DS2715

NiMH Battery Pack Charge Controller

www.maxim-ic.com

DESCRIPTION

The DS2715 is well suited for cost-sensitive charger applications where the battery is either internal or in a unique battery pack. It has been optimized for safe reliable charging of 1 to10 NiMH cells in series. The DS2715 has an internal gain block that can be selected as either a comparator or transconductance amplifier for charge current regulation. The DS2715 is configurable as a switched DC charger, a linear current regulator, or a switchmode current source. The DS2715 pre-conditions severely depleted cells are pre-conditioned before entering full charge mode. The DS2715 terminates full charge using the dT/dt technique. It requires an external thermistor for dT/dt detection. Over-temperature, under-temperature, and over-voltage detection prevents charging under unsafe environmental conditions. A user selectable charge timer allows charge rates from 0.15C to 2C. Fast-charge, top-off and charge done modes are included for highly reliable, safe charging of NiMH cells. Discharge mode allows the DS2715 to enter a low power sleep state while the cell pack is being discharged.

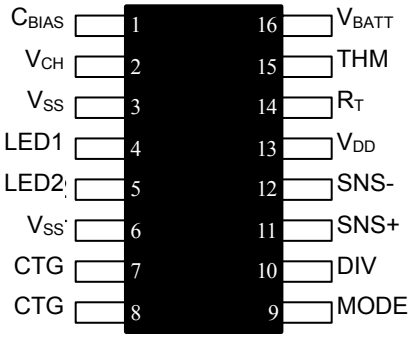
FEATURES

- Charges 1 to 10 NiMH Cells
- Fast Charges up to a 2C Rate
- Pre-Charge and Top-Off Charge Modes Help Cell Conditioning
- Load Detection Allows the DS2715 to Enter Low Power Sleep Mode (Less than 10µA) while the Cell Pack is Discharged
- dT/dt Charge Termination Eliminates Cell Charge Stress
- Monitors Voltage, Temperature, and Time for Safety and Secondary Termination
- Regulates Current through Either Linear Control or Switch-Mode Control
- LED Outputs Display Charge State
- Small 16-Pin SO Package

APPLICATIONS

Portable DVD Players
Portable Television Sets
Handheld Gaming
Test Equipment
Handheld POS Terminals

PIN CONFIGURATION



16 SO

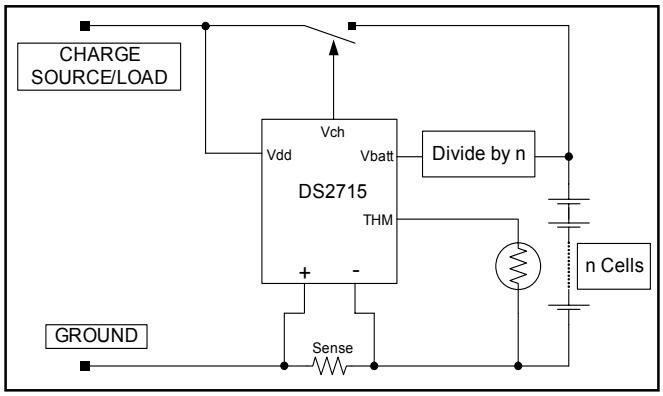
See Table 1 for Ordering Information.

Table 1. ORDERING INFORMATION

PART	MARKING	PIN-PACKAGE
DS2715Z+	DS2715+	16 SO
DS2715Z+T&R	DS2715+	16 SO Tape-and-Reel

+ Denotes lead-free package.

OPERATIONAL DIAGRAM



Note: *Some revisions of this device may incorporate deviations from published specifications known as errata. Multiple revisions of any device may be simultaneously available through various sales channels. For information about device errata, click here: www.maxim-ic.com/errata.*

ABSOLUTE MAXIMUM RATINGS*

Voltage on V_{DD} and V_{CH} Pins with Respect to V_{SS}	-0.3V to +18V
Voltage on LED1 and LED2 Pins	-0.3V to +18V
Voltage on SNS-	-0.3V to +0.3V
Voltage on C_{BIAS}	-0.3V to 6V
Voltage on all Other Pins	-0.3V to V_{Cbias}
Continuous Sink Current V_{CH}, LED1, and LED2	28mA
Operating Temperature Range	-20°C to +85°C
Storage Temperature Range	-55°C to +125°C
Soldering Temperature	See IPC/JEDECJ-STD-020

**This is a stress rating only and functional operation of the device at these or any other conditions above those indicated in the operation sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods of time may affect reliability.*

RECOMMENDED DC OPERATING CONDITIONS

($4.5V \le V_{DD} \le 16.5V$; T_A = 0°C to +70°C.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Supply Voltage	V_{DD}	(Note 1)	4.5		16.5	V
LED1, LED2 Voltage	V_{LED}	(Note 1)	0.0		16.5	V
Mode Voltage	V_{MODE}	(Note 1)	0.0		V_{Cbias}	V
V_{CH} Voltage	V_{VCH}	(Note 1)	0.0		16.5	V
C_{BIAS} Capacitor Range	C_{Cbias}		.02		.15	µF
R_T Resistor Range	R_{Rt}		20		240	KΩ

DC ELECTRICAL CHARACTERISTICS

($4.5V \le V_{DD} \le 16.5V$, T_A = 0°C to +70°C, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Operating Current (Note 2)	I_{DDA}	Linear Mode, V_{DD} = 16.5V		1.3	1.6	mA
		Comparator Mode, V_{DD} = 16.5V		150	250	µA
Idle Current	I_{DDS}	$V_{DD} < V_{UVLO}$			10	µA
Discharge Current	I_{DDD}	Discharge latch set (Note 2)			200	µA
UVLO Threshold	V_{UVLO}	V_{DD} Rising (Note 3)	3.8	3.9	4.0	V
UVLO Hysteresis	$V_{UVLO-HYS}$	V_{DD} Falling		35		mV
V_{CH} Sink Current	I_{OL-Vch}	V_{OL} = 1.5V	20			mA
LED1, LED2 Sink Current	I_{OL-LED}	V_{OL} = 1.0V	20			mA
Leakage Current, V_{CH}, LED1, LED2	I_{LKG}	Pin inactive or Device Idle	-1		+1	µA
THM Pin Leakage Current	$I_{LKG-THM}$		-1		+1	µA
V_{BATT} Pin Leakage Current	$I_{LKG-Vbatt}$		-50		+50	nA
C_{BIAS} Voltage	V_{Cbias}	$0 < I_{Cbias} < 0.4ma$	3.9	4.0	4.3	V
DIV Pin Load Current	I_{Div}				500	uA
Current Sense Amplifier Gain	G_{ERR}	$100\mu A < I_{Vch} < 20mA$	5	6.25	7.5	$\tilde{\Omega}^{-1}$
Current Sense Comparator Gain	G_{COMP}	(Note 7)	10			$\tilde{\Omega}^{-1}$

AC ELECTRICAL CHARACTERISTICS

($4.5V \le V_{DD} \le 16.5V$, T_A = 0°C to +70°C, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
UVLO Debounce Time	t_{UVLO}		10			µs
Current Sense Comparator Propagation Delay	t_{COMP}	(Note 7)			250	ns
Discharge Detect Propagation Delay	t_{DD}	From detection of current reversal			1	µs
Return To Normal Function (Op-Amp or Comparator Mode)	t_{RNF}	Time from reset of discharge latch			1	µs
R_T Timing Accuracy	t_{Rt}	(Note 4)	-10		+10	%
Internal Clock Accuracy	t_{BASE}		-10		+10	%

ELECTRICAL CHARACTERISTICS: CHARGING

($4.5V \le V_{DD} \le 16.5V$, T_A = 0°C to +70°C, unless otherwise noted.)

PARAMETER	SYMBOL	CONDITIONS	MIN	TYP	MAX	UNITS
Fast Charge Comparator Threshold	V_{FC}	Fast charge	-127	-121	-115	mV
Fast Charge Comparator Hysteresis	V_{HYS-FC}	Fast charge	-31	-28	-25	mV
Top-off and Pre-Charge Comparator Threshold	V_{TO}	Top-off and pre-charge	-38	-33	-28	mV
Top-off and Pre-Charge Comparator Hysteresis	V_{HYS-TO}	Top-off and pre-charge	-10	-8	-6	mV
Discharge Latch Reset Threshold	$V_{DCHG-RST}$		-15	-10	-5	mV
Discharge Latch Set Threshold	$V_{DCHG-SET}$	Reverse current through sense resistor	5	10	15	mV
Low Battery Detect Threshold	V_{LB}	From presence detect into pre-charge	0.95	1.0	1.05	V
Cell Detect Threshold	V_{DET}		1.50	1.55	1.60	V
No Cell Detect Threshold	V_{OPEN}		1.60	1.65	1.70	V
Presence Detect Threshold Hysteresis	V_{HYS-PD}		90	100	110	mV
Minimum Charge Temp	$V_{THM-MIN}$	(Note 5, 6)	2.88	2.92	2.96	V
				0		ºC
Maximum Charge Temp	$V_{THM-MAX}$	(Note 5, 6)	1.28	1.32	1.36	V
				45		ºC
Over Temp	$V_{THM-STOP}$	(Note 5, 6)	1.12	1.16	1.20	V
				50		ºC
dT/dt Detect	T_{TERM}		0.425	0.5	0.575	ºC/min
dT/dt Blanking Time	t_{BLANK}		3.85	4.3	4.75	Min
Fast Charge Timer Range	t_{FC}		0.5		6	Hours
Top-Off to Fast Charge Duration Ratio				1:2		

Note 1: Voltages relative to V_{SS}.
Note 2: Does not include current through V_{CH}, R_T, and DIV pins.
Note 3: Below this voltage no I/O pins are active.
Note 4: Does not include tolerance of R_T resistor.
Note 5: V_{BIAS} and resistor tolerances must be added to determine actual threshold.
Note 6: Specified temperature thresholds are only valid if recommended thermistor types are used.
Note 7: Specification is guaranteed by design.

DETAILED PIN DESCRIPTION

PIN	NAME	DESCRIPTION
1	C_{BIAS}	Bypass for Internal Voltage Regulator
2	V_{CH}	Cell Stack Charge Control Output
3	V_{SS}	Ground Reference and Chip Supply Return
4	LED1	Charging Indicator Output
5	LED2	Done Indicator Output
6	V_{SS}	Ground Reference and Chip Supply Return
7	CTG	Connect to Ground
8	CTG	Connect to Ground
9	MODE	Mode Select. Connect to V_{SS} for linear mode of operation or C_{BIAS} for comparator mode of operation.
10	DIV	Thermistor Divider. Stable output to form a resistor divider for measuring temperature on THM.
11	SNS+	Positive Current Sense. Connect to the pack side of the sense resistor.
12	SNS-	Negative Current Sense. Connect to the cell stack side of the sense resistor.
13	V_{DD}	Chip Supply Input: +4.0V to +5.5V range.
14	R_T	Failsafe Timeout. Timeout is selected by an external resistor from R_T to V_{SS}.
15	THM	Thermistor Input. Connect to a thermistor located in the cell pack and a divider resistor from the Div pin.
16	V_{BATT}	Battery Voltage Sense Input. Connect to a divider from the positive terminal of the cell stack to measure the voltage of a single cell.

Figure 1. BLOCK DIAGRAM

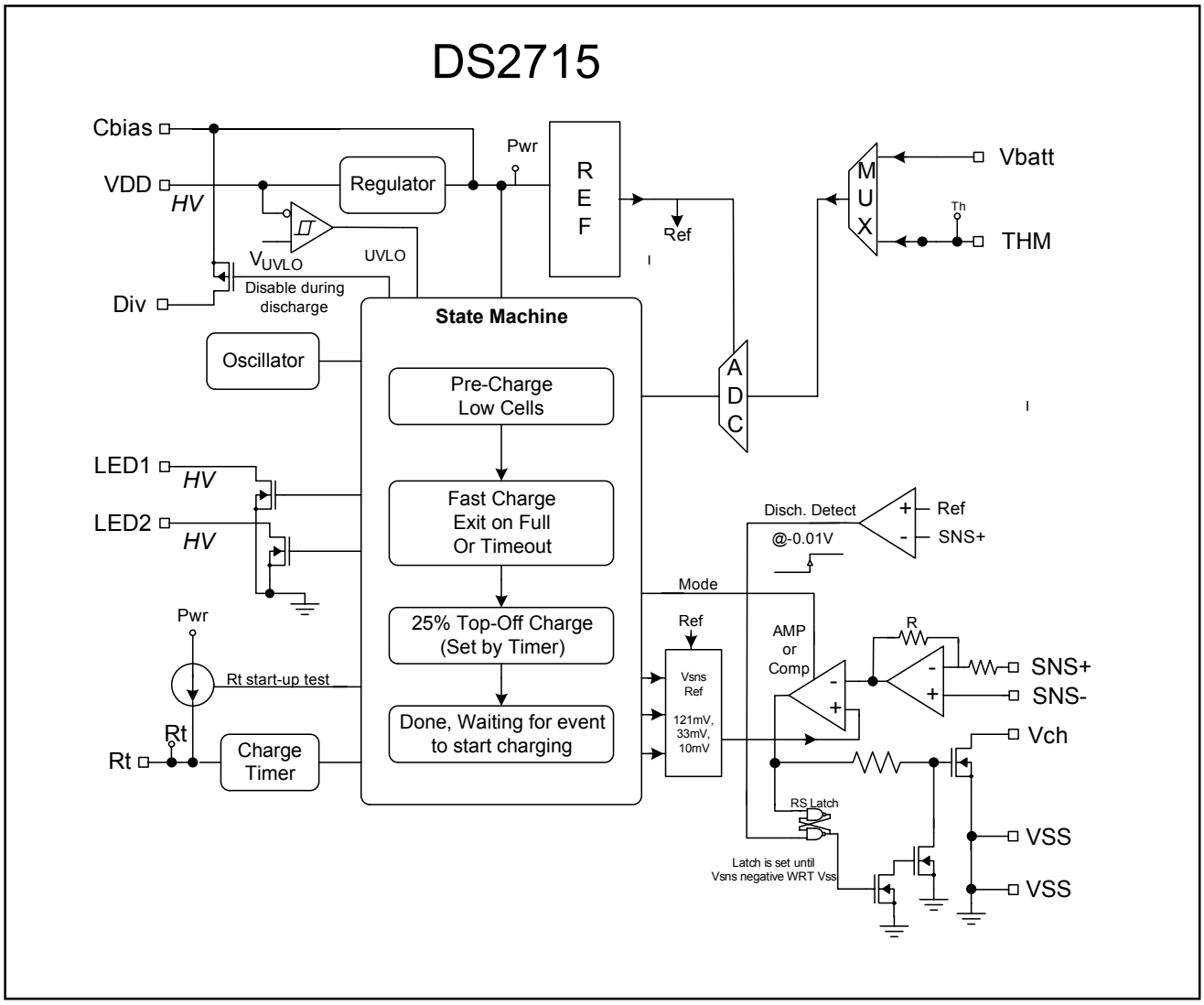
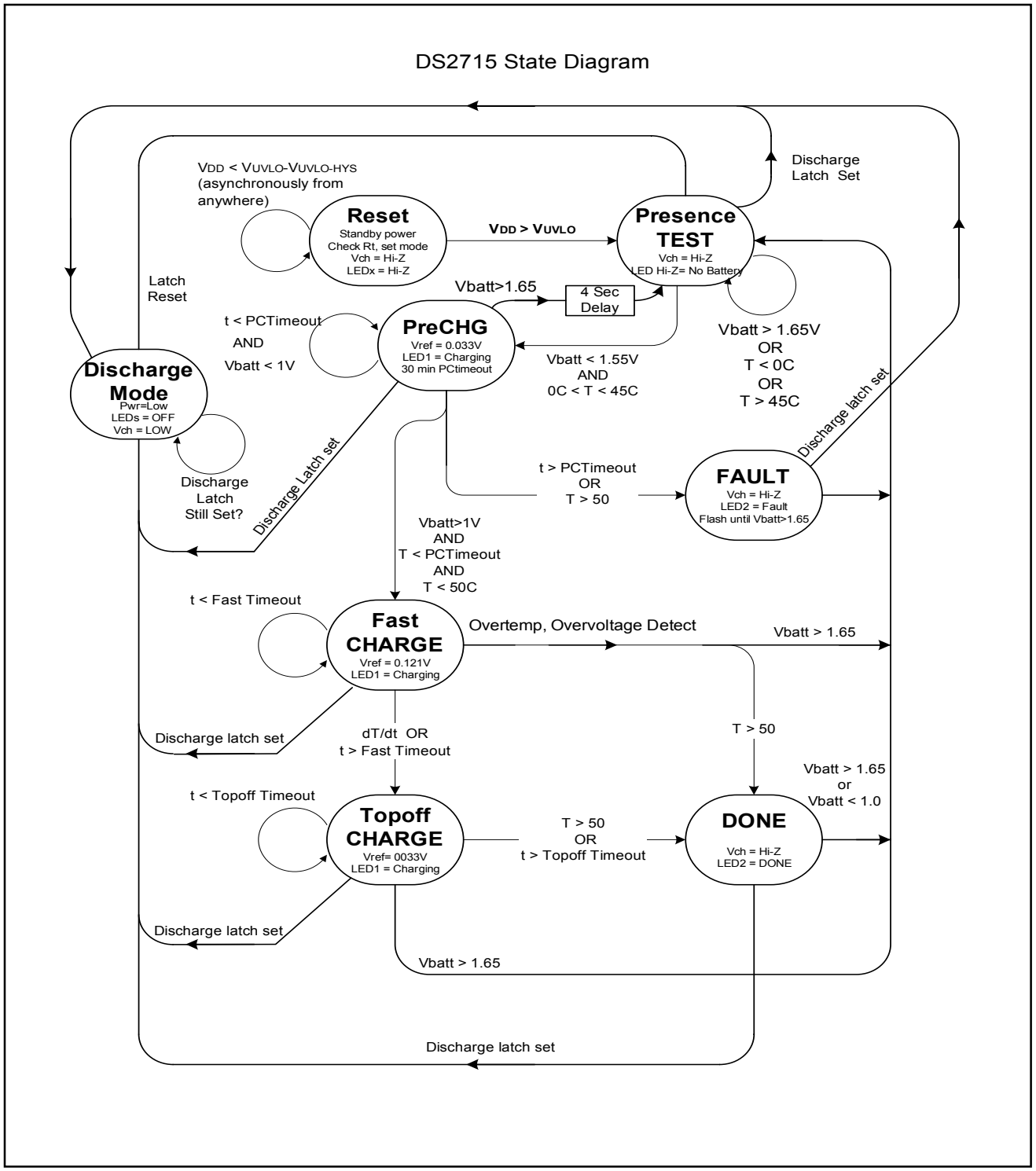


Figure 2. STATE DIAGRAM



DETAILED DESCRIPTION

Charge Cycle Overview

The DS2715 regulates the charge of up to 10 NiMH cells in a series configuration. With the mode select pin the DS2715 can be configured to regulate either as an error amplifier in linear mode or as a comparator in switched mode. A charge cycle begins in one of two ways: with the application of power to the DS2715 with cell pack already inserted or with the detection of cell insertion after power-up.

The charge cycle begins with pre-charge qualification to prevent fast charging of deeply depleted cells or charging under extreme temperature conditions. Pre-charging is performed at a reduced rate until each cell reaches 1V. The algorithm proceeds to a fast-charge phase. Fast charging continues as long as the cell pack temperature is less than 50°C based on the THM voltage, the cell voltage as measured by the V_{BATT} pin remains below 1.65V indicating the cell pack is still present. Fast charging terminates by measuring the cell pack's thermal rate of change dT/dt. When the cell pack's thermal rate of change exceeds 0.5°C per minute the DS2715 enters top-off. The DS2715 has an internal charge timer as secondary overcharge protection if the charge is not terminated by the dT/dt method. The charge termination timer duration is user selectable from 30 minutes up to 6 hours by an external resistor on the R_T pin.

The DS2715 remains in top-off for one-half of the period of the fast charge timer duration as selected by the external resistor on R_T. After the top-off charge timer expires, the done phase continues indefinitely until the cell pack is removed from the charger or a load is attached. When a load attached to the cell pack, the DS2715 switches to discharge mode. All charge functions are disabled and the regulation FET is driven on to allow the cell pack to discharge. Two LED indicators display the charge status to the user.

Undervoltage Lockout (Reset)

The UVLO circuit serves as a power-up and brownout detector by monitoring V_{DD} to prevent charging until V_{DD} rises above V_{UVLO}, or when V_{DD} drops below V_{UVLO} - $V_{UVLO-HYS}$. If UVLO is active, charging is prevented, the state machine is forced to the RESET state, and all charge timers are reset. A 10µs deglitch circuit provides noise immunity. Once V_{DD} reaches an acceptable operating voltage the DS2715 enters the PRESENCE state.

Presence

The DS2715 enters the PRESENCE state whenever $V_{DD} > V_{UVLO}$ and $V_{BATT} > V_{OPEN}$ indicating that the charge source is present, but no cell is available to charge. The DS2715 will remain in the presence state until a cell is inserted into the circuit causing the voltage on V_{BATT} to fall below 1.55V (V_{DET}) and the cell temperature is inside a valid charging range between 0°C and 45°C ($T_{THM-MIN}$ and $T_{THM-MAX}$). If both these conditions are met the DS2715 will enter pre-charge. If cells are inserted, but the temperature is outside the valid charging range the DS2715 will remain in the PRESENCE state until the cell temperature falls within the valid charging range.

Pre-Charge

The DS2715 enters the PRE-CHARGE state when a valid cell voltage is applied to V_{BATT} and the cell temperature as measured by the DS2715 is within the valid charging range. Pre-charge has a 4 second filter to suppress noise on V_{BATT} caused by cell insertion. The DS2715 pre-charges the cell by regulating the voltage drop across the sense resistor to -33mV (V_{TO}) in linear mode or -29mV (V_{TO} - 0.5 x V_{HYS-TO}) in comparator mode. Pre-charge will last until the cell voltage measured by V_{BATT} exceeds 1.0V ($V_{BATT} > V_{LB}$) at which time the DS2715 will enter FAST CHARGE state. If the cell voltage does not exceed V_{LB} within 30 minutes or if the cell temperature exceeds 50°C at any time during pre-charge, the DS2715 enters the FAULT state. If at any time during pre-charge the voltage on V_{BATT} exceeds 1.65V (V_{OPEN}), the DS2715 determines that the cell pack has been removed and returns to the PRESENCE state.

Fast Charge

In fast charge mode, the DS2715 regulates the voltage across the sense resistor to -121mV (V_{FC}) in linear mode or -107mV (V_{FC} - 0.5 x V_{HYS-FC}) in comparator mode. LED1 indicates the cell pack is being charged. During fast charge the DS2715 constantly measures the rate of change of the cell temperature (dT/dt). When the cell pack's dT/dt exceeds 0.5°C per minute (T_{TERM}) the DS2715 enters the TOP-OFF state. The DS2715 ignores changes in the cell temperature caused by charge initiation for the first 4.3 minutes (t_{BLANK}). As secondary overcharge protection, the DS2715 will terminate fast charge and enter top-off based on a time delay set by the external resistor on the R_T pin. This resistor value can set the secondary charge termination delay to anywhere from 30 minutes up to 6 hours. If the cell temperature exceeds 50°C at any time during fast charge, the DS2715 enters the

DONE state. If at any time during fast charge the voltage on V_{BATT} exceeds 1.65V (V_{OPEN}), the DS2715 determines that the cell pack has been removed and returns to the PRESENCE state.

Top-Off

In top-off mode, the DS2715 regulates the voltage across the sense resistor to -33mV (V_{TO}) in linear mode or -29mV (V_{TO} - 0.5 x V_{HYS-TO}) in comparator mode. LED1 indicates the cell pack is being charged. The charge timer is reset and restarted with a time-out period of one half the fast-charge duration. When the charge timer expires or if the measured temperature exceeds 50°C, the charger enters the DONE state.

DONE/Maintenance

The DS2715 enters the DONE state whenever the charge completes normally or if the measured cell temperature exceeds 50°C during the charge. While in the done state V_{CH} is driven to high impedance to prevent further charging of the cell pack and LED is driven on to indicate charge completion. A maintenance charge can be applied to the cells by providing a resistive path from the cell pack to the charge source bypassing the regulator. See the example circuit in Figure 3. The DS2715 remains in DONE until a cell voltage greater than 1.65V (V_{OPEN}) is detected on V_{BATT} indicating the cell pack has been removed. The DS2715 then enters the PRESENCE state and waits for the next cell insertion.

FAULT

The DS2715 enters FAULT if pre-charge is unable to charge the cell above 1.0V (V_{LB}) before the 30 minute pre-charge timeout of if the cell temperature exceeds 50°C during pre-charge. In the fault state V_{CH} is driven to high impedance and LED2 blinks to indicate the fault condition. The DS2715 remains in FAULT until a cell voltage greater than 1.65V (V_{OPEN}) is detected on V_{BATT} indicating the cell pack has been removed. The DS2715 then enters the PRESENCE state and waits for the next cell insertion.

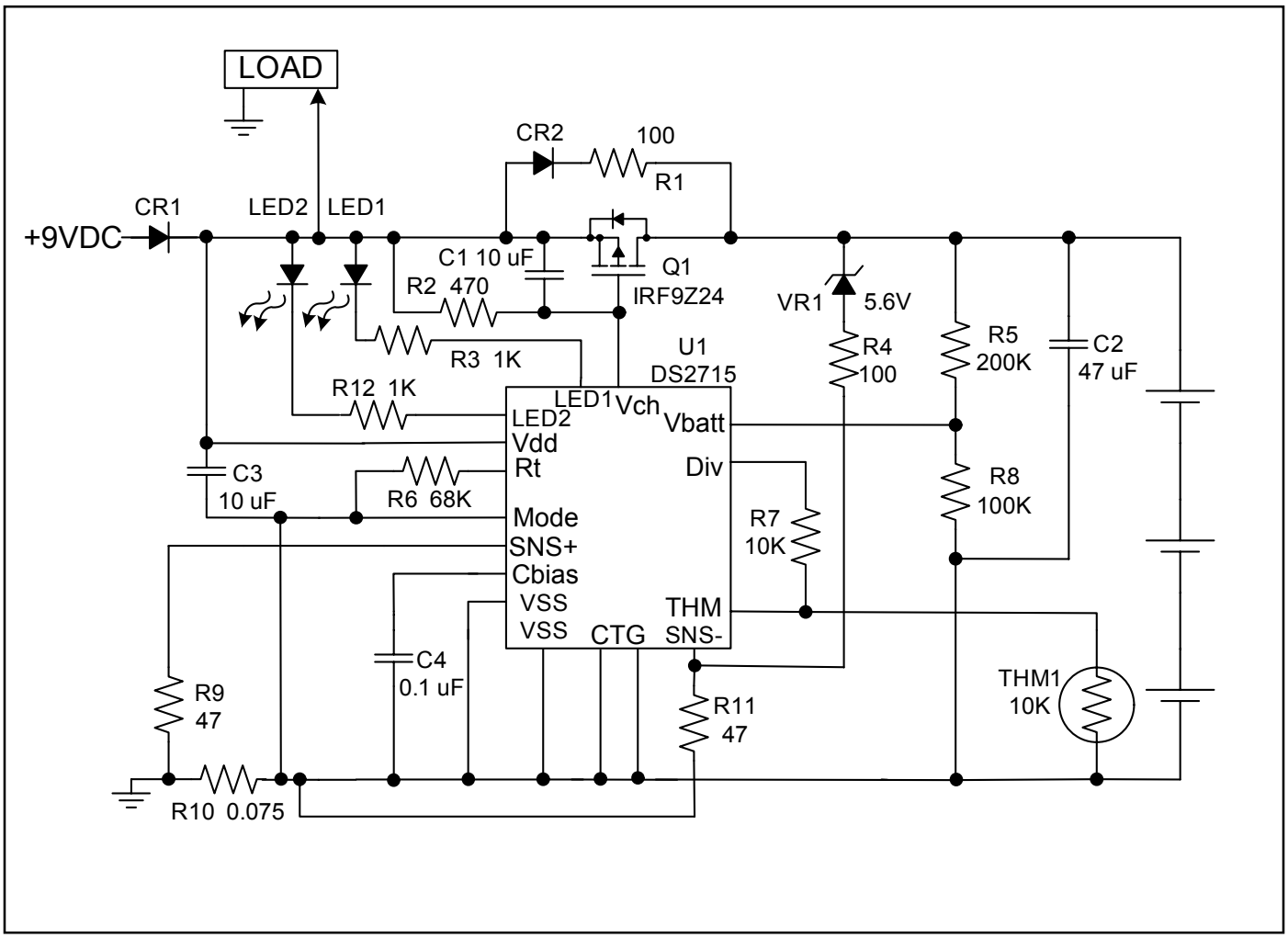
Discharge Mode

When the DS2715 detects a discharge current voltage drop of $V_{DCHG-SET}$ or greater across the sense resistor, charging is terminated and the DS2715 enters the DISCHARGE state. While in this mode, voltage sensing, thermal sensing, and LED outputs are disabled. The V_{CH} pin is driven low to allow the pack to be discharged. Current drain of the DS2715 drops to I_{DDD}. The DS2715 remains in discharge mode until a charge current of at least $V_{DCHG-RST}$ is detected. When this occurs the DS2715 enters the presence detect state to begin a new charge cycle.

Application Circuit

Figure 3 shows a typical application circuit for charging a 3-cell stack. The mode pin is tied to V_{SS} for linear operation. A 75mΩ sense resistor (R10) sets the charge current at 1.6A. The DS2715 regulates the current through Q1. 68kΩ on R_T (R6) sets the fast charge timeout to 102 minutes. R5 and R8 form a 1:3 voltage divider to allow V_{BATT} to measure the voltage of a single cell. The charge source is isolated with diode CR1 to prevent discharge through the source connection. R1 and CR2 form a maintenance charge path to supply the cell pack with ~40mA constant current after the charge completes. Lastly VR1 and R4 create a current leakage path to bias the regulator circuit and prevent an in-rush current spike when the cell stack is connected to the powered circuit.

Figure 3. TYPICAL APPLICATION CIRCUIT FOR A 3-CELL STACK



CURRENT REGULATION

Three basic modes of charging operation are supported by the DS2715: Offline switching through an optocoupler, linear regulation, and DC input switched mode. The DC Switched method requires a currrent-limited power source. Mode of operation is selected through the Mode pin. Connecting the Mode pin to V_{SS} configures the analog block as a transconductance amplifier for linear mode of operation. Connecting the Mode pin to the Cbias pin configures the DS2715 as a comparator for switched mode of operation.

Current-Sense Amplifier Mode

An error amplifier block provides several options to regulate the charge current. The 20mA open-drain output can drive a PMOS or PNP pass element for linear regulation, or the output can drive an optocoupler for isolated feedback to a primary-side PWM controller. The SNS- pin is a remote-sense return and should be connected to the grounded side of the sense resistor using a separate, insulated conductor. During fast charge, an error signal between the current-sense signal (across the sense resistor) and the internal reference is produced so the voltage across the sense resistor is maintained at V_{FC} in a closed-loop circuit. During top-off the voltage across the sense resistor is maintained at V_{TO}.

Current-Sense Comparator Mode

The comparator in the DS2715 switches between ON and OFF and is capable of driving a PNP bipolar or a PMOS transistor, enabling the use of a switched-mode power stage. Hysteresis on the comparator input provides noise rejection. In a closed-loop regulation circuit, the comparator regulates voltage across the sense resistor to a DC average of:

$V_{RSNS} = V_{FC} - 0.5 \times V_{HYS-FC} = -0.107V$ during fast charge

$V_{RSNS} = V_{TO} - 0.5 \times V_{HYS-TO} = -0.029V$ during top-off

Charge Rate Selection

The charge rate is determined by an external sense resistor connected between the SNS+ and SNS- pins. The DS2715 will regulate the charge current to maintain a voltage drop of V_{FC} ($V_{FC} - 0.5 \times V_{HYS-FC}$ in comparator mode) across the sense resistor during fast charge. The sense resistor can therefore be selected by:

Linear Mode: $R = V_{FC}$ / Desired Fast Charge Current

Comparator Mode: $R = (V_{FC} - 0.5 \times V_{HYS-FC})$ / Desired Fast Charge Current

Charge Time and Top-Off Time Selection

Pre-charge has a fixed 30 minute limit generated by an internal oscillator. Charge time and top-off time are controlled by an external resistor from the R_T pin to V_{SS}. Resistors can be selected to support fast-charge time-out periods of 0.5 to 6 hours and top-off charge time-out periods of 0.25 to 3 hours. If the timer expires in fast-charge, the timer count is reset and charging proceeds to the top-off charge phase. The top-off time-out period is half of the fast charge time-out period. If the timer expires in top-off, the DS2715 enters the DONE state. The programmed charge time approximately follows the equation:

$t = 1.5 \times R / 1000$ (time in minutes)

TEMPERATURE SENSE

Accurate temperature sensing is needed to determine end of charge by dT/dt and to detect over temperature fault conditions. Connecting an external 10kΩ NTC thermistor between THM and V_{SS}, and a 10kΩ bias resistor between Div and THM allows the DS2715 to sense temperature. To sense the temperature of the cell pack, locate the thermistor close to the body of a cell, preferably in the middle of the cell pack. Several recommended 10kΩ thermistors are shown in Table 2.

Min, Max Temperature Compare

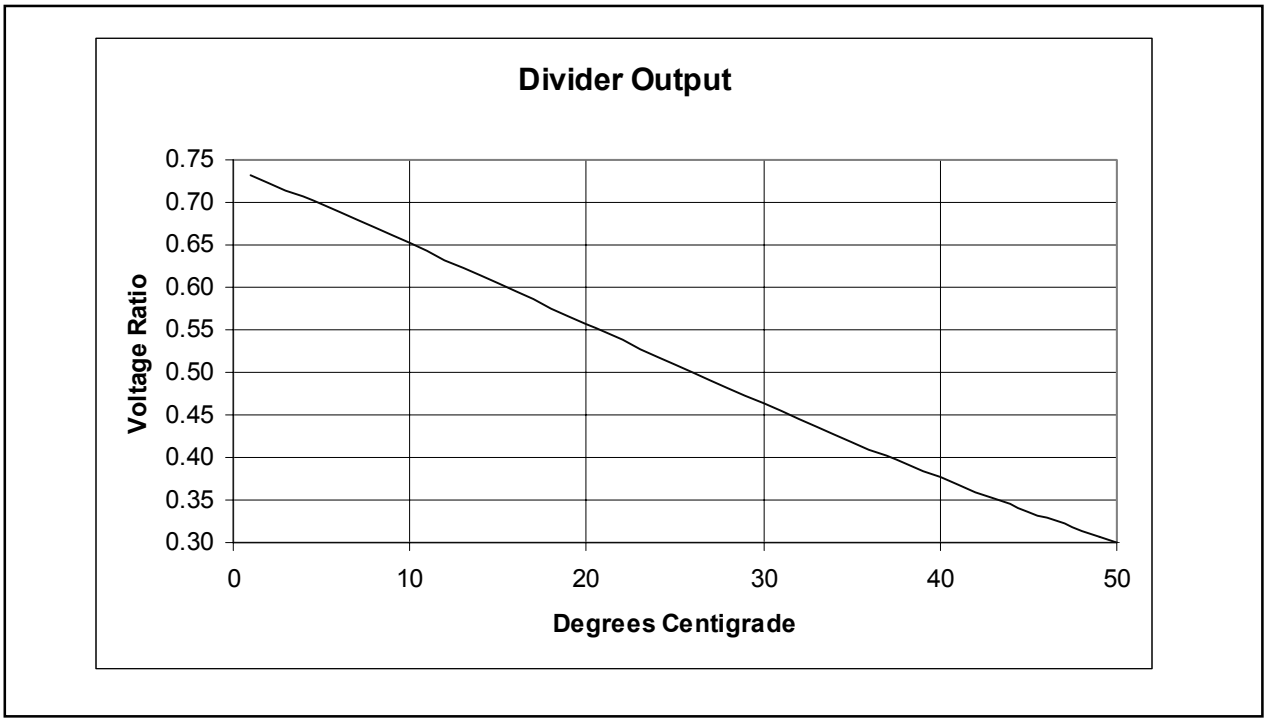
The voltage thresholds of the THM input ($V_{THM-MIN}$, $V_{THM-MAX}$) are set to allow charging to start if 0°C < T_{CELL} < 45°C when using the recommended 10kΩ bias and 10kΩ thermistor. If pre-charging is in progress, and the voltage on THM reaches $V_{THM-STOP}$, pre-charging stops and a fault condition is generated. If the voltage on THM reaches $V_{THM-STOP}$ during fast charge or top-off, charging stops and the DS2715 enters the DONE state. Fast charging will complete normally and top-off will begin if the voltage change on THM exceeds T_{TERM} ºC per minute (dT/dt charge termination).

Table 2. THM1, THM2 THRESHOLDS

THM THRESHOLD	RATIO OF V_{CBIAS}	THERMISTOR RESISTANCE (Ω)	TEMPERATURE (°C)	
			Semitec 103AT-2	Fenwal 197-103LAG-A01 173-103LAF-301
MIN	0.73	27.04k	0°C	4°C
MAX	0.33	4.925k	45°C	42°C
STOP	0.29	4.085k	50°C	47°C

Used with a 10k resistor the Semitec 103AT-2 provides about 0.9% full scale per degree sensitivity. This linearity is shown in the curve in Figure 4. The left axis is the ratio of the sensed voltage to the divider's input voltage (V_{Cbias}).

Figure 4. RATIO OF THM PIN TO CBIAS PIN OVER TEMPERATURE



LED1 and LED2 Outputs

Open-drain outputs LED1 and LED2 pull low to indicate charge status. When inactive, the outputs are high impedance. LED1 displays the state of charge and LED2 displays the charge results. The LED1 pin drives low in a 1Hz, 50% duty cycle “blink” pattern to indicate cells are charging. LED2 drives low with 100% duty cycle to signal a successful charge completion or blinks at 4Hz, 50% duty cycle to signal a charging fault has occurred. Both LED pins remain in a high-impedance state when no cells are present or the discharge latch is set. LED pins can be tied together if only one LED display is desired. Table 3 summarizes the LED operation for each charge condition.

Table 3. LED DISPLAY PATTERNS BASED ON CHARGE STATE

	CHARGE STATE				
	NO BATTERY	**CHARGING**	**DONE**	**FAULT**	**DISCHARGE MODE**
LED1	High-Z	Blinks at 1HZ, 50% duty cycle	High-Z	High-Z	High-Z
LED2	High-Z	High-Z	Low	Blinks at 4Hz, 50% duty cycle	High-Z
LED1 + LED2	High-Z	Blinks at 1HZ, 50% duty cycle	Low	Blinks at 4Hz, 50% duty cycle	High-Z

High-Z = High Impedance

Package Information

For the latest package outline information, go to **www.maxim-ic.com/DallasPackInfo**.