Standalone Linear Li-Ion Battery Charger in ThinSOT ME4054-4.2V

General Description

ME4054 is a constant-current/constant-voltage linear charger for single cell lithium-ion batteries. Its Thin SOT package and low external component count make the ME4054 ideally suited for portable applications. Furthermore, the ME4054 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 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 ME4054 automatically terminates he 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 ME4054 automatically enters a low current state, dropping the battery drain current to less than 2µA.The ME4054 can be put into shutdown mode, reducing the supply current to 25µA.

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

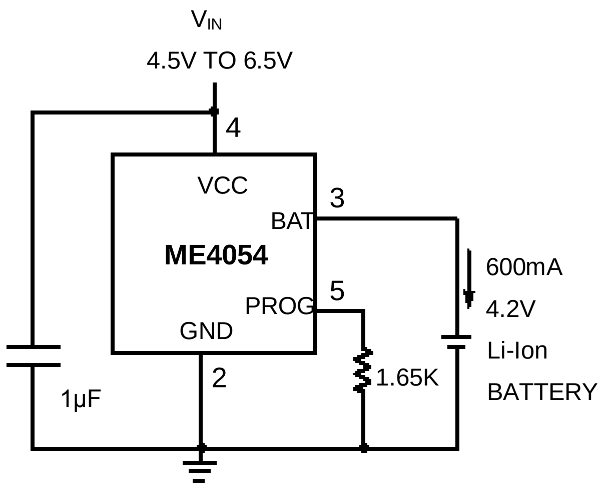
Features

- Programmable Charge Current Up to 800mA
- No MOSFET, Sense Resistor or Blocking Diode Required
- Complete Linear Charger in ThinSOT Package for Single Cell Lithium-Ion Batteries
- Constant-Current/Constant-Voltage Operation with Thermal Regulation to Maximize Charge Rate Without Risk of Overheating
- Charges Single Cell Li-Ion Batteries Directly from USB Port
- Preset 4.2V Charge Voltage with ±1% Accuracy
- Automatic Recharge
- Charge Status Output Pin
- C/10 Charge Termination
- 25µA Supply Current in Shutdown
- 2.9V Trickle Charge Threshold
- Soft-Start Limits Inrush Current
- Available in 5-Lead SOT-23 Package

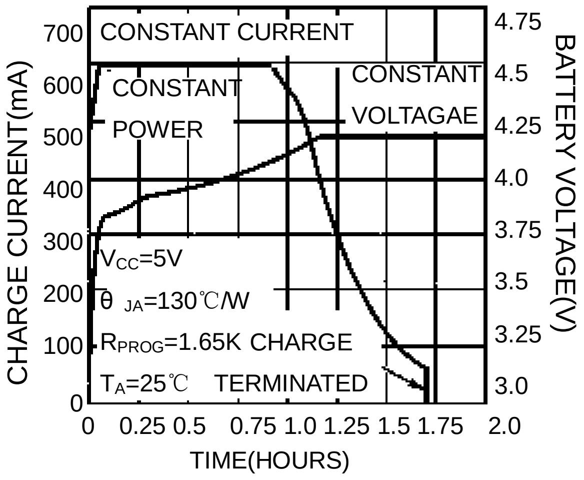
Applications

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

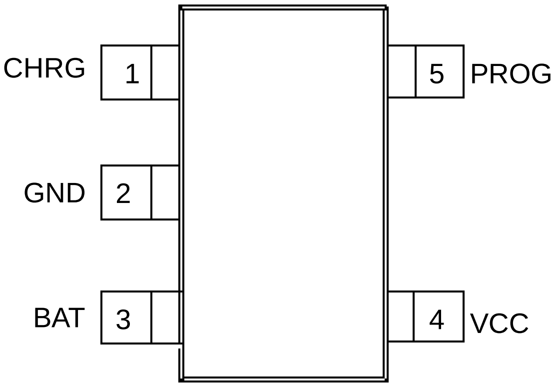
600mA Single Cell Li-Ion Charger



Complete Charge Cycle (750mAh Battery)



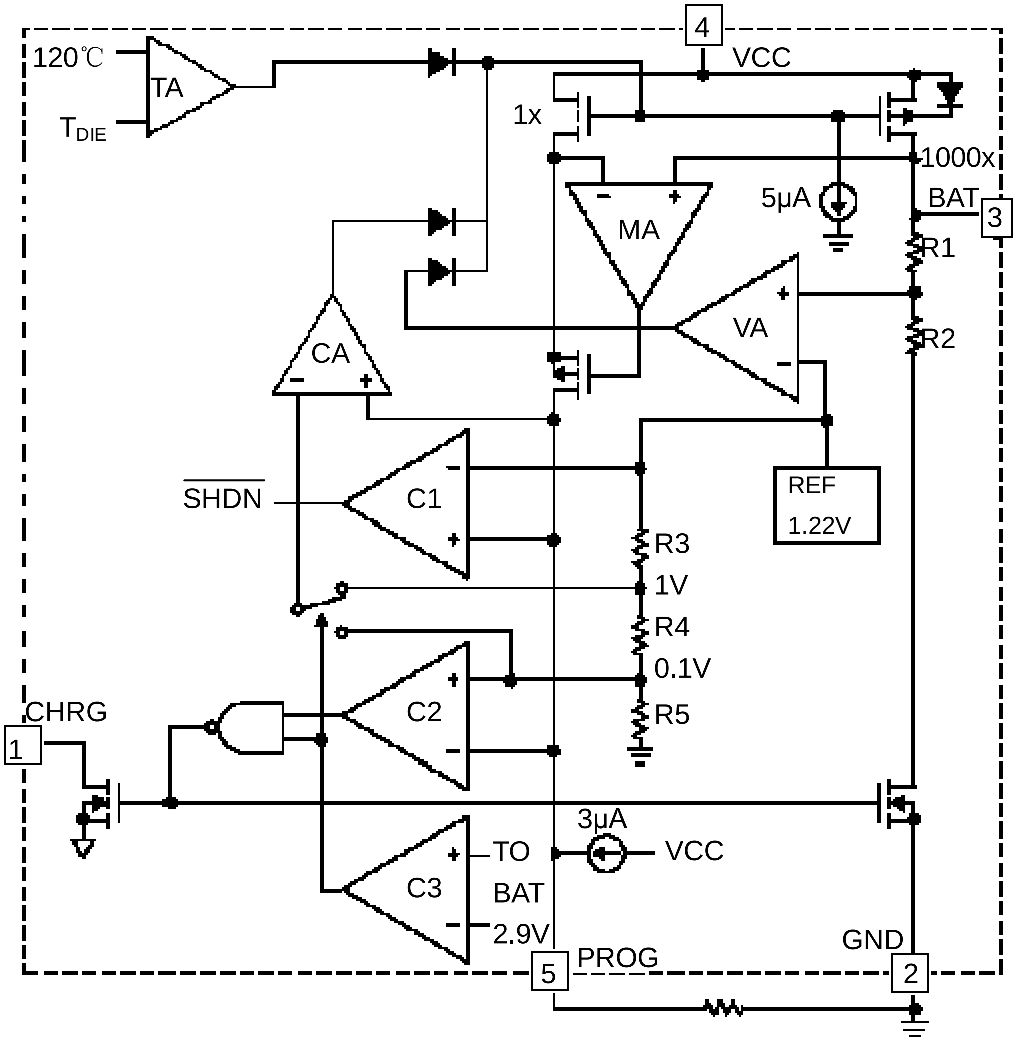
Pin Configuration



Pin Assignment

Pin	Symbol	Description
SOT23-5		
1	CHRG	Open-Drain Charge Status Output
2	GND	Ground θ_{JA}
3	BAT	Charge Current Output
4	VCC	Positive Input Supply Voltage
5	PROG	Charge Current Program

Block Diagram



Absolute Maximum Ratings

Parameter	**Ratings**
Input Supply Voltage (VCC)	－0.3V～10V
PROG	-0.3V～Vcc＋0.3V
BAT	-0.3V～7V
CHRG	-0.3V～10V
BAT Short-Circuit Duration	Continuous
BAT Pin Current	800mA
PROG Pin Current	800μA
Maximum Junction Temperature	125℃
Operating Ambient Temperature Range	-40℃～85℃
Storage Temperature Range	-65℃～125℃
Lead Temperature (Soldering, 10 sec)	260℃

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.

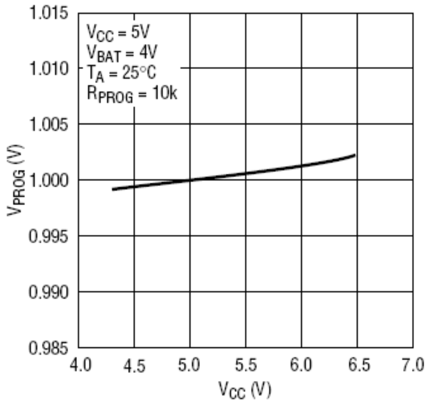
Electrical Characteristics

SYMBOL	PARAMETER	CONDITIONS	MIN	TYP	MAX	Unit
VCC	Input Supply Voltage	●	4.25		6.5	V
I_{CC}	Input Supply Current	●Charge Mode，R_{PROG}=10KΩ	-	300	2000	μA
		●Standby Mode (Charge Terminated)	-	200	500	μA
		Shutdown Mode（R_{PROG} Not Connected，VCC<V_{BAT}）	-	25	50	μA
V_{FLOAT}	Regulated Output (Float) Voltage	0℃≤T_A≤85℃,I_{BAT}=40mA	4.158	4.2	4.242	V
I_{BAT}	BAT Pin Current	●R_{PROG}=10KΩ,Current Mode	93	100	107	mA
		●R_{PROG}=2KΩ,Current Mode	465	500	535	mA
		●Standby Mode，V_{BAT}＝4.2V	0	-2.5	-6	μA
		Shutdown Mode（R_{PROG} Not Connected）	-	±1	±2	μA
		Sleep Mode, VCC＝0V		±1	±2	μA
I_{TRILK}	Trickle Charge Current	●V_{BAT}＜V_{TRILK}, R_{PROG}＝2KΩ	20	45	70	mA
V_{TRILK}	Trickle Charge Threshold Voltage	R_{PROG}＝10KΩ, V_{BAT} Rising	2.8	2.9	3.0	V
V_{TRHYS}	Trickle Charge Hysteresis Voltage	R_{PROG}＝10KΩ	60	80	110	mV
V_{UV}	VCC Undervoltage Lockout Threshold	●From VCC Low to High	3.7	3.8	3.92	V
V_{UVHYS}	VCC Undervoltage Lockout Hysteresis	●	150	200	300	mV
V_{MSD}	Manual Shutdown Threshold Voltage	●PROG Pin Rising	1.15	1.21	1.30	V
		●PROG Pin Falling	0.9	1.0	1.1	V
V_{ADS}	VCC-V_{BAT} Lockout Threshold Voltage	VCC from Low to High	70	100	140	mV
		VCC from High to Low	5	30	50	mV
I_{TERM}	C/10 Termination Current Threshold	●R_{PROG}＝10KΩ	0.085	0.10	0.115	mA
		●R_{PROG}＝2KΩ	0.085	0.10	0.115	mA
V_{PROG}	PROG Pin Voltage	●R_{PROG}＝10KΩ, Current Mode	0.93	1.0	1.07	V
I_{CHRG}	CHRG Pin Weak Pull-Down Current	V_{CHRG}＝5V	8	20	35	μA
V_{CHRG}	CHRG Pin Output Low	I_{CHRG}＝5mA		0.35	0.6	V
V_{RECHRG}	Recharge Battery Threshold Voltage	V_{FLOAT}－V_{RECHRG}	100	150	200	mV
T_{LIM}	Junction Temperature in Constant Temperature Mode		-	120	-	℃
R_{ON}	Power FET “ON” Resistance (Between VCC and BAT)		-	600	-	mΩ
T_{SS}	Soft-Start Time	I_{BAT}＝0 to I_{BAT}＝1000V/ R_{PROG}		100		μS
T_{RE}	Recharge Comparator Filter Time	V_{BAT} High to Low	0.75	2	4.5	mS
T_{TERM}	Termination Comparator Filter Time	I_{BAT} Falling Below I_{CHG}/10	400	1000	2500	μS
I_{PROG}	PROG Pin Pull-Up Current		-	3	-	μA

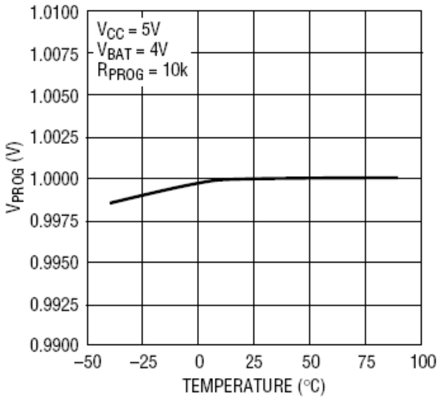
Note: The ● denotes specifications which apply over the full operating temperature rang, otherwise specifications are at T_A=25℃，V_{CC}=5V，unless otherwise specified.

Typical performance characteristics

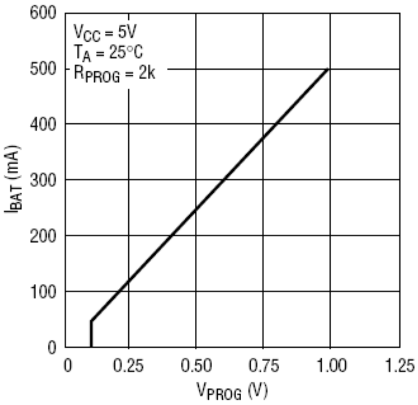
PROG Pin Voltage vs Supply Voltage(Constant Current Mode)



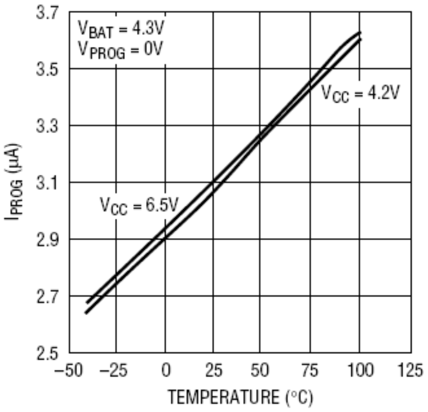
PROG Pin Voltage vs Temperature



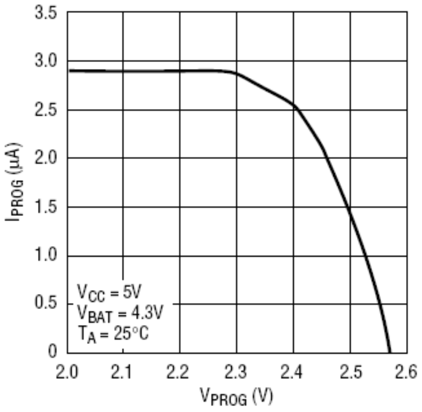
Charge Current vs PROG Pin Voltage



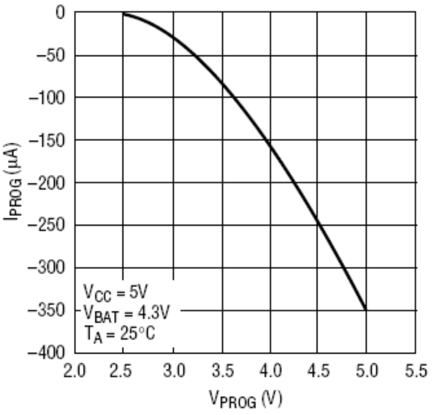
PROG Pin Pull-Up Current vs Temperature and Supply Voltage



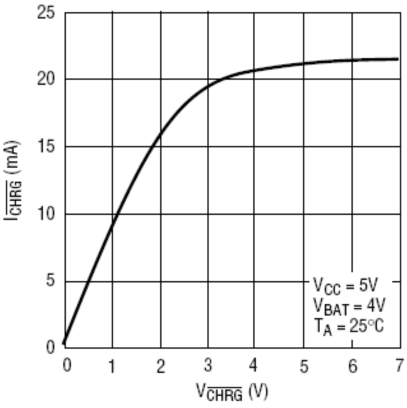
PROG Pin Current vs PROG Pin Voltage (Pull-Up Current)



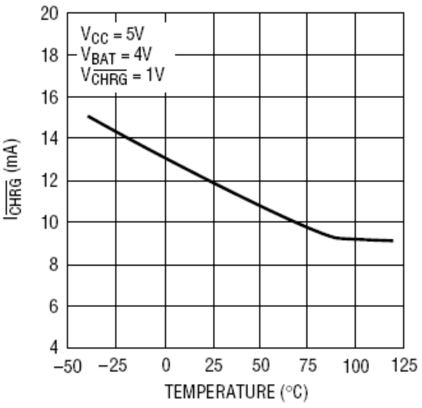
PROG Pin Current vs PROG Pin Voltage (Clamp Current)



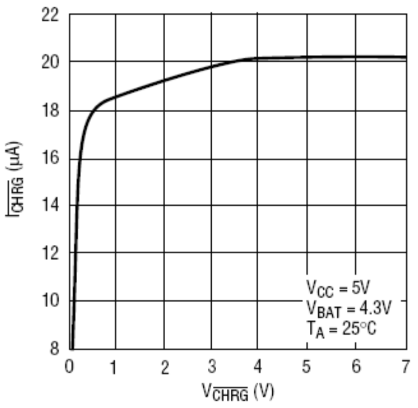
$\overline{\text{CHRG}}$ Pin I-V Curve (Strong Pull-Down State)



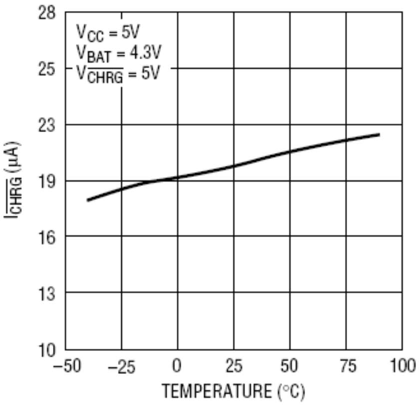
$\overline{\text{CHRG}}$ Pin Current vs Temperature (Strong Pull-Down State)



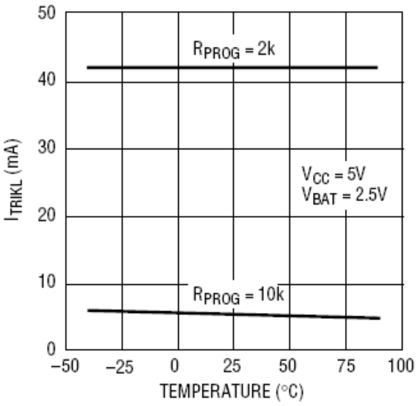
$\overline{\text{CHRG}}$ Pin I-V Curve (Weak Pull-Down State)



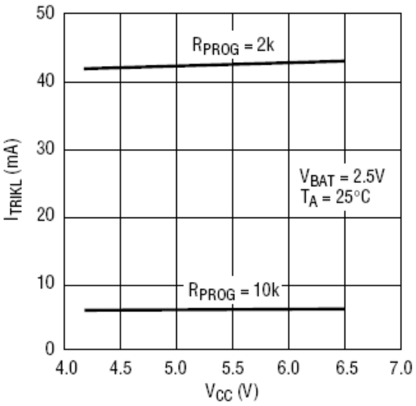
CHRG Pin Current vs Temperature (Weak Pull-Down State)



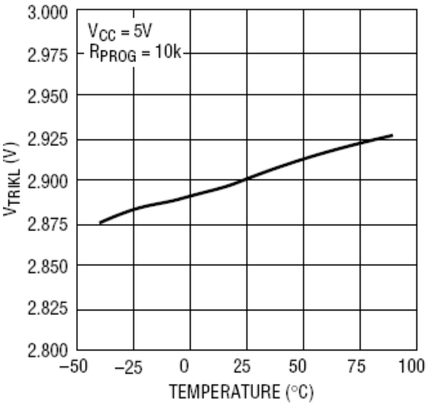
Trickle Charge Current vs Temperature



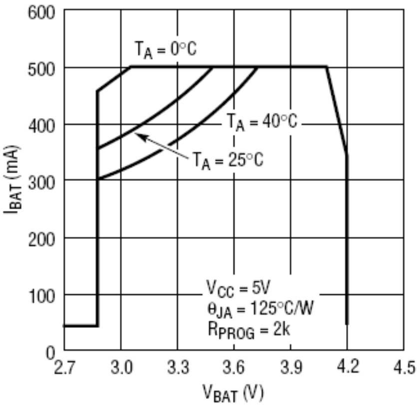
Trickle Charge Current vs Supply Voltage



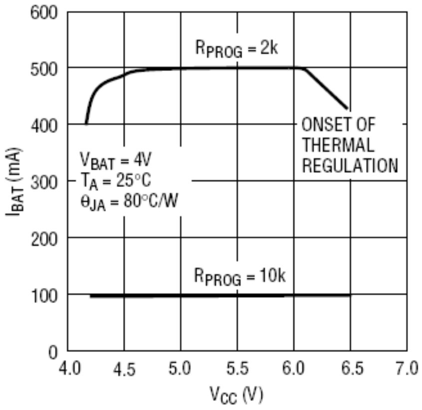
Trickle Charge Threshold vs Temperature



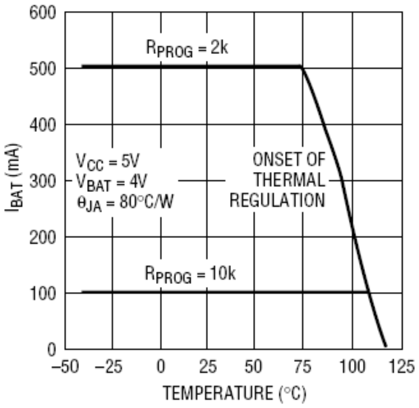
Charge Current vs Battery Voltage



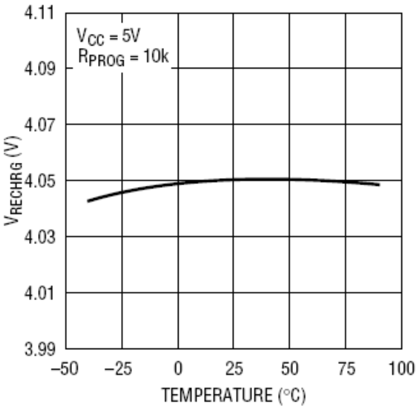
Charge Current vs Supply Voltage



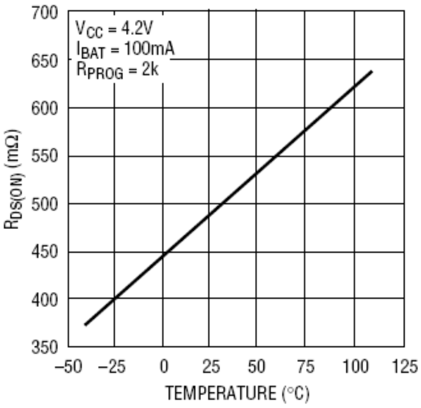
Charge Current vs Ambient Temperature



Recharge Voltage Threshold vs Temperature



Power FET "ON" Resistance vs Temperature



Description of the Principle

The ME4054 is a single cell lithium-ion battery charger using a constant-current/constant-voltage algorithm. It can deliver up to 800mA of charge current (using a good thermal PCB layout) with a final float voltage accuracy of±1%. The ME4054 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 ME4054 is capable of operating from a USB power source.

1.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 ME4054 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 ME4054 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.

2.Programming Charge Current

The charge current is programmed using a single resistor from the PROG pin to ground. The battery charge current is 1000 times the current out of the PROG pin. The program resistor and the charge current are calculated using the following equations:

$$R_{PROG}=1000V/I_{CHG}\ ,\ I_{CHG}=1000V/\ R_{PROG}$$

The charge current out of the BAT pin can be determined at any time by monitoring the PROG pin voltage using the following equation: $I_{BAT}=1000*\ V_{PROG}\ /\ R_{PROG}$

3.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_{TERM} (typically 1ms), charging is terminated. The charge current is latched off and the ME4054 enters standby mode, where the input supply current drops to 200μA.(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 ME4054 terminates the charge cycle and ceases to provide any current through the BAT pin. In this state, all loads on the BAT pin must be supplied by the battery.

The ME4054 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 1 shows the state diagram of a typical charge cycle.

4.Charge Status Indicator (CHRG)

The charge status output has three different states: strong pull-down (~10mA), weak pull-down (~20µA) and high impedance. The strong pull-down state indicates that the ME4054 is in a charge cycle. Once the charge cycle has terminated, the pin state is determined by undervoltage lockout conditions. A weak pull-down indicates that VCC meets the UVLO conditions and the ME4054 is ready to charge. High impedance indicates that the ME4054 is in undervoltage lockout mode: either VCC is less than 100mV above the BAT pin voltage or insufficient voltage is applied to the VCC pin. A microprocessor can be used to distinguish between these three states—this method is discussed in the Applications Information section.

5.Thermal Limiting

An internal thermal feedback loop reduces the programmed charge current if the die temperature attempts to rise above a preset value of approximately 120°C. This feature protects the ME4054 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 ME4054. 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. ThinSOT power considerations are discussed further in the Applications Information section.

6.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.

7.Manual Shutdown

At any point in the charge cycle, the ME4054 can be put into shutdown mode by removing RPROG thus floating the PROG pin. This reduces the battery drain current to less than 2uA and the supply current to less than 50uA. A new charge cycle can be initiated by reconnecting the program resistor. In manual shutdown, the CHRG pin is in a weak pull-down state as long as VCC is high enough to exceed the UVLO conditions. The CHRG pin is in a high impedance state if the ME4054 is in undervoltage lockout mode: either VCC is within 100mV of the BAT pin voltage or insufficient voltage is applied to the VCC pin.

8.Automatic Recharge

Once the charge cycle is terminated, the ME4054 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 output enters a strong pull-down state during recharge cycle

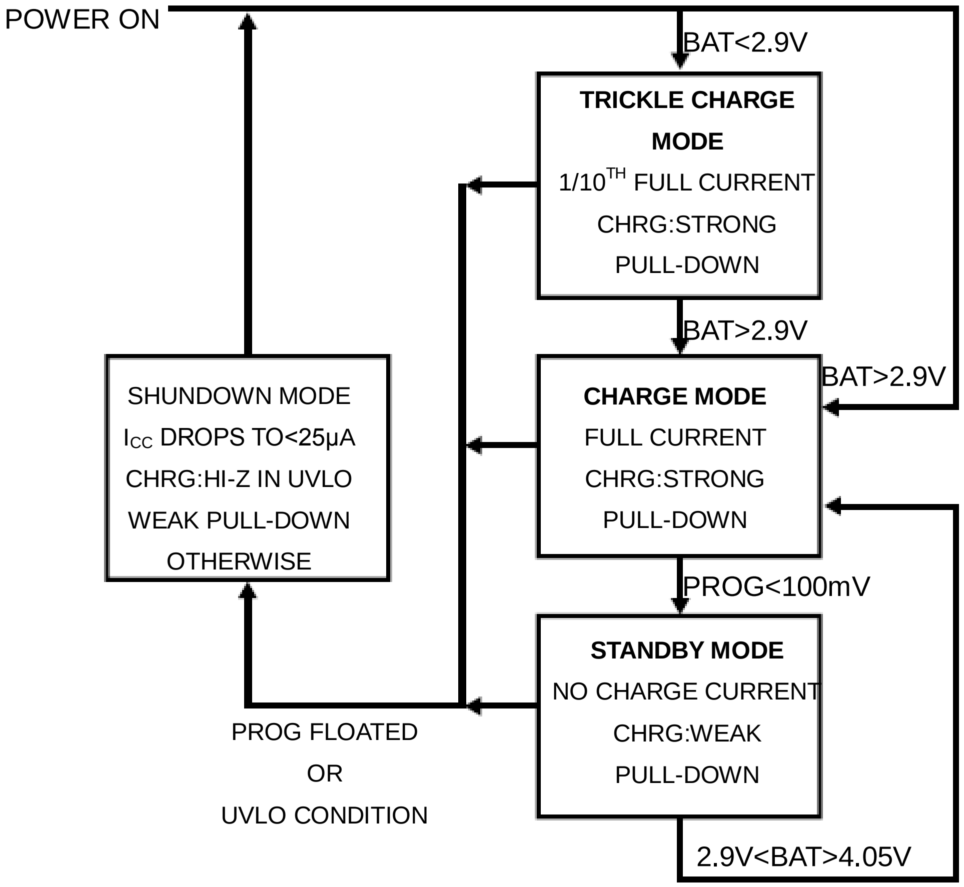


Fig.1 State Diagram of a Typical Charge Cycle

Application Information

1.Stability Considerations

The constant-voltage mode feedback loop is stable without an output capacitor provided a battery is connected to the charger output. With no battery present, an output capacitor is recommended to reduce ripple voltage (as Fig.2). When using high value, low ESR ceramic capacitors, it is recommended to add a 1Ω resistor in series with the capacitor. No series resistor is needed if tantalum capacitors are used.

In constant-current mode, the PROG pin is in the feedback loop, not the battery. The constant-current mode stability is affected by the impedance at the PROG pin. With no additional capacitance on the PROG pin, the charger is stable with program resistor values as high as 20KΩ. 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 I_{PROG} pin is loaded with a capacitance C_{PROG}, the following equation should be used to calculate the maximum resistance value for R_{PROG}:

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

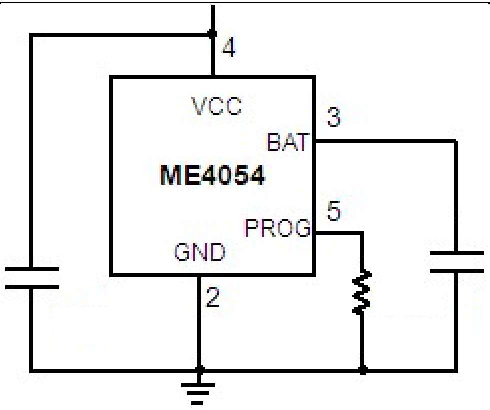


Fig.2

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 Fig.3. A 10KΩ resistor has been added between the PROG pin and the filter capacitor to ensure stability.

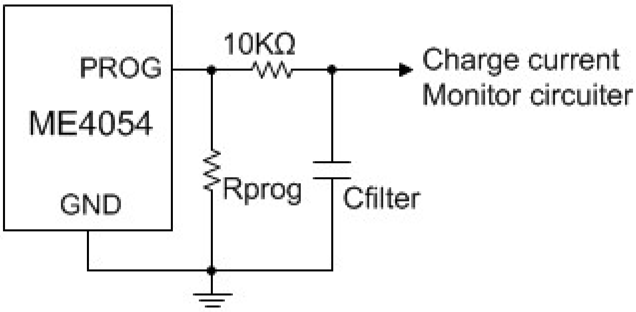


Fig.3 Isolating Capacitive Load on PROG Pin and Filtering

2.Power dissipation

The conditions that cause the ME4054 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: $P_D = (V_{CC} - V_{BAT}) * I_{BAT}$

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

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

For example: The ME4054 with 5V supply voltage through programmable provides full limiting current 400mA to a charge lithium-ion battery with 3.75V voltage. If θ_{JA} is 150℃/W (reference to PCB layout considerations), When ME4054 begins to decrease the charge current, the ambient temperature about:

$$T_A = 120℃ - (5-3.75V)*(400mA)*150 ℃/W = 120℃ - 0.5W* 150 ℃/W = 120℃ - 75℃ = 45 ℃$$

ME4054 can work in the condition of the temperature is above 45℃, the charge current is calculated to be approximately : $I_{BAT} = \dfrac{120℃ - T_A}{(VCC - V_{BAT}) * \theta_{JA}}$

Using the previous example with an ambient temperature of 60℃, the charge current will be reduced to approximately: $I_{BAT} = \dfrac{120℃ - 60℃}{(5V - 3.75V) * 150℃/W} = 320mA$

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

It is important to remember that ME4054 applications do not need to be designed for worst-case thermal conditions since the IC will automatically reduce power dissipation when the junction temperature reaches approximately120℃.

3.Thermal considerations

Because of the small size of the thinSOT 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.

The following table lists thermal resistance for several different board sizes and copper areas. All measurements were taken in still air on2/32” FR-4 board with the device mounted on topside.

Table.1 Measured Thermal resistance(2-layer board: each layer uses one ounce copper

Copper area		Board area（mm^2）	Thermal resistance junction-to ambient（℃/W）
Topside（mm^2）	Backside（mm^2）		
2500	2500	2500	125
1000	2500	2500	125
225	2500	2500	130
100	2500	2500	135
50	2500	2500	150

Table.2 Measured Thermal resistance (4-layer board: Top and bottom layers use two copper, inner layers use one ounce copper;10.0mm2 total copper area)

Copper area（mm^2）	Board area（mm^2）	Thermal resistance junction-to ambient （℃/W）
2500	2500	80

4.Increasing 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 ME4054 with 5V supply voltage through programmable provides full limiting current 800mA to a charge lithium-ion battery with 3.75V voltage. If θ_{JA} is 125℃/W, so that at 25℃ ambient temperature, the charge current is calculated to be approximately :

$$I_{BAT}=\frac{120℃-25℃}{(5V-3.75V)*125℃/W}=608mA$$

By dropping voltage across a resistor in series with a 5V wall adapter (shown in Fig.4), the on-chip power dissipation can be decreased, thus increasing the thermally regulated charge current:

$$I_{BAT}=\frac{120℃-25℃}{(V_S-I_{BAT}R_{CC}-V_{BAT})*\Theta_{JA}}$$

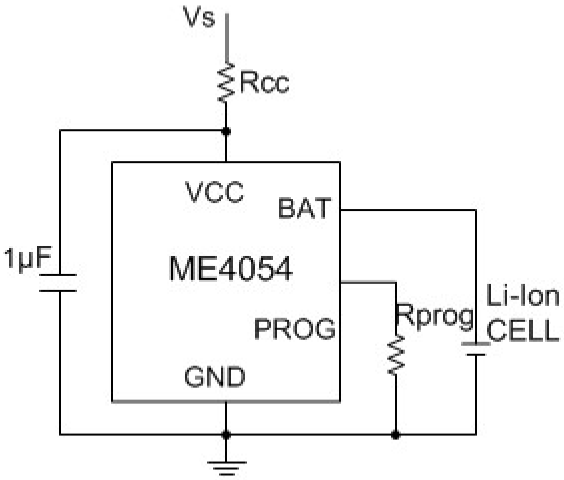


Fig.4 A circuit to maximize thermal mode charge current

Solving for I_{BAT} using the quadratic formula:

$$I_{BAT} = \frac{(V_S - V_{BAT}) - \sqrt{(V_S - V_{BAT})^2 \frac{4R_{CC}(120℃ - T_A)}{\Theta_{JA}}}}{2R_{CC}}$$

If R_{CC}=0.25Ω, V_S=5V, V_{BAT}=3.75V, T_A=25℃ and θ_{JA} =125℃/W, we can calculate the thermal regulation charge current: I_{BAT}＝708.4mA. While this application delivers more energy to the battery and reduces charge time in thermal mode, it may actually lengthen charge time in voltage mode if VCC becomes low enough to the ME4054 into dropout. Fig.5 shows how this circuit can result in dropout as R_{CC} becomes large.

This technique works best when R_{CC} values are minimized to keep component size small and avoid dropout. Remember to choose a resistor with adequate power handling capability.

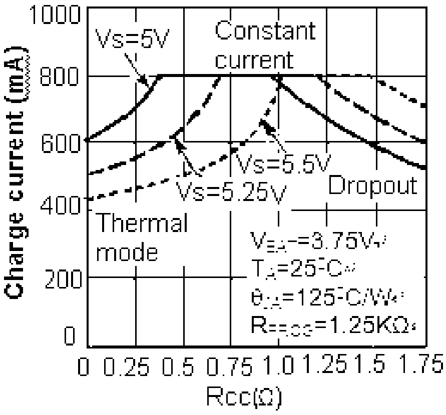


Fig.5 Charge current vs R_{CC}

5.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 an X5R ceramic capacitor will minimize start-up voltage transients.

6.Charging Current Soft Start

ME4054 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 over a period of approximately 100µs. This has the effect of minimizing the transient current load on the power supply during start-up.

7.CHRG status output Pin

The CHRG pin can provide an indication that the input voltage is greater than the undervoltage lockout threshold level. A weak pull-down current of approximately 20µA indicates that sufficient voltage is applied to VCC to begin charging. When a discharged battery is connected to the charger, the constant current portion of the charge cycle begins and the CHRG pin pulls to ground. The GHRG pin can sink up to 10mA to drive an LED that indicted that a charge cycle is in progress.

When the battery is nearing full charge, the charger enters the constant-voltage portion of the charge cycle and the charge current begins to drop. When the charge current drops below 1/10 of the programmed current, the charge cycle ends and the strong pull-down is replaced by the 20µA pull-down, indicating that the charge cycle has ended. If the input voltage is removed or drops below the undervoltage lockout threshold, the CHRG pin becomes high impedance. Fig.6 shows that by using two different value pull-up resistors, a microprocessor can detect all three states from this pin.

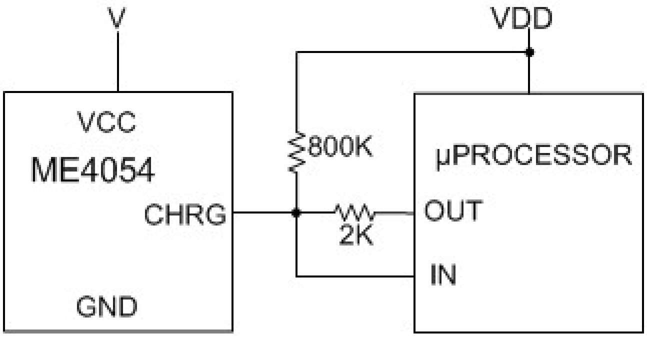


Fig.6 Using a Microprocessor to determine CHRG stage

To detect when the ME4054 is in charge mode, force the digital output pin (OUT) high and measure the voltage at the CHRG pin. The N-channel MOSFET will pull the pin voltage low even with the 2KΩ pull-up resistor. Once the charge cycle terminates, the N-channel MOSFET is turned off and a 20µA current source is connected to the CHRG pin. The IN pin will then be pulled high by the 2 KΩ pull-up resistor. To determine if there is a weak pull-down current, the OUT pin should be forced to a high impedance stage. The weak current source will pull the IN pin low through the 800KΩresistor; if CHRG is high impedance, the IN pin will be pulled high, indication than the part is in a UVLOstage.

Reverse polarity input voltage protection

In some applications, protection from reverse polarity voltage on VCC is desired. If the supply voltage is high enough, a series blocking diode can be used. In other cases, where the voltage drop must be kept low a P-channel MOSFET can be used (as shown in Fig.7).

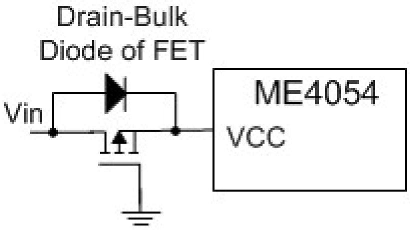


Fig.7 Low loss input reverse polarity protection

8.USB and Wall Adapter Power

ME4054 allows charging from a USB port, a wall adapter can also be used to charge Li-Ion/Li-polymer batteries. Figure 8 shows an example of how to combine wall adapter and USB power inputs. A P-channel MOSFET, MP1, is used to prevent back conducting into the USB port when a wall adapter is present and Schottky diode, D1, is used to prevent USB power loss through the 1KΩ pull-down resistor.

Generally, A wall adapter can supply more current than the 500mA-limited USB port. Therefore, an N-channel MOSFET (MN1) and an additional set resistor value as high as 10KΩ program resistor are used to increase the charge current to 600mA when the wall adapter is present.

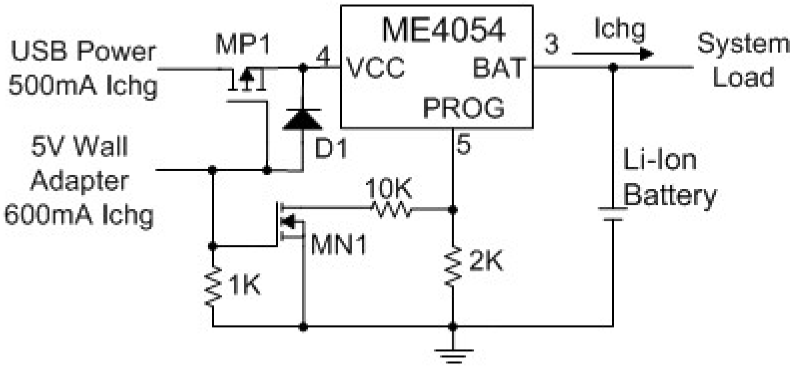
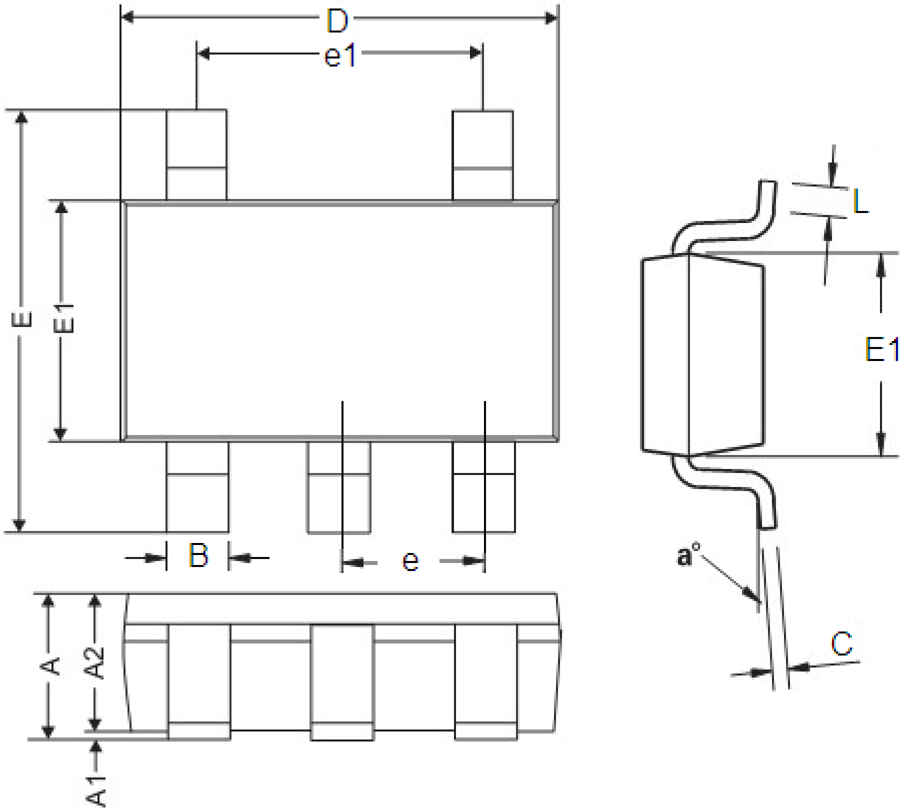


Fig.8 Combining wall adapter and USB power

Package Information

Package type:SOT23-5 Unit:mm(inch)



<table>
<tr><th rowspan="2">DIM</th><th colspan="2">Millimeters</th><th colspan="2">Inches</th></tr>
<tr><th>Min</th><th>Max</th><th>Min</th><th>Max</th></tr>
<tr><td>A</td><td>0.9</td><td>1.45</td><td>0.0354</td><td>0.0570</td></tr>
<tr><td>A1</td><td>0</td><td>0.15</td><td>0</td><td>0.0059</td></tr>
<tr><td>A2</td><td>0.9</td><td>1.3</td><td>0.0354</td><td>0.0511</td></tr>
<tr><td>B</td><td>0.2</td><td>0.5</td><td>0.0078</td><td>0.0196</td></tr>
<tr><td>C</td><td>0.09</td><td>0.26</td><td>0.0035</td><td>0.0102</td></tr>
<tr><td>D</td><td>2.7</td><td>3.10</td><td>0.1062</td><td>0.1220</td></tr>
<tr><td>E</td><td>2.2</td><td>3.2</td><td>0.0866</td><td>0.1181</td></tr>
<tr><td>E1</td><td>1.30</td><td>1.80</td><td>0.0511</td><td>0.0708</td></tr>
<tr><td>e</td><td colspan="2">0.95REF</td><td colspan="2">0.0374REF</td></tr>
<tr><td>e1</td><td colspan="2">1.90REF</td><td colspan="2">0.0748REF</td></tr>
<tr><td>L</td><td>0.10</td><td>0.60</td><td>0.0039</td><td>0.0236</td></tr>
<tr><td>a^0</td><td>0^0</td><td>30^0</td><td>0^0</td><td>30^0</td></tr>
</table>

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