# Two-Cell Lithium-Ion Battery Protection IC

## FEATURES

- Ultra-Low Quiescent Current at 10μA ($V_{CC}$=7V, $V_C$=3.5V).
- Ultra-Low Power-Down Current at 0.2μA ($V_{CC}$ =3.8V, $V_C$=1.9V).
- Wide Supply Range: 2 to 18V.
- Precision Overcharge Protection Voltage
  4.35V ± 30mV for the AIC1802A
  4.30V ± 30mV for the AIC1802B
  4.25V ± 30mV for the AIC1802C
- Built-in Delay Circuits for Overcharge, Over-discharge and Overcurrent Protection.
- Overcharge and Overdischarge Delay Time can be Extended by External Capacitors.
- Built-in Cell-balancing Bleeding Network under Overcharge Condition.

## DESCRIPTION

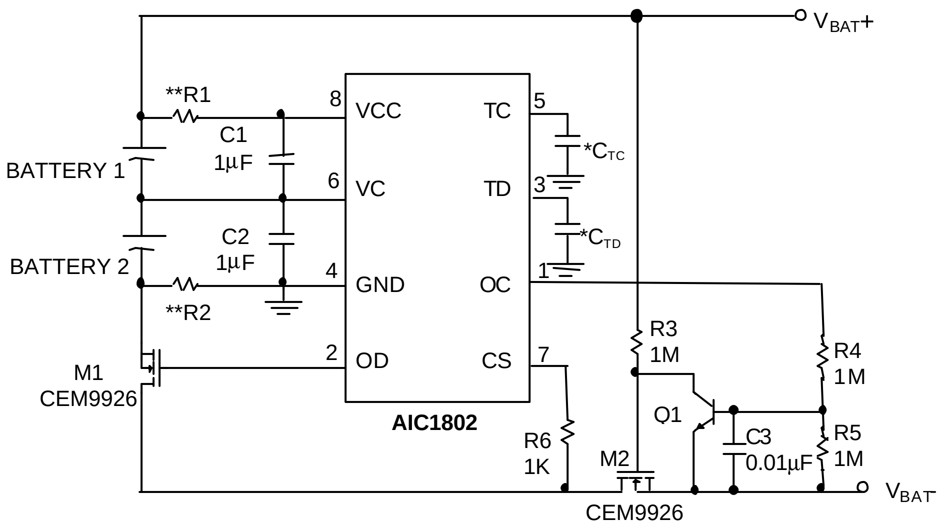
The AIC1802 battery protection IC is designed to protect lithium-ion batteries from damage due to overcharging, overdischarging, and overcurrent for two series cells in portable phones and laptop computers. It can be a part of the low-cost charge control system within a two-cell lithium-ion battery pack.

Safe and full utilization charging is ensured by the accurate ±30mV overcharge detection. Three different specification values for overcharge protection voltage are provided for various protection requirements. The very low standby current drains little current from the cells while in storage.

## APPLICATIONS

- Protection IC for Two-Cell Lithium-Ion Battery Pack.

## TYPICAL APPLICATION CIRCUIT



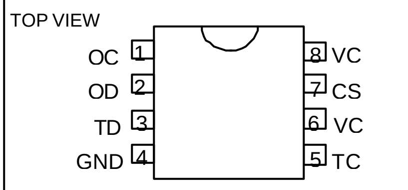

*$C_{TC}$ & $C_{TD}$ are optional for delay time adjustment.
**R1 & R2: Refer application informations.

**Protection Circuit for Two-Cell Lithium-Ion Battery Pack**

## ■ ORDERING INFORMATION

AIC1802 XCX

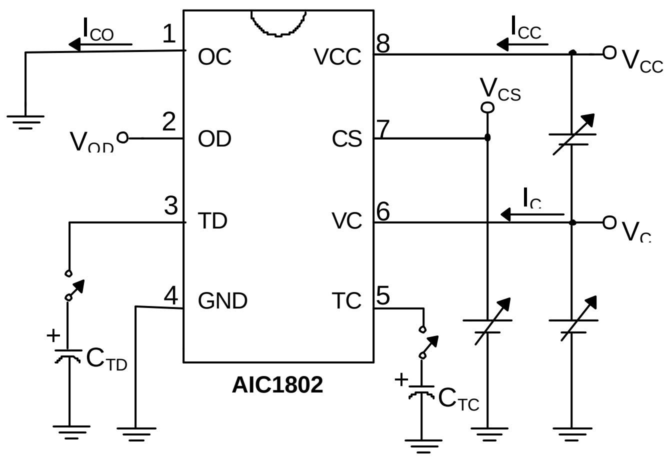
- PACKAGE TYPE
  S: SOP-8
- OVERCHARGE PROTECTION VOLTAGE
  A: 4.35V
  B: 4.30V
  C: 4.25V

| ORDER NUMBER | PIN CONFIGURATION |
|---|---|
| AIC1802ACS<br>AIC1802BCS<br>AIC1802CCS<br>(PLASTIC SO8) | <br> |

## ■ ABSOLUTE MAXIMUM RATINGS

Supply Voltage .......... 18V
DC Voltage Applied on VC, CS, OC, OD Pins .......... 18V
DC Voltage Applied on TC, TD Pins .......... 5V
Operating Temperature Range .......... -40°C~85°C
Storage Temperature Range .......... - 65°C~150°C

## ■ TEST CIRCUIT



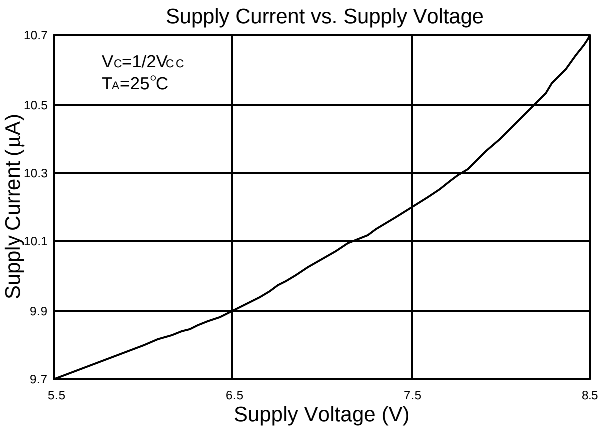
## ■ ELECTRICAL CHARACTERISTICS (Ta=25°C, unless otherwise specified.)

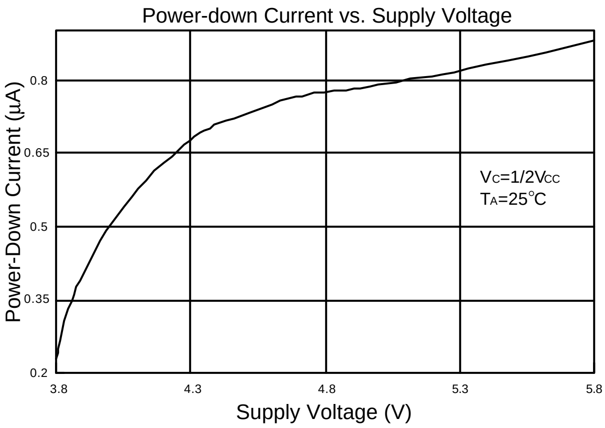
| PARAMETER | TEST CONDITIONS | SYMBOL | MIN. | TYP. | MAX. | UNIT |
|---|---|---|---|---|---|---|
| Supply Current in Normal Mode | $V_{CC}$=7V, $V_C$=3.5V | $I_{CC}$ | | 10 | 15 | μA |
| Supply Current in Power-Down Mode | $V_{CC}$=4.8V, $V_C$=2.4V | $I_{PD}$ | | 0.8 | 1.2 | μA |
| VC Pin Input Current | $V_{CC}$=7V, $V_C$=3.5V | $I_C$ | | 400 | 600 | nA |
| Overcharge Protection Voltage | AIC1802A | $V_{OCP}$ | 4.32 | 4.35 | 4.38 | V |
| | AIC1802B | | 4.27 | 4.30 | 4.33 | |
| | AIC1802C | | 4.22 | 4.25 | 4.28 | |
| Overcharge Release Voltage | | $V_{OCR}$ | 3.85 | 4.0 | 4.15 | V |
| Overdischarge Protection Voltage | | $V_{ODP}$ | 2.25 | 2.4 | 2.55 | V |
| Overdischarge Release Voltage | | $V_{ODR}$ | 2.85 | 3.0 | 3.15 | V |
| Overcurrent Protection Voltage | $V_{CC}$=7V | $V_{OIP}$ | 135 | 150 | 165 | mV |
| Overcharge Delay Time (1) | $V_{CC}$=8.6V, $V_C$=4.3V, $C_{TC}$=0μF | $T_{OC1}$ | 12 | 25 | 38 | mS |
| Overcharge Delay Time (2) | $V_{CC}$=8.6V, $V_C$=4.3V, $C_{TC}$=0.47μF | $T_{OC2}$ | 0.7 | 1.1 | 1.5 | S |
| Overdischarge Delay Time (1) | $V_{CC}$=4.8V, $V_C$=2.4V, $C_{TD}$=0μF | $T_{OD1}$ | 12 | 25 | 38 | mS |
| Overdischarge Delay Time (2) | $V_{CC}$=4.8V, $V_C$=2.4V, $C_{TD}$=0.47μF | $T_{OD2}$ | 0.7 | 1.1 | 1.5 | S |
| Overcurrent Delay Time (1) | $V_{CC}$=7V, $V_C$=3.5V, $V_{CS}$=0.15V | $T_{OI1}$ | 4 | 9 | 14 | mS |
| Overcurrent Delay Time (2) | $V_{CC}$=7V, $V_C$=3.5V, $V_{CS}$=0.36V | $T_{OI2}$ | 1.0 | 2.0 | 3.0 | mS |
| OC Pin Source Current | $V_{CC}$=8.6V, $V_C$=4.3V, OC Pin Short to GND | $I_{CO}$ | 270 | 400 | 530 | μA |
| OD Pin Output "H" Voltage | | $V_{DL}$ | $V_{CC}$-0.1 | $V_{CC}$-0.02 | | V |

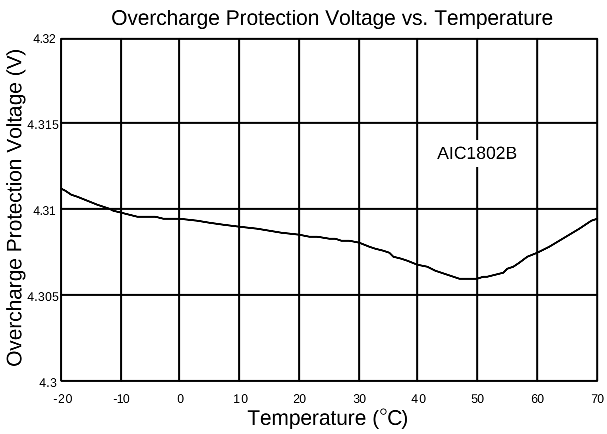
## ■ ELECTRICAL CHARACTERISTICS (Continued)

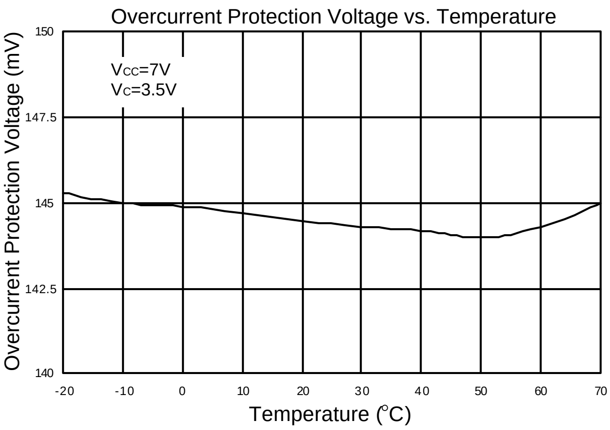
| PARAMETER | TEST CONDITIONS | SYMBOL | MIN. | TYP. | MAX. | UNIT |
|---|---|---|---|---|---|---|
| OD Pin Output “L” Voltage | | $V_{DH}$ | | 0.01 | 0.1 | V |
| Charge Detection Threshold Voltage | $V_{CC}$=4.8V | $V_{CH}$ | -0.55 | -0.4 | | V |
| Unbalance Discharge Current | $V_{CC}$=8.3V, $V_C$=4V | $I_{UD}$ | 5.4 | 7.7 | 10 | mA |

## ■ TYPICAL PERFORMANCE CHARACTERISTICS

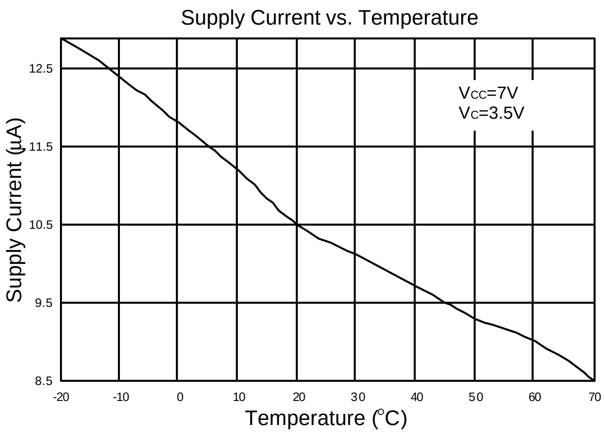


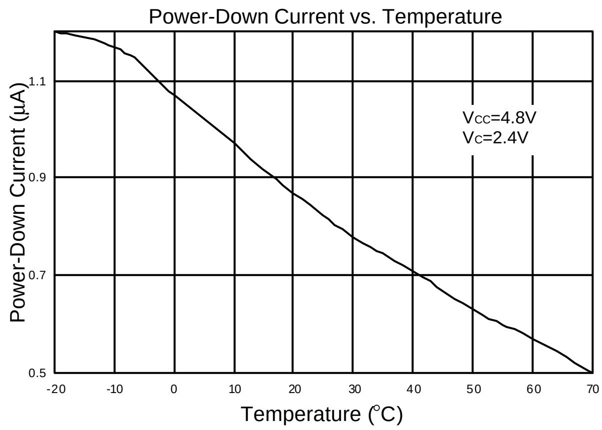



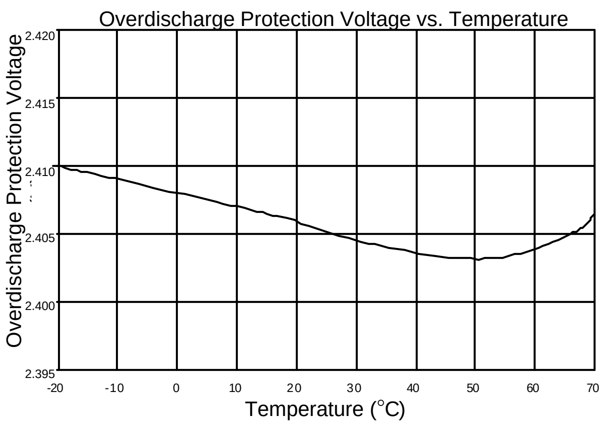



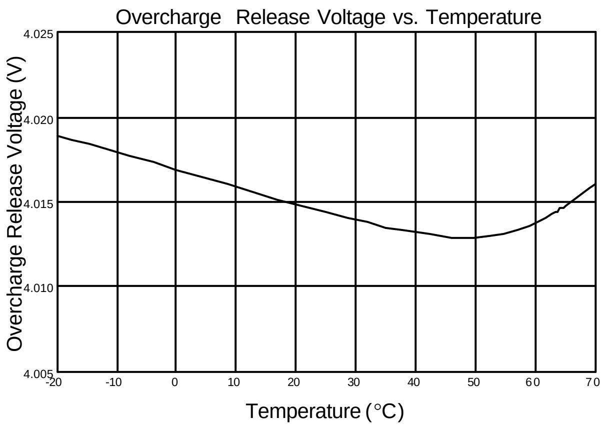



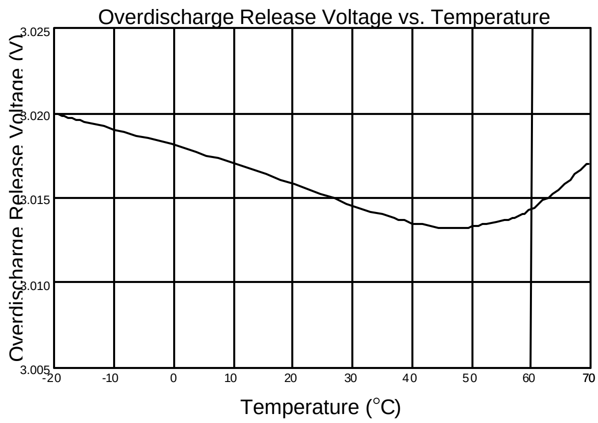
## ■ TYPICAL PERFORMANCE CHARACTERISTICS (Continued)



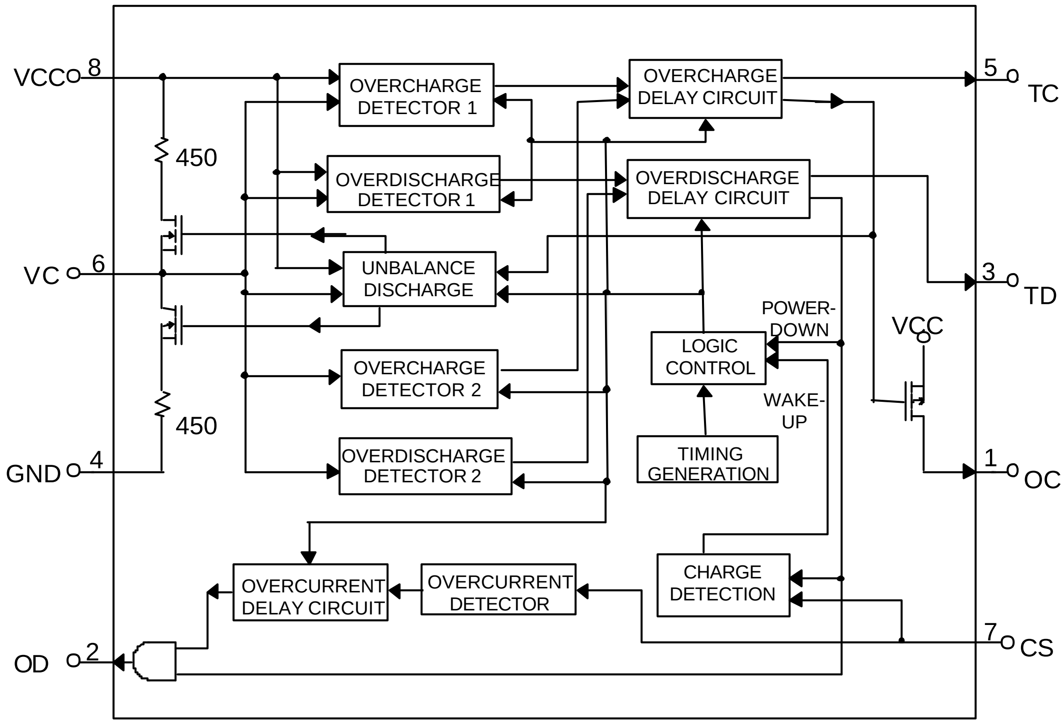



## ■ BLOCK DIAGRAM




## ■ PIN DESCRIPTIONS

PIN 1: OC - PMOS open drain output for control of the charge control MOSFET M2. When overcharge occurs, this pin sources current to switch the external NPN Q1 on, and charging is inhibited by turning off the charge control MOSFET M2.

PIN 2: OD - Output pin for control of the discharge control MOSFET M1. When overdischarge occurs, this pin goes low to turn off the discharge control MOSFET M1 and discharging is inhibited.

PIN 3: TD - Overdischarge delay time setting pin.

PIN 4: GND - Ground pin. This pin is to be connected to the negative terminal of the lower battery cell.

PIN 5: TC - Overcharge delay time setting pin.

PIN 6: VC - To be connected to the positive terminal of the lower cell and the negative terminal of the upper cell.

PIN 7: CS - Input pin for current sensing. Using the drain-source voltage of the discharge control MOSFET M1 (voltage between CS and GND), it senses discharge current during normal mode and detects whether charging current is present during power down mode.

PIN 8: VCC - Power supply pin. It is to be connected to the positive terminal of the upper cell.

## ■ APPLICATION INFORMATIONS

### THE OPERATION

#### Overcharge Protection

When the voltage of either of the battery cells exceeds $V_{OCP}$ (overcharge protection voltage) beyond the overcharge delay time period, charging is inhibited by the turning-off of the charge control MOSFET M2. The overcharge delay time ($T_{OC}$) defaults to 25mS and can be extended by adding a capacitor $C_{TC}$. Inhibition of charging is immediately released when the voltage of the overcharged cell becomes lower than $V_{OCR}$ (overcharge release voltage) through discharge.

#### Overdischarge Protection

When the voltage of either of the battery cells goes below $V_{ODP}$ (overdischarge protection voltage) beyond the overdischarge delay time period, discharging is inhibited by the turning-off of the discharge control MOSFET M1. The overdischarge delay time ($T_{OD}$) defaults to 25mS and can be extended by adding a capacitor $C_{TD}$. Inhibition of discharging is immediately released when the voltage of the overdischarged cell becomes higher than $V_{ODR}$ (overdischarge release voltage) through charging.

#### Power-Down after Overdischarge

When overdischarge occurs, the AIC1802 will go into power-down mode, turning off all the timing generation and detection circuitry to reduce the quiescent current to 0.8μA ($V_{CC}$=4.8V). In the unusual case where one battery cell is overdischarged while the other under overcharge condition, the AIC1802 will turn off all the detection circuits except the overcharge detection circuit for the cell under overcharge condition.

#### Charge Detection after Overdischarge

When overcharge occurs, the discharge control MOSFET M1 turns off and discharging is inhibited. However, charging is still permitted through the parasitic diode of M1. Once the charger is connected to the battery pack, the AIC1802 immediately turns on all the timing generation and detection circuitry and goes into normal mode. Charging is determined to be in progress if the voltage between CS and GND is below –0.4V (charge detection threshold voltage $V_{CH}$)

#### Overcurrent Protection

In normal mode, the AIC1802 continuously monitors the discharge current by sensing the voltage of CS pin. If the voltage of CS pin exceeds $V_{OIP}$ (overcurrent protection voltage) beyond overcurrent delay time $T_{OI}$ period, the overcurrent protection circuit operates and discharging is inhibited by turning-off of the discharge control MOSFET M1. Discharging must be inhibited for at least 256mS after overcurrent takes place to avoid damage to external control MOSFETs due to rapidly switching transient between $V_{BAT+}$ and $V_{BAT-}$ terminals. The overcurrent condition returns to the normal mode when the load is released and the impedance between the $V_{BAT+}$ and $V_{BAT-}$ terminals is 10MΩ or higher. For the sake of protection of the external MOSFETs, the larger the CS pin voltage (which means the larger discharge current) the shorter the overcurrent delay time. The relationship between voltage of CS pin and overcurrent delay time $T_{OI}$ is tabulated as below.

| $V_{CS}$ (V) | $T_{OI}$ (S) |
|---|---|
| 150m | 9.0m |
| 200m | 5.6m |
| 300m | 2.8m |
| 360m | 2.0m |
| 1V | 540μ |
| 3V | 290μ |
| 5V | 270μ |

### Unbalanced Discharge after Overcharge

When either of the battery cells is overcharged, the AIC1802 will automatically discharge the overcharged cell at about 7.7mA until the voltage of the overcharged cell is equal to the voltage of the other cell. If the voltage of the other cell is below $V_{OCR}$, the internal cell-balance "bleeding" will proceed until the voltage of the overcharged cell decreases to $V_{OCR}$.

## DESIGN GUIDE

### Adjustment of Overcharge and Overdischarge Delay Time

Both the overcharge and overdischarge delay times default to 25mS and can be extended by adding the external capacitors $C_{TC}$ and $C_{TD}$, respectively. Increasing the capacitance value will increase the delay time. The relationship between capacitance of the external capacitors and delay time is tabulated as below:

| $C_{TC}$ (F) | $T_{OC}$ (S) |
|---|---|
| 0μ | 25m |
| 0.1μ | 320m |
| 0.3μ | 890m |
| 0.47μ | 1.12 |
| 0.57μ | 1.43 |

| $C_{TD}$ (F) | $T_{OD}$ (S) |
|---|---|
| 0μ | 25m |
| 0.1μ | 320m |
| 0.3μ | 820m |
| 0.47μ | 1.08 |
| 0.57μ | 1.39 |

### Selection of External Control MOSFETs

Because the overcurrent protection voltage is preset, the threshold current for overcurrent detection is determined by the turn-on resistance of the discharge control MOSFET M1. The turn-on resistance of the external control MOSFETs can be determined by the equation: $R_{ON}=V_{OIP}/I_T$ ($I_T$ is the overcurrent threshold current). For example, if the overcurrent threshold current $I_T$ is designed to be 5A, the turn-on resistance of the external control MOSFETs must be 30mΩ. Users should be aware that turn-on resistance of the MOSFET changes with temperature variation due to heat dissipation. It changes with the voltage between gate and source as well. (Turn-on resistance of a MOSFET increases as the voltage between gate and source decreases). Once the turn-on resistance of the external MOSFET changes, the overcurrent threshold current will change accordingly.

### Suppressing the Ripple and Disturbance from Charger

To suppress the ripple and disturbance from charger, connecting C1 to cell 1 and C2 to cell 2 is necessary.

### Controlling the Charge Control MOSFET

R3, R4, R5 and NPN transistor Q1 are used to switch the charge control MOSFET M2. If overcharge does not occur, no current flows out from OC pin and Q1 are turned off, then M2 is turned on. When overcharge occurs, current flows out from OC pin and Q1 is turned on, which turns off M2 in turn. High resistance for R3, R4, and R5 is recommended for reducing loading of the batteries.

### Latch-Up Protraction at CS Pin

R6 is used for latch-up protection when charger is connected under overdischarge condition, and also for overstress protection when charger is connected in reverse. The charge detection function after overdischarge is possibly disabled by larger value of R6. Resistance of 1KΩ is recommended.

### Selection of R1 and R 2

R1 and R2 are used to avoid large current flow through the battery pack under the situation of IC damage or pin short. On the other hand, resistance of R1 and R2 will affect overcharge release voltage and bleeding function. The relationship among Vrelease1,Vrelease2, R1, and R2 is shown as following equations:

$Vrelease1=V_{OCR}+I_{UD}*R1$

$Vrelease2=V_{OCR}+I_{UD}*R2$

where

Vrelease1 is Battery 1, real overcharge release voltage

Vrelease2 is Battery 2, real overcharge release voltage

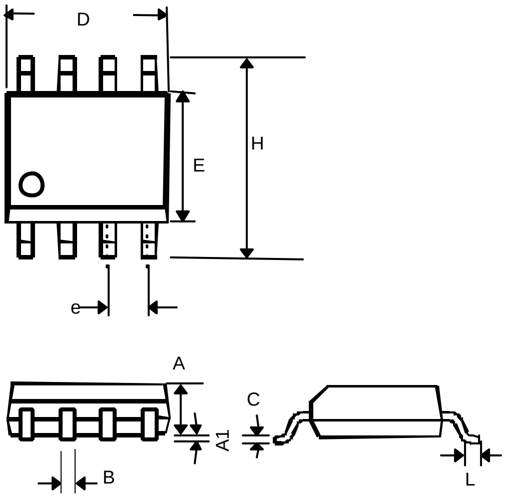
Therefore, resistance of R1 and R2 should not higher than 30Ω. Otherwise, overcharge release voltage would be higher than overcharge protection voltage and the charging current may oscillate. In addition, if overcharge protection function occurs, AIC1802 will discharge the overcharged cell and will stop bleeding function even if the voltage is not equal to the other. The recommended resistance of R1 and R2 is from 20 to 30Ω.

### Effect of C3

C3 has to be applied to the circuit. Because C3 will keep AIC1802 to be charged after overdischarge occurred. In addition, when the differential voltage between charger and battery pack is higher than 2.1V and overcharge protection function work, C3 will avoid battery pack from being charged even if the battery voltage lower than 4V (To avoid battery pack from being charged under charger malfunction situation). The battery pack can be charged again till remove it from charger.

## PHYSICAL DIMENSIONS

- **8 LEAD PLASTIC SO (unit: mm)**




| SYMBOL | MIN | MAX |
|---|---|---|
| A | 1.35 | 1.75 |
| A1 | 0.10 | 0.25 |
| B | 0.33 | 0.51 |
| C | 0.19 | 0.25 |
| D | 4.80 | 5.00 |
| E | 3.80 | 4.00 |
| e | 1.27(TYP) | |
| H | 5.80 | 6.20 |
| L | 0.40 | 1.27 |

# AIC1802 锂-离子电池保护 IC 及应用电路

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台湾沛亨公司的 AIC1802 是一种锂-离子电池保护 IC，是为两节串联的锂-离子电池在充电过程中防止过充、过放及过流造成损坏危险而设计的。它主要用于移动电话及便携式计算机等产品中。该 IC 往往与外围元件一起构成廉价实用的充电器控制系统的一个组成部分。

该器件主要特点有：静态电流极低（在 Vcc=7V, Vc=3.5V 时为 10μA）；掉电状态时（Vcc=3.8V, Vc=1.9V 时）耗电仅为 0.2μA；工作电压范围宽（2~18V）；精密的过充保护电压（4.3V±50mV，-20~+70℃范围内）；内部有过充、过放及过流保护延时电路；过充、过放延时时间可由外设电容设定；在发生过充时内部有电池平衡放电网络。

## 封装、管脚与内部结构

AIC1802 是贴片式 8 脚塑料 SO 封装器件，其管脚排列如图 1 所示，各管脚功能如表 1 所示，该器件内部结构框图如图 2 所示。

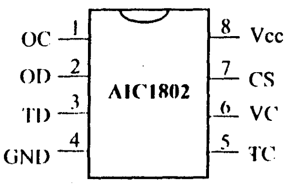


图 1

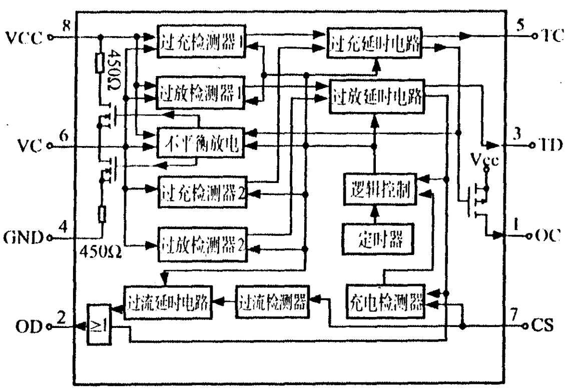


图 2

## 应用电路及各工作状态

典型应用电路如图 3 所示。电池一及电池二为两节充电的锂-离子电池，M1 为控制过放的 MOSFET，M2 为控制过充的 MOSFET，$C_{TD}$、$C_{TC}$ 为设定过放、过充延时时间设定电容器，Q1 为控制 M2 截止的三极管，$V_{BAT}+$、$V_{BAT}-$ 为外接充电电源。

表 1　AIC1802 各管脚功能

| 管脚 | 符号 | 功　能 |
|---|---|---|
| 1 | OC | PMOS 管开漏输出端，用于控制过充发生 |
| 2 | OD | 用于控制过放的输出端，外接MOSFET的栅极 |
| 3 | TD | 外接电容$C_{TD}$，设定过放延时时间 |
| 4 | GND | 地，外接第二电池的负端 |
| 5 | TC | 外接电容$C_{TC}$，设定过充延时时间 |
| 6 | VC | 接第一电池负端及第二电池正端 |
| 7 | CS | 电流检测输入端 |
| 8 | VCC | 接电源正端，同时也连接第一电池正端 |

该电路的功能有：过充保护；过放保护；掉电模式时降低功耗；过放后的充电检测；过流（短路）保护；过充后的不平衡放电。

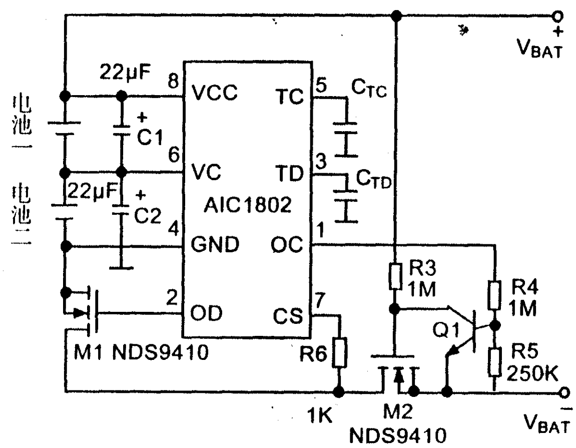


图 3

### 1. 过充保护

当任一电池电压超过过充保护电压$V_{OCP}$（4.3V）时，并超过过充延时时间$T_{OC}$，OC 端输出高电平，Q1 导通，M2 截止，停止充电。当两个电池的电压通过放电都低于过充解除电压$V_{OCR}$（4.0V），OC 端输出低电平，M2 立即导通。

### 2. 过放保护

当任一电池电压低于过放保护电压$V_{ODR}$（2.45V）并超过放电延时时间$T_{OD}$，OD 端输出控制信号使 M1 截止，停止放电。当两个电池的电压都高于过放解除电压$V_{ODR}$

(3.0V) 时，OD 端输出控制信号使 M1 立即导通。

**3. 过放后的掉电状态**

当发生过放，AIC1802 将进入“掉电”状态。在掉电状态时，关闭所有的定时器及检测电路使静态电流降低到 0.8μA (Vcc=5V)。在一个电池过放而另一个电池过充的异乎导常的情况时，AIC1802 除过充检测电路外其它检测电路都关闭。

**4. 过放后的充电检测**

当发生过放，放电控制 MOSFET M1 将截止而停止放电。然而通过 M1 内部的二极管仍然允许充电。一旦电池组连接到充电器上，AIC1802 立即开通所有定时器及检测电路使进入正常模式。是否进行充电取决于 CS 及 GND 之间的电压是否低于-0.4V(充电检测阈值电压$V_{CH}$)。

**5. 过流 (短路) 保护**

在正常模式工作时，放电电流由 AIC1802 的 CS 端连续监控，若此端检测的电压超过过流保护电压$V_{OIP}$(150mV)并超过过流延时时间$T_{OI}$，则过流保护电路工作使放电控制 MOSFET M1 转为截止，禁止放电。

**6. 过充后的不平衡放电**

当任一电池过充时，AIC1802 将自动地给过充电池以 7.7mA 左右电流放电，直放到此电池与另一电池电压相等为止。如果另一电池的电压低于$V_{OCR}$ (过充解除电压)，则内部电池平衡放电电路将继续进行直到电池电压达到$V_{OCR}$为止。

## 电路元器件选择

**1. 过充及过放延时电容**

若不接过充延时电容，其延时时间$T_{OC}$为 22±8ms，若外接电容$T_{OC}$则可增加延时时间，延时时间与外接电容$C_{TC}$关系如表 2 所示。

若不接过放延时电容，其延时时间$T_{OD}$为 22±8ms，若外接电容$T_{OD}$，则延时时间可增加，如表 3 所示。

**2. MOSFET 的选择**

因为过流保护电压$V_{OIP}$(150mV) 是设定好的，而过流阈值电流$I_T$可由用户设定。放电电流的检测 (过流电流检测) 是取决于放电控制 MOSFET M1 的导通电阻，因此，对 MOSFET 的导通电阻$R_{ON}$与过流阈值电流及过流保护电压$V_{OIP}$有如下的关系：$R_{ON}=V_{OIP}/I_T$。例如，过流阈值电流$I_T$设定为 5A，则 MOSFET 的导通电阻$R_{ON}$应是 30mΩ，并且用户应注意导通电阻$R_{ON}$与$V_{GS}$有关并与工作温度有关。

**3. C1、C2 不可省略**

为防止电源的纹波电压的干扰，C1、C2 是不可省略的。

**4. CS 端可控硅效应 (Latch-Up) 保护电阻**

在过放时，R6 用作可控硅效应保护，R6 建议用 1kΩ 电阻。

表 2 $T_{OC}$与$C_{TC}$关系

| $C_{TC}$(μF) | 不接 | 0.1 | 0.3 | 0.47 | 0.57 |
|---|---|---|---|---|---|
| $T_{OC}$(s) | 22m | 320m | 890m | 1.12 | 1.43 |

表 3 $T_{OD}$与$C_{TD}$关系

| $C_{TD}$(μF) | 不接 | 0.1 | 0.3 | 0.47 | 0.57 |
|---|---|---|---|---|---|
| $T_{OD}$(s) | 22m | 310m | 820m | 1.08 | 1.39 |

表 4 AIC1802 主要电参数 (Ta=25℃)

| 参数 | 符号 | 条件 | 最小 | 典型 | 最大 | 单位 |
|---|---|---|---|---|---|---|
| 正常工作模式时的工作电流 | $I_{CC}$ | Vcc=7V, Vc=3.5V | - | 10 | 15 | μA |
| 掉电模式时的工作电流 | $I_{PD}$ | Vcc-4.8V, Vc=2.4V | - | 0.8 | 1.2 | μA |
| 过充保护电压 | $V_{OCP}$ | -20℃≤Ta≤70℃ | 4.25 | 4.3 | 4.35 | V |
| 过充解除电压 | $V_{OCR}$ | | 3.85 | 4.0 | 4.15 | V |
| 过放保护电压 | $V_{ODP}$ | | 2.35 | 2.45 | 2.55 | V |
| 过放解除电压 | $V_{ODR}$ | | 2.85 | 3.0 | 3.15 | V |
| 过流保护电压 | $V_{OIP}$ | Vcc=7V | 135 | 150 | 165 | mV |
| OD 端输出高“H”电压 | $V_{DH}$ | | Vcc-0.5 | - | - | V |
| OD 端输出低“L”电压 | $V_{DL}$ | | | - | 0.1 | V |
| 充电检测阈值电压 | $V_{CH}$ | Vcc=4.8V | -0.5 | -0.4 | | V |

## AIC1802 的主要参数

AIC1802 工作温度范围为-20~+70℃，工作极限电压为 18V。主要电参数如表 4 所示。 ECN