

# NCL31000ASGEVB User Guide



## EVBUM2798/D

### Introduction

This guide explains how to use the NCL31000ASGEVB with an USB to I2C interface or with an arduino microcontroller board of choice to evaluate the product.

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## EVAL BOARD USER'S MANUAL

### Board Connections

The NCL31000ASGEVB (Figure 1) is an arduino shield form factor containing a single NCL31000MNTWG LED driver. These few steps are required to get started.

1. Connect a lab power supply from 24 V to 57 V to the DC IN connector. A reverse polarity protection circuit is in place to protect the system against faulty connections.
2. Connect a LED string rated for 16 V to 42 V to the LED connector.
3. Optionally, connect an NTC from the LED module to the TLED connector to measure the LED board temperature. If doing so, remove R24 and short R33, see section [LED Power](#).
4. Connect a microcontroller to the arduino interface connectors and develop firmware to evaluate the product.
5. An alternative for step 4 is to use an USB to I2C interface to send commands from the PC to NCL31000ASGEVB.

### Micro-Controller Interface

The NCL31000 hardware requires at least a GND connection and an I2C or SPI connection to control the main functions of the chip. The SCL/SDA and connections are designated to Arduino pins D15 and D14. All Nucleo boards can be programmed to route an I2C peripheral to these pins. The default I2C address is 0x52. This is configurable with zero-ohm resistors.

The NCL310xx devices are internally hardwired to use either SPI or I2C. For now, NCL31000ASGEVB is only available with the I2C version populated. Note that the SPI slave in NCL310xx only supports Mode 2.

For Visual Light Communication, preferably a DAC connection or alternatively 2 x PWM connections are needed. See section [Dimming](#) and [VLC – YellowDot](#). The DAC connection is not specified by the Arduino hardware interface and different microcontroller boards connect the DAC to different pins. By default, the NCL31000ASGEVB assumes the DAC can be connected to A2 or D13 (see [Schematic](#)). This is compatible with the ST Nucleo boards.

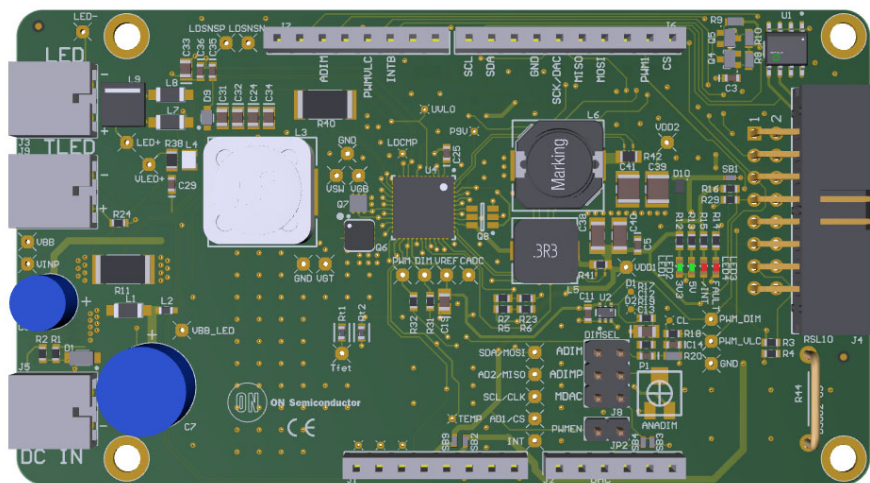


Figure 1. NCL31000ASGEVB

## DC-DCs

Two DC-DC supplies are available to supply different parts of the application. VDD1 is a fixed 3.3 V supply rated to deliver up to 150 mA and VDD2 is configurable, but on the EVB it is set for 5 V. It can source up to 500 mA. VDD1 and VDD2 are not connected to the arduino interface so VDD1 does not by default supply the arduino board because the arduino interface standard does not provide a 3V3 supply connection. Some arduino micro-controller boards can be adjusted so that they can be supplied with 3V3. For example, the nucleo boards normally need one or more solder bridge configuration changes to be able to get powered from a 3V3 supply. See the VDD1\_EXT connection in the schematic. The VDD2 cannot be used to supply the micro-controller since it has to be enabled first in a register after startup. Thus, by default, without making any changes to the hardware, the micro-controller board has to be supplied by the USB connection or another supply.

## LED Power

This EVB has a significant copper cooling plane for the top fet of the LED driver. It is therefore possible to drive LED loads up to 100 W with this EVB. 2 NTC's are placed onto the cooling plane to measure the plane's temperature to estimate the top fet junction temperature. One NTC is connected to the TLED metrology measurement pin so that the temperature can be monitored over I2C. The second NTC is electrically connected on one side to the copper plane and one side floating so that a multimeter can measure the voltage over the NTC. This is an alternative NTC sensing method. To measure the NTC voltage from the LED board, make the connection to the TLED connector and solder R24 and remove R33 to disable the top fet measurement.

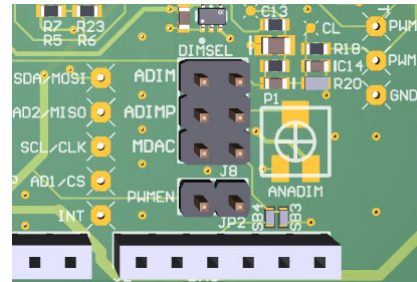
It is best to replace the sense resistor with 50 mΩ or place a second resistor in parallel to reduce the temperature of the

sense resistor and the dissipation when going above 1.6 A LED current or so. See the [Thermal](#) section for more info.

## Dimming

To make dimming possible, enable the LED driver by setting the LED\_EN bit in the CTRL register and close the PWM\_EN jumper on the EVB.

There are 5 ways to dim the LEDs. The selection for the first three methods is made with the DIMSEL jumpers. See Figure 2.



**Figure 2. Dimsel**

- MDAC: DAC in MCU connected to DIM pin (Arduino: A2 or D13)
  - ADIM: Analog dimming. A low-pass filtered DC signal converted from a PWM signal from MCU (Arduino: D5)
  - ADIMP: potmeter on the EVB connected to DIM pin
- The others are (DIMSEL does not matter):
- PWMDIM: PWM dimming. PWM from MCU directly to PWM pin (Arduino: D9)
  - INTDIM: The internal 7-bit DAC

### *INTDIM*

The internal 7-bit DAC can be used to DIM the LEDs. With 128 dimming steps in the entire range this method provides a coarse method to dim the LEDs. The lowest current value is about 10 mA if a 100 mΩ sense resistor is used. If deep dimming or VLC is not needed this method may suffice. No extra hardware is needed, only the I2C or SPI interface.

### *ADIM*

The ADIM signal can dim the LEDs with a higher accuracy and precision compared to the other methods. It is possible to accurately dim down to about 0.1% of the maximum range. The accuracy at these low dimming values is dominated by the relative offset error, which is no more than a few mV's or approximately 0.1% of VREF. The precision or resolution is defined by the amount of steps the duty-cycle has in the PWM period. For example, if an 8-bit timer is used, 256 steps are available. PWM oversampling can increase this number.

The ADIM method is an alternative to the INTDIM method. Switching between these methods is possible by controlling the INTDIMEN bit. To use the ADIM method, the micro-controller must provide a PWM signal with a frequency preferably between 1 to 10 kHz. The duty-cycle defines the dim value. This PWM signal is filtered heavily and the resulting average value is presented to the DIM input. The resulting LED current is thus a constant current, not a PWM'ed current. This ADIM or the MDAC method can use VLC. Next to low pass filtering the PWM signal, the filtering circuit also couples the VLC signal on the DIM signal. To make use of this method configure the DIMSEL jumper for ADIM and pull the PWM pin high by closing the PWM jumper.

### *PWMDIM*

The PWMDIM does not provide the widest dim range or best accuracy and should not be used as the primary dim method, but it can be used on top of the ADIM method to achieve hybrid dimming and dim to even lower LED currents. For example, set ADIM to 220 mV and apply a PWM signal of 1 kHz and 25% duty-cycle to achieve an average internal DIM voltage of:

$$200 \text{ mV} + 0.25 * 20 \text{ mV} = 205 \text{ mV}$$

Important to note is that the measured LED current from the ILED metrology register is not valid when using PWMDIM. This is because the ADC sampling is in the range of 100 ms and the PWMDIM frequency is the range of 400 Hz and higher and thus oversampling is not possible and no averaging can be done.

### *MDAC*

This method uses the DAC in the micro-controller, if available. This method can dim the LEDs and still have the possibility to use VLC. To use the DAC, route it to A2 or D13 on the Arduino interface (possible for Nucleo-64 or Nucleo-144 connections) and configure DIMSEL jumper for 'MDAC'. When using the DAC you cannot use the

SPI\_CLK and thus only I2C is an option. One exception is the Nucleo-64 boards, which connect the DAC to A2 on the Arduino interface. Also pull the PWM pin high by closing the PWM jumper.

### *ADIMP*

The potmeter on the EVB can be used to apply a voltage on the dim pin and manually control the LED current. To make use of this method configure the DIMSEL jumper for ADIMP and pull the PWM pin high by closing the PWM jumper.

### **Status Indication**

The boards have four LEDs. Two green LEDs to indicate the 3V3 (VDD1) and 5 V (VDD2) supplies are active. Note that VDD1 must be active on power up. This is a good check to see if the board (supplies) is operational. VDD2 is disabled at startup and can be enabled in a register. The orange INTB LED is active if the INTB line is low. This is the case when a fault bit is active or became active since the last read. The red FAULT LED can be used by the micro-controller.

### **VLC – YellowDot**

The YellowDot program is a luminaire certification program that allows manufacturers to test and certify that their LED luminaires are interoperable with Signify's indoor positioning technology. A key aspect of YellowDot ready LED drivers is that data can be transmitted by modulating data onto the LED current and thus in the light output. The NCL310xx products are Yellow-dot compatible. This means that it is possible to modulate the LED current conform to the Yellow-dot specification. Contact Signify for more information about this program and the technical requirements. Modulating the data on the DIM pin can be done either by using the MDAC (preferred) method or by using the ADIM method together with the PWMVLC signal.

#### *VLC with MDAC*

The DAC voltage controls the DIM voltage directly. When no data is transmitted, it should regulate a stable DC value to provide a stable LED current. When transmitting data, the DAC voltage swings between the 3 voltage levels at the symbol rate.

#### *VLC with ADIM + PWMVLC*

An alternative for the DAC is to use 2 PWM signals. One is for setting the DC dim value using the ADIM method and the other PWM signal is connected to the PWMVLC signal. The PWMVLC data is coupled onto the DIM signal. The frequency must be about 200 kHz or more. A digital one is represented by a duty-cycle of 50% + k. A digital zero is represented by a duty-cycle of 50% - k. The resulting signal is a 200 kHz PWM signal for which the duty-cycle varies between 2 values (0.5 - k and 0.5 + k). The symbol rate of the VLC signal (typ: 4 kHz) is defined by the rate at which the duty-cycles alternate. The 'k' value defines the amplitude of the VLC signal. After filtering the resulting

signal is a 4 kHz AC signal with a given amplitude. This signal is capacitively coupled on the DIM signal so for this to work the ADIM dimming method must be used to define the DC DIM level.

## Thermal

The highest temperatures on the board are to be expected in the top fet of the LED driver and in the sense resistor of the LED driver.

## LED Sense Resistor

It is best to keep the sense resistor value as small as possible without impacting the dynamic dimming range too much. Keep the power dissipation in the 6430 package below 400 mW. Ideally 200 mW. It is possible to add a sense resistor in parallel to spread the dissipation (1% or better). For example, a 120 mΩ 6430 package with a 0.62 Ω 3216 package in parallel gives 100 mΩ and a better spreading of heat.

## Thermal Plane

The power dissipation in the top fet is dominated by switching and conduction losses. The device used on the board is carefully selected to achieve the lowest power dissipation. Still, mainly depending on the input voltage, switching frequency and during highest current, the power dissipation (Pt) can reach up to about 1.2 W in this device. A copper cooling plane is required to transfer enough heat to the environment to keep the temperature of the fet in 4 check. The cooling plane is about 3 x 2 cm. It is present on 3 layers: top, bottom, and one internal layer. The remaining internal layer is reserved for a ground plane. The copper extends to the edges of the board. The layers are

interconnected by via's. See Figure 3. The red area is the copper plane on the top copper. This copper plane is a bit overkill for applications that do not require 90 W or more.

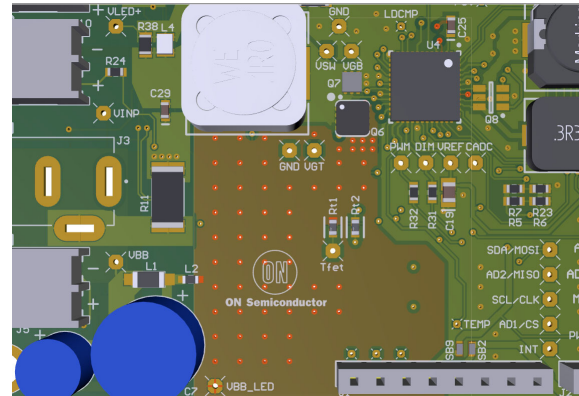


Figure 3. Copper Plane

## Erratum

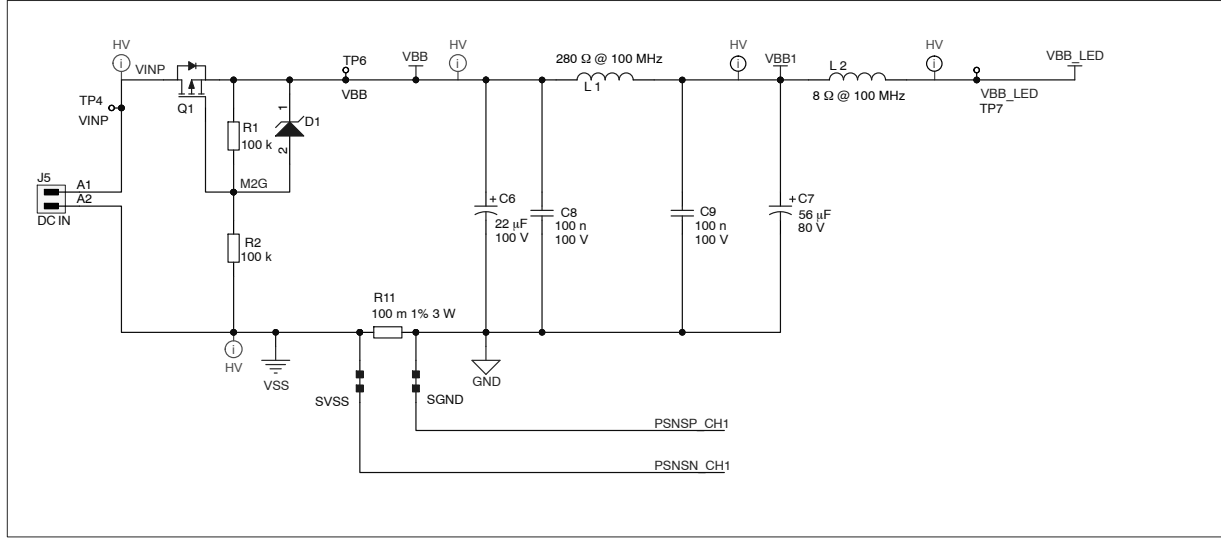
Boards with version «ncl31000as» and date «25/03/2021» had a mistake in the arduino pinout. Headers J6 and J7 are swapped in the layout and do not correspond with the correct arduino placement. Modifications have been made to these connectors so that the board can still be plugged on top of an arduino mcu. 5 pins have been cut and 3 connections rewired.

Because of this patch the arduino shield fits an arduino microcontroller board and it can be used as expected except for the PWM1 pin which is not available due to this patch.

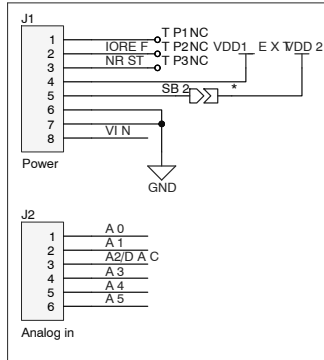
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## SCHEMATIC

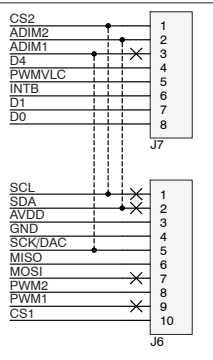
### Reverse polarity protection + overvoltage protection



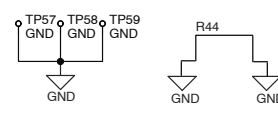
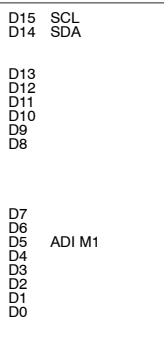
### Arduino headers



### Board pin-out

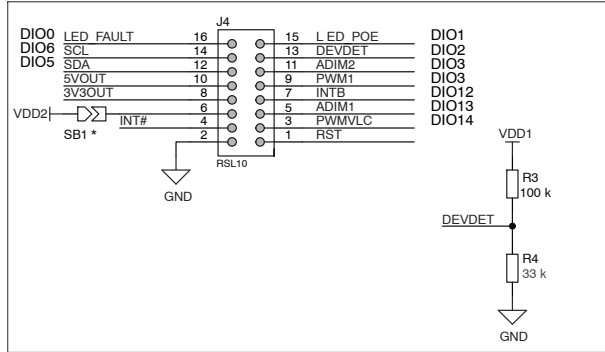


### Arduino pin-out

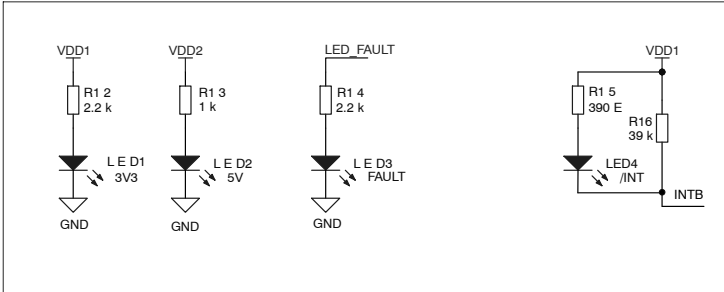


Headers J6 and J7 are swapped in the layout and do not correspond with the correct arduino placement. Modifications have been made to these connectors so that the board can still be plugged on top of an arduino mcu. The PWM1 pin is not available due to this patch.

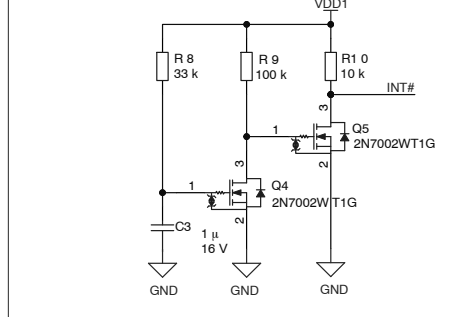
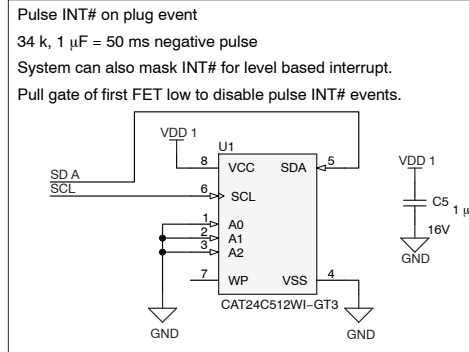
### RSL10 headers



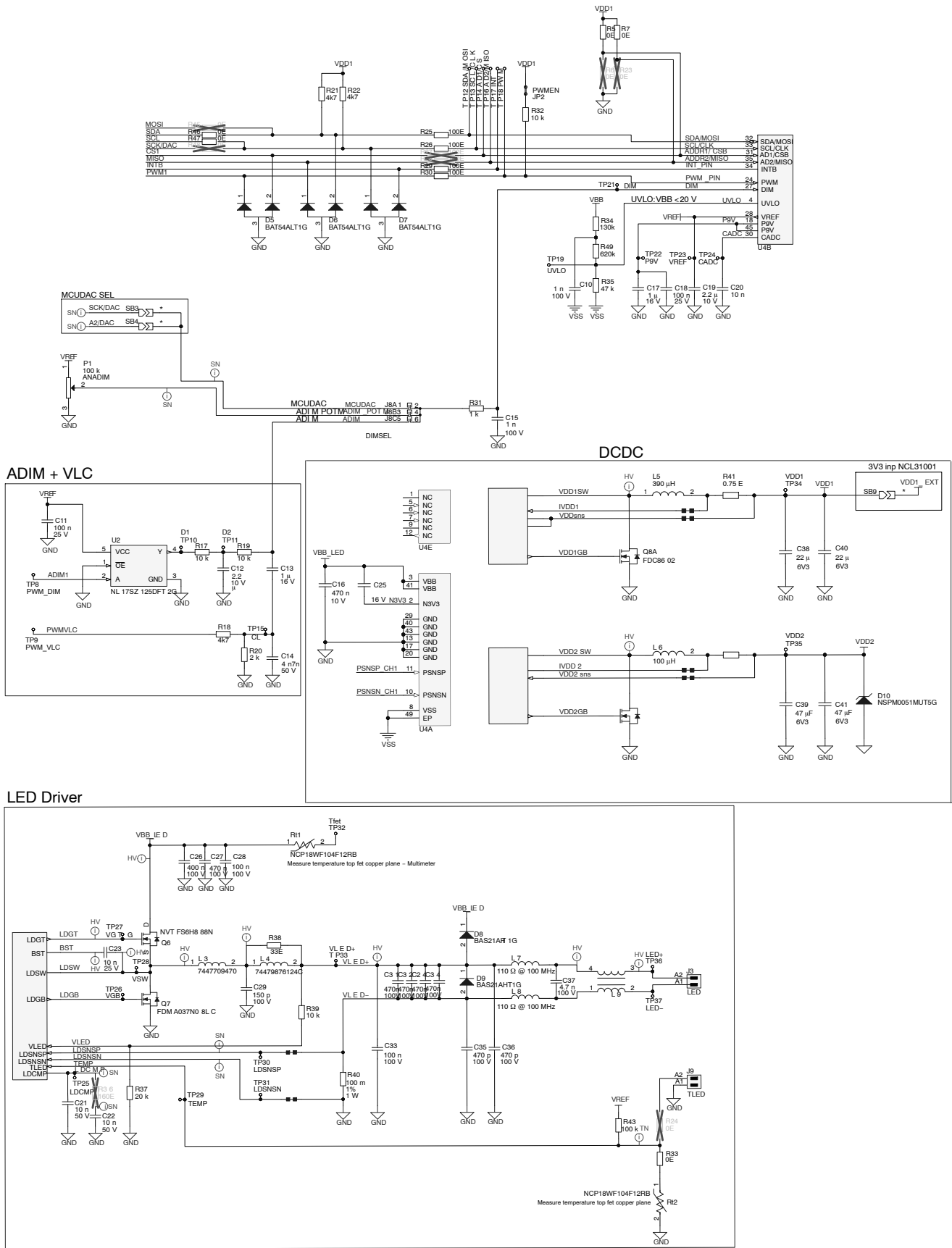
### Status



### Strata EEPROM & HOT PLUG Detection



# EVBUM2798/D





# EVBUM2798/D

**Table 1. BILL OF MATERIAL**

| Qty | Designator                    | Manufacturer      | Part No.        | Value | Footprint                   | Description                                                                              |
|-----|-------------------------------|-------------------|-----------------|-------|-----------------------------|------------------------------------------------------------------------------------------|
| 1   | D1                            | ON Semiconductor  | MMSZ5245BT1G    |       | ONSC-SOD-123-2-42<br>5-04_V | Zener Voltage Regulator, 500 mW, 2-Pin SOD-123, Pb-Free, Tape and Reel                   |
| 1   | J1                            | Samtec            | SSQ-108-03-F-S  |       | SSQ-108-03-X-S              | Board-To-Board Connector, 2.54 mm, 8 Contacts, Receptacle, Through Hole, 1 Rows          |
| 1   | J2                            | Samtec            | SSQ-106-03-G-S  |       | SSQ-106-03-X-S              | Board-To-Board Connector, 2.54 mm, 6 Contacts, Receptacle, Through Hole, 1 Rows          |
| 1   | J3                            | Weidmueller       | 1862960000      |       | SC_SMT_3_81_90G_0<br>2      | OMNIMATE Signal - series BC/SC 3.81                                                      |
| 1   | J4                            |                   | 61201621721     |       | 61201621721                 | Male Box Header WR-BHD, THT, Angled, pitch 2.54 mm, 16 pins                              |
| 1   | J5                            | Weidmueller       | 1862960000      |       | SC_SMT_3_81_90G_0<br>2      | OMNIMATE Signal - series BC/SC 3.81                                                      |
| 1   | J6                            | Samtec            | SSQ-110-03-G-S  |       | SSQ-110-03-X-S              | Board-To-Board Connector, 2.54 mm, 10 Contacts, Receptacle, Through Hole, 1 Rows         |
| 1   | J7                            | Samtec            | SSQ-108-03-G-S  |       | SSQ-108-03-X-S              | Board-To-Board Connector, 2.54 mm, 8 Contacts, Receptacle, Through Hole, 1 Rows          |
| 1   | J9                            | Weidmueller       | 1862960000      |       | SC_SMT_3_81_90G_0<br>2      | OMNIMATE Signal - series BC/SC 3.81                                                      |
| 1   | L3                            |                   | 7447709470      |       | WE-PD-XXL                   | SMD-Shielded Power Inductor WE-PD, L = 47.0 $\mu$ H                                      |
| 1   | L4                            | Würth Electronics | 74479876124C    |       | SMD 0806                    | Power Multilayer Inductor WE-PMI, L = 0.24 $\mu$ H                                       |
| 1   | L5                            | Würth Electronics | 744777239       |       | WE-PD 7345                  | SMD-Shielded Power Inductor WE-PD, L = 390 $\mu$ H                                       |
| 1   | L6                            | Würth Electronics | 7447714101      |       | WE-PD 1050                  | SMD-Shielded Power Inductor WE-PD, L = 100 $\mu$ H                                       |
| 1   | U1                            |                   | CAT24C512WI-GT3 |       | FP-751BD-01-IPC_C           | IC EEPROM 512K I2C 1 MHZ 8SOIC                                                           |
| 1   | U2                            | ON Semiconductor  | NL17SZ125DFT2G  |       | FP-419A-02-MFG              | IC BUFFER NON-INVERT 5.5 V SC88A                                                         |
| 1   | U4                            | ON Semiconductor  | NCL31000        |       | 485EP                       |                                                                                          |
| 2   | D8, D9                        | ON Semiconductor  | BAS21AHT1G      |       | ONSC-SOD-323-2-47<br>7-02_V | Low Leakage Switching Diode, 2-Pin SOD-323, Pb-Free, Tape and Reel                       |
| 2   | Q4, Q5                        | ON Semiconductor  | 2N7002WT1G      |       | ONSC-SC-70-3-419-<br>04_V   | Small Signal MOSFET, 60 V, 340 mA, Single, N-Channel, 3-Pin SC70, Pb-Free, Tape and Reel |
| 2   | Rt1, Rt2                      |                   | NCP18WF104F12RB |       | FP-NCP18-0_15-IPC_<br>C     | NTC Thermistor for Temperature Sensor, 0603, 100 k $\Omega$ , 1%, 0.032 mA, 5 V          |
| 3   | D5, D6, D7                    | ON Semiconductor  | BAT54ALT1G      |       | ONSC-SOT-23-3-318<br>-08_V  | Schottky Barrier Diodes, 3-Pin SOT-23, Pb-Free, Tape and Reel                            |
| 5   | SB1, SB2,<br>SB3, SB4,<br>SB9 |                   |                 |       | 1005-SB-2                   | Solder bridge                                                                            |
| 5   | R5, R7,<br>R33, R46,<br>R47   |                   | CRG0603ZR       | OE    | RESC1608L                   | Resistor                                                                                 |
| 1   | R42                           |                   | RL1220S-R20-F   | 0.2E  | RESC2012N                   | Resistor                                                                                 |

## EVBUM2798/D

**Table 1. BILL OF MATERIAL** (continued)

|   |                               |                   |                          |                                         |                    |                                                                                                       |
|---|-------------------------------|-------------------|--------------------------|-----------------------------------------|--------------------|-------------------------------------------------------------------------------------------------------|
| 1 | R41                           |                   | RCWE0603R750FKE<br>A     | 0.75E                                   | RESC1608N          | Resistor                                                                                              |
| 2 | R13, R31                      |                   | CRGCQ0603F1K0            | 1 k                                     | RESC1608L          | Resistor                                                                                              |
| 1 | C10                           | TDK               | CGA3E2X7R2A102M<br>080AA | 1 n                                     | CAPC1608L          | Capacitor                                                                                             |
| 1 | C15                           | TDK               | CGA3E2X7R2A102M<br>080AA | 1 n                                     | CAPC1608L          | Capacitor                                                                                             |
| 5 | C3, C5,<br>C13, C17,<br>C25   | TDK               | C1608X7R1C105K08<br>0AC  | 1 $\mu$                                 | CAPC1608L          | Capacitor                                                                                             |
| 1 | R44                           | Harwin            | D3082-05                 | 2 pins                                  | Groundbar D3082-05 | 2 (1 x 2) Position Shunt Connector<br>Non-Insulated 0.400 (10.16 mm)<br>Gold                          |
| 1 | R20                           |                   | CPF0603F2K0C1            | 2 k                                     | RESC1608L          | Resistor                                                                                              |
| 2 | R12, R14                      |                   | CRGCQ0603F2K2            | 2.2 k                                   | RESC1608L          | Resistor                                                                                              |
| 1 | C12                           | TDK               | C2012X7R1C225K12<br>5AB  | 2.2 $\mu$                               | CAPC2012N          | Capacitor                                                                                             |
| 1 | C19                           | TDK               | C2012X7R1C225K12<br>5AB  | 2.2 $\mu$                               | CAPC2012N          | Capacitor                                                                                             |
| 1 | J8                            | Würth Electronics | 61300621121              | 2.54 mm THT<br>Dual Pin<br>Header, 6p   | 61300621121        | Board-To-Board Connector,<br>Vertical, 2.54 mm, 6 Contacts,<br>Header, WR-PHD Series,<br>Through Hole |
| 3 | R18, R21,<br>R22              |                   | CRG0603F4K7              | 4k7                                     | RESC1608L          | Resistor                                                                                              |
| 1 | C14                           | TDK               | CGA3E2X7R1H472<br>M080AA | 4.7 n                                   | CAPC1608L          | Capacitor                                                                                             |
| 1 | C37                           | TDK               | C1608X7R2A472K08<br>0AA  | 4.7 n                                   | CAPC1608L          | Capacitor                                                                                             |
| 1 | L2                            | Würth Electronics | 7427922808               | 8 $\Omega$ @<br>100 MHz                 | WE-MPSB_0603       | WE-MPSB EMI Multilayer Power<br>Suppression Bead, size 0603,<br>8 $\Omega$ @ 100MHz                   |
| 5 | R10, R17,<br>R19, R32,<br>R39 |                   | CRGCQ0603F10K            | 10 k                                    | RESC1608L          | Resistor                                                                                              |
| 3 | C20, C21,<br>C22              | TDK               | CGA3E2X7R1H103K<br>080AA | 10 n                                    | CAPC1608L          | Capacitor                                                                                             |
| 1 | R37                           |                   | CPF0603F20KC1            | 20 k                                    | RESC1608L          | Resistor                                                                                              |
| 2 | C38, C40                      | KEMET             | C1206C226K9PACT<br>U     | 22 $\mu$                                | CAPC3216N          | Capacitor                                                                                             |
| 1 | C6                            | Nichicon          | UVR2A220MED              | 22 $\mu$ F                              | CAPPR2.5-6.3x11    | Capacitor                                                                                             |
| 1 | D10                           | ON Semiconductor  | NSPM0051MUT5G            | 30 kV ESD<br>70 A 8/20 $\mu$ s<br>Surge | Case 517CZ         | Transient Voltage Suppressors                                                                         |
| 1 | R38                           |                   | CRGCQ0603F33R            | 33E                                     | RESC2012L          | Resistor                                                                                              |
| 2 | R4, R8                        |                   | CRGCQ0603F33K            | 33 k                                    | RESC1608L          | Resistor                                                                                              |
| 1 | R16                           |                   | CRGH0603F39K             | 39 k                                    | RESC1608L          | Resistor                                                                                              |
| 1 | R35                           |                   | CRGCQ0603F47K            | 47 k                                    | RESC1608L          | Resistor                                                                                              |
| 2 | C39, C41                      | KEMET             | C1210C476M9PAC           | 47 $\mu$ F                              | CAPC3225N          | Capacitor                                                                                             |
| 1 | C7                            | KEMET             | A759MS566M1KAAE<br>045   | 56 $\mu$ F                              | CAPPR5-10x12.5     | Capacitor                                                                                             |
| 1 | Q6                            | ON Semiconductor  | NVTF56H888N              | 80 V, 13 A,<br>55 m $\Omega$            | MKT-MLP08T         | Power MOSFET 80 V, 55 m, 13 A,<br>Single N-Channel                                                    |
| 1 | Q7                            |                   | FDMA037N08LC             | 80 V, 6 A,<br>36.5 m $\Omega$           | Case 511DB         | MOSFET FET 80 V 3.7 M $\Omega$<br>MLP33                                                               |



## EVBUM2798/D

**Table 1. BILL OF MATERIAL** (continued)

|   |                        |        |                         |                 |           |                                                                                                       |
|---|------------------------|--------|-------------------------|-----------------|-----------|-------------------------------------------------------------------------------------------------------|
| 4 | R25, R26,<br>R29, R30  |        | CRGCQ0603F100R          | 100 E           | RESC1608L | Resistor                                                                                              |
| 1 | P1                     | Vishay | TS53YJ103MR10           | 100 k           | TS53YJ    | 5 mm Square Surface Mount<br>Miniature Trimmers Single-Turn<br>Cermet Sealed 5 K 250 mW<br>35.4 V 20% |
| 5 | R1, R2, R3,<br>R9, R43 |        | CRGCQ0603F100K          | 100 k           | RESC1608L | Resistor                                                                                              |
| 1 | R40                    |        | LVM25FVR100E-TR         | 100 m           | RESC6332N | Resistor                                                                                              |
| 1 | R11                    |        | CRA2512-FZ-R100<br>ELF  | 100 m 1%<br>3 W | RESC6332N | Resistor                                                                                              |
| 3 | C11, C18,<br>C23       | AVX    | 06033C104KAT4A          | 100 n           | CAPC1608L | Capacitor                                                                                             |
| 4 | C8, C9,<br>C28, C33    | TDK    | C2012X7R2A104K12<br>5AA | 100 n           | CAPC2012L | Capacitor                                                                                             |

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