DESCRIPTION

The A4055 is a complete constant-current/constant voltage linear charger for single cell lithium-ion batteries. Furthermore, the A4055 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/4.34V, and the charge current can be programmed externally with a single resistor.

The A4055 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 A4055 automatically enters a low current state dropping the battery drain current to less than 2μA. The A4055 can be put into shutdown mode reducing the supply current to 55μA.

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

The A4055 is available in SOT-25 and DFN6(2x2) Packages.

ORDERING INFORMATION

Package Type	Part Number	
SOT-25 SPQ: 3,000pcs/Reel	E5	A4055E5R
		A4055E5VR
DFN6 SPQ: 3,000pcs/Reel	J6	A4055J6R
		A4055J6VR
Note	V: Halogen free package R: Tape & Reel	
AiT provides all RoHS products		

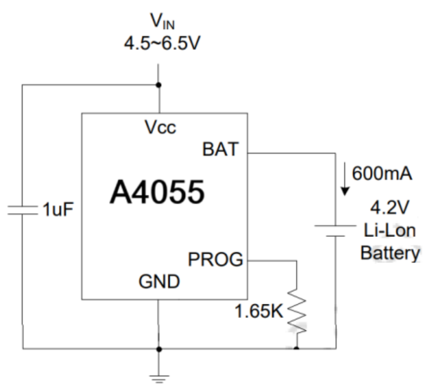
FEATURES

- Maximum operating voltage 9V, improve system reliability
- 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 、 4.34V 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

APPLICATION

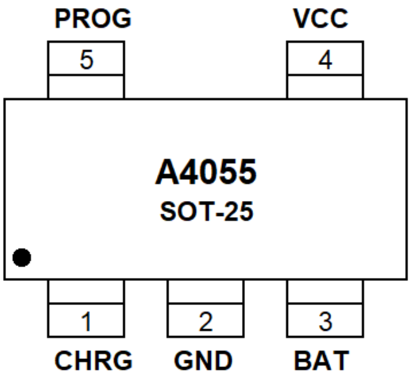
- Cellular Telephones, PDAs, MP3 Players
- Charging Docks and Cradles
- Bluetooth Applications

TYPICAL APPLICATION



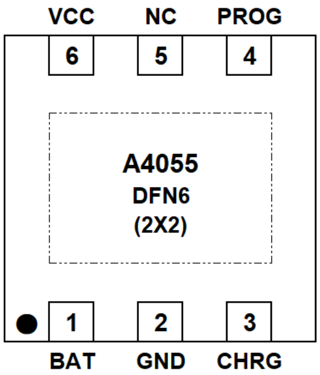
600mA Application Circuit

PIN DESCRIPTION



SOT-25, E5

Top View



DFN6(2x2), J6

Top View

Pin #		Symbol	Function
SOT-25	DFN6(2x2)		
1	3	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	2	GND	Ground.
3	1	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/4.34V.
4	6	V_{CC}	Positive input supply voltage Provides power to the internal circuit. When VCC drops to within 80mV of the BAT pin voltage, the A4055 enters low power sleep mode, dropping IBAT to less than 2μA.
5	4	PROG	Charge Current Program, Charge Current Monitor and Shutdown Pin. The charge current is programmed by connecting a 1% resistor, R_{PROG}, to ground. When charging in constant-current mode, this pin servos to 1V. In all modes, the voltage on this pin can be used to measure the charge current using the following formula: $I_{BAT} = (V_{PROG}/R_{PROG}) \cdot 1270$
-	5	NC	-

ABSOLUTE MAXIMUM RATINGS

V_{CC}, Input Supply Voltage		-0.3V ~ +10V
PROG Pin Voltage		-0.3V ~ +V_{CC}+0.3V
BAT Pin Voltage		-0.3V ~ +10V
CHRG Pin Voltage		-0.3V ~ +10V
BAT Pin Current		800mA
PROG Pin Current		1200μA
Maximum Junction Temperature		145°C
T_{OPA}, Operating Temperature Range		-40°C ~ +85°C
T_{str}, Storage Temperature Range		-55°C ~ +150°C
Soldering Temperature and Time		260°C (Recommended 10S)
θ_{JA}, Package Thermal Impedance	SOT-25	210°C/W
	DFN6(2x2)	95°C/W
Pd, Maximum Power Dissipation	SOT-25	0.6W
	DFN6(2x2)	1.32W

Stresses above 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 in the Electrical Characteristics are not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

V_{CC}=5V, T_A= 25°C, unless otherwise noted

Parameter	Symbol	Conditions	Min	Typ.	Max	Unit
Input Supply Voltage	V_{CC}	-	4	5	9	V
Static Current	I_{CC} - I_{BAT}	Charge Mode, R_{PROG}=2kΩ	-	150	500	μA
		Standby Mode (Charge End)	-	55	100	
		Shutdown Mode (RPROG not Connected, V_{CC}<V_{BAT}, or VCC<VUV)	-	55	100	
Regulated Output Voltage	F_{LOAL}	0°C≤T_A≤85°C, SOT-25	4.158	4.200	4.242	V
		0°C≤T_A≤85°C, DFN6(2x2)	4.297	4.340	4.383	
BAT pin current (The Condition of Current Mode is V_{BAT}=3.9V)	I_{BAT}	R_{PROG} =2.2kΩ, Current Mode	490	580	670	mA
		Standby Mode: V_{BAT}=4.2V/4.34V	-6	-2.5	0	μA
		Shutdown Mode, RPROG Not Connected	-	±1	±2	
		Sleep Mode, V_{CC}=0V	-	-1	-2	
Trickle Charge Current	I_{TRIKL}	V_{BAT}<V_{TRIKL}, R_{PROG}=2.2KΩ	46	73	163	mA
Trickle Charge Threshold Voltage	V_{TRIKL}	R_{PROG}=2.2KΩ, V_{BAT} Rising	2.7	2.85	3	V
Trickle Voltage Hysteresis Voltage	V_{TRHYS}	R_{PROG}=2.2KΩ	350	400	450	mV
V_{CC} Under Voltage Lockout Threshold	V_{UV}	V_{CC} from Low to High	3.50	3.70	3.90	V
V_{CC} Under Voltage Lockout Hysteresis	V_{UVHYS}	-	150	200	300	mV
V_{CC}-V_{BAT} Lockout Threshold Voltage	V_{ASD}	V_{CC} from Low to High	100	140	180	mV
		V_{CC} from High to Low	50	80	100	
Termination Current Threshold	I_{TEEM}	R_{PROG}=2.2KΩ	60	70	80	mA
PROG Pin Voltage	V_{PROG}	R_{PROG}=2.2KΩ, Current Mode	0.90	1	1.10	V
CHRG Pin Output Low Voltage	V_{CHRG}	I_{CHRG}=5mA	-	0.3	0.6	V
Recharge Battery Threshold Voltage	ΔV_{RECHRG}	V_{FLOAT} -V_{RECHRG}	60	150	240	mV
Thermal Protection Temperature	T_{LIM}	-	-	145	-	°C
The Resistance of power FET "ON" (Between V_{CC} and BAT)	R_{ON}	-	-	650	-	mΩ
Soft-Start Time	t_{SS}	I_{BAT}=0 to I_{BAT}=1270V/R_{PROG}	-	20	-	μS
Recharge Comparator Filter Time	$t_{RECHARGE}$	V_{BAT} from Low to High	0.80	1.80	4	mS
Termination Comparator Filter Time	t_{TERM}	I_{BAT} below I_{CHG}/10	0.80	1.80	4	mS
PROG Pin Pull-Up Current	I_{PROG}	-	-	2	-	μA

TYPICAL PERFORMANCE CHARACTERISTICS

Fig 1. V_{FLOAT} vs. VCC

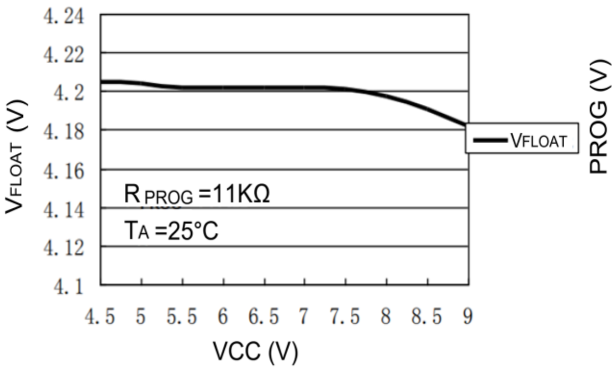


Fig 2. PRIG vs. VCC

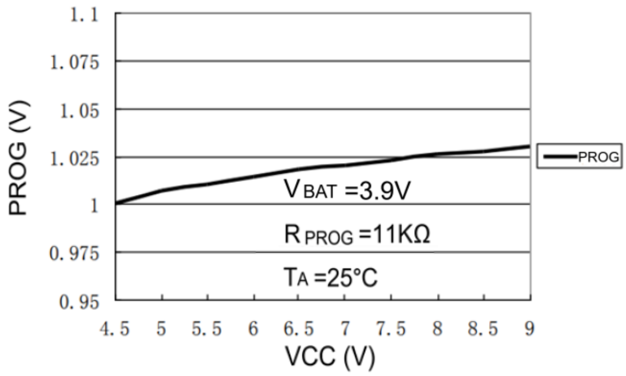


Fig 3. V_{FLOAT} vs. Temperature

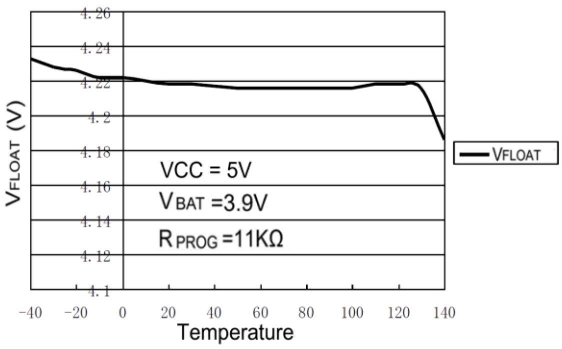
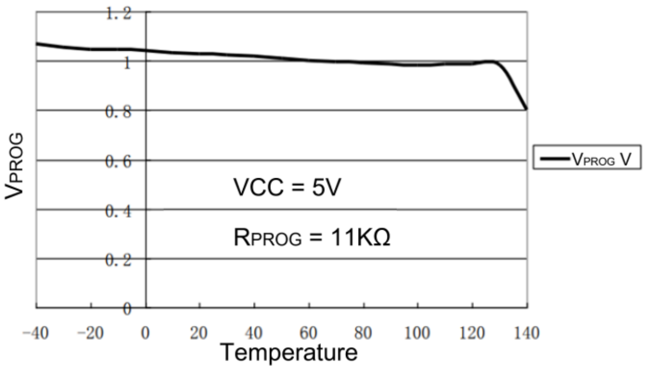
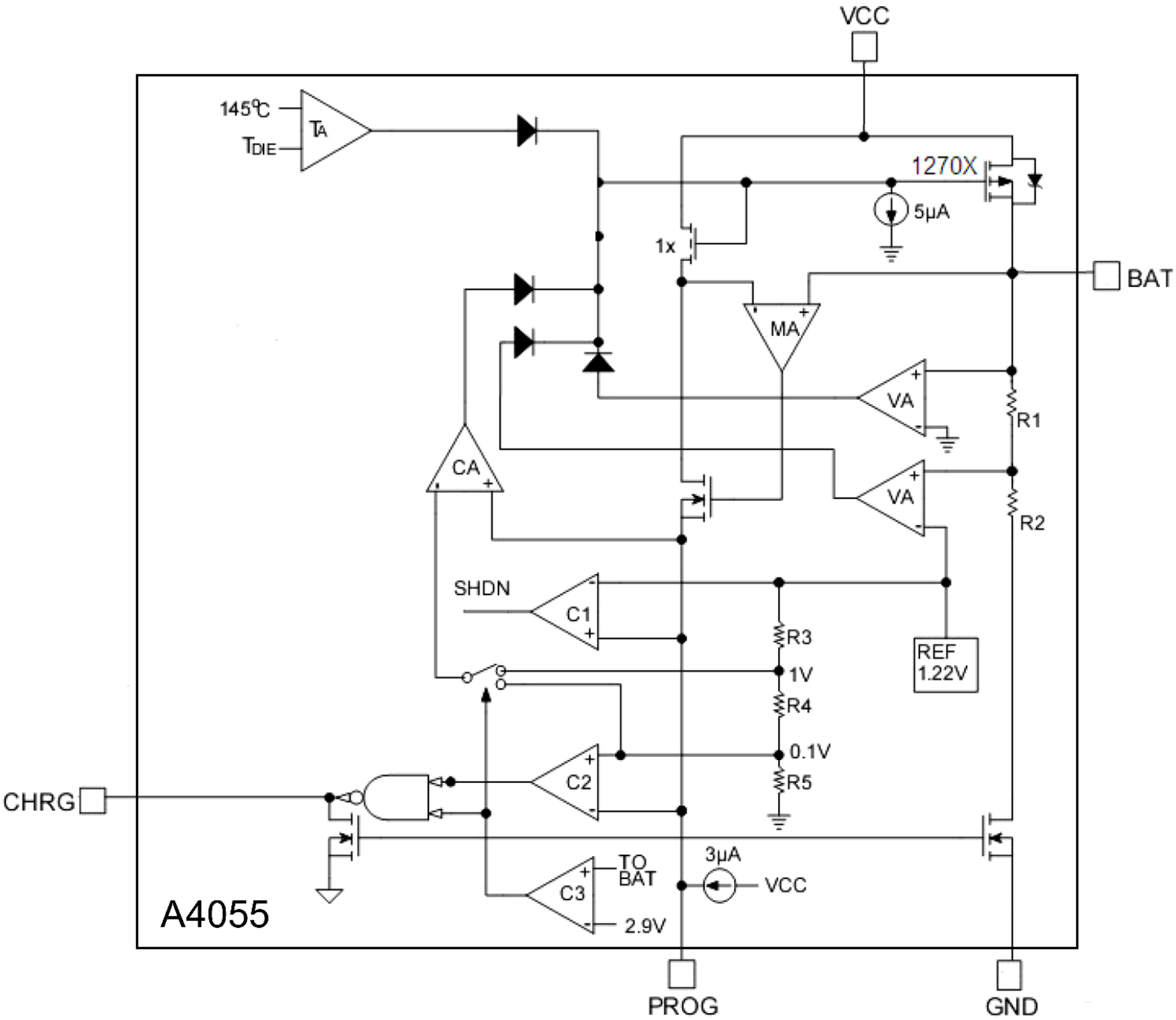


Figure 4. PROG vs. Temperature



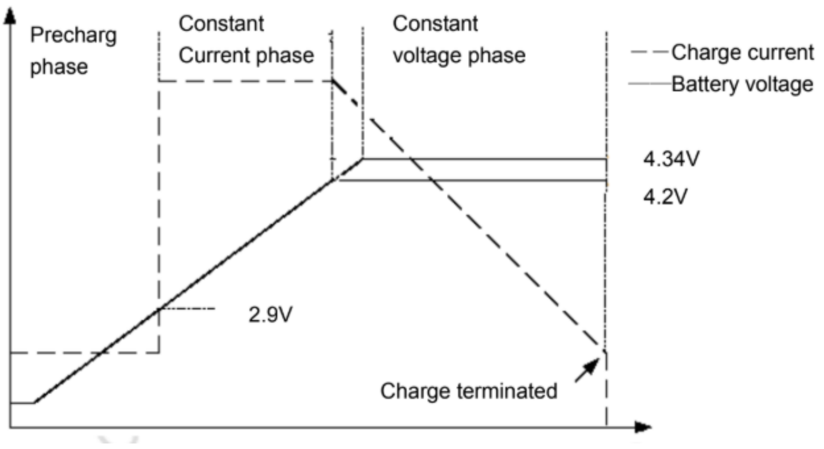
BLOCK DIAGRAM



DETAILED INFORMATION

The A4055 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. A4055 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 145°C. This feature protects the A4055 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 A4055 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 VCC 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 ongoing. At the beginning of the charge cycle, if the battery voltage is below 2.9V, the charge is in recharge 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 RPROG. When the battery approaches the regulation voltage 4.2V, the charge current begins to decrease as the A4055 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 VBAT, the charger goes into a sleep mode, dropping battery drain current to less than 2μA. 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.:

$$R_{PROG}=1270/I_{BAT}$$

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 A4055 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 A4055 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 A4055 constantly monitors the BAT pin voltage in standby mode. If this voltage drops below the 4.02V recharge threshold (VRECHRG), 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.

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. The feature protects the A4055 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 A4055. 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 VCC rises 100mV above the battery voltage.

Manual Terminates

At any time of the cycle of charging will put the A4055 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 A4055 in the under-voltage Lockout mode, the CHRG is in high impedance state.

Fig 1. State Diagram of a Typical Charge Cycle

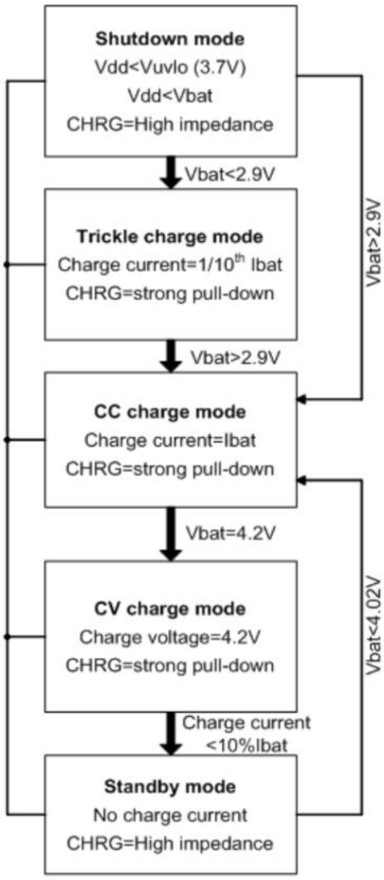
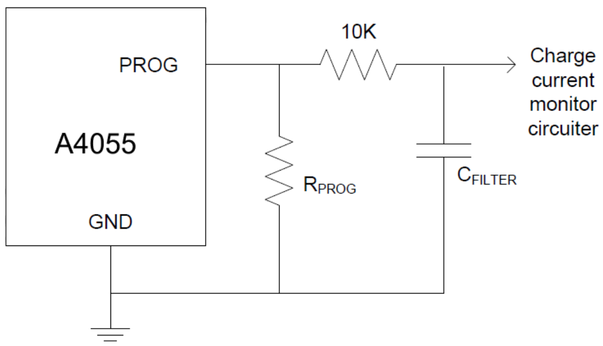


Fig 2. Isolating with Capacitive Load on PROG Pin



Auto Restart

Once charge is been terminated, A4055 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(A4055)/4.16V(A4055) recharge threshold (about between 80% and 90% of VCC), 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 IPROG pin is loaded with a capacitance C, the following equation should be used to calculate the maximum resistance value for RPROG:

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

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 IPROG 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.

Power Dissipation

The conditions that cause the A4055 to reduce charge current through thermal feedback can be approximated by considering the power dissipated in the IC. Nearly all 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:

$$T_A = 145°C - P_D\theta_{JA}; \qquad T_A = 145°C - (V_{CC} - V_{BAT}) \times I_{BAT} \times \theta_{JA}$$

In a fixed ambient temperature, the charge current is calculated to be approximately:

$$I_{BAT} = \frac{145°C - T_A}{(VCC - V_{BAT}) \cdot \theta_{JA}}$$

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 A4055 design applications don’t need to considerate the worst case of thermal condition, this point is importance, because if the junction temperature up to 145°C, IC will auto reduce the power dissipation.

Thermal Considerations

Because of the small size, 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 measures is through an external component (as a resistor or diode) to consume some power dissipation.

For example: The A4055 with 5V supply voltage through programmable provides full limiting current 800mA to a charge lithium-ion battery with 3.75V voltage. If JA is 145°C/W, so that at 25°C ambient temperature, the charge current is calculated to be approximately :

$$I_{BAT} = \frac{145^{\circ}C - 25^{\circ}C}{(Vs - I_{BAT} \times Rcc - V_{BAT})\theta_{JA}}$$

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 I_{BAT}:

$$I_{BAT} = \frac{(Vs - V_{BAT}) - \sqrt{(Vs - V_{BAT})^2 - \frac{4Rcc(145^{\circ}C - T_A)}{\theta_{JA}}}}{2Rcc}$$

After adding RCC, we can calculate the thermal regulation charge current: IBAT=948mA. 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 spread charge time, if A4055 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

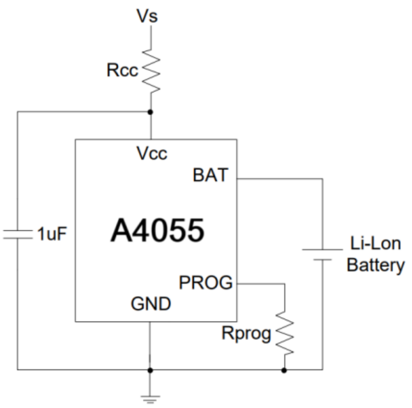
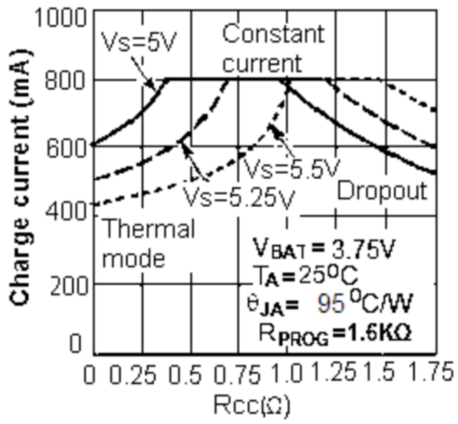


Fig.4. The relationship curve between charge current with R_{CC}



VCC 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.

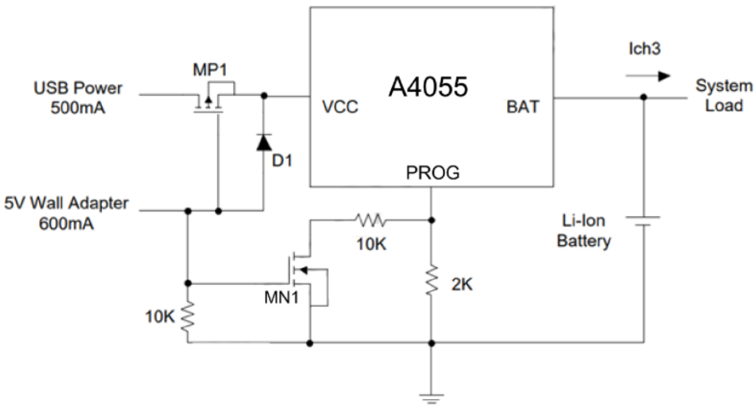
Charging Current Soft Start

A4055 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

A4055 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.

Fig 5. Combining Wall Adapter and USB Power

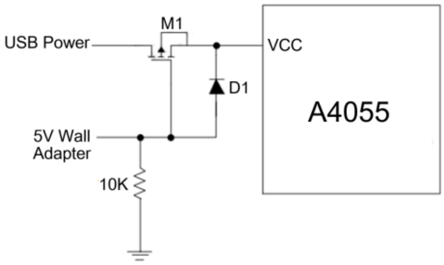


Generally, AC adaptor can provide bigger much current than the value of specific current limiting which is 500mA for USB port. So can rise charge current to 600mA with using a N-MOSFET (MN1) and an additional set resistor value as high as 10KΩ.

Typical Application Diagram

Mainly used in mobile phones, digital cameras, electronic dictionaries, GPS, mobile devices and various chargers.

Suitable for 5V adapter and USB mixed applications.



Board Layout Considerations

RPROG at PROG pin should be as close to A4055 as possible, also the parasitic capacitance at PROG pin should be kept as small as possible.

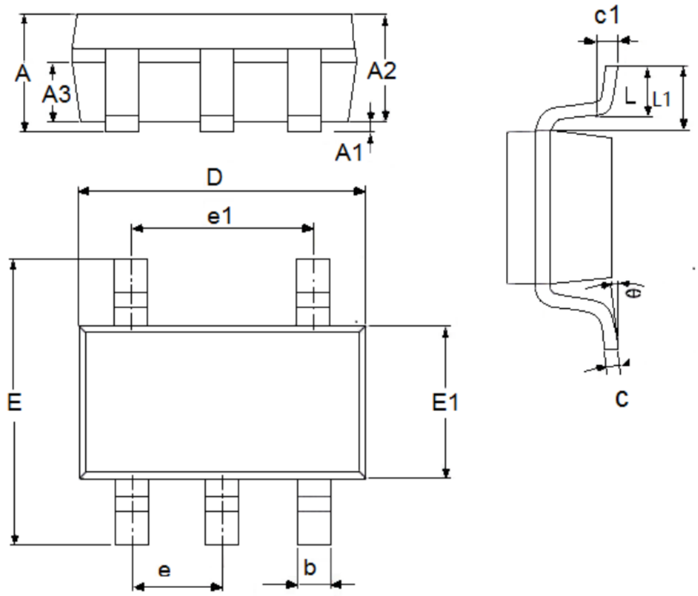
The capacitance at VCC pin and BAT pin should be as close to A4055 as possible.

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 A4055 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. All measurements were taken in still air on 3/32" FR-4 board with the device mounted on topside.

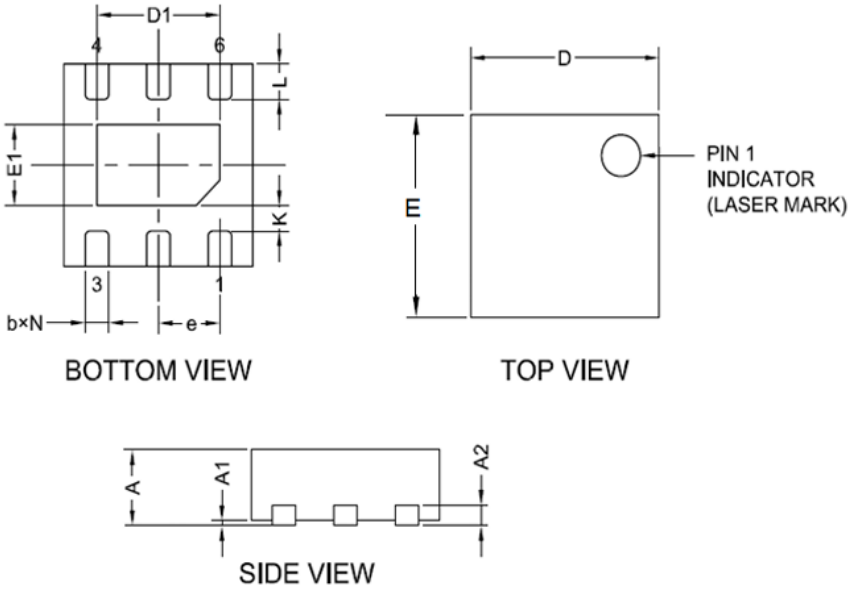
PACKAGE INFORMATION

Dimension in SOT-25 Package (Unit: mm)



Symbol	Min.	Max.
A	1.050	1.450
A1	0.000	0.150
A2	0.900	1.300
A3	0.600	0.700
b	0.250	0.500
c	0.100	0.230
c1	0.200 TYP.	
D	2.820	3.050
E	2.600	3.050
E1	1.500	1.750
e	0.950 TYP.	
e1	1.900 TYP.	
L	0.300	0.600
L1	0.590 TYP.	
θ	0°	8°

Dimension in DFN6(2x2) Package (Unit: mm)



Symbol	Min.	Max.
A	0.700	0.800
A1	0.000	0.500
A2	0.203 TYP.	
b	0.200	0.350
D	1.900	2.100
D1	1.000	1.450
E	1.900	2.100
E1	0.500	0.900
e	0.650 TYP.	
L	0.250	0.426
K	0.200	-

IMPORTANT NOTICE