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PRX Data Sheet

Features

- Complete Uninterruptable Power System (UPS) controller on a single board
- Allows up to 4 hot-swappable battery packs
- Handles all common battery chemistries
- Handles both smart and dumb battery packs
- Output voltage is independent of battery voltage
- Regulated output voltage can be adjusted on-the-fly
- Output current up to 10 A
- Output voltage up to 50 V
- On-board LED indicators for each battery and for overall system
- Remote LED option
- External bidirectional communication via I^2C
- USART communication (transmit only)
- Carries agency approvals

Description

The PRX is a complete uninterruptable power management system on a single board. It combines an input power control unit with four battery chargers and a buck-boost output regulator. When external power is present, the system automatically charges the battery pack(s) while supplying a regulated output voltage (which may be above, below, or equal to the battery voltage). When external power is removed, the system seamlessly switches to battery operation and continues to supply the regulated output voltage. When external power is restored, the system seamlessly reverts to input power and recharges the pack(s). When configured with multiple packs, the packs are all hot-swappable.

The PRX displays its present status via five on-board, bicolor LEDs. There is one LED for each battery pack and one for the overall system. For convenience, all the LEDs may be externally mirrored, and all status information can also be read electronically via an I^2C link. Additionally, status information is broadcast periodically on an USART link (output only).

The PRX supports all common battery chemistries including lithium ion, lithium polymer, lithium iron phosphate, nickel metal-hydride, nickel cadmium, and lead acid. Packs may be smart (SMBus) or dumb.

Absolute Maximum Ratings

	Minimum	Maximum	Unit
Input Voltage	-0.2	42	V
Battery Voltage	-0.2	38	V
Battery Charge Current	0.0	5.0	A
LED Monitor Terminals	-0.2	5.1	V
I^2C Terminals	-0.2	5.1	V
RS Terminal (USART out)	-0.2	5.1	V
Electrostatic Discharge	-2	2	kV
Operating Temperature	0	40	°C
Storage Temperature	-20	85	°C

NOTICE: Stresses beyond those listed in Absolute Maximum Ratings may cause permanent damage to the device.

Electrical Characteristics

Regulator Headroom (above max battery voltage) .....4.0 V
Maximum Charge Current .....5.0 A

Board Pin Assignments

Pin Label	Direction	Description
GND	I/O	Ground
Vin	Input	Input power - typically 10V to 48V
Vout	Output	Regulated output voltage
+5V	Output	+5V available for powering auxiliary circuitry
Red1	Output	Red LED indicator for battery 1
Grn1	Output	Green LED indicator for battery 1
Red2	Output	Red LED indicator for battery 2
Grn2	Output	Green LED indicator for battery 2
Grn5	Output	Green LED indicator for system status
Red5	Output	Red LED indicator for system status
D	I/O	I^2C data line for external communications
C	I/O	I^2C clock line for external communications
RS	Output	USART output of status
Red3	Output	Red LED indicator for battery 3
Grn3	Output	Green LED indicator for battery 3
Red4	Output	Red LED indicator for battery 4
Grn4	Output	Green LED indicator for battery 4

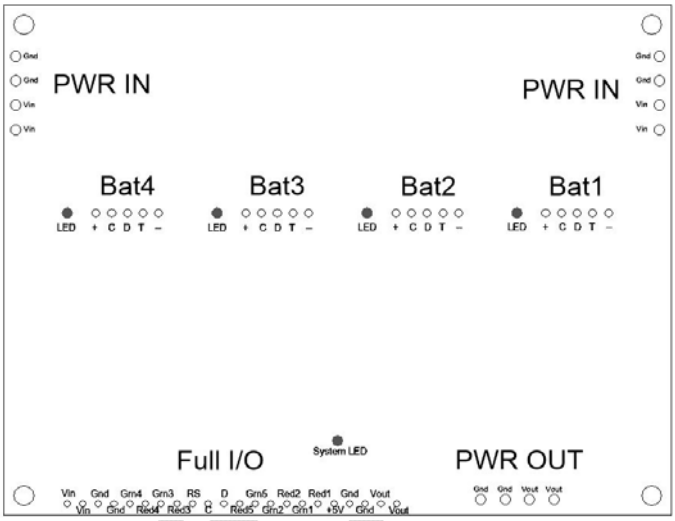


Figure 1: PRX Board Layout

Battery Pin Assignments

Pin Label	Name	Description
-	Battery -	Battery -
T	Thermistor	Thermistor
D	Data	I^2C Data (used only with smart pack)
C	Clock	I^2C Clock (used only with smart pack)
+	Battery +	Battery +

BLOCK DIAGRAM

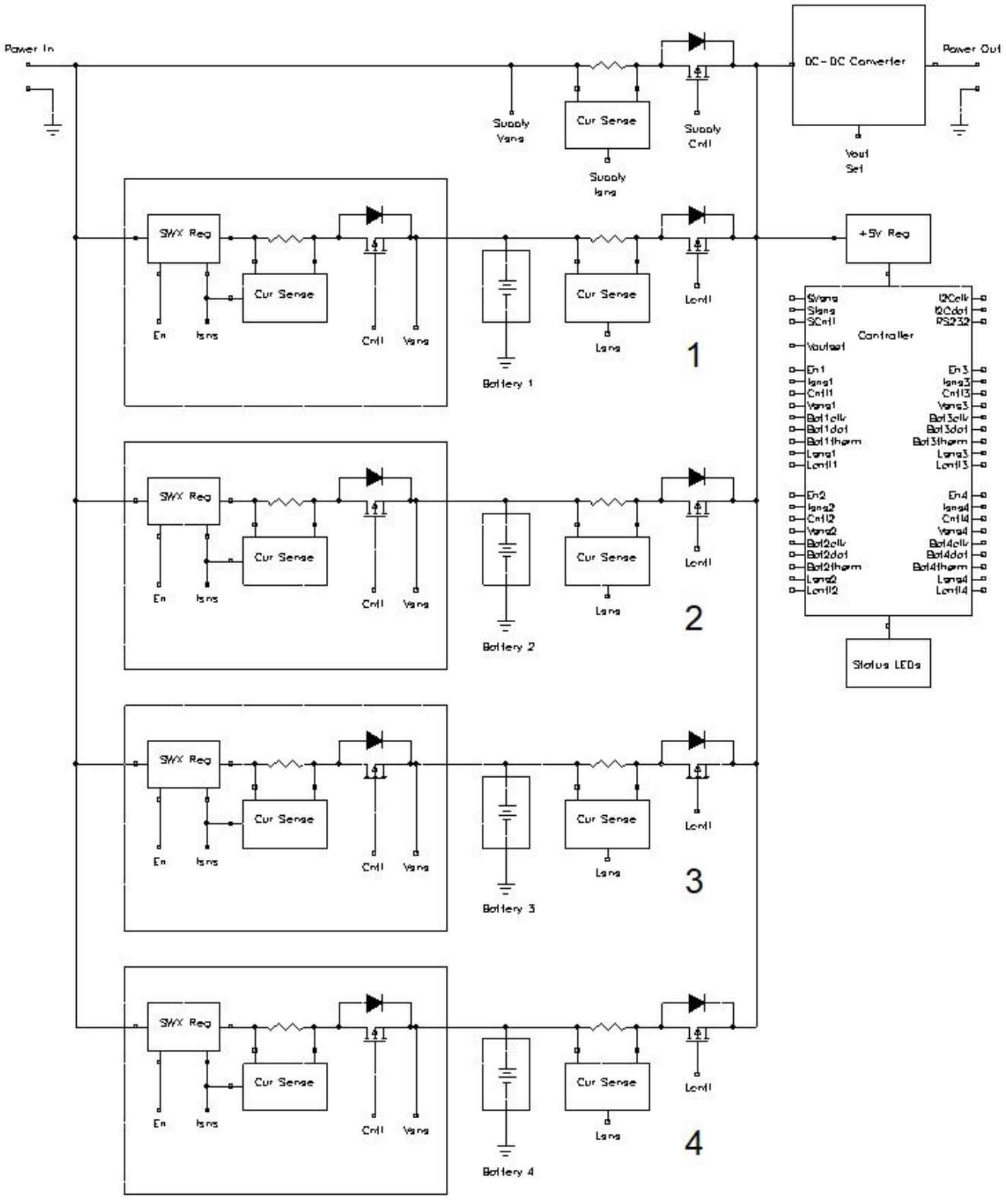


FIGURE 2: PRX BLOCK DIAGRAM

Software Algorithms

The PRX board comes factory programmed for a specific battery chemistry. Standard software algorithms target lithium-based packs (including lithium ion, lithium polymer, lithium iron phosphate, and lithium titanate), nickel metal-hydride packs, nickel cadmium packs, and lead acid packs. These algorithms are described below. Customized software is also available for specialty applications.

The PRX can handle up to 4 battery packs simultaneously. If dumb packs are used, they should all be of the same chemistry and have the same number of cells. If SMBus-compatible packs are used, they may be of different chemistries and voltages.

All Chemistries

When power is first applied to the PRX, the on-board LEDs cycles through a sequence of red-yellow-green-off. This takes about 1.5 seconds and shows the unit is ready to operate.

The PRX detects battery presence via the thermistor signal. To register as a valid battery, it must indicate a resistance between 0 Ω and 40 kΩ. Resistances between 3 kΩ and 40 kΩ will be assumed to be indicate the presence of a 10 kΩ NTC thermistor and will be translated into a temperature reading. Standard versions of software will assume this indicates a nickel-metal hydride pack. Anything less than 3 kΩ will be assumed to be a lithium-based pack.

Once a pack is detected, the PRX charges each battery in 4 distinct stages: Wake-up, fast charge, top off, and maintenance. The latter three stages are dependent on the specific battery chemistry and are discussed below.

The wake-up stage is common to all algorithms. During wake-up, a low value current is applied to the pack until its terminal voltage exceeds a predetermined threshold. This stage lasts for up to three minutes. If the voltage fails to reach the threshold in that time, the charger indicates an error. Once in an error state, charge current is terminated, and the only ways to exit the state are through removal of the battery or by cycling the input power.

Lithium-based chemistries

The PRX employs a CCCV algorithm in which a constant current is applied to the pack until its voltage reaches its maximum value. At that point, the voltage is held constant while the current is allowed to taper off. With dumb batteries, the pack is assumed to be full when the current falls to less than one-tenth of its original value. In SMBus-compatible smart packs, the Status bits are used to determine when the pack is full.

During the taper period, progressively less charge is stored in the pack. For this reason, the LED is set to indicate that the cycle is complete when the current falls to one-fifth of its original value. Current continues to be applied to the pack, however, for an additional hour or until the current falls below the one-tenth mark, whichever comes first. This additional charge period typically adds about 5 % to the run-time of the pack.

Once the current has fallen to one-tenth of its maximum value, it is completely turned off so as not to compromise the integrity of the cells. Every two hours thereafter, the current is turned on for a fraction of second to verify the pack is still fully charged. If it is, the current is again shut off. If the pack is found to be partially depleted, a new charge cycle is commenced.

Nickel Metal-Hydride

TBD.

Nickel Cadmium

TBD

Lead Acid

TBD

System Operation

When power is first applied to the PRX (either from an input supply or from an installed battery), all the LEDs will cycle red-yellow-green-off to indicate that the system is initializing.

The system will turn on the output regulator to whatever voltage is pre-programmed into the unit. This voltage may be re-programmed via the I^2C communications port, if desired, in which case the new level will be retained.

An assessment is then made of the resources available to the system:

- If only external power available, it will be directly shunted to the output regulator. The 4 battery LEDs will remain off (indicating no batteries are present), and the system LED will light yellow (indicating there is no back-up power source available).
- If only one battery is available, it will be directly shunted to the output regulator. That battery's LED will light solid green while the others will remain off. The system LED will flash green.
- If multiple batteries are available, the one with the highest voltage (most charge) will be shunted to the output regulator. As its charge is drawn down, its voltage will decrease until it matches one or more of the other batteries. They will then also be shunted to the output regulator so that the packs are depleted in parallel. All the batteries present will give a solid green indication throughout this process. The system LED will flash green.
- If external power and one or more batteries are available, the external power will be shunted to the output regulator while also charging the available batteries. The battery LED(s) will flash green as they charge and switch to solid green when they are full. The system LED will be solid green.

As resources are subsequently added or removed, the optimal source of power will be shunted to the output regulator and the appropriate status will be reflected in the LED indications.

The system constantly monitors all voltages and currents from the batteries and the input supply. All this information is available via the I^2C communications port. If smart batteries are used, their internal information is also available on this port.

BATTERY LED INDICATIONS

LED Indication	Meaning
Red-Yellow-Green-Off	Power-up sequence
Off	No battery detected
Green Flashing	Fast charge in progress
Solid Green	Charging complete or battery supplying power
Yellow	Charging suspended[1]
Red Flashing	Error[2]

SYSTEM LED INDICATIONS

LED Indication	Meaning
Red-Yellow-Green-Off	Power-up sequence
Off	No battery detected
Green Flashing	Fast charge in progress
Solid Green	Charging complete or battery supplying power
Yellow	Charging suspended
Red Flashing	Error

[1] With standard software, this only occurs when a NiMH or NiCd pack is outside of 0 °C to 45 °C range.

[2] Occurs when wake-up charge exceeds 3 minutes, the pack refuses to accept charge current, or an SMBus pack is unable to communicate.

COMMUNICATION PROTOCOLS

A 256-byte RAM storage table is accessible to host systems. This table can be read/written to via either I²C protocols or via a USART/RS-232 port. The I²C communications are bidirectional, but the USART is transmit only. The table of these values can be found in Appendix A: RAM Data Table.

I²C/SMBUS COMMUNICATION PROTOCOL

The PRX device can act as an SMBus slave to a target system. The pins can be found on the board labeled ***C*** for the I²C clock line and ***D*** for the I²C data line as shown in the "Full I/O" section of the board in Figure 1.

A 256-byte section of RAM is accessed by command code. The host system can read as much data as it wants until it generates a NACK. This way the host can choose to get two bytes of data (integer) from a specific location, or starting with command 0x00, the host device can read 256-bytes to get the full table.

Commands 0x00 through 0xBF are read only values. Commands 0xC0 through 0xFF are read/write values with reads coming from RAM and Writes going to EEPROM and RAM.

READS FROM I²C

The PRX device address is identical to a typical SMBus compatible battery, 0x16. The read protocol can be seen in Figure 3.

	7	1	1	8	1	1	7	1	1	8	1	8	1	1	
S	Address	W	A	Command Code	A	S	Address	R	A	Data Byte Low	A	Data Byte High	A	…	N	P

FIGURE 3: READ PROTOCOL

WRITES TO I²C

Writing to the PRX device is done with the protocol seen in Figure 4. This will write to the EEPROM of the PRX if the command is to a writable value. This allows for 2-byte writes to values such as the V_CAL high and low bytes.

	7	1	1	8	1	8	1	8	1	
S	Address	W	A	Command Code	A	Data Byte Low	A	Data Byte High	A	P

FIGURE 4: WRITE PROTOCOL

For instance, Figure 5 will write the BUS_V_CAL with 0x2800. The value of 0x28 will be written to the address 0xC0 and the value of 0x00 will be written to the address 0xC1.

	7	1	1	8	1	8	1	8	1	
S	0x0B	1	A	0xC0	A	0x00	A	0x28	A	P

FIGURE 5: WRITE EXAMPLE

USART/RS-232 COMMUNICATION PROTOCOL

A USART port is also present on the PRX device to allow for reading of the RAM table. The USART is transmit only and therefore cannot be used to write values to the PRX device. The USART pin can be found on the board labeled ***RS*** as shown in the "Full I/O" section of the board in Figure 1.

The serial configuration is as follows:

Speed (baud)	38400
Data bits	8
Stop bits	1
Parity	None
Flow control	None
Data format	#hhll,hhll,hhll,…,hhll<cr>

The data format is such that hh is the high byte and ll is the low byte of the transmitted value. The data is sent in ASCII HEX format. So, a value of 12600 decimal would be transmitted as the ASCII characters "3138" (0x33, 0x31, 0x33, 0x38). The stream ends in the termination character CR, or carriage return (0x0D). This allows for a delineation of each transmission.

APPENDIX A: RAM DATA TABLE

I²C Command (decimal)	I²C Command (hex)	RS232 USART Index	Name	Access	Notes
0	00	0	SMB_1_voltage_H	r	Battery 1 - SMBus reported Voltage (Code 0x09) - High
1	01		SMB_1_voltage_L	r	Battery 1 - SMBus reported Voltage (Code 0x09) - Low
2	02	1	SMB_1_current_H	r	Battery 1 - SMBus reported Current (Code 0x0A) - High
3	03		SMB_1_current_L	r	Battery 1 - SMBus reported Current (Code 0x0A) - Low
4	04	2	SMB_1_temperature_H	r	Battery 1 - SMBus reported Temperature (Code 0x08) - High
5	05		SMB_1_temperature_L	r	Battery 1 - SMBus reported Temperature (Code 0x08) - Low
6	06	3	SMB_1_RSOC_H	r	Battery 1 - SMBus reported RelativeStateOfCharge (Code 0x0D) - High
7	07		SMB_1_RSOC_L	r	Battery 1 - SMBus reported RelativeStateOfCharge (Code 0x0D) - Low
8	08	4	SMB_1_ASOC_H	r	Battery 1 - SMBus reported AbsoluteStateOfCharge (Code 0x0E) - High
9	09		SMB_1_ASOC_L	r	Battery 1 - SMBus reported AbsoluteStateOfCharge (Code 0x0E) - Low
10	0A	5	SMB_1_design_cap_H	r	Battery 1 - SMBus reported DesignCapacity (Code 0x18) - High
11	0B		SMB_1_design_cap_L	r	Battery 1 - SMBus reported DesignCapacity (Code 0x18) - Low
12	0C	6	SMB_1_FCC_H	r	Battery 1 - SMBus reported FullChargeCapacity (Code 0x10) - High
13	0D		SMB_1_FCC_L	r	Battery 1 - SMBus reported FullChargeCapacity (Code 0x10) - Low
14	0E	7	SMB_1_status_H	r	Battery 1 - SMBus reported BatteryStatus (Code 0x16) - High
15	0F		SMB_1_status_L	r	Battery 1 - SMBus reported BatteryStatus (Code 0x16) - Low
16	10	8	SMB_1_I_request_H	r	Battery 1 - SMBus reported ChargingCurrent (Code 0x14) - High
17	11		SMB_1_I_request_L	r	Battery 1 - SMBus reported ChargingCurrent (Code 0x14) - Low
18	12	9	SMB_1_V_request_H	r	Battery 1 - SMBus reported ChargingVoltage (Code 0x15) - High
19	13		SMB_1_V_request_L	r	Battery 1 - SMBus reported ChargingVoltage (Code 0x15) - Low
20	14	10	SMB_2_voltage_H	r	Battery 2 - SMBus reported Voltage (Code 0x09) - High
21	15		SMB_2_voltage_L	r	Battery 2 - SMBus reported Voltage (Code 0x09) - Low
22	16	11	SMB_2_current_H	r	Battery 2 - SMBus reported Current (Code 0x0A) - High
23	17		SMB_2_current_L	r	Battery 2 - SMBus reported Current (Code 0x0A) - Low
24	18	12	SMB_2_temperature_H	r	Battery 2 - SMBus reported Temperature (Code 0x08) - High
25	19		SMB_2_temperature_L	r	Battery 2 - SMBus reported Temperature (Code 0x08) - Low
26	1A	13	SMB_2_RSOC_H	r	Battery 2 - SMBus reported RelativeStateOfCharge (Code 0x0D) - High
27	1B		SMB_2_RSOC_L	r	Battery 2 - SMBus reported RelativeStateOfCharge (Code 0x0D) - Low
28	1C	14	SMB_2_ASOC_H	r	Battery 2 - SMBus reported AbsoluteStateOfCharge (Code 0x0E) - High
29	1D		SMB_2_ASOC_L	r	Battery 2 - SMBus reported AbsoluteStateOfCharge (Code 0x0E) - Low
30	1E	15	SMB_2_design_cap_H	r	Battery 2 - SMBus reported DesignCapacity (Code 0x18) - High
31	1F		SMB_2_design_cap_L	r	Battery 2 - SMBus reported DesignCapacity (Code 0x18) - Low
32	20	16	SMB_2_FCC_H	r	Battery 2 - SMBus reported FullChargeCapacity (Code 0x10) - High
33	21		SMB_2_FCC_L	r	Battery 2 - SMBus reported FullChargeCapacity (Code 0x10) - Low
34	22	17	SMB_2_status_H	r	Battery 2 - SMBus reported BatteryStatus (Code 0x16) - High
35	23		SMB_2_status_L	r	Battery 2 - SMBus reported BatteryStatus (Code 0x16) - Low
36	24	18	SMB_2_I_request_H	r	Battery 2 - SMBus reported ChargingCurrent (Code 0x14) - High
37	25		SMB_2_I_request_L	r	Battery 2 - SMBus reported ChargingCurrent (Code 0x14) - Low
38	26	19	SMB_2_V_request_H	r	Battery 2 - SMBus reported ChargingVoltage (Code 0x15) - High

I²C Command (decimal)	I²C Command (hex)	RS232 USART Index	Name	Access	Notes
39	27		SMB_2_V_request_L	r	Battery 2 - SMBus reported ChargingVoltage (Code 0x15) - Low
40	28	20	SMB_3_voltage_H	r	Battery 3 - SMBus reported Voltage (Code 0x09) - High
41	29		SMB_3_voltage_L	r	Battery 3 - SMBus reported Voltage (Code 0x09) - Low
42	2A	21	SMB_3_current_H	r	Battery 3 - SMBus reported Current (Code 0x0A) - High
43	2B		SMB_3_current_L	r	Battery 3 - SMBus reported Current (Code 0x0A) - Low
44	2C	22	SMB_3_temperature_H	r	Battery 3 - SMBus reported Temperature (Code 0x08) - High
45	2D		SMB_3_temperature_L	r	Battery 3 - SMBus reported Temperature (Code 0x08) - Low
46	2E	23	SMB_3_RSOC_H	r	Battery 3 - SMBus reported RelativeStateOfCharge (Code 0x0D) - High
47	2F		SMB_3_RSOC_L	r	Battery 3 - SMBus reported RelativeStateOfCharge (Code 0x0D) - Low
48	30	24	SMB_3_ASOC_H	r	Battery 3 - SMBus reported AbsoluteStateOfCharge (Code 0x0E) - High
49	31		SMB_3_ASOC_L	r	Battery 3 - SMBus reported AbsoluteStateOfCharge (Code 0x0E) - Low
50	32	25	SMB_3_design_cap_H	r	Battery 3 - SMBus reported DesignCapacity (Code 0x18) - High
51	33		SMB_3_design_cap_L	r	Battery 3 - SMBus reported DesignCapacity (Code 0x18) - Low
52	34	26	SMB_3_FCC_H	r	Battery 3 - SMBus reported FullChargeCapacity (Code 0x10) - High
53	35		SMB_3_FCC_L	r	Battery 3 - SMBus reported FullChargeCapacity (Code 0x10) - Low
54	36	27	SMB_3_status_H	r	Battery 3 - SMBus reported BatteryStatus (Code 0x16) - High
55	37		SMB_3_status_L	r	Battery 3 - SMBus reported BatteryStatus (Code 0x16) - Low
56	38	28	SMB_3_I_request_H	r	Battery 3 - SMBus reported ChargingCurrent (Code 0x14) - High
57	39		SMB_3_I_request_L	r	Battery 3 - SMBus reported ChargingCurrent (Code 0x14) - Low
58	3A	29	SMB_3_V_request_H	r	Battery 3 - SMBus reported ChargingVoltage (Code 0x15) - High
59	3B		SMB_3_V_request_L	r	Battery 3 - SMBus reported ChargingVoltage (Code 0x15) - Low
60	3C	30	SMB_4_voltage_H	r	Battery 4 - SMBus reported Voltage (Code 0x09) - High
61	3D		SMB_4_voltage_L	r	Battery 4 - SMBus reported Voltage (Code 0x09) - Low
62	3E	31	SMB_4_current_H	r	Battery 4 - SMBus reported Current (Code 0x0A) - High
63	3F		SMB_4_current_L	r	Battery 4 - SMBus reported Current (Code 0x0A) - Low
64	40	32	SMB_4_temperature_H	r	Battery 4 - SMBus reported Temperature (Code 0x08) - High
65	41		SMB_4_temperature_L	r	Battery 4 - SMBus reported Temperature (Code 0x08) - Low
66	42	33	SMB_4_RSOC_H	r	Battery 4 - SMBus reported RelativeStateOfCharge (Code 0x0D) - High
67	43		SMB_4_RSOC_L	r	Battery 4 - SMBus reported RelativeStateOfCharge (Code 0x0D) - Low
68	44	34	SMB_4_ASOC_H	r	Battery 4 - SMBus reported AbsoluteStateOfCharge (Code 0x0E) - High
69	45		SMB_4_ASOC_L	r	Battery 4 - SMBus reported AbsoluteStateOfCharge (Code 0x0E) - Low
70	46	35	SMB_4_design_cap_H	r	Battery 4 - SMBus reported DesignCapacity (Code 0x18) - High
71	47		SMB_4_design_cap_L	r	Battery 4 - SMBus reported DesignCapacity (Code 0x18) - Low
72	48	36	SMB_4_FCC_H	r	Battery 4 - SMBus reported FullChargeCapacity (Code 0x10) - High
73	49		SMB_4_FCC_L	r	Battery 4 - SMBus reported FullChargeCapacity (Code 0x10) - Low
74	4A	37	SMB_4_status_H	r	Battery 4 - SMBus reported BatteryStatus (Code 0x16) - High
75	4B		SMB_4_status_L	r	Battery 4 - SMBus reported BatteryStatus (Code 0x16) - Low
76	4C	38	SMB_4_I_request_H	r	Battery 4 - SMBus reported ChargingCurrent (Code 0x14) - High
77	4D		SMB_4_I_request_L	r	Battery 4 - SMBus reported ChargingCurrent (Code 0x14) - Low
78	4E	39	SMB_4_V_request_H	r	Battery 4 - SMBus reported ChargingVoltage (Code 0x15) - High
79	4F		SMB_4_V_request_L	r	Battery 4 - SMBus reported ChargingVoltage (Code 0x15) - Low

I²C Command (decimal)	I²C Command (hex)	RS232 USART Index	Name	Access	Notes
80	50	40	BUS_V_H	r	Input Bus Voltage - High
81	51		BUS_V_L	r	Input Bus Voltage - Low
82	52	41	BUS_I_H	r	Input Bus Current - High
83	53		BUS_I_L	r	Input Bus Current - Low
84	54	42	SMB_err_cnt_A	r	Charger 1 - Total failed SMBus readings
85	55		chg_state_1	r	Charger 1 - Current charger state Bit 0 CC = 1 CV = 0 Bit 2 Battery Present = 1 Bit 3 SMBus Error = 1 Bit 4 Wall adapter present = 1 Bit 5 Charge Done = 1
86	56	43	integral_1_M	r	Internal Use Only
87	57		integral_1_L	r	Internal Use Only
88	58	44	CHG_1_V_H	r	Charger 1 - A/D Battery Voltage - High
89	59		CHG_1_V_L	r	Charger 1 - A/D Battery Voltage - Low
90	5A	45	CHG_1_I_H	r	Charger 1 - A/D Charging Current - High
91	5B		CHG_1_I_L	r	Charger 1 - A/D Charging Current - Low
92	5C	46	CHG_1_L_H	r	Charger 1 - A/D Load Current (to Bus) - High
93	5D		CHG_1_L_L	r	Charger 1 - A/D Load Current (to Bus) - Low
94	5E	47	CHG_1_T_H	r	Charger 1 - A/D Battery Temperature - High
95	5F		CHG_1_T_L	r	Charger 1 - A/D Battery Temperature - Low
96	60	48	SMB_err_cnt_B	r	Charger 2 - Total failed SMBus readings
97	61		chg_state_2	r	Charger 2 - Current charger state Bit 0 CC = 1 CV = 0 Bit 2 Battery Present = 1 Bit 3 SMBus Error = 1 Bit 4 Wall adapter present = 1 Bit 5 Charge Done = 1
98	62	49	integral_2_M	r	Internal Use Only
99	63		integral_2_L	r	Internal Use Only
100	64	50	CHG_2_V_H	r	Charger 2 - A/D Battery Voltage - High
101	65		CHG_2_V_L	r	Charger 2 - A/D Battery Voltage - Low
102	66	51	CHG_2_I_H	r	Charger 2 - A/D Charging Current - High
103	67		CHG_2_I_L	r	Charger 2 - A/D Charging Current - Low
104	68	52	CHG_2_L_H	r	Charger 2 - A/D Load Current (to Bus) - High
105	69		CHG_2_L_L	r	Charger 2 - A/D Load Current (to Bus) - Low
106	6A	53	CHG_2_T_H	r	Charger 2 - A/D Battery Temperature - High
107	6B		CHG_2_T_L	r	Charger 2 - A/D Battery Temperature - Low
108	6C	54	SMB_err_cnt_C	r	Charger 3 - Total failed SMBus readings
109	6D		chg_state_3	r	Charger 3 - Current charger state Bit 0 CC = 1 CV = 0 Bit 2 Battery Present = 1 Bit 3 SMBus Error = 1 Bit 4 Wall adapter present = 1 Bit 5 Charge Done = 1
110	6E	55	integral_3_M	r	Internal Use Only
111	6F		integral_3_L	r	Internal Use Only

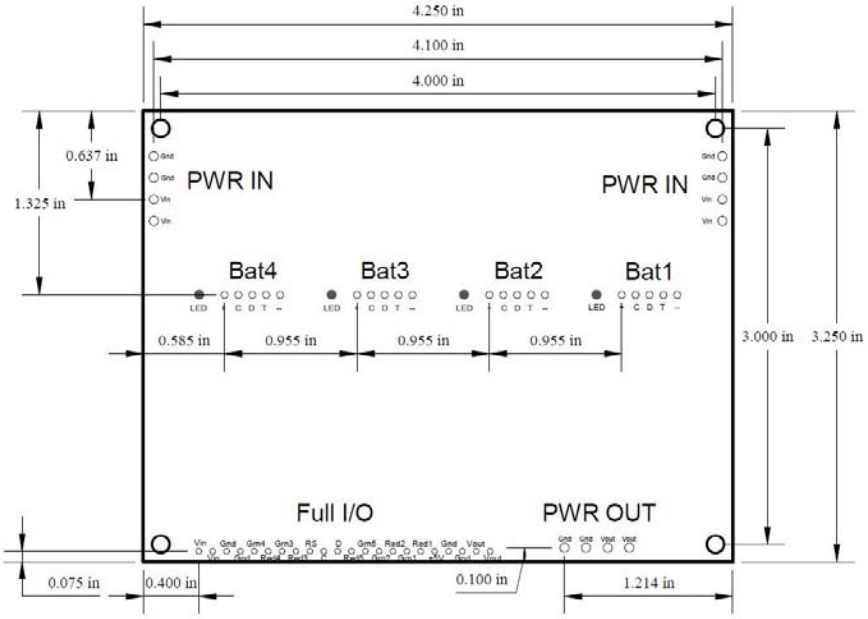
I²C Command (decimal)	I²C Command (hex)	RS232 USART Index	Name	Access	Notes
112	70	56	CHG_3_V_H	r	Charger 3 - A/D Battery Voltage - High
113	71		CHG_3_V_L	r	Charger 3 - A/D Battery Voltage - Low
114	72	57	CHG_3_I_H	r	Charger 3 - A/D Charging Current - High
115	73		CHG_3_I_L	r	Charger 3 - A/D Charging Current - Low
116	74	58	CHG_3_L_H	r	Charger 3 - A/D Load Current (to Bus) - High
117	75		CHG_3_L_L	r	Charger 3 - A/D Load Current (to Bus) - Low
118	76	59	CHG_3_T_H	r	Charger 3 - A/D Battery Temperature - High
119	77		CHG_3_T_L	r	Charger 3 - A/D Battery Temperature - Low
120	78	60	SMB_err_cnt_D	r	Charger 4 - Total failed SMBus readings
121	79		chg_state_4	r	Charger 1 - Current charger state Bit 0 CC = 1 CV = 0 Bit 2 Battery Present = 1 Bit 3 SMBus Error = 1 Bit 4 Wall adapter present = 1 Bit 5 Charge Done = 1
122	7A	61	integral_4_M	r	Internal Use Only
123	7B		integral_4_L	r	Internal Use Only
124	7C	62	CHG_4_V_H	r	Charger 4 - A/D Battery Voltage - High
125	7D		CHG_4_V_L	r	Charger 4 - A/D Battery Voltage - Low
126	7E	63	CHG_4_I_H	r	Charger 4 - A/D Charging Current - High
127	7F		CHG_4_I_L	r	Charger 4 - A/D Charging Current - Low
128	80	64	CHG_4_L_H	r	Charger 4 - A/D Load Current (to Bus) - High
129	81		CHG_4_L_L	r	Charger 4 - A/D Load Current (to Bus) - Low
130	82	65	CHG_4_T_H	r	Charger 4 - A/D Battery Temperature - High
131	83		CHG_4_T_L	r	Charger 4 - A/D Battery Temperature - Low
132	84	66	RESERVED	r	
133	85		RESERVED	r	
134	86	67	RESERVED	r	
135	87		RESERVED	r	
136	88	68	RESERVED	r	
137	89		RESERVED	r	
138	8A	69	RESERVED	r	
139	8B		RESERVED	r	
140	8C	70	RESERVED	r	
141	8D		RESERVED	r	
142	8E	71	RESERVED	r	
143	8F		RESERVED	r	
144	90	72	RESERVED	r	
145	91		RESERVED	r	
146	92	73	RESERVED	r	
147	93		RESERVED	r	
148	94	74	RESERVED	r	
149	95		RESERVED	r	

I²C Command (decimal)	I²C Command (hex)	RS232 USART Index	Name	Access	Notes
150	96	75	RESERVED	r	
151	97		RESERVED	r	
152	98	76	RESERVED	r	
153	99		RESERVED	r	
154	9A	77	RESERVED	r	
155	9B		RESERVED	r	
156	9C	78	RESERVED	r	
157	9D		RESERVED	r	
158	9E	79	RESERVED	r	
159	9F		RESERVED	r	
160	A0	80	RESERVED	r	
161	A1		RESERVED	r	
162	A2	81	RESERVED	r	
163	A3		RESERVED	r	
164	A4	82	RESERVED	r	
165	A5		RESERVED	r	
166	A6	83	RESERVED	r	
167	A7		RESERVED	r	
168	A8	84	RESERVED	r	
169	A9		RESERVED	r	
170	AA	85	RESERVED	r	
171	AB		RESERVED	r	
172	AC	86	RESERVED	r	
173	AD		RESERVED	r	
174	AE	87	RESERVED	r	
175	AF		RESERVED	r	
176	B0	88	RESERVED	r	
177	B1		RESERVED	r	
178	B2	89	RESERVED	r	
179	B3		RESERVED	r	
180	B4	90	RESERVED	r	
181	B5		RESERVED	r	
182	B6	91	RESERVED	r	
183	B7		RESERVED	r	
184	B8	92	RESERVED	r	
185	B9		RESERVED	r	
186	BA	93	RESERVED	r	
187	BB		RESERVED	r	
188	BC	94	RESERVED	r	
189	BD		RESERVED	r	
190	BE	95	RESERVED	r	

I²C Command (decimal)	I²C Command (hex)	RS232 USART Index	Name	Access	Notes
191	BF		RESERVED	r	
192	C0	96	BUS_V_cal_H	r/w	Calibration of the Bus Voltage - high
193	C1		BUS_V_cal_L	r/w	Calibration of the Bus Voltage - low
194	C2	97	BUS_I_cal_H	r/w	Calibration of the Bus Current - high
195	C3		BUS_I_cal_L	r/w	Calibration of the Bus Current - low
196	C4	98	CHG_1_V_cal_H	r/w	Charger 1 - Battery Voltage Calibration – High
197	C5		CHG_1_V_cal_L	r/w	Charger 1 - Battery Voltage Calibration – Low
198	C6	99	CHG_1_I_cal_H	r/w	Charger 1 - Battery Current Sense Calibration – High
199	C7		CHG_1_I_cal_L	r/w	Charger 1 - Battery Current Sense Calibration – Low
200	C8	100	CHG_1_L_cal_H	r/w	Charger 1 - Battery Load Current Sense Calibration – High
201	C9		CHG_1_L_cal_L	r/w	Charger 1 - Battery Load Current Sense Calibration – Low
202	CA	101	CHG_1_T_cal_H	r/w	Charger 1 - Battery Temperature Calibration – High
203	CB		CHG_1_T_cal_L	r/w	Charger 1 - Battery Temperature Calibration – Low
204	CC	102	CHG_2_V_cal_H	r/w	Charger 2 - Battery Voltage Calibration – High
205	CD		CHG_2_V_cal_L	r/w	Charger 2 - Battery Voltage Calibration – Low
206	CE	103	CHG_2_I_cal_H	r/w	Charger 2 - Battery Current Sense Calibration – High
207	CF		CHG_2_I_cal_L	r/w	Charger 2 - Battery Current Sense Calibration – Low
208	D0	104	CHG_2_L_cal_H	r/w	Charger 2 - Battery Load Current Sense Calibration – High
209	D1		CHG_2_L_cal_L	r/w	Charger 2 - Battery Load Current Sense Calibration – Low
210	D2	105	CHG_2_T_cal_H	r/w	Charger 2 - Battery Temperature Calibration – High
211	D3		CHG_2_T_cal_L	r/w	Charger 2 - Battery Temperature Calibration – Low
212	D4	106	CHG_3_V_cal_H	r/w	Charger 3 - Battery Voltage Calibration – High
213	D5		CHG_3_V_cal_L	r/w	Charger 3 - Battery Voltage Calibration – Low
214	D6	107	CHG_3_I_cal_H	r/w	Charger 3 - Battery Current Sense Calibration – High
215	D7		CHG_3_I_cal_L	r/w	Charger 3 - Battery Current Sense Calibration – Low
216	D8	108	CHG_3_L_cal_H	r/w	Charger 3 - Battery Load Current Sense Calibration – High
217	D9		CHG_3_L_cal_L	r/w	Charger 3 - Battery Load Current Sense Calibration – Low
218	DA	109	CHG_3_T_cal_H	r/w	Charger 3 - Battery Temperature Calibration – High
219	DB		CHG_3_T_cal_L	r/w	Charger 3 - Battery Temperature Calibration – Low
220	DC	110	CHG_4_V_cal_H	r/w	Charger 4 - Battery Voltage Calibration – High
221	DD		CHG_4_V_cal_L	r/w	Charger 4 - Battery Voltage Calibration – Low
222	DE	111	CHG_4_I_cal_H	r/w	Charger 4 - Battery Current Sense Calibration – High
223	DF		CHG_4_I_cal_L	r/w	Charger 4 - Battery Current Sense Calibration – Low
224	E0	112	CHG_4_L_cal_H	r/w	Charger 4 - Battery Load Current Sense Calibration – High
225	E1		CHG_4_L_cal_L	r/w	Charger 4 - Battery Load Current Sense Calibration – Low
226	E2	113	CHG_4_T_cal_H	r/w	Charger 4 - Battery Temperature Calibration – High
227	E3		CHG_4_T_cal_L	r/w	Charger 4 - Battery Temperature Calibration – Low
228	E4	114	V_hysteresis	r/w	Calibration of CCCV change over
229	E5		I_hysteresis	r/w	Calibration of CCCV change over
230	E6	115	KP_H	r/w	Internal Use Only
231	E7		KP_L	r/w	Internal Use Only

I²C Command (decimal)	I²C Command (hex)	RS232 USART Index	Name	Access	Notes
232	E8	116	KI_H	r/w	Internal Use Only
233	E9		KI_L	r/w	Internal Use Only
234	EA	117	CHG_max_I_H	r/w	Max Charging Current – High
235	EB		CHG_max_I_L	r/w	Max Charging Current – Low
236	EC	118	PWM_max_H	r/w	Maximum PWM value – High
237	ED		PWM_max_L	r/w	Maximum PWM value – High
238	EE	119	BUS_V_present_H	r/w	Voltage above which wall adapter present - High
239	EF		BUS_V_present_L	r/w	Voltage above which wall adapter present - Low
240	F0	120	batt_detect_H	r/w	A/D level above which thermistor indicates battery present – High
241	F1		batt_detect_L	r/w	A/D level above which thermistor indicates battery present – Low
242	F2	121	output_V_H	r/w	Output voltage value in A/D counts – High
243	F3		output_V_L	r/w	Output voltage value in A/D counts – Low
244	F4	122	inhibit_usart_H	r/w	Non-zero value turns off USART broadcast
245	F5		inhibit_usart_L	r/w	Non-zero value turns off USART broadcast
246	F6	123	RESERVED	r/w	
247	F7		RESERVED	r/w	
248	F8	124	RESERVED	r/w	
249	F9		RESERVED	r/w	
250	FA	125	RESERVED	r/w	
251	FB		RESERVED	r/w	
252	FC	126	RESERVED	r/w	
253	FD		RESERVED	r/w	
254	FE	127	RESERVED	r/w	
255	FF		RESERVED	r/w	

APPENDIX B: DIMENSIONS



Mounting holes are 0.125" diameter (4 places)
Power connector holes are 0.080" diameter and have 0.156" pitch
Battery connector holes are 0.050" diameter and have 0.100" pitch
Full I/O connector holes are 0.040" diameter and have 0.100" pitch

COMPONENT HEIGHTS

LED Side	0.11” (2.8 mm)
Non-LED Side	0.43” (10.9 mm)

APPENDIX C: REVISION HISTORY

Revision	Date	Editor	Notes
01.00.00	12/11/18	B. Shover	Initial Revision