

Application Note

DA1468x Battery Charging

AN-B-035

Abstract

This document describes the battery charging operation for a lithium-ion or lithium-polymer battery using the DA1468x device.

DA1468x Battery Charging

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Terms and Definitions

CDP	Charging Downstream Port
DCP	Dedicated Charging Port
I_{PRECHG}	Precharge current
Li-Ion	Lithium-Ion (battery)
Li-Po	Lithium-Polymer (battery)
NTC	Negative Temperature Coefficient
PS2	Personal System 2
SDP	Standard Downstream Port
USB	Universal Serial Bus
V_{PRECHG}	Precharge voltage
V_{RECHG}	Re-charging voltage

References

- [1] A Guide to the Safe Use of Secondary Lithium Ion Batteries in Notebook-type Personal Computers, JEITA Specification, April 2007.
- [2] [S-8261 Series, Battery protection IC for 1-cell pack](#), Seiko.

Introduction

Overview

Dialog's DA1468x series of devices support the charging circuit that enables charging a rechargeable battery.

Scope

Several battery chemistry types can be supported but the latest version of firmware in the DA1468x device supports charging a Li-Ion or a Li-Po battery (other battery types may be supported in the future). The device does not support automatic detection of the battery chemistry.

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Circuit Diagram

The battery and the external components should be connected to the DA1468x as shown in Figure 1.

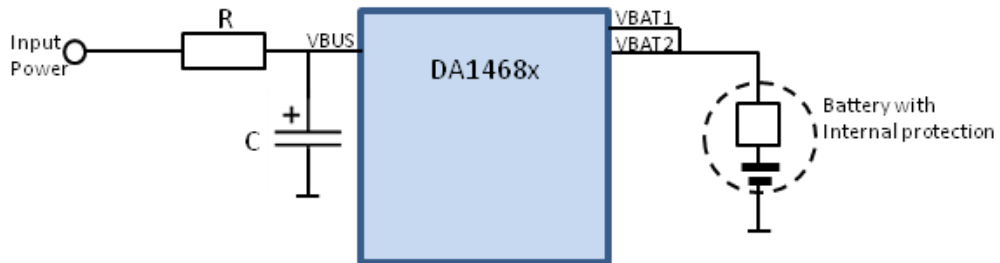


Figure 1: Connection of the External Components and a Lithium Battery to a DA1468x Device

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Input Power

Power input to the device can be from any one of the sources listed below.

- Proprietary charger
- PS2 port
- USB port
 - Dedicated Charging Port (DCP)
 - Standard Downstream Port (SDP)
 - Charging Downstream Port (CDP)

External Components

External components a **0.4 Ω resistor** and a **10 μ F capacitor** should be connected as close as possible to the Vbus pin of the DA1468x device.

Input Voltage and Current Requirements

The input voltage at the Vbus pin should be in the range 4.2 V to 5.75 V.

The maximum current that the power source should be able to provide must be at least equal to the battery capacity plus the current used by the device in the active mode. It is recommended that the maximum current from the power source should be at least 150 % of the battery capacity (e.g. for 100 mAh battery the maximum current should be at least 150 mA).

Note: The maximum current from a USB port in some cases may be limited to 100 mA. Supply currents lower than the recommended value may result in a longer charging time of the battery.

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Overview of the Charging Process

As shown in [Figure 2](#), the charging solution works in four main phases of operation, depending on the battery voltage:

1. Low battery voltage signifies a deeply discharged battery. Hence, it must be charged by a low value of current until it is brought to the threshold value, V_{PRECHG} . This phase is known as the precharge phase. The charging current in this phase is known as precharge current (I_{PRECHG}) and it is recommended that it is set to 2 % of the battery capacity.
2. Once the battery voltage increases to the V_{PRECHG} threshold, the prescribed maximum charge current is allowed to flow. It is recommended that the charging current is set to 70 % of the battery capacity. This phase is known as the constant-current phase.
3. After the battery voltage increases to the set regulation voltage the charging process enters this phase which is known as the constant voltage phase. In this phase the charging current reduces until the current equals 10 % of the battery capacity after which the charging process stops charging the battery and the battery is regarded as fully charged. The typical regulation voltage is 4.2 V for lithium based cells.
4. This phase is entered after the battery is fully charged. In this phase the charging process monitors the battery voltage periodically and if the voltage drops to V_{RECHG} (recharging voltage) then the charging process enters phase 2 else the process continues looping in this phase.

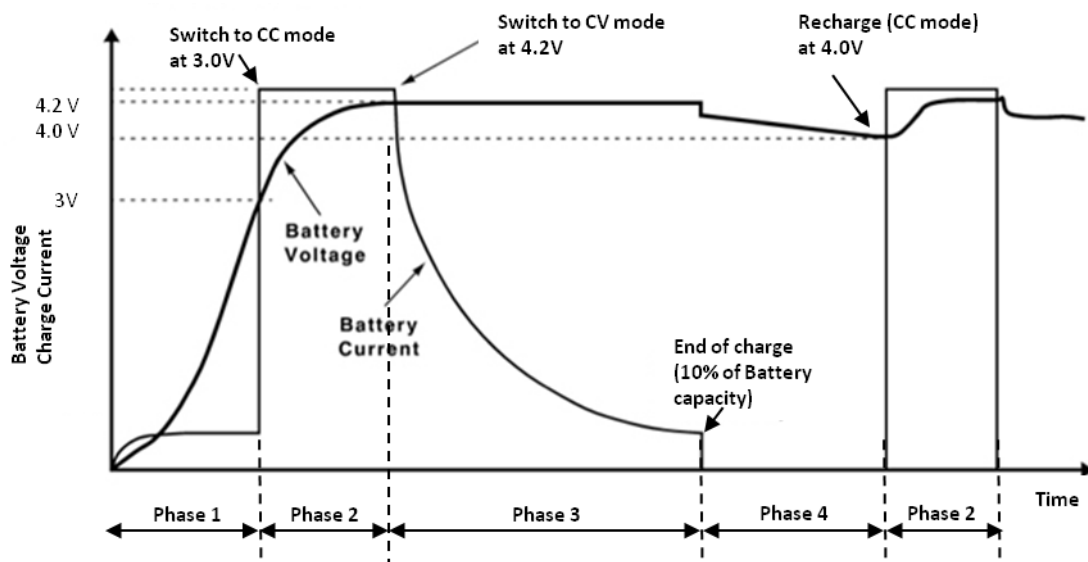


Figure 2: Four Phases of Charging Solution for Lithium Based Battery

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Safety Requirements

Several factors should be considered when charging a Li-Ion or Li-Po rechargeable battery correctly (i.e. within the operating limits). Incorrect operation of the battery or charging outside the limits of the battery may result in the battery melting (or even exploding). All Li-Ion and Li-Po battery have an internal protection circuit to protect the battery from severe charging or discharging conditions which depends on the chemistry, size and the manufacturer of the battery. [Table 1](#) shows the list of all the safety parameters that should be considered for a lithium battery charging solution.

Table 1: Charging Safety Requirements

No.	Detail of Safety Requirement
1	Short circuit of Vbus protection
2	Loose connection of Vbus (rapid on/off voltage on Vbus) protection
3	Short circuit of Vbat protection
4	Open circuit Vbat protection (removal of battery at any stage of charging process)
5	Reverse battery polarity protection
6	Primary cell charging protection
7	Battery chemistry change protection
8	Dead battery charging protection
9	Overvoltage charging protection
10	Overcurrent charging protection
11	Undervoltage discharging protection
12	Long period of precharging protection
13	Long period of constant current charging protection
14	Long period of constant voltage charging protection
15	Low temperature protection
16	High temperature protection

Some of the safety requirements are met by the internal protection circuit of the battery and some of the safety parameters are met by the hardware and firmware in the DA1468x device.

Safety Provided by Internal Protection Circuit

Most lithium based batteries come with a built-in protection circuit. An example of a protection circuit is based on the Seiko S-8261 device [2]. The protection circuit is suitable for protection of single-cell lithium-ion / lithium-polymer battery from:-

- Overvoltage charging
- Undervoltage discharging
- Overcurrent charging
- Overcurrent discharging (short circuit)

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Safety Provided by DA1468x

The hardware and the software in the DA1468x device provide the following protections:

- Undervoltage discharging (voltage limit can be set in the device which can be higher than that provided by the internal protection circuit). The device supports a brownout detection that switches the DC-DC off when the battery voltage drops below 2.5 V. The software can set the minimum voltage for the device to operate in LDO operation (after the DC-DC is switched off).
- Overvoltage charging (voltage can be set in the device). The user can set the maximum charging voltage (default is 4.2 V) and the software charging algorithm stops the charger when the maximum voltage is reached.
- Overcurrent charging (the maximum is set as 400 mA in the hardware and a lower limit can be set in the device).
- Long period of precharging protection (the time can be set in the device).
- Long period of constant current charging protection (the time can be set in the device).
- Long period of constant voltage charging protection (the time can be set in the device).
- Low temperature of battery protection by fitting external components (NTC thermistor and a resistor, as shown in [Figure 1](#)).
- High temperature of battery protection by fitting external components (NTC thermistor and a resistor, as shown in [Figure 1](#)).

Operation within Temperature Limits

Charging a battery should only be done within the operating temperature of the battery. The lower and upper temperature limits are defined by the manufacturer of the battery. A resistor should be connected in series with a NTC thermistor which should be fitted on the battery. The value of the resistor should be equal (or nearest) to the resistance value of the NTC thermistor at the upper temperature limit. Temperature measurement using DA1468x device is done by measuring the voltage between the NTC thermistor and the resistor connected as shown in [Figure 1](#). When enabled (NTC_Disable = 0 in the CHARGER_CTR1_REG) the charging circuit will automatically stop the charging process when the temperature is outside the operating temperature range.

Low temperature value is set such that the voltage = 7/8 of VDD. High temperature value is set such that the voltage = 1/2 of VDD.

Note: JEITA and Battery Association of Japan have defined the specification reference [1]. The specification defines a method of having three charging algorithms – one for low temperature, one for medium temperature and one for high temperature charging. The DA1468x device only supports one charging algorithm for the temperature range -40 °C to 100 °C.

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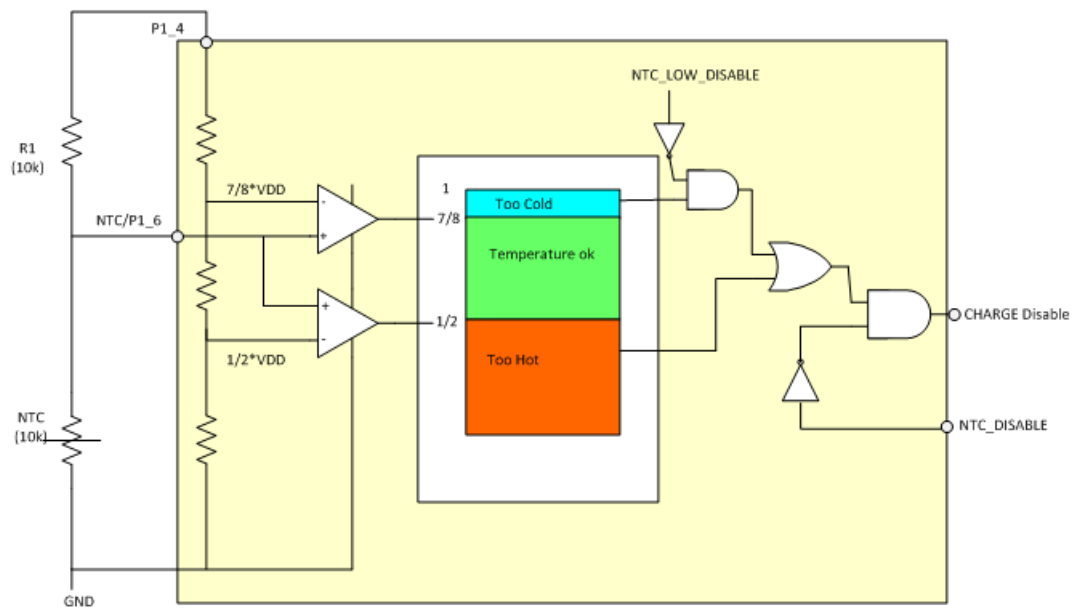


Figure 3: Connection of an NTC Thermistor to the DA1468x Device

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Charging Toolbox in the SDK

The SDK v1.0.6 and higher provides the customer the easiest way for setting the charging parameters to complete a charging solution in a product. The toolbox assumes that the customer is using the default values for USB configuration. For default USB configuration and charging algorithm values see [Appendix A](#).

The SDK toolbox provides access to four parameters that users can set within the defined range. Values outside the range are not permitted since it may damage the battery and cause the battery to malfunction.

Table 2: SDK Charging Toolbox

Toolbox Parameter	Range	Comments
Battery capacity	20 mAh to 500 mAh	Enter correct battery capacity. (Warning – Value should be checked with the battery manufacturer before entering)
Maximum battery voltage	4.2 V to 4.4 V	Battery voltage can be set to higher than 4.2 V. (Warning –A higher voltage may degrade the battery faster than setting it at 4.2 V)
Maximum charging current	10 mA to 400 mA	Charging current is normally 100 % of battery capacity. The lifetime of the battery can be improved if the charging current is set to 70 % of battery capacity. (Warning – The setting a value higher than 100 % maybe harmful and should be only done after consulting the battery manufacturer. The SDK will not allow the user to enter a value that exceeds 150 % of battery capacity, even though the value is within the range specified)
Precharge battery voltage	2.9 V to 3.1 V	Enter precharge voltage specified for the battery used. (Default value = 3.05 V)
Precharging current	1 mA to 5 mA	Precharging current is normally 2 % of battery-capacity. (Warning – The SDK will not allow the user to enter a value that exceeds 5 % of battery-capacity, even though the value is within the range specified)

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Appendix A Complete Set of Charging Parameters

A.1 Parameters for Charging

The configuration of the complete charging solution can be divided into three parts:

1. Configuration of the USB.
2. Charging algorithm configuration.
3. Charging parameters.

A.1.1 Configuration of the USB

Configuring of the USB connection is done using the four configuration registers as shown in [Table 3](#). The configuration register values in [Table 3](#) depend on the enumeration capability of the USB port.

Table 3: Registers for USB Configuration

Configuration Register	Value With Enumeration	Value Without Enumeration	Comment
dg_configUSE_USB_CHARGER Enable or disable the use of the charger.	1	1	
dg_configUSE_USB_ENUMERATION Enable or disable USB enumeration by the Host.	1	0 (default value)	
dg_configALLOW_CHARGING_NOT_ENUM Enable or disable charging before the enumeration is completed.	1	1	
dg_configUSE_NOT_ENUM_CHARGING_TIMEOUT Enable or disable timeout of power drawn from USB (only used without enumeration).	0	0	Set to 1 if USB specification is mandatory else set to 0.

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A.1.2 Charging Algorithm Configuration

The configuration of the charging algorithm requires the setting of various voltage levels in ADC measurement units. Voltage to ADC value calculation is done using the formula:

$$[\text{ADC units}] = (4095 * V_{\text{bat}}) / 5$$

Table 4 lists the configuration for the charging algorithm.

Table 4: Configuration Settings for the Charging Algorithm

Configuration Register	Value	Comment
dg_configPRECHARGING_INITIAL_MEASURE_DELAY	Undefined	Default setting: 30 ms.
dg_configPRECHARGING_THRESHOLD Voltage below which precharging starts.	2462	3.006 V
dg_configCHARGING_THRESHOLD Voltage when precharging stops and charging starts.	2498	3.05 V
dg_configPRECHARGING_TIMEOUT If precharging exceeds this value, the charging will stop.	180 000	30 min (unit: 0.01 s) Default setting: 15 min.
dg_configCHARGING_CC_TIMEOUT If CC phase of charging exceeds this value, the charging will stop.	720 000	2 h (unit: 0.01 s) Default setting: 3 h.
dg_configCHARGING_CV_TIMEOUT If CV phase of charging exceeds this value, the charging will stop.	1 080 000	3 h (unit: 0.01 s) Default setting: 6 h.
dg_configUSB_CHARGER_POLLING_INTERVAL This is the interval that the Vbat is polled to decide whether to re-charge – used when battery is fully charged.	6000	1 min (unit: 0.01 s) Default setting: 1 s.
dg_configBATTERY_CHARGE_GAP This is the safety limit used to check for battery overcharging.	Undefined	Default setting of 0.1 V is used.
dg_configBATTERY_REPLENISH_GAP This is the threshold below the maximum voltage level of the battery where charging will be restarted in order to recharge the battery.	Undefined	Default setting of 0.2 V is used.

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A.1.3 Charging Parameters

The Charger configuration depends on the characteristics of the battery that is used in the system. For example, a battery with charging voltage of 4.35 V and a charging profile as shown in [Figure 4](#). Below 3.0 V, the precharging current of 2.1 mA is supplied until the 3.0 V level is reached. Then the normal charging current of 30 mA is supplied. In the constant voltage phase the current decreases and charging is considered complete when the current reaches 10 % of the nominal value, i.e. 3 mA.

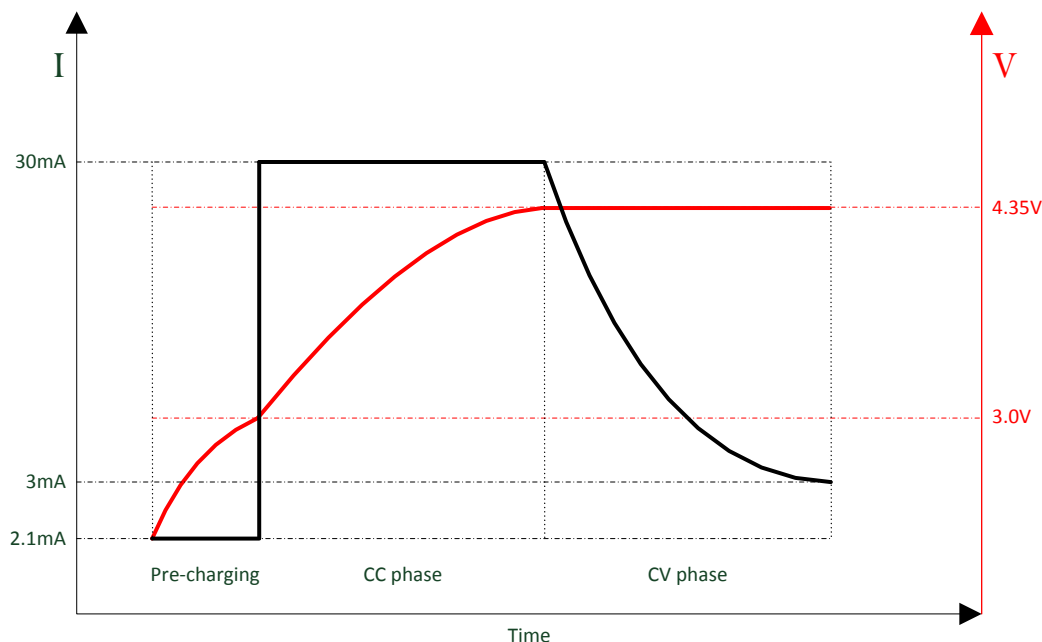


Figure 4: Example Charging Profile of a Battery

The configuration of the charger for specific battery types is listed in [Table 5](#).

Table 5: Configuration Settings for Specific Battery Types

Configuration Register	Value	Comment
dg_configBATTERY_TYPE Select battery type.	BATTERY_TYPE_LICOO2 BATTERY_TYPE_LIMN2O4 BATTERY_TYPE_LIFEPO4 BATTERY_TYPE_LINICOAIO2 BATTERY_TYPE_CUSTOM BATTERY_TYPE_NO_RECHARGE	Charging voltage 4.2 V. Charging voltage 4.2 V. Charging voltage 4.2 V. Charging voltage 4.2 V. Charging voltage NOT 4.2 V . For use with primary cells.
dg_configBATTERY_TYPE_CUSTOM_ADC_VOLTAGE Set charging voltage (only used for BATTERY_TYPE_CUSTOM).	7124	Charging voltage 4.35 V.
dg_configBATTERY_CHARGE_VOLTAGE Voltage level that is set in hardware	0xD	Charging voltage 4.35 V.
dg_configBATTERY_CHARGE_CURRENT Current level that is set in hardware.	2	Charging current 30 mA.
dg_configBATTERY_PRECHARGE_CURRENT Pre-charge current level that is set in hardware.	20	Pre-charge current 2.1 mA.
dg_configBATTERY_LOW_LEVEL Voltage limit for normal operation, below which the system enters hibernation mode.	2496	Battery low voltage 3.05 V.

DA1468x Battery Charging**Revision History**

Revision	Date	Description
1.0	26-Apr-2016	Initial version.
1.1	14-Jul-2016	<ul style="list-style-type: none">• ADC Calculator Excel sheet replaced with ADC-to-voltage formula.• Added information regarding the safety of undervoltage discharging and overvoltage charging.• Figure 3: Drawing with the NTC updated.• Table 4: Default delay specified, threshold values corrected.

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Status Definitions

Status	Definition
DRAFT	The content of this document is under review and subject to formal approval, which may result in modifications or additions.
APPROVED or unmarked	The content of this document has been approved for publication.

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