DOMINANT™
Opto Technologies
Innovating Illumination

APPLICATION NOTES: seddLED3.0 (A3A-FKG)

Introduction

seddLED (Smart Embedded Digital Driver LED) is the world's first digital LED which combines RGB LED, LED Driver and advanced ISELED® communication protocol integrated into a single package. It is a revolutionary approach for automotive ambient lighting with fully-calibrated RGB LED to target coordinates. seddLED3.0 A3A-FKG-1400-1 is pre-calibrated to D65 white point with an accuracy within 3 SDCM steps at 1,400mcd.

This document provides guidelines on how to drive the seddLED3.0 with the focus on the LED package design, PCB design, microcontroller and ISELED® module to module connection setup. All functions can be controlled via the microcontroller unit (MCU) that provides the ISELED® serial communication protocol.

List of Abbreviations and Acronyms

API	Application Programming Interface
CAN	Controller Area Network
EMI	Electromagnetic Interference
ESD	Electrostatic Discharge
GND	Ground
LIN	Local Interconnect Network
MCU	Microcontroller Unit
PCB	Printed Circuit Board

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1. User Application Development Setup

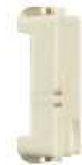
This section provides guidelines to the development of seddLED3.0 LED typical application setup. Selection of right external component and PCB layout is critical to ensure proper functionality and heat dissipation when daisy-chain many seddLED3.0 LED together onto a small PCB surface.

1.1 seddLED3.0 A3A-FKG-1400-1

Function and Features:

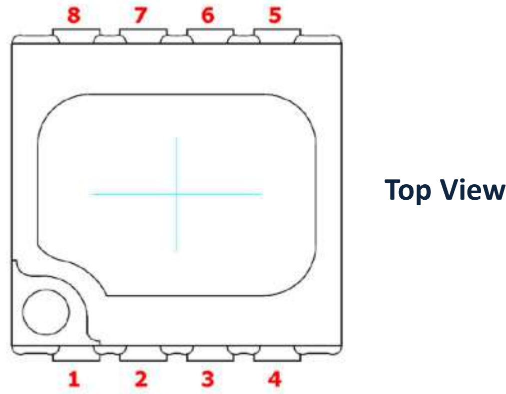
- Small package outline (LxWxH) of 3.2 x 3.3 x 1.35mm.
- Low thermal resistance.
- Superior corrosion resistant.
- Qualified according to JEDEC moisture sensitivity Level 2.
- Compatible to IR reflow soldering.
- Serial communication with ISELED® compliance.

- Bi directional, half-duplex, 2MBit/s, serial communication.
- 8-bit brightness resolution for red, green, and blue LED.
- Build-in temperature sensor.
- Temperature compensation on red for constant brightness.
- Build-in diagnostic functions.
- Environmentally friendly, RoHS compliance
- Compliance to automotive standard; AEC-Q102 & AEC-Q100.



A3A-FKG Pin out

Please follow this pin-out for connection and pin functionality:



Pin	Pin	Direction	Description
1	PRG	IN	Has to be connected to GND for proper operation
2	SiO1_N	IO	Serial Communication Interface Master Side, Negative Polarity
3	SiO1_P	IO	Serial Communication Interface Master Side, Positive Polarity
4	GND	Supply	Ground
5	GND	Supply	Ground
6	SiO2_P	IO	Serial Communication Interface Slave Side, Positive Polarity
7	SiO2_N	IO	Serial Communication Interface Slave Side, Negative Polarity
8	VCC_5V	Supply	5V Supply

1.2. NXP Semiconductors

NXP Semiconductors offer full MCU series of S32Kxx custom part number with ISELED® driver library. However, user still can use the non-ISELED® S32Kxx part number which come with evaluation license and the sending commands are limited to maximum of 150,000. Please consult your nearest NXP Sales representative to enquire S32Kxx ISELED® Part Offering.

User also can get more information regarding the evaluation license and NXP ISELED® custom part number, please click below link:

https://www.nxp.com/S32K-iseled

For step by step Get Started guide, please click below link:

https://www.nxp.com/document/guide/get-started-with-the-s32k-iseled:GS-S32K-ISELED

For advanced technical information, user can get support from the NXP S32K community site: https://community.nxp.com/community/s32/s32k

1.3. Microchip Technology Inc

Microchip Technology Inc offer a variety of scalable 8-, 16- and 32-bit MCUs and 16-bit dsPIC® Digital Signal Controllers (DSCs) to help user develop ISELED® protocol-based in-car lighting system. Please consult your nearest Microchip Sales representative to enquire MCU part offering.

User also can get more information regarding the evaluation license and Microchip ISELED® custom part number, please click below link:

https://www.microchip.com/design-centers/automotive-solutions/automotive-applications/body-electronics/iseled

1.4. Basic External Component guide

Figure 1 shows a typical setup layout for seddLED3.0 LED, connecting MCU to a series of seddLED3.0 LEDs.

- In order to prevent voltage drops, it is recommended to mount the capacitors C1 closely to each seddLED3.0 5V_LED (pin 8). The dimensioning of the capacitors depends on the PCB layout and the supply concept.
- Incoming data (SIO1_P) and clock (SIO1_N) can be connected with ESD protection diode in parallel to GND, for protection against voltage spike to the SIO1_P and SIO1_N.
- First communication connection in between microcontroller to the seddLED3.0 is based on single-ended format. Thus, for each line, please add-on 1K pull-up resistor in parallel to the 5V supply.
- Last device's SIO2_P and SIO2_N can be terminated with ESD protection device as well.
- As the incoming supply must be kept within 4.5V – 5.5V, it's recommended to install 5.5V zener to protect against over-voltage.

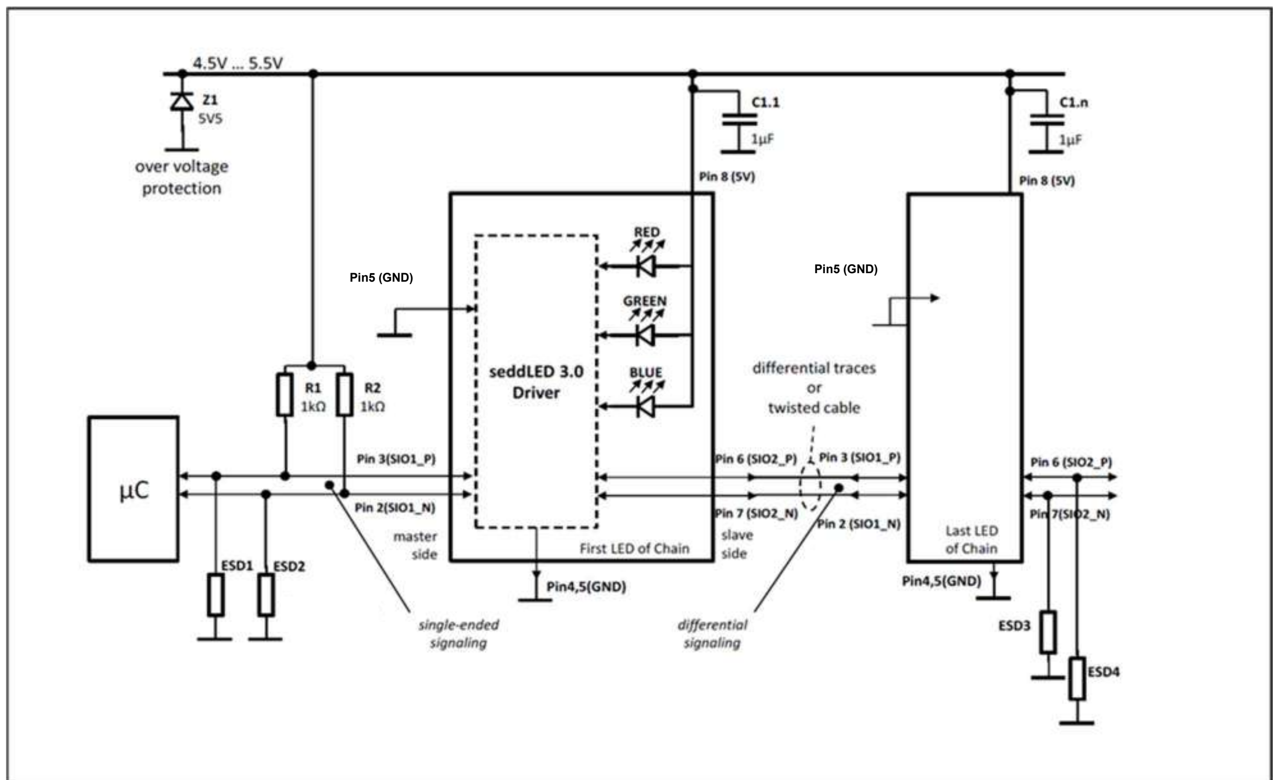


Figure 1: Typical Application Layout

1.5 PCB design guide, pin-per-pin explanation:

Figure 2 below shows a brief wiring setup from MCU to the first and second seddLED3.0 LED.

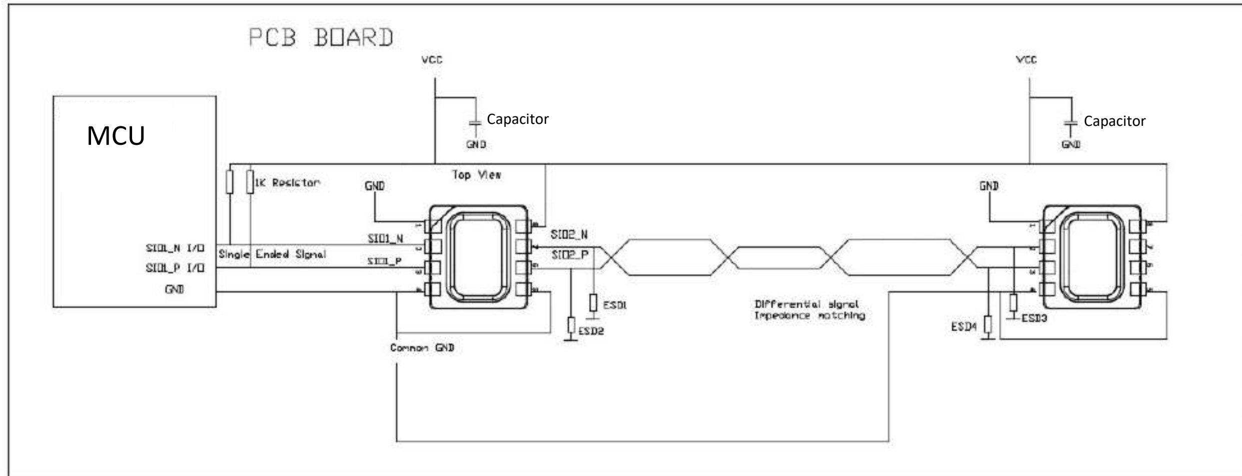


Figure 2: Wiring Setup Guidelines

seddLED3.0 LED needs to be powered up with 5V supply.

- There must be a common ground connecting seddLED3.0 and MCU together.
- A dedicated ground plane is desirable as it offers lowest possible inductance for current to return to its source.
- Communication protocol from first device to microcontroller (both data and clock) is configured to be single-ended format. Most of the microcontroller I/O pins are configured to be single-ended TX/RX format. Thus, it is vulnerable to noise and interference. It's advisable to keep the connection short and best if first seddLED3.0 LED mounted on the same PCB board to the MCU and communication connection is routed via impedance matching PCB trace.
- Keep both signal connection near to GND for ground shielding advantage.
- Connection from 1st seddLED3.0 LED to 2nd seddLED3.0 LED is configured with differential format. User does not need to worry about the conversion from single-ended format to differential format. All will be taken care by seddLED3.0 LED internal module.

1.6. Extended connection guide (module-to-module) explanation

For multiple modules in vehicle installation, we recommend user to install a stand-alone, ISELED® compatible, low cost microcontroller to each individual module. Each microcontroller should represent own PCB module slave connections.

Example of good suggestion will be Microchip PIC16F153xx, PIC16F188xx, PIC18FxxK42, PIC18FxxK83 and NXP S32K11x/14x Arm Cortex M4+ & M0+ microcontroller.

Each microcontroller can interact with each other and connected to the automobile CAN/LIN Bus. NXP also offers a good range of CAN/LIN transceiver. E.g TJA1051 proposed for below typical 4 door panel seddLED3.0 strip connected to NXP S32K1xx microcontroller, and routed to CAN/LIN BUS network.

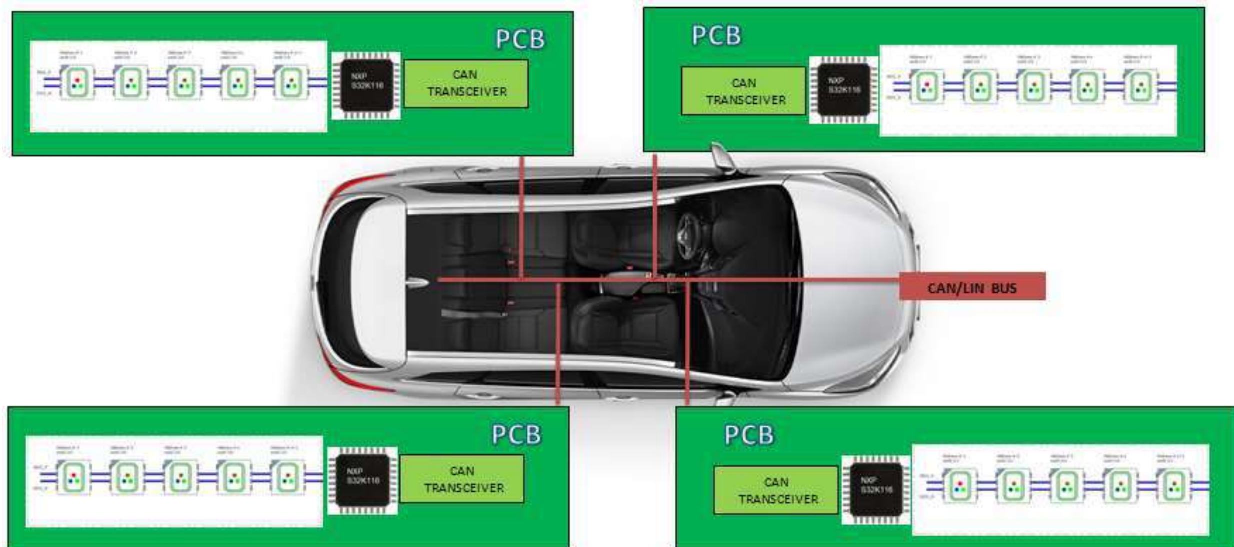


Figure 3: seddLED3.0 Door Panel Strip with S32K1xx Microcontroller Connected to Integrated CAN/LIN Bus.

1.7 Extended connection guide (module-to-module) via twisted pair harness

ISELED® communication protocol is designed to enable ease of inter-component connection on the printed circuit board.

Within the same PCB, first seddLED3.0 LED and microcontroller has to be routed as close as possible as its single-ended communication format. Connection from 1st seddLED3.0 LED to 2nd seddLED3.0 LED onwards will be converted to differential format internally.

Under unavoidable circumstances where customer needs to connect from PCB module to PCB module, the maximum wire harness length is subject to respective OEM EMI/EMC requirements.

For the harness connection setup, it's advisable to use twisted-pair wire across SIOx_P and SIOx_N communication path.

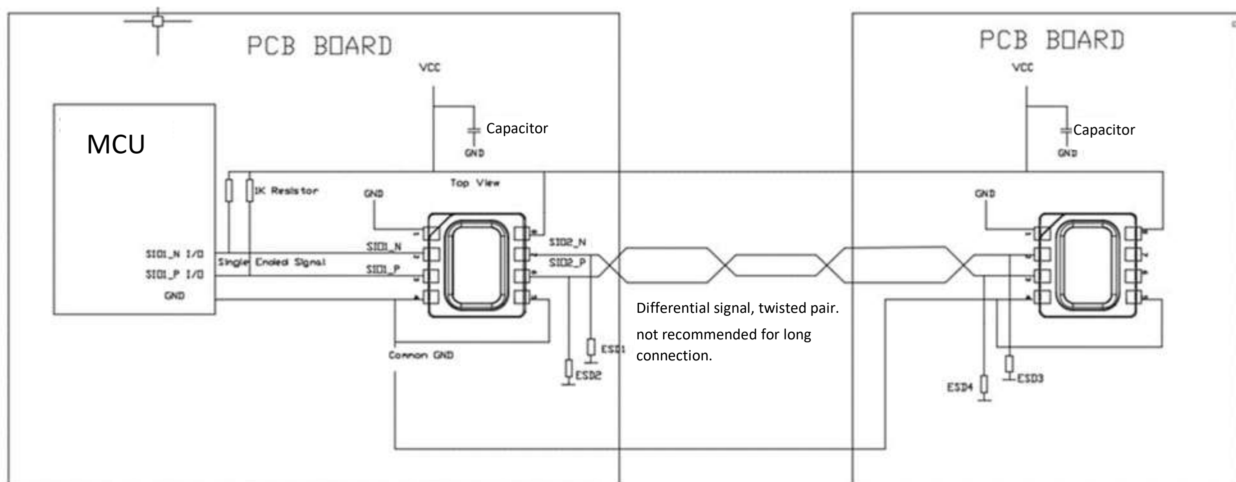
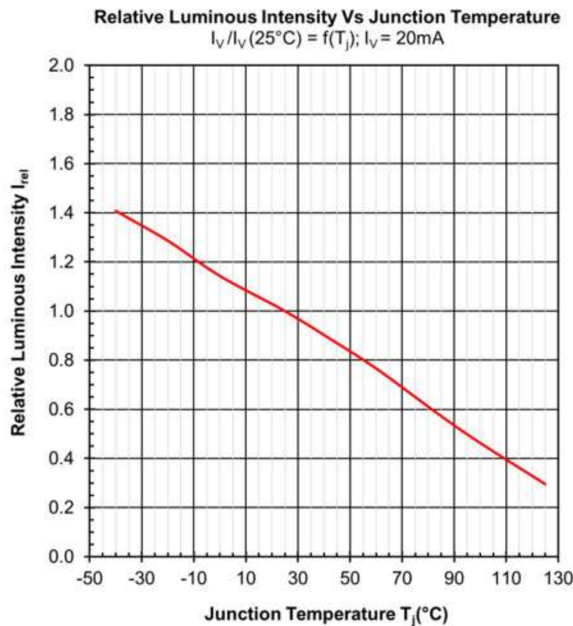


Figure 4: Module to Module connection via twisted pair harness

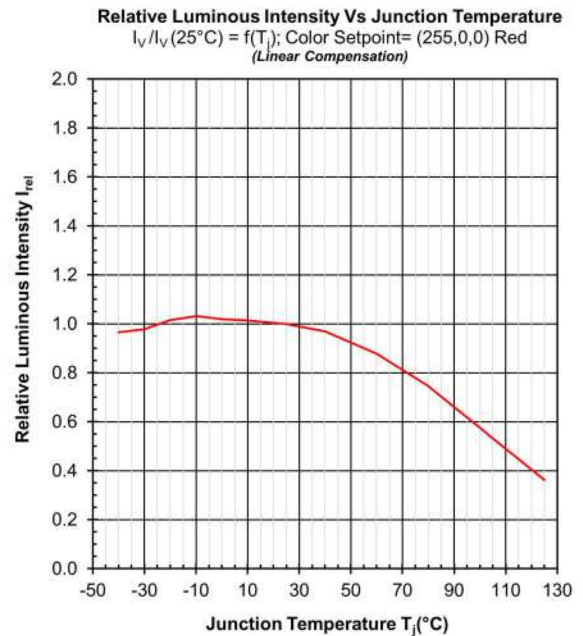
2. Temperature Compensation for Red LED

2.1 Linear Compensation

Red LEDs brightness is very sensitive to temperature. ISELED® IC is embedded with auto compensation feature with linear temperature compensation to stabilize the brightness fluctuation across full operating range. Figure 5 shows the difference in Red LED brightness without temperature compensation and with a seddLED3.0 linear temperature compensation.



Red LED Without Temperature Compensation



Red LED With Linear Temperature Compensation

Figure 5: Red LED brightness: without compensation (left) and with compensation (right)

2.2 Non-Linear Compensation

A3A-FKG-1400-1 is special calibrated to D65 white color at 1400mcd. To further improve the D65 white color mixed homogeneity across full operating temperature, we recommend to use non-linear compensation. Figure 6 shows the Red LED brightness in non-linear temperature compensation. Figure 7 show the in D65 white color mixed improvement of non-linear temperature compare to linear temperature compensation. We can observe significant D65 white color mixed improvement at extreme cold and hot temperature.

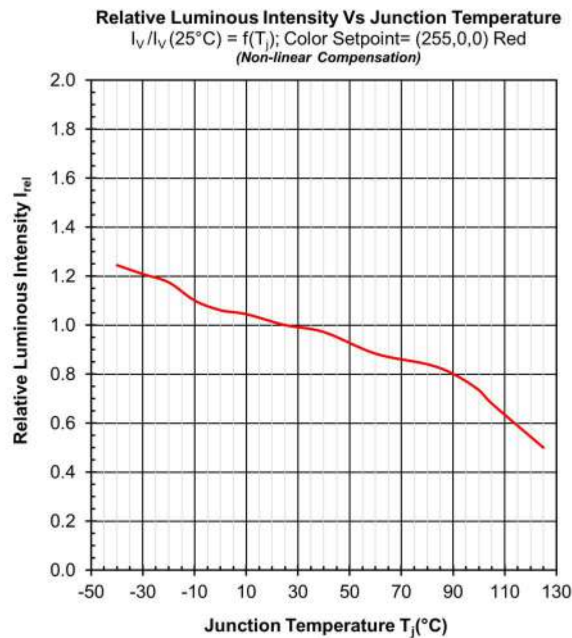


Figure 6: Red LED brightness in non-linear temperature compensation

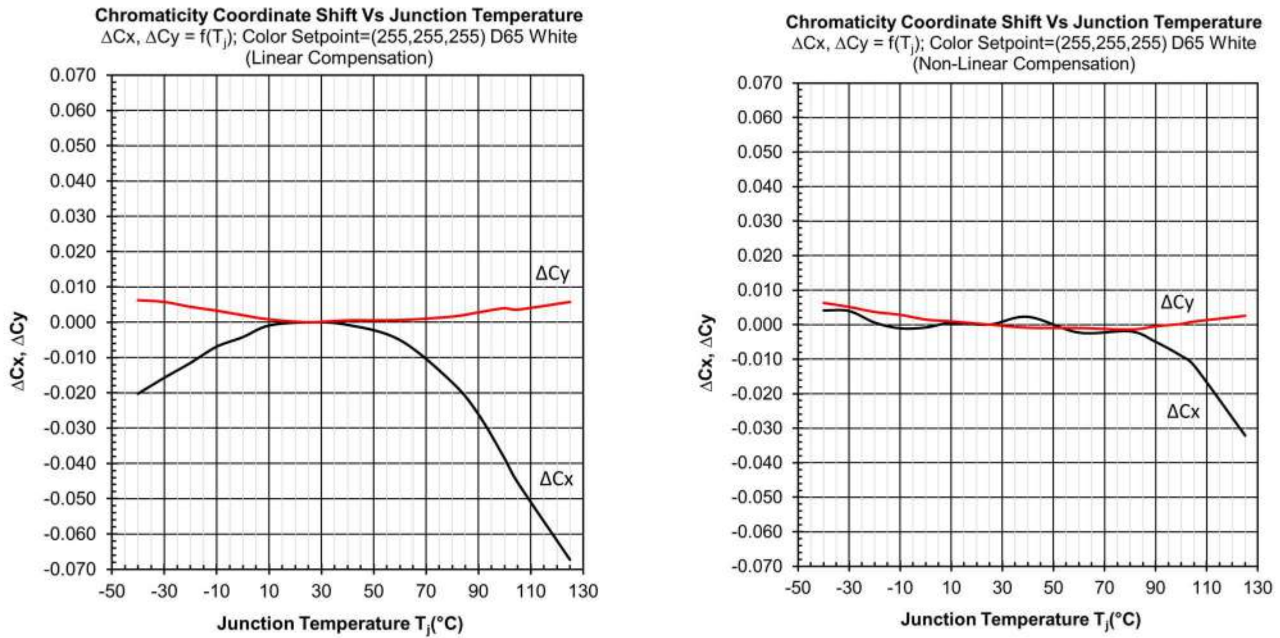


Figure 7: D65 Color: Linear compensation (left) and non-linear compensation (right)

2.3 Non-linear temperature compensation look up table

Look-up table for non-linear temperature compensation entry for red LED is written with increasing values from LUT Address 10 to LUT Address 0. Figure 8 shows the example of the table for each entry. Look up Table API command need to be written into microcontroller source code main interface right after INIT strip command. During debugging mode, this source code will need to be flashed into MCU memory to operate as usual. These setting will manually overwritten the linear compensation TC_BASE and TC_OFFSET values pre-recorded in the OTP of the seddLED3.0.

API command (reference to NXP S32Kxx series):

digLED_ReturnType digLED_Set_TC_Lookup(uint16_t LUT_Adr, uint16_t LUT_Value, uint16_t Address, uint8_t StripNr);

@param LUT_Adr 0-10: 4-bit look-up table entry (address)

@param LUT_Value 0-511: 9-bit look-up table value, in increasing values

@param Address 0-4079: Address of the target LED. 0 addresses all LEDs of the chain.

@param StripNr Number of the strip on which the commands will be sent

LUT_Address	LUT_Values
0	511
1	482
2	380
3	370
4	320
5	300
6	295
7	290
8	285
9	280
10	270

Figure 8: Non-linear temperature compensation look-up table entry

These 11 values will not store permanently in the OTP and need to be set again by the host after every reset.

Below steps give an example commands for the INIT of the strip and how to set these 11 values with the NXP MCU. The INIT command may only be executed after power-up or hardware reset or after a CAL_RESET command has been executed. Otherwise it is considered an illegal command and the undefined command error status bit is set, if an INIT command is encountered.

1. Reset seddLED3.0 LED strip
2. INIT of LED strip with example of NXP digLED_Init_Strip command

   Example Usage:

   uint32_t nrOfLEDs = 10;

   digLEDResultStrip1.chainLength = nrOfLEDs;

   digLED_InitStrip (&testInitType, &digLEDResultStrip1, STRIP1);

   delay (100000);

```
appState = OPERATION_ONGOING;
digLED_Init_Strip(&testInitType, &digLEDResultStrip1, strip);
while (appState == OPERATION_ONGOING);
delay(100000);
```

3. Set 11 values of non-linear look-up table with example of NXP digLED_Set_TC_Lookup command

```
appState = OPERATION_ONGOING;
digLED_Set_TC_Lookup(0, 511, 1, 0);//105C
while (appState == OPERATION_ONGOING);

appState = OPERATION_ONGOING;
digLED_Set_TC_Lookup(1, 482, 1, 0);//100C
while (appState == OPERATION_ONGOING);

appState = OPERATION_ONGOING;
digLED_Set_TC_Lookup(2, 380, 1, 0);//85C
while (appState == OPERATION_ONGOING);

appState = OPERATION_ONGOING;
digLED_Set_TC_Lookup(3, 370, 1, 0);// 65C
while (appState == OPERATION_ONGOING);

appState = OPERATION_ONGOING;
digLED_Set_TC_Lookup(4, 320, 1, 0);// 55C
while (appState == OPERATION_ONGOING);

appState = OPERATION_ONGOING;
digLED_Set_TC_Lookup(5, 300, 1, 0);// 45C
while (appState == OPERATION_ONGOING);

appState = OPERATION_ONGOING;
digLED_Set_TC_Lookup(6, 295, 1, 0);//35C
while (appState == OPERATION_ONGOING);

appState = OPERATION_ONGOING;
digLED_Set_TC_Lookup(7, 290, 1, 0);//25C
while (appState == OPERATION_ONGOING);

appState = OPERATION_ONGOING;
digLED_Set_TC_Lookup(8, 285, 1, 0);//0C
while (appState == OPERATION_ONGOING);

appState = OPERATION_ONGOING;
digLED_Set_TC_Lookup(9, 280, 1, 0);//-20C
while (appState == OPERATION_ONGOING);

appState = OPERATION_ONGOING;
digLED_Set_TC_Lookup(10, 270, 1, 0);//-40C
while (appState == OPERATION_ONGOING);
```

Please refer to respective MCU supplier for the API command if different MCU is used. However, the non-linear temperature compensation look-up table entry (figure 8) will remain the same.

3.0. Surface Mounting Guideline

3.1 A3A-FKG Package Outline

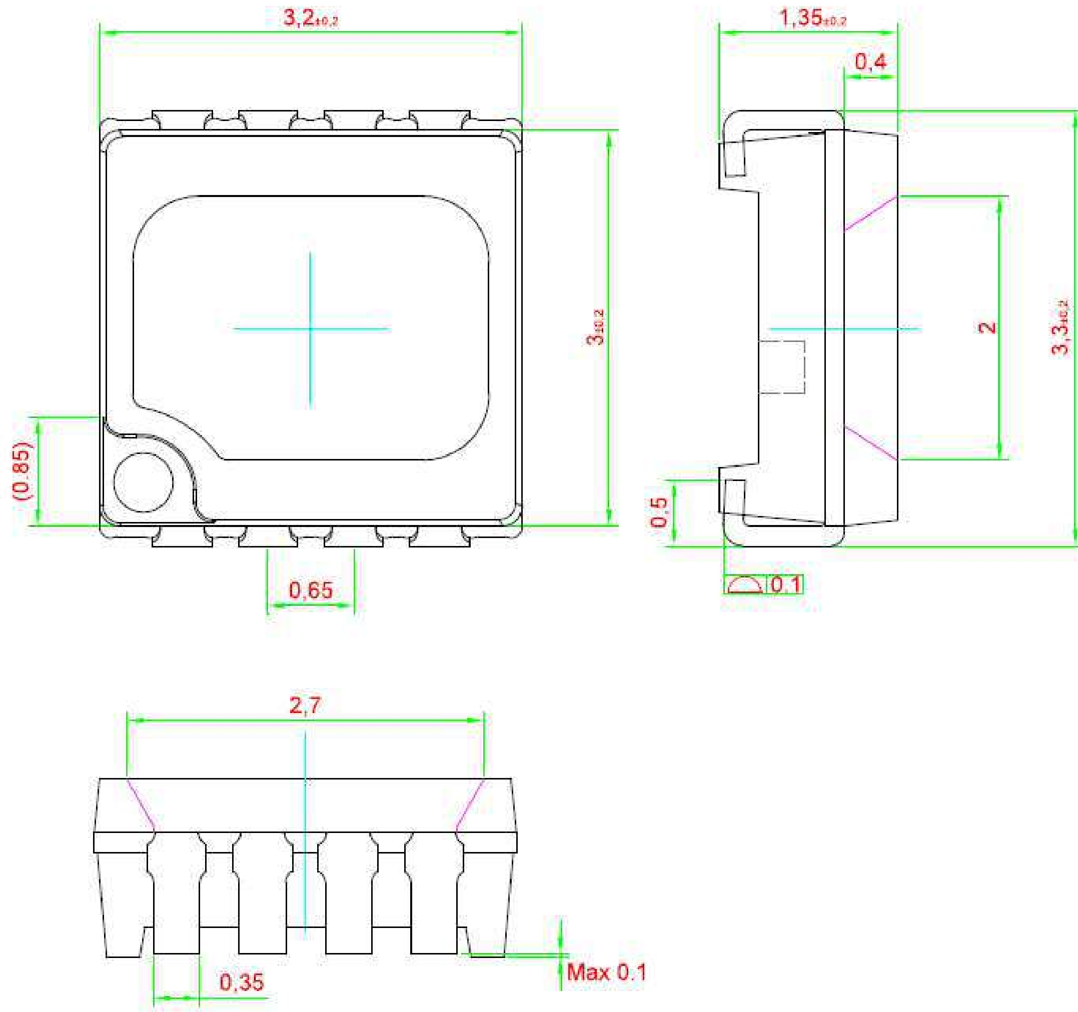


Figure 9: A3A-FKG Package Outline

3.2 Standard Soldering Process:

The seddLED3.0 package soldering surfaces are plated with gold (Au) and are therefore RoHs compliant. The component is designed to be compatible to the existing industry SMT process and IR-reflow. As for the soldering process, the component is qualified for Pb-free soldering profile. The profiles are as per described in the datasheet.

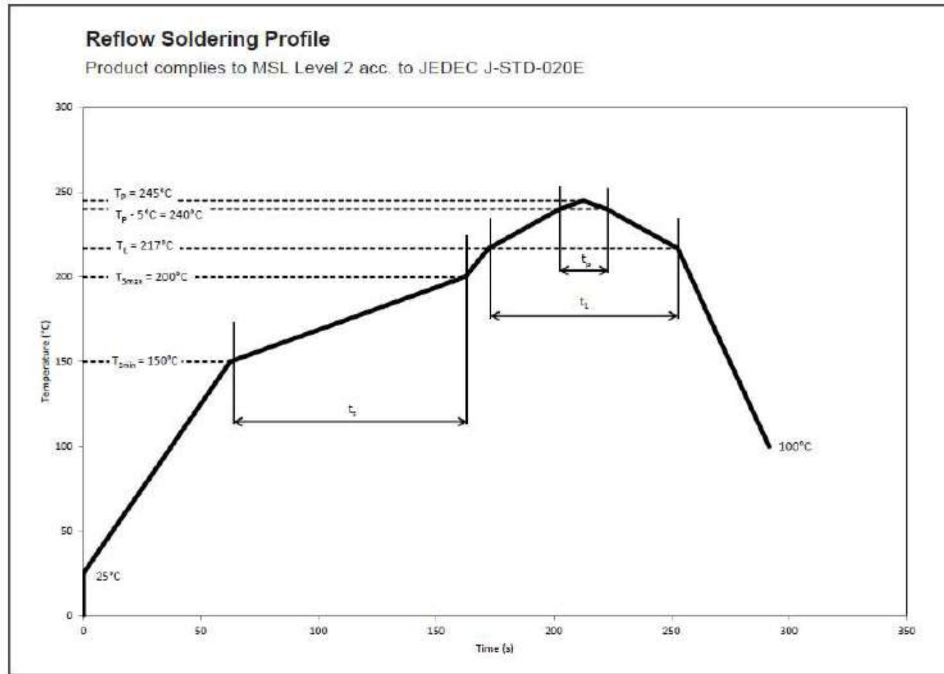


Figure 10: Recommended Reflow Soldering Profile

Profile Feature	Symbol	Pb-Free Assembly			Unit
		Minimum	Recommended	Maximum	
Ramp-up rate to preheat 25°C to T_{smin}			2	3	°C/s
Time t_S, T_{smin} to T_{smax}	t_S	60	100	120	s
Ramp-up rate to peak, T_L to T_P			2	3	°C/s
Liquidous temperature	T_L		217		°C
Time above liquidous temperature	t_L	60	80	150	s
Peak temperature	T_P		245	260	°C
Time within 5°C of the specified peak temperature T_P - 5°C	t_P	10	20	30	s
Ramp-down rate, T_P to 100°C			3	6	°C/s
Time 25°C to T_P				480	s

3.3 Surface Mounting – Factors to Consider:

This application note provides a guideline for the surface mounting of seddLED3.0. The following parameters have to be considered in order to optimize the surface mounting performance.

- Solder pad size
- Solder stencil size
- Solder paste thickness
- Nozzle
- Solder quality check

Solder Pad Size

The recommended solder pad design illustrated the additional copper area to assist on the heat dissipation. Please make sure no solder mask/solder resist, silk screen and copper under the keep out areas as shown in Figure.3.

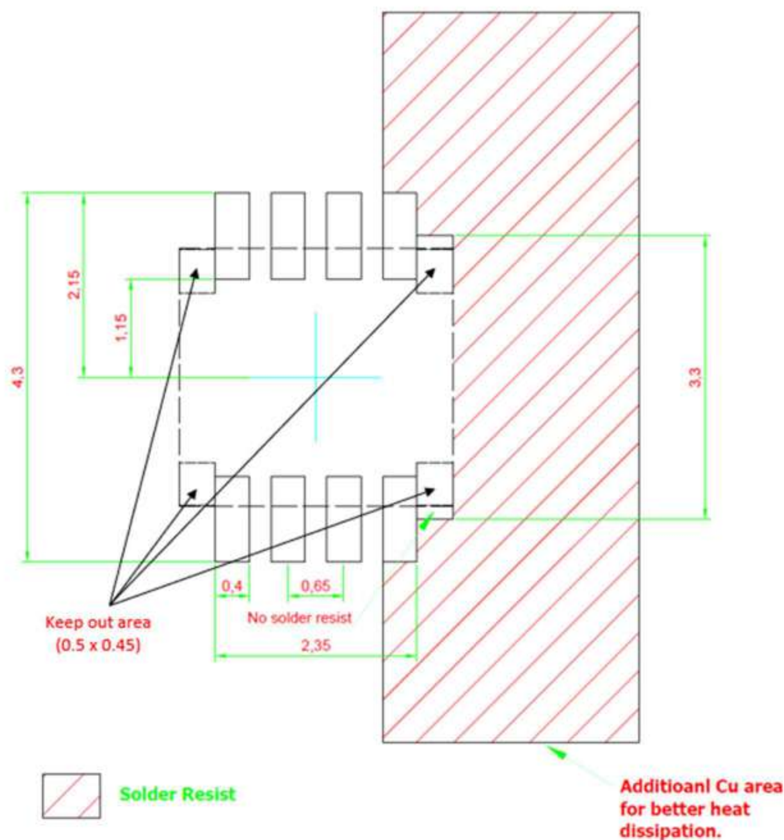


Figure 3: Recommended solder pad size

Solder Stencil Size

In order to minimize solder bridging problems, it is common to design stencil aperture size smaller than the recommended solder pad. Excessive amount of solder paste deployed will result to tilted parts and inaccurate placement position. It is recommended that the aperture is reduced to 90% of the recommended solder pad design.

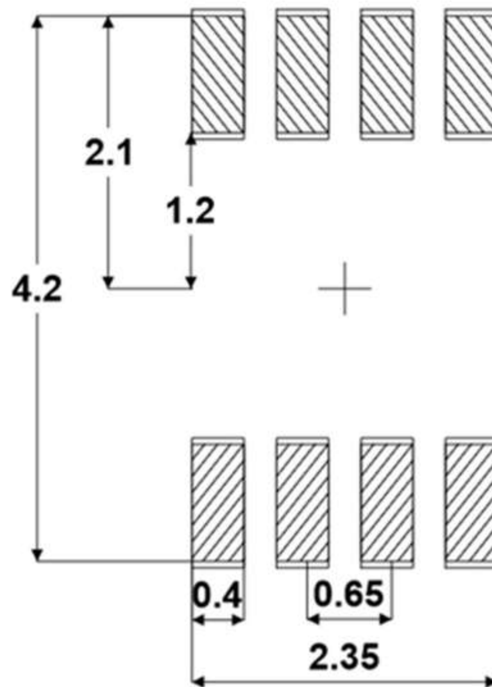


Figure 11: Recommended solder stencil size

Solder Paste Thickness

We recommend using minimum solder paste in order to achieve a good solder formation. A solder paste thickness of 0.150 mm will be optimum.

Nozzle

Pick and place machine should be able to process seddLED3.0 devices with the required placement accuracy. Care should be observed that the surface of the nozzle which is in contact with the LED is flat and smooth. Pick up area should be observed for this seddLED3.0 as shown in Figure 12. Parameter settings for the pick and place process should also be evaluated to ensure no damage to the LEDs. For recommended nozzle design, please refer to our *Recommended Pick and Place Tools for LEDs from DOMINANT Opto Technologies* application note.

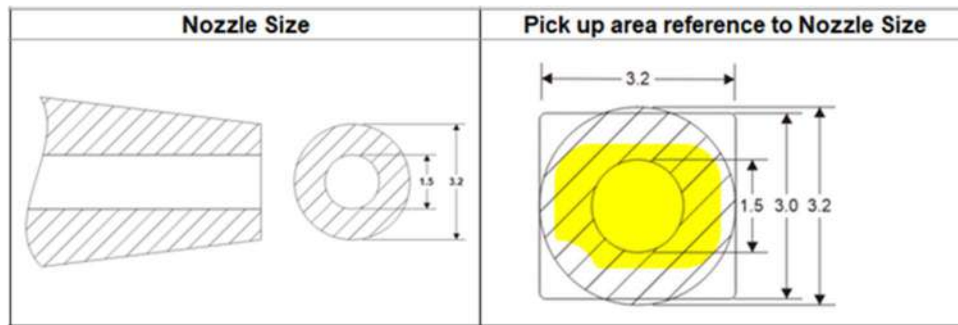


Figure 12: Recommended nozzle size and pick up area

Solder Quality Check after SMT Process

For seddLED3.0, the primary soldering surfaces are at the bottom and side of the LED component. The solder fillet can be observed easily at the side of the LED package.

Package Side View 1 Package Side View 2

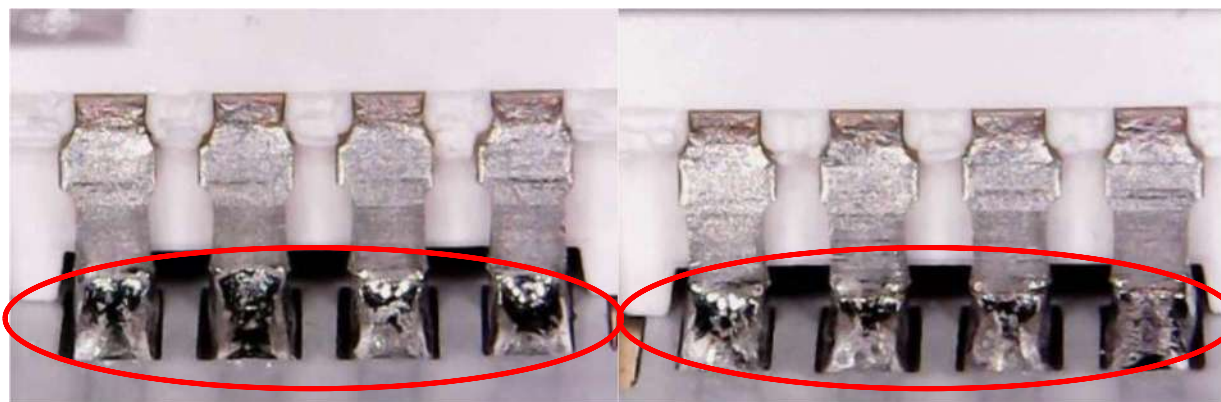


Figure 13: Example of good solder formation on lead

Solder Paste Type

Dominant has tested the SAC305 solder paste with satisfactory results. However, since application environments vary widely, we recommend that customers perform their own solder paste evaluation in order to ensure it is suitable for the targeted application.

Storage Method after SMT

For PCB assembly that mounted with seddLED3.0, it should not be stack together after IR reflow, else it would have high chance of damaging the LED. Recommended method is having a dedicated carrier so that each PCB assembly is with at least 5mm away from each other.

Figure 14: Example of carrier to store the LED

Handling Precautions

1. Mechanical forces exerted onto the black silicone overcoat area (bottom view) of seddLED3.0 should be minimized.

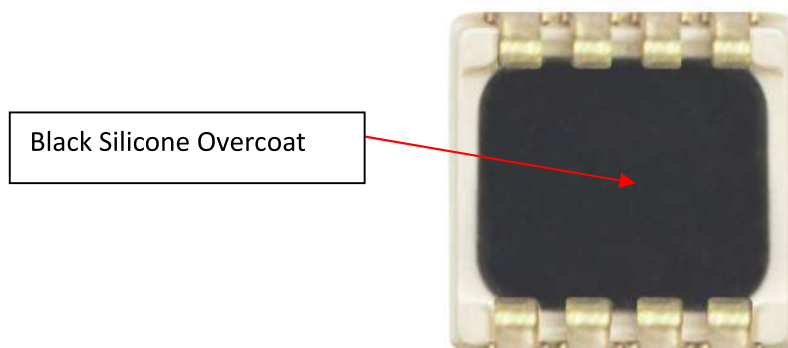


Figure 15: Bottom view of seddLED3.0

2. For manual handling, anti-static/conductive plastic tweezers should be use to pick up seddLED3.0. Avoid touching sensitive area such as the package lead, LES and black silicone overcoat area during pick up.

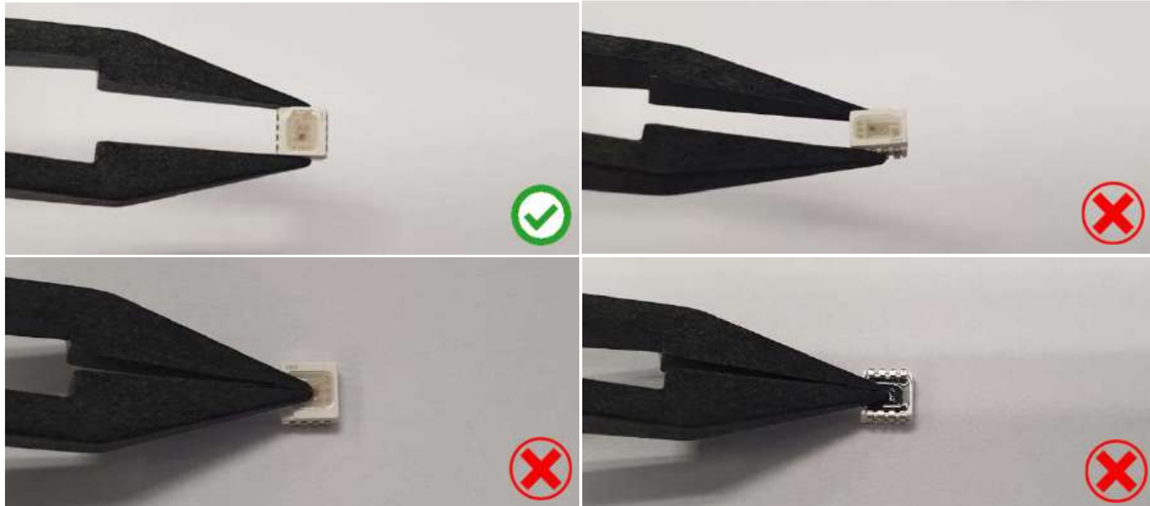


Figure 16: Example of correct and wrong method on LED handling

3. A better alternative for manual handling of seddLED3.0 package is using vacuum suction pen. The suction tip should be made of a soft material such as rubber to minimize the mechanical force exerted onto sensitive area. Care should be taken to avoid the soft material from contaminating the top side surface of the LED emitting area.

Figure 17: Example of vacuum suction pen

4.0 Light Bar Functionality Check After SMT

It is common practice to perform Read Diagnostic and light up test to check for any light bar anomalies as part of End Of Line Testing after SMT. Please refer to the ISELED API user guide for the Read Diagnosis explanation. For seddLED devices, recommended light up check condition is set to 50% of device full intensity. At intensity setting less than 100%, the random PWM generator in seddLED IC will be activated to check for the memory integrity and whether there is any issue of loading up the calibrated data from One Time Programmable memory of IC to IC internal register. The random PWM generator will be disabled when the device intensity is set at 100%. Device failing the memory integrity check will show sign of flickering or display random color compare to normal devices when light up at 50% of device full intensity.

5.0 Revision History

Changes	Date
Initial Release	15 Jan 2019
• Updated NXP MCU detail • Added Microchip detail • Remove NXP software drive installation and demo guide (duplicate from seddLED demo kit user guide) • Added Temperature Compensation explanation and application guide • Added SMT handling and guideline	17 Aug 2020
• Update package outline • Update solder pad drawing	24 Sep 2021
• Update product photo • Add light bar light up test intensity setting condition • Update photo for figure 15: Bottom view of seddLED3.0	01 Aug 2022
• Update Extended connection guide (module-to-module) explanation • Update recommended solder pad description • Update solder stencil size and description • Update solder paste thickness • Update recommended nozzle size and pick up area	07 Jan 2025