2	4.242	V
			4.306	4.35	4.394	V
			4.009	4.05	4.091	V
			4.356	4.4	4.444	V
			4.059	4.1	4.141	V
I_{BAT}	BAT Pin Current: ($V_{BAT}=4.0V$)	$R_{PROG}=1K$, Current Mode	900	1000	1100	mA
		Standby Mode, $V_{BAT}=V_{FLOAL}$	0	-2	-6	μA
		Shutdown Mode (R_{PROG} Not Connected)		± 1	± 2	μA
		Sleep Mode, $V_{CC}=0V$		-1	-2	μA
I_{TRIKL}	Trickle Charge Current	$V_{BAT}<V_{TRIKL}$, $R_{PROG}=1K$		100		mA
V_{TRIKL}	Trickle Charge Threshold Voltage	$R_{PROG}=1K$, V_{BAT} Rising	2.7	2.9	3.1	V
V_{TRHYS}	Trickle Charge Hysteresis Voltage	$R_{PROG}=1K$		300		mV
V_{UV}	V_{CC} Undervoltage Lockout Threshold	From V_{CC} Low to High		3.9		V
V_{UVHYS}	V_{CC} Undervoltage Lockout Hysteresis			260		mV
V_{ASD}	$V_{CC} - V_{BAT}$ Lockout Threshold Voltage	From V_{CC} Low to High		150		mV
		From V_{CC} High to Low		70		mV
I_{TERM}	C/10 Termination Current Threshold	$R_{PROG}=1K$		115		mA
V_{PROG}	PROG Pin Voltage	$R_{PROG}=1K$, Current Mode	0.9	1.0	1.1	V
V_{CHRG}	Pin Weak Pull-Down Current	$V_{CHRG}=5mA$		1.2	2	V
V_{STDBY}	Pin Weak Pull-Down Current	$V_{STDBY}=5mA$		1.2	2	V
V_{TEMP-H}	TEMP High Shift Voltage Level		42	45		$\%V_{CC}$
V_{TEMP-L}	TEMP Low Shift Voltage Level			80	83	$\%V_{CC}$
ΔV_{RECHRG}	Pin Weak Pull-Down Current	$V_{FLOAL}-V_{RECHRG}$		250		mV
V_{CEON}	CE Pin Logic Input High		2.0			V
V_{CEOFF}	CE Pin Logic Input low				0.4	V

Note1: *---The parameter is guaranteed by design.

6 Operation information

6.1 Functional Block Diagram

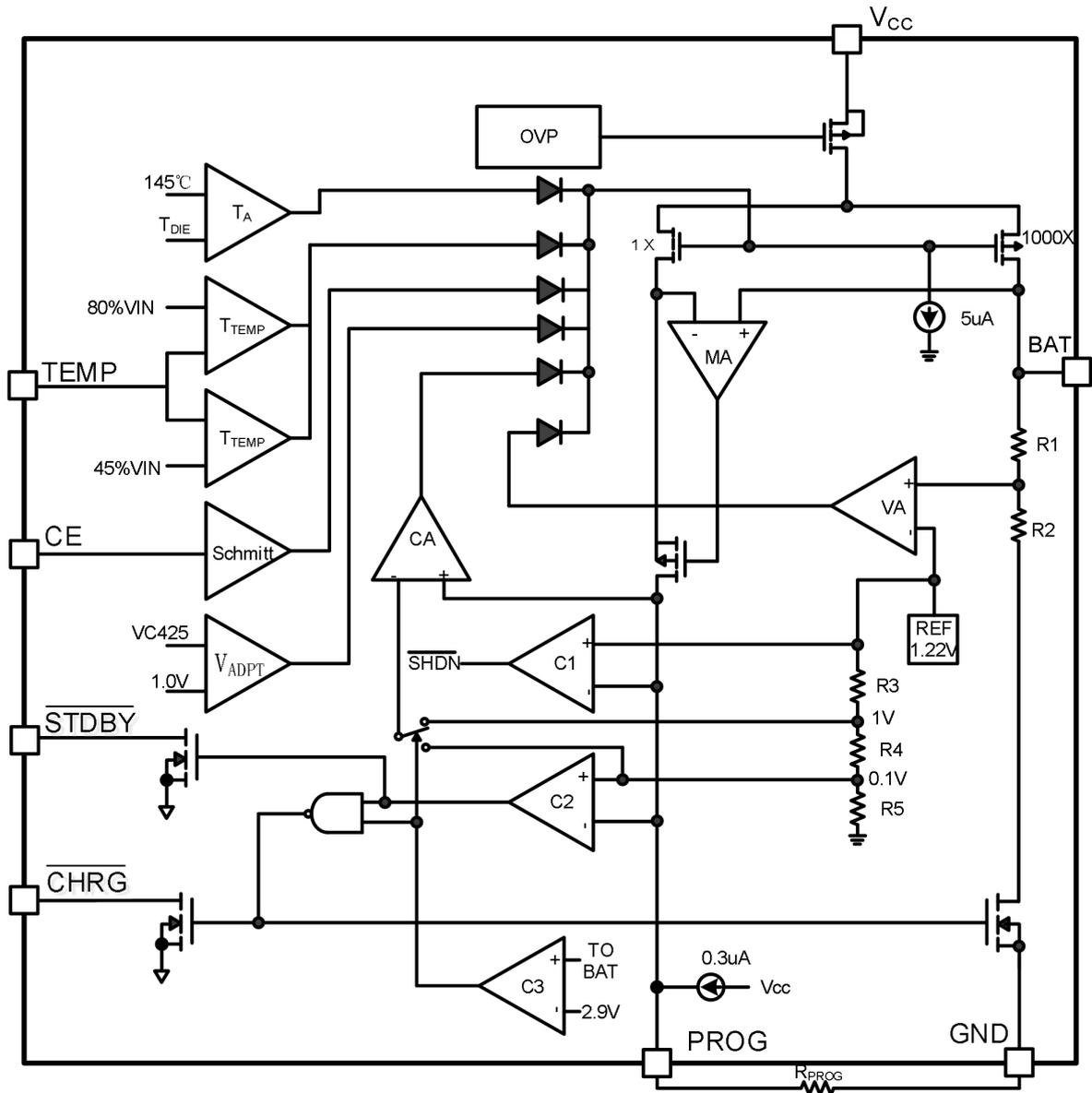


Figure 2. MX4036 Functional Block Diagram

6.2 Operation information

The MX4036 is a single cell Lithium-Ion battery charger using a constant-current/constant-voltage algorithm. It can deliver up to 1000mA of charge current with a final float voltage accuracy of 1%. The MX4036 uses an internal P-Channel MOSFET to work in constant current and constant voltage method. No blocking diode and sensing resistor are required. It is also possible to use an USB port as power supply voltage. The series charge status output pin, $\overline{\text{CHRG}}$ pin and $\overline{\text{STDBY}}$ pin, is capable of checking the IC's charging state via connection to an external LED.

Battery Preconditioning

Before the start of charging, the MX4036 checks several conditions in order to assure a safe charging

environment. The input supply must be above the minimum operating voltage, or under-voltage lockout threshold (V_{UV}), for the charging sequence to begin. When these conditions have been met and a battery is connected to the BAT pin, the MX4036 checks the state of the battery. If the BAT pin is less than 2.9V, the charge control begins preconditioning the cell. The battery preconditioning trickle charge current is equal to the fast charge constant current divided by 10. For example, if the programmed fast charge current is 300mA, then the preconditioning mode (trickle charge) current will be 30mA. Cell preconditioning is a safety precaution for deeply discharged battery cells and also aids in limiting power dissipation in the pass transistor when the voltage across the device is at the greatest potential.

Programming Charge Current

Programming Charge Current The charge current is programmed using a single resistor from the PROG pin to ground. The battery charge current is 1000 times the current out of the PROG pin. The program resistor and the charge current are calculated using the following equations:

$$R_{PROG} = \frac{1000V}{I_{BAT}}$$

When the BAT pin voltage rises above 2.9V, the charger enters constant-current mode, where the programmed charge current is supplied to the battery. The charge current out of the BAT pin can be determined at any time by monitoring the PROG pin voltage using the following equation:

$$I_{BAT} = \frac{V_{PROG}}{R_{PROG}} * 1000$$

This actual current will vary from IC to IC. The typical variation is within +/-20%.

Charge Termination

Charge Termination The MX4036 keeps monitoring the PROG pin during the charging process. It terminates the charge cycle when the charge current falls to 1/10 the programmed value after the final float voltage is reached. MX4036DxB version, after the indicator light turns, but the charging current does not stop, the charging current gradually decreases and the battery voltage is maintained at VFLOAL. When the PROG pin voltage falls below 100mV for longer than t_{TERM} (typically 1.8ms), charging is terminated. The charge current is latched off and the MX4036 enters standby mode, where the input supply current drops to 100 μ A. (Note: C/10 termination is disabled in trickle charging and thermal limiting modes).

During charging, the transient response of the circuit can cause the PROG pin to fall below 100mV temporarily before the battery is fully charged, thus can cause a premature termination of the charge cycle. A 1.8ms filter time on the termination comparator can prevent this from happening. Once the average charge current drops below 1/10 the programmed value, the MX4036 terminates the charge cycle and ceases to provide any current through the BAT pin.

In this state, all loads on the BAT pin must be supplied by the battery. The MX4036 constantly monitors the BAT pin voltage in standby mode and resume another charge cycle if this voltage drops below the recharge threshold. User can also manually restart a charge cycle in standby mode either by removing and then reapplied the input voltage or restart the charger using the PROG pin.

6.3 Charge Status Indicator

CHRG

$\overline{\text{CHRG}}$ pin and $\overline{\text{STDBY}}$ pin is internally connected to an N-channel open drain MOSFET. The MX4036 family provides battery charge status via $\overline{\text{CHRG}}$ and $\overline{\text{STDBY}}$ status pin.

The open drain status output that is not used should be tied to ground. The following table lists the indicator status and its corresponding charging state.

Charge State Description		$\overline{\text{CHRG}}$	$\overline{\text{STDBY}}$
Charging Mode		ON	HI-Z
Charge Termination ($I_{\text{BAT}} < I_{\text{TERM}}$, Charge Done)		HI-Z	ON
Power Down (Undervoltage Lockout) Mode、 Sleep Mode、 Shutdown Mode		HI-Z	HI-Z
BAT Reverse		HI-Z	HI-Z
No battery with Charge Enabled (TEMP=GND、 $C_{\text{BAT}}=10\mu\text{F}$)	MX4036A/B/C	FLASH Rate depends on C_{BAT} ($T=1 - 4\text{S}$)	ON
	MX4036DxB	HI-Z	ON

6.4 Undervoltage Lockout (UVLO)

An internal undervoltage lockout circuit monitors the input voltage and keeps the charger in shutdown mode until V_{CC} rises above the undervoltage lockout threshold. The UVLO circuit has a built-in hysteresis of 200mV. If the UVLO comparator is tripped, the charger will not come out of shutdown mode until V_{CC} rises 100mV above the battery voltage.

6.5 Manual Shutdown

At any point in the charge cycle, the MX4036 can be put into shutdown mode by removing R_{PROG} thus floating the PROG pin. This reduces the battery drain current to less than $1\mu\text{A}$ and the supply current to less than $100\mu\text{A}$. A new charge cycle can be initiated by reconnecting the program resistor.

6.6 Automatic recharge

Once the charge cycle is terminated, the MX4036 continuously monitors the voltage on the BAT pin using a comparator with a 2ms filter time (T_{RECHRG}). A charge cycle restarts when the battery voltage falls below $V_{\text{RECHRG}}(\text{Typ.})$ (which corresponds to approximately 80% to 90% battery capacity). This ensures that the battery is kept at or near a fully charged condition and eliminates the need for periodic charge cycle initiations. $\overline{\text{CHRG}}$ output enters a pull-down state during recharge cycles.

6.7 Thermal regulation

An internal thermal feedback loop reduces the output current if the die temperature attempts to rise above a present value of approximately 140°C . This feature protects the device from excessive temperature and allows the user to push the limits of the power handling capability of a given circuit board without risk of damaging the device.

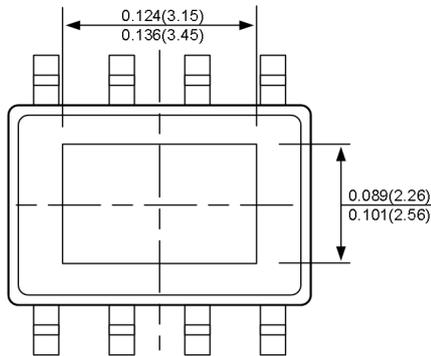
6.8 Power dissipation

It is very important to use a good thermal PC board layout to maximize the available output current. The thermal path for the heat generated by the IC is from the die to the copper lead frame through the package leads and exposed pad to the PC board copper. The PC board copper is the heat sink. The footprint copper pads should be as wide as possible and expand out to larger copper areas to spread and dissipate the heat to the surrounding ambient. Feed through vias to inner or backside copper layers are also useful in improving the overall thermal performance of the device. Other heat sources on the board, not related to the device, must also be considered when designing a PC board layout

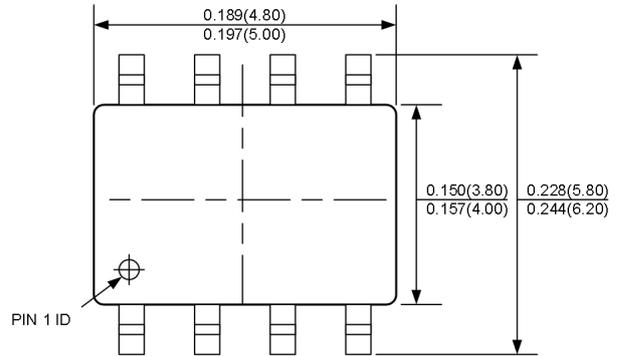
because they will affect overall temperature rise and the maximum output current.

7 Package Outline

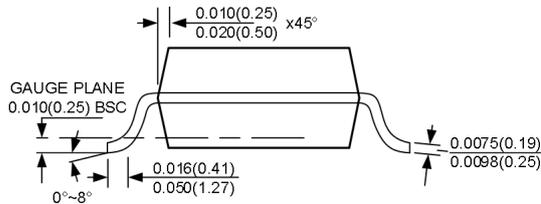
ESOP8 (EXPOSED PAD)



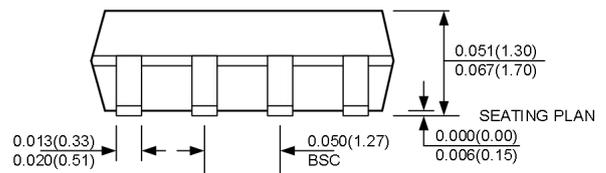
BOTTOM VIEW



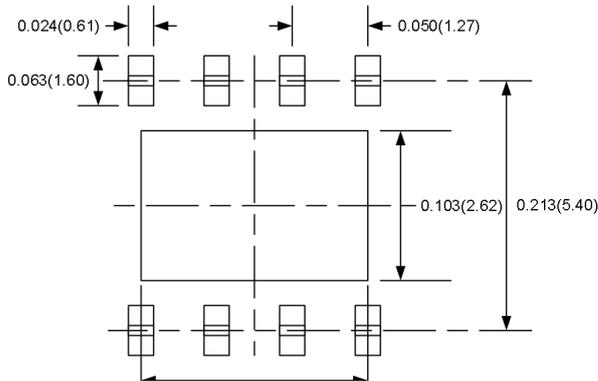
TOP VIEW



SIDE VIEW



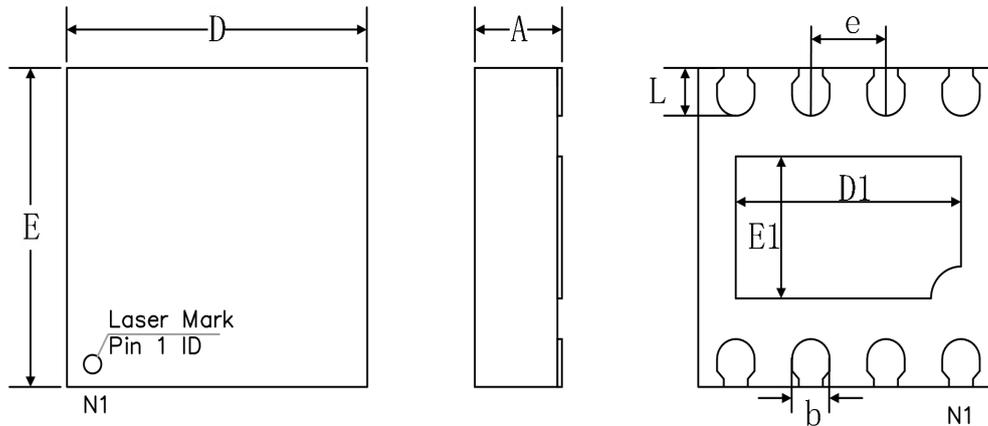
FRONT VIEW



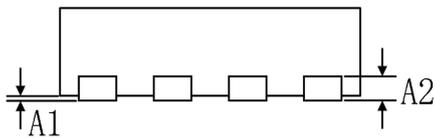
NOTE:

- CONTROL DIMENSION IS IN INCHES. DIMENSION IN BRACKET IS IN MILLIMETERS.
- PACKAGE LENGTH DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS.
- PACKAGE WIDTH DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSIONS.
- LEAD COPLANARITY (BOTTOM OF LEADS AFTER FORMING) SHALL BE 0.004" INCHES MAX.
- DRAWING CONFORMS TO JEDEC MS-012, VARIATION BA.
- DRAWING IS NOT TO SCALE.

DFN2*2-8

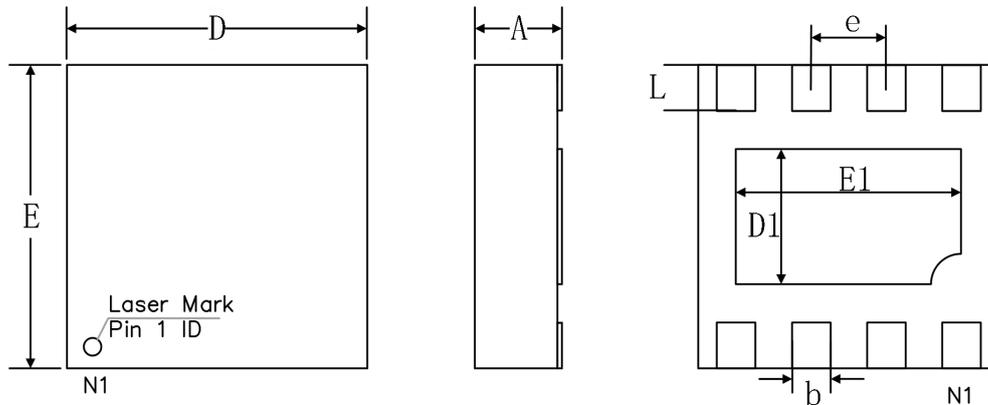


COMMON DIMENSIONS (UNITS OF MEASURE=MILLIMETER)

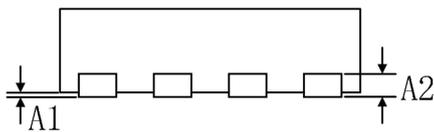


	SYMBOL	MIN	NOM	MAX
TOTAL THICKNESS	A	0.50	0.55	0.60
STAND OFF	A1	0.00	0.03	0.05
L/F THICKNESS	A2	0.152 REF		
LEAD WIDTH	b	0.20	0.25	0.30
BODY SIZE X	D	1.90	2.00	2.10
EP SIZE X	D1	1.40	1.50	1.60
BODY SIZE Y	E	1.90	2.00	2.10
EP SIZE Y	E1	0.79	0.89	0.99
LEAD PITCH	e	0.50 TYP		
LEAD LENGTH	L	0.25	0.30	0.35

0.65DFN3X3-08-0.75



COMMON DIMENSIONS
(UNITS OF MEASURE=MILLIMETER)



	SYMBOL	MIN	NOM	MAX
TOTAL THICKNESS	A	0.70	0.75	0.80
STAND OFF	A1	0.00	-	0.05
L/F THICKNESS	A2	0.203 REF		
LEAD WIDTH	b	0.23	0.28	0.33
BODY SIZE X	D	2.925	3.00	3.075
EP SIZE X	D1	1.40	1.50	1.60
BODY SIZE Y	E	2.925	3.00	3.075
EP SIZE Y	E1	2.20	2.30	2.40
LEAD PITCH	e	0.65 TYP		
LEAD LENGTH	L	0.25	0.30	0.35