DIO5060

Standalone 1-Cell 500mA Linear Battery Charger with PowerPath, 1mA Termination and ＜1uA Battery Leakage

Features

- Input Rating of 28V
- Input Overvoltage Protection with 6.6V
- Charge Status Indicator
- 10% Charge Current Accuracy
- 0.7% Charge Voltage Accuracy
- Battery Supplement Mode
- Supports from 5mA up to 500mA charge current with current monitoring output (ISET)
- Programmable Pre Charge Current by resistor
- Programmable ITERM Charge Current by resistor
- Pre-charge for 30 minutes safety timing
- Fast-charge for 10 hours safety timing
- ＜1uA Leakage off the Battery, when no input power attached
- 0.5C, 1C, 2C, 3C of fast-charge will be controlled by SEL1 and SEL2 pins
- 40uA Standby current into IN pin after full charge

Descriptions

The DIO5060 series of devices are integrated Li-Ion linear chargers and system power path management devices targeted at space-limited portable applications. The charger accepts an input voltage up to 28V but is disabled when the input voltage exceeds the OVP threshold, typically 6.6V, to prevent excessive power dissipation. The 28V rating eliminates the over-voltage protection circuit required in a low input voltage charger. The input voltage range with input overvoltage protection supports unregulated adapters.

Applications

- Smart phones
- Portable media players
- Portable navigation devices
- Low-power handheld device

Ordering Information

Order Part Number	Top Marking		T_A	Package	
DIO5060A420CN10	FVAA	Green	-40 to 85°C	DFN2*2-10	Tape & Reel, 3000
DIO5060A440CN10	FVAC	Green	-40 to 85°C	DFN2*2-10	Tape & Reel, 3000
DIO5060A445CN10	FVAD	Green	-40 to 85°C	DFN2*2-10	Tape & Reel, 3000

Pin Assignment

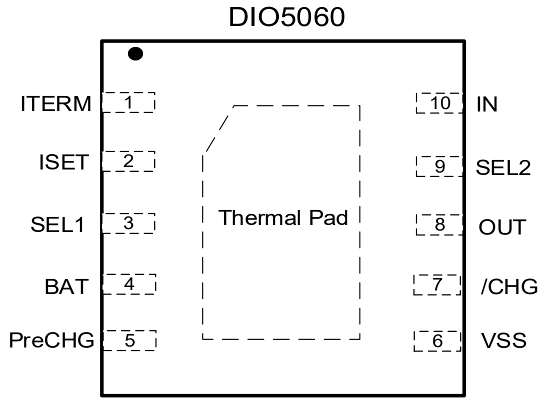

Figure 3. Top View

Pin Descriptions

Name	I/O	Description
BAT	I/O	Charger Power Stage Output and Battery Voltage Sense Input. Connect BAT to the positive terminal of the battery. Bypass BAT to VSS with a 4.7μF to 47μF ceramic capacitor.
VSS	–	Ground. Connect to the thermal pad and to the ground rail of the circuit.
/CHG	O	Open-Drain Charging Status Indication Output. /CHG pulls to VSS when the battery is charging. /CHG is high impedance when charging is complete and when charger is disabled. Connect /CHG to the desired logic voltage rail using a 1kΩ to 100kΩ resistor, or use with an LED for visual indication.
OUT	O	System Supply Output. OUT provides a regulated output when the input is below the OVP threshold and above the regulation voltage. Connect OUT to the system load. Bypass OUT to VSS with a 4.7μF to 47μF ceramic capacitor.
PreCHG	O	Pre-Charge Current Programming Input. Connect a 1kΩ to 50kΩ resistor from PreCHG to GND to program the fast charge current level.
IN	I	Input Power Connection. Connect IN to the external DC supply (AC adapter or USB port). The input operating range is 4.35V to 6.4V. The input can accept voltages up to 26V without damage but operation is suspended. Connect bypass capacitor 1μF to 10μF to VSS.
ITERM	I	Termination Current Programming Input. Connect a 0Ω to 15kΩ resistor from ITERM to VSS to program the termination current. Leave ITERM unconnected to set the termination current to the default 10% termination threshold.
ISET	I/O	Fast Charge Current Programming Input. Connect a 500Ω to 10kΩ resistor from ISET to VSS to program the fast charge current level. Charging is disabled if ISET is left unconnected. While charging, the voltage at ISET reflects the actual charging current and can be used to monitor charge current.
SEL1	I	Choose charging current.
SEL2	I	Choose charging current.

Thermal Pad	–	There is an internal electrical connection between the exposed thermal pad and the VSS pin of the device. The thermal pad must be connected to the same potential as the VSS pin on the printed circuit board. Do not use the thermal pad as the primary ground input for the device. VSS pin must be connected to ground at all times.

Truth Table

SEL1	SEL2	I_{charge}
0	0	1*C
0	1	2*C
1	0	0.5*C
1	1	0
1	floating	3*C

Typical Application Circuit

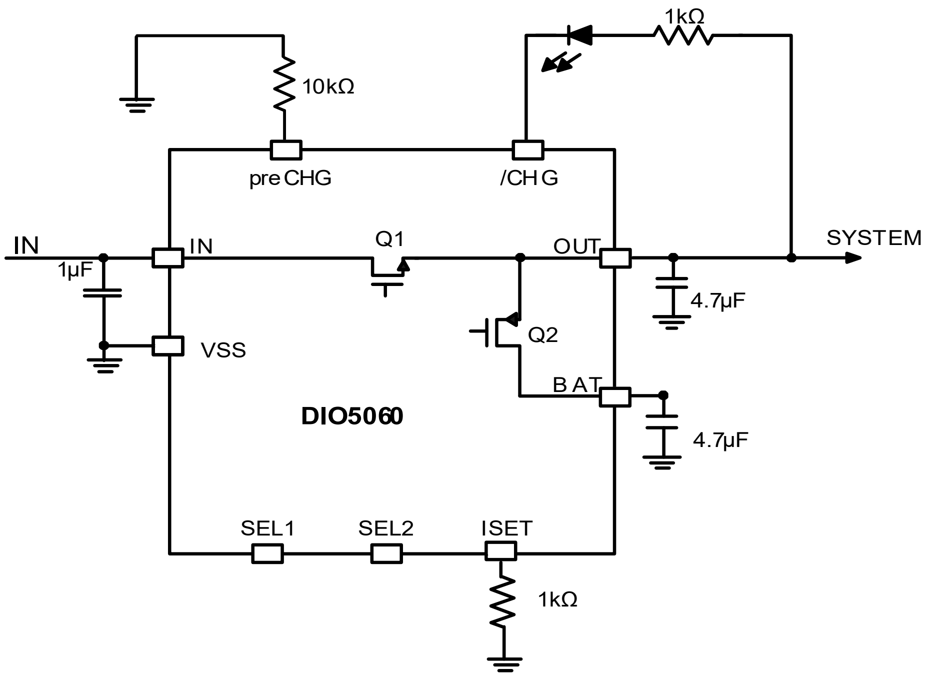

Figure 1. Application for DIO5060

Absolute Maximum Ratings

Stresses beyond those listed under "Absolute Maximum Rating" may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other condition beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Parameter			MIN	MAX	UNIT
V_I	Input Voltage	IN (with respect to VSS)	-0.3	28	V
		BAT (with respect to VSS)	-0.3	5	V
		OUT, ISET, /CHG, ITERM(with respect to VSS)	-0.3	7	V
I_I	Input Current	IN		600	mA
I_O	Output Current (Continuous)	OUT		1	A
		BAT (Discharge mode)		2	A
		BAT (Charging mode)		500(1)	mA
	Output Sink Current	/CHG		15	mA
T_J	Junction temperature		-40	150	°C
T_{stg}	Storage temperature		-65	150	°C
ESD	HBM		-2000	2000	V

Recommend Operating Conditions

The Recommended Operating Conditions table defines the conditions for actual device operation. Recommended Operating conditions are specified to ensure optimal performance to the datasheet specifications. DIOO does not Recommend exceeding them or designing to Absolute Maximum Ratings.

Parameter		MIN	MAX	UNIT
V_I	IN voltage range	4.35	28	V
	IN operating voltage range	4.35	6.4	V
I_{IN}	Input current, IN pin		500	mA
I_{OUT}	Current, OUT pin		1	A
I_{BAT}	Current, BAT pin (Discharging)		1	A
I_{CHG}	Current, BAT pin (Charging)		500(1)	mA
T_J	Junction Temperature	-40	125	°C
R_{ILIM}	Maximum input current programming resistor	500	10k	Ω
R_{ISET}	Fast-charge current programming resistor (2)	500	10k	Ω
R_{ITERM}	Termination current programming resistor	0	15	kΩ

$R_{θJA}$	Junction-to-ambient thermal resistance	44.5	°C/W
$R_{θJC(top)}$	Junction-to-case (top) thermal resistance	54.2	
$R_{θJC(bot)}$	Junction-to-case (bottom) thermal resistance	3.8	

Note:

(1) The IC operational charging life is reduced to 20,000 hours, when charging at 1A and 125°C. The thermal regulation feature reduces charge current if the IC's junction temperature reaches 125°C; thus without a good thermal design the maximum programmed charge current may not be reached.

(2) Use a 1% tolerance resistor for R_{ISET} to avoid issues with the R_{ISET} short test when using the maximum charge current setting.

Electrical Characteristics

Over junction temperature range (0° ≤ T_J ≤ 125°C) and the recommended supply voltage range (unless otherwise noted).

Parameter		Test Conditions	MIN	TYP	MAX	UNIT
INPUT						
UVLO	Undervoltage lock-out	V_{IN}: 0V → 4V	3.2	3.3	3.4	V
V_{hys}	Hysteresis on UVLO	V_{IN}: 4V → 0V		220		mV
$V_{IN(DT)}$	Input power detection threshold	Input power detected when V_{IN} > V_{BAT} + $V_{IN(DT)}$ V_{BAT} = 3.6V, V_{IN}: 3.5V → 4V		50		mV
V_{hys}	Hysteresis on $V_{IN(DT)}$	V_{BAT} = 3.6V, V_{IN}: 4V → 3.5V		20		mV
V_{OVP}	Input overvoltage protection threshold	V_{IN}: 5V → 7V	6.4	6.6	6.8	V
V_{hys}	Hysteresis on OVP	V_{IN}: 7V → 5V		200		mV
$t_{DGL(OVP)}$	Input overvoltage blanking time (OVP fault deglitch)			10		μs
ISET SHORT-CIRCUIT DETECTION (CHECKED DURING STARTUP)						
I_{SC}	Current source	V_{IN} > UVLO and V_{IN} > V_{BAT} + $V_{IN(DT)}$		1		mA
V_{SC}		V_{IN} > UVLO and V_{IN} > V_{BAT} + $V_{IN(DT)}$		500		mV
QUIESCENT CURRENT						
$I_{BAT(PDWN)}$	Sleep current into BAT pin	Input power not detected, No load on OUT pin, T_J = 85°C			1.0	μA
I_{IN}	Standby current into IN pin	VIN = 6V, T_J= 85°C charge done, No load on OUT pin			50	μA
		VIN = 10V, T_J= 85°C charge done, No load on OUT pin			80	μA
I_{CC}	Active supply current, IN pin	V_{IN} = 6V, no load on OUT pin, V_{BAT} > $V_{BAT(REG)}$			500	uA
POWER PATH						
$V_{DO(IN-OUT)}$	V_{IN} – V_{OUT}	V_{IN} = 5V, I_{IN} = 100mA, V_{BAT} = 4.4V		40	56	mV
$V_{DO(BAT-OUT)}$	V_{BAT} – V_{OUT}	I_{OUT} = 100mA, V_{IN} = 0V, V_{BAT} > 3V		22		mV
$V_{O(REG)}$	OUT pin voltage regulation	V_{IN} > V_{OUT} + $V_{DO(IN-OUT)}$	4.4	4.6	4.8	V
$I_{IN}max$	Programmable input current limit range	R_{ILIM} = 20kΩ to 2kΩ			500	mA
V_{BSUP1}	Enter battery supplement mode	V_{BAT} = 3.6V, R_{LOAD} = 10Ω → 2Ω	V_{OUT}≤ V_{BAT}– 40mV			V

V_{BSUP2}	Exit battery supplement mode	V_{BAT} = 3.6V, R_{LOAD} = 2Ω → 10Ω	$V_{OUT} \geq V_{BAT} – 20mV$			V
$V_{O(SC1)}$	Output short-circuit detection threshold, power-on	$V_{IN} > V_{UVLO}$ and $V_{IN} > V_{BAT} + V_{IN(DT)}$	0.8	0.9	1	V
$V_{O(SC2)}$	Output short-circuit detection threshold, supplement mode $V_{BAT} – V_{OUT} > V_{O(SC2)}$ indicates short-circuit	$V_{IN} > V_{UVLO}$ and $V_{IN} > V_{BAT} + V_{IN(DT)}$	200	250	300	mV
$t_{DGL(SC2)}$	Deglitch time, supplement mode short circuit			250		µs
$t_{REC(SC2)}$	Recovery time, supplement mode short circuit			60		ms
BATTERY CHARGER						
I_{BAT}	Source current for BAT pin short-circuit detection	V_{BAT} = 0.5V		1.2		mA
$V_{BAT(REG)}$	Battery regulation voltage	V_{IN} = 5V,	4.37	4.4	4.43	V
$V_{BAT(SC)}$	BAT pin short-circuit detection threshold	V_{BAT} rising	0.75	0.8	0.85	V
V_{LOWV}	Pre-charge to fast-charge transition threshold	$V_{IN} > V_{UVLO}$ and $V_{IN} > V_{BAT} + V_{IN(DT)}$	2.4	2.5	2.6	V
$t_{DGL1(LOWV)}$	Deglitch time on pre-charge to fast-charge transition			25		ms
$t_{DGL2(LOWV)}$	Deglitch time on fast-charge to pre-charge transition			25		ms
I_{CHG}	Battery fast charge current range	R_{ISET}=1K		70		mA
	Battery fast charge current	$V_{BAT} > V_{LOWV}$, V_{IN} = 5V, $I_{IN}max > I_{CHG}$, no load on OUT pin and thermal loop not active	K_{ISET} / R_{ISET}			A
K_{ISET}	Fast charge current factor		63	70	77	AΩ
I_{PRECHG}	Pre-charge current	$V_{BAT(S)} < V_{BAT} < V_{LOW}$, V_{IN} = 5V, $I_{IN}max > I_{CHG}$, no load on OUT pin and thermal loop not active	K_{IPre}/R_{IPre}			A
K_{PRECHG}	Pre-charge current factor		45	50	55	AΩ
V_{RCH}	Recharge detection threshold	$V_{IN} > V_{UVLO}$ and $V_{IN} > V_{BAT} + V_{IN(DT)}$	$V_{BAT(RE)}$ –200mV	$V_{BAT(RE)}$ –150mV	$V_{BAT(RE)}$ –100mV	V
$t_{DGL(RCH)}$	Deglitch time, recharge threshold detected			60		ms
$t_{DGL(NO-IN)}$	Delay time, input power loss to OUT LDO turn-off	V_{BAT} = 3.6V. Time measured from V_{IN}: 5V → 3V 1µs fall-time		20		ms
$I_{BAT(DET)}$	Sink current for battery detection	V_{BAT} = 2.5V		10		mA

t_{DET}	Battery detection timer			25		ms
TERM						
I_{TERM}	Termination comparator detection threshold (internally set)		K_{ITERM} / R_{ITERM}			A
K_{ITERM}			55	50	45	AΩ
$t_{DGL(TERM)}$	Deglitch time, termination detected			25		ms
THERMAL REGULATION						
$T_{J(REG)}$	Temperature regulation limit			125		°C
$T_{J(OFF)}$	Thermal shutdown temperature	T_J Rising		150		°C
$T_{J(OFF-HYS)}$	Thermal shutdown hysteresis			20		°C
LOGIC LEVELS ON /CHG						
V_{OL}	Output LOW voltage	I_{SINK} = 5mA			0.4	V

Specifications subject to change without notice.

Detailed Description

Overview

The DIO5060 devices are integrated Li-Ion linear chargers and system power path management devices targeted at space-limited portable applications. The device powers the system while simultaneously and independently charging the battery. This feature reduces the number of charge and discharge cycles on the battery, allows for proper charge termination and enables the system to run with a defective or absent battery pack. This feature also allows instant system turn-on even with a totally discharged battery. The input power source for charging the battery and running the system can be an AC adapter or a USB port. The power-path architecture also permits the battery to supplement the system current requirements when the adapter cannot deliver the peak system currents.

Under voltage Lockout (UVLO)

The DIO5060 family remains in power down mode when the input voltage at the IN pin is below the under voltage threshold (UVLO).

The Q1 FET connected between IN and OUT pins is off, and the status outputs /CHG is high impedance. The Q2 FET that connects BAT to OUT is ON. During power down mode, the $V_{OUT(SC2)}$ circuitry is active and monitors for overload conditions on OUT.

Power On

When the input voltage at IN is within the valid range: V_{IN} > UVLO and $V_{IN} > V_{BAT} + V_{IN(DT)}$ and $V_{IN} < V_{OVP}$, and all internal timers and other circuit blocks are activated. The device then checks for short-circuits at the ISET pin. If no short conditions exists, the device switches on the input FET Q1 with a 100mA current limit to checks for a short circuit at OUT. When V_{OUT} is above $V_{O(SC1)}$, the FET Q1 switches to the current limit threshold set R_{ILIM} and the device enters into the normal operation. During normal operation, the system is powered by the input source (Q1 is regulating).

Overvoltage Protection (OVP)

The DIO5060 accepts inputs up to 28V without damage. Additionally, an overvoltage protection (OVP) circuit is implemented that shuts off the internal LDO and discontinues charging when $V_{IN} > V_{OVP}$ for a period long than $t_{DGL(OVP)}$. Once the OVP condition is removed, a new power on sequence starts (see Power On). The safety timers are reset and a new charge cycle will be indicated by the CHG output.

Input Source Connected

The OUT output is regulated to a fixed voltage ($V_{O(REG)}$). This allows for proper startup of the system load even with a discharged battery. The current into IN is shared between charging the battery and powering the system load at OUT.

The input current limit is adjustable up to 1A. The valid resistor range is 500Ω to 5kΩ. When the IN source is connected, priority is given to the system load. The Battery Supplement modes are used to maintain the system load.

Battery Supplement Mode

If the charging current falls to zero and the system load current increases beyond the programmed input current limit, the voltage at OUT reduces further. When the OUT voltage drops below the V_{BSUP1} threshold, the battery supplements the system load. The battery stops supplementing the system load when the voltage at OUT rises above the V_{BSUP2} threshold.

During supplement mode, the battery supplement current is not regulated (BAT-FET is fully on), however there is a short circuit protection circuit built in. If during battery supplement mode, the voltage at OUT drops $V_{O(SC2)}$ below the BAT voltage, the OUT output is turned off if the overload exists after $t_{DGL(SC2)}$. The short circuit recovery timer then starts counting. After $t_{REC(SC2)}$, OUT turns on and attempts to restart. If the short circuit remains, OUT is turned off and the counter restarts. Battery termination is disabled while in supplement mode.

Input Source Not Connected

When no source is connected to the IN input, OUT is powered strictly from the battery. During this mode the current into OUT is not regulated, similar to Battery Supplement Mode, however the short circuit circuitry is active. If the OUT voltage falls below the BAT voltage by 250mV for longer than $t_{DGL(SC2)}$, OUT is turned off. The short circuit recovery timer then starts counting. After $t_{REC(SC2)}$, OUT turns on and attempts to restart. If the short circuit remains, OUT is turned off and the counter restarts. This ON/OFF cycle continues until the overload condition is removed.

Battery Charging

First, the device checks for a short-circuit on the BAT pin by sourcing $I_{BAT(SC)}$ to the battery and monitoring the voltage. When the BAT voltage exceeds $V_{BAT(SC)}$, the battery charging continues. The battery is charged in three phases: conditioning pre-charge, constant current fast charge (current regulation) and a constant voltage tapering (voltage regulation). In all charge phases, an internal control loop monitors the IC junction temperature and reduces the charge current if an internal temperature threshold is exceeded.

In the pre-charge phase, the battery is charged at with the pre-charge current (I_{PRECHG}). Once the battery voltage crosses the V_{LOWV} threshold, the battery is charged with the fast-charge current (I_{CHG}). As the battery voltage reaches $V_{BAT(REG)}$, the battery is held at a constant voltage of $V_{BAT(REG)}$ and the charge current tapers off as the battery approaches full charge. When the battery current reaches I_{TERM}, the /CHG pin indicates charging done by going high-impedance.

The value of the pre-charge current is set by the resistor (1 kΩ to 50 kΩ) connected from the ISET pin to VSS, and is given by the equation:

$$I_{PreCHG} = \frac{K_{PreCHG}}{R_{PreCHG}}$$

The charge current limit is adjustable up to 0.5A connected a resistor (1 kΩ to 50 kΩ) and is given by the equation:

$$I_{ITEM} = \frac{K_{ITEM}}{R_{ITEM}}$$

The valid resistor range is 150Ω to 20kΩ and is given by the equation:

$$I_{CHG} = \frac{K_{ISET}}{R_{ISET}}$$

If I_{CHG} is programmed as greater than the input current limit, the battery will not charge at the rate of

I_{CHG}, but at the slower rate of $I_{IN(MAX)}$ (minus the load current on the OUT pin, if any). In this case, the charger timers will be proportionately slowed down.

Battery Detection and Recharge

The DIO5060 automatically detects if a battery is connected or removed. Once a charge cycle is complete, the battery voltage is monitored. When the battery voltage falls below V_{RCH}, the battery detection routine is run. During battery detection, current ($I_{BAT(DET)}$) is pulled from the battery for a duration t_{DET} to see if the voltage on BAT falls below V_{LOWV}. If not, charging begins. If it does, then it indicates that the battery is missing or the protector is open. Next, the pre-charge current is applied for t_{DET} to close the protector if possible. If $V_{BAT} < V_{RCH}$, then the protector closed and charging is initiated. If $V_{BAT} > V_{RCH}$, then the battery is determined to be missing and the detection routine continues.

Status Indicators (/CHG)

The charge cycle after power-up, CE going low, or exiting OVP is indicated with the CHG pin on (low - LED on), whereas all refresh (subsequent) charges will result in the /CHG pin off (open - LED off). In addition, the /CHG signals timer faults by flashing at approximately 2Hz.

Table 1. /CHG Status Indicator

Charge State	CHG Output
Charging	Low (for first charge cycle)
Charging suspended by thermal loop	
Safety timers expired	Flashing at 2 Hz
Charging done	High-impedance
Recharging after termination	
IC disabled or no valid input power	
Battery absent	

Thermal Regulation and Thermal Shutdown

The DIO5060 contains a thermal regulation loop that monitors the die temperature. If the temperature exceeds $T_{J(REG)}$, the device automatically reduces the charging current to prevent the die temperature from increasing further. In some cases, the die temperature continues to rise despite the operation of the thermal loop, particularly under high VIN and heavy OUT system load conditions. Under these conditions, if the die temperature increases to $T_{J(OFF)}$, the input FET Q1 is turned OFF. FET Q2 is turned ON to ensure that the battery still powers the load on OUT. Once the device die temperature cools by $T_{J(OFF-HYS)}$, the input FET Q1 is turned on and the device returns to thermal regulation. Continuous over temperature conditions result in a "hiccup" mode. During thermal regulation, the safety timers are slowed down proportionately to the reduction in current limit.

Note that this feature monitors the die temperature of the DIO5060. This is not synonymous with ambient temperature. Self heating exists due to the power dissipated in the IC because of the linear nature of the battery charging algorithm and the LDO associated with OUT.

CONTACT US

Dioo is a professional design and sales corporation for high-quality and performance analog semiconductors. The company focuses on industry markets, such as, cell phone, handheld products, laptop, and medical equipment and so on. Dioo's product families include analog signal processing and amplifying, LED drivers and charger IC. Go to http://www.dioo.com for a complete list of Dioo product families.

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