ADVANCED LINEAR CHARGER IC

For LITHIUM-ION AND LITHIUM-POLYMER Battery

FEATURES

- **Ideal for Single (4.2V) Li-ion or Li-Polymer Packs**
- **Better Than ±1% Voltage Regulation Accuracy With Preset Voltage**
- **Adjustable precharge current with an external resistor**
- **Adjustable Charging Current During Constant Current Charging Stage**
- **Constant Voltage Charging**
- **Automatic Battery-Recharge Feature**
- **Cell-Temperature Monitoring Before and During Charge**
- **Dynamic compensation of Battery Pack's Internal Impedance to Reduce Charge Time**
- **Charge Status Output for Dual Led**
- **Cell Condition Monitoring**
- **Automatic Low-Power Sleep Mode When Vcc is Removed or When Voltage Supply is Lower than battery voltage**
- **Requires Small Number of External Components**
- **Packaging: 8-Pin SOP or MSOP**

DESCRIPTION

The VA7205 series advanced Lithium-Ion (Li-Ion) and Lithium-Polymer (Li-Pol) Linear Charger ICs are designed for cost-sensitive and compact portable electronics. They combine high-accuracy current and voltage regulation, battery condition monitoring, temperature monitoring, charge termination, charge-status indication, and internal impedance compensation in a single 8-pin IC. It is the best suitable device to be used in the PDA, mobile phones, and other portable devices.

The VA7205 monitors the battery charging status by detecting the battery voltage level. The VA7205 charges the battery in three phases: conditioning, constant current, and constant voltage.If the battery voltage is below the low-voltage threshold, Vmin (normally at 3V), the VA7205 precharges using a low current to condition the battery. The conditioning charge rate can be adjusted with an external resistor. After the battery is precharged to Vmin, the VA7205 applies a constant current to the battery. An external sense-resistor sets the current. The constant-current phase continues until the battery reaches the charge-regulation voltage (normally at 4.2V) and then the VA7205 begins the constant-voltage phase. The accuracy of the voltage regulation is better than ±1% over the operating-temperature and supply-voltage ranges. Under this stage the charging current will gradually decrease. Charge stops when the current tapers to the charge termination threshold, I_{TERM}. The VA7205 will continue monitoring the battery voltage level and entering a new cycle of charging if the battery's voltage level has fell below V_{RECHG} (normally at VREG - 125mV).

During the charging process, for the safety concern, the VA7205 continuously measures battery temperature using the battery's internal heat sensitive resistor and an external resistors. If the temperature of the battery exceeds the pre-set temperature range, the charging process will come to a halt after 0.5 seconds; After the temperature fell back into the pre-set temperature range, the charging will continue again after 0.5 seconds. The VA7205 can also dynamically compensate the battery pack's internal impedance to reduce the charge time.

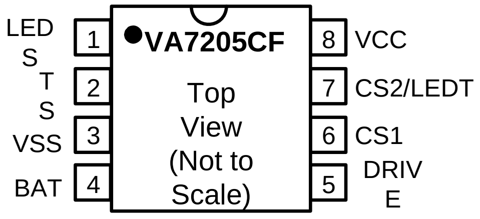

Figure 1 VA7205CF 8-Pin SOP

FUNCTION BLOCK DIAGRAM

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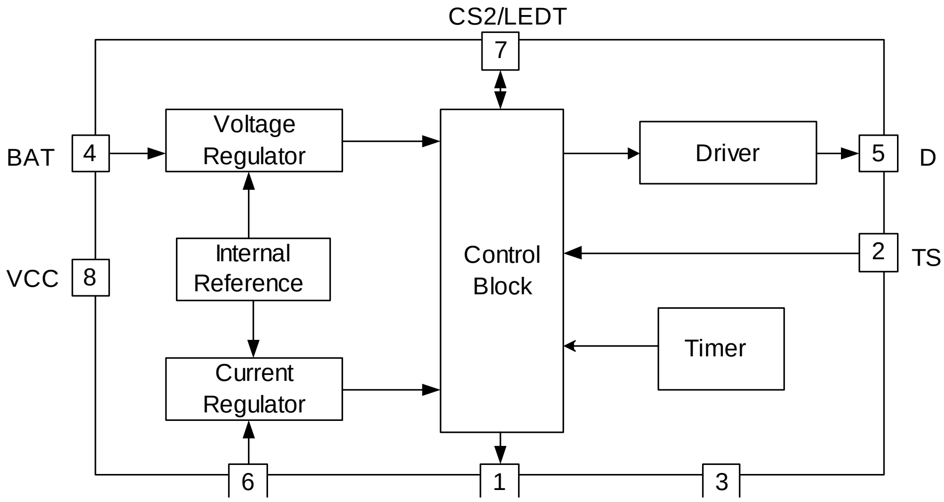


Figure 2 VA7205 Function Block Diagram

Ordering Information

MODEL	OUTPUT VOLTAGE	RECHARGING VOLTAGE	PACKAGING	PIN COUNT
VA7205CF	4.2V	4.075V	SOP	8
VA7205DF	4.2V	4.075V	MSOP	8

PIN DESCRIPTION

PIN NAME	PIN NO.	I/O	PIN DESCRIPTION
LEDS	1	O	***Charge Status Output*** During the charging, this pin is pulled low to VSS. After the charging completed, this pin will be appear as high-impedance state. Under the case of abnormal battery operation or abnormal high temperature, a 50% duty-cycle 2Hz pulse will be generated. This pin can be connected to the LED diode via a 330 ohm resistor.
TS	2	I	***Temperature Sense Input*** Input for an external battery-temperature monitoring circuit. The input voltage level for this pin has to be between V_{TS1} and V_{TS2}, otherwise, VA7205 will treat as abnormal temperature range.
VSS	3	PWR	***Ground***
BAT	4	I	***Battery Voltage Sense Input*** This pin should be tied directly to the positive side of the battery via a 300~680Ω resistor. A 10uF capacitor should be connected between battery's positive and negative terminals.
DRIVE	5	O	***External Pass Transistor Drive Output*** This output drives an external pass-transistor (PNP or P-Channel MOSFET) for current and voltage regulation.
CS1	6	I	***Current-Sense Input*** Battery current is sensed via the voltage developed on this pin by an external sense resistor. The external resistor can be placed between positive terminal of the power supply and the emitter (PNP transistor) or source (PMOS transistor).

CS2/LEDT	7	I/O	***Charge-Rate Compensation Input/charge termination status output*** During charging, this pin can be used for battery resistance cancellation. After the charging termination, this pin is pulled low to VSS and it can be used as a charging termination indicator.
VCC	8	PWR	***Supply Voltage*** Connect to positive terminal of power supply. A 10uF capacitor should be connected between VCC and VSS.

Absolute Maximum Rating (Unless otherwise noted)

Supply Voltage (VCC) .... －0.3V ~ ＋18V
CS1、CS2/LED、DRIVE、BAT、
LEDS、TS Input Voltage .... －0.3V ~ VCC＋0.3V
Operating Ambient Temperature Range, T_A .... －40℃ ~ ＋85℃
Junction Temperature ....150℃

Total Power Dissipation, P_D（T_A＝25℃）
SOP8 ....TBD
MSOP8 ....TBD
Storage Temperature Range..................................... －65℃ ~ 150℃
Lead Temperature（Soldering，10 seconds）........................300℃

Note: Stresses beyond those listed under "absolute maximum ratings" 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 the recommended operating condition is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

Electrical Characteristics

（Unless otherwise noted，VCC＝5V。The operating temperature for items marked with "♦"：－40℃ ≤ T_A ≤ 85℃；The operating temperature for items marked without "♦: T_A＝25℃；The temperature for typical value: T_A＝25℃）

PARAMETER	SYMBOL	TEST CONDITION		MIN	TYP	MAX	UNIT
Power Supply Voltage	VCC		♦	4.5		12	V
Power Supply Current	I_{SUPPLY}	VCC＝5V	♦		1	3	mA
		VCC＝12V	♦		2		mA
Input Voltage Under Voltage lockout	V_{UVLO}	VCC rising	♦	3.8	4.07	4.3	V
Sleep Current	I_{SLEEP}	VCC No Connect，V_{BAT} = 4.2V	♦		7	20	μA
BATTTERY VOLTAGE REGULATION							
Regulation Voltage	V_{REG}	VCC＝V_{CS1}＝$V_{CS2/LEDT}$		4.168	4.200	4.232	V
			♦	4.158	4.200	4.242	V
Line Regulation		VCC＝5V ~ 12V			0.05		%
RECHARGE							
Recharge Threshold	V_{RECHG}			V_{REG}－0.175	V_{REG}－0.125	V_{REG}－0.075	V
CURRENT REGULATION							
Current Regulation Threshold	V_{CSREG}	Referenced to VCC (see note 1)	♦	135	150	165	mV
PRECHARGE CURRENT REGULATION							
Precharge Current Regulation threshold	V_{CSPRE}	Referenced to VCC		10	18	28	mV
CHARGE TERMINATION DETECTION							
Charge Termination Threshold	V_{CSTERM}	Referenced to VCC		8	15	22	mV
TEMPERATURE SENSE (VOLTAGE AT TS PIN)							
Lower Temperature Threshold	V_{TS1}			26	28	30	%VCC
Upper Temperature	V_{TS2}			55	58	61	%VCC

Threshold							
PRECHARGE TERMINATION							
Rising Precharge Threshold	V_{MIN}			2.94	3.00	3.06	V
BATTERY RESISTANCE CANCELLATION							
Battery Resistance Cancellation Gain (see note 3)	G_{COMP}			2.5	2.8	3.1	V/V
DRIVE							
Pull-up Resistance		V_{BAT} = 4.5V			5		kΩ
High Output Voltage		VCC = 12V，V_{BAT} = 4.5V	♦	11.9			V
Sink Current		V_{BAT} = 3.6V，V_{DRIVE} = 1V	♦	30			mA
BATTERY PACK ABNORMAL OPERATION DETECTION							
Battery Short Circuit Threshold	V_{BSC}			0.3	0.8	1.2	V
Battery Failure Timeout	t_{FAIL}			10	15	20	min
LEDS Output Pulse Period				0.3	0.5	0.75	s
LEDS Output Pulse Duty Cycle					50		%
LEDS,CS2/LEDT Output Sink Current		V_{LEDS}=$V_{CS2/LEDT}$=0.3V		10			mA
BAT Input Current		V_{BAT} = 3.6V			4.2	10	µA
BAT External Cap				4.7		47	µF
TS Input Current		V_{TS} = 2.5V			0.01		µA
CS1 Input Current		V_{CS1} = 4.95V，V_{BAT} = 3.6V				5	µA
CS2/LEDT Input Current		V_{CS1} = 4.95V，V_{BAT} = 3.6V				5	µA

Note: 1. Unless otherwise noted, all voltage levels in the table are referenced to VSS.

2. Please use application circuit schematic in Figure 3 and Figure 5.

3. Definition for the Compensation Gain: $G_{COMP} = \Delta V_{REG}/(V_{CS2/LEDT} - V_{CS1})$.

FUNCTION DESCRIPTION

The VA7205 is an advanced linear charge controller for single Li-Ion or Li-Pol applications . Figure 3 shows the schematic of charger using a PNP pass transistor. Figure 4 is a typical charge profile. Figure 5 shows the schematic of a charger using P-Channel MOSFET. Figure 6 is an operational state diagram.

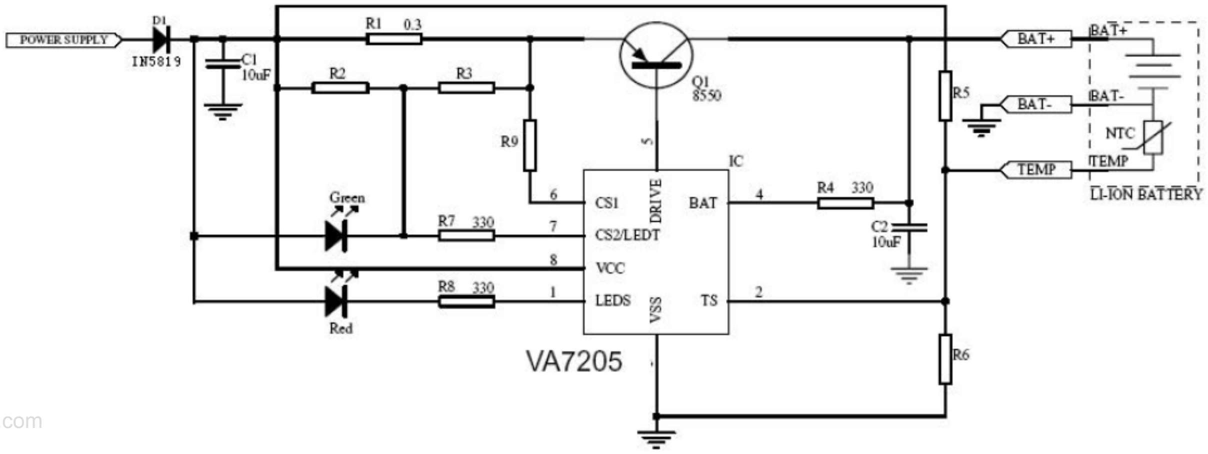

POWER SUPPLY
D1
IN5819
C1
10uF
R1 0.3
R2
R3
R9
Q1
8550
5
IC
DRIVE
6
CS1
BAT
4
R4 330
7
CS2/LEDT
8
VCC
1
LEDS
VSS
TS
2
Green
Red
R7 330
R8 330
C2
10uF
R5
R6
BAT+
BAT-
TEMP
BAT+
BAT-
NTC
TEMP
LI-ION BATTERY
VA7205

Figure 3 Li-ion/Li-Pol Charger Using a PNP Pass Transistor

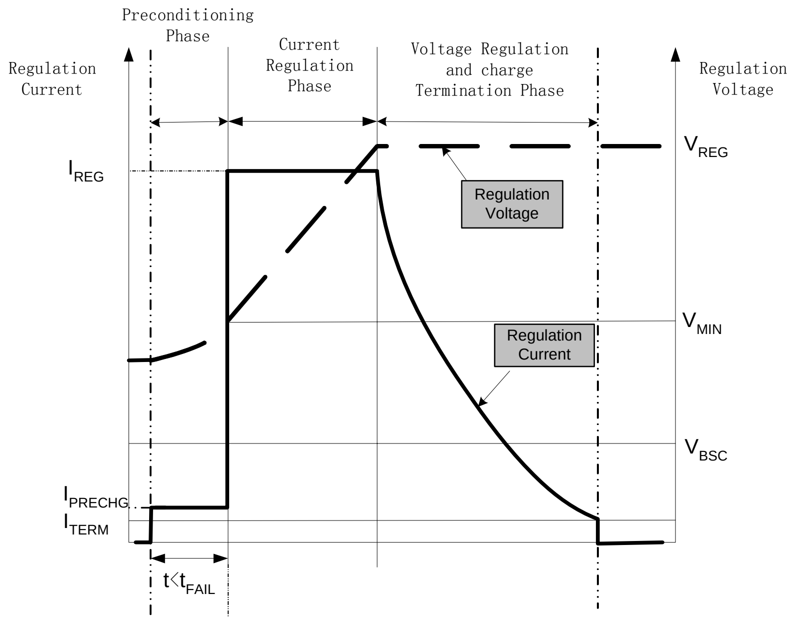


Figure 4 Typical Charge Profile

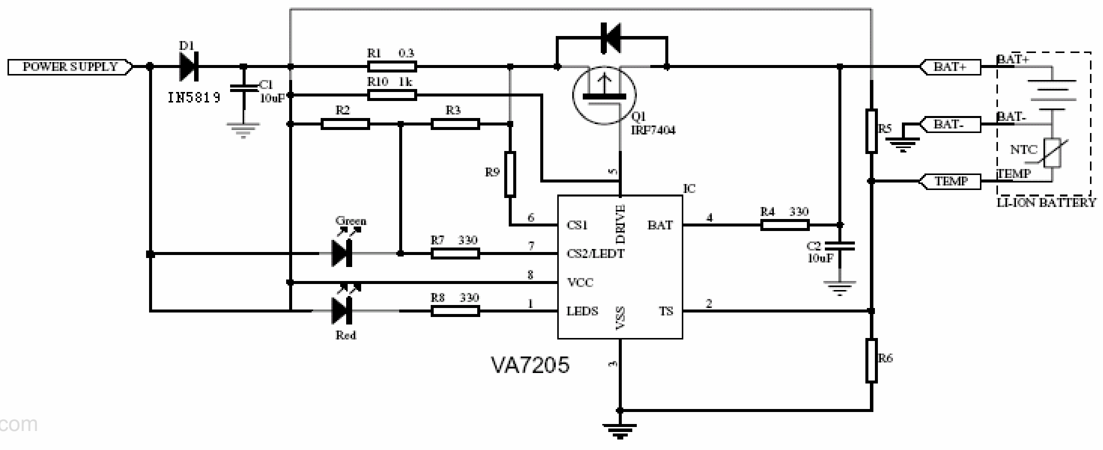

POWER SUPPLY
D1
IN5819
C1
10uF
R1 0.3
R10 1k
R2
R3
R9
Q1
IRF7404
IC
Green
Red
R7 330
R8 330
6
7
8
1
5
3
CS1
CS2/LEDT
VCC
LEDS
DRIVE
VSS
BAT
TS
4
2
R4 330
C2
10uF
VA7205
R5
R6
BAT+
BAT-
TEMP
NTC
LI-ION BATTERY

图 5 用 PMOS 管作为调整管的应用线路图

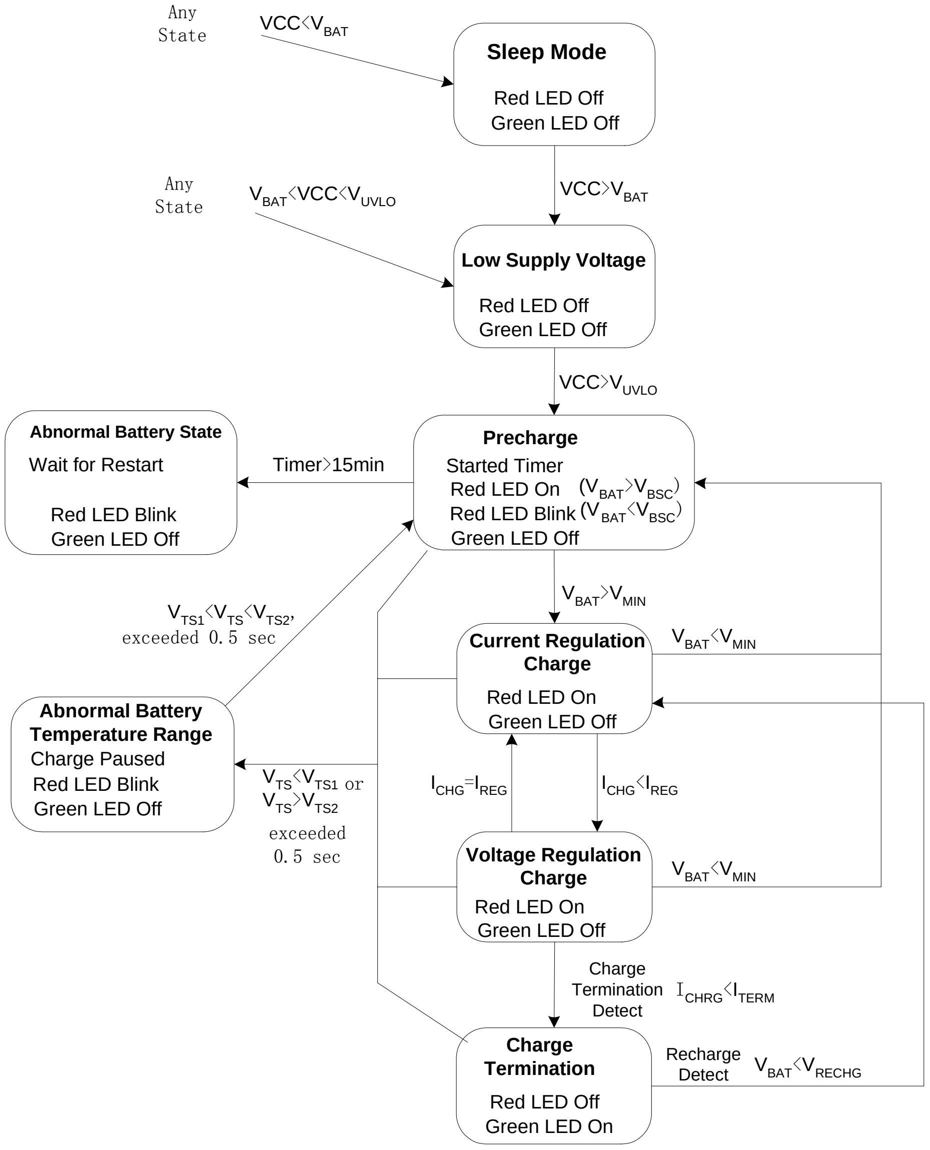

Any State
VCC<VBAT
Sleep Mode
Red LED Off
Green LED Off
VCC>VBAT
Any State
VBAT<VCC<VUVLO
Low Supply Voltage
Red LED Off
Green LED Off
VCC>VUVLO
Abnormal Battery State
Wait for Restart
Red LED Blink
Green LED Off
Timer>15min
Precharge
Started Timer
Red LED On (VBAT>VBSC)
Red LED Blink (VBAT<VBSC)
Green LED Off
VTS1<VTS<VTS2,
exceeded 0.5 sec
VBAT>VMIN
Current Regulation Charge
Red LED On
Green LED Off
VBAT<VMIN
Abnormal Battery Temperature Range
Charge Paused
Red LED Blink
Green LED Off
VTS<VTS1 or
VTS>VTS2
exceeded
0.5 sec
ICHG=IREG
ICHG<IREG
Voltage Regulation Charge
Red LED On
Green LED Off
VBAT<VMIN
Charge Termination Detect
ICHRG<ITERM
Charge Termination
Red LED Off
Green LED On
Recharge Detect
VBAT<VRECHG

Figure 5 Operation State Diagram

1. Qualification and Pre-charge

The VA7205 starts a charge-cycle if any of the following situations is detected:

a) The power is supplied（VCC＞4.2V）, and a battery is inserted (V_{BAT}<V_{RECHG});

b) A battery is already present (V_{BAT}<V_{REG}) and power is supplied (VCC>4.2V).

Charge qualification is based on battery voltage and temperature. If the battery voltage is below the pre-charge threshold V_{MIN}, the VA7205 uses pre-charge to condition the battery. The conditioning charge current I_{PRECHG} is adjustable with an external resistor R9 shown in Figure 3 and Figure 5.R9 is connected between CS1 pin and the emitter of external PNP or source of external PMOS. There is also an on-chip 5.1KΩ resistor connected between CS1 pin and VCC. During pre-charge stage, the voltage drop between VCC and CS1 pin is V_{CSPRE}, so the pre-charge current is set to be

$$I_{PRECHG} = \left(1 + \frac{R9}{5.1}\right) \times \frac{V_{CSPRE}}{R1}$$

Where R9's dimension is KΩ, and R9's value should be less than 10KΩ.The voltage divider is disabled if charger is not in pre-charge stage.

The conditioning charge current is much smaller compared to the regulation current. This is because when battery voltage level (V_{BAT}) is very low, a high charge current can cause safety hazard. The conditioning current also minimizes heat dissipation in the external pass-element (Q1) during the initial stage of charge.

Note in scenario (a), if battery voltage level (VBAT) is greater than Recharge Threshold Voltage (V_{RECHG}), the VA7205 will not immediately go into the charging mode. The VA7205 will wait until $V_{BAT} < V_{RECHG}$ and then start the recharging cycle. In the scenario (b), whenever V_{BAT} is smaller than V_{REG}, regardless if V_{BAT} is higher than V_{RECHG} or not, the VA7205 will immediately enter the charging cycle until charging is complete.

2. Current Regulation Phase

After the battery voltage level reaches V_{MIN}, the VA7205 enters the Current Regulation Phase. The charging current is set as: $I_{REG} = V_{CSREG}/R1$. Therefore, the charging current can be set to a desired level by adjusting the external resistor (R1).

3. Voltage Regulation Phase

During the Current Regulation Phase, the battery voltage level will gradually increase. When V_{BAT} reaches V_{REG}, the VA7205 enters Voltage Regulation Phase. During this phase, the V_{BAT} will stop increase and stop at the V_{REG} level, the charging current will also gradually decrease.

4. Charge Termination

During the Voltage Regulation Phase, the charge current gradually decreases. After the charge current decreased to $I_{TERM} = V_{CSTERM}/R1$, charge terminates and the charge current drops to zero.

5. Battery Temperature Monitoring

To prevent the damage caused by the very high (or very low) temperature done to the battery pack, during the charge process, the VA7205 continuously monitors temperature by measuring the voltage in the voltage divider circuit between the battery's internal heat sensitive resistor and TS pin.

The VA7205 compares the voltage at TS pin (V_{TS}) against its internal V_{TS1} and V_{TS2} thresholds to determine if charging is allowed. If V_{TS}<V_{TS1} or V_{TS}>V_{TS2} for 0.5 seconds, it indicates that the battery temperature is too high or too low and the charge cycle is paused. When V_{TS} recovered back to the range between V_{TS1} and V_{TS2} for more than 0.5 seconds, the charge cycle resumes.

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

6. Charge status Indication

The VA7205 has two charge indicator pin: LEDS and CS2/LEDT.

The LEDS pin is the charge status indicator. It can be connected to VCC via a red LED and a 330 ohm current limit resistor. During the normal operation in precharge phase, current regulation phase, and voltage regulation phase, the LEDS pin is pulled low and the red LED lights up. Under the abnormal operation (VBAT<VBSC, or

pre-charge time exceeds 15 minutes, or abnormal battery temperature in the case of VTS<VTS1 or VTS>VTS2 for at least 0.5 seconds), the LEDS pin outputs a 50% duty cycle 2Hz pulse and cause red LED to blink. Upon the charge termination, the LEDS pin will change to high impedance state and turn off the red LED.

The LEDT/CS2 pin is charge-termination indicator. It can be connected to VCC via a green LED and a 330 ohm current limit resistor. During the charge process, the voltage level at LEDT/CS2 is set close to VCC and the green LED is turned off. Upon the charge termination, LEDT/CS2 is pulled low and lights up the green LED.

7. Low-Power Sleep Mode

The VA7205 enters the sleep mode if the VCC fails below the voltage at the BAT input. This feature prevents draining the battery pack during the absence of VCC.

When power supply is 0V, the DRIVE terminal connects to the VCC via the internal pull up resistor, therefore a conducting channel is created between PNP pass transistor's Collector and Base. This can cause a battery leakage current form to leak through this PNP pass transistor and the internal resistor. For the charger with PMOS transistor, due to the existence of the internal protection diode, the battery can dis-charging via this protection diode and the internal resistor. To prevent such kind of leakage current, a reverse bias diode (D1 refer to Figure 5) is recommended.

8. Indication of Abnormal Battery Operation

If the battery voltage (V_{BAT}) is lower than V_{BSC}, the VA7205 will "think" that battery may have a short circuit problem. In this case, the red LED will blink, but the charge process continuous. If the V_{BAT} is increased to be higher than V_{BSC}, then red LED will stop blink and light up while continue charging.

There is an internal timer within the VA7205. The timer starts at the same time as the precharge stage. If precharge didn't complete ($V_{BAT}<V_{MIN}$) within 15 minutes, then VA7205 will "think" that battery is malfunction and force the charge to stop, meanwhile, the red LED will flash to bring up user's attention. At this time, the user must disconnect the power supply to VM7025 and then connect it back on again to start a new charge cycle.

9. Recharge

Upon the charge termination, battery voltage level (V_{BAT}) will be same as V_{REG}. The red LED is turned off and Green Led is turned on to indicate the charge termination. Whenever the VBAT is decreased to below the recharge threshold voltage (V_{RECHG}), the VA7205 will automatically enter the recharge phase and light up the red LED and turn off the green LED to indicate a new charge cycle.

10. Automatic Charge-Rate Compensation

In reality, due to the charge protection circuit in the Li-ion battery, there is some internal resistance ($R_{PACK)}$) presented in the battery pack. During the charge, the charge current can cause some voltage drop over this internal resistance. As a result, in the voltage regulation phase, the actual battery voltage is less than V_{REG}. As the charge current decrease, V_{PACK} decrease as well and eventually bring the battery voltage level very close to V_{REG}. However, due to the existence of the R_{PACK}, the battery charging time in the voltage regulation phase is considerably longer.

In order to overcome the effect of the RPACK, the VA7205 provides a pin, CS2/LEDT, for battery internal resistance cancellation. By adjusting the external resistor R2 and R3 and controlling the voltage difference between CS2 signal and CS1 signal（$V_{CS2/LEDT}-V_{CS1}$）, an extra offset voltage $\triangle V_{REG}$ can be added to V_{REG} to cancel the effect of R_{PACK} and therefore effectively reduce the charge time.

Application Information

1. Selecting R5 and R6

We can determine R5 and R6 values in the application circuit according to the assumed temperature monitor range. Following is the example:

Assuming temperature range is $T_L \sim T_H$, ($T_L < T_H$); the thermistor in battery has negative temperature coefficient (NTC), R_{TL} is the resistance value at T_L, R_{TH} is the resistance value at T_H, so $R_{TL} > R_{TH}$, then at T_L, the voltage drop across TS is:

$$V_{TSL} = \frac{R6 \| R_{TL}}{R5 + R6 \| R_{TL}} \times VCC$$

At T_H, the voltage drop across TS is:

$$V_{TSH} = \frac{R6 \| R_{TH}}{R5 + R6 \| R_{TH}} \times VCC$$

Therefore, if we assume

$V_{TSL} = V_{TS2} = k_2 \times VCC$

$V_{TSH} = V_{TS1} = k_1 \times VCC$

The solutions are:

$$R5 = \frac{R_{TL} R_{TH} (k_2 - k_1)}{(R_{TL} - R_{TH}) k_1 k_2} \text{ .... } (1)$$

$$R6 = \frac{R_{TL} R_{TH} (k_2 - k_1)}{R_{TL}(k_1 - k_1 k_2) - R_{TH}(k_2 - k_1 k_2)} \text{ ..... } (2)$$

Likewise, for positive temperature coefficient thermistor in battery, we have $R_{TH} > R_{TL}$ and we can calculate:

$$R5 = \frac{R_{TL} R_{TH} (k_2 - k_1)}{(R_{TH} - R_{TL}) k_1 k_2} \text{ .... } (3)$$

$$R6 = \frac{R_{TL} R_{TH} (k_2 - k_1)}{R_{TH}(k_1 - k_1 k_2) - R_{TL}(k_2 - k_1 k_2)} \text{ ..... } (4)$$

We can conclude that temperature monitor range is independent of power supply voltage VCC and it only depends on R5, R6, R_{TH} and $R_{T:}$ The values of R_{TH} and R_{TL}可can be found in related battery handbook or deduced from testing data.

In actual application, if we only concern about on terminal temperature property (normally protecting overheating), there is no need to use R6 but R5. It becomes very simple to calculate R5 in this case.

2. Selecting R2 and R3

Let's analyze Fig. 3, considering R2 is in parallel with LED Green, in addition, after finishing charging, R3 is in parallel with LED Green as well (R1 is very small so we can neglect its effect), therefore, both R2 and R3 cannot be too small or LED Green will be dim. Generally, we choose R2 and R3 over 3kΩ. In order to determine the value of R2 and R3, we first find the equation between R2 and R3.

From Fig. 3, we can get:

$V_{CS2/LEDT} - V_{CS1} = (VCC - V_{CS1}) \times R3/(R2 + R3)$

$I_{CHRG} = (VCC - V_{CS1})/R1$

As well as, $\triangle V_{REG} = G_{COMP} \times (V_{CS2/LEDT} - V_{CS1})$

In ideal compensating state:

$\triangle V_{REG} = R_{PACK} \times I_{CHRG}$

From above four equations, we can get:

$R3 = R2 \times R_{PACK}/(R1 \times G_{COMP} - R_{PACK})$

$$= \frac{R2}{\frac{R1 \times G_{COMP}}{R_{PACK}} - 1} \text{ .... } (5)$$

Put R1 = 0.3Ω, G_{COMP} = 2.7into equation（5）, we have:

$$R3 = \frac{R2}{\frac{0.81}{R_{PACK}} - 1}$$

a) If $R_{PACK} \leqslant 0.405\Omega$, then $R3 \leqslant R2$, we can select R3 = 3.3kΩ and calculate R2 from equation（5）.

For example: if R_{PACK} = 0.1Ω, then R2 = 23.43kΩ, we can select a standard value of 24 kΩ.

b) If $R_{PACK} > 0.405\Omega$, then $R3 > R2$, we can select R2 = 3.3kΩ and calculate R3 from equation（5）.

For example: if R_{PACK} = 0.6Ω, then R3 = 9.43kΩ, we can select standard value of 10 kΩ.

In summary, the principle of determining R2 and R3 is: choose the smaller one of R2 and R3 in the range of 3kΩ ~ 5kΩ, then using equation（5）to determine the other; if there is no requirement for battery resistance cancellation, we can simply choose R3 in the range of 3kΩ ~ 5kΩ while neglecting R2.

From equation（5）, we also know that in order to get ideal temperature compensation effect, R1, G_{COMP} and R_{PACK} need to satisfy following condition:

$R_{PACK} < R1 \times G_{COMP}$ .... （6）

3. Selecting PNP transistor

In the process of selecting PNP bipolar transistor, we need to consider its maximum allowed current I_{CM}, maximum allowed power dissipation $P_{D,}$ Collector-Emitter breakdown voltage BV_{CEO}, β and theta θ_{JA} etc. We use following example to show the method of determining each of the parameters.

In this example, we assume there is no blocking diode D1, VCC = 6V and R1 = 0.3Ω, then the constant-current charging current is: $I_{REG} = V_{CSREG}/R1 = 150mV/0.3\Omega = 0.5A$。

a) Selecting BV_{CEO}

At beginning of charging, the voltage drop across the collector-emitter is the largest and $V_{CE} = V_{CS1} - V_{BAT}$. At the beginning, V_{BAT} is very small, even smaller than V_{BSC} so V_{CS1} is very close to VCC. To guarantee transistor won't get damaged, there is a need to have some margin on breakdown voltage. It is generally required to have BV_{CEO} larger than VCC. In this example, we choose $BV_{CEO} > 15V$.

b) Selecting P_D

Even though at the beginning of charging, the voltage drop across collector-emitter is the largest but the power dissipation isn't as the pre-charging current is small. After pre-charging finishes and it just enters into constant-current charging state, the power dissipation is at maximum for the transistor. AT this moment, the voltage drop across the collector-emitter is:

$V_{CE} = V_{CS1} - V_{BAT} = 6 - 0.15 - 3.0 = 2.85V$;

Collector current $I_C = I_{REG} = 0.5A$。

Therefore the power dissipation P_D is:

$P_D = V_{CE} \times I_C$ .... （7）

$= 2.85 \times 0.5 = 1.425W$

c) Selecting theta θ_{JA}

Theta θ_{JA} is related to packaging size of the transistor. Properly selecting θ_{JA} will keep the junction temperature below manufacturer's recommended value T_{JMAX} when transistor is at its maximum power dissipation. Assuming maximum junction temperature $T_{JMAX} = 150℃$, at room temperature $T_A = 40℃$, we can calculate the transistor's maximum allowed theta θ_{JAMAX} is:

$\theta_{JAMAX} = (T_{JMAX} - T_A)/P_D$ .... （8）

$= (150℃ - 40℃)/1.425W = 77.2℃/W$

Likewise, we need to select the transistor whose θ_{JA} is smaller than θ_{JAMAX} with 10% margin. In this example, we choose a PNP transistor with theta $\theta_{JA} = 60℃/W$ in SOT223 package.

d) Selecting maximum allowed current I_C

The maximum current conducting through the transistor is the current when charger in constant-current charging state. To leave 50% margin, in this reference design, we select following value:

$I_C = I_{REG} \times 150\%$ .... （9）

$= 0.5 \times 150\% = 0.75A$

e) Selecting β

We can use the maximum collector current I_{CMAX} and its corresponding base current I_B to determine the value of β. In this example, $I_{CMAX} = I_{REG}$ and I_B is the transistor's forcing current in VA7205.We choose $I_B = 30mA$, we have:

$\beta = I_{CMAX}/I_B$ .... （10）

$= 0.5/0.03 = 17$

It is common for a bipolar transistor's β larger than 17, it is easy to find a transistor that will meet the requirement for VA7205.

Following steps a～e above, we can select the type of transistor. 8850 with TO-92 package transistor will meet the requirement.

4. Selecting P-channel MOSFET

When selecting PMOS to work with VA7205, we need to considering maximum allowed drain current I_D, maximum allowed power dissipation P_D, theta θ_{JA}, source-drain breakdown voltage V_{DS} and gate-source driving voltage V_{GS} as well. The following example will demonstrate the methods of determine those parameters.

In this example, blocking diode D1 exists, VCC = 6.5V, R1 = 0.3Ω and constant-current charging current is $I_{REG} = 0.5A$

a) Selecting V_{DS}

At the beginning of charging, the voltage drop across PMOS source-drain is the largest and $V_{DS} = VCC - V_{D1} - V_{R1} - V_{BAT}$（$V_{D1}$is blocking diode D1's forward voltage drop at ~ 0.7V; V_{R1} is the voltage drop across resistor R1 and it is very small as well）. Again, we require V_{DS} is larger than VCC for this PMOS and we can select $V_{DS} > 15V$.

b) Selecting P_D

For the same reason, when VA7205 just enters constant-current charging state, PMOS has the largest power dissipation and the source-drain voltage is:

$V_{DS} = VCC - V_{D1} - V_{R1} - V_{BAT}$

$= 6.5 - 0.7 - 0.15 - 3.0 = 2.65V$;

Drain current $I_D = I_{REG} = 0.5A$

Therefore PMOS transistor's power dissipation P_D is:

$P_D = V_{DS} \times I_D$ .... （11）

$= 2.65 \times 0.5 = 1.325W$

c) Selecting θ_{JA}

The maximum allowed theta θ_{JAMAX} for PMOS transistor is:

$\theta_{JAMAX} = (T_{JMAX} - T_A)/ P_D$

= (150℃ − 40℃)/1.325W = 83℃/W

Therefore, it's ample to select a PMOS transistor with TSSOP-8 package that has a theta θ_{JA} of 70℃/W.

d) Selecting maximum allowed current I_D

The maximum allowed current for PMOS is same as using PNP transistor: $I_D = 0.75A$

e) Gate-source driving voltage V_{GS}

Referencing Fig. 5, we can conclude that the voltage across gate-source of the PMOS is:

$V_{GS} = VCC - (V_{D1} + V_{R1} + V_{DRIVE})$

When DRIVE terminal of VA7205 outputs low voltage V_{OL}（~ 1.0V）, PMOS transistor is turned on. At same time, at constant-current charging state, V_{R1} is at maximum so V_{GS} is at minimum:

$V_{GSMIN} = VCC - (V_{D1} + V_{R1} + V_{OL})$ .... （12）

$= 6.5 - (0.7 + 0.1 + 1.0) = 4.65V$

We need to make sure we choose a PMOS whose V_{GS} at I_{REG} is smaller than V_{GSMIN}, of course, the PMOS's threshold voltage must be smaller than $V_{GSMIN.}$

Likewise, following steps a ~ e above, we can determine the type of PMOS to choose.

5. Blocking Diode D1

The main purpose of this blocking diode D1 is to prevent battery reversing discharging at the circumstance when power supply voltage VCC is lower than battery voltage V_{BAT}. In actual application, customer can decide whether the diode D1 is required in the specific situation.

In an actual charger power supply, if diode rectifying is used (half wave or full wave), its reversing resistance is huge and battery discharging current will be very small even if VCC is zero; if switch power supply is used, in general, there is a ~3.8V Zener diode at the negative electrode of the power supply, combining with circuit resistance, the discharging current should be small as well.

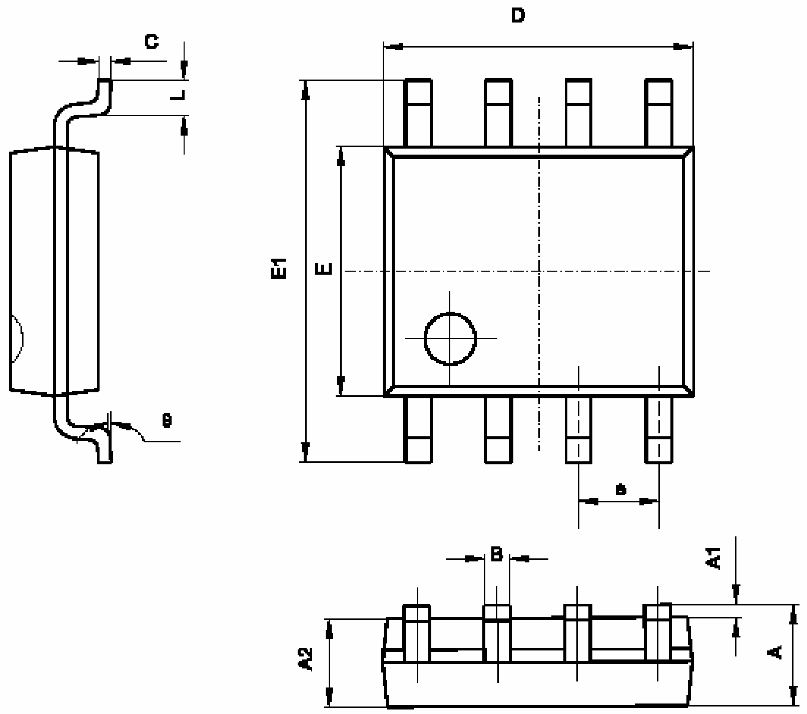
Therefore, customer can choose whether to use the blocking diode based on actual application circuit and its specific requirement.

6. PCB layout

When layout PCB, R1 should be put between VCC and VA7205's CS1 pin and the connection line to R1 from both sides should be as short as possible. C1 should be placed tightly with R1 and C2 should be placed tightly with VA7205. Every effort should be made to ensure the lines between C1, R1, Q1, C2 and VA7205 as short and wide as possible.

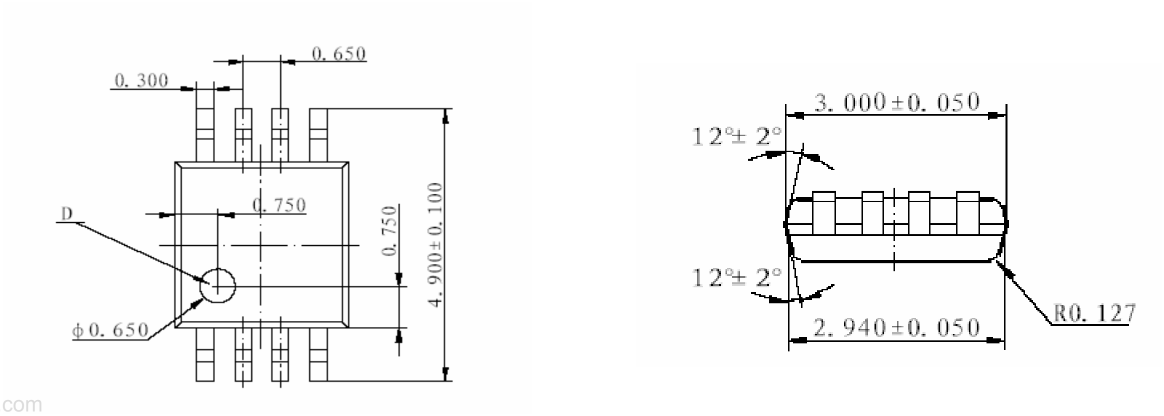
For best performance, it is suggested to minimize the area of PCB. Of course, this is also required for small form factor, reducing manufacturing cost.

Packaging



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	1.350	1.750	0.053	0.069
A1	0.100	0.250	0.004	0.010
A2	1.350	1.550	0.053	0.061
B	0.330	0.510	0.013	0.020
C	0.190	0.250	0.007	0.010
D	4.780	5.000	0.188	0.197
E	3.800	4.000	0.150	0.157
E1	5.800	6.300	0.228	0.248
e	1.270(TYP)		0.050(TYP)	
L	0.400	1.270	0.016	0.050
θ	0°	8°	0°	8°

Figure 6 VA7205 8-Pin SOP Mechanical Date
(unit: mm unless otherwise specified)


0. 650
0. 300
D
0. 750
0. 750
4. 900±0. 100
ϕ0. 650
3. 000±0. 050
12°± 2°
12°± 2°
2. 940±0. 050
R0. 127

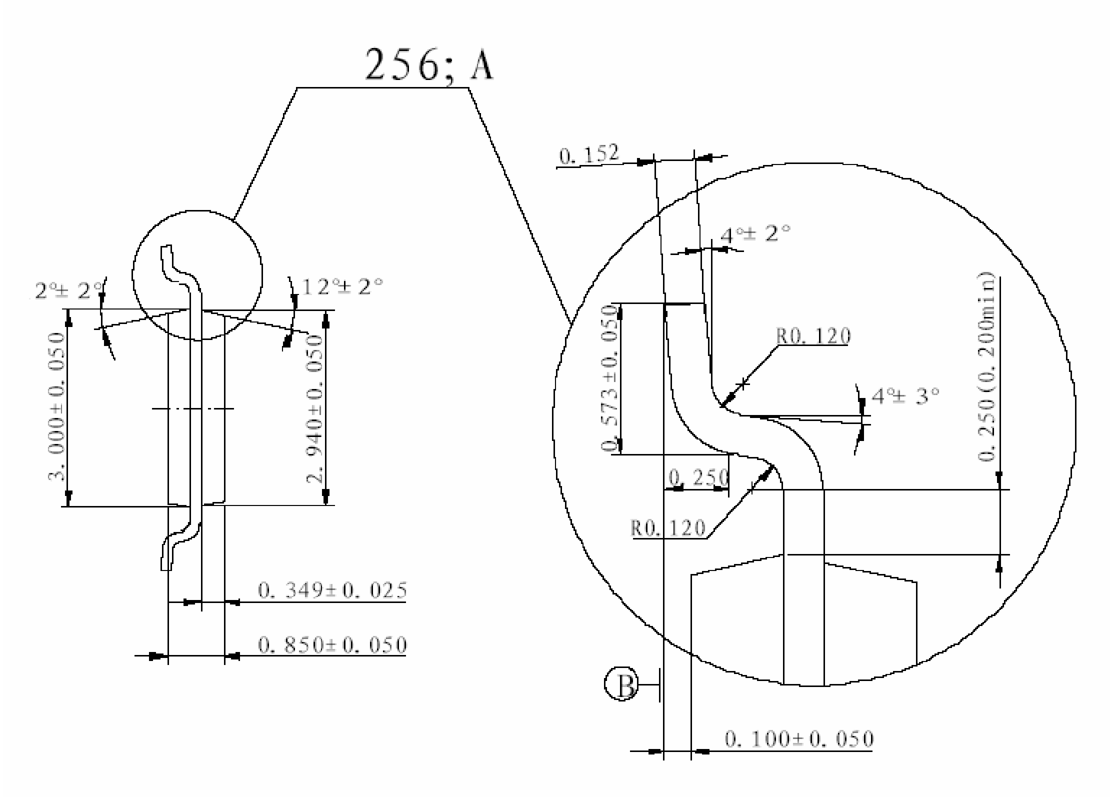
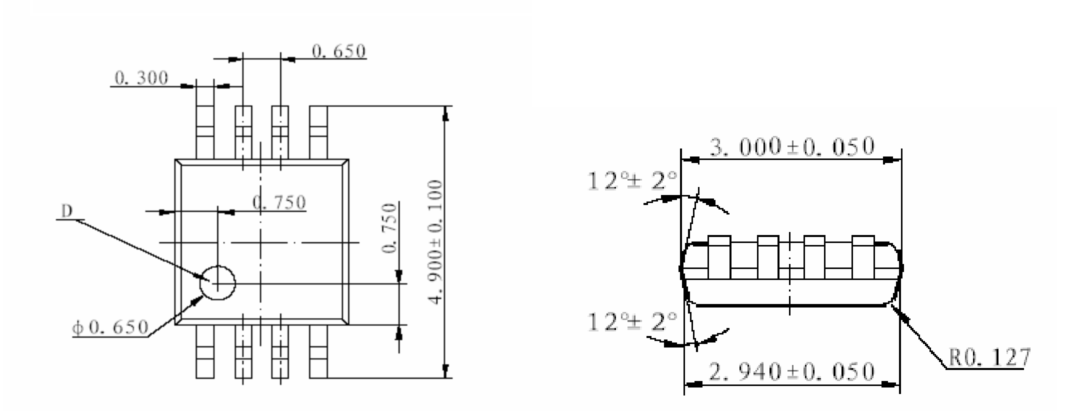
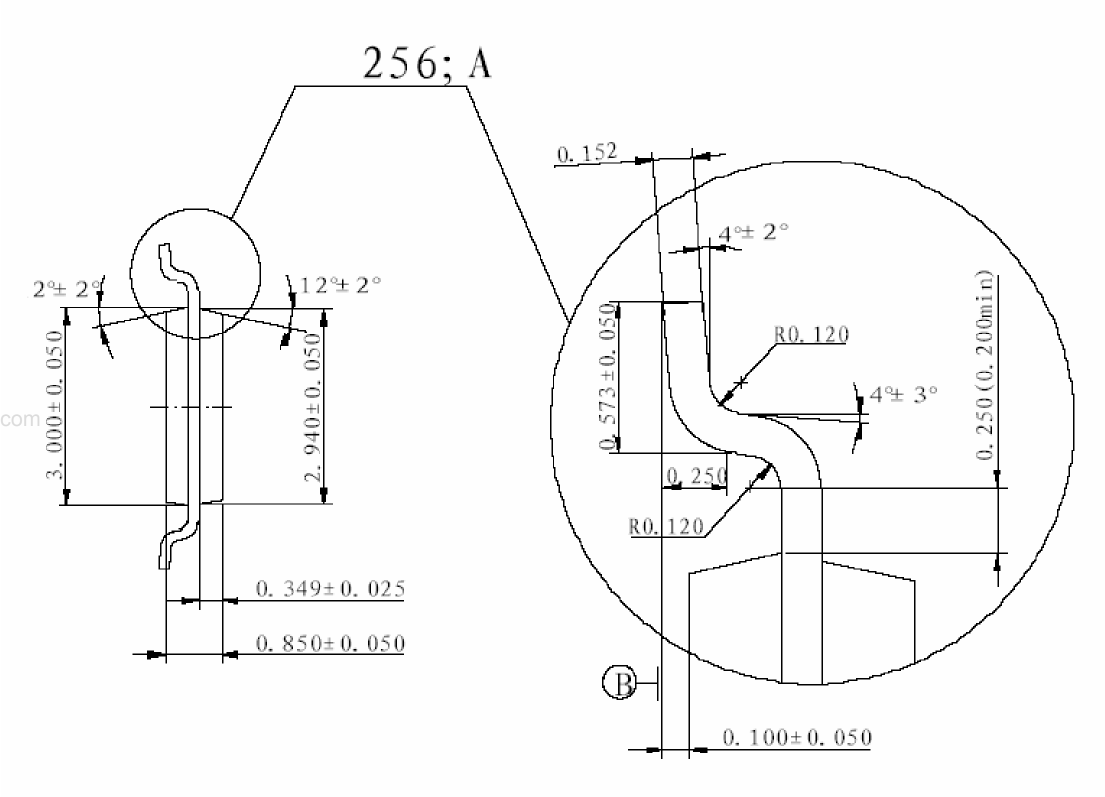

256; A
0. 152
4°± 2°
2°± 2°
12°± 2°
3. 000±0. 050
2. 940±0. 050
0. 573±0. 050
R0. 120
4°± 3°
0. 250(0. 200min)
0. 250
R0. 120
0. 349±0. 025
0. 850±0. 050
B
0. 100±0. 050

Figure 8 VA7205 8-Pin MSOP Mechanical Date

(unit: mm unless otherwise specified)


0. 650
0. 300
D
0. 750
0. 750
4. 900±0. 100
ϕ0. 650
3. 000±0. 050
12°± 2°
12°± 2°
2. 940±0. 050
R0. 127


256; A
2°± 2°
12°± 2°
3. 000±0. 050
2. 940±0. 050
0. 349±0. 025
0. 850±0. 050
0. 152
4°± 2°
R0. 120
0. 573±0. 050
4°± 3°
0. 250(0. 200min)
0. 250
R0. 120
B
0. 100±0. 050