FEATURES

- Reliable Fast Charge Control of NiMH/NiCd Batteries.
- Quick and Easy Testing for Production.
- Fast Charge Termination by:
    1. Accurate -ΔV Detection Level with Respect to Peak Battery Voltage Value.
       AIC1761 ....…………….......-1%
       AIC1766 ....………...……….........-0.25%
    2. Peak Voltage Timer (0ΔV).
- Adjustable Fast Charge Safety Timer.
- Protection against Temperature Fault.
- Protection against Short-Circuited and Open Batteries.
- Wide Operation Voltage Range: 9V to 18V, no Extra Regulator Needed.
- Large Battery Voltage Detection Range: 0.65V to 3.7V.
- LED Drivers to Indicate Charge Status or Fault Conditions.
- Voltage Reference Output.
- Space-Saving Packages:
  8-PIN DIP, SO
  14-PIN DIP, SO

APPLICATIONS

Battery Chargers for :
- Mobile Phones
- Notebook and Laptop Personal Computers
- Portable Power Tools and Toys
- Portable Communication Equipments
- Portable Video and Stereo Equipments

DESCRIPTION

The AIC1761/1766 fast charge controller IC is designed for intelligent charging of NiMH or NiCd batteries without overcharging. It detects a voltage drop (-ΔV) occurring in the final stage of a fast charging cycle and correspondingly controls the charging current. Fast charge can also be cut off by a peak voltage timer (0ΔV).

The detection of -ΔV is a very reliable method to terminate fast charging for NiMH and NiCd batteries. The AIC1761/1766 uses -ΔV detection as one of primary decisions for fast charge cut-off. The -ΔV value for the AIC1761 is as small as 16mV per cell, suitable for NiCd batteries. The -ΔV value for the AIC1766 is as small as 4mV per cell, particularly suitable for NiMH as well as the NiCd batteries. The peak voltage timer is particularly useful when the voltage drop at the end of charge for some batteries, e.g. NiMH cells, is not pronounced enough for reliable detection. An adjustable safety timer (3 settings) is used as a back-up termination method. Provisions are made with the AIC1761/1766 to prevent fast charge under temperature fault conditions. Two LED outputs are used to indicate the charging status. Another flash LED output can be used alone to indicate charge status.

AC mode allows the battery to drive its loads while being charged. Test mode is provided to dramatically reduce production test time.

■ TYPICAL APPLICATION CIRCUIT
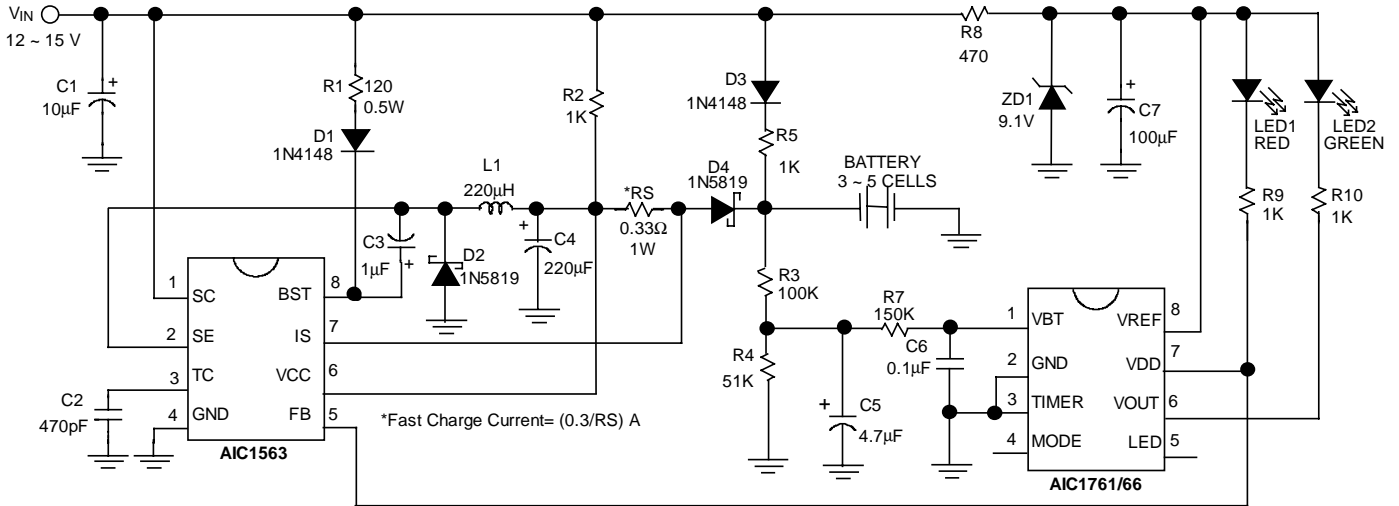
Simple Battery Charger for NiMH / NiCd Battery

■ ORDERING INFORMATION

AIC176X-XXXX

- VERSION
  08: 8 PIN VERSION
  14: 14 PIN VERSION

- PACKAGE TYPE
  N: PLASTIC DIP
  S: SMALL OUTLINE

- TEMPERATURE RANGE
  C=0°C~70°C
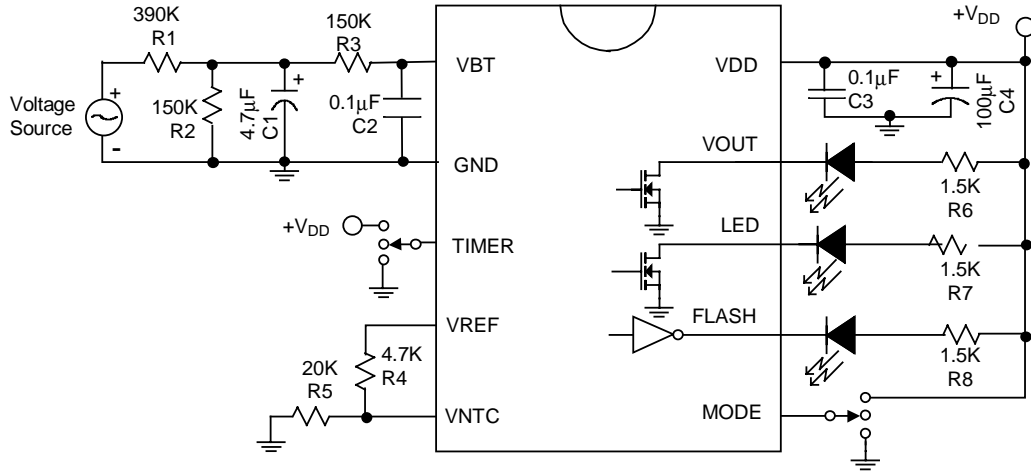
- -ΔV DETECTION LEVEL
  1: -1%
  6: -0.25%

ORDER NUMBER	PIN CONFIGURATION
AIC1761-CN08 AIC1766-CN08 (PLASTIC DIP)	TOP VIEW VBT [1] — [8] VREF GND [2] — [7] VDD TIMER [3] — [6] VOUT MODE [4] — [5] LED
AIC1761-CS08 AIC1766-CS08 (PLASTIC SO)	
AIC1761-CN14 AIC1766-CN14 (PLASTIC DIP)	TOP VIEW GND [1] — [14] GND TIMER [2] — [13] NC MODE [3] — [12] VBT LED [4] — [11] NC VOUT [5] — [10] VREF NC [6] — [9] VNTC FLASH [7] — [8] VDD
AIC1761-CS14 AIC1766-CS14 (PLASTIC SO)	

■ ABSOLUTE MAXIMUM RATINGS

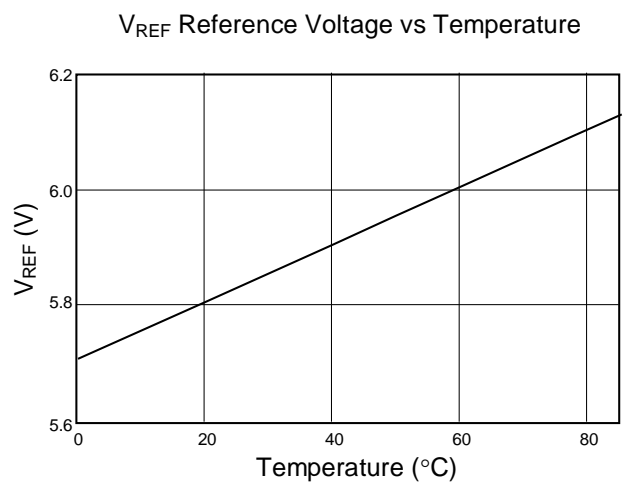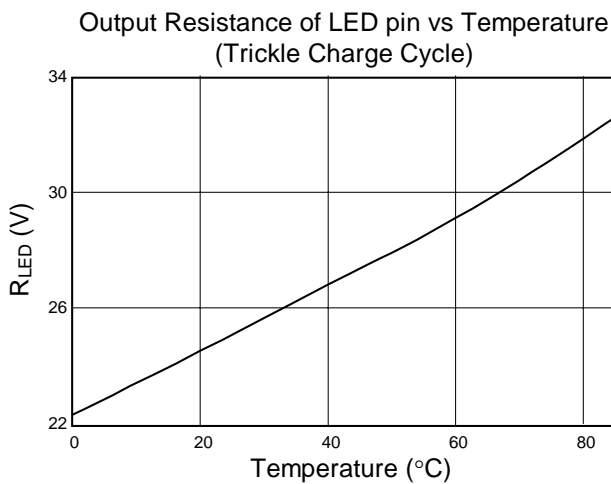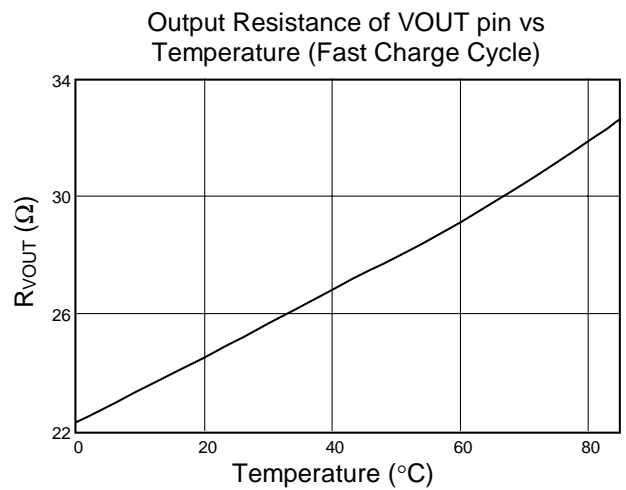|	
Supply Voltage	18V
DC Voltage Applied on any Pin	18V
Sink Current of VOUT Pin, LED Pin, and FLASH Pin	20mA
Operating Temperature Range	0°C to 70°C
Storage Temperature Range	-65°C to 150°C

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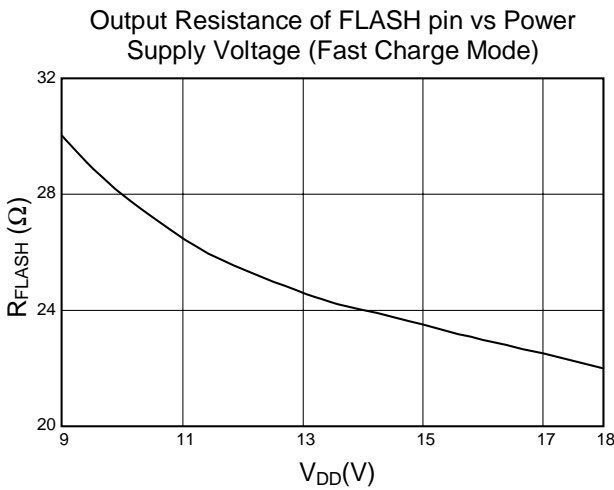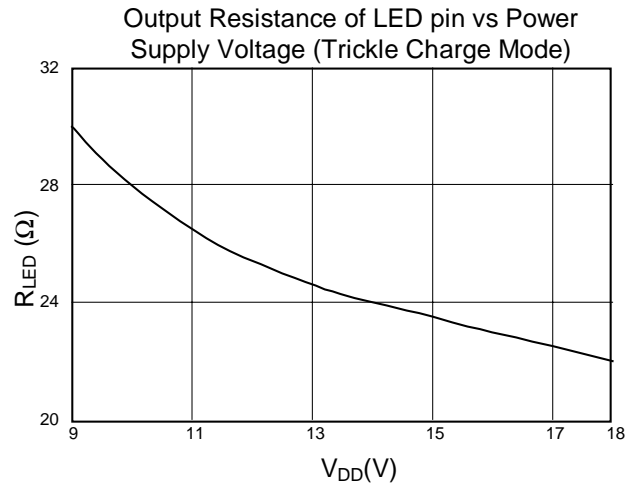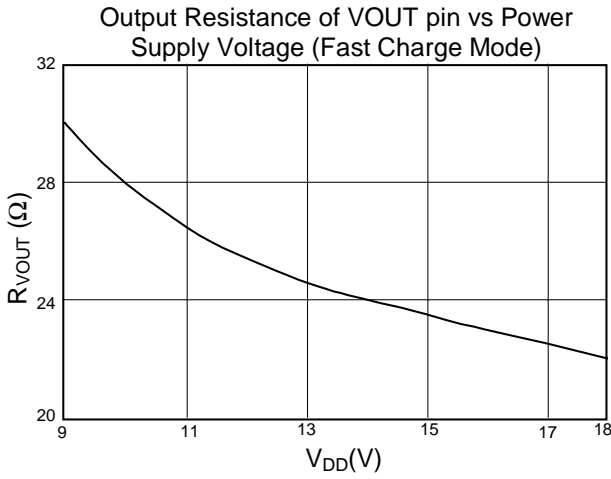
■ TEST CIRCUIT

■ ELECTRICAL CHARACTERISTICS (V_{DD}=12.5V, Ta=25°C, unless otherwise specified.)

PARAMETER	TEST CONDITIONS	SYMBOL	MIN.	TYP.	MAX.	UNIT
Supply Voltage		V_{DD}	9		18	V
Supply Current		I_{DD}			1.5	mA
-ΔV Detection Level w.r.t.* Peak Value	AIC1761			-1		%
	AIC1766			-0.25		%
Voltage Protection Limits	Battery Low	V_{BT}	0.5	0.65	0.8	V
	Battery High		3.5	3.7	3.9	V
Input Impedance of TIMER Pin		Z_{TIMER}	100			KΩ
Input Impedance of MODE Pin		Z_{MODE}	100			KΩ
Output Resistance of LED Pin	Fast Charge	R_{LED}	1			MΩ
	Trickle Charge			25		Ω
Output Resistance of VOUT Pin	Fast Charge	R_{VOUT}		25		Ω
	Trickle Charge		1			MΩ
FLASH pin						
Output Resistance	Fast Charge	R_{FLASH}		25		Ω
Frequency	Trickle Charge	F_{FLASH}		1		Hz
Duty Cycle		D_{FLASH}		50		%
Reference Voltage		V_{REF}		5.85		V
Reference Source Current		I_{REF}	1.5			mA
Temperature Fault Voltage Limits as Fraction of V_{REF}	Under-Temperature	αNTCL	0.60	0.7	0.80	V_{REF}
	Over-Temperature	αNTCH	0.15	0.2	0.25	V_{REF}

*w.r.t.: with respect to

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■ TYPICAL PERFORMANCE CHARACTERISTICS

Output Resistance of VOUT pin vs Power Supply Voltage (Fast Charge Mode)

Output Resistance of LED pin vs Power Supply Voltage (Trickle Charge Mode)

Output Resistance of FLASH pin vs Power Supply Voltage (Fast Charge Mode)

Output Resistance of VOUT pin vs Temperature (Fast Charge Cycle)

Output Resistance of LED pin vs Temperature (Trickle Charge Cycle)

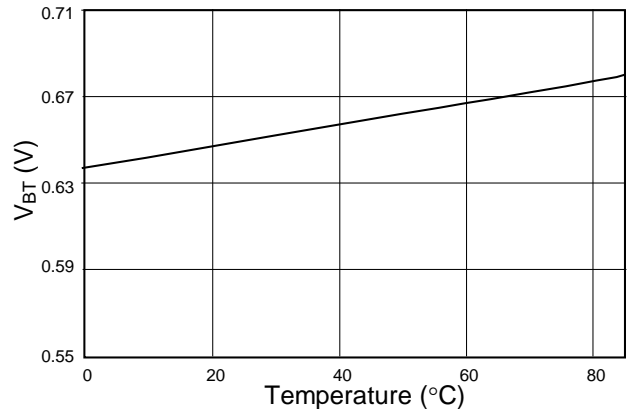V_{REF} Reference Voltage vs Temperature

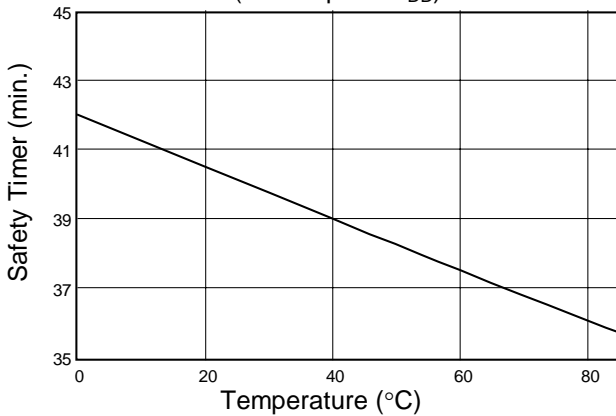**4**

■ TYPICAL PERFORMANCE CHARACTERISTICS (CONTINUED)

V$_{BT}$ (High) Limit vs Temperature
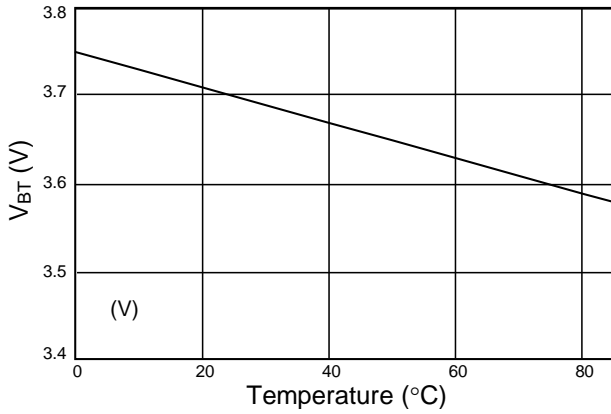
V$_{BT}$ (Low) Limit vs Temperature

Safety Timer vs Temperature
(MODE pin = V$_{DD}$)

■ BLOCK DIAGRAM

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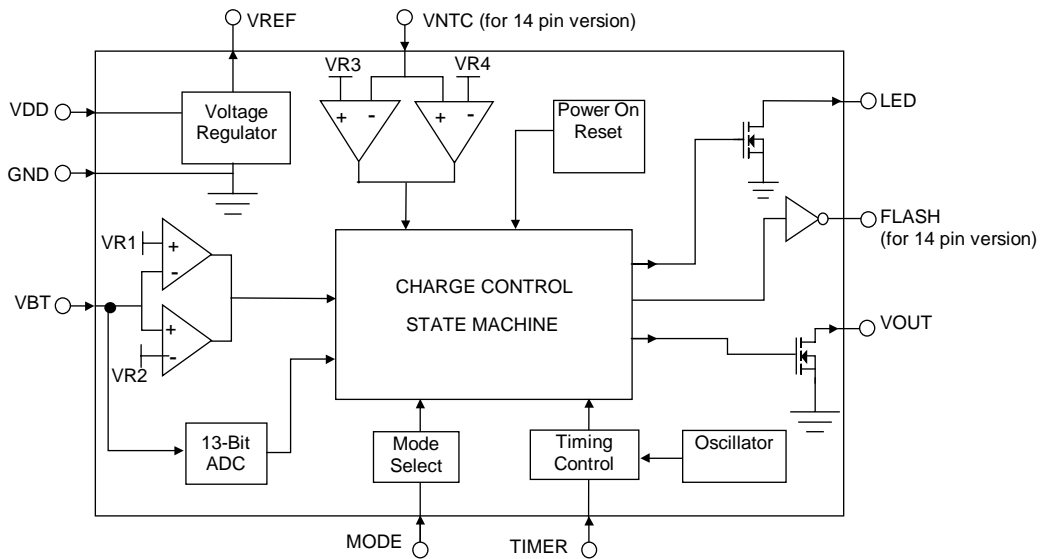
■ PIN DESCRIPTIONS

VDD PIN   -   Supply voltage input.

GND PIN   -   Ground.

VBT PIN   -   Input, to sense battery voltage.

MODE PIN -   Input, to set IC operation mode.

TIMER PIN -   Input, for safety timer control.

VREF PIN   -   Voltage reference output.

LED PIN   - Output, for LED indicator.

VOUT PIN   - Output, for LED indicator.

FLASH PIN - Output, for LED indicator.

      (Available for 14-pin version only.)

VNTC PIN   - Input, for temperature protection.

      (Available for 14-pin version only.)

■ APPLICATION INFORMATIONS

● BATTERY PROPERTIES

The basic principle of rechargeable battery systems, including NiMH and NiCd cells, is that the processes of charge and discharge are reversible. The charge characteristics of NiMH and NiCd cells look similar in that (1) the cell voltage at the end of charge drops and (2) the cell temperature increases rapidly near the end of charge. Fig. 1 shows the charge voltage and charge temperature characteristics of NiMH and NiCd cells. Notice that the cell voltage decline of NiMH cells at the end of charge is less pronounced than for NiCd cells.
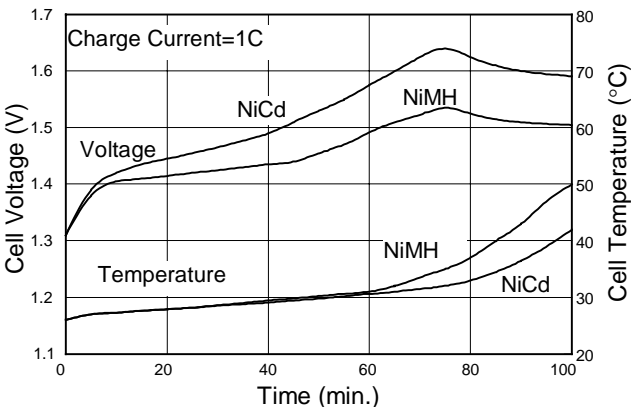

Fig. 1   Typical Charge Characteristics of NiMH/NiCd Battery

Fast-charge batteries are available where recharging takes for only 1 hour or less with a simple control circuit. One main purpose of the control circuit is to terminate the fast-charge process to prevent the temperature and internal pressure of the battery cell from building up to a damaging level which degrades or even destroys the battery cell.

The AIC1761/1766 is a battery fast charge controller IC that utilizes the following methods to terminate the fast charge process for NiMH or NiCd battery cells:

● Negative delta voltage cutoff (-ΔV).
● Peak voltage timer cutoff (0ΔV).
● Maximum temperature cutoff (TCO).
● Maximum voltage cutoff (VCO).
● Safety timer cutoff.

The principle of operation of the AIC1761/1766 is described in the following section.

● THE AIC1761/1766 OPERATION

When power is first applied to the charge system, consisting of rechargeable battery cells, charge current source, the AIC1761/1766 and its associated external circuit, all internal digital circuit blocks of the AIC1761/1766 are reset by internal power-on-reset circuitry. The internal control unit then checks the battery condition to prevent fast charge from taking place under battery fault conditions, i.e. cell voltage fault ($V_{BT}<0.65V$ or $V_{BT}>3.7V$) or cell temperature fault (αNTC>αNTCL or αNTC<αNTCH, for the 14-pin version). Temperature fault limits corresponding to αNTCL and αNTCH are determined by an external thermistor divider circuit as included in the Application Examples, Fig. 10. After the battery passes condition fault checks, VOUT pin goes to low to start fast charge while initial timer and safety timer of the AIC1761/1766 start counting. Both the negative delta voltage detector and the peak voltage timer, however, are disabled until the initial timer period in the initial stage of a charge circle elapses.

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The AIC1761/1766 constantly monitors the voltage at VBT pin, which rises as battery cells are being fast-charged till battery full condition is nearly approached. The battery temperature is also constantly being sensed to guard against abnormal temperature situations. VOUT pin will be pulled high by an external pull-up device and the fast charge process be switched to trickle charge when one of the following situations is encountered:

- A negative delta voltage (-ΔV) at VBT pin is detected when compared to its peak value. The sampling rate of -ΔV detection is 2seconds/sample. The detection level of -ΔV is -1% for the AIC1761 and -0.25% for the AIC1766.

- The battery voltage stays at its peak value for the duration determined by the peak voltage timer setting (0ΔV).

- The VBT pin voltage exceeds the "high" battery voltage protection limit (VCO).

- The battery temperature, sensed by the thermistor divider, exceeds the fault temperature range (TCO).

- The selected safety timer period has finished.

TIMER PIN

The TIMER pin can be used as follows to select one of the preset safety timer period and its corresponding periods of initial timer and peak voltage timer:

TIMER Pin	Safety Timer	Peak Voltage Timer	Initial Timer
V_{DD}	40 min.	2 min.	1.5 min.
GND	80 min.	4 min.	3.0 min.
Floating	160 min.	8 min.	3.0 min.
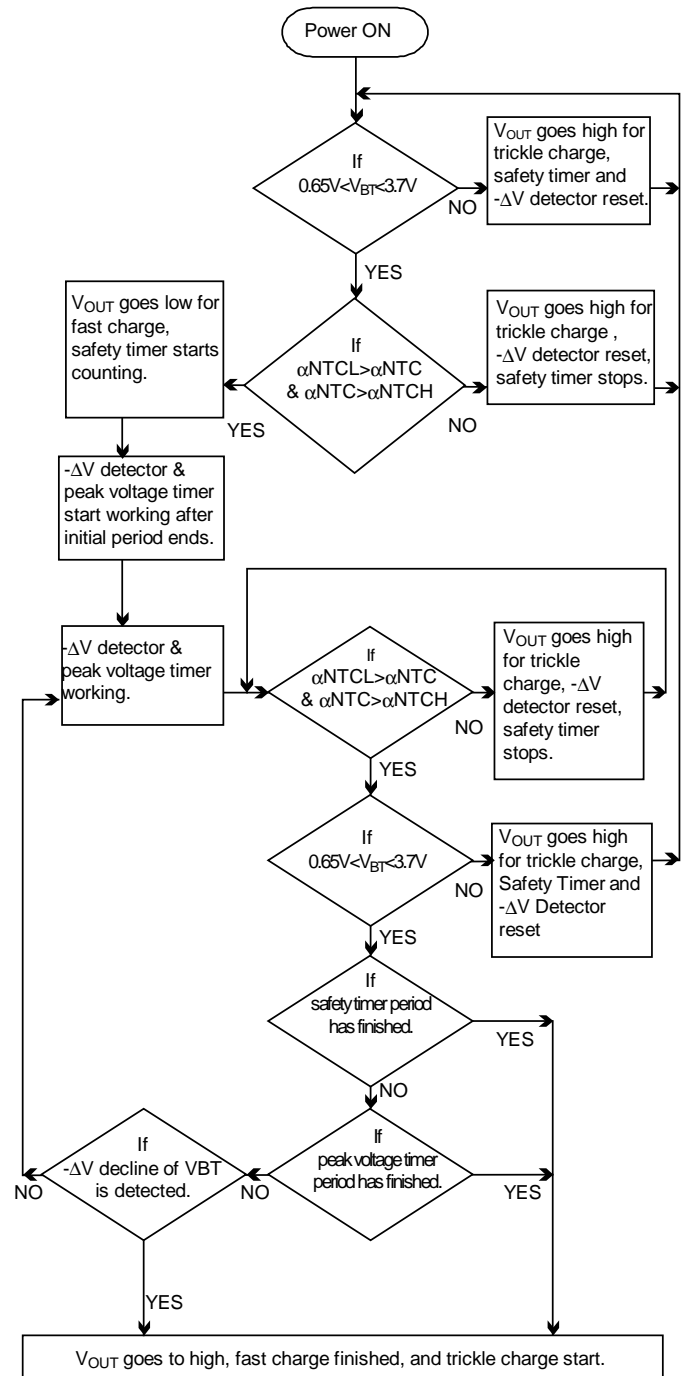
Fig. 2 Operation Chart of the AIC1761/1766

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MODE PIN

The MODE pin determines the mode in which the IC works:

MODE Pin	Mode	Function
Floating	NORMAL	Normal operation
V_{DD}	TEST	1/512 safety timer
GND	AC	$-\Delta V$ detector reset, timer stops (not reset)

The AIC1761/1766 will operate normally when the MODE pin is left floating (a 0.1µF capacitor is recommended to be tied to MODE pin if the charge circuit works in a noisy environment). The AIC1761/1766 otherwise works in following ways if the MODE pin is biased either to V_{DD} or to GND:

(A) AC Mode (MODE pin biased to GND)

In the midst of normal charge operation, where VBT pin voltage is in the range from 0.8V to 3.5V and the preset safety timer has not run out, the safety timer will stop if the MODE pin is somehow pulled down to GND level. As long as the MODE pin remains low, the VOUT pin stays ON and LED pin OFF regardless whether the battery pack voltage declines (-ΔV present) or not.

The AC mode can be activated by pulling MODE pin to GND to avoid premature battery charge cutoff due to fluctuating charge current source. Switching MODE pin after the end of the safety timer has no effect on the AIC1761/1766 display outputs, i.e., VOUT pin stays OFF while LED pin stays ON.

(B) TEST Mode (MODE pin biased to V_{DD})

An unique feature of the AIC1761/1766 is that it can be put into a TEST mode by pulling the MODE pin to V_{DD}, allowing verification tests for the AIC1761/1766 charge circuit to be performed in a few tens of seconds, extremely valuable in final phase of production.
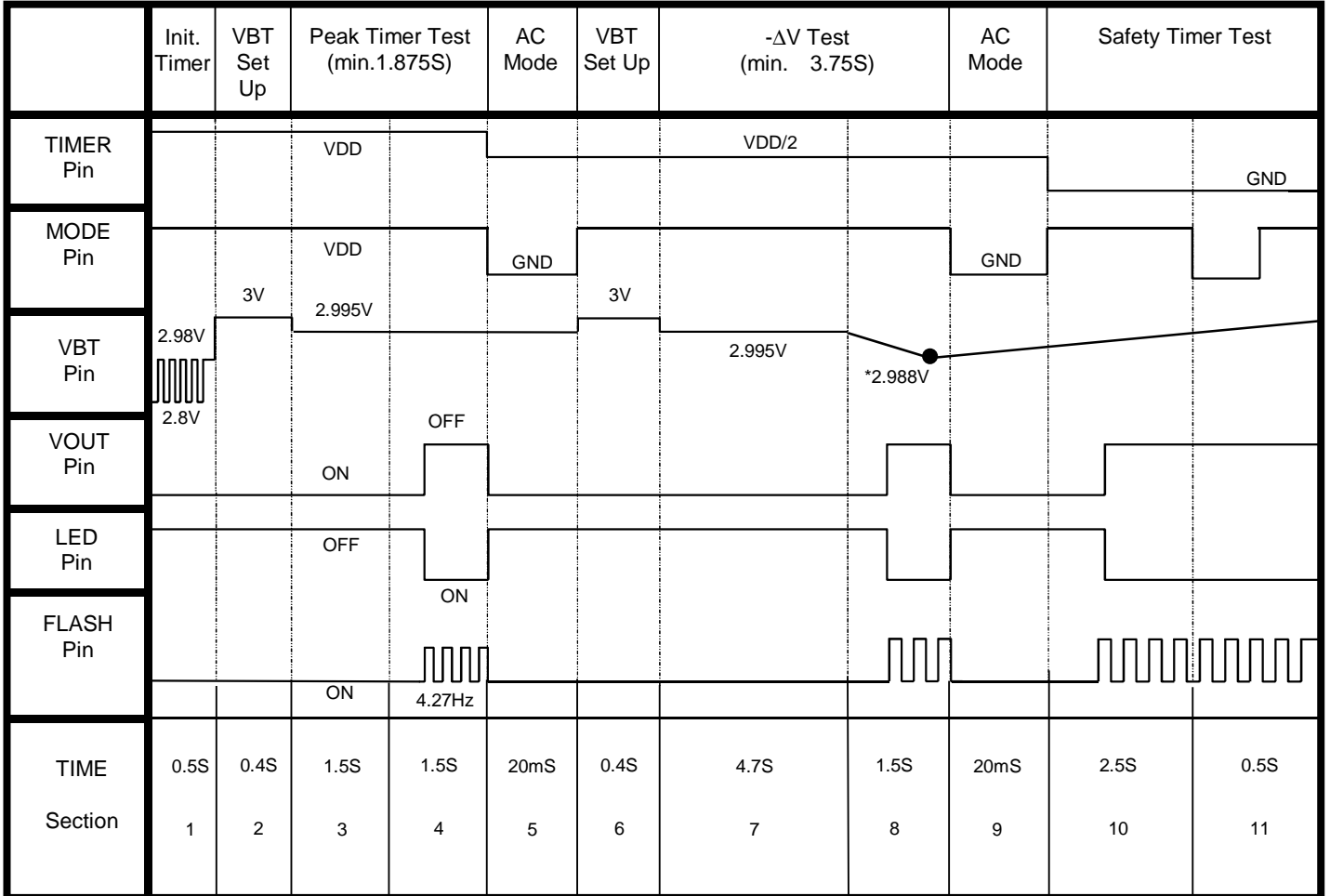
When the AIC1761/1766 is in TEST mode, all the internal timers are reduced by the following factors when compared to normal operation:

1. Safety timer reduced by 512 times.
2. Initial timer reduced by 512 times.
3. Peak timer reduced by 64 times.

One critical requirement needs to be observed for -ΔV detector of the AIC1761/1766 to work properly in TEST mode. That is, VBT pin voltage must be kept between approximately 2.8V to 3.3V, rather than 0.8V to 3.5V in NORMAL mode.

If the TEST mode function is to be utilized in production test, it has to be well planned and included in circuit design phase to make the voltages of VBT pin and MODE pin externally controllable. In addition, an externally controllable TIMER pin can further reduce test time required for testing the AIC1761/1766 in TEST mode.

Fig. 3 shows the timing diagram for externally controlled VBT, TIMER, and MODE pin voltages of a recommended AIC1766 charge circuit production test scheme, utilizing TEST mode function. Output waveforms of VOUT and LED pins (and FLASH pin for 14 pin version) of a properly functioning AIC1766 are also shown in the figure. In timer segments 4, 8 and 10, VOUT pin should change from ON to OFF, LED pin from OFF to ON, and FLASH pin from ON to flashing output (approximately 4 Hz). For the reset of time, VOUT pin should remain ON, LED pin OFF, and FLASH pin ON.

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	Init. Timer	VBT Set Up	Peak Timer Test (min.1.875S)	AC Mode	VBT Set Up	-ΔV Test (min. 3.75S)		AC Mode	Safety Timer Test	
TIMER Pin		VDD				VDD/2				GND
MODE Pin		VDD		GND				GND		
VBT Pin	2.98V ‖‖‖‖‖ 2.8V	3V 2.995V			3V	2.995V *2.988V				
VOUT Pin		ON	OFF							
LED Pin		OFF	ON							
FLASH Pin		ON	4.27Hz							
TIME Section	0.5S 1	0.4S 2	1.5S 3	1.5S 4	20mS 5	0.4S 6	4.7S 7	1.5S 8	20mS 9	2.5S 10 0.5S 11

* 2.972V for the AIC1761

Fig. 3   Timing Diagram of AIC1766 in Test Mode

The LED indicators work as the following table:

	LED PIN	VOUT PIN	FLASH PIN
Fast Charge	OFF	ON	ON
Trickle Charge	ON	OFF	FLASH
V_{BT} Abnormal	OFF	OFF	OFF

LED pin is used in conjunction with VOUT pin while FLASH pin works alone.

Referring to the APPLICATION EXAMPLES (Fig. 10), the temperature limits beyond where the fast charge is prohibited can be set by choosing values for resistors and the thermistor of the thermistor divider according to the following formula:

$R18 = 3.57 \, R_{T1} \, R_{T2} / (R_{T1} - R_{T2})$

$R19 = 10 \, R_{T1} \, R_{T2} / (1.218 \, R_{T1} - 11.2 \, R_{T2})$

R_{T1} : Thermistor resistance at low temperature limit.

R_{T2} : Thermistor resistance at high temperature limit.

BATTERY VOLTAGE DIVIDER

To ensure proper operation of the AIC1761/1766, selection of resistor values for battery voltage divider must meet the following two crucial requirements:

1. When the battery pack is disconnected from the charge circuitry, the voltage of VBT pin must be higher than 4.0V or lower than 0.5 V to put the AIC1761/1766 in reset status, where VOUT and LED pins become high impedance and FLASH pin (only for 14 pin version) goes to high level.

2. When the battery pack is connected in normal operation, the VBT pin voltage must remain in the range of 0.8V to 3.5V even when the battery pack voltage reaches to its peak when near full charge.

Take charging a 8-cell battery pack as an example. The highest voltage would be 16V when fully charged if the highest voltage of a fully charged battery cell is assumed to be 2V. Since the VBT pin voltage is restricted to be no higher than 3.5V, the battery voltage divider ratio must be higher than 3.57 (16V/3.5V -1). In other words, resistor

R14+R13 must be greater than 535KΩ if R15 is 150KΩ (refer to Fig. 4). When the battery pack is disconnected from the charging circuitry the VBT pin voltage must be higher than 4.0V, dictating V_{BAT} node voltage of the charging circuitry to be higher than 18.3V (4V x 4.57). Practically, however, the charging circuit supply voltage +V_{IN} should be higher than 18.5V in order to ensure proper operation. In the case that supply voltage +V_{IN} can not meet this requirement, application circuit of Fig. 4 can be adopted to get around this problem.
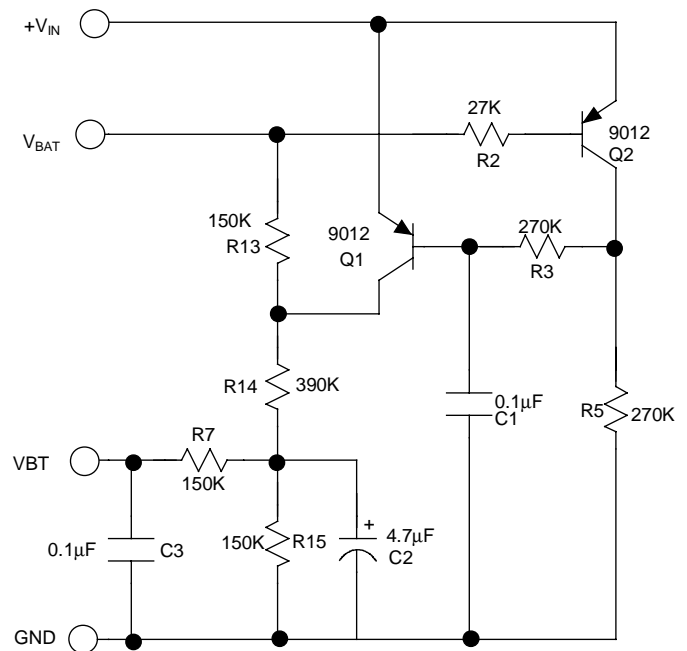

Fig. 4 Battery Voltage can be Raised to V_{IN} - 0.9V when being Charged.

● CHARGER CIRCUIT DESIGN TIPS

1. A stable constant charge current is crucial for reliable precision $-\Delta V$ detection by the AIC1761/1766 since fluctuation of the charge current can cause fluctuation of the battery terminal voltage due to battery internal series resistance, which will likely result in errors $-\Delta V$ detection by a properly functioning AIC1761/1766.

2. To prevent the AIC1761/1766 from over-voltage damage, make sure that none of AIC1761/1766 pins sees any voltage beyond the supply voltage, which needs to be between +9V and +18V.

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3. If the battery charge current is high, say, over 1.5A, quality of circuit board layout and wiring connection points become increasingly important in the charger circuit reliability.

4. Critical components need to meet adequate rating to prevent heating-up of these components from causing circuit malfunction.

5. Since the AIC1761/1766 is fabricated with CMOS process, cares must be taken in handling this device to avoid possible damage from electro-static discharge.

● **EXPERIMENTAL RESULTS**

Experiments have been conducted to verify the AIC1761/1766 operation with NiCd and NiMH battery cells of various brands. Actual results shown in the following figures clearly indicate that the negative delta voltage detector and the peak voltage timer of the AIC1761/1766 have precisely detected the tiny cell voltage drops or the cell voltage peaks and subsequently terminated the fast charge process after batteries are fully charged. The battery cell temperatures were all under safety levels. Note that the fast charge for the NiMH battery in Fig. 5 is terminated by the peak voltage timer ($0\Delta V$) while the fast charge for the NiCd battery in Fig. 6 is terminated by the $-\Delta V$ detector.
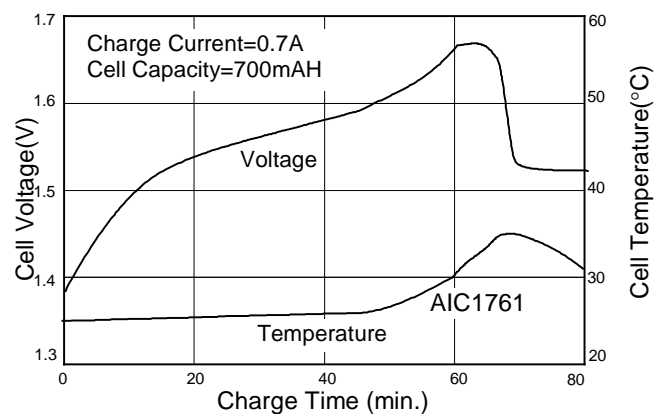

Fig. 5   Charge Characteristics of NiMH Battery

Both Fig. 5 and Fig. 6 were obtained by using the AIC1766. Results of similar experiments by using the AIC1761 are shown in Fig. 7 and Fig.8.
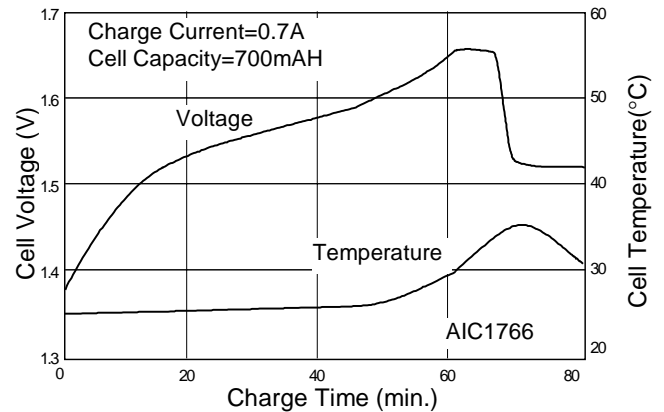
Fig. 6   Charge Characteristics of NiCd Battery
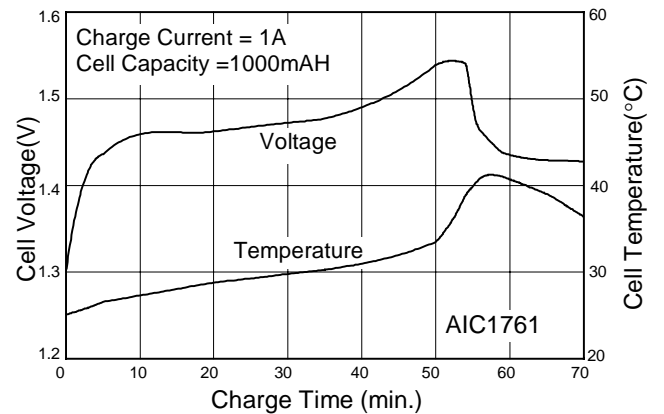
Fig. 7   Charge Characteristics of NiMH Battery
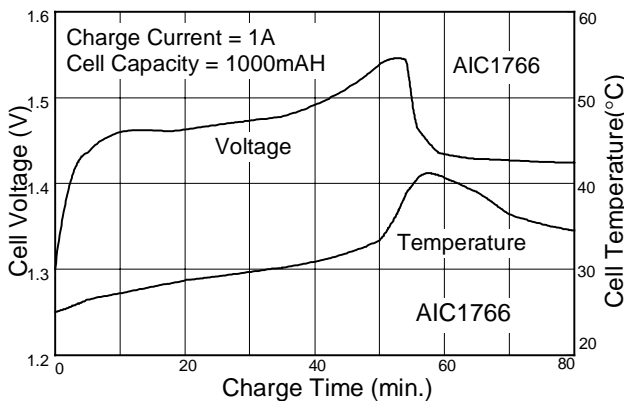
Fig. 8   Charge Characteristics of NiCd Battery

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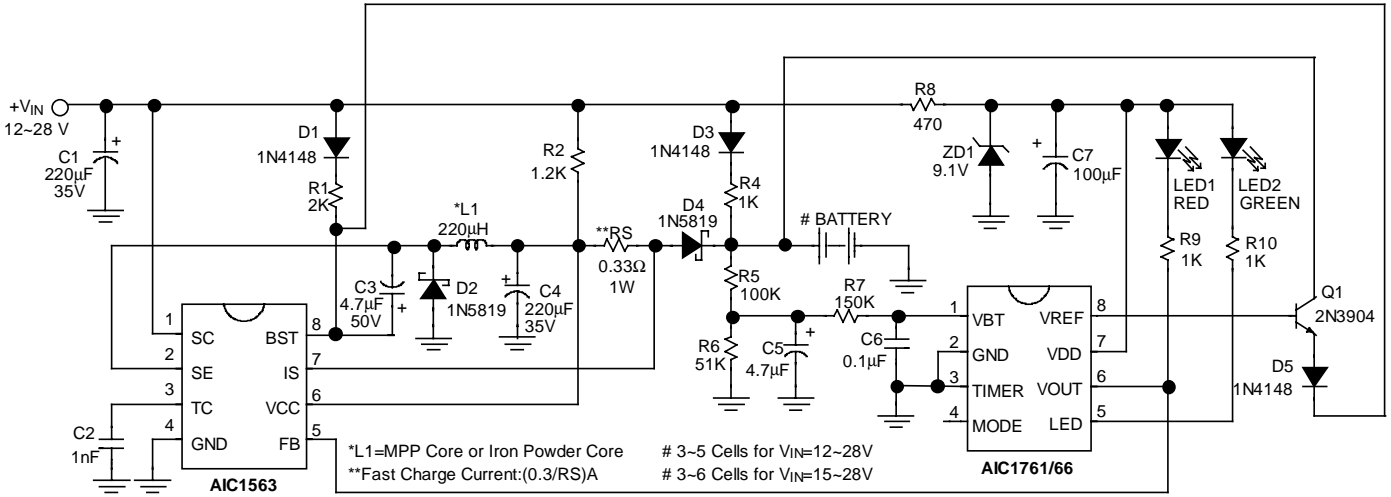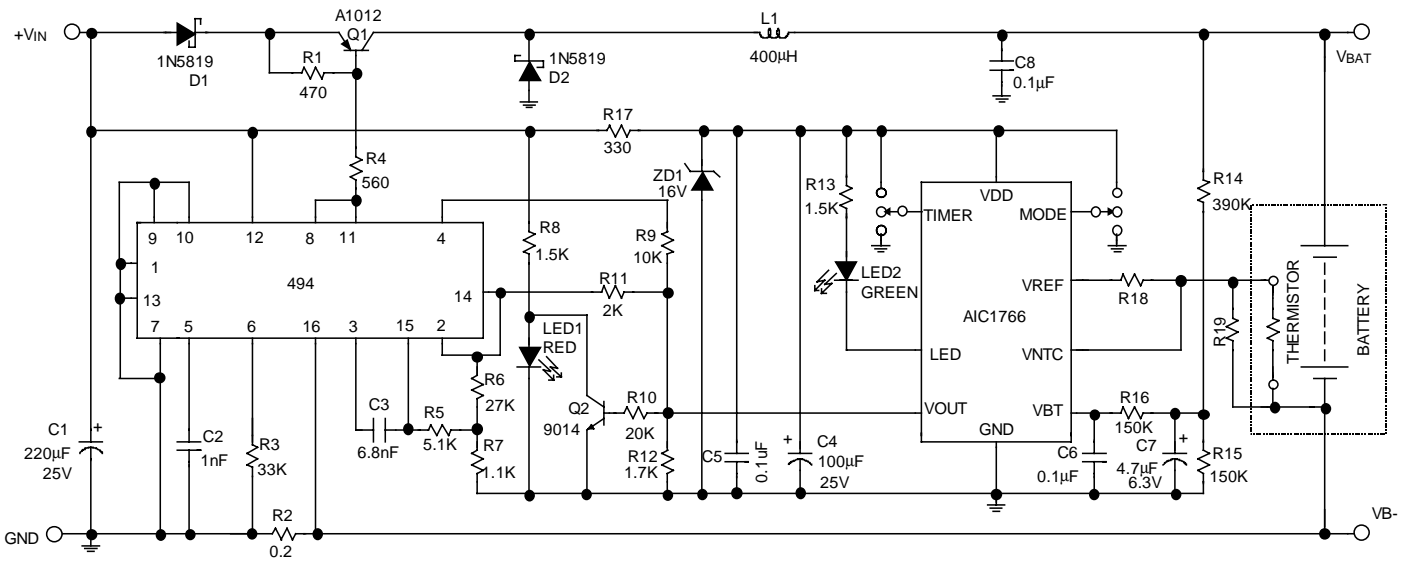
APPLICATION EXAMPLES

Fig. 9   Battery Charge Circuit for NiMH/NiCd Battery with Wide Range Input Voltage
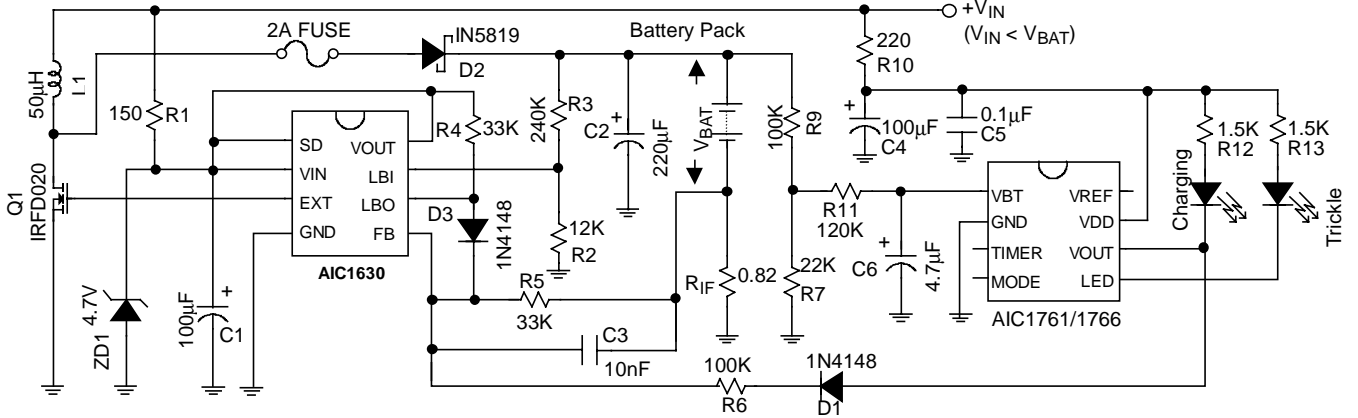

Note: V_{IN} should be higher than 10V, ZD1 is required when V_{IN} exceed 18V.
          Fast charge current is approximately 1A. Adjustable through R7.
          Trickle charge current is adjustable through R12

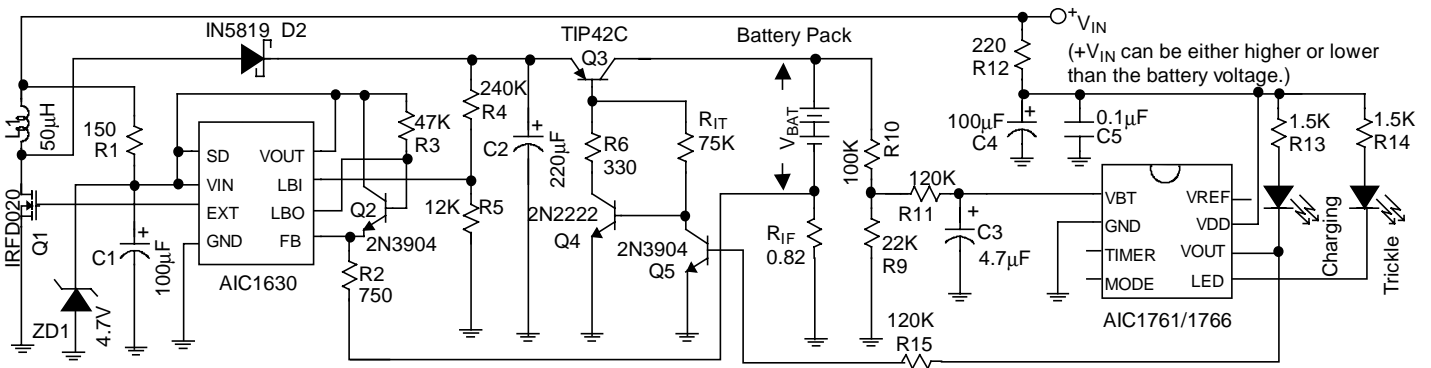**Fig. 10   Step-Down Rechargeable Battery Charger**

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■ APPLICATION EXAMPLES (CONTINUED)

Note: Charging current =0.8A V_{IN} must be lower than V_{BAT}.
(R$_{IF}$ sets the Charging Current)   Short Circuit Condition is protected with a 2A Fuse.

FIG. 11   Step-Up Rechargeable Battery Charger

Note: Fast Charge Current = 0.8A @$V_{IN}<V_{BAT}$ R$_{IF}$ sets Fast Charge Current, R$_{IT}$ sets Trickle Charge Current
=(V_{IN} - V_{BAT} - 0.5)/0.82 @$V_{IN}>V_{BAT}$ Typical Efficiency = 75%.
Trickle charge Current = 30mA.   With Short Circuit Protection.

FIG. 12   Step-Up/Down Rechargeable Battery Charger
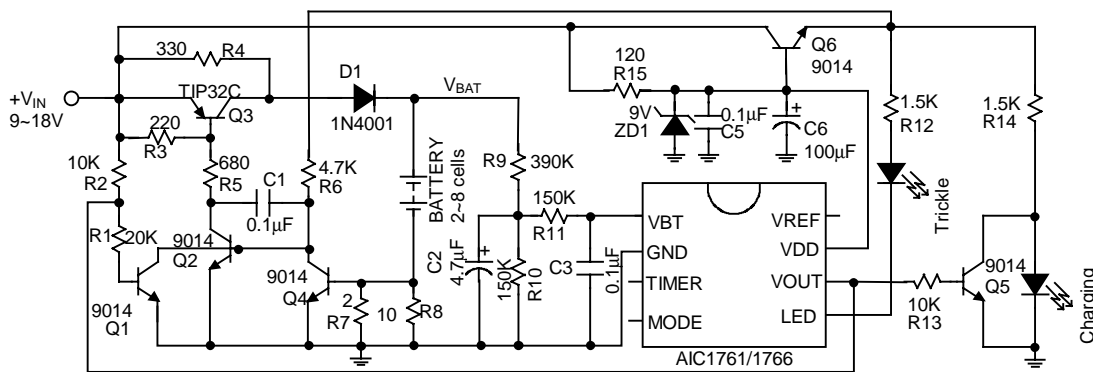
Note: V_{IN}=9V~18V for 2~8 cells

Fast Charge Current=400mA $\left(\dfrac{V_{BE}}{R7//R8} \cong \dfrac{0.65}{R7//R8} \right)$

FIG. 13   Step-Down Low-Side Current Sense Pulse Battery Charger

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■ APPLICATION EXAMPLES (CONTINUED)
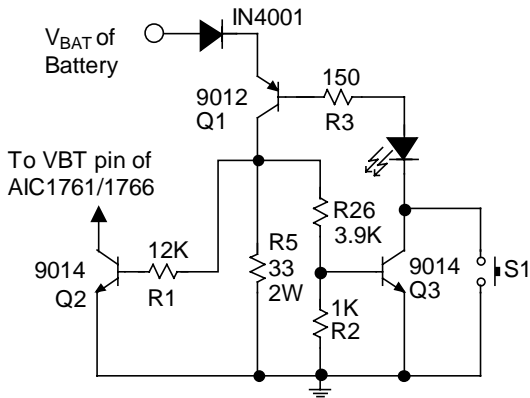
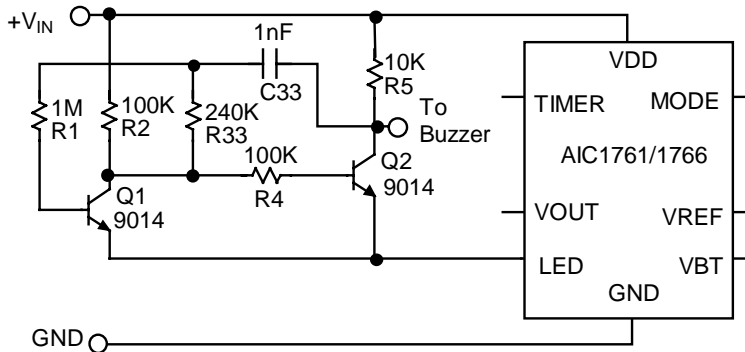| Final Voltage of Battery	R26
6V	6.8K
5V	5.1K
4V	3.9K
3V	2.7K

Note: The final voltage of battery is determined by R26.
Discharge current is decided by R5.
S1: Push to initiate discharge

Fig. 14   Discharge Circuit of Rechargeable Battery
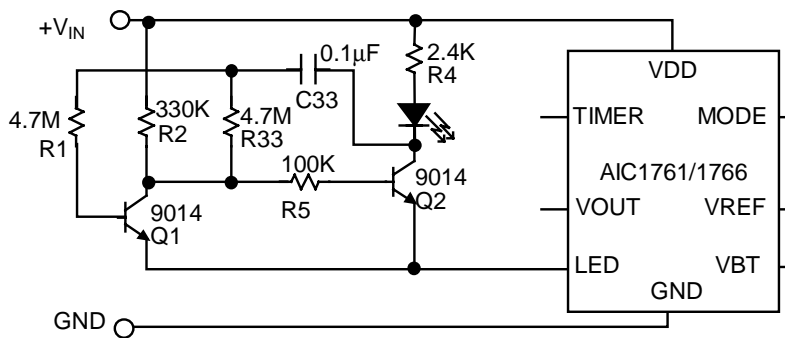
Note: Frequency (about 1Hz) is determined by R33 and C33.
LED will flash when LED pin goes low.
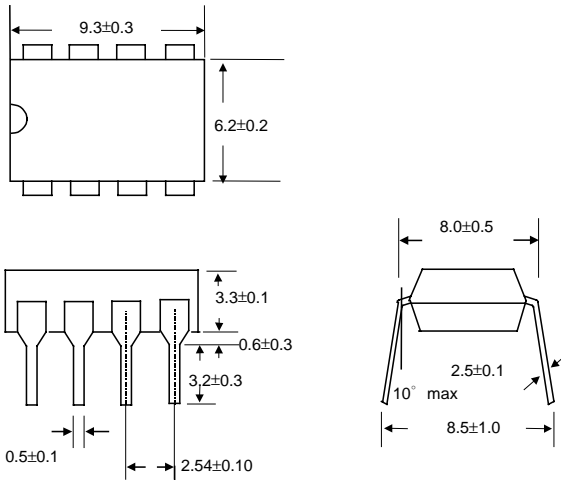
Fig. 15   Flashing-LED Circuit for Trickle Mode

Note: Frequency (about 1Hz) is determined by R33 and C33.
Buzzer will be activated when LED pin goes low.

Fig. 16   Buzzer Circuit for Trickle Mode
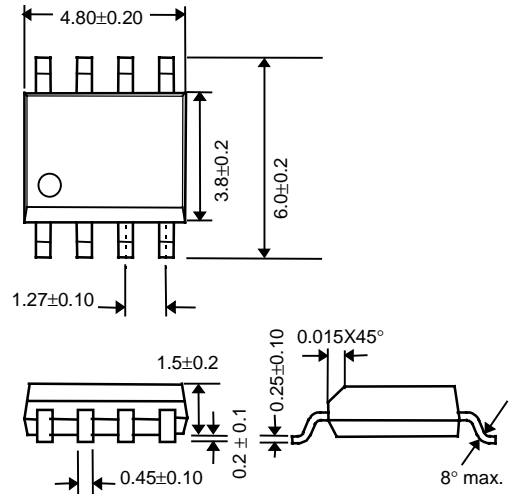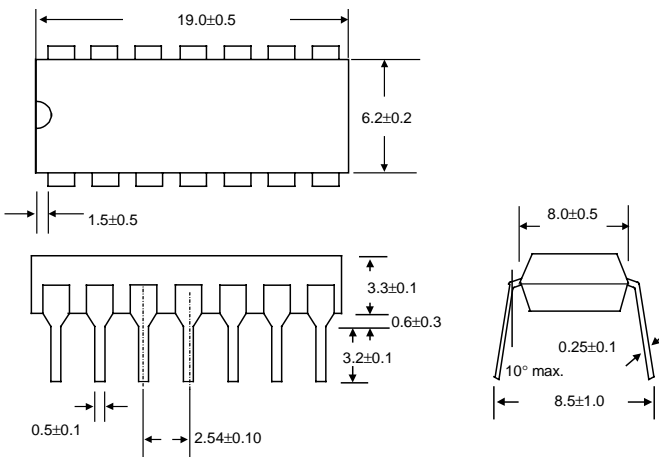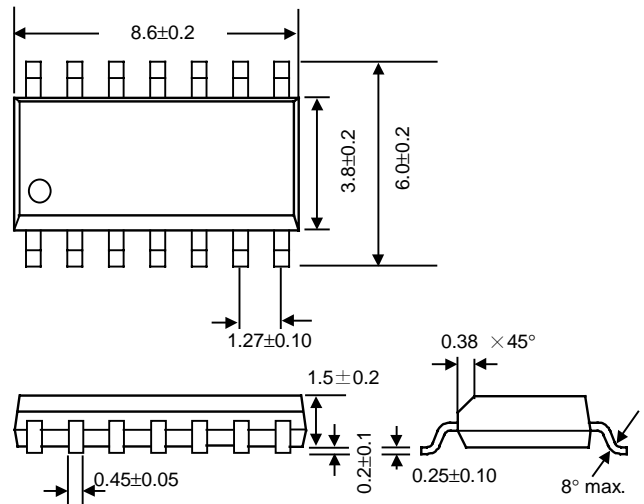
■ PHYSICAL DIMENSION

● **8 LEAD PLASTIC DIP**

● **8 LEAD PLASTIC SO**

● **14 LEAD PLASTIC DIP**

● **14 LEAD PLASTIC SO**

UNIT: mm