800mA Lithium Ion Battery Linear Charger ME4055A

General Description

ME4055A is a complete constant-current/constant voltage linear charger for single cell lithium-ion batteries. Furthermore the ME4055A is specifically designed to work within USB power specifications.

No external sense resistor is needed and no blocking diode is required due to the internal PMOSFET 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 ME4055A 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 ME4055A automatically enters a low current state dropping the battery drain current to less than 2µA.The ME4055A can be put into shutdown mode reducing the supply current to 55µA.

Other features include charge current monitor, undervoltage lockout, automatic recharge and a status.

Features

- Protection of battery cell reverse connection
- No MOSFET sense resistor or blocking diode required
- Complete Linear Charger in Thin SOT Package for Single Cell Lithium-Ion Batteries
- Constant- Current/Constant- Voltage operation with thermal regulation to maximize Rate Without risk of overheating.
- Preset 4.2V charge voltage with ±1% accuracy
- Automatic Recharge
- Charges Single Cell Li-Ion Batteries Directly from USB Port
- C/10 charge termination
- 55µA supply current in shutdown
- 2.9V trickle current charge threshold
- Soft-Start limits inrush current
- Charge Status Output Pin

Typical Application

- Cellular Telephones, PDAs, MP3 Players
- Charging Docks and Cradles
- Bluetooth Applications
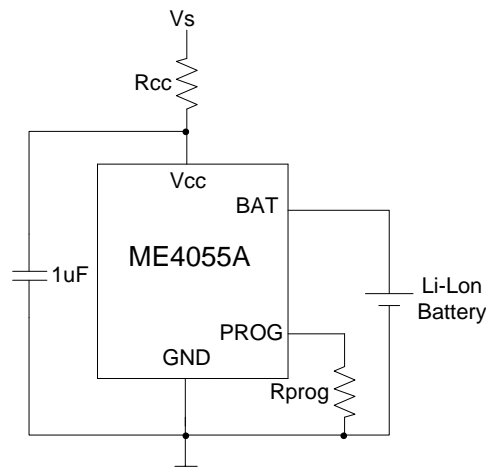
Package

- 6-pin SOT23-6

Typical Application circuit

Mainly used in Cellular telephones, MP3, MP4 players, digital still cameras, electronic dictionary, GPS, portable devices and vary chargers.
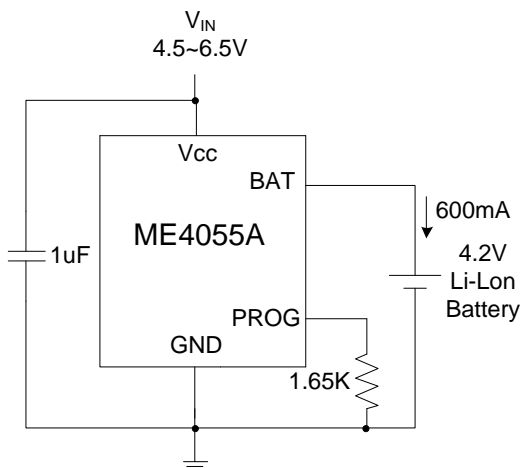
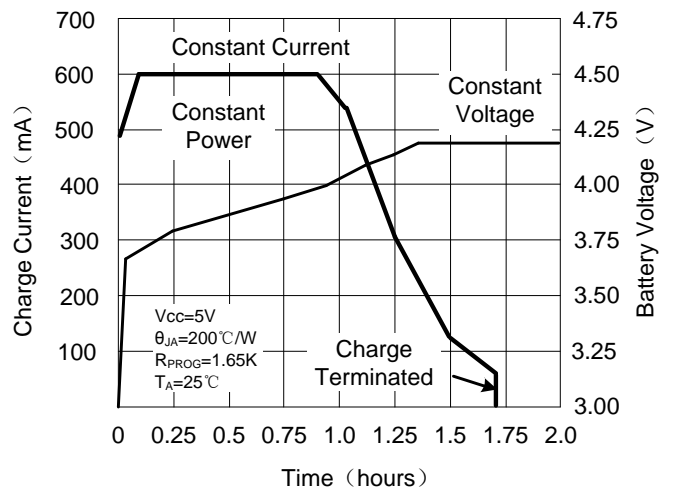### 1. Suitable for the application of USB power and the charge of wall adapter
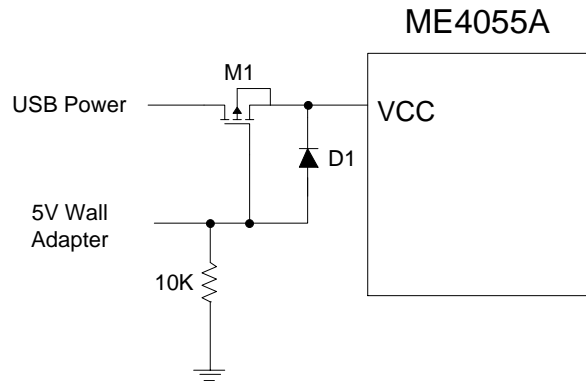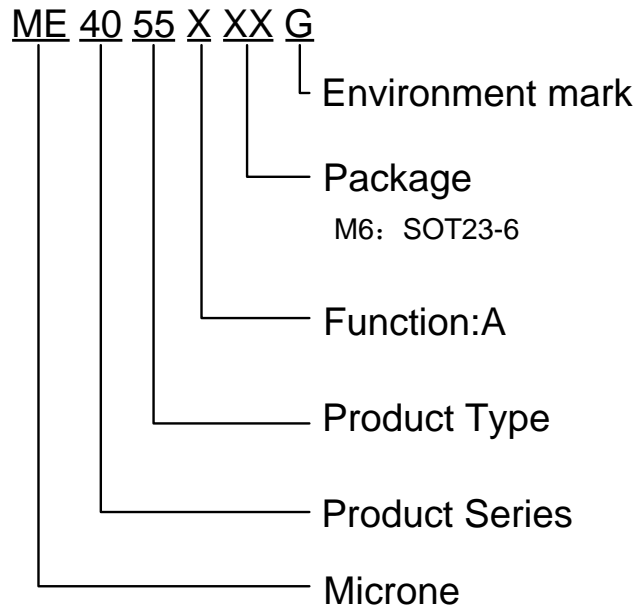
ME4055A

2. Add a resistor for power dissipation

600mA Single Cell Li-Ion Charger

Typical charge cycle（750mAh battery）

Selection Guide

ME 40 55 X XX G

- Environment mark
- Package
  M6：SOT23-6
- Function:A
- Product Type
- Product Series
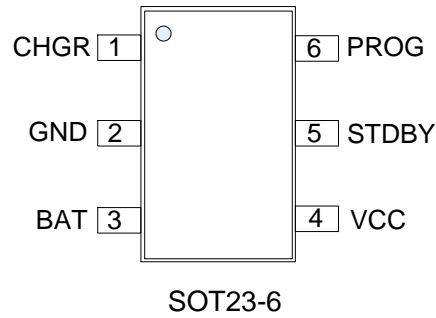- Microne

product series	product description
ME4055AM6G	Package:SOT23-6；The Thermal protection temperature is 110℃ and charge termination；Constant current accuracy：±18%
ME4055AM6G-1	Package:SOT23-6；The Thermal protection temperature is 110℃ and charge termination；Constant current accuracy：±10%

**NOTE:** If you need other package, please contact our sales staff。

Pin Configuration& Pin Assignment

SOT23-6

Pin Assignment

Pin Num.	Symbol	Function
1	CHRG	**Open-Drain charge status output** When the battery is being charged, the CHRG pin is pulled low by an internal switch, otherwise, CHRG pin is in high impedance state.
2	GND	**Ground**
3	BAT	**Battery connection Pin** Connect the positive terminal of the battery to this pin. Dropping BAT pin's current to less than 2μA when IC in disable mode or in sleep mode. BAT pin provides charge current to the battery and provides regulation voltage of 4.2V.
4	VCC	**Positive input supply voltage** Provides power to the internal circuit. When V_{CC} drops to within 80mV of the BAT pin voltage, the ME4055A enters low power sleep mode, dropping I_{BAT} to less than 2μA.
5	STDBY	**Charge terminated status output** STDBY is pulled low by an internal switch to indicate a battery charge terminated; this means Charge termination. Otherwise STDBY pin is in high impedance state.
6	PROG	**Constant Charge Current Setting and Charge Current Monitor Pin** The charge current is programmed by connecting a resistor R_{PROG} from this pin to GND. When in precharge mode, the PROG pin's voltage is regulated to 0.1V. When charging in constant-current mode this pin's voltage is regulated to 1V. In all modes during charging, the voltage on this pin can be used to measure the charge current using the following formula: $I_{BAT} = \dfrac{V_{PROG}}{R_{PROG}} * 1100$

Block Diagram
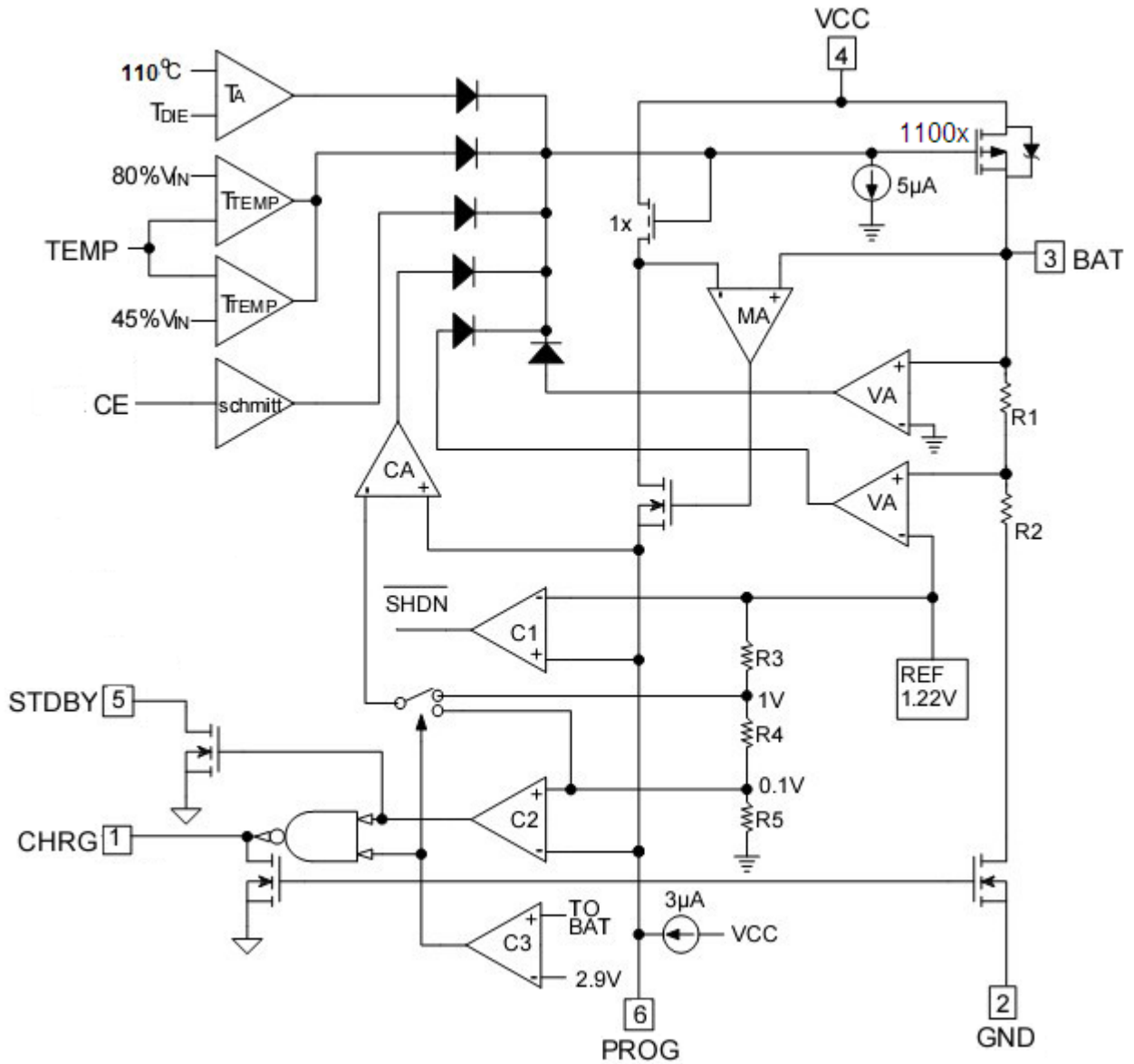
Absolute Maximum Ratings

Parameter	Rating	Unit
Input supply voltage : V_{CC}	-0.3～6.5	V
PROG pin voltage	-0.3～VCC+0.3	V
BAT pin voltage	-0.3～6.5	V
CHRG pin voltage	-0.3～6.5	V
STDBY pin voltage	-0.3～6.5	V
BAT pin current	800	mA
PROG pin current	1200	µA
Maximum Power Dissipation Pd	0.63	W
Package thermal impedance θ_{JA}	200	℃/W
Maximum junction temperature	-40～150	℃
Operating ambient temperature :T_{opa}	-40～85	℃
Storage temperature :T_{str}	-55～150	℃
Soldering temperature and time	+260（Recommended 10S）	℃

Caution: The absolute maximum ratings are rated values exceeding which the product could suffer physical damage.

These values must therefore not be exceeded under any conditions.

Electrical Characteristics

Symbol	Parameter	Condition		Min	Typ.	Max	Unit
V_{CC}	Input supply voltage	●		4.0	5.0	6.5	V
I_{CC} -I_{BAT}	static current	●Charge mode, R_{PROG}=1.1KΩ		-	150	500	µA
		●Standby mode(charge end)		-	55	100	µA
		●Shutdown mode（R_{PROG} not connected, V_{CC}<V_{BAT}, or V_{CC}<V_{UV}）		-	55	100	µA
V_{FLOAT}	Regulated output voltage	0℃≤T_A≤85℃		4.158	4.2	4.242	V
I_{BAT}	BAT pin current (The condition of current mode is V_{BAT}=3.9V)	●R_{PROG}=2.2KΩ, current mode	ME4055A	463	550	645	mA
			ME4055A-1	495	550	605	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
I_{TRIKL}	Trickle charge current	●V_{BAT}<V_{TRIKL}, R_{PROG}=2.2KΩ		48	68	87	mA
V_{TRIKL}	Trickle charge threshold voltage	R_{PROG}=2.2KΩ, V_{BAT} rising		2.8	2.9	3.0	V
V_{TRHYS}	Trickle voltage hysteresis voltage	R_{PROG}=2.2KΩ		150	200	250	mV
V_{UV}	V_{CC} under voltage lockout threshold	● V_{CC} from low to high		3.5	3.7	3.9	V
V_{UVHYS}	V_{CC} under voltage lockout hysteresis	●		150	200	300	mV
V_{ASD}	V_{CC}-V_{BAT} lockout threshold voltage	V_{CC} from low to high		100	140	180	mV
		V_{CC} from high to low		50	80	110	mV
I_{TERM}	termination current threshold	●R_{PROG}=2.2KΩ		46	55	65	mA

V_{PROG}	PROG pin voltage	● R_{PROG}=2.2KΩ, current mode	0.9	1.0	1.1	V
V_{CHRG}	CHRG Pin output low voltage	I_{CHRG}=5mA	-	0.3	0.6	V
ΔV_{RECHRG}	Recharge battery threshold voltage	V_{FLOAT} -V_{RECHRG}	100	150	240	mV
T_{LIM}	Thermal protection temperature		-	110	-	℃
R_{ON}	The resistance of power FET ”ON”（between V_{CC} and BAT）		-	650	-	mΩ
t_{SS}	Soft-start time	I_{BAT}=0 to I_{BAT}=1100V/R_{PROG}	-	20	-	μS
$t_{RECHARGE}$	Recharge comparator filter time	V_{BAT} from high to low	0.8	1.8	4	mS
t_{TERM}	Termination comparator filter time	I_{BAT} below I_{CHG}/10	0.8	1.8	4	mS
I_{PROG}	PROG pin pull-up current		-	2.0	-	μA

Note: The ● denotes specifications which apply over the full operating temperature rang, otherwise specifications are

at T_A=25℃，V_{CC}=5V，unless otherwise specified.

## Typical performance characteristics
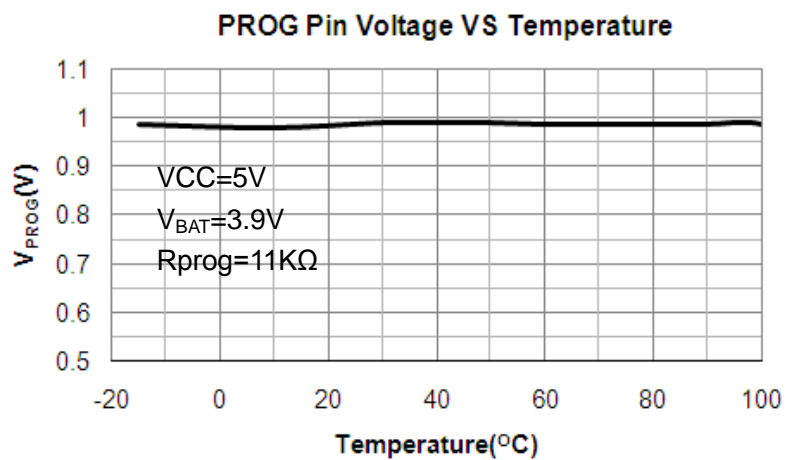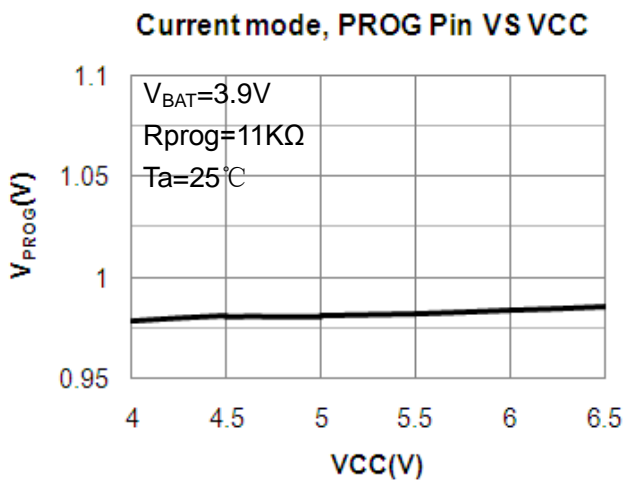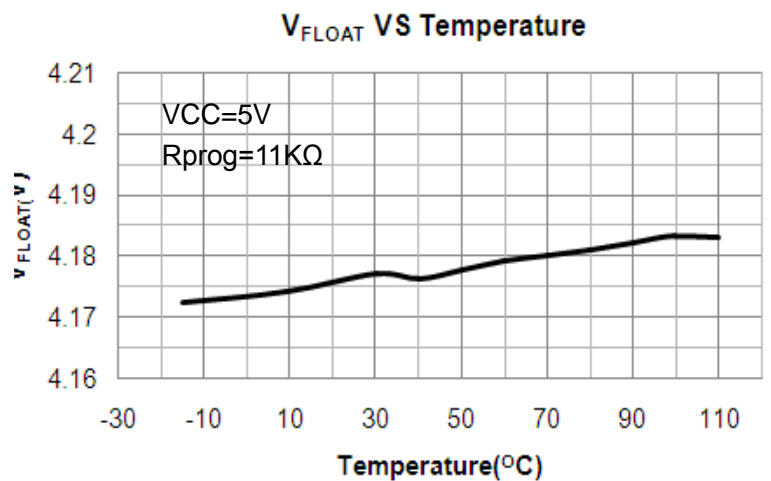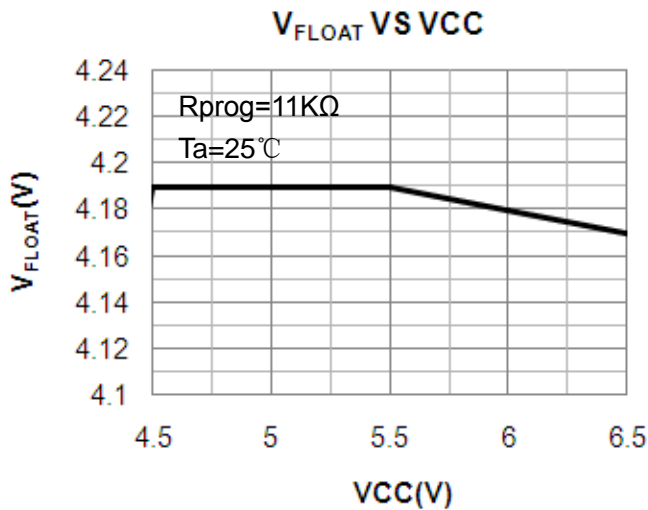
Description of the Principle

The ME4055A is a complete constant-current/constant-voltage linear charger for single cell lithium-ion batteries. Constant-current/constant-voltage to charger batter by internal MOSFET .It can deliver up to 800mA of charge current .No blocking diode or external current sense resistor is required. ME4055A include one Open-Drain charge status Pin: Charge status indicator CHRG

The internal thermal regulation circuit reduces the programmed charge current if the die temperature attempts to rise above a preset value of approximately 110℃. This feature protects the ME4055A 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 ME4055A or the external components. Another benefit of adopting thermal regulation is that charge current can be set according to typical, not worst-case, ambient temperatures for a given application with the assurance that the charger will automatically reduce the current in worst-case conditions.

The charge cycle begins when the voltage at the V_{CC} pin rises above the UVLO level, a current set resistor is connected from the PROG pin to ground. The CHRG pin outputs a logic low to indicate that the charge cycle is on going. At the beginning of the charge cycle, if the battery voltage is below 2.9V, the charge is in precharge mode to bring the cell voltage up to a safe level for charging. The charger goes into the fast charge constant-current mode once the voltage on the BAT pin rises above 2.9 V. In constant current mode, the charge current is set by R_{PROG}. When the battery approaches the regulation voltage 4.2V, the charge current begins to decrease as the ME4055A enters the constant-voltage mode. When the current drops to charge termination threshold, the charge cycle is terminated, and CHRG pin assumes a high impedance state to indicate that the charge cycle is terminated . The charge termination threshold is 10% of the current in constant current mode. To restart the charge cycle, remove the input voltage and reapply it . The charge cycle can also be automatically restarted if the BAT pin voltage falls below the recharge threshold. The on-chip reference voltage, error amplifier and the resistor divider provide regulation voltage with 1% accuracy which can meet the requirement of lithium-ion and lithium polymer batteries. When the input voltage is not present, or input voltage is below V_{BAT}, the charger goes into a sleep mode, dropping battery drain current to less than 3μA. This greatly reduces the current drain on the battery and increases the standby time. The charging profile is shown in the following figure:
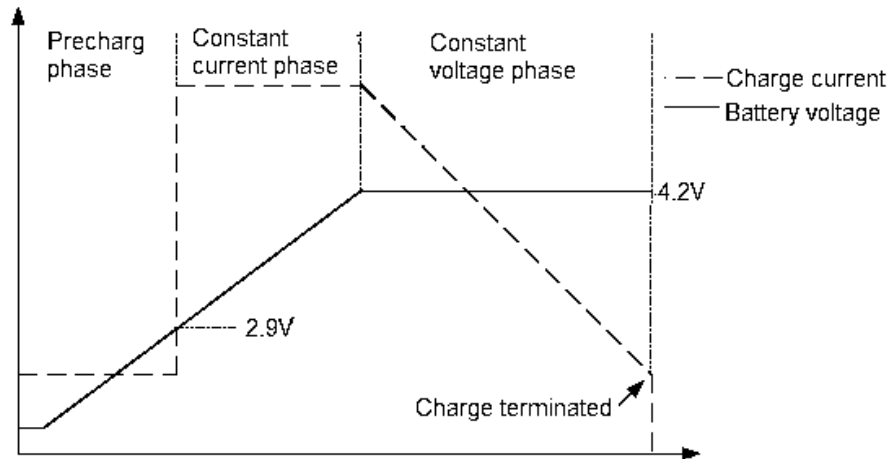
Programming charge current

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

$$R_{PROG}=1100/I_{BAT}$$

In application, according the charge current to determine R_{PROG}, the relation between R_{PROG} and charge current can reference the following chart:

$K=\dfrac{1100}{R_{PROG} \times I_{BAT}}$	I_{BAT} (mA)	R_{PROG} (KΩ)
0.9	30	40
0.75	60	24
0.8	114	12
0.9	305	4
1	650	1.7
1.1	1000	1

Note:

a. K is the coefficient of variation, It generally is 1, but due to the vary operating environment, K is varied in the range: 0.8~1.4

b. The up form is just for reference, it will varied ±10% according to the heat dissipation of the using PCB board;

c. 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.

Charge termination

A 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_{TEMP} (typically 1.8mS), Charging is terminated. The charge current is latched off and the ME4055A 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 1.8mS filter time (t_{TEMP}) 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 ME4055A terminated 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 ME4055A constantly monitors the BAT pin voltage in standby mode. If this voltage drops below the 4.02V 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 1 shows the state diagram of a typical charge cycle.

Charge status indicator

ME4055A has two open-drain status indicator output CHRG and STDBY. CHRG is pull-down when the ME4055A in a charge cycle. In other status CHRG 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 in typical connecting, or the charger with no battery: red LED and green LED all don't light. The battery temperature sense function is disabled by connecting TEMP pin to GND. If battery is not connected to charger, CHRG pin outputs a PWM level to indicate no battery. If BAT pin connects a 10µF capacitor, the frequency of CHRG flicker about 1-4S, If not use status indicator should set status indicator output connected to GND.

charger's status	Red led CHRG	Green led STDBY
Charging	light	dark
Battery in full state	dark	light
Under-voltage, battery's temperature is to high or too low, or not connect to battery(use TEMP)	dark	dark
BAT pin is connected to 10µF capacitor，No battery mode (TEMP=GND)	Green LED bright, Red LED flicker F=1-4 S（At this time, reverse-battery, the light does not shine, this phenomenon is normal. Such a case, after the battery is properly connected to the indicator light back to light and flicker.）	

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 110℃ . The feature protects the ME4055A 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 ME4055A. 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.

Under Voltage lockout (UVLO)

An internal under voltage lockout circuit monitors the input voltage and keeps the charger in shutdown mode until VCC rises above the under voltage lockout threshold. If the UVLO comparator is tripped, the charger will not come out of shutdown mode until V_{CC} rises 140mV above the battery voltage.

Manual terminate

At any time of the cycle of charging will put the ME4055A into disable mode to remove RPROG （PROG pin is float）. This made the battery drain current to less than 2µA and reducing the supply current to 55µA. To restart the charge cycle, connect a programming resistor.

If ME4055A in the under voltage Lockout mode, the CHRG is in high impedance state, or VCC is above BAT pin 140mV, or VCC is too low.

Auto restart

Once charge is   been terminated, ME4055A immediately use a 1.8ms filter time（$t_{RECHARGE}$）on the termination comparator to constant monitor the voltage on BAT pin.   If this voltage drops below the 4.02V recharge threshold (about between 80% and 90% of V_{CC}), another charge cycle begins. This ensured the battery maintained (or approach) to a charge full status and avoid the requirement of restarting the periodic charging cycle. In the recharge cycle, CHRG pin enters a pulled down status.

Stability Considerations

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 20KΩ. However, additional capacitance on this node reduces the maximum allowed program resistor. Therefore, if I_{PROG} pin is loaded with a capacitance C, the following equation should be used to calculate the maximum resistance value for R_{PROG}：

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

As user, may think charge current is important, not instantaneous current. For example, to run a low current mode switch power which parallel connected with battery, the average current from BAT pin usually importance to instantaneous current. In this case, In order to measure average charge current or isolate capacitive load from I_{PROG} pin, a simple RC filter can be used on PROG pin as shown in Figure 2. In order to ensure the stability add a 10KΩ resistor between PROG pin and filter capacitor.
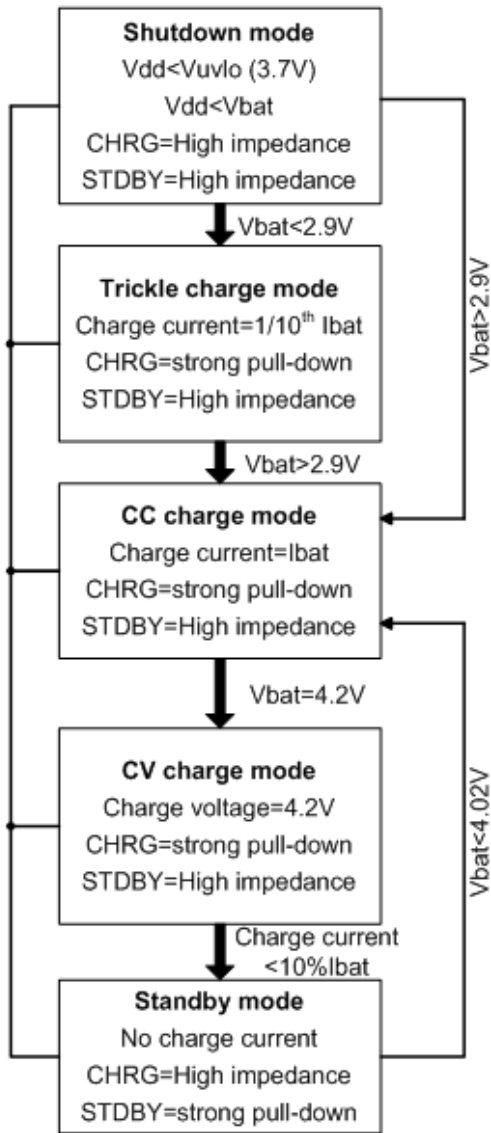
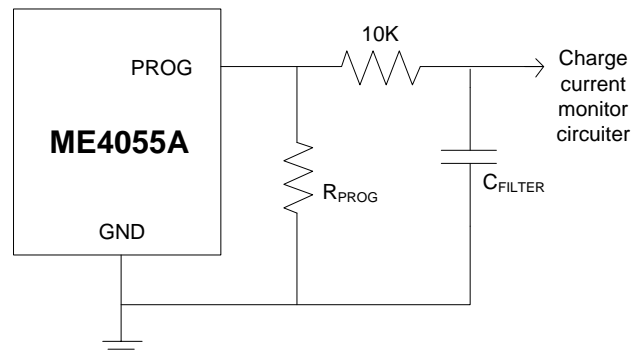Fig.1 State diagram of a typical charge cycle

Fig.2 Isolating with capacitive load on PROG Pin

Power dissipation

The conditions that cause the ME4055A 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:

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

The approximate ambient temperature at which the thermal feedback begins to protect the IC is:

$$T_A = 110°C - P_D\theta_{JA}; \qquad T_A = 110°C - (V_{CC} - V_{BAT}) \times I_{BAT} \times \theta_{JA}$$

For example: The ME4055A with 5V supply voltage through programmable provides full limiting current 800mA to a charge lithium-ion battery with 3.75V voltage. If θJA is 150℃/W (reference to PCB layout considerations), When ME4055A begins to decrease the charge current, the ambient temperature about:

$$T_A = 110°C - (5V - 3.75V) \times (800mA) \times 150°C / W$$

$$T_A = 110°C - 0.5W \times 150°C / W = 110°C - 75°C \qquad T_A = 35°C$$

ME4055A can work in the condition of the temperature is above 35℃, but the charge current will pull down to below 800mA. In a fixed ambient temperature, the charge current is calculated to be approximately :

$$I_{BAT} = \frac{110℃ - T_A}{(VCC - V_{BAT}) * \theta_{JA}}$$

Just as Description of the Principle part talks about so, the current on PROG pin will reduce in proportion to the reduced charge current through thermal feedback. In ME4055A design applications don't need to considerate the worst case of thermal condition, this point is importance, because if the junction temperature up to 110℃ ,IC will auto reduce the power dissipation.

Thermal considerations

Because of the small size of the thin SOT23-6 package, it is 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. 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.

Add thermal regulation current

It will effective to decrease the power dissipation through reduce the voltage of both ends of the inner MOSFET. In the thermal regulation, this action of transporting current to battery will raise. One of the measure is through an external component(as a resistor or diode) to consume some power dissipation.

For example: The ME4055A with 5V supply voltage through programmable provides full limiting current 800mA to a charge lithium-ion battery with 3.75V voltage. If θJA is 105℃/W, so that at 25℃ ambient temperature, the charge current is calculated to be approximately :

$$I_{BAT} = \frac{110℃ - 25℃}{(Vs - I_{BAT} \times Rcc - V_{BAT})\theta_{JA}}$$

In order to increase the thermal regulation charge current, can decrease the power dissipation of the IC through reducing the voltage (as show fig.3) of both two ends of the resistor which connecting in series with a 5V AC adapter.

With square equation to calculate IBAT ：

$$I_{BAT} = \frac{(Vs - V_{BAT}) - \sqrt{(Vs - V_{BAT})^2 - \frac{4Rcc(110℃ - T_A)}{\theta_{JA}}}}{2Rcc}$$

If RCC=0.25Ω, VS=5V, VBAT=3.75V, TA=25℃ and θJA =105℃/W, we can calculate the thermal regulation

charge current: IBAT＝764mA. It means that in this structure it can output 800mA full limiting charge current at more high ambient temperature environment.

Although it can transport more energy and reduce the charge time in this application, but actually spread charge time, if ME4055A stay in under-voltage state, when VCC becomes too low in voltage mode. Fig.4 shows how the voltage reduced with increase RCC value in this circuit. This technique will act the best function when in order to maintain the minimize the dimension of the components and avoid voltage decreased to minimize RCC .
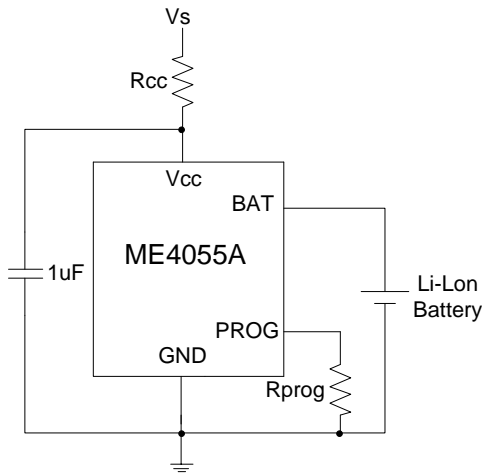

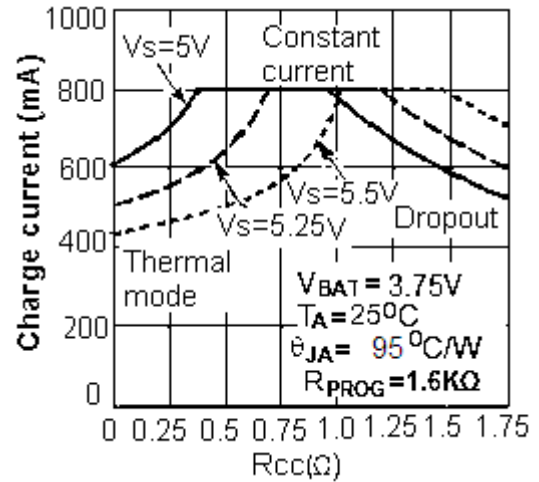Fig.3:A circuit to maximum the thermal regulation charge current

Fig.4:The relationship curve between charge current with R_{CC}

V_{CC} bypass capacitor

Many types of capacitors can be used for input bypassing, however, caution must be exercised when using multilayer ceramic capacitors. Because of the self-resonant and high Q characteristics of some types of ceramic capacitors, high voltage transients can be generated under some start-up conditions, such as connecting the charger input to a live power source. Adding a 1.5Ω resistor in series with a ceramic capacitor will minimize start-up voltage transients.

Charging Current Soft Start

ME4055A includes a soft start circuit which used to maximize to reduce the surge current in the begging of charge cycle. When restart a new charge cycle, the charging current ramps up from 0 to the full charging current within 20μs. In the start process it can maximize to reduce the action which caused by surge current load.

USB and Wall Adapter Power

ME4055A allows charging from a USB port, a wall adapter can also be used to charge Li-Ion/Li-polymer batteries. Figure 5 shows an example of how to combine wall adapter and USB power inputs. A P-channel MOSFET, M1, is used to prevent back conducting into the USB port when a wall adapter is present and Schottky diode, D1, is used to prevent USB power loss through the 1KΩ pull-down resistor.

Generally, AC adaptor is able to provide bigger much current than the value of specific current limiting which is

500mA for USB port. So can rise charge current to 600mA with using a N-MOSFET (MN1) and an additional set resistor value as high as 10KΩ.
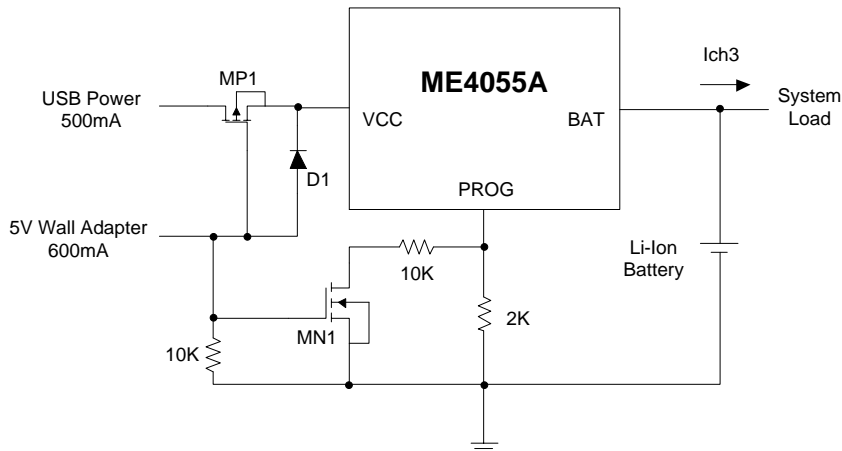

Fig.5:Combining Wall Adapter and USB Power

Board Layout Considerations

●R_{PROG} at PROG pin should be as close to ME4055A as possible, also the parasitic capacitance at PROG pin should be kept as small as possible.

●The capacitance at V_{CC} pin and BAT pin should be as close to ME4055A as possible.

● It is very important to use a good thermal PC board layout to maximize charging current. The thermal path for the heat generated by the IC is from the die to the copper lead frame through the package lead (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. Feed through 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.

●The ability to deliver maximum charge current under all conditions require that the exposed metal pad on the back side of the ME4055A package be soldered to the PC board ground. Failure to make the thermal contact between the exposed pad on the backside of the package and the copper board will result in larger thermal resistance.

Package Information

- **Package Type:SOT23-6**
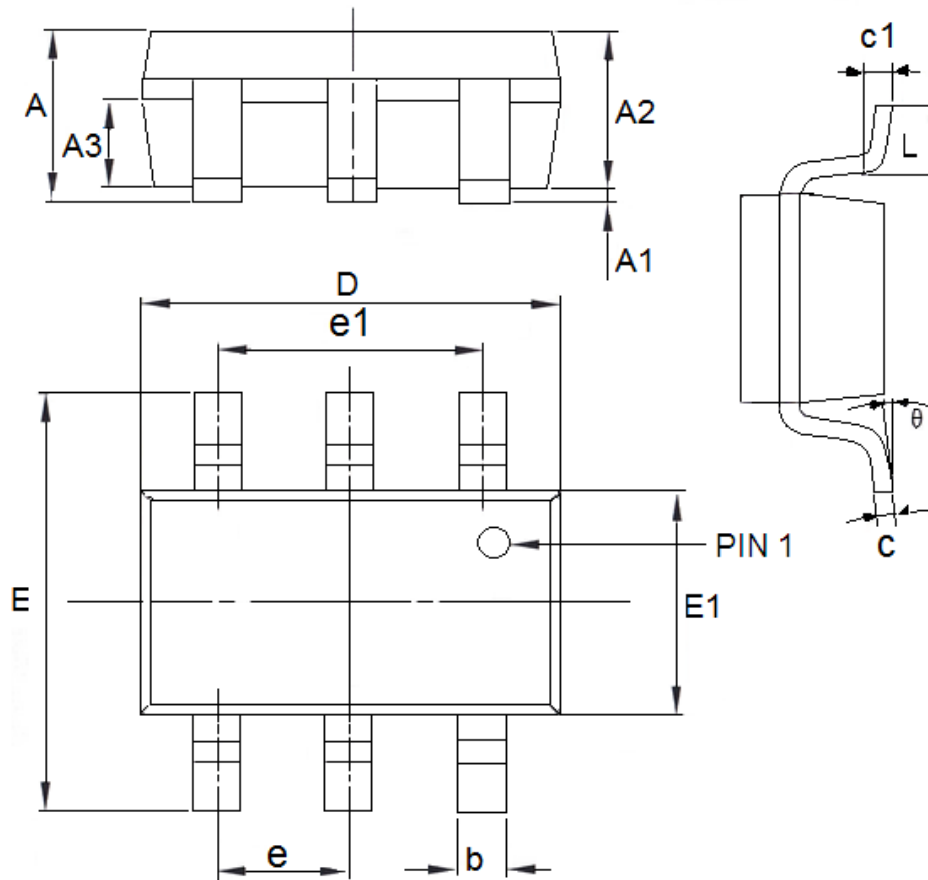
DIM	Millimeters		Inches	
	Min	**Max**	**Min**	**Max**
A	1.05	1.45	0.0413	0.0571
A1	0	0.15	0.0000	0.0059
A2	0.9	1.3	0.0354	0.0512
A3	0.55	0.75	0.0217	0.0295
b	0.25	0.5	0.0098	0.0197
c	0.1	0.25	0.0039	0.0098
D	2.7	3.12	0.1063	0.1228
e1	1.9(TYP)		0.0748(TYP)	
E	2.6	3.1	0.1024	0.1220
E1	1.4	1.8	0.0551	0.0709
e	0.95(TYP)		0.0374(TYP)	
L	0.25	0.6	0.0098	0.0236
θ	0	8°	0.0000	8°
c1	0.2(TYP)		0.0079(TYP)	

- The contents of this document will be updated with the product's improvement without prior notice. Please consult our sales staff before using this document to ensure that you are using the latest version.
- The application circuit examples described in this document are only used to indicate the representative use of the product and do not guarantee the design of mass production.
- Please use this product within the limits stated in this document. We will not be responsible for any damage caused by improper use.
- The products described in this document are not allowed to be used in equipment or devices that affect the human body without the written permission of our company, including but not limited to: health equipment, medical equipment, disaster prevention equipment, fuel control equipment, automobile equipment, aviation equipment and vehicle equipment.
- Although our company has always been committed to improving product quality and reliability, semiconductor products have a certain probability of malfunction or wrong work. To prevent personal injury or property damage caused by such accidents, please pay full attention to safety design, for example: Alternate design, fire protection design, and prevention of wrong action design.
- When exporting this product or this document overseas, you should abide by applicable import and export control laws.
- Copying or reprinting part or all of this document in any form without the permission of our company is strictly prohibited.