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API9221EV1 USER GUIDE

Performance

- **Dual Input – DC (6.8V OVP) and USB (5.4V OVP)**
- **Double layer capacitors on board to demonstrate battery charge cycle**
- **Load resistors on board up to 1A**
- **Programmable charging currents**
- **Ambient temperature range -40°C to +85°C**

Ordering Information

Order Number
API9221EV1

Introduction

This evaluation circuit demonstrates the API9221 Lithium Ion Battery Charger. The charge and discharge cycle can be quickly and simply demonstrated without a battery. The circuit includes a load consisting of an electrolytic double layer capacitor bank of 5 Farads to facilitate this demonstration. The assembly also includes a set of resistive loads. There is a logic enable input, which disables charging when pulled high. Manual links are provided for these functions.

The construction is a double-sided FR4 printed circuit board, 95 x 60 x 1.6 mm with 1oz/sq ft copper (35µm).

CAUTION: Do not connect a Lithium Ion cell before first removing the link CAP SW, or setting it to the "0F" position. (A cell is not required for the tests described here.)
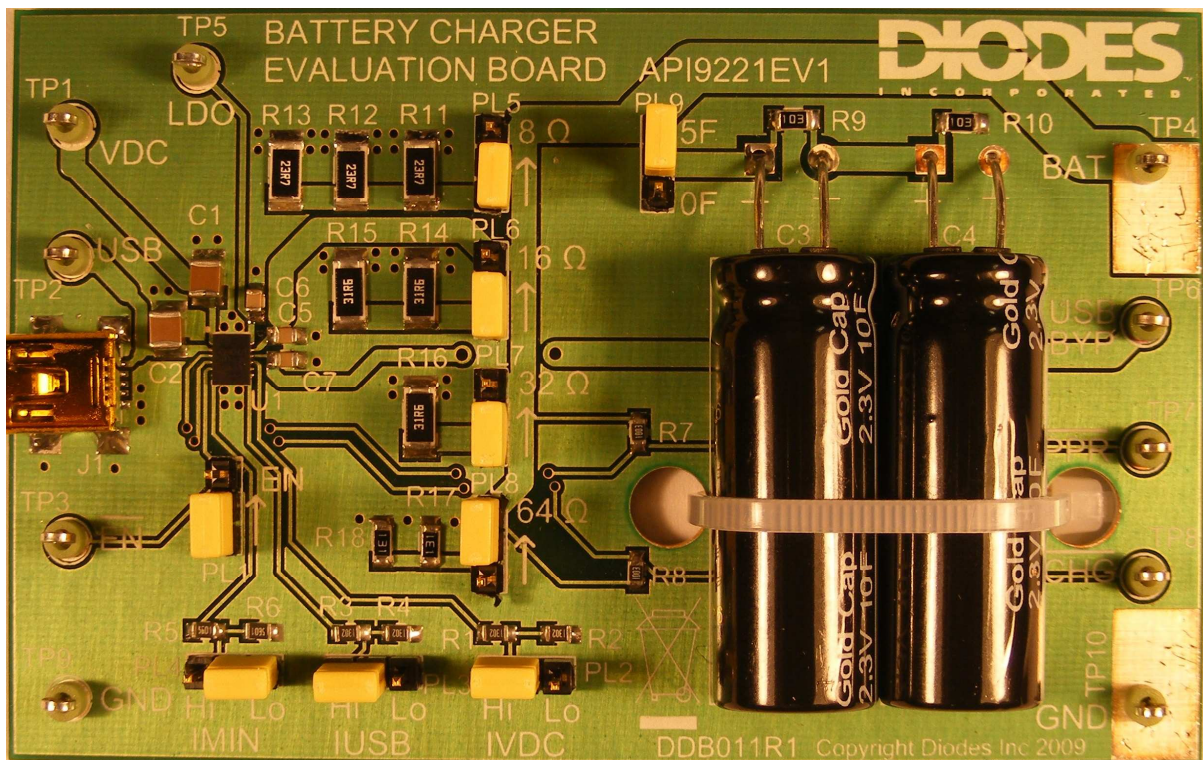
Quick Start Guide

> **CAUTION: Do not connect a Lithium Ion cell before first removing the link CAP SW, or setting it to the "0F" position. (A cell is not required for the tests described here.)**

Suitable test equipment is given in the table below. The oscilloscope is optional, but gives a display of the output voltage against time. The demonstration is slow enough that the performance can be observed on the multimeters.

Operation using AC Adapter Input (VDC)

1. On the API9221EV1 board set the links as follows:
    PL1: Disable position (EN de-selected)
    PL2: IVDC Hi
    PL3: IUSB Hi
    PL4: IMIN Lo
    PL5: 8Ω closed (selected): (this discharges the double-layer capacitors)
    PL6: 16Ω open (de-selected)
    PL7: 32Ω open (de-selected)
    PL8: 64Ω open (de-selected)
    PL9: 5F (capacitor load selected)

2. Set the power supply to 5.0V but do not switch on. Set the current limit to 1.0A.

3. Connect up the API9221EV1 board to the equipment as in **Figure 1** below. Set DMM1 to measure voltage. Set DMM2 to measure current.

4. Note the output voltage (DMM1). (Do not switch on the supply.) If necessary, wait for the load capacitor to fully discharge to 1V or less (DMM1).

5. Set the oscilloscope as follows:

CH1 sensitivity:	1V/div	Trace vertical position:	-3 div (approx)
CH2 sensitivity:	2V/div	Trace vertical position:	+1 div (approx)
CH3 sensitivity:	2V/div	Trace vertical position:	+1.5 div (approx)
CH4 sensitivity:	2V/div	Trace vertical position:	+2 div (approx)
Time base:	25s/div		
Trigger Source:	AC Line		
Trigger Mode:	Auto		

    Press RUN/STOP so that the sweep is stopped.

6. Move the link at PL5 (8Ω) to the open position. Switch on the power supply. Note that the input current (DMM2) is 1mA or less. The output voltage remains close to 0V. The EN\ input voltage is high (3V to 5V), and the output PPR\ is low (0V). The output LDO is now 4.9V. (The output USB_BYP remains at 0V.)

7. On the oscilloscope press RUN/STOP so that the sweep is initiated. Within about 20 seconds, but after the sweep is seen to begin, move the link at PL1 to the EN position. The EN\ voltage goes low. Note that the current has increased to about 90mA to 100mA. The voltage at DMM1 increases and the CH1 oscilloscope trace begins to climb.

8. After about 3 minutes, when the output reaches 2.7V, the current suddenly increases to about 500mA. The oscilloscope trace may rise suddenly (a step of 0.5V or less), due to the internal resistance of the capacitors. After a few seconds, the current decreases gradually as the voltage approaches 4.2V. When the current reaches the IMIN value of about 50mA, the output CHG\ is seen to go high. The current then reduces further, and the voltage now changes very little.

9. Before the sweep finishes, switch off the power supply. The output PPR\ goes high. Press RUN/STOP to freeze the oscilloscope waveform before the end of the sweep. **Figure 2** below shows the resulting oscilloscope waveform.

10. Move the link at PL5 to connect the 8Ω load. This discharges the capacitor for safe shipping. This concludes the demonstration using VDC input. See below for USB input demonstration.
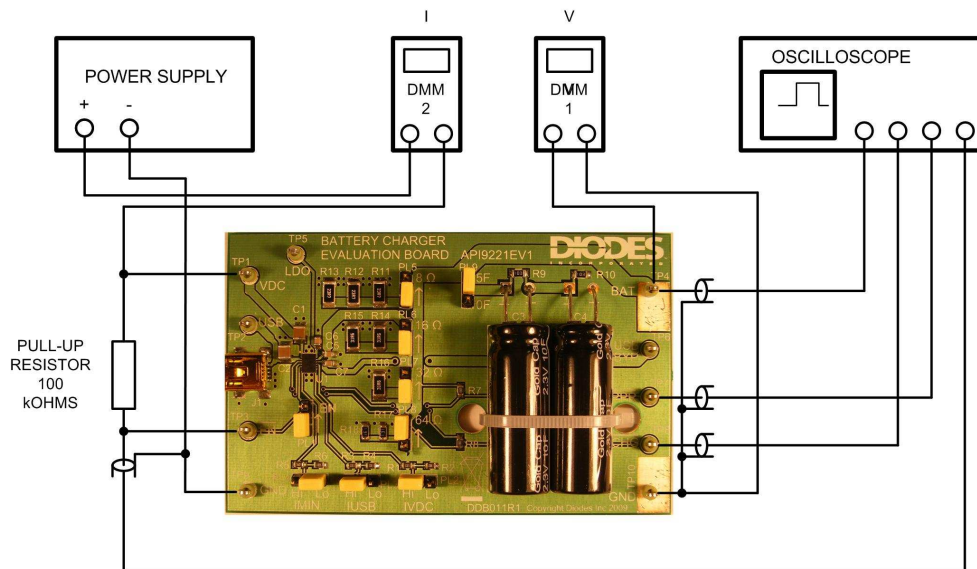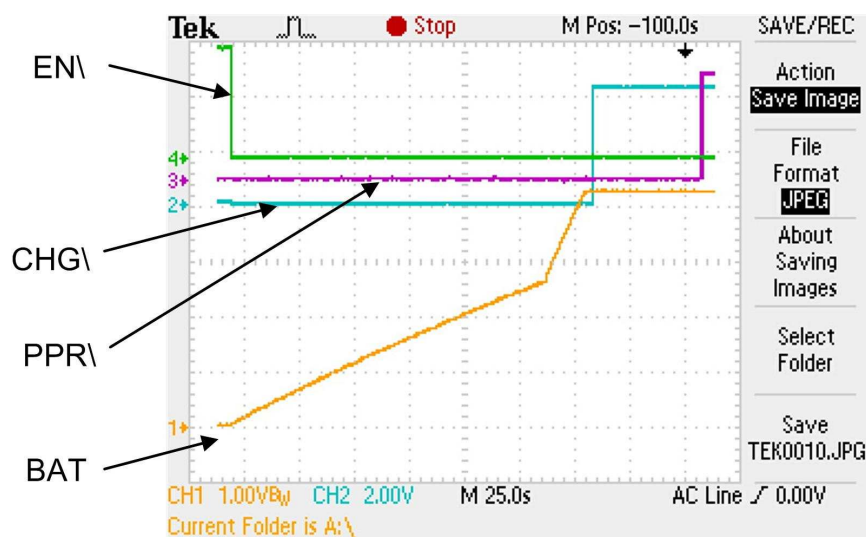
Figure 1: Test Schematic using VDC Input

Figure 2: Oscilloscope Waveforms

About the BAT waveform: The initial constant pre-charge current of about 90 mA charging the capacitance of 5Farads gives a ramp rate of nearly 2.7V in 150 seconds, or about 0.018 V/s, as predicted from:

$$\frac{dV}{dt} = \frac{I}{C} = \frac{0.09}{5} = 0.018 \text{ V/s}$$

When the charging current increases to 0.5A, the ramp rate increases accordingly until the limiting voltage of 4.2V is reached.

Operation using USB Input

11. Repeat steps 1 to 10 above, but at step 3, connect as in **Figure 3** below. Note that in step 6, the output LDO is 0V and USB_BYP is 5V. The waveform is again similar to that of **Figure 2**.
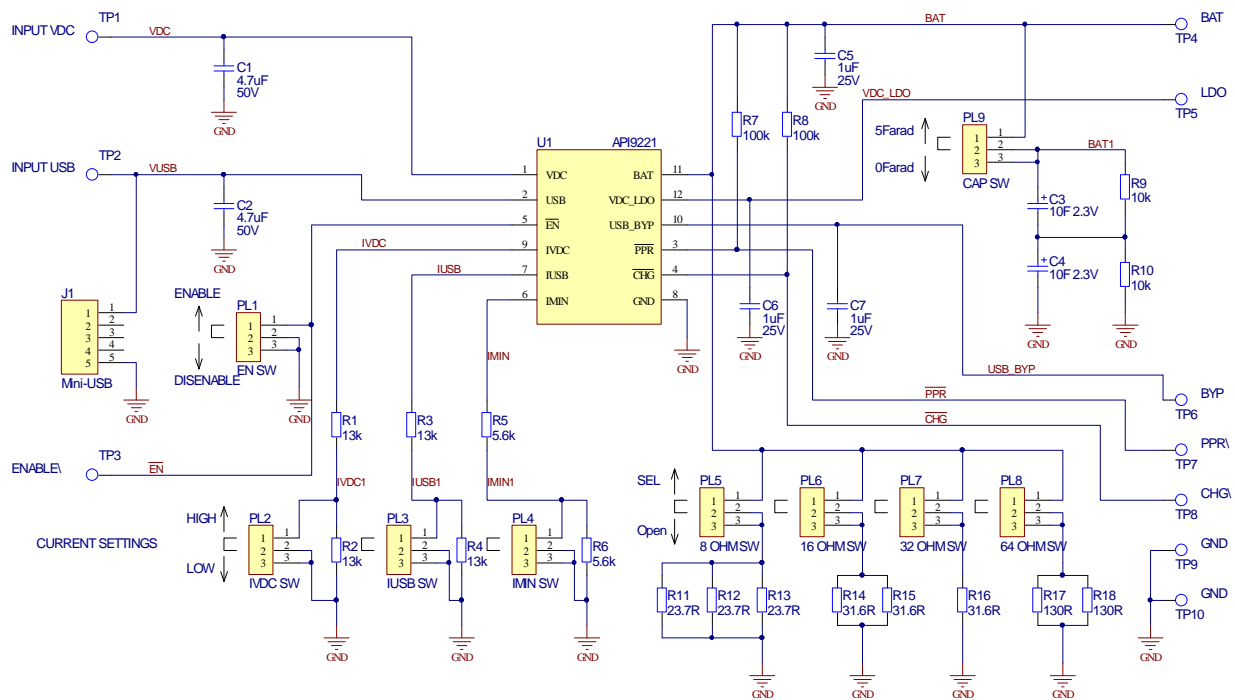
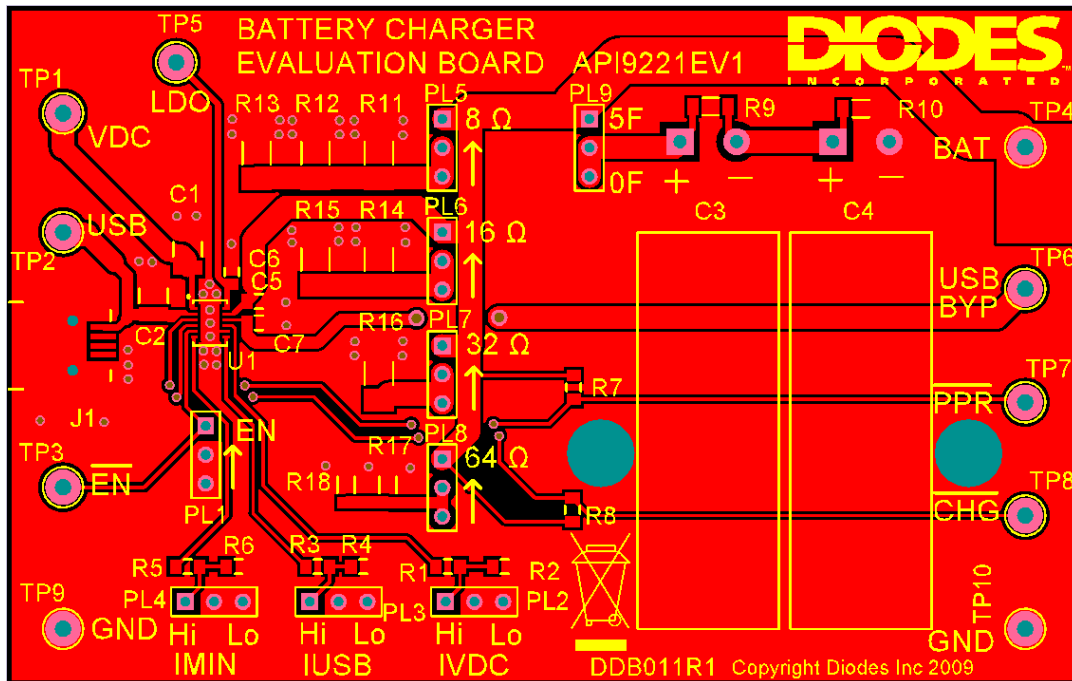**Figure 3: Test Schematic using USB Input**
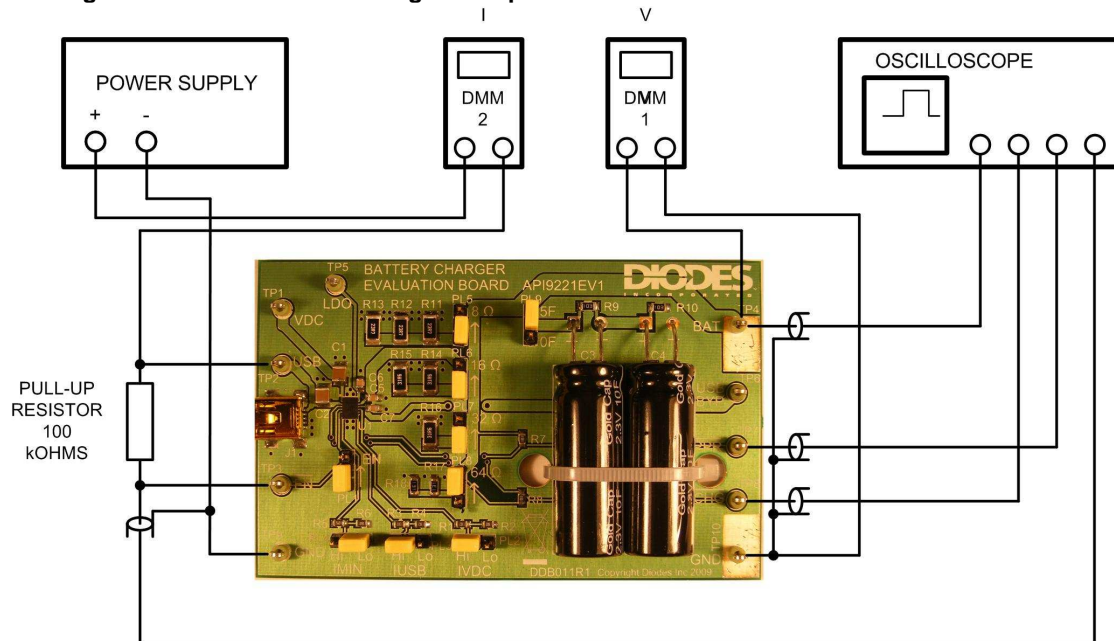
Suitable Test Equipment

Count	Description	Manufacturer	Part Number
1	Adjustable Power Supply, 10V 1A	Thurlby Thandar	CPX400A
2	Digital Multimeter	Fluke	179
1	Digital Storage Oscilloscope, 4 channels	Tektronix	TDS2024B
1	Resistor, 100k ohms ± 5%, 250mW		

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Schematic

PCB Copper Layout & Silk Screen -Top

PCB Copper Layout & Silk Screen – Bottom
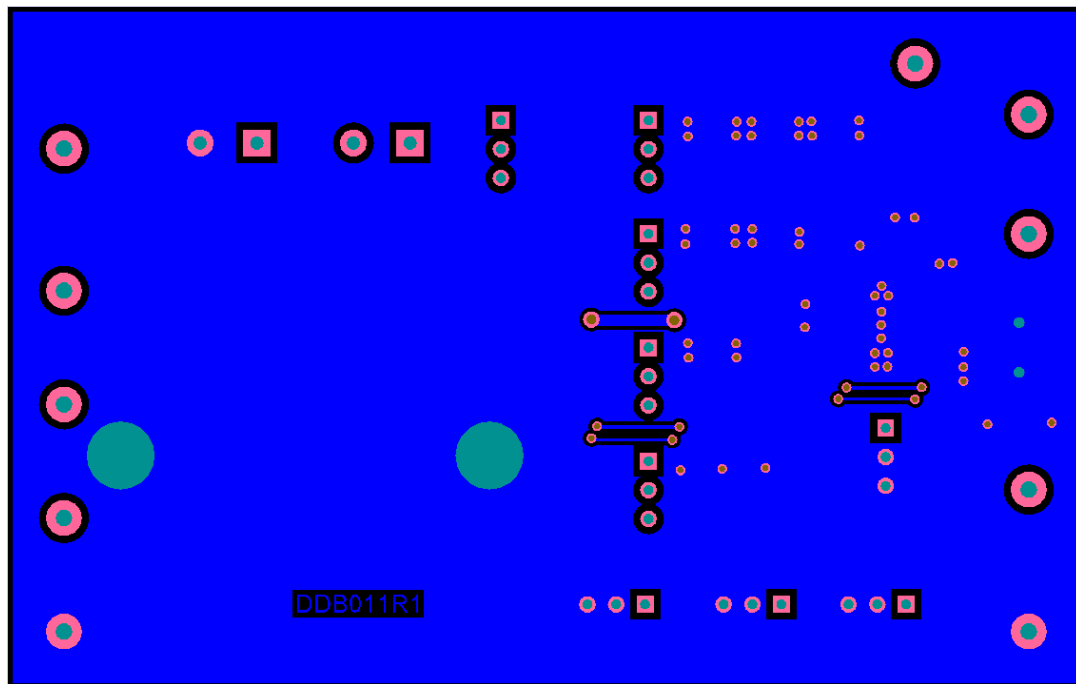
Parts List

Count	Designator	Description	Package	Manufacturer	Part Number
2	C1, C2	Capacitor, X7R, 4.7uF 50V	1210	Kemet	C1210C475K5RACTU
2	C3, C4	Capacitor, Gold Cap 10F 2.3V	Radial, 35x12.5mm	Panasonic	EECHW0D106
3	C5, C6, C7	Capacitor, X7R, 1uF 25V	0805	Kemet	C0805C105K3RAC
4	R1, R2, R3, R4	Resistor, 13k, 1%	0805	various	
2	R5, R6	Resistor, 5k6, 1%	0805	various	
2	R7, R8	Resistor, 100k, 1%	0805	various	
2	R9, R10	Resistor, 10k, 1%, 0.25W	1206	various	
3	R11, R12, R13	Resistor, 23.7R, 1%, 0.75W	2010	Panasonic	ERJ-12SF23R7U
3	R14, R15, R16	Resistor, 31.6R, 1%, 0.75W	2010	Panasonic	ERJ-12SF31R6U
2	R17, R18	Resistor, 130R, 1%, 0.25W	1206	various	
1	U1	IC, Battery Charger, Li-Ion	DFN4x3-12	Diodes Zetex	API9221
9	PL1, PL2, PL3, PL4, PL5, PL6, PL7, PL8, PL9	Header, SIL 3pins	SIL 3 pins	Phoenix	HDR1X3

I/O and Test points

Count	Designator	Description	Function	Manufacturer	Part Number
1	TP1	Loop Terminal, 2.15mm, Green	VDC Input	Hughes	100-108
1	TP2	Loop Terminal, 2.15mm, Green	USB Input	Hughes	100-108
1	TP3	Loop Terminal, 2.15mm, Green	EN\ Input	Hughes	100-108
1	TP4	Loop Terminal, 2.15mm, Green	BAT battery connection	Hughes	100-108
1	TP5	Loop Terminal, 2.15mm, Green	LDO output	Hughes	100-108
1	TP6	Loop Terminal, 2.15mm, Green	USB BYPass	Hughes	100-108
1	TP7	Loop Terminal, 2.15mm, Green	PPR\ Power Present logic output	Hughes	100-108
1	TP8	Loop Terminal, 2.15mm, Green	CHG\ Charging logic output	Hughes	100-108
1	TP9	Loop Terminal, 2.15mm, Green	GND ground	Hughes	100-108
1	TP10	Loop Terminal, 2.15mm, Green	GND ground	Hughes	100-108
1	J1	Mini-USB	USB Input	Wurth	65100516121

Recommended Operating Conditions

Symbol	Parameter	Min	Max	Units
VDC	Input Supply Voltage, VDC (when VUSB=0)	4.5	6.7	V
VUSB	Input Supply Voltage, USB (when VDC=0)	4.5	5.3	V
IVDC	Charge current via VDC	0.1	1.1	A
IUSB	Charge current via USB	50	500	mA
IUSB_BYP	USB Bypass Current	0	200	mA
ILDO	LDO Output Current	0	10	mA
T_A	Operating Ambient Temperature	-40	+85	℃

Current Settings

The maximum charge current is set by a resistor, one for each input, VDC and USB. For the VDC input, the resistor R1 sets the current. The link IVDC SW can be set to add a series resistor, R2. For the USB input, resistor R3 sets the current. The link IUSB SW can be set to add a series resistor R4. In each case the full charge current is given by I_{VDC} when using the VDC input, or I_{USB} when using the USB input, according to the following equations.

$$I_{VDC} = \frac{6820}{R_{IVDC}} \quad \text{Amp} \tag{1}$$

where R_{IVDC} is the resistance, in ohms, (R1 or R1 + R2) between IVDC and GND pins.

$$I_{USB} = \frac{6820}{R_{IUSB}} \quad \text{Amp} \tag{2}$$

where R_{IUSB} is the resistance, in ohms, (R3 or R3 + R4) between IUSB and GND pins.

For example if the IVDC SW link is set to LOW, and R_{IVDC} is chosen to be 26k, then the charge current is nominally 262mA when using the VDC input.

When the battery voltage V_{BAT} is below 2.7V, the charging current is typically 18% of the full values I_{VDC} or I_{USB}. When V_{BAT} is above this level, the charging current rises to the full value given by the equations (1) and (2) above. When V_{BAT} approaches the output control value of nominally 4.2V, the current is reduced to a low level. As the battery crosses the end-of-charge threshold voltage, the current value I_{MIN} is reached and the CHG\ output flag goes high. The current is further reduced gradually to a very low leakage value as the final battery voltage is reached. I_{MIN} is set by resistor R5. The link IMIN SW can be set to add an additional resistor, R6. I_{MIN} is determined as follows:

$$I_{MIN} = \frac{550}{R_{IMIN}} \quad \text{Amp} \tag{3}$$

where R_{IMIN} is the resistance, in ohms, (R5 or R5 + R6) between IMIN and GND pins.

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