Smart Battery Charging with GC8051

Content

GC8051
1 Cell Li-ion Battery Charger

1. OVERVIEW

The GC8051 is a single Lithium-Ion (Li-Ion) and Lithium–Polymer (Li-Pol) linear charge management controller for use in cost sensitive and portable applications. It combines high accuracy constant-current and constant-voltage regulation, cell preconditioning, temperature monitoring, automatic charge termination, charge-status indication, in a space-saving MSOP-8 package.

The GC8051 applies a constant current up to 1A to the battery and the charge current can be programmed externally with a sense-resistor.

The GC8051 automatically terminates the charge cycle when the charge current drops to the charge termination threshold (I_{TERM}) after the charge-regulation voltage is reached.

When the input supply is removed, the GC8051 automatically enters a low-power sleep mode, dropping the battery drain current to less than 1μA.

A battery charge state output pin is provided to indicate battery charge status through a display LED. The battery charge status output is a serial interface which may also be read by a system microcontroller.

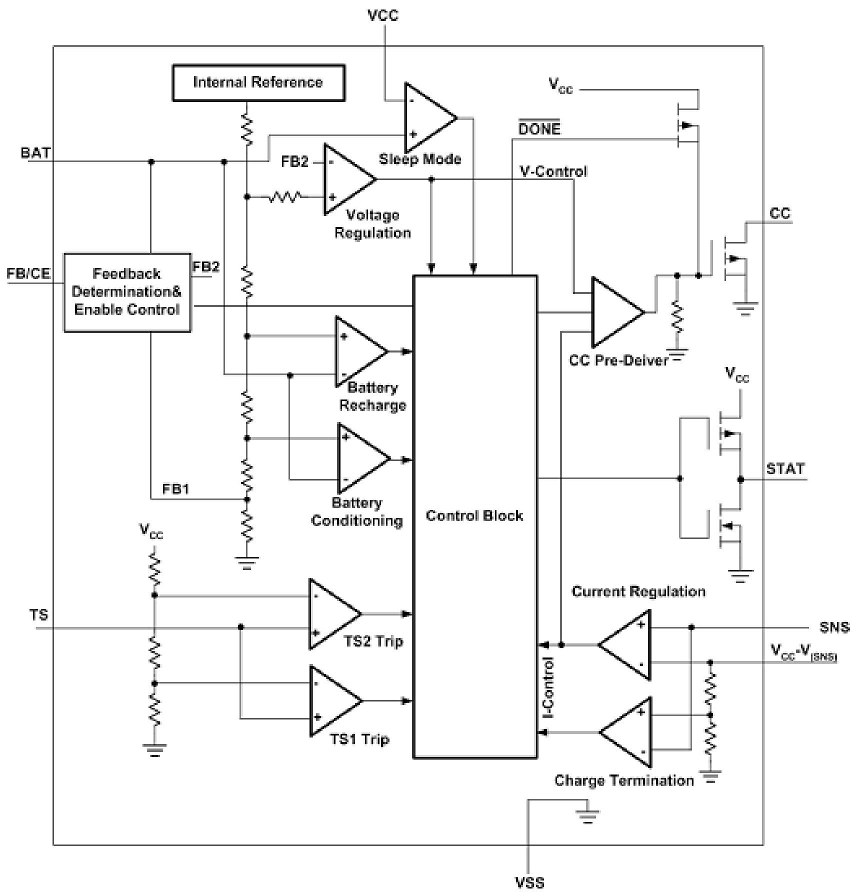
2. FEATURES

- Programmable Charge Current up to 1A
- 4.5V-7V Input Voltage Range
- Ideal for Single Cell (4.1V or 4.2V) Li-Ion or Li-Pol Batteries
- Preset Charge Voltage with ±1% Accuracy
- Constant-Current/Constant Voltage Operation
- Preconditioning of Low Voltage Cells
- Optional Cell-Temperature Monitoring Before and During Charge
- Charge Status Indication
- Automatic Battery Recharge
- Charge Termination by Minimum Current
- Automatic Low-Power Sleep Mode When Input Power is Removed
- Available in MSOP-8 Package
- RoHS Compliant and 100% Lead (Pb)-Free

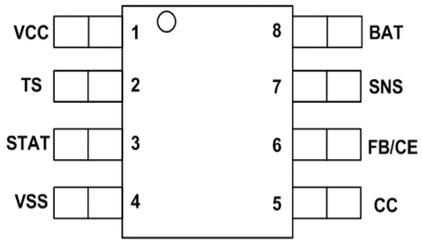
3. APPLICATIONS

- Chargers for MP3, Digital Camera, Hand-Held home appliance.

4. BLOCK DIAGRAM



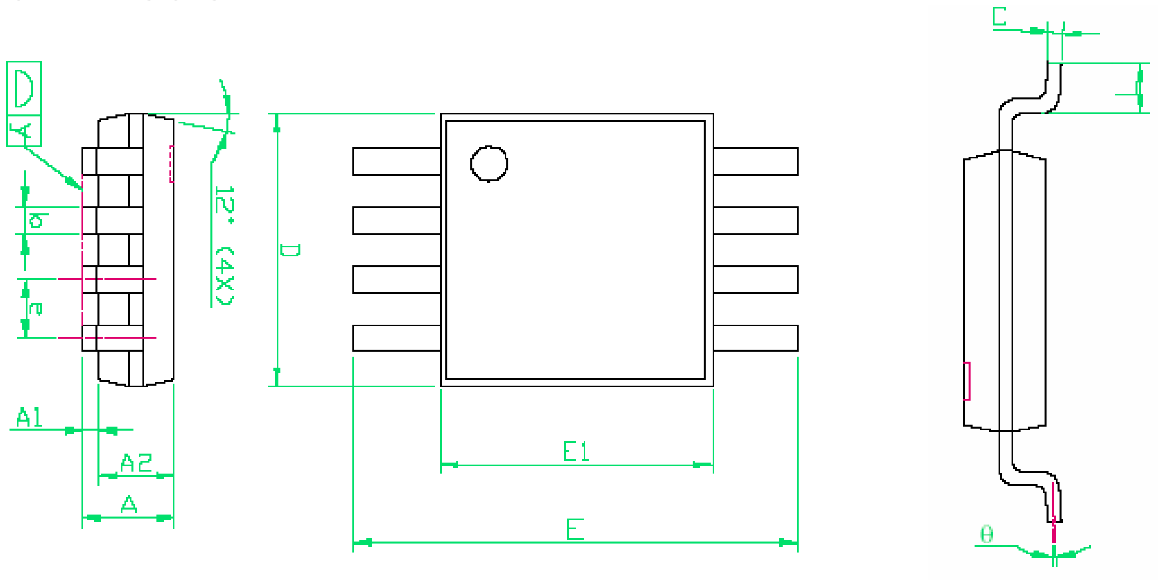
5. PINOUT



6. DESCRIPTION

Number	Name	I/O	Description
1	VCC	--	Supply Voltage Input
2	TS	I	Temperature Sense Input
3	STAT	O	Charge Status Output
4	VSS	--	Ground
5	CC	O	Charge Control Output
6	FB/CE	I	External Feedback input or Charge Enable Function. Input from controller or finely adjust the battery regulated voltage with external voltage divider
7	SNS	I	Current Sense Input
8	BAT	I	Battery Voltage Input

7. PACKAGE DIMENSIONS



NOTE

1. Package body sizes exclude mold flash and gate burrs
2. Dimension L is measured in gage plane
3. Tolerance 0.10mm unless otherwise specified
4. Controlling dimension is millimeter. Converted inch dimensions are not necessarily exact.

SYMBOLS	DIMENSIONS IN MILLIMETERS			DIMENSIONS IN INCHES		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	0.81	0.95	1.10	0.032	0.0375	0.043
A1	0.05	0.09	0.15	0.002	0.004	0.006
A2	0.76	0.86	0.97	0.030	0.034	0.038
b	0.28	0.30	0.38	0.011	0.012	0.015
C	0.13	0.15	0.23	0.005	0.006	0.009
D	2.90	3.00	3.10	0.114	0.118	0.122
E	4.70	4.90	5.10	0.185	0.193	0.201
E1	2.90	3.00	3.10	0.114	0.118	0.122
e	------	0.65	-----	------	0.026	------
L	0.40	0.53	0.66	0.016	0.021	0.026
y	------	------	0.10	------	------	0.004
θ	0	------	6	0	------	6

8. Absolute Maximum Ratings

- Input voltage between V_{DD} and V_{SS} -- V_{SS} -0.3 V to V_{SS} +12 V
- Input pin voltage for VM -- V_{DD} -30 V to V_{DD} +0.3 V
- Output pin voltage for CO --- V_{VM} -0.3 V to V_{DD} +0.3 V
- Output pin voltage for DO -- V_{SS} -0.3 V to V_{DD} +0.3 V
- Power dissipation SOT-23-6 -- 250mW
- Operating temperature range --- -40°C to +85°C
- Storage temperature range -- -55°C to +125°C
- ESD Susceptibility
  HBM (Human Body Mode) -- >1KV
  MM (Machine Mode) -- >200V

9. Ordering Information

Order Number	Package Type	Marking	Operating Temperature range
GC8051-41MIR1	MSOP-8	xxxx 8051	-20 °C to 70°C
GC8051-41MIR0	MSOP-8	xxxx 8051	-20 °C to 70°C
GC8051-42MIR1	MSOP-8	xxxx 8051C	-20 °C to 70°C
GC8051-42MIR0	MSOP-8	xxxx 8051C	-20 °C to 70°C

GC8051-□ □ □ □ □ □

Lead Free Code
1: Lead Free 0: Lead

Packing
R: Tape& Reel

Operating temperature range
I: Industry Standard

Package Type
M: MSOP

Output Voltage
41: 4.1V
42: 4.2V

10. Application Circuit

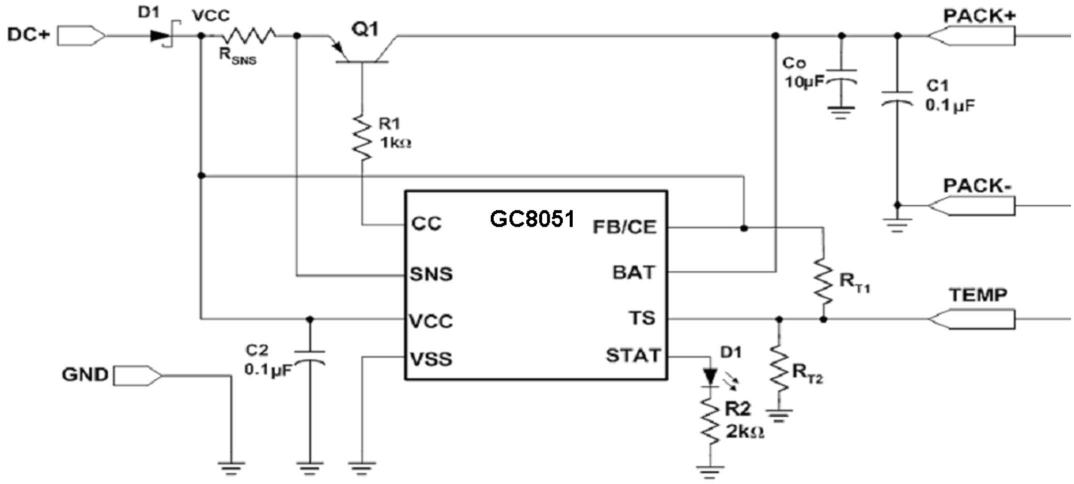


Figure1. Linear Charging Using P-N-P Transistor

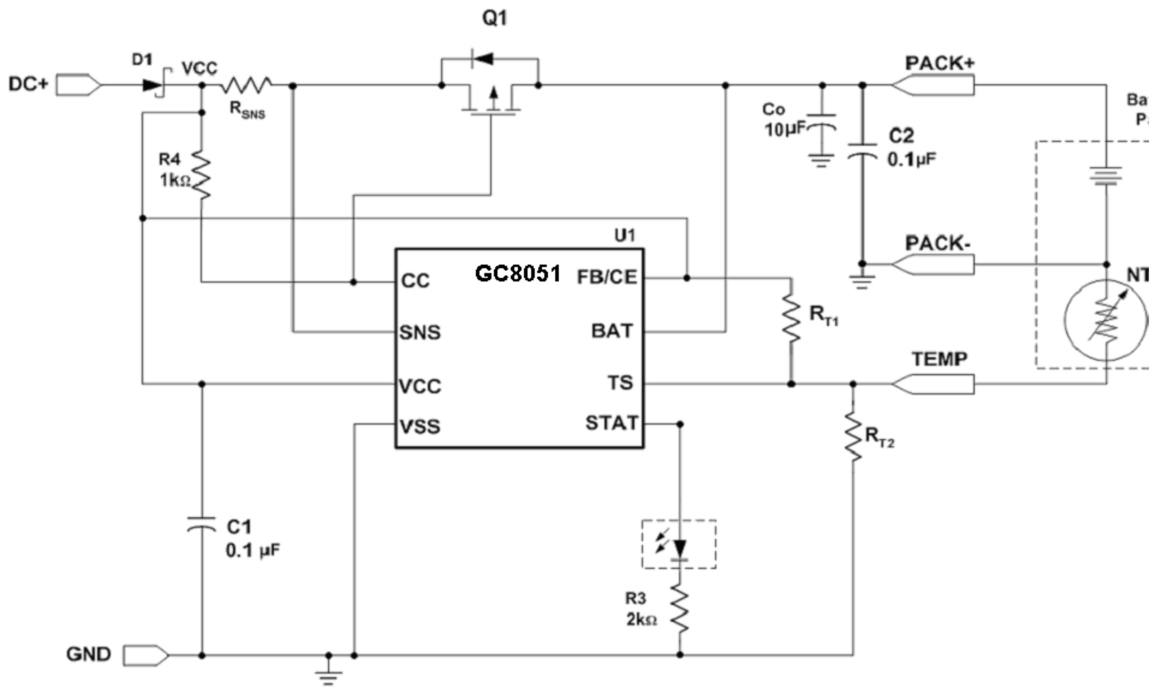


Figure1. Linear Charging Using P Channel MOSFET

11. Absolute Maximum Ratings

- Supply voltage, (Vcc with respect to GND) -- -0.3 to +7V
- Input voltage, SNS, BAT, TS, PI (all with respect to GND)------------------------- -0.3V to V_{CC} +0.3V
- Sink current (STAT pin) not to exceed P_D -- 20mA
- Source current (STAT pin) not to exceed P_D --- 10mA
- Output current (CC pin) not to exceed P_D --- 40mA
- Maximum Junction Temperature, T_J --- 150°C
- Storage temperature range, Tstg --- -65°C to 150°C
- Lead temperature (soldering, 10s) -- 300°C
- Package Thermal Resistance, θ_{JA}- MSOP8 -- 80°C/W

12. Recommended Operating Conditions

	Min.	Max.	Unit
Supply voltage, V_{CC}	4.5	7	V
Operating free-air temperature range, T_A	-20	70	°C

13. Electrical Characteristics over Recommended Operating Free-Air Temperature Range

Symbol	Parameter	Conditions	GC8051			Unit
			Min.	Typ.	Max.	
$I_{(VCC)}$	V_{CC} current	V_{CC}=5V >$V_{CC(min)}$, Excluding external loads		0.6	1	mA
$I_{(VCCS)}$	V_{CC} Sleep current	$V_{(BAT)} \geq V_{(min)}$, $V_{(BAT)}-V_{CC} \geq$ 0.8V		2	6	μA
$I_{IB(BAT)}$	Input bias current on BAT pin	$V_{(BAT)}=V_{(REG)}$			1	μA
$I_{IB(SNS)}$	Input bias current on SNS pin	$V_{(SNS)}$=5V			1	μA
$I_{IB(TS)}$	Input bias current on TS pin	$V_{(TS)}$=5V			1	μA
$I_{IB(PI)}$	Input bias current on PI pin	$V_{(PI)}$=5V			1	μA
Battery Voltage Regulation						
$V_{O(REG)}$	Output voltage	GC8051-4.1	4.059	4.10	4.141	V
		GC8051-4.2	4.158	4.20	4.242	

14. Electrical Characteristics Over Recommended Operating Free-Air Temperature Range

Symbol	Parameter	Conditions	GC8051			Unit
			Min.	Typ.	Max.	
$V_{(SNS)}$	Current regulation threshold	Voltage at pin SNS, relative to V_{CC}	198	220	242	mV
Charge Termination Detection						
$I_{(TERM)}$	Charge termination current detect threshold	Voltage at pin SNS, relative to V_{CC} 0°C $\leq T_A \leq$ 50°C	-25	-15	-5	mV
Temperature Comparator						
$V_{(TS1)}$	Lower temperature threshold	TS pin voltage	29	30	31	$\%V_{CC}$
$V_{(TS2)}$	Upper temperature threshold		58	60	62	
Precharge Comparator						
V(min)	Precharge threshold	GC8051-4.1	2.94	3	3.06	V
		GC8051-4.2	3.04	3.1	3.16	
Precharge Current Regulation						
$I_{(PRECHG)}$	Precharge current regulation	Voltage at pin SNS, relative to V_{CC} 0°C $\leq T_A \leq$ 50°C		15		mV
		Voltage at pin SNS, relative to V_{CC} 0°C $\leq T_A \leq$ 50°C , V_{CC}=5V	5	15	25	mV
V_{RCH} comparator(Battery Recharge Threshold)						
$V_{(RCH)}$	Recharge threshold	GC8051-4.1 and GC8051-4.2	$V_{O(REG)}$-98mV	$V_{O(REG)}$-100mV	$V_{O(REG)}$-102mV	V
STAT Pin						
$V_{OL(STAT)}$	Output(low)voltage	I_{OL}=10mA			0.5	V
$V_{OH(STAT)}$	Output(high)voltage	I_{OH}=5mA	V_{CC}-0.5			
CC Pin						
$V_{OL(CC)}$	Output low voltage	$I_{O(CC)}$=5mA(sink)			1.5	V
$I_{O(CC)}$	Sink current	Not to exceed power rating specification(P_D)	5		40	mA

15. Qualification and Precharge

When power is applied, the GC8051 starts a charge-cycle if a battery is already present or when a battery is inserted. Charge qualification is based on battery temperature and voltage.

The GC8051 suspends charge if the battery temperature is outside the $V_{(TS1)}$ to $V_{(TS2)}$ range and suspends charge until the battery temperature is within the allowed range. The GC8051 also checks the battery voltage. If the battery voltage is below the precharge threshold V(min), the GC8051 uses precharge to condition the battery. The conditioning charge rate $I_{(PRECHG)}$ is set at approximately 10% of the regulation current. The conditioning current also minimizes heat dissipation in the external pass-element during the initial stage of charge. See Figure5 for a typical charge-profile.

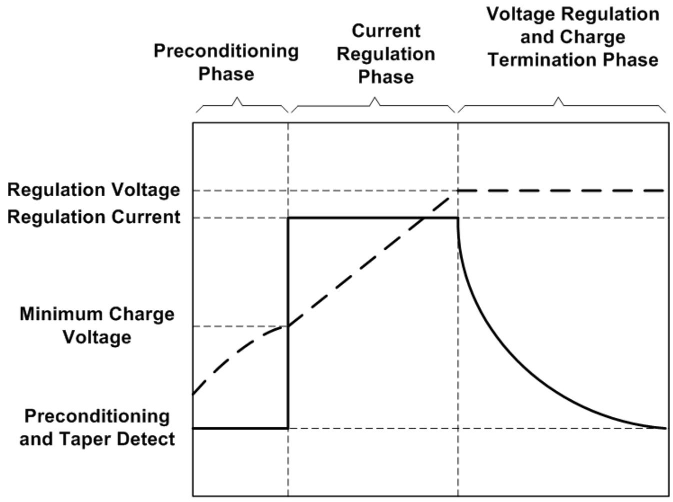


Figure5. Typical Charge Profile

16. Current Regulation Phase

The GC8051 regulates current while the battery-pack voltage is less than the regulation voltage, $V_{O(REG)}$. The GC8051 monitors charge current at the SNS input by the voltage drop across a sense-resistor, R_{SNS}, in series with the battery pack. In current sensing configuration (Figure6), R_{SNS} is between the VCC and SNS pins, charge-current feedback, applied through pin SNS, maintains a voltage of $V_{(SNS)}$ across the current sense resistor. The following formula calculates the value of the sense resistor:

$$R_{SNS} = \frac{V_{(SNS)}}{I_{O(REG)}} \quad \text{----------------------------- (1)}$$

Where $I_{O(REG)}$ is the desired charging current.

Example: For 0.55A, R_{SNS}: 0.22V/0.55A: 0.4Ω

For 1.0A, R_{SNS}: 0.22V/1.0A: 0.22Ω

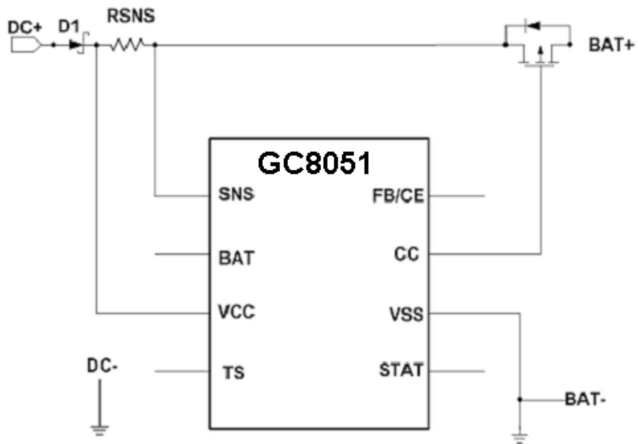


Figure6. Current Sensing Circuit

17. Voltage Regulation Phase

The voltage regulation feedback is through the BAT pin. This input is tied directly to the positive side of the battery pack. The GC8051 monitors the battery-pack voltage between the BAT and VSS pins. The GC8051 is offered in two fixed-voltage versions: 4.1V, 4.2V.

18. FB/CE Pin Function

This pin has two functions, one is to enable/disable the charge function, and the other is to finely adjust battery regulation voltage. Connect this pin to VDD to enable GC8051, and connect to ground to disable it (Figure7). If this pin is connected to a voltage divider as shown in Figure8, it can be a 2.15V reference voltage to adjust the output regulation voltage as desired.

$$V_{O(REG)} = 2.15 \times (1 + \frac{R_{FB1}}{R_{FB2}})V$$

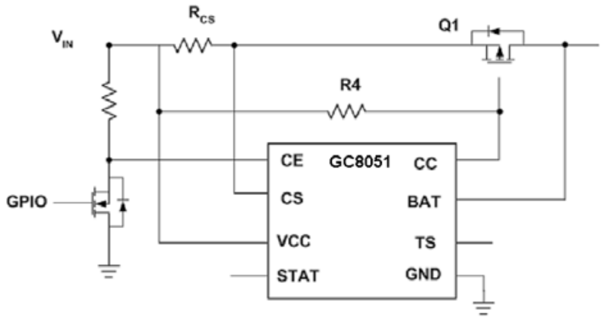


Figure7. For CE pin Function

19. Charge Termination and Recharge

The GC8051 monitors the charging current during the voltage-regulation phase. The GC8051 declares a done condition and terminates charge when the current drops to the charge termination threshold, $I_{(TERM)}$. A new charge cycle begins when the battery voltage falls below the $V_{(RCH)}$ threshold.

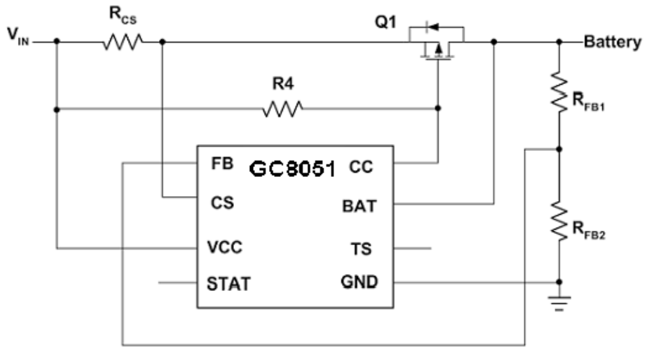


Figure8. For FB pin Function

20. Battery Temperature Monitoring

The GC8051 continuously monitors temperature by measuring the voltage between the TS and VSS pins. A negative-or a positive-temperature coefficient thermistor (NTC, PTC) and an external voltage divider typically develop this voltage (See Figure9). The GC8051 compares this voltage against its internal $V_{(TS1)}$ and $V_{(TS2)}$ thresholds to determine if charging is allowed. (See Figure10). The temperature sensing circuit is immune to any fluctuation in VCC, since both the external voltage divider and the internal thresholds ($V_{(TS1)}$ and $V_{(TS2)}$) are referenced to VCC.

The resistor values of $R_{(T1)}$ and $R_{(T2)}$ are calculated by the following equations:

For NTC Thermistors

$$R_{T1} = \frac{5 \times R_{TH} \times R_{TC}}{3 \times (R_{TC} - R_{TH})} \text{ ----------------------- (3)}$$

$$R_{T2} = \frac{5 \times R_{TH} \times R_{TC}}{[(2 \times (R_{TC}) - (7 \times R_{TH})]} \text{ -------------- (4)}$$

For PTC Thermistors

$$R_{T1} = \frac{5 \times R_{TH} \times R_{TC}}{3 \times (R_{TH} - R_{TC})} \text{ ---------------------- (5)}$$

$$R_{T2} = \frac{5 \times R_{TH} \times R_{TC}}{[(2 \times (R_{TH}) - (7 \times R_{TC})]} \text{ ------------- (6)}$$

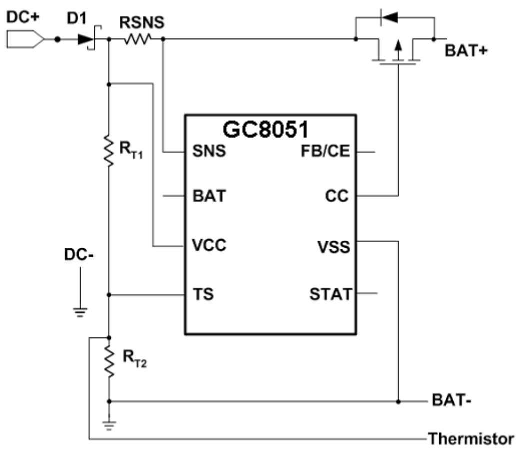


Figure9. Temperature Sensing Circuits

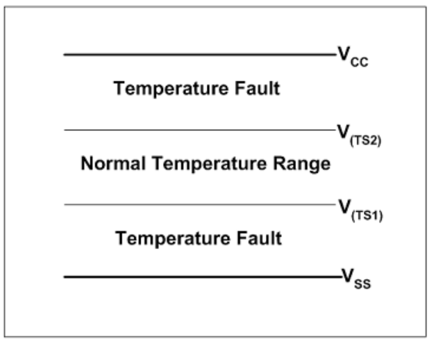


Figure10. TS Input Thresholds

Where $R_{(TC)}$ is the cold temperature resistance and $R_{(TH)}$ is the hot temperature resistance of thermistor, as specified by the thermistor manufacturer.

R_{T1} or R_{T2} can be omitted if only one temperature (hot or cold) setting is required. Applying a voltage between the $V_{(TS1)}$ and $V_{(TS2)}$ thresholds to pin TS disables the temperature-sensing feature.

21. Charge Inhibit Function

The TS pin can be used as charge-inhibit input. The user can inhibit charge by connecting the TS pin to VCC or VSS (or any level outside the $V_{(TS1)}$ to $V_{(TS2)}$ thresholds). Applying a voltage between the $V_{(TS1)}$ and $V_{(TS2)}$ thresholds to pin TS returns the charger to normal operation.

22. Charge Status Indication

The GC8051 reports the status of the charger on the 3-state STAT pin. The following table summarized the operation of the STAT pin.

Condition	STAT pin
Battery conditioning and charging	High
Charge complete(done)	Low
Temperature fault or sleep mode	Hi-Z

The STAT pin can be used to drive a single LED (Figure1), dual-chip LEDs (Figure2) or for interface to a host or system processor (Figure11). When interfacing the GC8051 to a processor, the user can use an output port, to recognize the high-Z state of the STAT pin. In this configuration, the user needs to read the input pin, toggle the output port and read the STAT pin again. In a high-Z condition, the input port always matches the signal level on the output port.

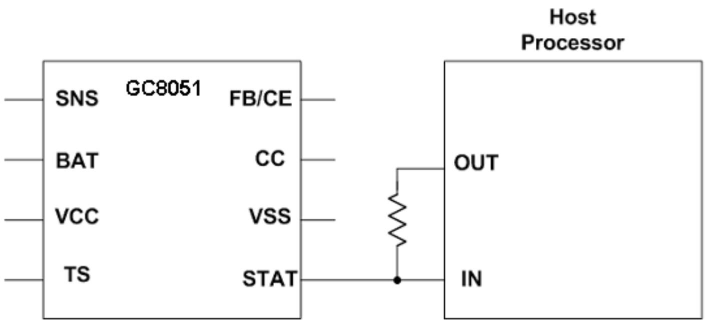


Figure11. Interfacing the GC8051 to a Host Processor

23. Low-Power Sleep Mode

When the input supply is disconnected, the charger automatically enters power-saving sleep mode.

Only consuming an ultra-low 1μA in sleep mode, the GC8051 minimizes battery drain when it is not charging.

24. Selecting Input Capacitor

In most applications, all that is needed is high-frequency decoupling capacitor. A 0.1μF ceramic, placed in proximity to VCC and VSS pins, works well. The GC8051 works 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 must be added to the input of the charger.

25. Selecting Output Capacitor

The GC8051 does not require any output capacitor for loop stability.

In order to maintain good AC stability in the Constant Voltage mode, a minimum capacitance of 10μF is recommenced to bypass the V_{BAT} pin to V_{SS}. This capacitance provides compensation when there is no battery load. In addition, the battery and interconnections appear inductive at high frequencies. These elements are in the control feedback loop d＞uring Constant Voltage mode. Therefore, the bypass capacitance may be necessary to compensate for the inductive nature of the battery pack.

Virtually any good quality output filter capacitor can be used, independent of the capacitor's minimum ESR (Effective Series Resistance) value. The actual value of the capacitor and its associated ESR depends on the forward transconductance (gm) and capacitance of the external pass transistor. A 10μF tantalum or aluminum electrolytic capacitor at the output is usually sufficient to ensure stability for up to a 1A output current.

26. Selecting An External Pass-Device (PMOS or PNP)

The GC8051 is designed to work with both P-channel MOSFET or PNP transistor. The device should be chosen to handle the required power dissipation, given the circuit parameters, PCB layout and heat sink configuration. The following examples illustrate the design process for PMOS device:

27. P-Channel MOSFET

Selection steps for a P-channel MOSFET: We will use the following conditions: V_I=5V (with 10% supply tolerance); $I_{(REG)}$=1A, 4.2-V single-cell Li-Ion. V_I is the input voltage to the charger and $I_{(REG)}$ is the desired charge current. (See Figure2)

1. Determine the maximum power dissipation, P_D , in the transistor.
   The worst case power dissipation happens when the cell voltage, $V_{(constant)}$, is at its lowest (typically 3.1V at the beginning of current regulation phase) and V_I is at its maximum. Where V_D is the forward voltage drop across the reverse-blocking diode (if one is used), and V_{CS} is the voltage drop across the current sense resistor.

   $P_D=(V_{I(MAX)}-V_D-V_{CS}-V_{BAT})\times I_{REG}$ --------- (7)
   $P_D=(5.5-0.4-0.2-3.1)\times 1A$
   $P_D=1.8W$

2. Determine the package size needed in order to keep the junction temperature below the manufacturer's recommended value, T_{JMAX}. Calculate the total theta, θ(°C/W), needed.

$$\theta_{JA} = \frac{(T_{max(J)} - T_{A(max)})}{P_D} \quad \text{--------------(8)}$$

$$\theta_{JA} = \frac{(150 - 40)}{1.8} \qquad \theta_{JA} = 61°C/W$$

It is recommended to choose a package with a lower θ_{JA} than the number calculated above.

3. Select a drain-source voltage, $V_{(DS)}$, rating greater than the maximum input voltage. A 12V device will be adequate in this example.
4. Select a device that has at least 50% higher drain current (I_D) rating than the desired charge current $I_{(REG)}$.
5. Verify that the available drive is large enough to supply the desired charge current.

   $V_{(GS)}=(V_D+V_{(CS)}+V_{OL(CC)})-V_{I(min)}$ -------------- (9)
   $V_{(GS)}=(0.4+0.2+1) - 4.5$
   $V_{(GS)}=-2.9$

Where $V_{(GS)}$ is the gate-to-source voltage, V_D is the forward voltage drop across the reverse-blocking diode (if one is used), and V_{CS} is the voltage drop across the current sense resistor, and $V_{OL(CC)}$ is the CC pin output low voltage specification for the GC8051.

Select a MOSFET with gate threshold voltage, $V_{(GSth)}$, rating less than the calculated $V_{(GS)}$.

28. Reverse Blocking Protection

The optional reverse-blocking protection diode, depicted in Figure1&2 provides protection from a faulted or shorted input, or from a reversed-polarity input source. Without the protection diode, a faulted of shorted input would discharge the battery pack through the body diode of the external pass transistor.

If a reverse-protection diode is incorporated in the design, it should be chosen to handle the fast charge current continuously at the maximum ambient temperature. In addition, the reverse-leakage current of the diode should be kept as small as possible.

Document Amended History

Date	Details	By	File Name
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