USB Li-Ion Battery Charger

PRELIMINARY DATA SHEET

DESCRIPTION

The LX2201 Linear Battery Charger is a 2-stage multi-state L-ion battery charger (Constant current/Constant voltage) that can supply up to 2A of charging current into a single cell Lithium-Ion battery.

While the LX2201 is a general-purpose charger, it features several built in programming states specifically for compliance with USB bus specifications. Monitoring the input current supplied by the system and then dynamically allocating any unused power to the charging circuitry maintains USB compliance with respect to peripheral current limitations. This feature insures that the battery will be charged as soon as possible without sacrificing system performance or features.

The LX2201 is a highly integrated charger that requires just three external programming resistors; one for setting the constant charge current level, one for setting the termination charge current, and one for setting the Vin maximum current. It also has an internal thermostat that will throttle back the charge current to keep the die temperature from exceeding 150C; this feature insures the LX2201 delivers the maximum charge rate for a given thermal environment.

A logic input is provided to select either 4.1V or 4.2V battery chemistries. A high accuracy current sensing circuit is implemented allowing batteries to be filled to the fullest capacity before terminating the charge cycle. Since the battery terminal voltage is separated from the system load when charging from an adapter, trickle charging, which can prematurely age the Li-ion battery, is avoided.

The LX2201 provides a charging status indicator. The integrated PMOS pass element features low drop out voltage while providing an inherent load disconnect with virtually no drain on the battery when disabled or when the input power is removed. Additionally a battery load disconnect switch has been integrated providing seamless power switching when transitioning between charge and discharge.

The LX2201 features a pre-charge conditioning mode for batteries that have been deeply discharged and also has a top off charge mode for batteries that are left on the charger for extended periods.

The LX2201 is packaged in a high power 20-pin MLP 4x4 mm miniature surface mount package.

IMPORTANT: For the most current data, consult *MICROSEMI*'s website: http://www.microsemi.com

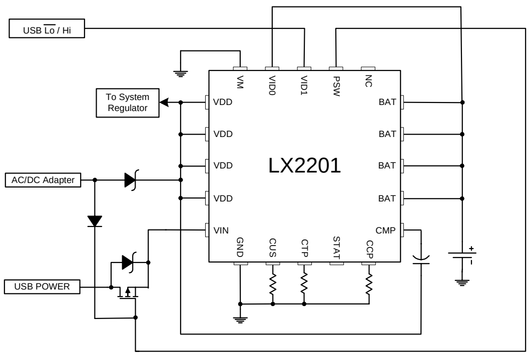
KEY FEATURES

- USB compliant Charging States
- Small, High Power 20-lead MLP package
- Internal Pass element can function as a reverse direction load switch
- No Sense Resistor Required
- Full Capacity Charging
- Always Cool Running
- 4.1 or 4.2V Applications
- Tolerates 5V + 10% Wall Supply Regulation
- Conditioning Mode For Deep Discharge
- Built In MOSFET Driver For Easy AC Adapter/USB Implementation
- Topping Charge For Long Periods Of Non-Use.
- Inherent Load Disconnect

APPLICATIONS

- Batteries with 350mAH to 2AH ratings
- Cell Phones
- PDAs
- Charging cradles
- Digital Cameras
- Low Cost Single L-Ion Cell Chargers

PRODUCT HIGHLIGHT



State Select Truth Table

VID0	VID1	VDD > VBAT	VBAT > VDD
0	0	Switch open – charging disabled.	Switch open – discharge disabled.
0	1	Charging – USB high level if using VIN.	Switch open – discharge disabled.
1	0	Charging – USB low level if using VIN.	Battery Discharging. MOSFET fully enhanced with current flow VBAT to VDD.
1	1	Charging – USB high level if using VIN.	Battery Discharging. MOSFET fully enhanced with current flow VBAT to VDD.

PACKAGE ORDER INFO

T_A(°C)	LQ Plastic MLP 4x4mm 20-Pin
0 to 70	LX2201CLQ

Note: Available in Tape & Reel.
Append the letter "T" to the part number.
(i.e. LX2201CLQT)

LX2201

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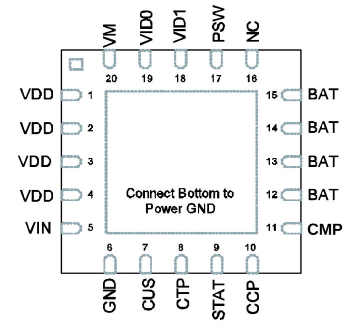
ABSOLUTE MAXIMUM RATINGS

Supply Voltage (VIN)..-0.3V to 7V
Analog Input Signals (VIDx, VM, SNS) ....-0.3V to 7V
Battery Charging Current (I_{BAT})..2A
Discharge Current (I_{VDD})...3A
Operating Junction Temperature.. 150°C
Storage Temperature Range...-65°C to 150°C
Lead Temperature (Soldering 180 seconds) .... 235°C
Vin Maximum DC Current 500mA
Vin Maximum Surge Current 2A

Note: Exceeding these ratings could cause damage to the device. All voltages are with respect to Ground. Currents are positive into, negative out of specified terminal.

PACKAGE PIN OUT



LQ PACKAGE
(Top View)

N.C. – No Internal Connection
N/U – Not Used
RSVD – Do Not Use

THERMAL DATA

LQ	**Plastic Micro Lead Frame Quad Package 20-Pin**
THERMAL RESISTANCE-JUNCTION TO AMBIENT, θ_{JA}	**40°C/W**

Junction Temperature Calculation: $T_J = T_A + (P_D \times \theta_{JA})$.
The θ_{JA} numbers are guidelines for the thermal performance of the device/pc-board system. All of the above assume no ambient airflow.

FUNCTIONAL PIN DESCRIPTION

Name	Description
BAT	Charging Output - This pin is wired to the positive terminal of the battery. (The negative battery terminal is wired to GND.)
CCP	Charge Current Programming Pin - A resistor (RCP) is connected between this pin and GND. The constant current is determined by the following relationship: $I_{BAT(MAX)} = \frac{75000}{RCP}$
CMP	Compensation Pin – Connect a 0.1uF compensation capacitor from this pin to VDD.
CTP	Charge Termination Programming Pin – A resistor (RTP) is connected between this pin and GND. The termination charge current is determined by the following relationship: $I_{BAT(MIN)} = \frac{7500}{RTP}$
CUS	Maximum VIN Current Programming Pin – A resistor (RUS) is connected between this pin and GND. The Hi Level charge current is determined by the following relationship: $I_{IN(HI))} = \frac{1250}{RUS}$
GND	Common Ground
NC	Not Connected. This pin is connected internally and should be left floating.
PSW	PMOS Switch driver – This output is designed to drive the gate of an external PMOS power switch. The driver is pulled low (PMOS on state) when VDD > VBAT.
VDD	Common Power Node – Connects to system power bus.
VIDx	State Select Input – Applying a two bit TTL compatible signal sets the desired state of the charger corresponding to the Truth Table.
VIN	Voltage Input – Current limited USB input. Apply a USB compliant power input.
VM	Voltage Mode Select - Selects the constant voltage charge level. Wired to VIN for 4.1V and GND for 4.2V.
STAT	Status - This pin is a logic high level when the battery is being charged. A low signal indicates either under voltage lockout, charge completed, or VBAT > VDD, or VID0 = VID1 = 0.

ELECTRICAL CHARACTERISTICS

Unless otherwise specified, the following specifications apply over the operating ambient temperature 0°C ≤ T_A ≤ 70°C except where otherwise noted and the following test conditions:.

Parameter	Symbol	Test Conditions	LX2201 Min	LX2201 Typ	LX2201 Max	Units
MAIN CIRCUITRY						
Input Voltage	V_{DD}		4.5		6	V
Quiescent Current	I_{GND}	$V_{DD} > V_{BAT}$		4	8	mA
		$V_{DD} < V_{BAT}$		3	5	µA
CTP Bias Voltage	V_{CTP}	R_{CTP} = 150K, I_{BAT} > 100mA		1.25		V
CCP Bias Voltage	V_{CCP}			1.25		V
CUS Bias Voltage	V_{CUS}			2.5		V
CONSTANT VOLTAGE MODE						
Constant Current Charge Voltage	V_{CCL}	VM = Hi	4.16	4.2	4.24	V
		VM = Lo	4.06	4.1	4.14	
Maximum Dropout Voltage	$V_{IN} – V_{BAT}$	I_{BAT} = 1A			300	mV
Top Off Charge Droop Threshold	V_{DRP}		96	97	98	% V_{BAT}/V_{CVL}
CONSTANT CURRENT MODE						
BAT Constant Current Accuracy	I_{CCL}	R_{CCP} = 75K	0.9	1	1.1	A
BAT Constant Current Level	I_{BAT}	$V_{BAT} < (V_{CVL}$ – 100mV)	0.35		2	A
Conditioning Current	I_{COND}	$V_{BAT} < V_{CTV}$	4	5	6	% I_{BAT}/I_{CCL}
Conditioning Current Mode Threshold Voltage	V_{CTV}		55	60	65	% V_{BAT}/V_{CVL}
Charge Termination Current Accuracy	I_{BAT}	R_{CTP} = 150K	40	50	60	mA
USB CURRENT LIMIT						
USB Low Current Limit	I_{IN}	V_{IN} = 5V, $V_{DD} < V_{IN}$, VID1 = Lo, R_{USB} = 2.5K	90	95	100	mA
USB High Current Limit	I_{IN}	V_{IN} = 5V, $V_{DD} < V_{IN}$, VID1 = Hi, R_{USB} = 2.5K	450	475	500	mA
LOGIC						
STAT Logic High Output	V_{STAT}	V_{IN} = 5.0V, I_{STAT} = -5mA		4.5	5	V
STAT Logic Low Output	V_{STAT}	V_{IN} = 5.0V, I_{STAT} = 100µA			0.8	V
State Select Threshold	V_{VID}	Logic Hi	2.0			V
		Logic Lo			0.8	
VM Select Threshold	V_{VM}	Logic Hi	2.0			V
		Logic Lo			0.8	
THERMAL SHUTDOWN						
Maximum Junction Temperature	T_J	V_{IN} = 5.0V, I_{OUT} = 1A, Temperature Rising	130	140	150	°C
BI-DIRECTIONAL PASS ELEMENT CONTROL						
Discharge Switch On Resistance	$R_{DS(ON)}$	I_{BAT} = -1A		130	150	mΩ
Charging Threshold	V_{CHG}	$V_{IN} > V_{BAT} + V_{CHG}$	15	20	25	mV
Discharging Threshold	V_{DCH}	$V_{IN} > V_{BAT} + V_{DCH}$	0	5	10	mV
Pass Element Switch Mode Delay	tsw	Charge–to–discharge or Discharge–to–charge	0	5	10	µs
PSW FET DRIVER						
High Output Voltage	V_{PSW}	$V_{IN} > V_{BAT}$, I_{PSW} = 0	4.75	5		V
Low Output Voltage	V_{PSW}	$V_{IN} > V_{BAT}$, I_{PSW} = 0		0	0.2	V
OR-ing Resistance	R_{PSW}		5	10	20	KΩ
Switch Delay ($V_{DD} > V_{BA}T$ to $V_{DD} < V_{BAT}$)	t_{PSW}	C_{PSW} = 1000pF, to $V_{PSW} = (V_{BAT}$ – 1V)	0	500	1000	Ns

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SIMPLIFIED BLOCK DIAGRAM

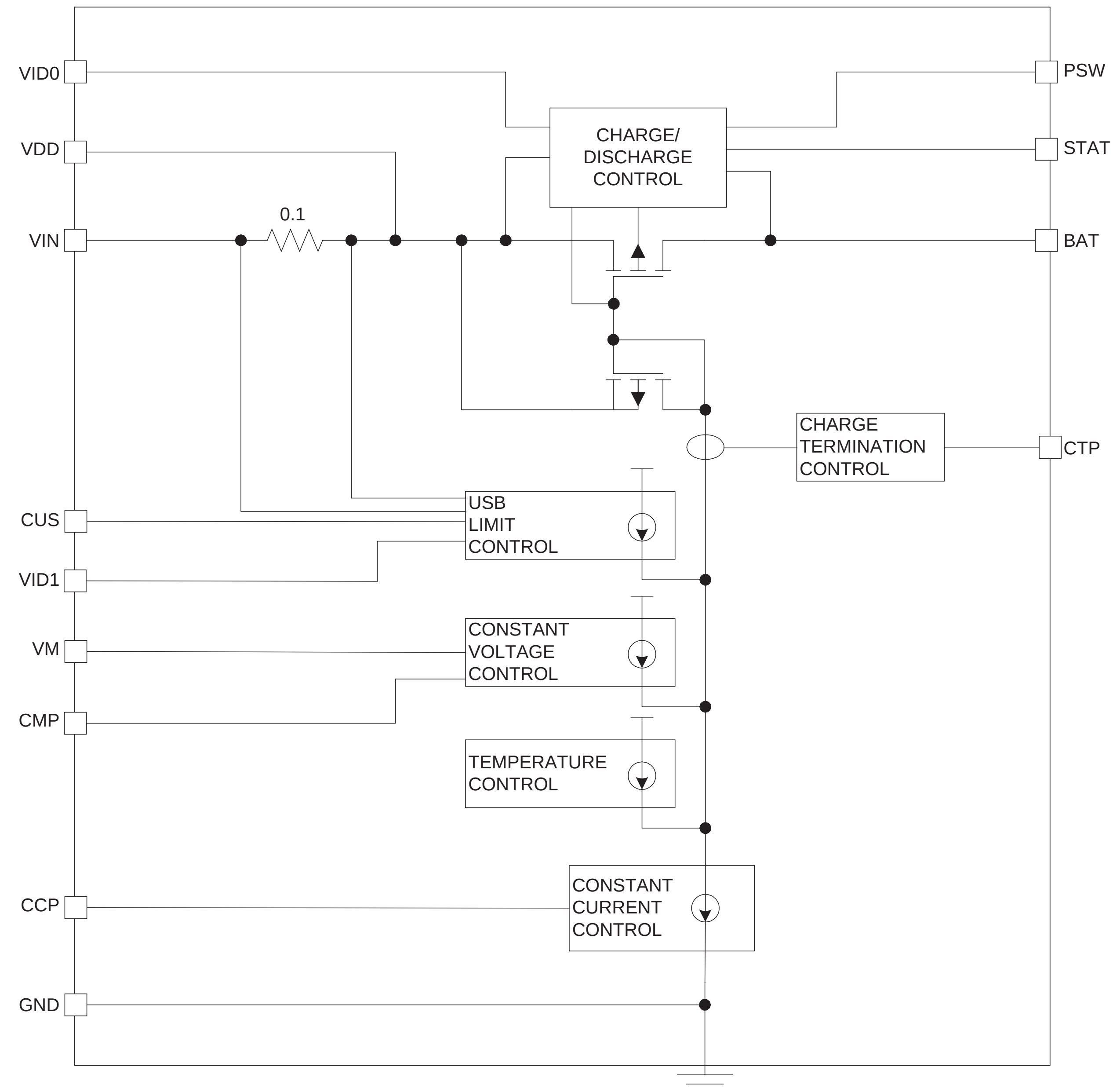


Figure 1 – Simplified Block Diagram

APPLICATION CIRCUITS

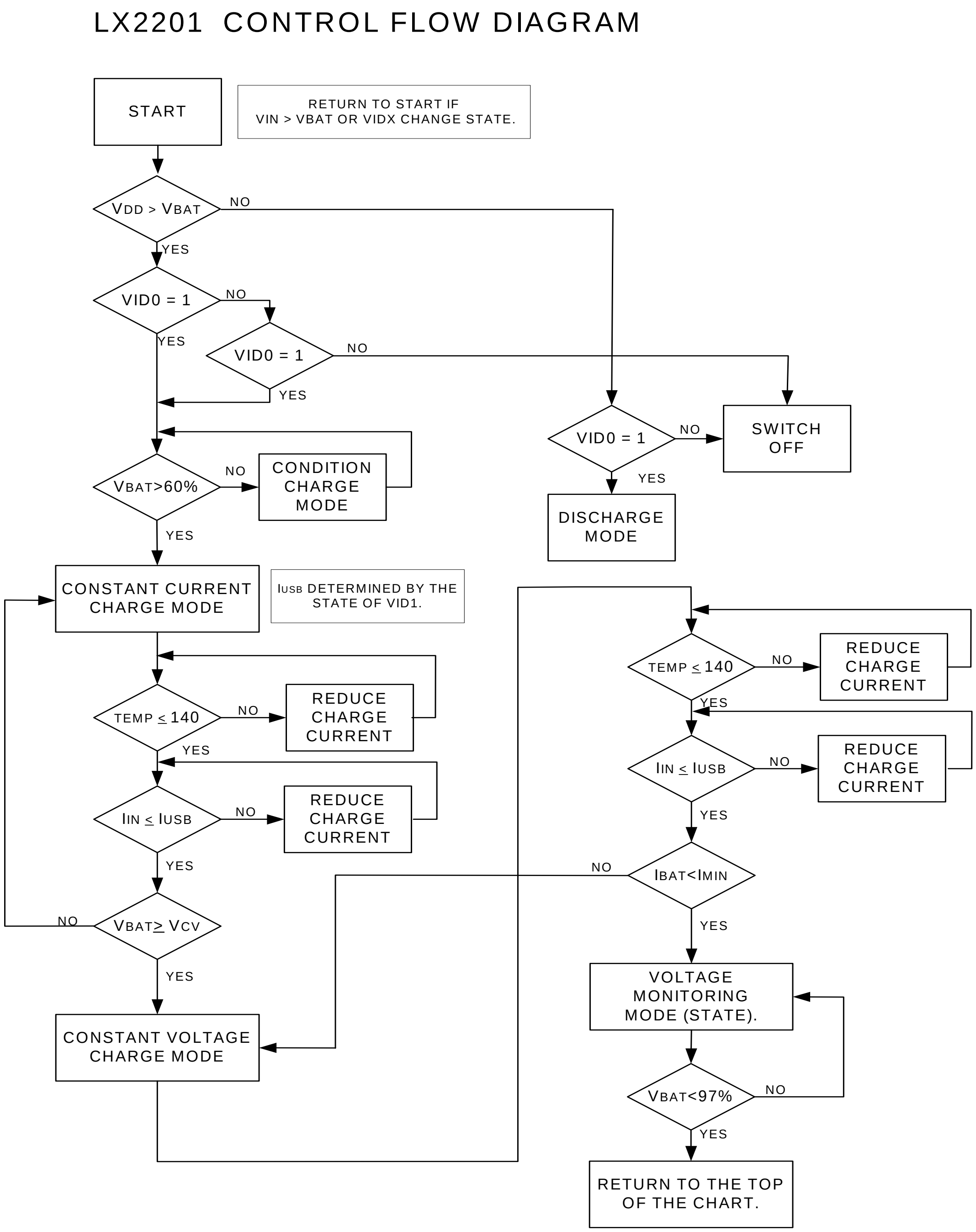


Figure 2 – Control Flow Diagram

APPLICATION SCHEMATICS

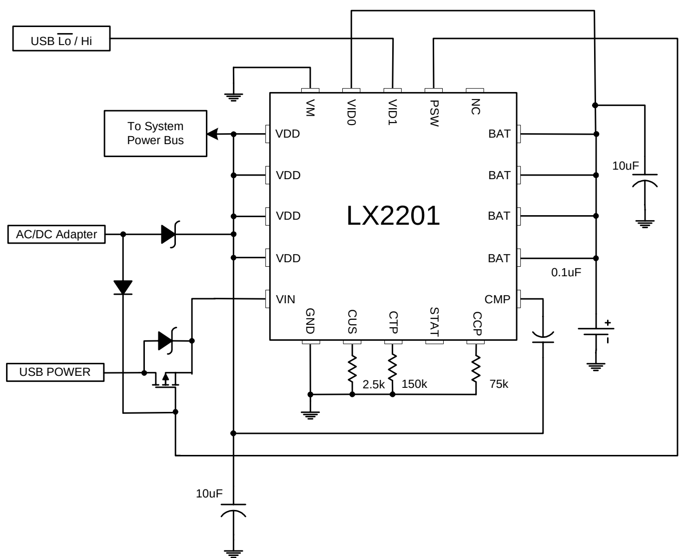


Figure 3 – AC Adapter and USB Supply (Charge and Discharge Modes)

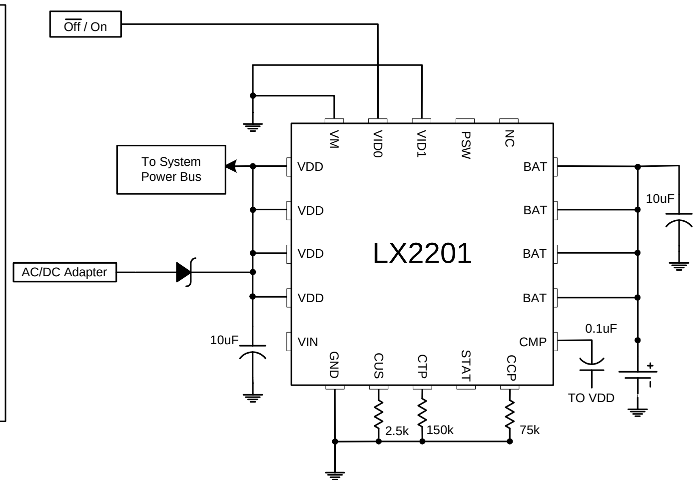


Figure 4 – AC Adapter (Charge and Discharge Modes)

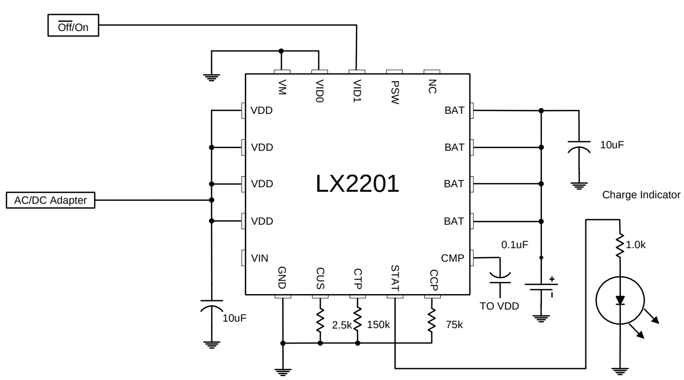


Figure 5 – AC Adapter Supply Only (Charge Only Mode) with Charging Indicator

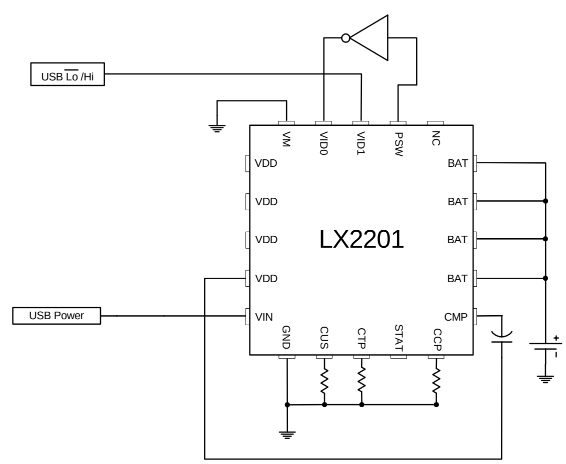


Figure 6 – USB Supply Only (Charger Only Mode)

APPLICATION SCHEMATICS (CONTINUED)

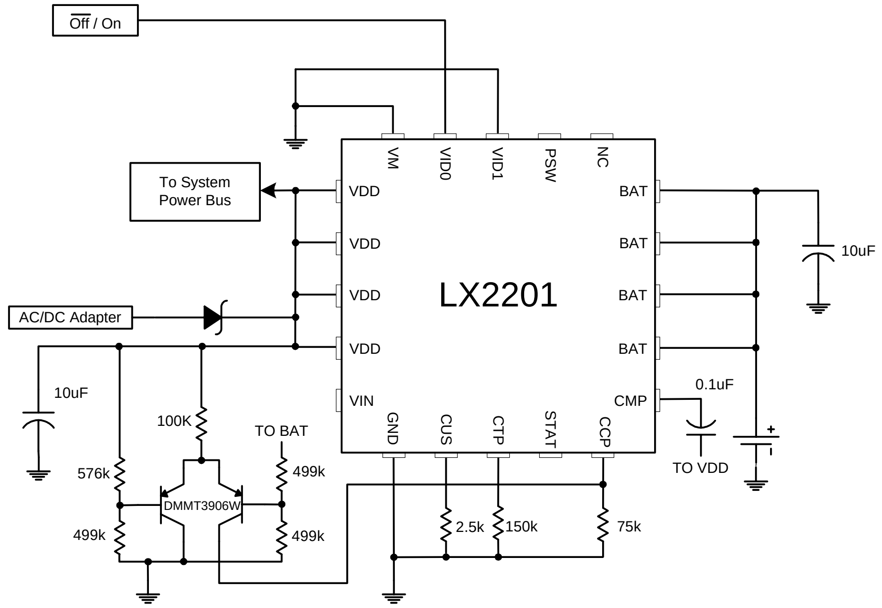


Figure 7 – AC Adapter with charging voltage headroom regulation (for use with a current limited power supply).

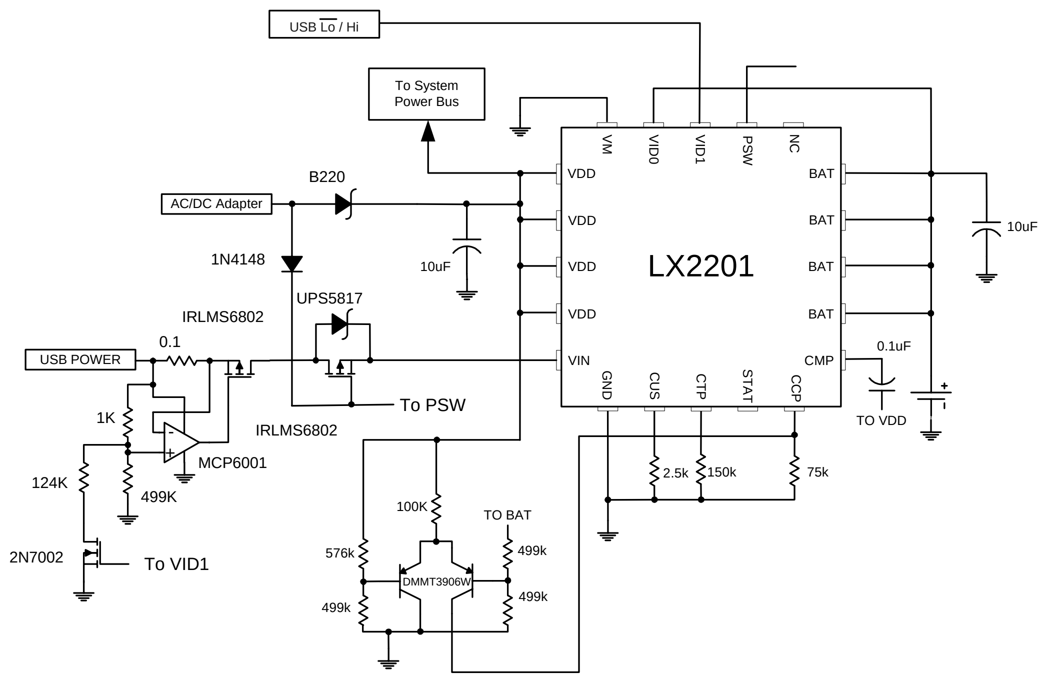


Figure 8 – Current limited USB interface with isolated battery and bi-directional pass element.

THEORY OF OPERATION

GENERAL DESCRIPTION

The LX2201 is designed to charge a single cell Lithium Ion battery using two steps, a constant current step followed by a constant voltage step. The basic charger function uses the VDD pins as an input and BAT pins as the output. This basic charger has a programmable maximum current (programmable by the resistor value between pin CCP to GND) which is the maximum charging current during the CONSTANT CURRENT MODE of the charging profile. The low dropout of the pass element allows the battery to be charged from a loosely regulated power supply. In the CONSTANT VOLTAGE MODE of the charging profile the battery terminal voltage can be regulated to 4.1V or 4.2V by strapping the VM pin to VDD or GND, respectively. The charger will terminate constant voltage charging once the current drops below the minimum current setting (programmable by the resistor value between pin CTP to GND).

In the CONDITIONING CHARGE mode a conditioning current is applied to batteries that are deeply discharged and have a terminal voltage less than 60% of the constant voltage level. The conditioning current is 5% of the CCP programmable constant current level (except where it might be limited in the USB states). Once the battery terminal voltage exceeds the 60% level, the full constant current level is applied (unless charging current is limited by one of the other charger control loops).

The LX2201 has a built in thermostat that will throttle back the charging current to prevent the internal die temperature from exceeding 150ºC. This feature prevents the IC from getting hot enough to damage the board. This feature can reduce the settings dictated by the constant voltage and constant current control loops to reduce power dissipation in the IC.

The LX2201 will turn off the pass element once the battery has been fully charged. This is to prevent float charging, which has been shown to reduce Lithium ion battery life. The charge termination state occurs at the end of the constant voltage charge mode where the battery draws less current as it nears full capacity. The high precision of the LX2201 in low current state lets the battery continue charging to the point where the charging current has dropped to the Charge Termination Current set by the Charge Termination Programming Pin.

Once the charger has completed a charge cycle, if power remains applied, the LX2201 enters a VOLTAGE MONITORING mode. In this mode the LX2201 monitors the battery terminal voltage and applies a top off charge if the battery voltage drops by more than 3% of full scale. This feature is especially important for charging systems in emergency equipment were usage is infrequent.

The USB states insure compliance with the USB specification. There are two current limitations imposed by the specification; a Low Power peripheral is to draw less than 100mA unless configure by the host controller as a High Power peripheral which increases the current limitation to 500mA. While the LX2201 will not negotiate the host for the power designation it must insure that the total current through VIN is less than, or equal to, the stated current limitation. To accomplish this the constant current loop will sense the current through VIN and dynamically scale I_{BAT} to maintain the desired input current. It must be noted that the circuit does not limit the input current and only scales the charging current. It is possible that a system would draw more than 100mA through VDD, and as a result fail USB compliance. In this case the LX2201 would have scaled the charging current to zero. This feature allows for the fastest possible charge time in a USB configuration by allocating unused power for the charger without limiting system performance or features.

The LX2201 has two unique features which assist in the power control design. The pass element can be programmed by the VID0 pin to be bi-directional. This allows the pass element to be used as a power switch to provide a low impedance path around the Oring diode without the need to use an external MOSFET. The other feature is a logic output that enhances an external PMOS FET when the LX2201 is in a charging mode (ie VDD > VBAT). This provides a low impedance path around the Oring diode that is typically used in a multiple source power distribution. Lowering the voltage drop across the Oring diode is especially helpful for use with low voltage power inputs such as USB.

APPLICATION NOTE

CURRENT LIMITED POWER SUPPLIES

When using input power supplies that are current limited or have a high source impedance, the battery charging current and/or load current can pull the VDD pin down very close to the battery terminal voltage. This may cause the LX2201 to enter an indeterminate state where it switches between charge and discharge modes. To prevent this, the PNP differential amplifier circuit of Figure 7 can be added; this circuit adds an additional control loop that regulates the charger headroom to 300mV by scaling back the battery charging current.

The internal power switch within the LX2201 requires the power supply have a minimal level of strength to switch from discharge mode to charge mode. If the power source is severely current limited, the LX2201 may not open the discharge switch. In this case, a small amount of current will be allowed to flow into the battery unregulated. If left in this state indefinitely, the current will eventually raise the battery terminal voltage to the point where the batteries internal protection circuitry will open the circuit. Typically, the LX2201 requires a minimum of 80mA in USB mode and 200mA using the VDD input to force the switchover to charge mode. Alternatively, if weak power sources are used, the switchover from discharge to charge mode can be forced by momentarily setting VID0 and VID1 to a low state, which will open the discharge switch allowing the VDD voltage to rise so the LX2201 can enter charge mode.

USB COMPLIANCE

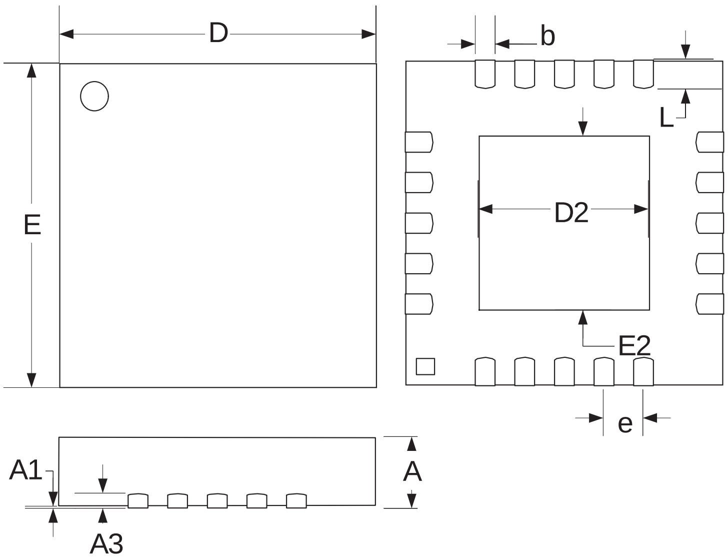
To be compliant with the USB specification, the +5V current must be less than 100mA in the low power mode and less than 500mA in the high power mode. If the LX2201 is configured as shown in Figure 3, it is possible for the system to consume more than the maximum allowed USB current (in which case the battery charging current will have been fully scaled back). If it is not possible to regulate the load current when charging from a USB power source and strict adherence to the USB power budget is required, the LX2201 configuration as shown in Figure 6 can be used. In this case the system load can be applied directly to the battery and the LX2201 will prevent the load + battery from drawing more power than is allowed for USB compliance. A better approach that provides battery isolation is shown in Figure 8; in this approach, the op amp circuit provides a current limiter that prevents the system from exceeding the USB power limits. The battery is only discharged if the AC adapter or USB inputs are removed or current limited.

LAYOUT GUIDELINES

- It is important when laying out the LX2201 to place 10uF ceramic capacitors close to the VDD and VBAT IC terminals to filter switching transients.
- It is important to provide a low thermal impedance path from the thermal pad on the bottom of the LX2201 package to the ground plane of the circuit board to maximize the heat dissipation.

PACKAGE DIMENSIONS

LQ **20-Pin MLPQ Plastic 4x4mm (114x114DAP)**



Dim	MILLIMETERS MIN	MILLIMETERS MAX	INCHES MIN	INCHES MAX
A	0.80	1.00	0.031	0.039
A1	0.00	0.05	0.000	0.002
A3	0.20 REF		0.008 REF	
b	0.18	0.30	0.007	0.088
D	4.00 BSC		0.157 BSC	
D2	2.59	2.79	0.102	0.110
E	4.00 BSC		0.157 BSC	
E2	2.59	2.79	0.102	0.110
e	0.50 BSC		0.019 BSC	
L	0.30	0.50	0.011	0.019

Note:

1. Dimensions do not include mold flash or protrusions; these shall not exceed 0.155mm(.006") on any side. Lead dimension shall not include solder coverage.

NOTES