# Standalone Linear Li-Ion Battery Charger with Thermal Regulation

## FEATURES

- **Programmable Charge Current up to 1A**
- **No MOSFET, Sense Resistor or Blocking Diode Required**
- **Constant-Current/Constant-Voltage Operation with Thermal Regulation to Maximize Charge Rate without Risk of Overheating**
- **Charge Single Cell Li-Ion Batteries Directly from USB Port**
- **Charge Current Monitor Output for Gas Gauging**
- **Preset 4.2V Charge Voltage with 1% Accuracy**
- **2.9V Trickle Charge Threshold**
- **C/10 Charge Termination**
- **55µA Supply Current in Shutdown Mode**
- **Automatic Recharge**
- **Soft-Start Limits Inrush Current**
- **Available in the Green ESOP8 Package**

## APPLICATIONS

- **Mobile Phones, PDAs, MP3 Players**
- **Charging Docks and Cradles**
- **Bluetooth Applications**
- **Other Handheld Devices**

## DESCRIPTION

The HM4056G is a complete constant-current/constant voltage linear charger for single cell lithium-ion batteries. Its compact size and low external component count make the HM4056G ideally suited for portable applications. Furthermore, the HM4056G is specifically designed to work charging the battery from the power supplies of the 5V adapter and the USB port.

No external sense resistor is needed, and no blocking diode is required due to the internal MOSFET architecture. Thermal feedback regulates the charge current to limit the die temperature during high power operation or high ambient temperature. The charge voltage is fixed at 4.2V, and the charge current can be programmed externally with a single resistor. The HM4056G automatically terminates the charge cycle when the charge current drops to 1/10th the programmed value after the final float voltage is reached.

Other features include charge current monitor, under voltage lockout, automatic recharge and a status pin to indicate charge termination and the presence of an input voltage.

The HM4056G is available in ESOP8 package requiring minimum board space and smallest components. It is rated over the -40°C to +85°C temperature range.

## TYPICAL APPLICATIONS

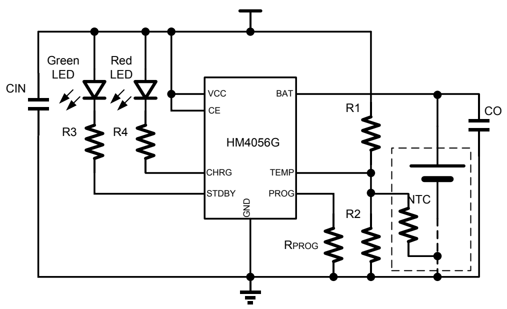


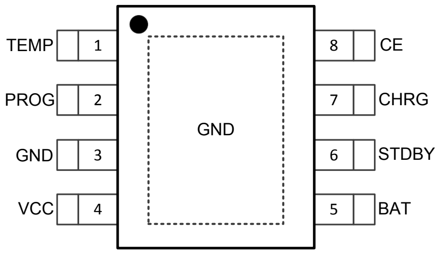

**Figure 1. Typical Application Circuit**

# ORDERING INFORMATION

| DEVICE | ORDER NUMBER | PACKAGE DESCRIPTION | AMBIENT TEMPERATURE | PACKAGE MARKING | PACKAGE OPTION |
|---|---|---|---|---|---|
| HM4056G | HM4056G | ESOP8 | -40℃ to +85℃ | 4056G HMXXXX | Tape and Reel |
| HM4056G | HM4056G | TDFN-3×3-8L | -40℃ to +85℃ | 4056G HMXXXX | Tape and Reel |

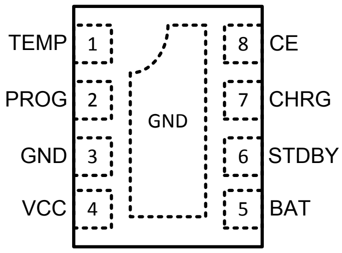
# PIN CONFIGURATION

HM4056G




ESOP8

HM4056G




TDFN-3×3-8L

**Table 1. PIN Descriptions**

| PIN | NAME | PIN FUNCTION |
|---|---|---|
| 1 | TEMP | Temperature sense input. |
| 2 | PROG | Constant Charge Current Setting and Charge Current Monitor Pin. |
| 3 | GND | Ground voltage. |
| 4 | VCC | Power input supply voltage. |
| 5 | BAT | Charge current output. |
| 6 | STDBY | Charge terminated status output. |
| 7 | CHRG | Open-drain charge status output. |
| 8 | CE | Chip enable input, high voltage activity. |
| 9 | Thermal PAD | Connect this PAD to GND |

## ABSOLUTE MAXIMUM RATINGS

| Description | | Ratings / Value / Range | Units |
|---|---|---|---|
| Supply Input Voltage ( VIN ) | | -0.3 ~ 9 | V |
| Other Pins | | -0.3 ~ 9 | V |
| Storage Temperature Range | | -65 ~ +150 | °C |
| Junction Temperature | | 150 | °C |
| Lead Temperature | | 260 | °C |
| ESD Rating | HBM ( Human Body Mode ) | 4000 | V |
| | CDM ( Charge Device Mode ) | 250 | V |

## THERMAL INFORMATION

| Description | | Ratings / Value / Range | Units |
|---|---|---|---|
| Package Thermal Resistance ( $\theta_{JA}$ ) | ESOP8 | 50 | °C/W |
| | TDFN-3×3-8L | 80 | °C/W |
| Power Dissipation, $P_D$@$T_A$=25°C | ESOP8 | | W |
| | TDFN-3×3-8L | | W |

## RECOMMENDED OPERATION CONDITIONS

| Description | Ratings / Value / Range | Units |
|---|---|---|
| Operating Junction Temperature | -40 ~ 125 | °C |
| Operating Ambient Temperature | -40 ~ 85 | °C |
| Supply Input Voltage | +2.5 ~ +5.5 | V |
| Continuous Output Current | 1 | A |

Note 1. Stresses beyond those listed as the above *ABSOLUTED MAXIMUM RATINGS* may cause permanent damage to the device. These are for stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated in the *RECOMMENDED OPERATION CONDITIONS* section of the specifications are not implied. Exposure to absolute maximum rating conditions for extended periods may remain possibility to affect device reliability.

Note 2. Devices are ESD sensitive. Handling precaution recommended.

Note 3. $\theta_{JA}$ is measured in the natural convection at $T_A$=25°C on a low effective thermal conductivity test board of JEDEC 51-3 thermal measurement standard.

Note 4. The device is not guaranteed to function outside its operating conditions.

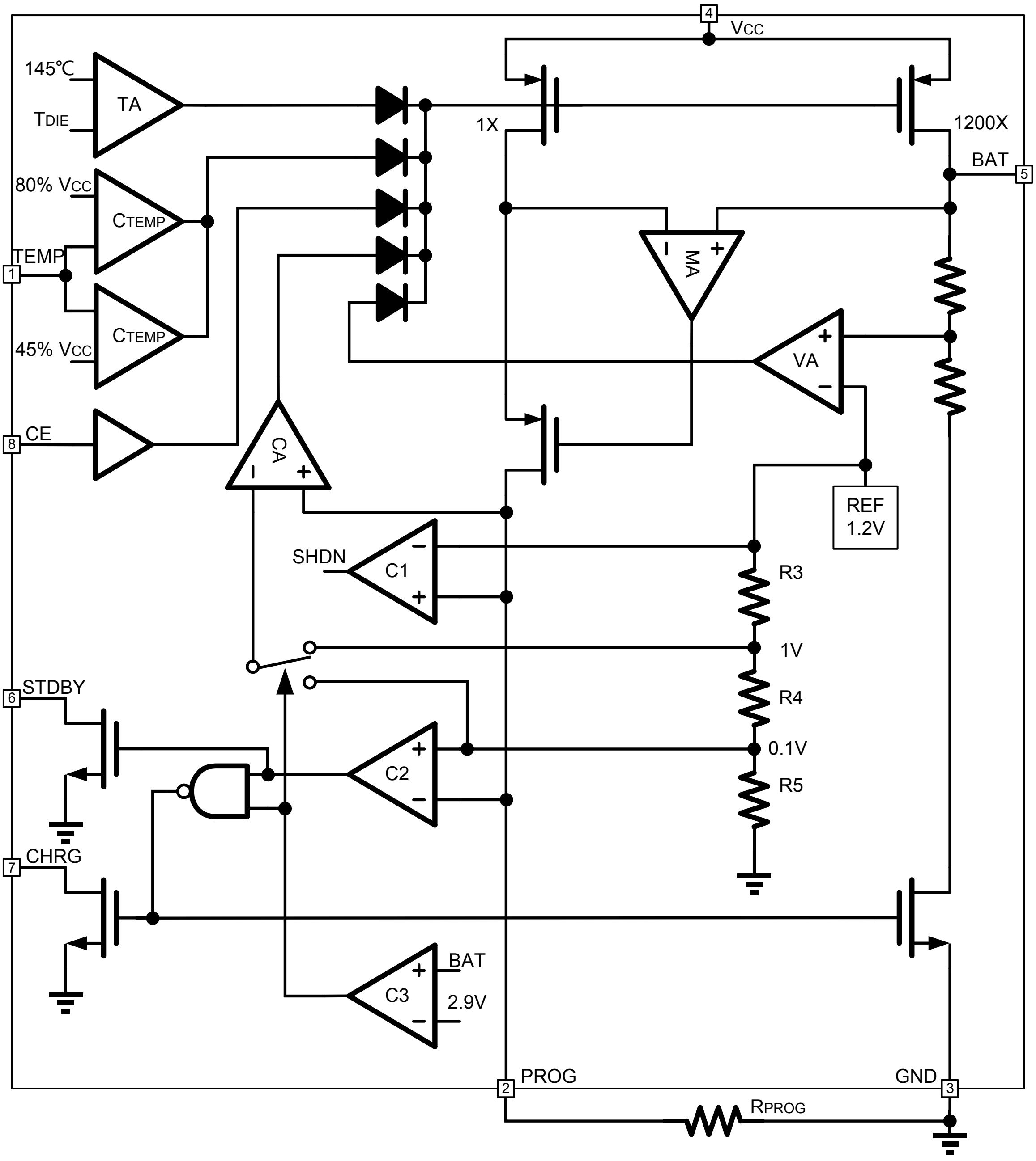
**Important information and disclaimer**:
ShiningIC reserves the right to make any change in circuit design, specification or other related things if necessary without notice at any time.

# ELECTRICAL CHARACTERISTICS

($V_{IN}$ = 5.0V, $T_A$ = 25°C, unless otherwise specified.)

| Parameter | Symbol | Test Conditions | Min | Typ | Max | Units |
|---|---|---|---|---|---|---|
| Input Voltage Range | $V_{IN}$ | | 4.0 | 5 | 5.5 | V |
| Quiescent Supply Current | $I_Q$ | Charge Mode，$R_{PROG}$=1.2k | | 150 | 500 | µA |
| | | Standby Mode(Charge Terminated) | | 55 | 100 | µA |
| | | Shutdown Mode($R_{PROG}$ Not Connected, $V_{CC}$ < $V_{BAT}$, or $V_{CC}$ < $V_{UV}$) | | 55 | 100 | µA |
| Regulated Output(Float)Voltage | $V_{FLOAT}$ | 0°C≤$T_A$≤85°C, IBAT = 40mA | 4.158 | 4.200 | 4.242 | V |
| BAT Pin Current | $I_{BAT}$ | $R_{PROG}$ = 2.4k, Current Mode | 400 | 500 | 550 | mA |
| | | $R_{PROG}$ = 1.2k, Current Mode | 950 | 1000 | 1050 | mA |
| | | Standby Mode, $V_{BAT}$ = 4.2V | 0 | -2.5 | -6 | µA |
| | | Shutdown Mode ($R_{PROG}$ Not Connected) | | ±1 | ±2 | µA |
| | | Sleep Mode, $V_{CC}$ = 0V | | -1 | -2 | µA |
| Trickle Charge Current | $I_{TRIKL}$ | $V_{BAT}$ < $V_{TRIKL}$, $R_{PROG}$ = 1.2k | 110 | 120 | 130 | mA |
| Trickle Charge Threshold Voltage | $V_{TRIKL}$ | $R_{PROG}$ = 1.2k, VBAT Rising | 2.8 | 2.9 | 3.0 | V |
| Trickle Charge Hysteresis Voltage | $V_{TRHYS}$ | $R_{PROG}$ = 1.2k | 60 | 80 | 100 | mV |
| VCC Undervoltage Lockout Threshold | $V_{UV}$ | From $V_{CC}$ Low to High | 3.5 | 3.7 | 3.9 | V |
| VCC Undervoltage Lockout Hysteresis | $V_{UVHYS}$ | | 150 | 200 | 300 | mV |
| Manual Shutdown Threshold Voltage | $V_{MSD}$ | PROG Pin Rising | 3.4 | 3.5 | 3.6 | V |
| | | PROG Pin Falling | 1.9 | 2.0 | 2.1 | V |
| VCC – VBAT Lockout Threshold Voltage | $V_{ASD}$ | $V_{CC}$ from Low to High | 60 | 100 | 140 | mV |
| | | $V_{CC}$ from High to Low | 5 | 30 | 50 | mV |
| C/10 Termination Current Threshold | $I_{TERM}$ | $R_{PROG}$ = 2.4k | 50 | 60 | 70 | mA |
| | | $R_{PROG}$ = 1.2k | 110 | 120 | 130 | mA |
| PROG Pin Voltage | $V_{PROG}$ | $R_{PROG}$ = 1.2k, Current Mode | 0.9 | 1.0 | 1.1 | V |
| CHRG Pin Output Low Voltage | $V_{CHRG}$ | $I_{CHRG}$ = 5mA | | 0.3 | 0.6 | V |
| STDBY Pin Output Low Voltage | $V_{CHRG}$ | $I_{STDBY}$ = 5mA | | 0.3 | 0.6 | V |
| Recharge Battery Threshold Voltage | $\Delta V_{RECHRG}$ | $V_{FLOAT}$ - $V_{RECHRG}$ | 100 | 150 | 200 | mV |
| Junction Temperature in Constant Temperature Mode | $T_{LIM}$ | | | 145 | | ℃ |
| Power FET "ON" Resistance (Between VCC and BAT) | $R_{ON}$ | | | 650 | | mΩ |
| Soft-Start Time | $t_{SS}$ | $I_{BAT}$ = 0 to $I_{BAT}$ =1000V/$R_{PROG}$ | | 20 | | µs |
| Recharge Comparator Filter Time | $t_{RECHARGE}$ | $V_{BAT}$ High to Low | 0.8 | 1.8 | 4.0 | ms |
| Termination Comparator Filter Time | $t_{TERM}$ | $I_{BAT}$ Falling Below $I_{CHG}$/10 | 0.8 | 1.8 | 4.0 | ms |
| PROG Pin Pull-Up Current | $I_{PROG}$ | | | 1.0 | | µA |
| TEMP Pin High Side Protection Voltage | $V_{TEMP-H}$ | | | 80 | 82 | %$V_{CC}$ |
| TEMP Pin Low Side Protection Voltage | $V_{TEMP-L}$ | | 43 | 45 | | %$V_{CC}$ |
| EN Pin Input Rising Threshold | $V_{ENH}$ | | 1.2 | | | V |
| EN Pin Input Falling Threshold | $V_{ENL}$ | | | | 0.6 | V |

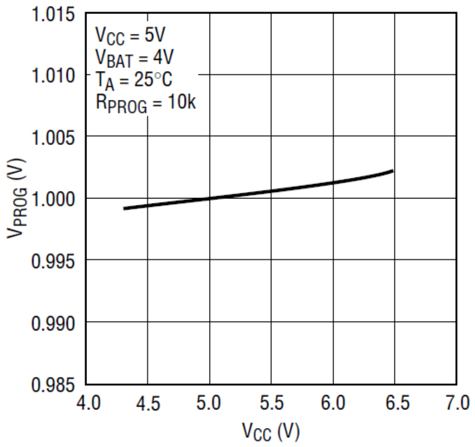
## BLOCK DIAGRAM



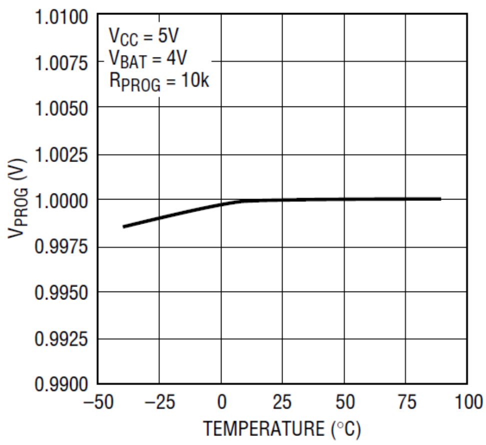
## TYPICAL CHARACTERISTICS

$V_{IN}$ = 5.0V, $T_A$ = 25°C, unless otherwise specified.

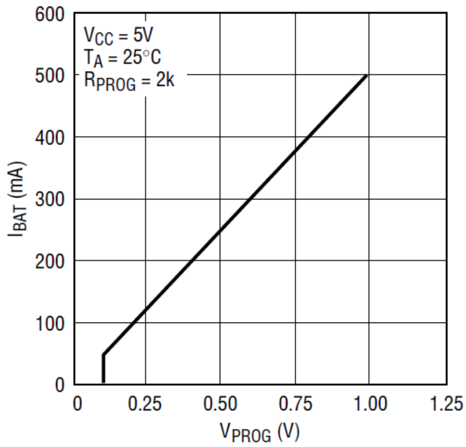
**PROG Pin Voltage vs Supply Voltage (Constant Current Mode)**



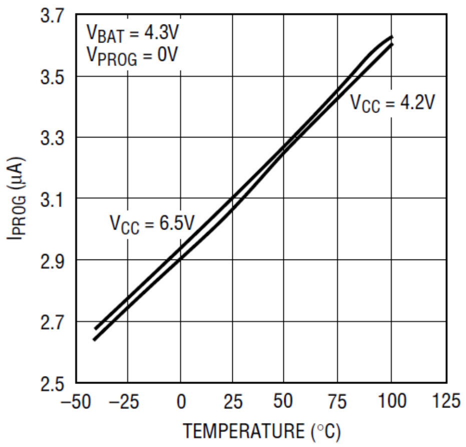

**PROG Pin Voltage vs Temperature**



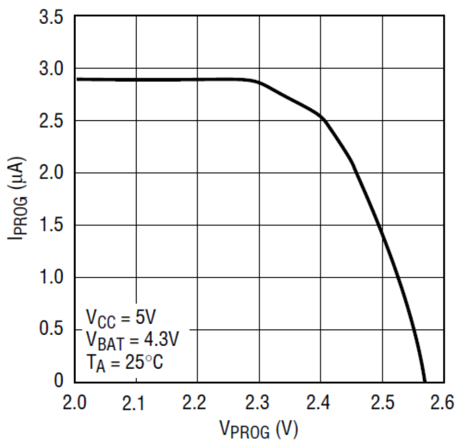

**Charge Current vs PROG Pin Voltage**



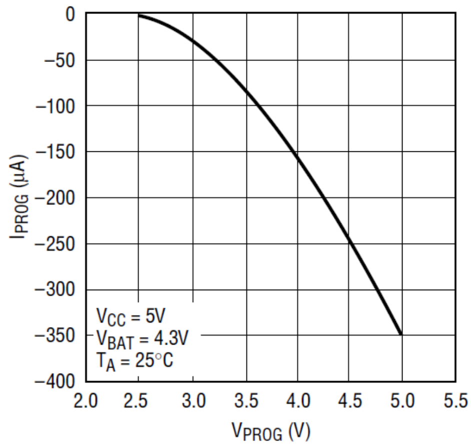

**PROG Pin Pull-up Current vs Temperature and Voltage**



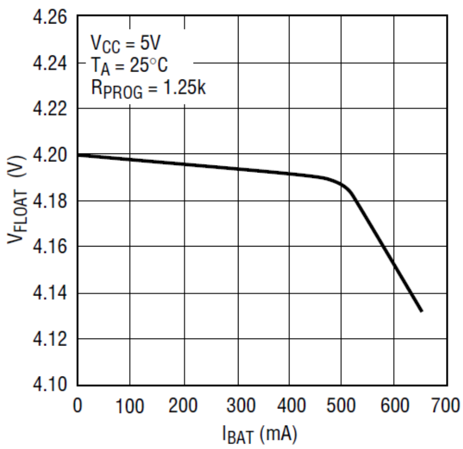

**PROG Pin Current vs PROG Pin Voltage(Pull-Up Current)**



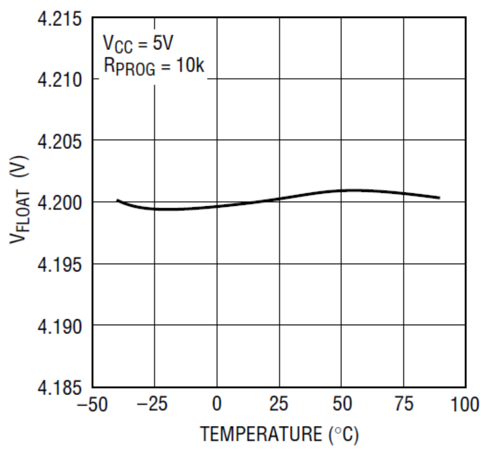

**PROG Pin Current vs PROG Pin Voltage(Clamp Current)**



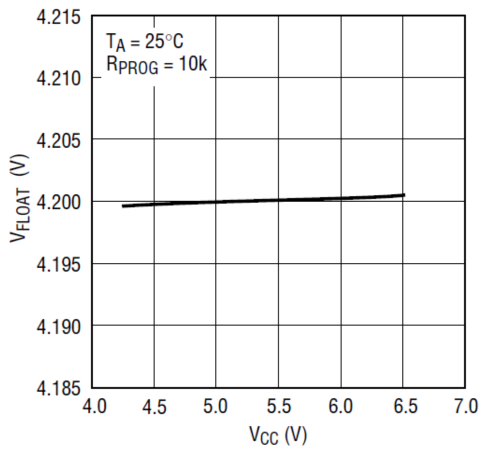

**Regulated Output(Float) Voltage vs Charge Current**




**Regulated Output(Float) Voltage vs Temperature**



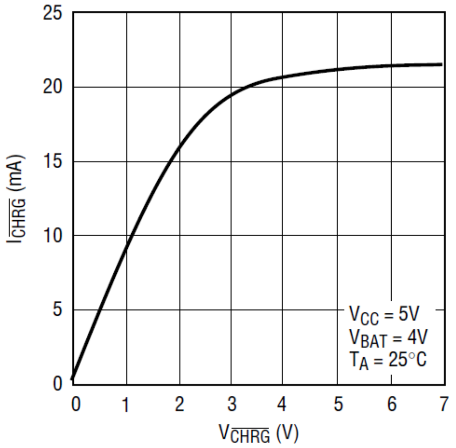

**Regulated Output(Float) Voltage vs Supply Voltage**



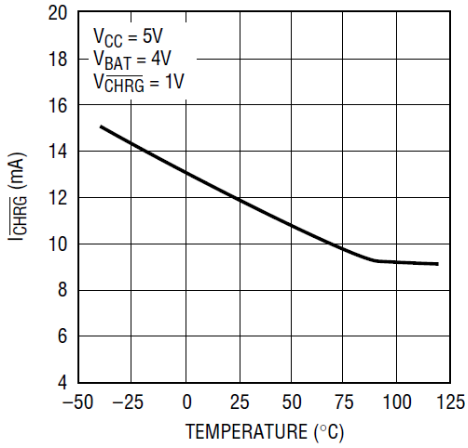
# TYPICAL CHARACTERISTICS

$V_{IN}$ = 5.0V, $T_A$ = 25°C, unless otherwise specified.

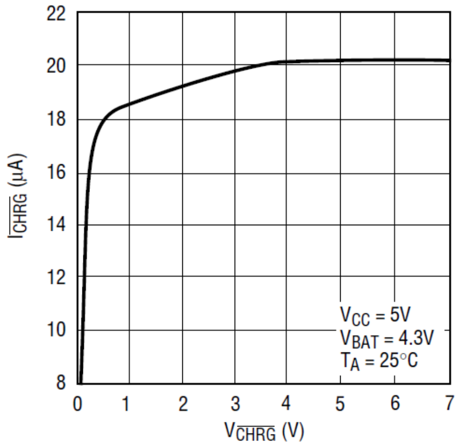
### CHRG Pin I-V Curve (Strong Pull-Down State)



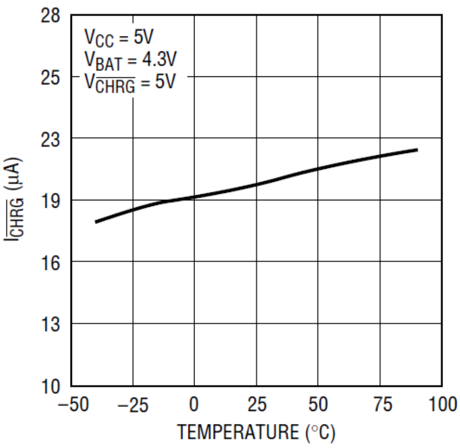

### CHRG Pin Current vs Temperature (Strong Pull-Down State)



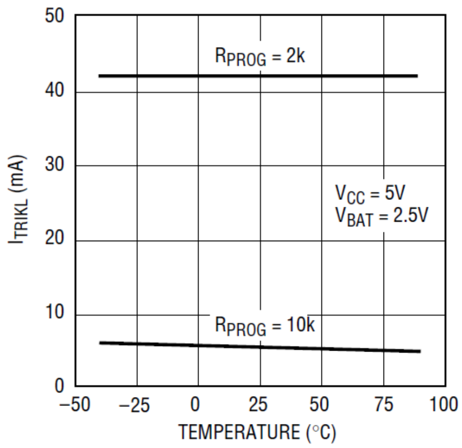

### CHRG Pin I-V Curve (Weak Pull-Down State)



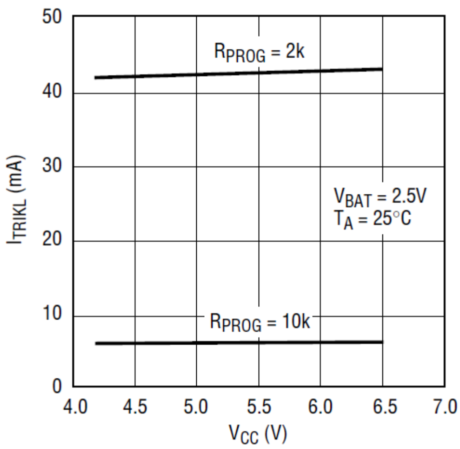

### CHRG Pin Current vs Temperature (Weak Pull-Down State)



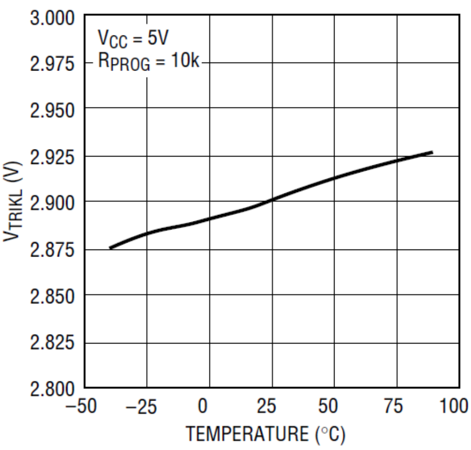

### Trickle Charge Current vs Temperature



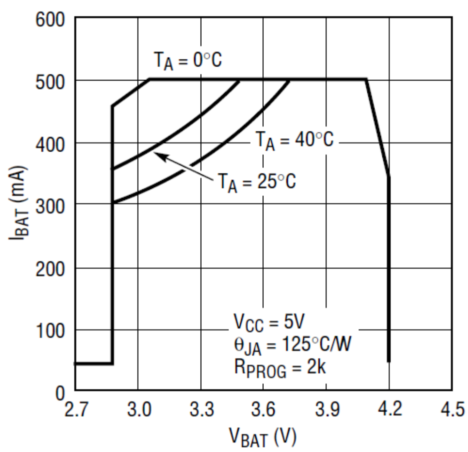

### Trickle Charge Current vs Supply Voltage



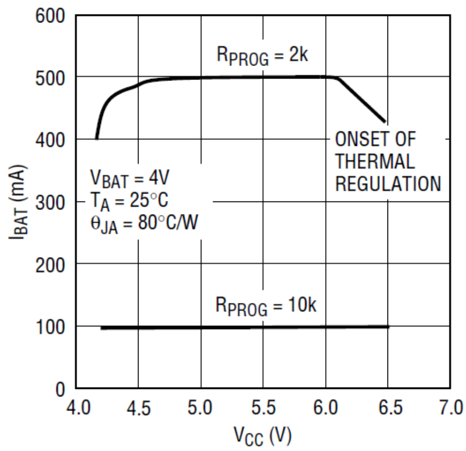

### Trickle Charge Thershold vs Temperature




### Charge Current vs Battery Voltage



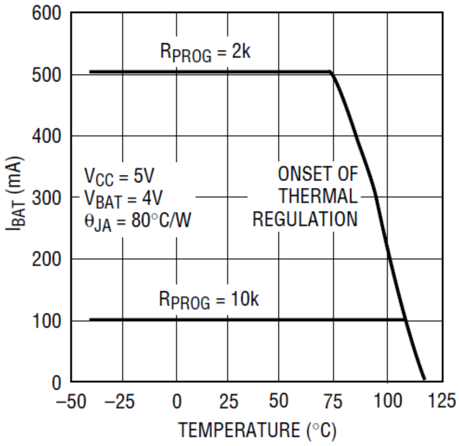

### Charge Current vs Supply Voltage



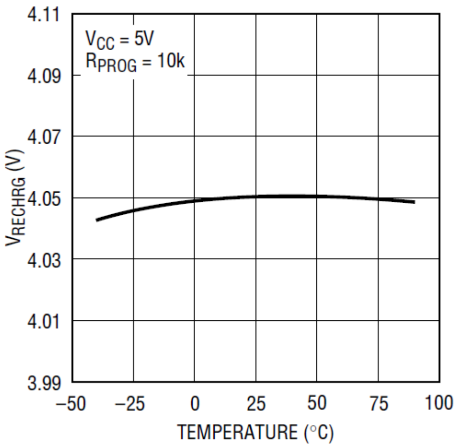
# TYPICAL CHARACTERISTICS

$V_{IN}$ = 5.0V, $T_A$ = 25°C, unless otherwise specified.

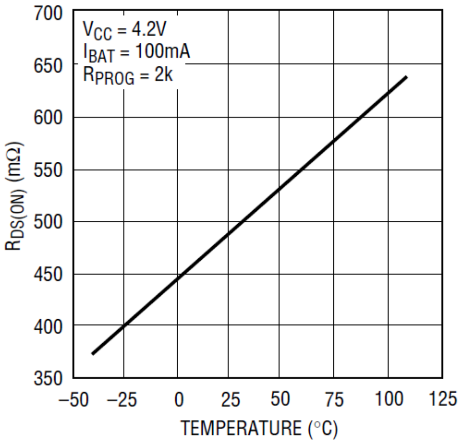
**Charge Current vs Ambient Temperature**




**Recharge Voltage Threshold vs Temperature**




**Power FET ON Resistance vs Temperature**



# FUNCTION DESCRIPTION

The HM4056G is a single cell lithium-ion battery charger using a constant-current/constant-voltage algorithm. It can deliver up to 1A of charge current (using a good thermal PCB layout) with a final float voltage accuracy of ±1%. The HM4056G includes an internal P-channel power MOSFET and thermal regulation circuitry. No blocking diode or external current sense resistor is required; thus, the basic charger circuit requires only two external components. Furthermore, the HM4056G is capable of operating from a USB power source.

## Normal Charge Cycle

A charge cycle begins when the voltage at the VCC pin rises above the UVLO threshold level and a 1% program resistor is connected from the PROG pin to ground or when a battery is connected to the charger output. If the BAT pin is less than 2.9V, the charger enters trickle charge mode. In this mode, the HM4056G supplies approximately 1/10 the programmed charge current to bring the battery voltage up to a safe level for full current charging. 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. When the BAT pin approaches the final float voltage (4.2V), the HM4056G enters constant voltage mode and the charge current begins to decrease. When the charge current drops to 1/10 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 1200 times the current out of the PROG pin. The program resistor and the charge current are calculated using the following equations:

$$R_{PROG} = \frac{1200}{I_{CHG}}, \text{ or } I_{CHG} = \frac{1200}{R_{PROG}}$$

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

$$I_{BAT} = \frac{V_{PROG} \bullet 1200}{R_{PROG}}$$

## Charge Termination

Charge cycle is terminated when the charge current falls to 1/10th 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 100mV for longer than $t_{TERM}$, charging is terminated. The charge current is latched off and the HM4056G enters standby mode, where the input supply current drops to 55μA. (Note: C/10 termination is disabled in trickle charging and thermal limiting modes).

When charging, transient loads on the BAT pin can cause the PROG pin to fall below 100mV for short periods of time before the DC charge current has dropped to 1/10th 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 1/10th the programmed value, the HM4056G 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.

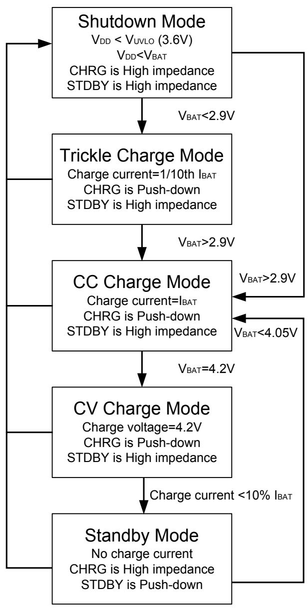



**Figure 2. State Diagram of a Typical Charge Cycle**

The HM4056G 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 2 shows the state diagram of a typical charge cycle.

## Charge Status Indicator

HM4056G has two open-drain status indicator output CHRG and STDBY. CHRG is pull-down when the HM4056G in a charge cycle. In other status CHRG is in high impedance. CHRG and STDBY are all in high impedance when the battery out of the normal temperature.

Represent in failure state, when TEMP pin is in typical connecting, and the battery is not connected, red LED and green LED are all not light. The battery temperature sense function is disabled by connecting TEMP pin to ground, if BAT pin connects a 10μF capacitor and the battery is not connected, the green LED is light and the red LED is blinked with 1-4s cycle time.

| Charger's status | Red LED CHRG | Green LED STDBY |
|---|---|---|
| Charging | Light | Dark |
| Charge termination | Dark | Light |
| UVLO, Battery out of the normal temperature, or battery is not connected(TEMP is used) | Dark | Dark |
| 10uF capacitor is connected to BAT pin, and battery is not connected(TEMP=GND) | Green LED is light, red LED is blinked with T=1-4s | |

## 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 145°C. This feature protects the HM4056G 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 HM4056G. 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.

## Undervoltage Lockout (UVLO)

An internal undervoltage lockout circuit monitors the input voltage and keeps the charger in shutdown mode until VCC rises above the undervoltage lockout threshold. The UVLO circuit has a built-in hysteresis of 200mV. Furthermore, to protect against reverse current in the power MOSFET, the UVLO circuit keeps the charger in shutdown mode if VCC falls to within 30mV of the battery voltage. If the UVLO comparator is tripped, the charger will not come out of shutdown mode until VCC rises 100mV above the battery voltage.

## Automatic Recharge

Once the charge cycle is terminated, the HM4056G 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. CHRG is push-down and the STDBY is in high impedance during recharge cycles.

## Stability Considerations

The constant-voltage mode feedback loop is stable without an output capacitor provided and a battery is connected to the charger output.

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 $R_{PROG}$:

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

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 as shown in Figure 3. A 10k resistor has been added between the PROG pin and the filter capacitor to ensure stability.

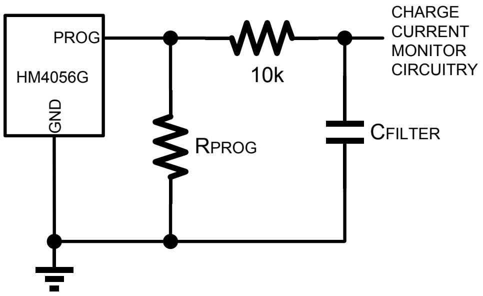



**Figure 3. Isolating Capacitive Load on PROG Pin and Filtering**

## Power Dissipation

The device's junction temperature depends on several factors such as ambient temperature, PCB layout, the load and package type. Equations that can be used to calculate power dissipation and junction temperature are found below:

$P_D = R_{DS(ON)} \times I_{OUT}^2$

To relate this $P_D$ to junction temperature, the following equation can be used:

$T_J = P_D \times \theta_{JA} + T_A$

Where:

$T_J$ is junction temperature,

$T_A$ is ambient temperature,

$\theta_{JA}$ is the thermal resistance of the package type.

# TYPICAL APPLICATION

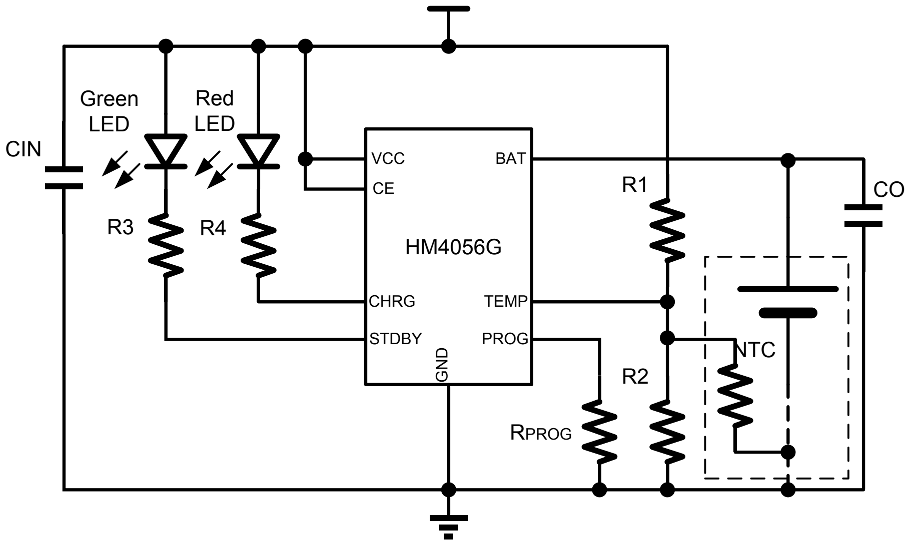
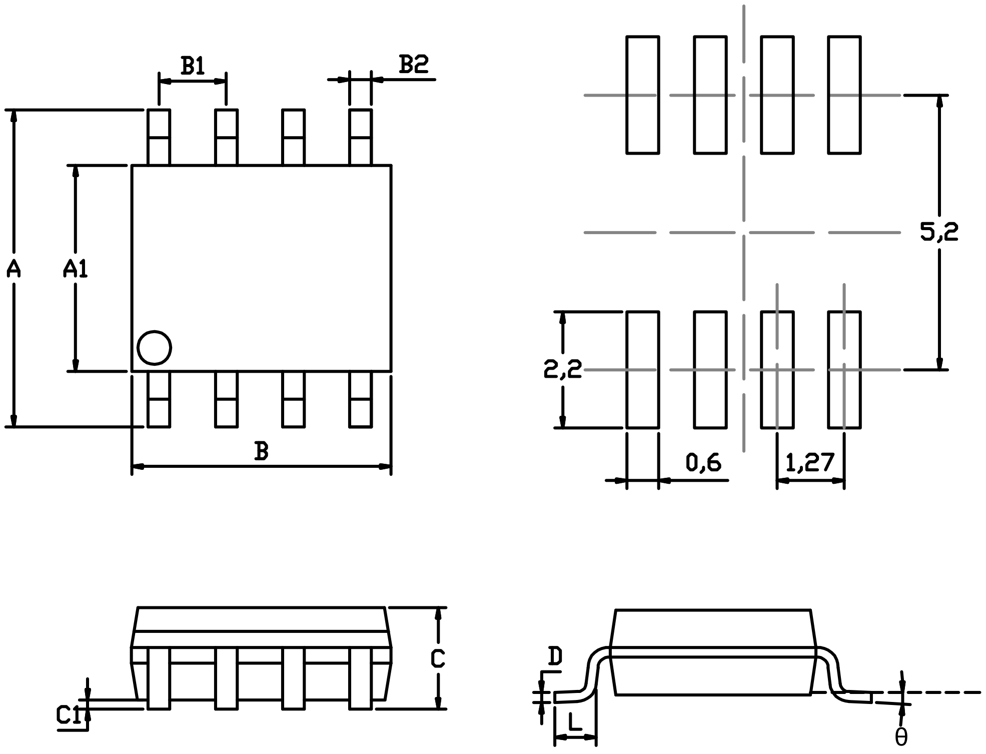



**Figure 4. Typical Application Circuit**

# PACKAGE DESCRIPTION

**ESOP8 package mechanical drawing**




ESOP8 package mechanical data

| symbol | dimensions | | | |
|---|---|---|---|---|
| | millimeters | | inches | |
| | min | max | min | max |
| A | 5.8 | 6.2 | 0.2283 | 0.2441 |
| A1 | 3.8 | 4 | 0.1496 | 0.1575 |
| B | 4.8 | 5 | 0.1890 | 0.1969 |
| B1 | 1.27 | | 0.0500 | |
| B2 | 0.31 | 0.51 | 0.0122 | 0.0201 |
| C | | 1.75MAX | | 0.0689MAX |
| C1 | 0.1 | 0.25 | 0.0039 | 0.0098 |
| L | 0.4 | 1.27 | 0.0157 | 0.0500 |
| D | 0.13 | 0.25 | 0.0051 | 0.0098 |
| θ | 0° | 8° | 0° | 8° |