Galaxy
Power
Incorporated

ICS1718

QuickSaver ® Pulse Conditioning Charge Control IC for NiMH and NiCd Batteries

Features

- Ideal for embedded NiMH/NiCd designs
- 13 bit ADC
- Cost effective for charger stand designs
- Termination methods
  - Voltage slope (+ΔV/dt and +/- peak detect)
  - Fast charge time out to maintenance mode
  - Optional over temperature shutdown
  - Optional charge current removal
- Four stage charge sequence
  - *SoftStart* conditioning
  - Fast charge
  - Topping charge
  - Maintenance charge
- Four (4) user selectable charge rates
  - 15 minutes (4C)
  - 30 minutes (2C)
  - 60 minutes (1C)
  - 120 minutes (C/2)
- 16 bit RISC processor
- Packaging: 8 pin SOIC, 8 pin DIP

Benefits -compared to other methods

- Peak battery performance and extended service
- Improved battery efficiency and reliability
- Lower internal resistance build-up
- Lower capacity fade acceleration
- Lower battery self discharge rate

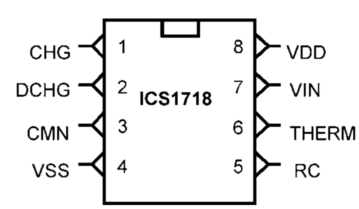
Applications

- Embedded and charger stands
- Portable consumer products
- Power tools
- Audio/video products
- Communications productsRC toys
- Wireless products

Description

The **ICS1718** is a low cost 8 pin CMOS control IC designed for the intelligent charging of nickel-cadmium (NiCd) and nickel-metal hydride (NiMH) batteries. The **ICS1718** has four (4) user selectable charge rates, user accessible clock, thermistor or temperature switch input, and a charge status output pin. The **ICS1718** uses a pulsed-current conditioning technique and voltage slope methods for a complete recharge without overcharging, irrespective of the charge state of the battery at the start of its charge. A brief polling mode during the first moments after powerup provides overvoltage protection. Charge current is gradually increased up to the fast charge level during a soft-start conditioning stage. A two stage maintenance charge provides an opportunity to further optimize the charge level in the battery. The **ICS1718** is ideal for applications where battery temperature protection is required in the charger.

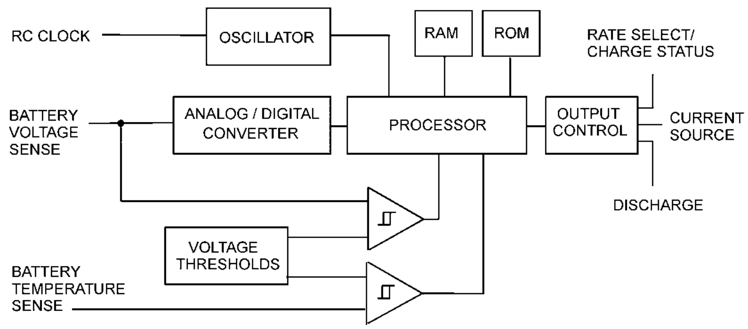
Charge rates are user selected. Four different charge times between 15 minutes (4C) and two hours (C/2) are available. The **ICS1718** has options to prevent charging at temperatures above a designer set maximum as well as low current charge at battery temperatures below a designer set minimum. Internal maximum and minimum battery voltage references set voltage thresholds provide over/under voltage shutdown protection.



This document contains information that describes this design as completely as possible at the time of this revision. <u>Some or all of this information may be deemed confidential and should not be released</u> without a non-disclosure agreement. Data and specification characterizations are in process and may be changed in subsequent releases.

GPI Internal Information Only
Revision 2.1 - August 3, 2001

Block Diagram



Pin Descriptions

Pin	Name	Type	Description
1	CHG	OUT	Active high (PFET), active low (NFET) 16Ω, 25mA max., TTL compatible signal. High (5V) turns on and a low (0V) turns off an external current limited voltage regulated charging source to provide pulse charge to the battery.
2	DCHG	OUT	Active high (PFET), active low (NFET) 16Ω, 25mA max., TTL compatible signal. High (5V) turns on and a low (0V) turns off an external transistor to sink a conditioning pulse discharge current from the battery using an external resistor.
3	CMN	OUT	Charge mode indicator. NFET drain rated 10Ω, 40mA max. Goes low to turn on external indicator showing battery is in soft start/fast charge. Alternately goes low and off (open) at a 1Hz rate to show battery is ready as topping/maintenance charges are applied. Off (open) with input power indicates over-voltage shutdown and/or missing battery in charger stand
4	VSS	PWR	Ground that connects directly to a solid (low impedance) ground at or close to battery minus
5	RC	IN	An external resistor from this pin to VDD and an external capacitor from this pin to VSS set the frequency of the internal oscillator, providing the clock for the device. 15KΩ and 100pF are normally used. Pin 5 can be driven by a 1 MHz external 0 to 5V rectangular pulse with duty cycle 10 to 60 %, capable of supplying 7 mA.
6	THERM	IN	Thermistor or thermal switch input referenced to battery negative for hot and cold battery sensing. If not used, connect to ground.
7	VIN	IN	Battery voltage is divided down with an external resistor divider for ending fast charge; back-up over-voltage shutdown
8	VDD	PWR	Device supply = Series regulated 5.0 VDC +/- 10%, 100mA. The ICS1718 maximum average includes brief 50mA peak currents. When used, LEDs, pull-up resistors, and drivers require additional current from the +5VDC supply. A .01uF or larger ceramic capacitor between (and close to) VDD and VSS is used for bypassing, in addition to the output capacitor required by the regulator.

Input and output pins all have internal ESD proteection diodes to VDD and VSS for 2KV protection per MIL STD 883 method 3015.7. Depending on the application,set-up, board layout, etc. additonal ESD protection may be required.

Charging Stages

The normal charging sequence consists of four stages. The application of current is shown graphically in Fig. 1. The soft-start charge stage gradually increases during the first two or four minutes of charge depending on the charge rate selected. The soft-start is followed by a near full duty cycle constant amplitude current charge, which continues until termination. After termination, either a two hour or four hour topping charge, depending on the charge rate selected, is applied, followed by a maintenance charge.

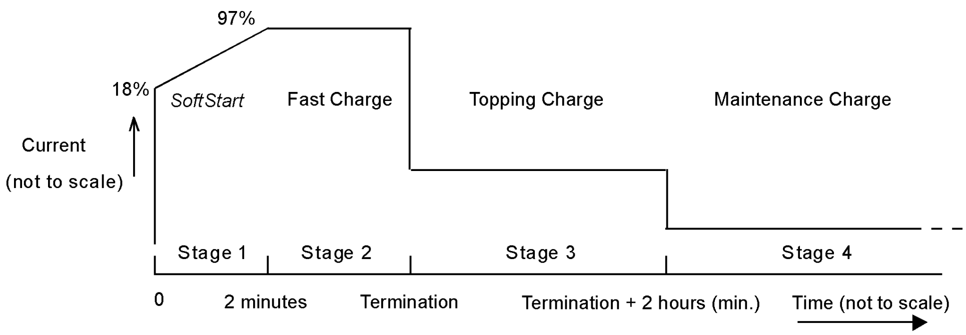


Fig. 1: Graphical representation of current levels during the four charging stages.

Stage 1: Soft-Start Charge

New, overdischarged, and batteries out of long term storage may exhibit a high impedance condition initially. The high impedance causes a voltage spike at the beginning of the charge cycle as shown in Fig. 2.

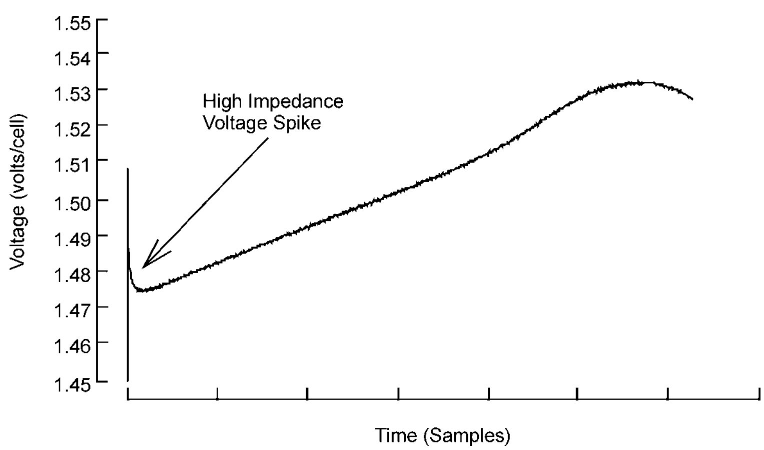


Fig. 2: High impedance voltage spike at the beginning of charge.

The voltage-time integral of the voltage spike remains constant regardless of the charge rate. At higher charge rates the amplitude of the spike is relatively high, but the time duration is short. At lower charge rates, the amplitude of the spike is less but the time duration is proportionally longer. Unless remedied the spike might be misinterpreted as a fully charged battery by a voltage slope termination method. So the soft-start charge is applied to ease the battery into fast charge by gradually increasing the duty cycle of the charge from 20% to nearly 100% the first two or four minutes of charge. The gradual increase in duty cycle alleviates the high impedance condition before fast charge stage begins. The applied current is raised to the desired fast charge duty cycle by extending the charge pulse width on every cycle until the current is applied for the entire fast charge pulse width (t_{CPW}), as shown in Fig. 3. The initial pulse width (t_{IPW}) is approximately 1/5th of the fast charge pulse width. The soft-start pulse width increases by t_{inc} over 120 cycles that is determined by

$$t_{inc} = \frac{t_{CPW} - t_{IPW}}{120}.$$

The cycle time, denoted by t_{cycle} in Fig. 3, is slightly longer than the fast charge pulse width. The timing relationship of the charge pulse to the cycle time is shown in Fig. 4. The charge indicator (CMN) is active low during this stage.

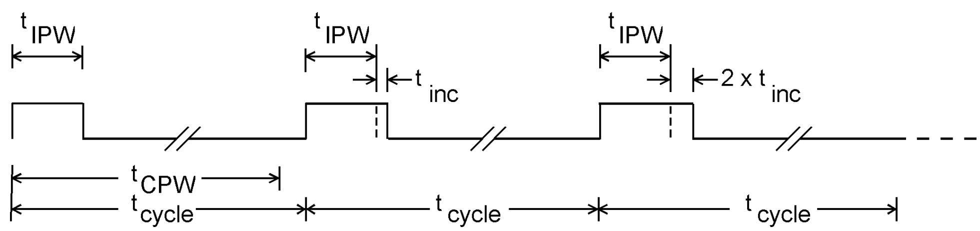


Fig. 3: Cycle to cycle increase of the soft-start current pulse widths.

Stage 2: Fast Charge

The **ICS1718** applies the charge current in a repetitive sequence consisting of charge and discharge pulses with rest times throughout the fast charge. The pulsed conditioning technique consists of a relatively long charging pulse followed by a very short high current discharge pulse. The cycle, shown with charge, discharge, rest and data acquisition periods in Fig. 4, repeats until the battery is fully charged.

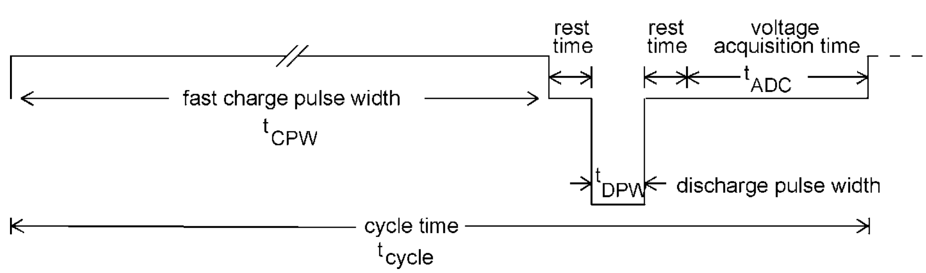


Fig. 4: Charge cycle showing charge and discharge current pulses.

The conditioning discharge pulse amplitude is normally set at 2.5 times the amplitude of the actual charging current based on 1.4V/cell. Setting the discharge pulse to the same amplitude as the charge current still provides some conditioning.

The discharge pulse width is typically 5ms every 1.1 seconds for the 4C and 1C rates (and 10ms every 2.2 seconds for the 2C and C/2 rates), so the external transistor and resistor selected for accomplishing the discharge pulse are determined using conservative pulse ratings. The duty cycle of the reverse pulse is 0.5% maximum of the fast charge duty cycle. Since the discharge current is rectangular, the RMS current in the resistor and transistor (logic NFET, high gain NPN, or NPN darlington) is equal to the peak current times the square root of the duty cycle. So the RMS heating effect current is about 7% of the discharge current peak amplitude. Using conservative pulsed, rather than steady-state ratings, for selecting the discharge resistor and transistor results in relatively small, low cost devices.

An ADC acquisition window for measuring the cell voltage immediately follows a brief rest time after the conditioning discharge pulse. No current is applied during the rest time or the window to allow the battery voltage to stabilize. Since no current is flowing, the measured voltage is not obscured by any internal or external drops and distortions caused by surface charge have been removed. The **ICS1718** takes one voltage reading of the quiet time battery voltage during the acquisition window. The voltage measured during this window provides a most accurate representation of the true state of charge of the battery.

Stage 3: Topping Charge

The topping charge stage applies current at a duty cycle that provides cell equalization in multiple cell packs. When the **ICS1718** completes the fast charge, the battery is ready to use as the CMN indicator alternates ON and OFF at a 1 to 2 second rate. If charging is allowed to continue, the topping charge is applied for a minimum of two or four hours, depending on the charge rate selected. The charging current consists of the same pulsed current technique used during fast charge, however a delay time is introduced as shown in Fig. 5. Extending the delay time between charge pulses allows the use of the same amplitude current used in fast charge so no altering of the current source is required.

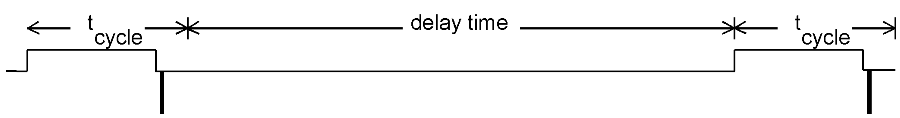


Fig. 5: Representative timing diagram for topping and maintenance charges.

Stage 4: Maintenance Charge

The maintenance charge offsets the natural self-discharge of NiCd or NiMH batteries keeping the battery primed at peak charge. After topping ends, the **ICS1718** begins maintenance by once again extending the duty cycle of the applied current pulses. The topping charge delay is increased by a factor of four and continues for as long as a battery voltage is present at the voltage sense (VIN) pin. As in the topping charge, the charge mode indicator (CMN) alternates on and off at a one to two second rate.

Cold Battery Temperature Charge

The efficiency of the oxygen-recombination reaction in a NiCd or a NiMH cell at low temperatures is reduced. To reduce the pressure generated by hydrogen gas at the negative electrode, the **ICS1718** provides an option to charge at the topping rate until the battery warms up. Cold temperature charging is activated if a voltage at the temperature sense (THERM) pin is in the cold temperature voltage range as shown in Table 4 and Figure 7. The voltage at THERM pin 6 is produced by a NTC thermistor in the battery pack. A series resistor to THERM pin 6 and an external pull-up resistor to +5V (VDD) in the charge circuit are used to set cold battery charging. The **ICS1718** only checks for a cold battery prior to the start of fast charge.

If a cold battery is detected prior to fast charge, the **ICS1718** applies the topping charge. The charge mode indicator (CMN) alternates on and off, indicating that a low current charge is being applied to the cold battery. The voltage at THERM pin 6 is monitored continually to see if the battery has warmed. If so, the **ICS1718** quits the topping charge and begins a fast charge at the rate selected starting with soft start.

If a battery becomes cold while a normal charge is in progress, fast charging at the selected charge rate continues until termination. The two (or four) hour topping charge is then applied, followed by the maintenance charge.

Charge Termination Methods

Three main fast charge termination methods are used: positive voltage slope ($\Delta V/\Delta t$) and +/- peak voltage detect. Over voltage (V_{max}), maximum temperature (T_{max}) and a fast charge time out are available as backups. The voltage slope methods may be used with or without the maximum temperature method. An initial voltage slope check after soft start is performed to detect an already full battery.

Voltage Slope Termination ($\Delta V/\Delta t$)

The most distinctive point on a charging voltage curve in response to a constant current charge is the rise towards peak voltage that occurs as the battery transitions to its full charge state. The voltage peak is characterized by a relatively shallow voltage slope that becomes much steeper until it reaches a maximum shown in Fig. 6.

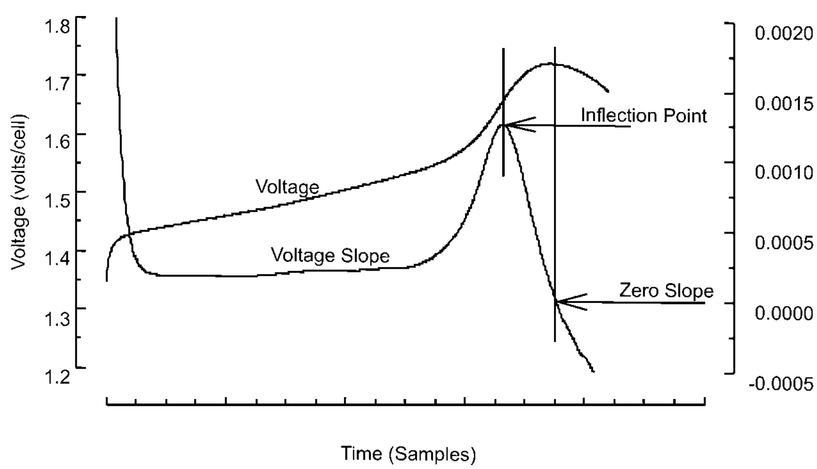


Fig. 6: Voltage and slope curves showing inflection and zero slope points.

The voltage slope is calculated using a modified linear regression algorithm that smoothes the slope. The slope reachs a maximum, known as the inflection point, prior to the actual voltage peak as shown in Fig. 6. Using milestone voltage data stored during the charging progress and applying appropriate thresholds, the **ICS1718** determines full charge and accurately terminates the applied current in between the inflection point and peak voltage, prior to overcharge.

New, overdischarged, old, and already full batteries produce a voltage profile that varies from that shown in Fig. 6. The **ICS1718** fast charge termination in these cases is based on a slight decrease in the voltage. Some new and old batteries may need several charge use cycles before their response stabilizes to that shown in Fig. 6.

Temperature Sensing

Battery temperature can be sensed by THERM pin 6 using either a thermistor or a thermal switch inside the battery pack referenced to the pack's minus terminal. The maximum temperature shutdown option can be bypassed or altered if desired. See the section Applications Information. It is strongly recommended that in line over temperature protection such as a PTC or Thermal Switch always be a part of the battery pack design.

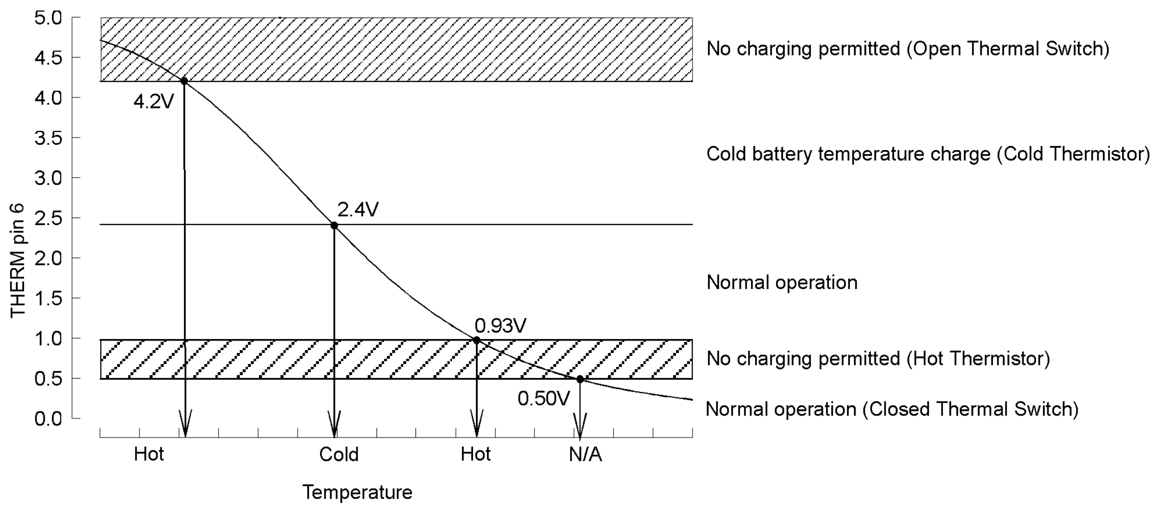


Fig. 7: Voltage levels for temperature sensing with a thermistor or thermal switch.

If a thermistor is used, the **ICS1718** uses voltage thresholds to determine the battery temperature. Fig. 7 shows the voltage at THERM pin 6 from a NTC thermistor circuit vs. temperature using an appropriate external pull-up resistor (see the section Applications Information). As temperature increases the voltage across the thermistor circuit drops. The voltage across the thermistor circuit normally resides between the cold battery and hot battery thresholds in the "normal operation" region. If the thermistor circuit voltage is allowed to drop to 0.93V, the **ICS1718** assumes the battery is hot and the ICS1718 shuts down removing charge current. If a normally closed thermal switch referenced to battery minus is used, THERM pin 6 connects to ground through the switch. When the switch opens for the hot battery condition, the **ICS1718** shutsdown as THERM pin 6 internal pullup resistor pulls the THERM pin voltage up to VDD.

If a battery is determined to be hot at any time, either through an opened thermal switch or a thermistor circuit threshold, and the **ICS1718** shutsdown, the **ICS1718** must be powered down and powered up again when battery temperature returns to the normal range for charging to restart. A cold battery temperature charge is activated if the voltage across the thermistor circuit is between 2.4V and 4.2V when the **ICS1718** is powered up. An alternating CMN indicator at power-up indicates cold battery charge. See the section *Applications Information* for options using thermistors and thermal switches.

Fast Charge Timer

As a safety back-up the **ICS1718** uses a timer to end fast charge and begin the topping charge. These times for the 4C to C/2 rates are listed below in Table 1. These times allow the use of charging currents that aren't exact multiples of the C rate and can be adjusted by changing the clock speed.

Charge Rate	Fast Charge Time (nominal)	Fast Charge Time Limit	Maximum Time Before Initial Slope Check (after power up)
4 C	15 min.	30 min.	2.6 min.
2 C	30 min.	60 min.	5.2 min.
1 C	60 min.	90 min.	4.3 min.
½ C	120 min.	180 min.	8.6 min.

Table 1: Fast Charge Time Limit and Initial Slope Check Information

Initial Slope Check

The initial slope check is a test to detect a fully charged battery at the beginning of fast charge after soft start. Once the soft-start sequence completes, voltages are acquired, added together, and averaged to be stored as a sample. The number of acquisitions to be averaged varies with charge rate. The last column indicates the elapsed time from powerup that the **ICS1718** needs to determine a charge was started on an already fully charged battery.

If the battery voltage decreases over the sampling period, the battery is assumed to be fully charged. The **ICS1718** then enters the topping stage. If the battery voltage increases over the sampling period, the **ICS1718** stores the slope and continues charging.

Open and Hot Battery Detection in Embedded Applications

Embedded applications include those where the **ICS1718** is physically in the battery pack and those where the **ICS1718** is in a product along with the battery pack and the battery pack is not normally removed except for service or repair. So for embedded applications, there is often no need for external circuits for detecting battery insertion and removal, however note that during evaluations the over/under-voltage and over temperature features activate when the battery is disconnected.

The following sequences describe the **ICS1718** battery polling function. If the voltage at the VIN pin exceeds the internal 2V reference any time after soft-start begins, the **ICS1718** assumes an open to (or in) the battery ocurred, and shutsdown. Similarly, in the topping and maintenance stages, if the voltage at the VIN pin drops below 0.5V the ICS1718 assumes an open to (or in) the battery occurred. For both open conditions, the indication is CMN OFF with input power applied.

After power-up, the **ICS1718** uses six short discharge pulses spaced a tenth (or a fifth) of a second apart, depending on the charge rate selected, to remove excess charge from any output filter capacitors at the current source output. The CMN indicator is inactive during the discharge pulses. When the discharge pulse sequence is complete, **ICS1718** pin 1 goes high for either 100 ms or 200 ms, switching on the current source. If a battery is present, the current pulse is clamped by the battery so VIN stays below the internal 2V reference. The 100 ms or 200 ms pulse continues on to become the first Soft-Start pulse. If VIN rises above the internal 2V reference during the 100 ms or 200 ms pulse there is an open to (or in) the battery, and a 10 second polling routine begins for the 4C and 1C charge rates. The routine is 20 seconds for the 2C and C/2 rates. Charge pulses are applied every half-second, or second per pulse, for 20 pulses. If an open protection circuit, for example, resets during the polling routine, fast charge begins. If the open remains the **ICS1718** shutsdown.

When in soft-start or fast charge, the voltage at VIN pin 7 is compared to the internal 2V reference. If the voltage is greater than the internal 2V reference during the first 5ms of the current source turning ON, an open to (or in) the battery is assumed to have occurred and the **ICS1718** shuts down. If the voltage at the VIN pin is clamped below the internal 2V reference, charging continues. Voltage comparisons are made the first 5ms of each charge cycle as the current source turns on. When in the topping charge or maintenance charge stages, charge pulses occur infrequently. The **ICS1718** compares the voltage on VIN to an internal 0.5V reference when the current source is off. An open to (or in) the battery is assumed to have occurred if the voltage at VIN drops below 0.5V and the **ICS1718** shuts down.

If the **ICS1718** shutdown is due to the above described conditions, input power must be removed and reapplied to restart the **ICS1718**. If the battery has an NTC thermistor or normally closed thermal switch referenced to battery minus for THERM pin 6 sensing, the above described polling mode will not activate if battery is hot. Hot battery shutdown overrides the polling function.

Automatic Battery Detection for Charger Stand Applications

When the battery is removable from the product for charging in a stand or when the **ICS1718** is in a charger that connects to the battery, battery or charger insertion and removal can be is managed using external provisions to briefly override the **ICS1718** under/over-voltage shut down features. Switching on and off the input of the 5V supply to the **ICS1718** or the 5V to the **ICS1718** is recommended. The simplest, lowest cost automatic approaches involve using a mechanical switch in the battery well or slot in the stand, or battery connector positions that deliver 5V to the **ICS1718** when the battery connects. The battery's physical presence activates switch contacts that either connects the input supply to the input of the 5V regulator powering **ICS1718** VDD pin 8 or connects the 5V directly to **ICS1718** VDD pin 8. See the section *Application Examples* for detailed information on automatic electronic methods for managing battery insertion and removal for charger stand applications. Power-up and down transitional voltage states should not have plateaus in between 1V and 4.50VDC. For the **ICS1718** to shutdown completely, its VDD pin 8 supply must drop below 1V. The resistance between the 5V supply and **ICS1718** VDD pin 8 should not exceed 1Ω.

Set-up Information

The **ICS1718** requires some external components for 5V power to VDD, to set the clock charge rate, sense battery voltage and temperature (if required), interface to an external current source, and to a transistor and resistor for discharge pulse conditioning. The **ICS1718** does not control the amplitude of current flowing into the battery in any way other than switching it ON and OFF. The current for the selected charge rate is provided by a regulated current source. The constant current source is set according to the charge rate selected. For example, to charge a 1.2 ampere hour battery at the 30 minute (2C) rate, 2.4 amperes of current is needed. See Applications Examples for deteiled information.

Output Drive Signals: *CHG, DCHG* Pins

The CHG and DCHG drives are active high, TTL compatible rated for 25mA maximum. These PFET/NFET outputs are capable of sourcing and sinking adding flexibility when interfacing. A high on the CHG pin 1 turns the current source on. A high out of DCHG pin 2 activates the discharge conditioning circuit. Care must be taken to control wiring resistance, and the discharge current sink must be capable of handling this short-duration high-amplitude pulse.

Indicator: *CMN* Pin

An indicator can be connected to CMN pin 3 to display the charging mode status. CMN pin 3 is an open drain NFET referenced to ground. CMN pin 3 can sink 40 mA maximum, so the use of an external current limiting resistor is required when the indicator is an LED. The indicator must be powered from the same 5V used to supply the **ICS1718**. CMN pin 3 is low continuously during the soft-start and fast charge stages. When the controller is in the topping and maintenance charge stages, the CMN pin 3 alternates ON and OFF at a 1HZ rate for the 4C and 1C rates and at 1/2HZ for the 2C and C/2 rates.

CMN	Description
blink	Battery ready to use as topping or maintenance charge is applied
on	Soft-Start/Fast charge
blink	At power-up or insertion, Battery is cold as topping charge is applied
off	Power down or over/under voltage shut down

Table 2: CMN Indicator Activity Description List

Charge Rate Selection:

The voltage on CMN pin 3 at power up prior to the start of fast charge sets the **ICS1718** charge rate. An internal 75K pull-up resistor to VDD at CMN sets the **ICS1718** for the 1C (60 minute) rate as shown in Fig 8. The C/2 (120 minute) is created by changing the timing resistor from 15K (60 minutes) to 30K for the C/2 (120 minute) rate. For the 4C (15 minute) and 2C (30 minute) rates, CMN must be held low (below 0.5V) at power up until CMN goes low of its own accord as fast charge starts. See Fig. 9 for a simple circuit to accomplish this setting. The 2C (30 minute) rate is created by changing the timing resistor from 15K (15 minute) to 30K for the 2C (30 minute) rate.

RC C = 100pF	Charge Rate	Fast Charge Time (nominal)	Topping Charge Pulse Period	Maintenance Charge Pulse Period	Fast Charge Timer
R = 15K	4 C	15 min. (¼ hr)	41 sec	161 sec	30 min.
R = 30K	2 C	30 min. (½ hr)	82 sec	322 sec	60 min.
R = 15K	1 C	60 min. (1 hr)	11 sec	41 sec	90 min.
R = 30K	1/2 C	120 min. (2 hr)	22 sec	82 sec	180 min.

Table 3: Charge Rate Information (Ref. Fig. 5)

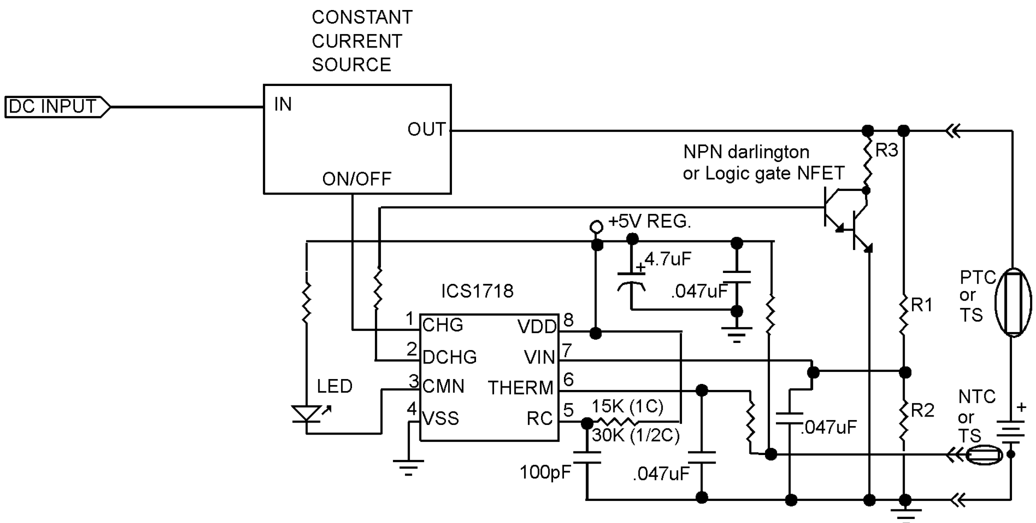


Fig. 8: CMN pin 3 and RC pin 5 Set-up for 1C (60 minute) and 1/2C (120 minute) Charge Rates

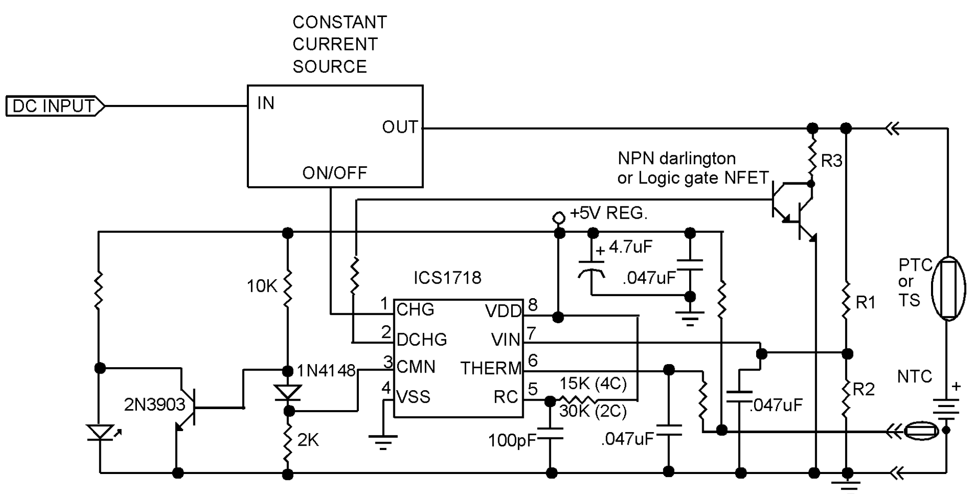


Fig. 9: CMN pin 3 and RC pin 5 Set-up for 4C (15 minute) and 2C (30 minute) Charge Rates

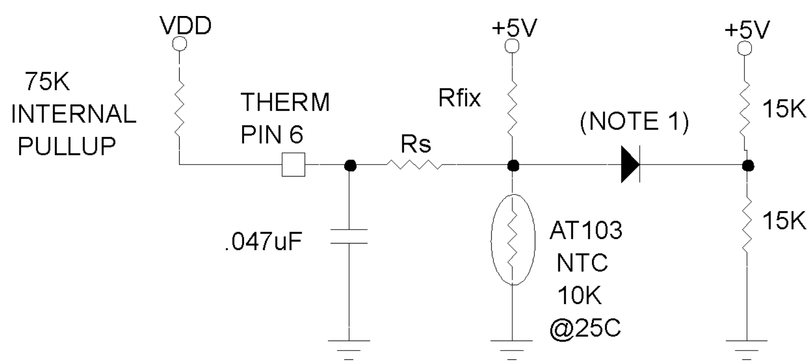
Clock Input: *RC* Pin

RC pin 5 is used to set the frequency on the internal clock. For the rates detailed in this data sheet, either a 15K Ω or a 30KΩ resistor is connected between this pin and V_{DD}, and a 100 pF capacitor is connected between this pin and ground.

Temperature Sense: *THERM* Pin

The THERM pin 6 uses external resistors for battery temperature sensing. The examples in Table 4A use a 10K Ω at 25°C NTC thermistor such as the Semitec USA (Ishizuka Electronics Corp.) part # AT103-1 (2).

The first example is for cold battery charging below 10°C and above 45°C, the **ICS1718** shutsdown. At 10°C, the resistance of the thermistor is nominally 18.0KΩ. At 45°C, the resistance drops to 4.75KΩ. The **ICS1718** has a voltage threshold for the low temperature at 2.4 , and a voltage threshold for the high temperature at 0.93 V. Voltages inside this window allow the **ICS1718** to operate as shown in Fig. 7. THERM pin 6 has an internal 75KΩ pull-up. A 0.02μF or larger capacitor from THERM pin 6 to ground is required for proper operation when using an NTC thermistor input.



Note 1) Diode to 15K divider is an option in charger stand applications for a battery with a NTC. THERM pin 6 is clamped below its 4.2V shutdown threshold with missing battery at power-up or battery removal allowing the polling mode to activate. See ApplicationsExamples. Diode to 15K divider is not applicable for batteries with thermal switch to groud.

Fig. 10: Voltage divider example for setting cold and hot battery levels

Typical Range	NTC cold/hot	R_s	R_{fix}
10 to 45°C	18.0K/4.75K	0	27K
5 to 51°C	22.05K/4.03K	1.8K	39K
4 to 58°C	23.00K/3.32K	3.3K	47K
1 to 60°C	26.13K/3.02K	4.3K	56K

Table 4A: Normal resistor values for various cold and hot battery levels (see Fig. 10)

A shorted thermal switch threshold of around 0.50 V at the THERM pin is available when either an opened thermal switch or no temperature sense device is used. If a voltage is below the shorted thermal switch threshold, the **ICS1718** assumes the thermal switch is closed to ground and the part is allowed to operate. When the thermal switch opens at high temperature, pin 6 internal 75KΩ pull-up resistor raises the voltage above the high temperature voltage threshold as shown in Fig. 9, and the **ICS1718** shuts down. If no temperature sense device is used, THERM pin 6 must be grounded.

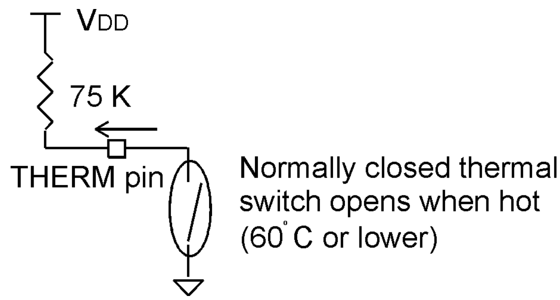


Fig. 11: Thermal switch connection to ground at the THERM pin.

Parameter	Voltage	Battery Temperature
Opened Thermal Switch Voltage	4.2	Switch opens in 50-60°C range
Cold Temperature Thermistor Voltage	2.4	Designer sets – See Table 4A
Hot Temperature Thermistor Voltage	0.93	Designer sets – See Table 4A
Shorted Thermal Switch Voltage	0.50	Not Applicable

Table 4B: THERM pin 6 Voltage Thresholds

Voltage Sense: *VIN* Pin

The normalized battery voltage is connected to the voltage sense (VIN) pin. The battery voltage must be normalized through a resistor divider network to the voltage of one cell. For example, if the battery consists of six cells in a series, the voltage at the VIN pin must be equal to the total battery voltage divided by six. This can be accomplished with two external resistors. To determine the correct resistor values, count the number of cells to be charged in series. Then choose either R_1 or R_2 and solve for the other resistor using:

$$R_1 = R_2 \times (\#\ \text{of cells} - 1) \quad \text{or} \quad R_2 = \frac{R_1}{(\#\ \text{of cells} - 1)}$$

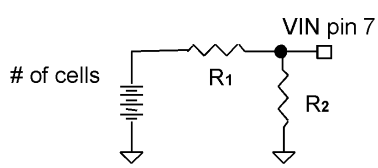


Fig. 12: Resistor divider network at the VIN pin 7.

Power: *VDD* Pin

The device power supply is connected to the VDD pin. The voltage is +5 VDC and is to be supplied to the part through a regulator rated for 100mA or more for handling periodic dynamic current demands.

Grounding: *VSS* Pin

The grounding pin is used to return the current that the indicator and output drivers must sink along with the internal digital logic. Connect the VSS pin directly to a solid ground point as close to the battery minus as practical. It is very important that care be taken to minimize noise coupling and ground bounce. Be sure to connect the ground side of the discharge transistor as close as possible to the negative of the battery. This will help reduce ground bounce and coupled noise. Make sure that signal power and ground traces are heavy, with bypass capacitors close to the IC.

Applications Information

VIN and OPREF Divider Resistors

R1 and R2 must be selected properly to ensure that battery detection and voltage termination methods operate properly. Refer to Figure 8 or figure 9. R1 and R2 are selected to scale the battery voltage down to the voltage of one cell. The following table shows some typical values.

Cells	R1	R2
1	20K	*
2	20K	20K*
3	39K	20K
4	62K	20K
5	82K	20K
6	100K	20K
7	120K	20K
8	150K	20K
9	160K	20K
10	180K	20K
11	200K	20K
12	220K	20K
13 & Above	R1=R2 x (# cells - 1)	

* UsE 5.1V Zener as required depending on input voltage

To ensure proper operation of the **ICS1708**, external components must be properly selected. The external current source used must meet several important criteria to ensure adequate performance of the charging system. The charging current source amplitude should be fairly constant.

PC Board Design Considerations

It is very important that care be taken to minimize noise coupling and ground bounce. Careful placement of wires and connectors helps minimize resistance and inductance.

When designing the printed circuit board, make sure ground and power traces are wide and bypass capacitors are used right at IC power and ground pins. Use separate heavy grounds for both signal and power circuits, connecting their grounds together close to where the negative lead of the battery connects. For power circuits, keep the physical separation between power and return (ground) to a minimum to minimize field effects. This precaution is most applicable to the constant current source, particularly if it is a switch mode type. Keep the **ICS1718** and the constant current source control circuits outside the power and return loop described above. These precautions will prevent high fields and coupled noise from disturbing normal operation. Avoid jumping across power and return with signal lines.

Using the Voltage Slope Termination Method

If the current source is a switch mode type, normal ripple current does not effect the ICS1718. However, the effects of line frequency ripple may interfere with proper performance.

In general the voltage slope termination method works best for products where the battery is fast charged with the product off, or the battery is removed from the product for fast charge in a charger stand.

The voltage slope termination method used by the **ICS1718** requires a nearly constant amplitude current flow into the battery during fast charge. Charging the battery in products that draw a known and fairly constant current while the battery is charging should have this current draw added to the fast charge current. Using the **ICS1718** for charging the batteries in products that randomly or periodically requires moderate current from the battery during fast charge needs evaluation. Products that randomly or periodically require high current from the battery during fast charge may cause a voltage inflection that results in termination before full charge. A voltage inflection can occur due to the charge current decreasing or fluctuating as the load changes rather than by the battery reaching full charge. The voltage slope method will terminate charge based on voltage inflections that are characteristic of a fully charged battery. The ICS1702 and ICS1712 charge controllers have temperature termination methods for products that randomly or periodically draw significant current from the battery during fast charge.

Charging sources that produce decreasing current as fast charge progresses may also cause a voltage inflection that may result in termination before full charge. For example, if the charge current is supplied through a resistor or if the charging source is a constant current type that has insufficient input voltage, the current will decrease and may cause a termination before full charge. Other current source abnormalities that may cause a voltage inflection that is characteristic of a fully charged battery are inadequate line frequency ripple attenuation capability or charge current decreasing due to thermal drift or thermal limiting. Charging sources that have any of the above characteristics need evaluation to access their suitability for the application if the use of voltage slope termination is desired.

The controller *SoftStart* stage, built-in noise filtering, and fast charge timer operate optimally when the constant amplitude current source charges the battery at the rate selected. If the actual charge current is significantly less than the rate selected, the conditioning effect of the *SoftStart* stage and the controller noise immunity are lessened. Also, the fast charge timer may cause termination based on time duration rather than by the battery reaching full charge due to inadequate charge current.

Data Tables

Absolute Maximum Ratings

Supply Voltage	6.5	V
Input /output pins	-0.5 to V_{DD} + 0.5	V
Ambient Operating Temperature	70	°C
Storage Temperature	-55 to 150	°C

Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these or other conditions above those listed in this document is not intended. Exposure to absolute maximum ratings adversely affects product performance.

DC Characteristics

Parameter	Symbol	Conditions	Min	Typ	Max	Units
Supply Voltage	V_{DD}		4.5	5.0	5.5	V
Supply Current, Average	I_{DD}		4.50	6.25	8.25	mA
Upper A/D Converter Range			2.2	2.3	2.3	V
Lower A/D Converter Range			0	0	0	V
A/D Resolution		8191 max count (13 bits)	400	353	280	µV
High Level Source Current, Pull-up	I_{PU}	THERM=2.0V	26	35	47	µA
High Level Source Current Maximum	I_{HCD}	CHG, DCHG	25	25	25	mA
Low Level Sink Current Maximum	I_{LCD}	CHG, DCHG	25	25	25	mA
Low Level Sink Current, CMN Max	I_{LL}	CMN	40	40	40	mA

Voltage Thresholds (Vdd = 5.0V), T_{amb}=25°C

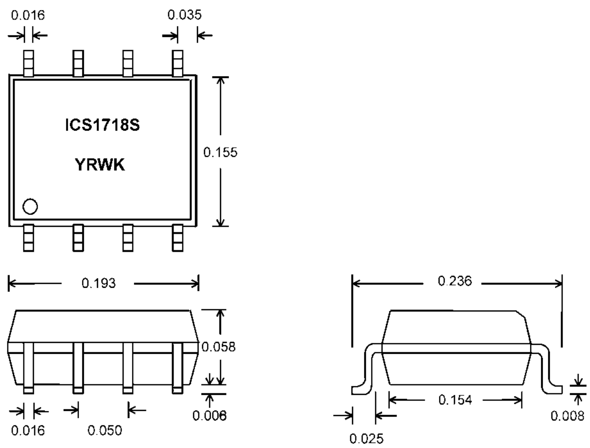
Parameter	Symbol	Pin Reference	Min	Typ	Max	Units
Minimum Internal Voltage Threshold	V_{MIN}	VIN	.47	.50	.53	V
Maximum Internal Voltage Threshold	V_{MIN}	VIN	1.85	2.00	2.12	V
Thermal Switch - Opened		THERM	4.00	4.20	4.45	V
Thermal Switch - Shorted		THERM	0.47	0.50	0.53	V
Thermistor - Cold Battery		THERM	2.26	2.4	2.55	V
Thermistor – Hot battery		THERM	0.88	0.93	0.98	V

Timing Characteristics (Vdd = 5.0V), T_{amb}=25°C, Ref. Fig. 3 and Fig. 4

Parameter	Symbol	R=15.0KΩ, C=100 pF	Min	Typ	Max	Units
Clock Frequency, Note 1	f_{CLK}	RC	.97	1	1.03	MHz
Thermal Switch Debounce		THERM	6.8	7.2	7.6	ms
Charge Pulse Width	t_{CPW}	CHG	1015	1048	1080	ms
Discharge Pulse Width	t_{DPW}	DCHG	4.7	5.0	5.3	ms
Voltage Rest Time		CHG	3.75	4.00	4.25	ms
Voltage Acquisition Time	t_{ADC}	VIN	15.4	16.4	17.4	ms
Cycle Time	t_{cycle}		1045	1077	1110	ms
Power-up Discharge Pulse Period	τ_{CD}	DCHG	97	100	103	ms
Polling Pulse Width	t_{PDW}	CHG	107	109	113	ms
Polling Pulse Period	τ_{PD}	CHG	605	624	645	ms
Polling Mode Duration		CHG	8.7	10.5	10.8	s
Soft-Start Initial Pulse Width	t_{IPW}	CHG	194	200	206	ms
Soft-Start Incremental Pulse Width	t_{inc}	CHG	6.7	7	7.3	ms
Soft-Start Length		CHG	1.9	2	2.1	min.
Topping Charge Length	t_{TC}	CHG	2	2.2	2.4	hrs

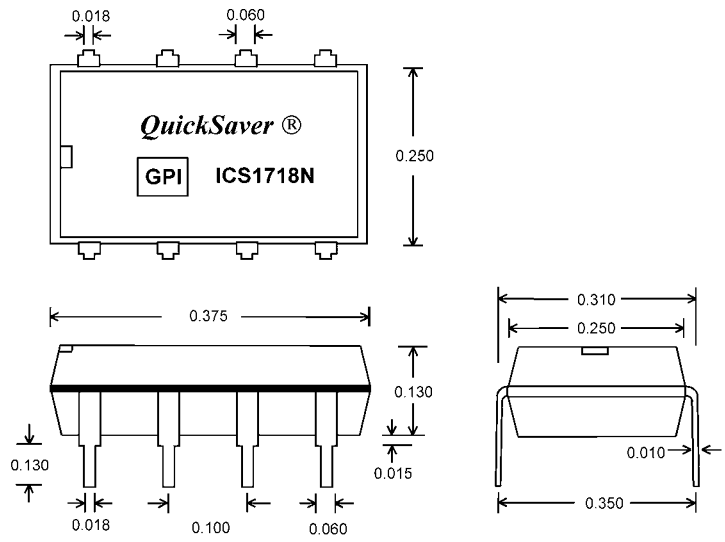
Note1: The timing characteristics above are for the 4C and 1C charge rates. For the 2C and C/2 charge rates, R=30.0K and C=100pF, so all of the above time durations double since the clock frequency is half (i.e. 500 KHz +/- 15KHz).

Package Information



All package dimensions are in inches.

8-Pin SOIC Package (150 mil)



All package dimensions are in inches.

8-Pin DIP package (300 mil)

Ordering Information

ICS1718S, ICS1718ST, ICS1718N

Example:

ICS 1718 ST

Package type: N= DIP 300 mil (Plastic)
S= SOIC 150 mil
ST= SOIC 150 mil Tape and Reel

Device type: Consists of 3 to 5 digits or numbers

Prefix: **ICS** = **I**ntelligent **C**harging **S**olution standard device

IMPORTANT NOTICE

Galaxy Power Incorporated makes no claim about the capability of any particular battery (NiCd or NiMH) to accept a fast charge. GPI strongly recommends that the battery manufacturer be consulted before fast charging. GPI shall be held harmless for any misapplication of this device such as: exceeding the rated specifications of the battery manufacturer; charging batteries other than nickel-cadmium or nickel-metal hydride type; personal or product damage caused by the charging device, circuit, or system itself; unsafe use, application, and/or manufacture of a charging system using this device.

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