NICHICON SLB Battery

Evaluation Board User Manual

REV 1.02

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1. Description

The Nichicon EHV 2107.111 evaluation board is a printed circuit board assembly (PCBA) featuring all required components to quickly operate and evaluate an energy harvesting concept using an ultra-small lithium titanate battery (LTO), so-called “SLB series” as the energy storage device. As for the harvesting, the power management is operated with the integrated circuit (IC) AEM30330 from E-Peas.

1.1. Why using an E-Peas PMIC?

The E-Peas features an ultra-low power and high-efficiency PMIC for energy harvesting where users can configure specific setups, that allows the usage for a wider range of IoT harvesting applications:

- Indoor solar harvesting (DC source)
- Vibration harvesting from low frequency (AC source)
- Open circuit voltage sensing for Maximum Power Point Tracking (MPPT) between 35% to 80%
- MPPT voltage range 100mV to 4.5V
- Cold start (harvesting from 275mV and 3mW)
- Output current 30mA (low power) or 60mA (high power)
- Load voltage 1.2V to 3.3V
- Overcharge / discharge protection
- Quiescent current as low as 875nA
- Ultra-low-power

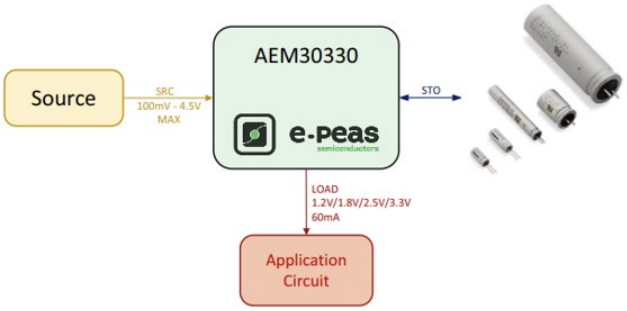


Figure 1 - E-Peas AEM30330 schematic (simplified)

For more information on the PMIC, please visit:

AEM30330 product brief: PB_AEM30330.pdf (e-peas.com)

AEM30330 datasheet: DS-AEM30330-v1.4.pdf (e-peas.com)

1.2. Why using LTO batteries from NICHICON?

- Ultra-low harvesting charge with i.e. 0.01C (5µA) due to low internal resistance
- Rapid charge/discharge with 20C
- Increased charge/discharge cycles (up to 25.000 cycles)

- Very low self-discharge and operation at as low as -30°C
- Extremely safe against rupture / ignition (UL1642 / IEC62133-2:2017)
- Maintenance-free
- 0.35mAh (3.3x9mm L) up to 150mAh (12.5x40mm L)

For more information, please visit our dedicated site:

SLB series: Nichicon Small Lithium Titanate Rechargeable Batteries (nichiconbattery.com)

2. Product specification

- Space for up to three parallel SLB batteries (no series connection available)
- USBC charging with up to 20C / charge current can be set via switch
- PMIC E-Peas AEM30330 with configuration jumpers (i.e. MPPT, load configuration etc.)
- Harvesting source from either DC (i.e. indoor PV) or AC (i.e. piezo) available
- 11 measure and test point for evaluation purposes
- DC and AC harvesting sources
- PCBA size: 110 x 60mm

3. User Guide

The PCBA was initially designed as a harvester demonstration board including CO2 sensor (CozIR-Blink), a gas sensor (Bosch BME688) and a Light sensor (LITE-ON LTR-329ALS) with data transmission via BLE /LoRa (Insight ISP4520). For this evaluation board variant, these components have been removed from the PCBA so that individual harvesting solutions can be designed.

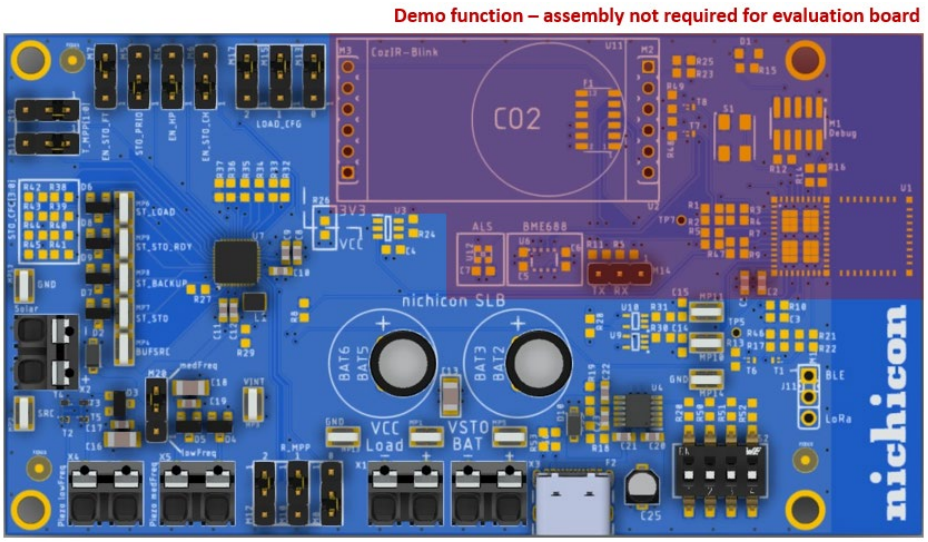


Figure 2 - PCBA assembly

NOTE: The SLB batteries are not included, please contact NICHICON in order to obtain any of below battery ratings:

- SLB03070LR35 2.4V / 0.35mAh, 12Ohm MAX 7mA max discharge current
- SLB03090LR80 2.4V / 0.8mAh, 8Ohm MAX, 16mA max discharge current
- SLB04255L040 2.4V / 4mAh, 0.6Ohm MAX, 80mA max discharge current
- SLB08115L140 2.4V / 14mAh, 0.24Ohm MAX, 280mA max discharge current
- SLB12400L151 2.4V / 150mAh, 0.06Ohm MAX, 3000mA max discharge current

3.1 Board features (connectors and jumpers)

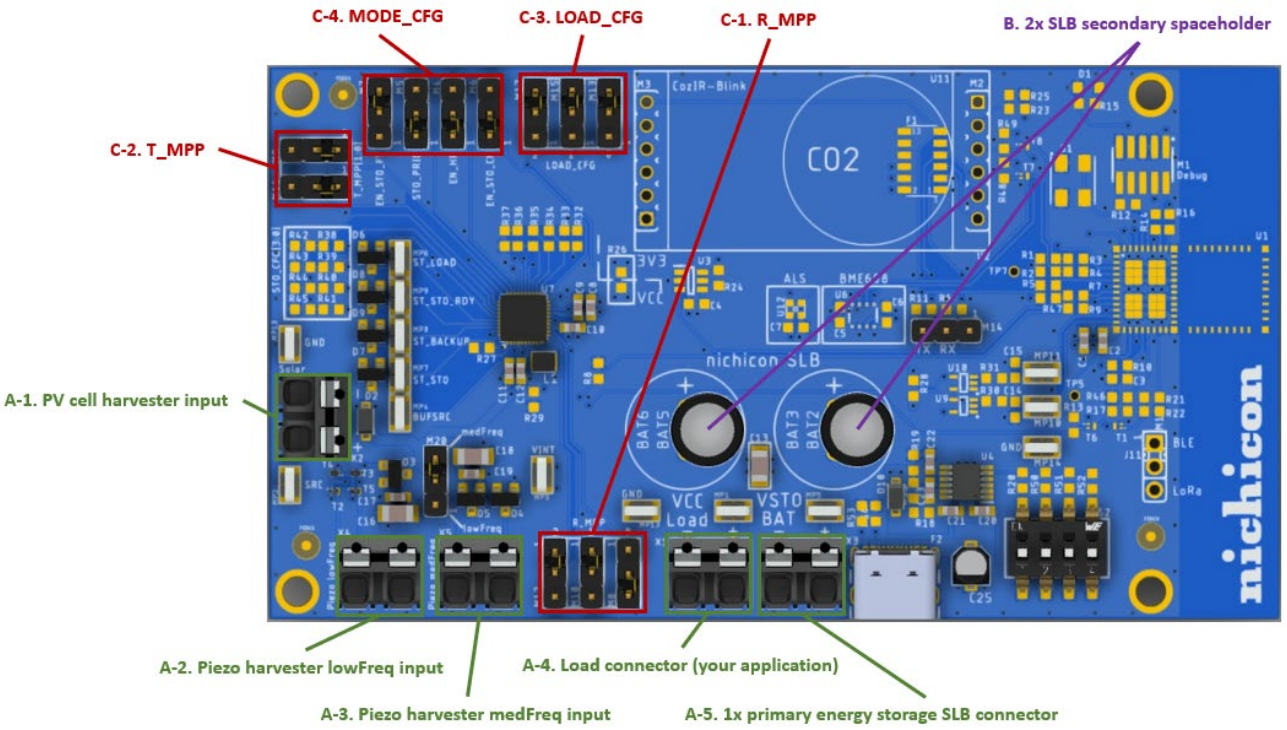


Figure 3 - Connectors and PMIC jumper settings

A. Five push-in connectors:

A-1. PV cell harvester input

A-2. Piezo harvester lowFreq input

A-3. Piezo harvester medFreq input

A-4. Load connector (your application)

A-5. Primary energy storage SLB connector

Note: the PCBA together with the PMIC is optimized to operate the energy storage device in the range of 1.8V to 2.8V, hence please connect SLB series battery only for proper operation!

B. PCBA solder connection for energy storage

B-1. 2x SLB secondary placeholder

Each placeholder contains three lead pitch holes for different SLB battery ratings. The two placeholder pads

are connected in parallel.

C. Four sets of 3-pin headers for PMIC adjustment:

C-1. Maximum power point ratio (R_MPP) configuration, for details refer to E-Peas charging IC

C-2. Maximum power point timing (T_MPP) configuration, for details refer to E-Peas charging IC

C-3. Load voltage configuration for VCC Load push-in terminal block. Please note that [3] has been removed from E-Peas latest documentation and [1] and [0] are required:

Configuration pins		LOAD output voltage			
LOAD_CFG[1:0]		$V_{LOAD,MIN}$	$V_{LOAD,MID}$	$V_{LOAD,TYP}$	$V_{LOAD,MAX}$
L	L	3.15 V	3.23 V	3.28 V	3.34 V
L	H	2.35 V	2.47 V	2.50 V	2.53 V
H	L	1.64 V	1.75 V	1.79 V	1.82 V
H	H	1.14 V	1.16 V	1.20 V	1.23 V

Table 1 - E-Peas load configuration (updated v.1.20 - removed L*OAD_CFG[2]*)

C-4. PMIC mode configurations

4. Getting started

Always connect the elements in the following order:

A. Reset the board: Short VINT, LOAD, STO and SRC test points to GND

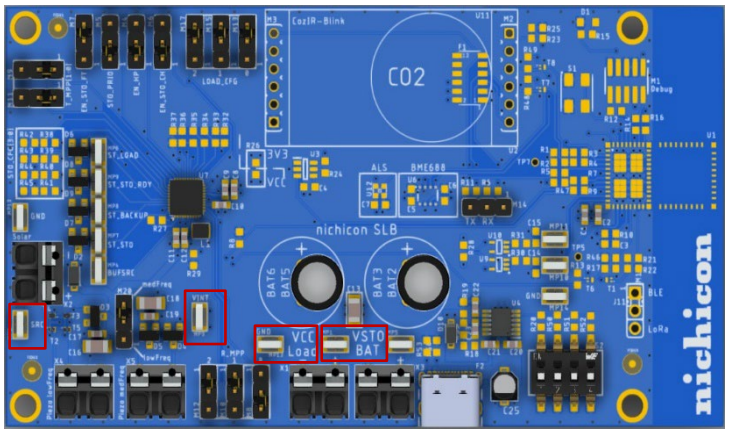


Figure 4 - Getting started

B. Configure the PCBA jumpers C-1 to C-4 according to your application requirements, see E-Peas AEM30330 datasheet as well as circuit diagram for PMIC in 9.1 for details on the jumper setting. These setting may contain:

- PMIC MPPT configuration (ratio / timing etc.)

Configuration pins		MPPT timing	
T_MPP[1:0]		Sampling duration	Sampling period
L	L	3.82 ms	18.28 ms
L	H	5.19 ms	280 ms
H	L	71.6 ms	1.12 s
H	H	1.12 s	71.7 s

Table 2 - MPPT timing configuration

Configuration pins			MPPT ratio
R_MPP[2:0]			V_{MPP} / V_{OC}
L	L	L	35%
L	L	H	50%
L	H	L	60%
L	H	H	65%
H	L	L	70%
H	L	H	75%
H	H	L	80%
H	H	H	ZMPP

Table 3 - MPP ratio configuration

- Output load voltage configuration

Configuration pins		LOAD output voltage			
LOAD_CFG[1:0]		$V_{LOAD,MIN}$	$V_{LOAD,MID}$	$V_{LOAD,TYP}$	$V_{LOAD,MAX}$
L	L	3.15 V	3.23 V	3.28 V	3.34 V
L	H	2.35 V	2.47 V	2.50 V	2.53 V
H	L	1.64 V	1.75 V	1.79 V	1.82 V
H	H	1.14 V	1.16 V	1.20 V	1.23 V

Table 4 - Load voltage configuration

- Mode configuration (EN_STO_FT; STO_PRIO; EN_HP; EN_STO_CH)

C. Connect the SLB storage element on VSTO_STO or on the SLB secondary placeholder (soldering required!)

D. Connect your application to A-4 load connector

E. Connect the harvesting source (DC or AC) to either one of the SRC connectors:

A-1 for DC input (i.e. indoor PV cell)

A-2 for vibration harvester with lower frequency

A-3 for vibration harvester with medium frequency

NOTES:

- **To avoid damaging the board, users are required to follow this procedure!**
- **Please select M28 jumper according to the frequency range (lowFreq / medFreq).**
- **Please note E-Peas documentation are to be changed/modified after releasing this documentation. This may affect the need to adjust the PMIC setting for an appropriate operation. Therefore, please always refer to the latest E-Peas AEM30330 documentation!**

5. PCBA measure points

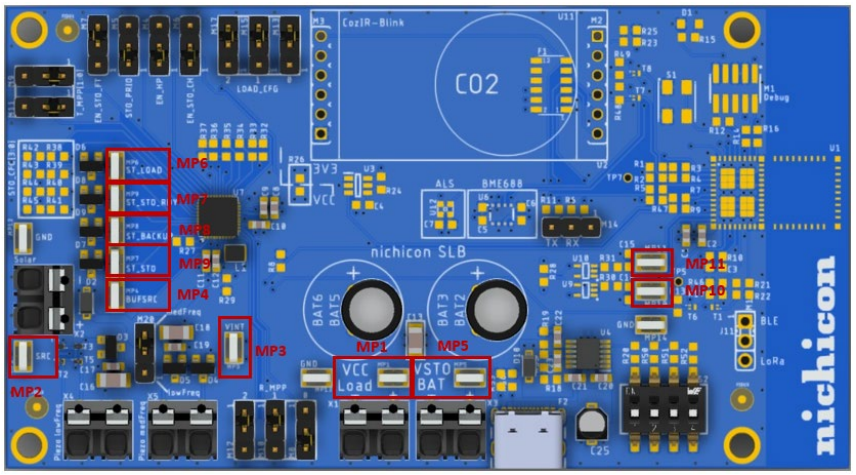


Figure 5 - PCBA Measure points

Please refer to below table for description on each measure point:

No.	Signal Name	Function:
MP1	VCC_Load	E-Peas harvesting IC output voltage. Supply for Sensors, MCU etc for your individual application. Output voltage 1.2V to 3.3V.
MP2	SRC	+DC energy harvesting input, max 4.5V, 100mA
MP3	VINT	Internal voltage supply, 2.2V
MP4	BUFSRC	Connection to an external capacitor buffering the DCDC converter input.
MP5	VSTO_BAT	Measure point for connected energy storage on Nichicon SLB battery voltage.
MP6	ST_LOAD	Logic output. Asserted when VCC_Load rises above the typical load voltage $V_{LOAD,TYP}$ threshold. Reset when VCC_Load drops below $V_{LOAD,MIN}$ threshold. High level is VCC_Load.
MP7	ST_STO	Logic output. Asserted when the storage device voltage rises above the V_{CHRDY} threshold. Reset when the storage device voltage drops below V_{OVDIS} threshold. High level is V_{STO}.
MP8	ST_BACKUP	Logic output. Asserted when the storage element voltage V_{STO} drops below V_{OVDIS}. High level is V_{LOAD}.
MP9	ST_STO_RDY	Logic output. Asserted when the storage element is above V_{CHRDY}. High level is V_{LOAD}.
MP10	I_CHRG	Current Sense Amplifier Output for charge current.
MP11	I_DISCHRG	Current Sense Output Amplifier for discharge current.

Table 5 - Test and measure points

6. SLB charging via USBC interface:

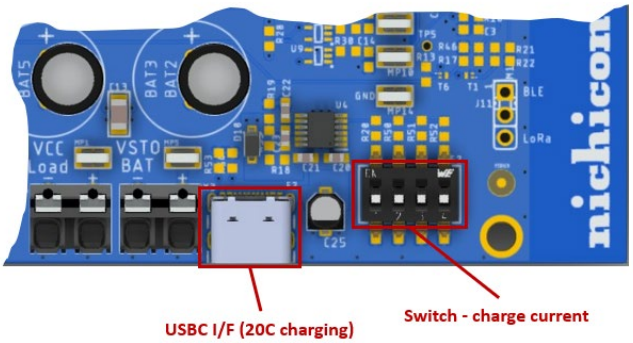


Figure 6 - USBC fast charge I/F

The PCBA features external USBC charging of the SLB battery with charging current up to 20C for quick validation. Please select the correct charge current via the switches as shown in Table 6 below, which is also printed onto the PCBA backside. Please note that the charge current reduces with the number of assembled SLB batteries.

Please always make sure not to apply charging current beyond 20C for proper board usage!

SLB PN	SLB ratings	case size	switch setting				charge current
[-]	[-]	[mm]	1	2	3	4	[mA]
SLB03070LR35*	3x7 (0.35mAh)	3x7L	ON	OFF	OFF	OFF	7
SLB03090LR80*	3.3x9 (0.8mAh)	3.3x9L	OFF	ON	OFF	OFF	16
SLB04255L040*	4x25.5 (4mAh)	4x25.5L	OFF	OFF	ON	OFF	80
SLB08115L140*	8x11.5 (14mAh)	8x11.5L	OFF	OFF	OFF	ON	280
SLB12400L151*	12.5x40 (150mAh)	12.5x40L	ON	ON	ON	ON	380

*please note this is a generic part number and 3-digits will be added based on the lead wire configuration

Table 6 - SLB quick charging switch settings

7. Appearance and PCBA interfaces

7.1. Appearance front

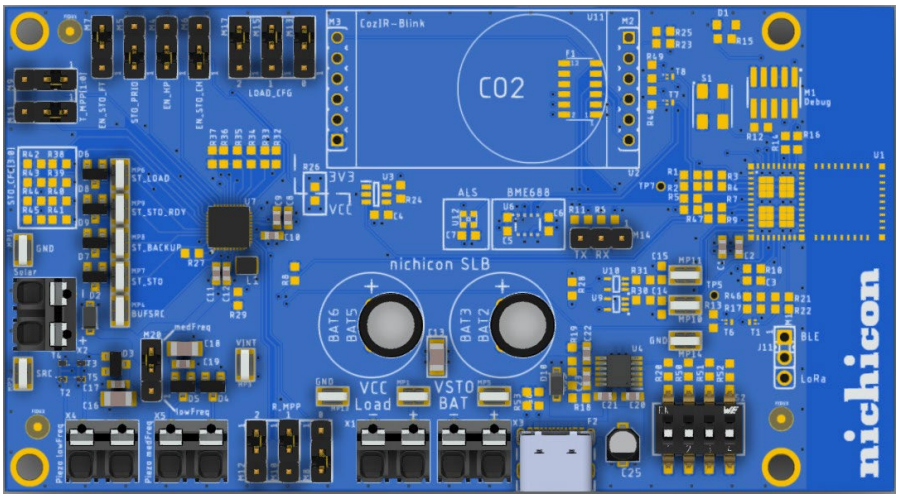


Figure 7 - PCBA front picture

7.2. Appearance back

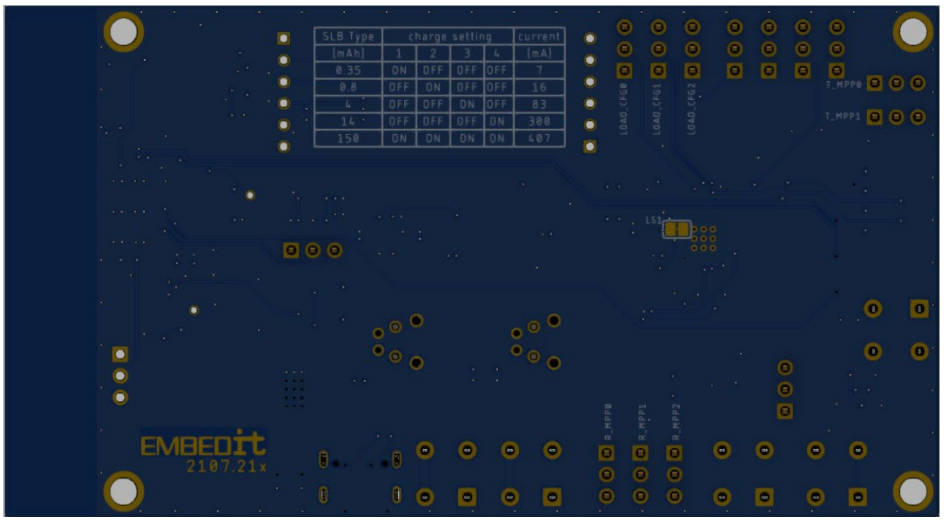


Figure 8 - PCBA rear picture

8. Precaution for use

- Please use energy harvesting source according to the PMIC variant. Please also do not use both harvesting input sources (PV and Piezo) at the same time!
- Do not short-circuit the secondary battery output. There is a risk of reduce in performance or component damage.
- Nichicon SLB batteries are polarized. Using with wrong polarity may cause reduce in performance or component damage. Please connect Nichicon SLB battery with correct polarity onto the PCBA.
- Running the PMIC without C13 (100mF) minimum capacitance on STO or the SLB battery will permanently damage the circuit.

9. SLB performance charts

9.1. Charge/discharge characteristics (SLB03070LR35*)

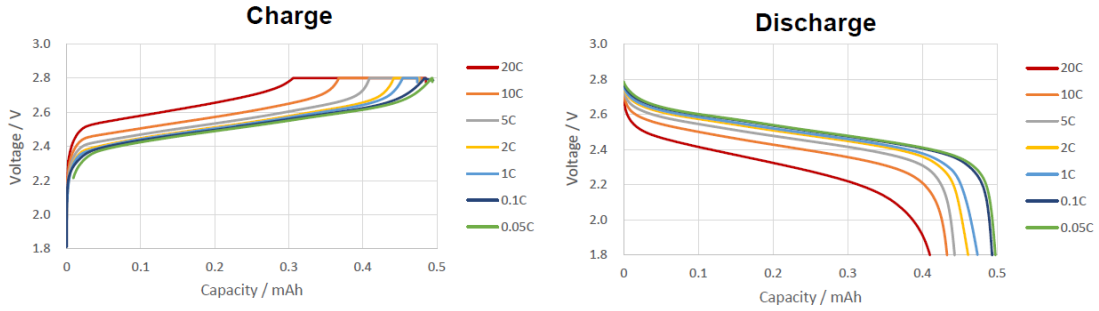


Figure 9- SLB charge/discharge characteristics (SLB03070LR35)*

9.2. Self-discharge characteristics & SoC OCV plot(SLB03090LR80*)

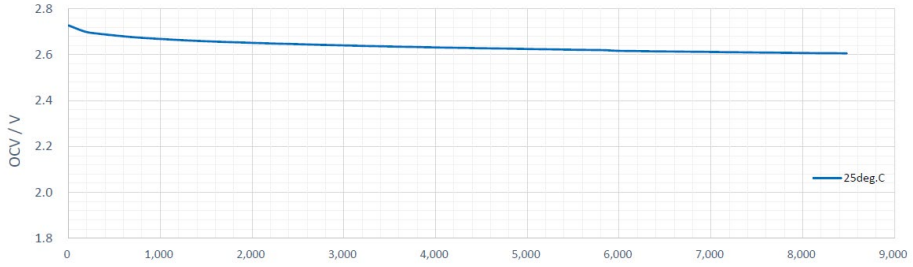
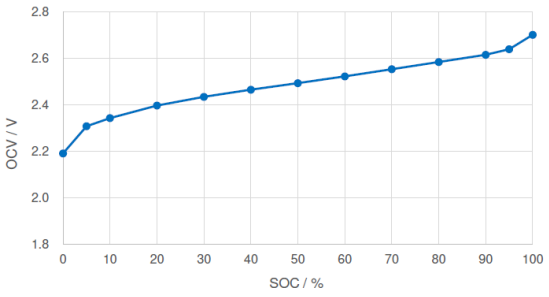


Figure 10 - self-discharge (SLB03090LR80)*



SOC / %	OCV / V
100	2.70
95	2.64
90	2.62
80	2.59
70	2.55
60	2.52
50	2.49
40	2.47
30	2.44
20	2.40
10	2.34
5	2.31
0	2.19

※ This result is the data when discharging at 1C rate

Figure 11 - SoC OCV curve (SLB03090LR80)*

10. Default PMIC settings

- PMIC priority setting has been set as default to LOAD.
- Custom storage element configuration for Nichicon SLB battery is set as below via resistors:

  $V_{\_OVDIS}$: 1,80V

  $V_{\_CHRDY}$: 2,40V

  $V_{\_OVCH}$: 2,77V
- MPPT default configuration setting:

	Configuration pins			MPPT ratio
	R_MPP[2]	R_MPP[1]	R_MPP[0]	VMPP / VOC
AEM30330	1	1	0	85%

Note: Please make sure to adjust configuration based on the optimum MPPT ratio of the used harvesting device!

11. Nichicon Ecosystem partners

Please visit Ecosystem Partners - Nichicon Small Lithium Titanate Rechargeable Batteries (nichiconbattery.com) for ecosystem partners to explore available demos, distribution partners, manufacturers for PV cell, PMIC's as well as battery validation devices etc.

12. Circuit diagram

12.1. Power Management IC (PMIC) block

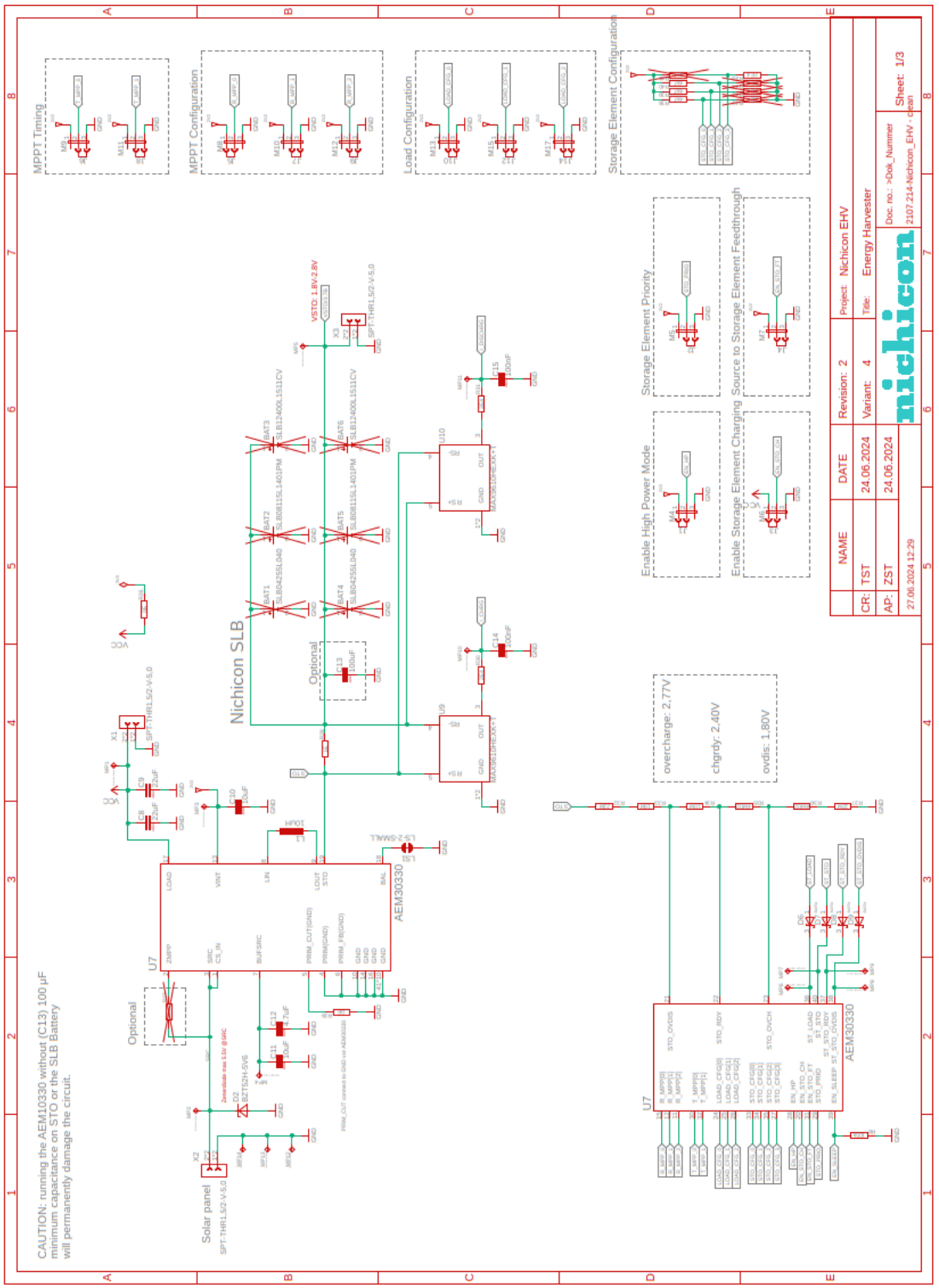


Figure 12 - PMIC schematic

12.2. AC-Source block

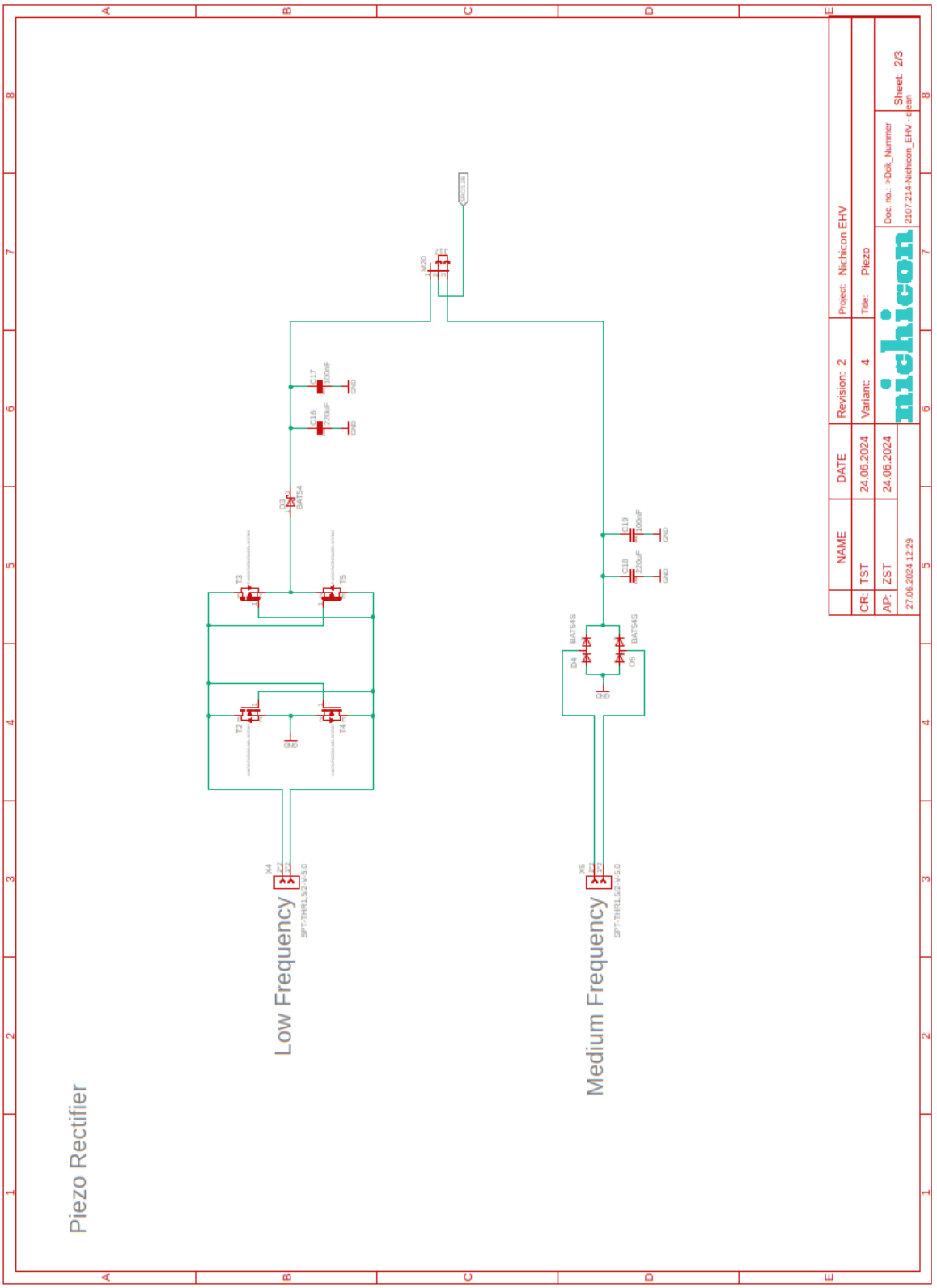
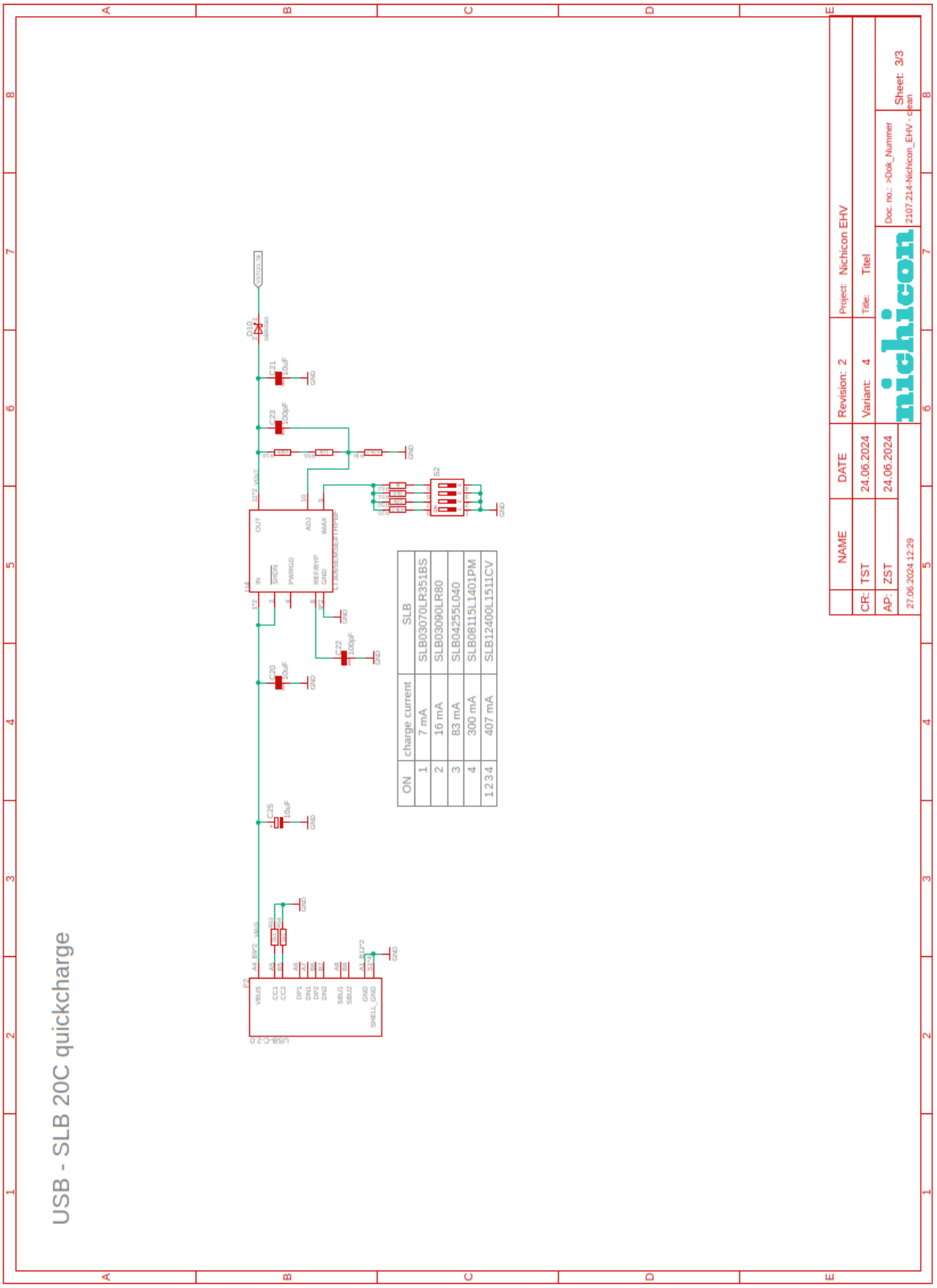


Figure 13 - Harvesting input


USB - SLB 20C quickcharge
ON | charge current | SLB
1 | 7 mA | SLB03070LR351BS
2 | 16 mA | SLB03090LR80
3 | 83 mA | SLB04255L040
4 | 300 mA | SLB08115L1401PM
1234 | 407 mA | SLB12400L1511CV
NAME | DATE | Revision: 2 | Project: Nichicon EHV
CR: TST | 24.06.2024 | Variant: 4 | Titel:
AP: ZST | 24.06.2024 | Doc. no.: >Dok_Nummer 2107-214-Nichicon_EHV - clean | Sheet: 3/3
27.06.2024 12:29

Ref.No.	Description	Value	Manufacturer	Q't y	SchematicID
BT-100016	Chip-Resistor 1k 1% 0603	1k		1	R52
BT-100022	Chip-Resistor 0R 1% 0603	0		2	R26, R29
BT-100026	Chip-Resistor 4k7 1% 0603	4.7k		3	R38, R39, R40
BT-100027	Chip-Resistor 10k 1% 0603	10k		1	R55
BT-100053	Kerko 100nF 50V 10% X7R 0603	100nF		4	C14, C15, C17, C19
BT-100077	Jumper RM2,54 Standard	Jumper RM2,54 Standard		14	J1, J2, J3, J4, J5, J6, J7, J8, J9, J10, J11, J12, J14, J17
BT-100405	Chip-Resistor 18k 1% 0603	18k		1	R50
BT-100537	Schottkydiode 30V/0.2A 5ns (BAT54) SOT23	BAT54	Diodes Inc.	5	D3, D6, D7, D8, D9
BT-100539	Chip-Resistor 3.6k 1% 0603	3.6k		1	R51
BT-100561	Z-Diode 5.6V 0.4W 5% SOD-123 (BZT52H)	BZT52H-5V6	Nexperia	1	D2
BT-100689	Dual Schottky Diode 30V, 0.2A	BAT54A	OnSemi	2	D4, D5
BT-100775	Kerko 100pF, 50V, NP0, 5% 0603	100pF		2	C22, C23
BT-100892	Kerko 100uF 6.3V, 20% X5R, 1206	100uF		1	C13
BT-100897	Chip-Resistor 105k 1% 0603	105k		1	R8
BT-101017	Stiftleiste 1x3-position stehend, RM2.54mm, THR	STL-3-254-V-THR		13	M4, M5, M6, M7, M8, M9, M10, M11, M12, M13, M15, M17, M20
BT-101057	Chip-Resistor 5k1 1% 0603	5.1k		2	R53, R54
BT-101082	Phoenix Contact SPT - THR 1,5/ 2-V-5,0 P26 - vertical terminal block, 5mm pitch, 2-pin	SPT-THR1,5/2-V-5,0		5	X1, X2, X3, X4, X5
BT-101086	Kerko 220uF 6.3V 20% X5R 1206	220uF		2	C16, C18
BT-101131	Chip-Resistor 10M 1% 0603	10M		2	R33, R34
BT-101213	Schottkydiode 60V/0.5A SBR0560 SOD123 SMD	SBR0560		1	D10
BT-101299	Kerko 10uF 35V 20% X5R 0603	10uF		4	C10, C11, C20, C21
BT-101301	Chip-Resistor 43k2 1% 0603	43.2k		2	R19, R20
BT-101304	Kerko 4.7uF 35V 20% X5R 0603	4.7uF		1	C12

BT-101312	Chip-Resistor 162k 1% 0603	162k		2	R18, R46
BT-101449	Kerko 22uF 10V X5R 0603	22uF		2	C8, C9
BT-101464	AEM30330 Ambient Energy Manager from e-peas	AEM30330	e-Peas	1	U7
BT-101469	Drossel 10uH 600mOhm, 0.9A, 2520 SMD	10uH	Murata	1	L1
BT-101470	MAX9610 1µA, µDFN/SC70, Lithium-Ion Battery, Precision Current-Sense Amplifier	MAX9610HEXK+T	Analog Devices	2	U9, U10
BT-101471	N-Channel MOSFET 20V 0.6A 470mE RDSon PMZ600UNEL SOT883	N-MOS-PMZ600UNEL-SOT883	NXP	2	T2, T4
BT-101472	P-Channel MOSFET -20V -0.5A 1.4E RDSon PMZB950UPEL SOT883	P-MOS-PMZB950UPEL-SOT883	NXP	2	T3, T5
BT-101473	Chip-Resistor 2.4R 1% 0603	2,4		3	R30, R31, R45
BT-101482	Testpoint 5019 SMD	TESTPOINT-TP5019	Keystone	14	MP1, MP2, MP3, MP4, MP5, MP6, MP7, MP8, MP9, MP10, MP11, MP12, MP13, MP14
BT-101487	Chip-Resistor 22M 5% 0603	22M		2	R32, R37
BT-101488	Chip-Resistor 4.02M 1% 0603	4.02M		2	R35, R36
BT-101495	USB-Buchse Typ-C USB 2.0 Connector 24 (16+8 Dummy)	USB-C-2.0		1	F2
BT-101507	DIP-switch with raised actuators, 2.54mm pitch, 4-positions, SMD			1	S2
BT-101508	LT3065 500mA 45V LDO Programmable Current Limit 12MSOP	LT3065EMSE#TRPBF	LT	1	U4
BT-101515	Elko 10uF/35V SMD 4x5.4mm	10uF		1	C25
BT-101524	Chip-Resistor 1R 1% 0603	1		1	R28

Revision history

Revision No.	Date	Content
1.00	2024/06/20	Initial release
1.01	2024/06/27	Fixed typos and spelling
1.02	2024/06/28	Include ecosystem partners on www.nichiconbattery.com
1.03		
1.04		
1.05		

Table 7 - Revision History

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Note: This board has been developed to help accelerating time to market for new harvesting devices with the use of Nichicon SLB series. Therefore, the board is not intended to be used for commercial products etc.

supersedes and replaces information previously supplied in any prior versions of this document.