■ **INTRODUCTION:**

The CE3102XM1 is a complete, constant-current/ constant-voltage linear charger for single cell lithium-ion batteries. Its small size and ability to regulate low charge currents make the CE3102XM1 especially well-suited for portable applications using low capacity rechargeable lithium-ion coin cells. Furthermore, the CE3102XM1 is specifically designed to work within USB Power specifications.

No external sense resistor is needed, and no blocking diode is required due to internal MOSFET architecture. The charge voltage is fixed at 4.2V and the charge current can be programmed externally with a single resistor. The CE3102XM1 automatically terminates the charge cycle when the charge current drops to 2/10th the programmed value after the final float voltage is reached.

When the input supply (wall adapter or USB supply) is removed, the CE3102XM1 automatically enters a low current state, dropping the battery drain current to less than 2μA. The CE3102XM1 can be put into shutdown mode, reducing the supply current to 25μA.

Other features include charge current monitor, undervoltage lockout, automatic recharge and a status pin to indicate charge termination.

■ **FEATURES:**

● Programmable Charge Current Range: 10mA to 120mA

● No External MOSFET, Sense Resistor or Blocking Diode Required

● Complete Linear Charger in SOT Package for Single Cell/Coin Cell Lithium-Ion Batteries

● Constant-Current/Constant-Voltage Operation

● Charges Single Cell Li-Ion Batteries Directly from USB Port

● Preset 4.2V Charge Voltage with ±1% Accuracy

● Charge Current Monitor Output for Gas Gauging*

● Automatic Recharge

● Charge Status Output Pin

● 0.2C Charge Termination

● 25μA Supply Current in Shutdown Mode

● Without Trickle Charge

● Soft-Start Limits Inrush Current

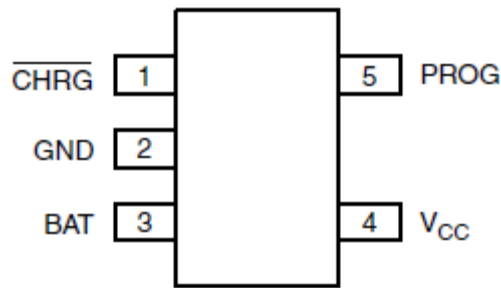● Available in 5-Lead SOT-23 Package

■ **APPLICATIONS：**

● Multifunction Wristwatches

● Bluetooth Applications

● Point of Service (POS)

● 3D Glasses

■ **ORDER INFORMATION[1]**

Operating free air temperature range	Battery Float Voltage	Package	Device No.
-40~+85℃	4.20V	SOT-23-5	CE3102XM1

(1)Contact Chipower to check availability of other battery float voltage versions.

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■ **PIN CONFIGURATION**

SOT-23-5 (Top View)

Tabel1. Pin Description

PIN NO.	PIN NAME	FUNCTION
1	$\overline{\text{CHRG}}$	**Open-Drain Charge Status Output**. When the battery is charging, the $\overline{\text{CHRG}}$ pin is pulled low by an internal N-channel MOSFET. When the charge cycle is completed, $\overline{\text{CHRG}}$ is forced high impedance. When the CE3102XM1 detects an undervoltage lockout condition, $\overline{\text{CHRG}}$ is forced high impedance.
2	GND	**Ground Terminal**.
3	BAT	**Charger Power Stage Output and Battery Voltage Sense Input**. BAT pin provides charge current to the battery and regulates the final float voltage to 4.2V. An internal precision resistor divider from this pin sets this float voltage and is disconnected in shutdown mode. Connect the positive terminal of the battery to BAT pin.
4	V_{CC}	**Charge Input Voltage and Internal Supply**. V_{CC} is the power supply to the internal circuit. V_{CC} can range from 4.25V to 6.5V and should be bypassed with at least a 1µF capacitor. When V_{CC} drops to within 30mV of the BAT pin voltage, the CE3102XM1 enters shutdown mode, dropping I_{BAT} to less than 2µA.
5	PROG	**Charge Current Program, Charge Current Monitor and Shutdown Pin.** The charge current is programmed by connecting a 1% accuracy metal film resistor, R_{PROG}, from this pin to ground. When charging in constant-current mode, this pin servos to 1V. In all modes during charging, the voltage on PROG pin can be used to measure the charge current as the following formula: $I_{BAT} = (V_{PROG}/R_{PROG}) \cdot 120$ The PROG pin is also used to shut down the charger. Disconnecting the program resistor from ground allows a 3µA current to pull the PROG pin high. When it reaches the 1.21V shutdown threshold voltage, the charger enters shutdown mode, charging stops and the input supply current drops to 25µA. This pin is also clamped to approximately 2.4V. Driving this pin to voltages beyond the clamp voltage will draw currents as high as 1.5mA. Reconnecting R_{PROG} to ground will return the charger to normal operation.

■ **ABSOLUTE MAXIMUM RATINGS**[1]

(Unless otherwise specified, T_A=25°C)

PARAMETER	SYMBOL	RATINGS	UNITS
Input Supply Voltage[2]	V_{CC}	-0.3~8	V
PROG Voltage[2]	V_{PROG}	-0.3~V_{CC}+0.3	V
$\overline{CHRG}$ Voltage[2]	$V_{\overline{CHRG}}$	-0.3~8	V
BAT Voltage[2]	V_{BAT}	-0.3~7	V
BAT Short-Circuit Duration		Continuous	-
BAT Pin Output Current (Continuous)	I_{BAT}	200	mA
PROG Pin Current		1.5	mA
Output sink current	$I_{\overline{CHRG}}$	10	mA
Junction to Ambient Thermal Resistance[3]	θ_{JA},SOT-23-5	250	°C/W
Maximum Junction Temperature[4]	$T_{j(MAX)}$	125	°C
Operating Free Air Temperature Range[5]	T_A	-40~+85	°C
Storage Temperature Range	T_{stg}	-40~+125	°C
Lead Temperature (Soldering, 10s)	T_{solder}	260	°C
ESD rating[6]	Human Body Model - (HBM)	2000	V
	Machine Model- (MM)	200	V

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

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

(3)θ_{JA} is measured in the natural convection at T_A = 25°C on a low effective thermal conductivity single layer test board of JEDEC 51-3 thermal measurement standard.

(4)This IC includes overtemperature protection that is intended to protect the device during momentary overload. Junction temperature will exceed 125°C when overtemperature protection is active. Continuous operation above the specified maximum operating junction temperature may impair device reliability.

(5)ESD testing is performed according to the respective JESD22 JEDEC standard.

　The human body model is a 100 pF capacitor discharged through a 1.5kΩ resistor into each pin. The machine model is a 200pF capacitor discharged directly into each pin.

■ **RECOMMENDED OPERATING CONDITIONS**

PARAMETER	MIN	NOM	MAX	UNITS
Supply voltage at V_{CC}	4.5[7]		5.5	V
Charge current, I_{BAT}			120	mA
Operating free air temperature range, T_A	0		70	°C
Operating junction temperature range, T_j	0		125	°C

(7) If V_{CC} is between UVLO and 4.5V, and above the battery voltage, then the IC is active (can deliver some charge to the battery), but the IC will have limited or degraded performance (some functions may not meet data sheet specifications). The battery may be undercharged (V_{FLOAT} less than in the specification), but will not be overcharged (V_{FLOAT} will not exceed specification).

■ ELECTRICAL CHARACTERISTICS

CE3102XM1 Series (V_{IN}= 5.0V, T_A=25℃, Test Circuit Figure1, unless otherwise specified)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Input Supply Voltage	V_{CC}		4.25	5.00	6.50	V
Input Supply Current	I_{CC}	Charge Mode[8], R_{PROG}=10k		200	500	µA
		Standby Mode(Charge Terminated)		70	100	µA
		Shutdown Mode(R_{PROG} Not Connected, V_{CC}<V_{BAT}, or V_{CC}<V_{UV})		25	50	µA
Regulated Output (Float) Voltage	V_{FLOAT}	0°C ≤ T_A ≤ 85°C, I_{BAT}=2mA, R_{PROG}=12k	4.158	4.2	4.242	V
BAT Pin Current	I_{BAT}	R_{PROG} = 12k, Current Mode	7.5	10	12.5	mA
		R_{PROG} = 1k, Current Mode	90	120	150	mA
		Standby Mode, V_{BAT} = 4.2V	0	-2.5	-6.0	µA
		Shutdown Mode (R_{PROG} Not Connected)		±1	±2	µA
		Sleep Mode, V_{CC} = 0V		±1	±2	µA
V_{CC} Undervoltage Lockout Threshold	V_{UV}	V_{CC} from Low to High	3.7	3.8	3.9	V
V_{CC} Undervoltage Lockout Hysteresis	V_{UVHYS}			100		mV
Manual Shutdown Threshold Voltage	V_{MSD}	PROG Pin Rising	1.15	1.21	1.30	V
		PROG Pin Falling	0.9	1.0	1.1	V
V_{CC} – V_{BAT} Lockout Threshold Voltage	V_{ASD}	V_{CC} from Low to High	70	100	140	mV
		V_{CC} from High to Low	5	30	50	mV
0.2C Termination Current Threshold	I_{TERM}	R_{PROG} = 12k(I_{BAT}=10mA) [9]		0.20		mA/mA
		R_{PROG} = 1k(I_{BAT}=120mA) [9]		0.20		mA/mA
PROG Pin Voltage	V_{PROG}	R_{PROG} = 1k, Current Mode	0.93	1.0	1.07	V
PROG Pin Pull-Up Current	I_{PROG}		1	3	5	µA
$\overline{CHRG}$ Pin Output Low Voltage	$V_{\overline{CHRG}}$	$I_{\overline{CHRG}}$=5mA		0.35	0.6	V
Recharge Battery Threshold	$\triangle V_{RECHRG}$	V_{FLOAT}－V_{RECHRG}		100		mV
Power FET "ON" Resistance (Between V_{CC} and BAT)	R_{ON}			1.5		Ω
Soft-Start Time	t_{SS}	I_{BAT} = 0 to I_{BAT} =120V/R_{PROG}		100		µS
Recharge Comparator Filter Time	$t_{RECHARGE}$	V_{BAT} from High to Low	0.8	1.8	4	mS
Termination Comparator Filter Time	t_{TERM}	I_{BAT} Drops Below I_{CHG}/10	0.8	1.8	4	mS

(8) Supply current includes PROG pin current (≈1mA) but does not include any current delivered to the battery through the BAT pin.

(9) I_{TERM} is expressed as a fraction of measured full charge current with indicated PROG resistor.
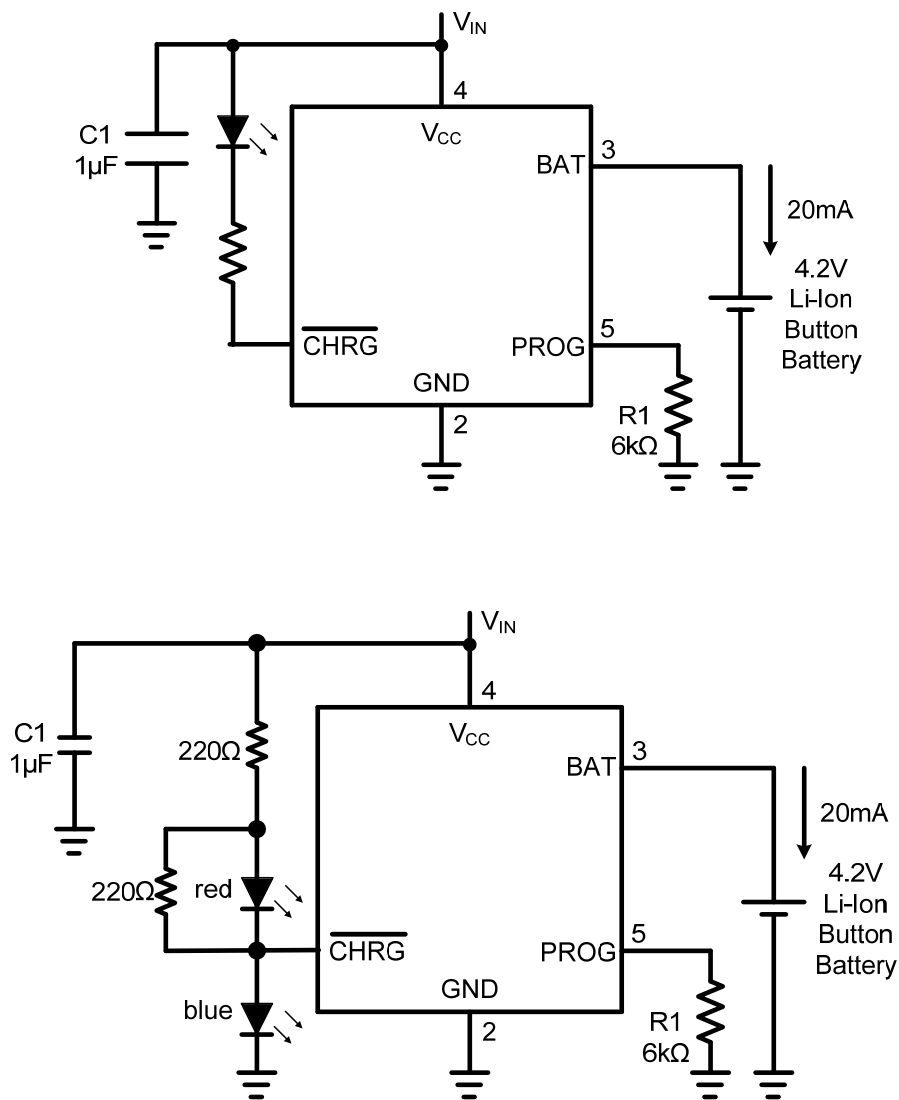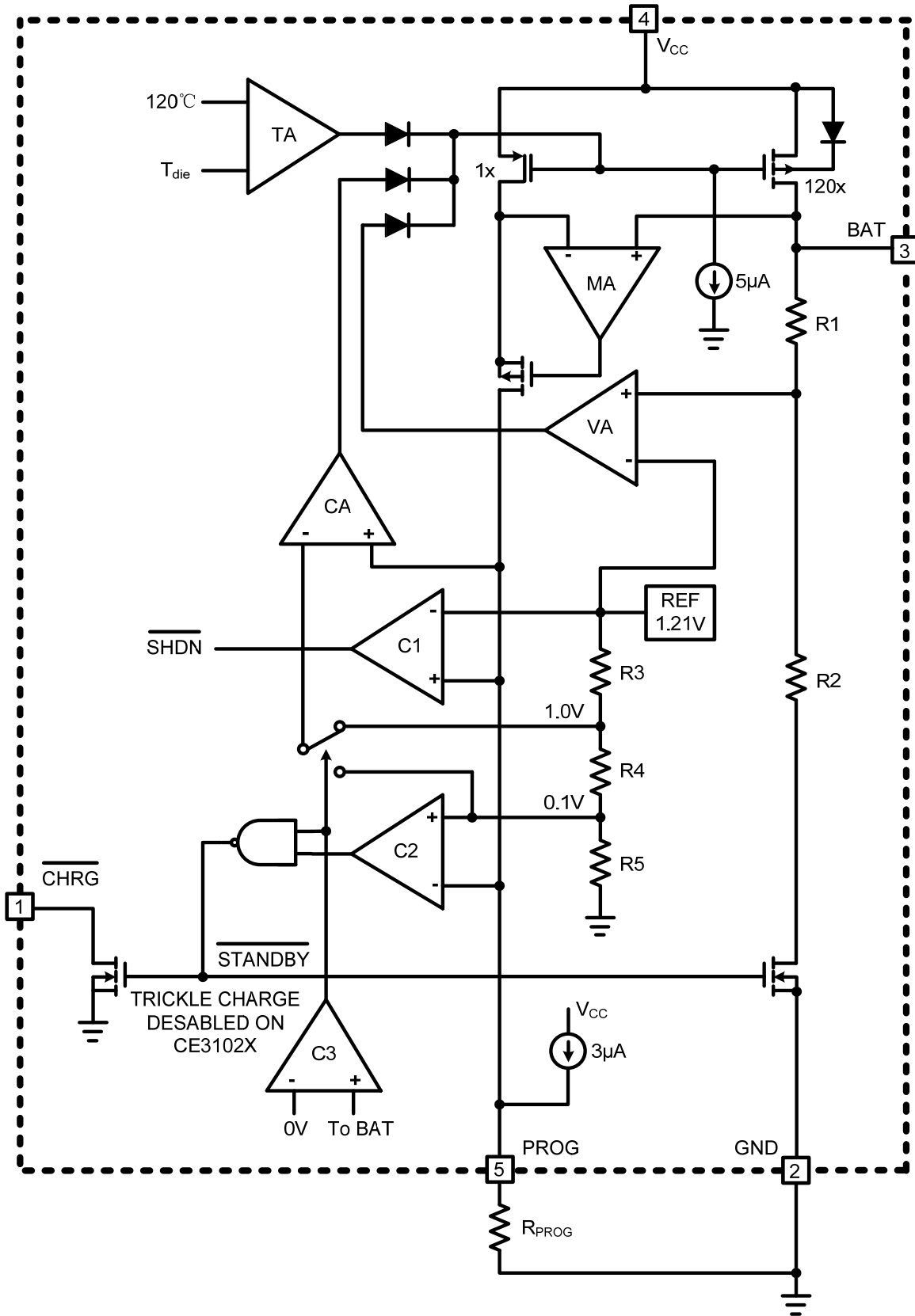
■ TYPICAL APPLICATION CIRCUITS

Figure1 Basic Application Circuit

■ **BLOCK DIAGRAM**

■ OPERATION

The CE3102XM1 is a single cell lithium-ion battery charger using a constant-current/constant-voltage algorithm. Its ability to control charge currents as low as 10mA make it well-suited for charging low capacity lithium-ion coin cell batteries. The CE3102XM1 includes an internal P-channel power MOSFET and thermal regulation circuitry. No blocking diode or external sense resistor is required; thus, the basic charger circuit requires only three external components.

Normal Charge Cycle

The charge cycle begins when the voltage at the V_{CC} pin rises above the UVLO level and a 1% program resistor is connected from the PROG pin to ground. (Note: The CE3102XM1 does not include this trickle charge feature).

The charger enters constant-current mode, where the programmed charge current is supplied to the battery. When the BAT pin approaches the final float voltage (4.2V), the CE3102XM1 enters constant-voltage mode and the charge current begins to decrease. When the charge current drops to 2/10 of the programmed value, the charge cycle ends.

Programming Charge Current

The charge current is programmed using a single resistor from the PROG pin to ground. The battery charge current is 120 times the current out of the PROG pin. The program resistor and the charge current are calculated using the following equations:

$$R_{PROG} = \frac{120V}{I_{\overline{CHRG}}} \quad , \quad I_{\overline{CHRG}} = \frac{120V}{R_{PROG}}$$

The charge current out of the BAT pin can be determined at any time by monitoring the PROG pin voltage using the following equation:

$$I_{BAT} = \frac{V_{PROG}}{I_{PROG}} \bullet 120$$

Charge Termination

The charge cycle is terminated when the charge current falls to 2/10th the programmed value after the final float voltage is reached. This condition is detected by using an internal, filtered comparator to monitor the PROG pin. When the PROG pin voltage falls below 200mV[10] for longer than t_{TERM} (typically 1ms), charging is terminated. The charge current is latched off and the CE3102XM1 enters standby mode, where the input supply current drops to 70µA. (Note: 0.2C termination is disabled in thermal limiting modes.)

While charging, transient loads on the BAT pin can cause the PROG pin to fall below 200mV for short periods of time before the DC charge current has dropped to 2/10th the programmed value. The 1ms filter time (t_{TERM}) on the termination comparator ensures that transient loads of this nature do not result in premature charge cycle termination. Once the *average* charge current drops below 2/10th the programmed value for longer than t_{TERM} , the CE3102XM1 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 CE3102XM1 constantly monitors the BAT pin voltage in standby mode. If this voltage drops below the 4.05V recharge threshold (V_{RECHRG}), another charge cycle begins and current is once again supplied to the battery. To manually restart a charge cycle when in standby mode, the input voltage must be removed and reapplied, or the charger must be shut down and restarted using the PROG pin. Figure 3 shows the state diagram of a typical charge cycle.

(10) Any external sources that hold the PROG pin above 100mV will prevent the CE3102XM1 from terminating a charge cycle.

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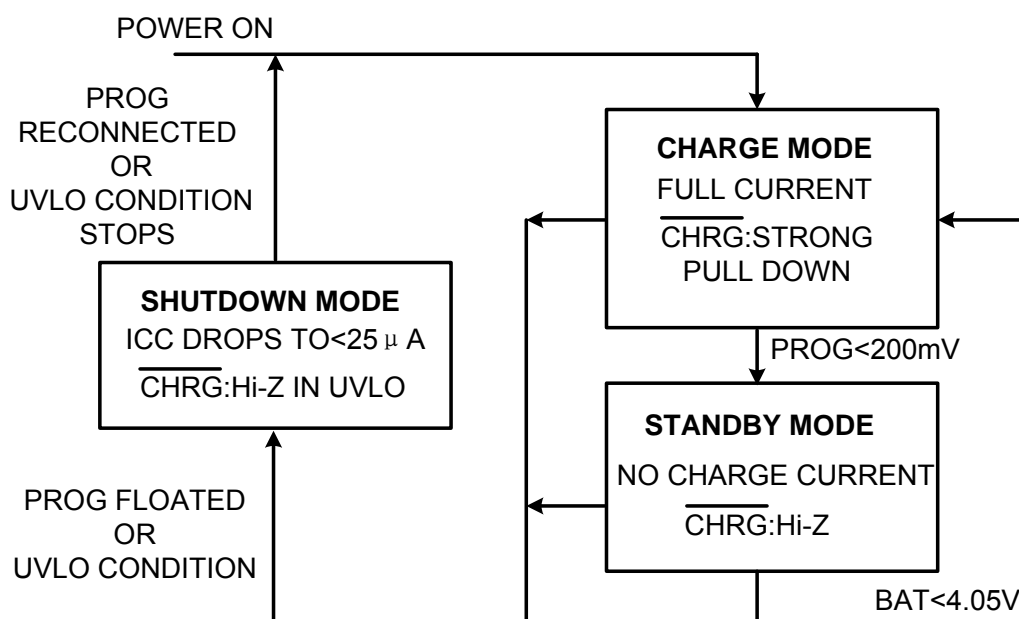TECHNOLOGY

■ **OPERATION**

POWER ON

PROG
RECONNECTED
OR
UVLO CONDITION
STOPS

CHARGE MODE
FULL CURRENT
$\overline{CHRG}$:STRONG
PULL DOWN

SHUTDOWN MODE
ICC DROPS TO<25 μ A
$\overline{CHRG}$:Hi-Z IN UVLO

PROG<200mV

STANDBY MODE
NO CHARGE CURRENT
$\overline{CHRG}$:Hi-Z

PROG FLOATED
OR
UVLO CONDITION

BAT<4.05V

Figure 3. State Diagram of a Typical Charge Cycle

Charge Status Indicator ($\overline{CHRG}$)

The charge status output has two different states: strong pull-down (~10mA), and high impedance. The strong pull-down state indicates that the CE3102XM1 is in a charge cycle. Once the charge cycle has terminated, the $\overline{CHRG}$ pin state is determined by undervoltage lockout conditions. High impedance indicates that CE3102XM1 is in undervoltage lock-out mode: either V_{CC} is within 100mV of the BAT pin voltage or insufficient voltage is applied to the V_{CC} pin. A microprocessor can be used to distinguish between these two states—this method is discussed in the Applications Information section.

Thermal Limiting

An internal thermal feedback loop reduces the programmed charge current if the die temperature attempts to rise above a preset value of approximately 120°C. This feature protects the CE3102XM1 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 CE3102XM1. The charge current can be set according to typical (not worst-case) ambient temperature with the assurance that the charger will automatically reduce the current in worst-case conditions. SOT power considerations are discussed further in the Applications Information section.

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 100mV. Furthermore, to protect against reverse current in the power MOSFET, the UVLO circuit keeps the charger in shutdown mode if V_{CC} falls to within 30mV of the battery voltage. If the UVLO comparator is tripped, the charger will not come out of shutdown mode until V_{CC} rises 100mV above the battery voltage.

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■ OPERATION

Manual Shutdown

At any point in the charge cycle, the CE3102XM1 can be put into shutdown mode by removing R_{PROG} thus floating the PROG pin. This reduces the battery drain current to less than 2μA and the supply current to less than 50μA. A new charge cycle can be initiated by reconnecting the program resistor.

In manual shutdown, the $\overline{CHRG}$ pin is in a high impedance state if the CE3102XM1 is in under voltage lockout mode: either V_{CC} is within 100mV of the BAT pin voltage or insufficient voltage is applied to the V_{CC} pin.

Automatic Recharge

Once the charge cycle is terminated, the CE3102XM1 continuously monitors the voltage on the BAT pin using a comparator with a 2ms filter time ($t_{RECHARGE}$). A charge cycle restarts when the battery voltage falls below 4.05V (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. $\overline{CHRG}$ output enters a strong pull-down state during recharge cycles.

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TECHNOLOGY

■ APPLICATIONS INFORMATION

Stability Considerations

The constant-voltage mode feedback loop is stable without an output capacitor provided a battery is connected to the charger output. With no battery present, an output capacitor is recommended to reduce ripple voltage. When using high value, low ESR ceramic capacitors, it is recommended to add a 1Ω resistor in series with the capacitor. No series resistor is needed if tantalum capacitors are used.

In constant-current mode, the PROG pin is in the feedback loop, not the battery. The constant-current mode stability is affected by the impedance at the PROG pin. With no additional capacitance on the PROG pin, the charger is stable with program resistor values as high as 20K. However, additional capacitance on this node reduces the maximum allowed program resistor. The pole frequency at the PROG pin should be kept above 100kHz. Therefore, if the PROG pin is loaded with a capacitance, C_{PROG}, the following equation can be used to calculate the maximum resistance value for R_{PROG}:

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

Average, rather than instantaneous, charge current may be of interest to the user. For example, if a switching power supply operating in low current mode is connected in parallel with the battery, the average current being pulled out of the BAT pin is typically of more interest than the instantaneous current pulses. In such a case, a simple RC filter can be used on the PROG pin to measure the average battery current. A 10k resistor has been added between the PROG pin and the filter capacitor to ensure stability.
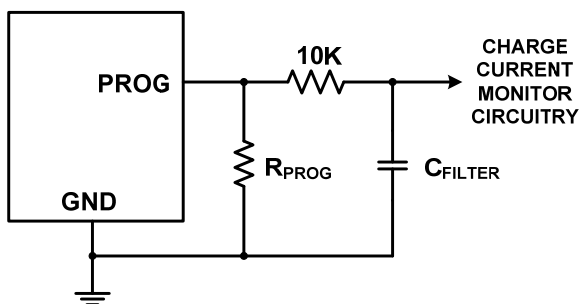

Figure 4. Isolating Capacitive Load on PROG

Pin and Filtering

Power Dissipation

The conditions that cause the CE3102XM1 to reduce charge current through thermal feedback can be approximated by considering the power dissipated in the IC. Nearly all of this power dissipation is generated by the internal MOSFET—this is calculated to be approximately:

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

where P_D is the power dissipated, V_{CC} is the input supply voltage, V_{BAT} is the battery voltage and I_{BAT} is the charge current. The approximate ambient temperature at which the thermal feedback begins to protect the IC is:

$T_A = 120°C - P_D\theta_{JA}$

$T_A = 120°C - (V_{CC} - V_{BAT}) \cdot I_{BAT} \cdot \theta_{JA}$

Example: An CE3102XM1 operating from a 6V wall adapter is programmed to supply 120mA full-scale current to a discharged Li-Ion battery with a voltage of 3.75V. Assuming θ_{JA} is 250°C/W (see Board Layout Considerations), the ambient temperature at which the CE3102XM1 will begin to reduce the charge current is approximately:

$T_A = 120°C - (6V - 3.75V) \cdot 120mA \cdot 250°C/W$

$T_A = 120°C - 0.27W \cdot 250°C/W = 120°C - 67.5°C$

$T_A = 52.5°C$

The CE3102XM1 can be used above 52.5°C ambient, but the charge current will be reduced from 120mA. The approximate current at a given ambient temperature can be approximated by:

$$I_{BAT} = \frac{120°C - T_A}{(V_{CC} - V_{BAT}) \times \theta_{JA}}$$

Using the previous example with an ambient temperature of 60°C, the charge current will be reduced to approximately:

$$I_{BAT} = \frac{120°C - 60°C}{(6V - 3.75V) \times 250°C/W} = \frac{60°C}{562.5°C}$$

$I_{BAT} = 107mA$

Moreover, when thermal feedback reduces the charge current, the voltage at the PROG pin is also reduced proportionally as discussed in the Operation section.

■ APPLICATIONS INFORMATION

It is important to remember that CE3102XM1 applications do not need to be designed for worst-case thermal conditions since the IC will automatically reduce power dissipation when the junction temperature reaches approximately 120°C.

Thermal Considerations

Because of the small size of the SOT package, it is very important to use a good thermal PC board layout to maximize the available charge current. The thermal path for the heat generated by the IC is from the die to the copper lead frame, through the package leads, **(especially the ground lead)** 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. Feedthrough vias to inner or backside copper layers are also useful in improving the overall thermal performance of the charger. Other heat sources on the board, not related to the charger, must also be considered when designing a PC board layout because they will affect overall temperature rise and the maximum charge current.

Selecting Input V_{CC} Bypass Capacitor

The CE3102XM1 is designed to work with both regulated and unregulated external dc supplies. If a non-regulated supply is chosen, the supply unit should have enough capacitance to hold up the supply voltage to the minimum required input voltage at maximum load. If not, more capacitance has to be added to the input of the charger.

A 4.7μF chip ceramic capacitor placed in close proximity to V_{CC} and GND pins is recommended for the input bypass capacitor, because it provides low ESR and ESL and can handle the high RMS ripple currents. However, some high Q capacitors may produce high transients due to self-resonance under some start-up conditions, such as connecting the charger input to a hot power source. Adding a 1Ω resistor in series with an X5R ceramic capacitor will minimize start-up voltage transients.

Protecting the V_{CC} Pin from Overvoltage Transients

Many types of capacitors can be used for input bypassing, however, caution must be exercised when using multilayer ceramic capacitors to bypass the V_{CC} pin, which powered by USB bus or Wall Adapter Input. High voltage transients can be generated under some start-up conditions, depending on the power supply characteristics and cable length, such as when the USB or wall adapter is hot plugged. When power is supplied via the USB bus or wall adapter, the cable inductance along with the self resonant and high Q characteristics of some types of ceramic capacitors can cause substantial ringing which could exceed the maximum voltage pin ratings and damage the CE3102XM1. The long cable lengths of most wall adapters and USB cables makes them especially susceptible to this problem. To bypass the V_{CC} pin, add a 1Ω resistor in series with an X5R ceramic capacitor to lower the effective Q of the network and greatly reduce the ringing. A tantalum, OS-CON, or electrolytic capacitor can be used in place of the ceramic and resistor, as their higher ESR reduces the Q, thus reducing the voltage ringing.

The oscilloscope photograph in Figure 5 shows how serious the overvoltage transient can be for the USB and wall adapter inputs. For both traces, a 5V supply is hot-plugged using a three foot long cable. For the top trace, only a 4.7μF capacitor (without the recommended 1Ω series resistor) is used to locally bypass the input. This trace shows excessive ringing when the 5V cable is inserted, with the overvoltage spike reaching 10V. For the bottom trace, a 1Ω resistor is added in series with the 4.7μF capacitor to locally bypass the 5V input. This trace shows the clean response resulting from the addition of the 1Ω resistor.
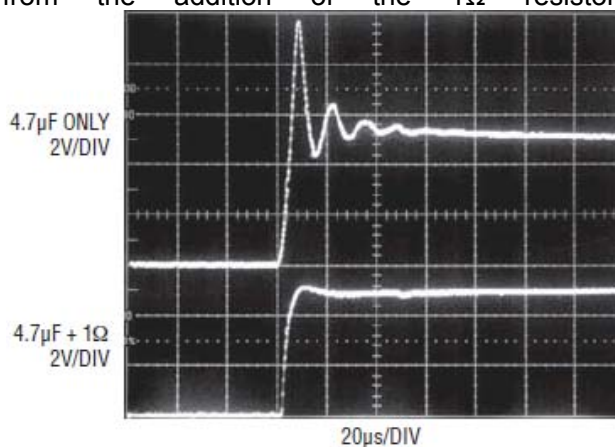

Figure 5. Waveforms Resulting from Hot-Plugging a 5V Input Supply

■ APPLICATIONS INFORMATION

Even with the additional 1Ω resistor, bad design techniques and poor board layout can often make the overvoltage problem even worse. System designers often add extra inductance in series with input lines in an attempt to minimize the noise fed back to those inputs by the application. In reality, adding these extra inductances only makes the overvoltage transients worse. Since cable inductance is one of the fundamental causes of the excessive ringing, adding a series ferrite bead or inductor increases the effective cable inductance, making the problem even worse. For this reason, **do not** add additional inductance (ferrite beads or inductors) in series with the USB or wall adapter inputs. For the most robust solution, 6V transorbs or zener diodes may also be added to further protect the USB and wall adapter inputs. Two possible protection devices are the SM2T from ST Microelectronics and the EDZ series devices from ROHM. **Always use an oscilloscope to check the voltage waveforms at the V_{CC} pin during USB and wall adapter hot-plug events to ensure that overvoltage transients have been adequately removed.**

USB Inrush Limiting

When a USB cable is plugged into a portable product, the inductance of the cable and the high-Q ceramic input capacitor form an L-C resonant circuit. If the cable does not have adequate mutual coupling or if there is not much impedance in the cable, it is possible for the voltage at the input of the product to reach as high as twice the USB voltage (~10V) before it settles out. In fact, due to the high voltage coefficient of many ceramic capacitors (a nonlinearity), the voltage may even exceed twice the USB voltage. To prevent excessive voltage from damaging the CE3102XM1 during a hot insertion, it is best to have

a low voltage coefficient capacitor at the V_{CC} pin to the CE3102XM1 family. This is achievable by selecting an MLCC capacitor that has a higher voltage rating than that required for the application. For example, a 16V, X5R, 10µF capacitor in a 1206 case would be a better choice than a 6.3V, X5R, 10µF capacitor in a smaller 0805 case. Alternatively, the following soft connect circuit in Figure 6 can be employed. In this circuit, capacitor C2 holds MN1 off when the cable is first connected. Eventually C2 begins to charge up to the USB input voltage applying increasing gate support to MN1. The long time constant of R1 and C2 prevent the current from building up in the cable too fast thus dampening out any resonant overshoot.
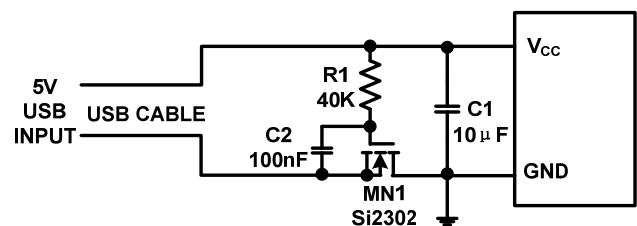

Figure 6. USB Soft Connect Circuit

Charge Current Soft-Start and Soft-Stop

The CE3102XM1 includes a soft-start circuit to minimize the inrush current at the start of a charge cycle. When a charge cycle is initiated, the charge current ramps from zero to the full-scale current over a period of approximately 100µs. During charger soft-start, the CE3102XM1 ramps up the voltage on PROG pin with constant well-controlled slew rate. The charging current is proportional to the PROG voltage. Likewise, internal circuitry slowly ramps the charge current from full-scale to zero when the charger is shut off or self terminates. This has the effect of minimizing the transient current load on the power supply during start-up and charge termination.

■ **APPLICATIONS INFORMATION**

Charge Cycle Status Output

$\overline{CHRG}$ pin is internally connected to an N-channel open drain MOSFET. The CE3102XM1 family provides battery charge status via $\overline{CHRG}$ 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.

Table 2. Charge Status Indicator[11]

Charge State Description	$\overline{CHRG}$
Constant-Current Mode (Fast) Charge	ON
Constant-Voltage Mode (Taper) Charge, $I_{BAT} > I_{TERM}$	ON
Charge Temination ($I_{BAT} < I_{TERM}$, Charge Done)	HI-Z
Power Down (Undervoltage Lockout) Mode	HI-Z
Sleep Mode ($V_{UVL} < V_{CC} < V_{CC} + V_{SLP}$, or the V_{CC} is removed)	HI-Z
Shutdown Mode(PROG pin floating)	HI-Z
No battery with Charge Enabled	FLASH Rate depends on C_{BAT}
Fault Condition (Battery Short Circuit)	ON
Fault Condition (Battery Overvoltage)	HI-Z

(11) Pulse loading on the BAT pin may cause the IC to cycle between Done and charging states (LEDs Flashing)

The $\overline{CHRG}$ status pin can be used to communicate to the host processor or drive LEDs.

It is supposed that a red LED and a green LED are connected to $\overline{CHRG}$ pin

The LEDs should be biased with as little current as necessary to create reasonable illumination, therefore, a ballast resistor should be placed between the LED cathode and the status pin. LED current consumption will add to the overall thermal power budget for the device package, hence it is good to keep the LED drive current to a minimum 2mA should be sufficient to drive most low cost red or green LEDs. It is not recommended to exceed 10mA for driving an individual status LED. The required ballast resistor values can be estimated using following formula:

$R_{BALLAST} = [V_{CC} - V_{F(LED)}] / I_{LED}$

Example:

$R_{BALLAST} = [5.0V - 2.0V] / 2mA = 1.5k\Omega$

Note: Red LED forward voltage (V_F) is typically 2.0V@ 2mA.

$\overline{CHRG}$ Status Output Pin

When a discharged battery is connected to the charger, the constant current portion of the charge cycle begins and the $\overline{CHRG}$ pin pulls to ground. The $\overline{CHRG}$ pin can sink up to 10mA to drive an LED that indicates that a charge cycle is in progress.

When the battery is nearing full charge, the charger enters the constant-voltage portion of the charge cycle and the charge current begins to drop. When the charge current drops below 2/10 of the programmed current, the charge cycle ends and the strong pull-down is replaced by the high impedance, indicating that the charge cycle has ended. If the input voltage is removed or drops below the undervoltage lockout threshold, the $\overline{CHRG}$ pin becomes high impedance. Figure 7 shows that by using a pull-up resistor, a microprocessor can detect all two states from this pin.
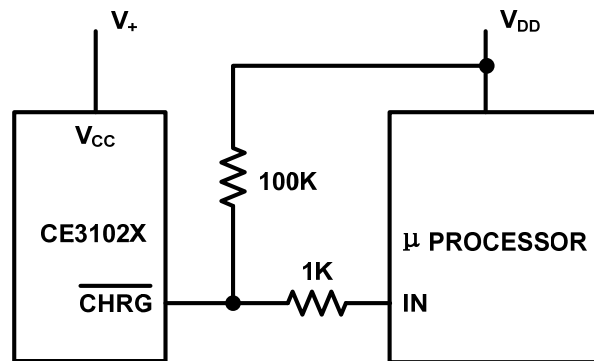
■ **APPLICATIONS   INFORMATION**

Figure 7. Using a Microprocessor to Detect $\overline{CHRG}$ State

BATTERY ABSENT DETECTION

The CE3102XM1 provides a battery absent detection scheme to reliably detect insertion and/or removal of battery packs.

If the battery is not present, the charger will charge the output capacitor to the regulation voltage quickly, then the BAT pin's voltage decays slowly to recharge threshold because of low leakage current at BAT pin, which results in a 100mV ripple waveform at BAT pin, in the meantime, $\overline{CHRG}$ pin outputs a pulse to indicate that the battery's absence. The pulse's frequency is around 1Hz when a 10μF output capacitor is used.

REVERSE POLARITY INPUT VOLTAGE PROTECTION

In some applications, protection from reverse polarity voltage on V_{CC} is desired. If the supply voltage is high enough, a series blocking diode can be used. In other cases, where the voltage drop must be kept low a P-channel MOSFET can be used (as shown in Figure 8).
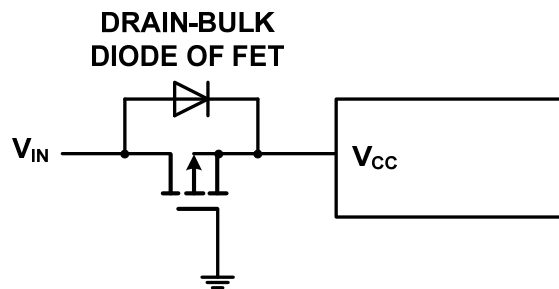

Figure 8. Low Loss Input Reverse Polarity Protection

USB and WALL ADAPTER POWER

The CE3102XM1 family allows charging from both a wall adapter and a USB port. Figure 9 shows an example of how to combine wall adapter and USB power inputs. A P-channel MOSFET, MP1, is used to prevent back conducting into the USB port when a wall adapter is present and a Schottky diode, D1, is used to prevent USB power loss through the 1k pull-down resistor.
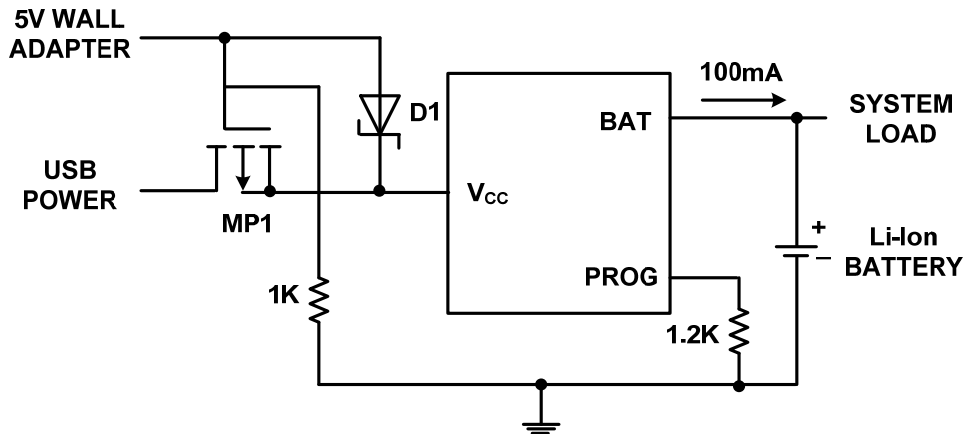
■ **APPLICATIONS   INFORMATION**

**Figure 9. Combining Wall Adapter and USB Power**

PCB LAYOUT CONSIDERATIONS

The CE3102XM1 series are fully integrated single-chip low cost single-cell Li-Ion or Li-Pol battery chargers ideal for portable applications. Careful PCB layout is necessary. For optimal performance, place all peripheral components as close to the IC as possible. A short connection is highly recommended. Several layout tips are listed below for the best electric and thermal performance.

● Input bypass capacitor from V_{CC} to GND should be placed as close as possible to CE3102XM1, with short trace runs to both V_{CC} and GND pins, and connected to ground plane. The trace of input in the PCB should be placed far away the sensitive devices or shielded by the ground.

● The GND should be connected to a strong ground plane for heat sinking and noise protection.

● Output bypass capacitors from BAT to GND should be placed as close as possible to CE3102XM1, with short trace runs to both BAT and GND pins, and connected to ground plane to reduce noise coupling.

● The connection of R_{PROG} should be isolated from other noisy traces. The short wire is recommended to prevent EMI and noise coupling.

● All low-current GND connections should be kept separate from the high-current charge or discharge paths from the battery. Use a single-point ground technique incorporating both the small signal ground path and the power ground path.

● The BAT pin is the voltage feedback to the device and should be connected with its trace as close to the battery pack as possible.

■ PACKAGING INFORMATION

● SOT-23-5 Package Outline Dimensions
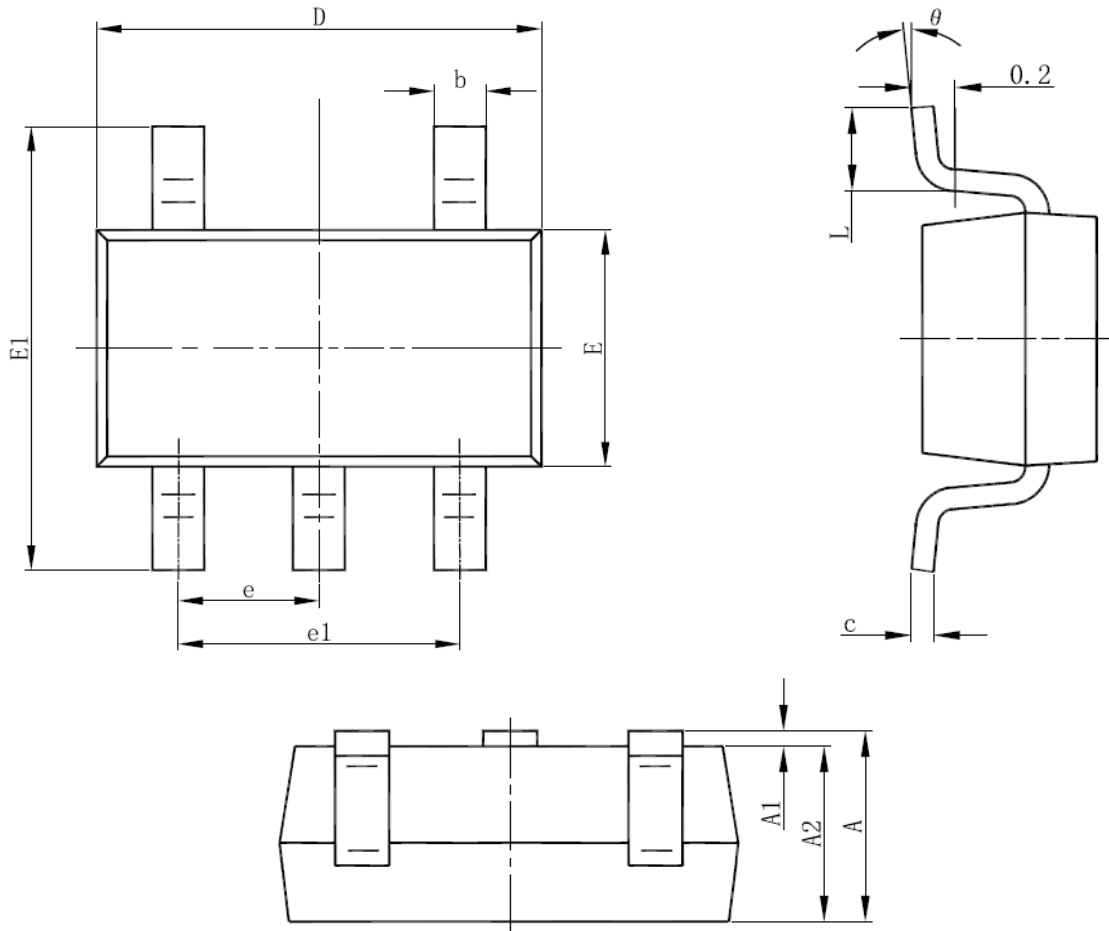
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D	2.820	3.020	0.111	0.119
E	1.500	1.700	0.059	0.067
E1	2.650	2.950	0.104	0.116
e	0.950(BSC)		0.037(BSC)	
e1	1.800	2.000	0.071	0.079
L	0.300	0.600	0.012	0.024
θ	0°	8°	0°	8°