NSL21610/1
Single-Channel 450mA Automotive Linear LED Driver with Thermal Balancing
Datasheet (EN) 1.0

Product Overview

The NSL21610/1 is an automotive-grade single-channel linear constant current LED driver, with up to 450 mA current capability. Wide supply voltage up to 40 V enables NSL21610/1 a good fit for automotive battery directly powered application.

For linear-type constant current LED driver, thermal dissipation limit is a common issue to prevent it to be applicable for larger current conditions. By implementing a unique thermal balancing design, the NSL21610 is able to enlarge the output current capability with an automatic power balancing loop between the output channel and the external shunt resistor. It can address the thermal dissipation limit issue effectively with the majority of power conducted on the external shunt resistor, instead of the device itself.

The NSL21610/1 is able to support full diagnostics including the LED open-load and short-to-GND detection. With different FAULT bus connections, the NSL21610/1 can realize either "all off if one fails" or "others remain on if one fails".

Key Features

- AEC Q-100 Qualified for Grade 1: T_A from −40 °C to 125 °C
- 5 V to 40 V wide supply voltage range
- Single-channel high accuracy constant current with PWM dimming
- Automatic thermal balancing between device and external shunt resistor (NSL21610 only)
- Up to 450 mA current capability (NSL21610)
- Up to 300 mA current capability (NSL21611)
- Low dropout voltage : Max 350 mV at 100 mA
- EN control pin to enable/disable device for low power operation
- RoHS & REACH Compliance
- Full protections and diagnostics:
  - LED open-load detection with auto-recovery and adjustable enable threshold
  - LED short-to-GND detection with auto-recovery
  - Flexible FAULT bus connection options: "all off if one fails" and "others remain on if one fails"
  - Thermal shutdown

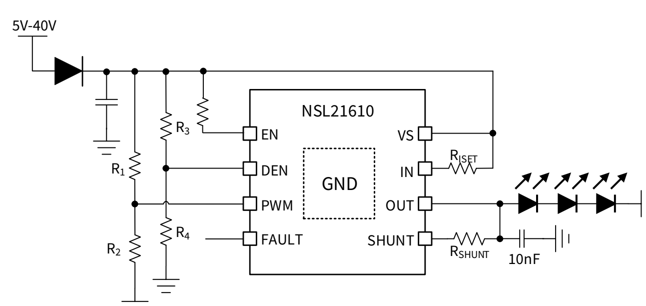
Applications

- Automotive exterior rear lighting: position light, fog light, stop light, tail light
- Automotive miscellaneous exterior lighting: center high mounted stop lamp, daytime-running lamp, turn indicator, door handle, blind spot detection indicator
- Automotive interior lighting: reading lamp, overhead console
- General-purpose LED driver applications

Device Information

Part Number	*Function Description*	*Package*	*Body Size*
NSL21610	With SHUNT	HMSOP-8	3.0mm x 3.0 mm
NSL21611	Without SHUNT		

Typical Application



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1. Pin Configuration and Functions

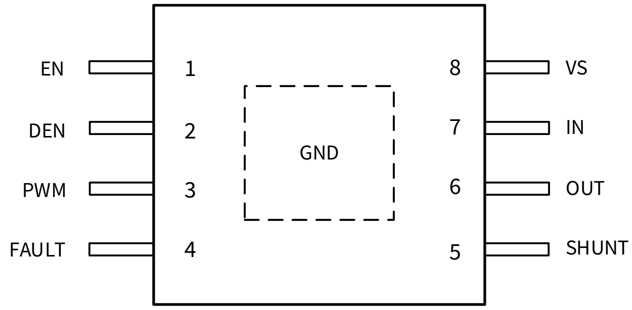


Figure 1.1 NSL21610 Package

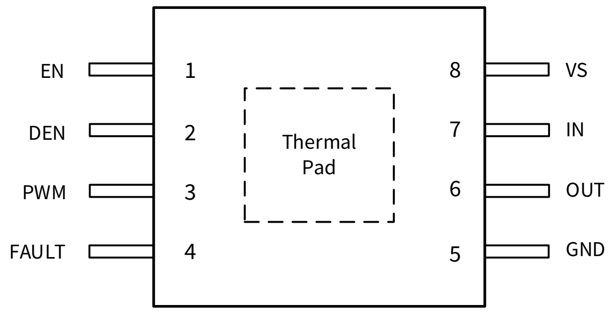


Figure 1.2 NSL21611 Package

Table 1.1 Pin Configuration and Description

PIN NO.	SYMBOL	FUNCTION
1	EN	Device enable pin
2	DEN	Diagnosis enable pin for open-circuit detection. Can be used to avoid false open-circuit detection during low-dropout operation
3	PWM	PWM control input
4	FAULT	Fault output
5	SHUNT	NSL21610: Current output with thermal balancing shunt resistor
	GND	NSL21611: Ground
6	OUT	Constant-current output
7	IN	Current input
8	VS	Power supply pin
Thermal Pad	GND	NSL21610: Ground
	Thermal pad	NSL21611: Suggest to connect to GND

2. Absolute Maximum Ratings

Parameters	*Symbol*	*Min*	*Max*	*Unit*
Supply voltage	VS	−0.3	45	V
High voltage input	IN	Max{V_{VS}−1, −0.3}	V_{VS}+0.3	V
High voltage input	DEN, PWM, EN	−0.3	V_{VS}+0.3	V
High voltage output	OUT, SHUNT (NSL21610 only)	−0.3	V_{VS}+0.3	V
Fault report pin	FAULT	−0.3	V_{VS}+0.3	V
Ambient temperature	T_A	−40	125	°C
Junction temperature	T_J	−40	150	°C
Storage temperature	T_{stg}	−65	150	°C

3. ESD Ratings

	Ratings	*Value*	*Unit*
Electrostatic discharge	Human body model (HBM), per AEC-Q100-002-RevD ● All pins ● Corner pins	 ±3.0 ±3.0	 kV kV
	Charged device model (CDM), per AEC-Q100-011-RevB ● All pins ● Corner pins	 ±1.0 ±1.0	 KV KV

4. Recommended Operating Conditions

Parameters	*Symbol*	*Min*	*Typ*	*Max*	*Unit*
Supply voltage	VS	5		40	V
High voltage input	IN		V_{VS}−V_{ISET}		
High voltage input	DEN, PWM, EN	0		V_{VS}	V
High voltage output	OUT, SHUNT (NSL21610 only)	0		V_{VS}	V
Fault report pin	FAULT	0		V_{VS}	V

5. Thermal Information

Parameters	Symbol	HMSOP-8	Unit
IC Junction-to-Ambient Thermal Resistance	θ_{JA}	58.1	°C/W
Junction-to-case (top) thermal resistance	$\theta_{JC(top)}$	56.8	°C/W
Junction-to-board thermal resistance	θ_{JB}	25.2	°C/W
Junction-to-top characterization parameter	ψ_{JT}	4.6	°C/W
Junction-to-board characterization parameter	ψ_{JB}	30.2	°C/W
Junction-to-case (bottom) thermal resistance	$\theta_{JC(bot)}$	9.4	°C/W

6. Specifications

6.1. Electrical Characteristics

(V_{VS} from 5 V to 40 V, T_J = – 40 °C to 150 °C unless otherwise noted)

Parameters	Symbol	Condition	Min	Typ	Max	Unit
Supply voltage	V_{VS}		5		40	V
Supply voltage POR threshold (Rising)	$V_{VS,TH1}$	V_{VS} ramps up		4.8	5	V
Supply voltage POR threshold (Falling)	$V_{VS,TH2}$	V_{VS} ramps down	4.4	4.6		V
Shutdown current	I_{SD}	V_{VS} = 12 V, EN low		8	15	µA
Quiescent current	I_Q	V_{VS} = 12 V, PWM high, EN high		0.41	0.55	mA
	I_{Q_FAULT}	V_{VS} = 12 V, PWM high, EN high, FAULT externally pulled low		0.3	0.38	mA
EN input threshold	V_{EN_H}	EN high level logic input	2			V
	V_{EN_L}	EN low level logic input			0.7	V
EN internal pulldown current	I_{EN}	V_{EN} = 12 V	1.5	3.3	5	µA
DEN, PWM input threshold	V_{Logic_H}		1.162	1.21	1.258	V
	V_{Logic_L}		1.066	1.11	1.154	V
Total output current range (NSL21610)	I_{TOTAL_MAX}	$I_{TOTAL\_MAX} = (I_{OUT} + I_{SHUNT})_{\_MAX}$			450	mA
Output current range (NSL21611)	I_{OUT_MAX}				300	mA
Regulated voltage on current setting resistor	V_{ISET}		94	99	104	mV
Dropout voltage	$V_{Dropout}$	$V_{Dropout} = V_{IN} - V_{OUT}$, SHUNT floating (NSL21610), I_{SET} = 100 mA		200	350	mV

Parameters	*Symbol*	*Condition*	*Min*	*Typ*	*Max*	*Unit*
Ron of Switch FET in SHUNT loop (NSL21610)	R_{SW_SHUNT}	$R_{SW\_SHUNT} = (V_{IN} - V_{SHUNT})/I_{SET}$, DEN low, OUT pin floating, I_{SET} = 100 mA		2.7	4.5	Ω
Channel open-load rising threshold	$V_{OPEN,TH1}$	$V_{VS} - V_{OUT}$	300	430	510	mV
Channel open-load falling threshold	$V_{OPEN,TH2}$	$V_{VS} - V_{OUT}$	200	300	370	mV
Channel short-to-ground rising threshold	$V_{SHORT,TH1}$	V_{OUT} or V_{SHUNT}	1.162	1.21	1.258	V
Channel short-to-ground falling threshold	$V_{SHORT,TH2}$	V_{OUT} or V_{SHUNT}	0.8	0.85	0.9	V
Channel open-load / short-to-ground retry current	I_{O/S_Retry}		0.6	1	1.35	mA
FAULT logic input high threshold	V_{FAULT_IH}		2			V
FAULT logic input low threshold	V_{FAULT_IL}				0.7	V
FAULT logic output high voltage	V_{FAULT_OH}	With 2μA external pulldown current	4.9		5.5	V
FAULT logic output low voltage	V_{FAULT_OL}	With 2 mA external pullup current			0.45	V
FAULT internal pullup current	I_{FAULT_PU}		4	13	20	μA
FAULT internal pulldown current	I_{FAULT_PD}	V_{FAULT} = 0.5 V	2	2.7	4	mA
FAULT leakage current	I_{FAULT_LKG}	V_{FAULT} = 40 V			1	μA
Device thermal shutdown temperature	T_{SD}			170		°C
Device thermal shutdown temperature hysteresis	T_{HYST}			17		°C
Channel open-load / short-to-ground deglitch time	t_{O/S_Deg}			160		μs
PWM rising delay time	t_{PWM_D1}	From PWM rising edge to 10% of I_{OUT} rising edge, V_{VS} = 12 V, V_{OUT} = 6 V, I_{SET} = 100 mA		5		μs
PWM falling delay time	t_{PWM_D2}	From PWM falling edge to 90% of I_{OUT} falling edge, V_{VS} = 12 V, V_{OUT} = 6 V, I_{SET} = 100 mA		5		μs
IOUT rising edge time	t_{IOUT_E1}	From 10% of I_{OUT} rising edge to 90% of I_{OUT} rising edge, V_{VS} = 12 V, V_{OUT} = 6 V, I_{SET} = 100 mA		3.4		μs

Parameters	Symbol	Condition	Min	Typ	Max	Unit
IOUT falling edge time	t_{IOUT_E2}	From 90% of I_{OUT} falling edge to 10% of I_{OUT} falling edge, V_{VS} = 12 V, V_{OUT} = 6 V, I_{SET} = 100 mA		2.8		µs
Device propagation delay	t_{Prop}	From EN rising edge to 10% of I_{OUT} rising edge, V_{VS} = 12 V, V_{OUT} = 6 V, I_{SET} = 100 mA		62		µs

6.2. Typical Performance Characteristics

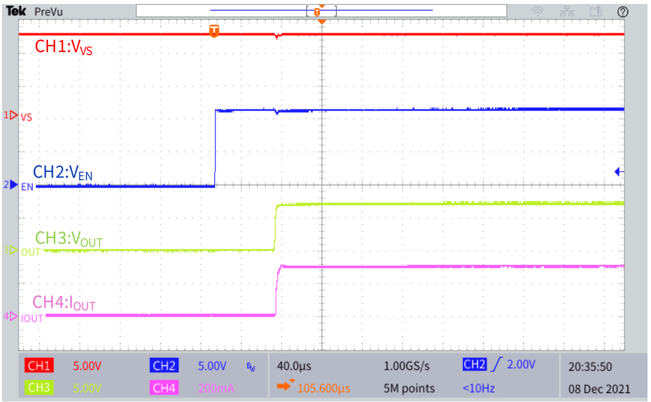


Figure 6.1 Start Up

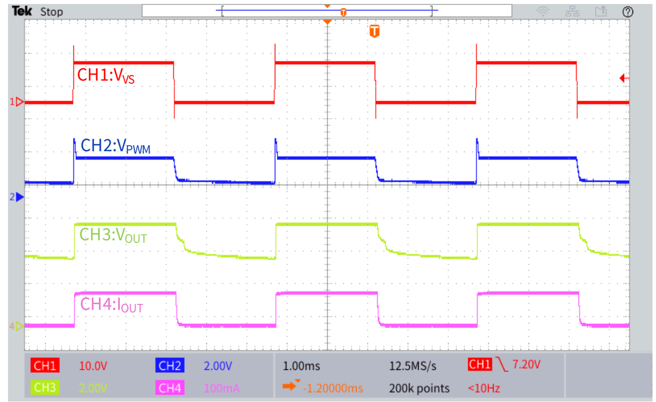


Figure 6.2 Power Supply Dimming at 200Hz

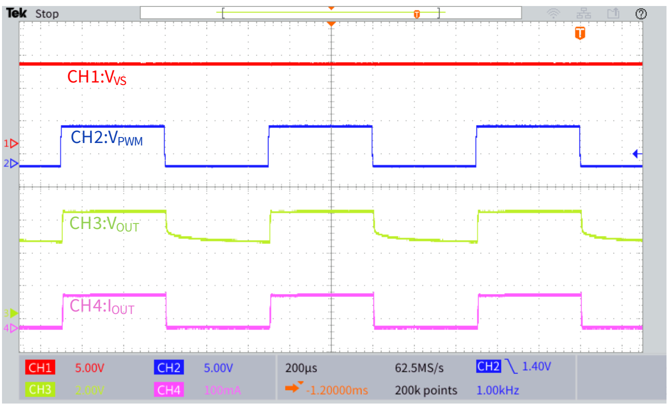


Figure 6.3 PWM Dimming at 1kHz

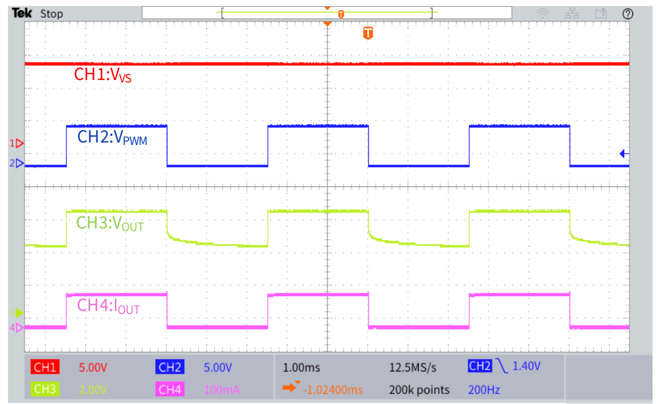


Figure 6.4 PWM Dimming at 200Hz

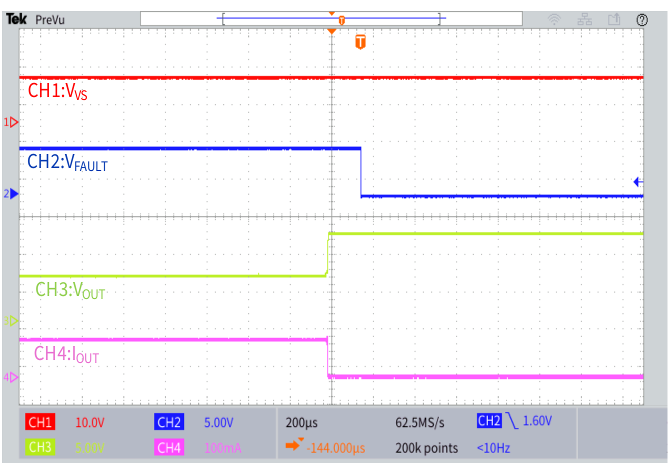


Figure 6.5 Open-Load Protection

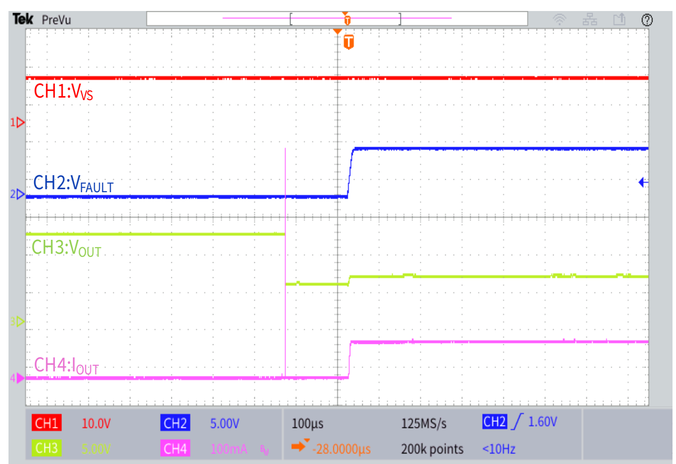


Figure 6.6 Open-Load Protection Recovery

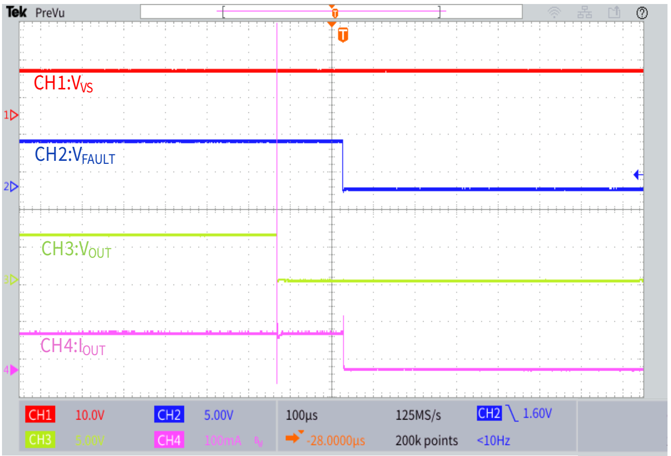


Figure 6.7 LED Short-to-GND Protection

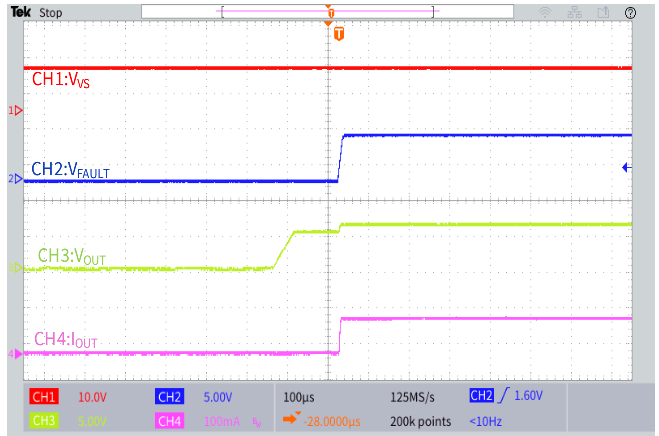


Figure 6.8 LED Short-to-GND Protection Recovery

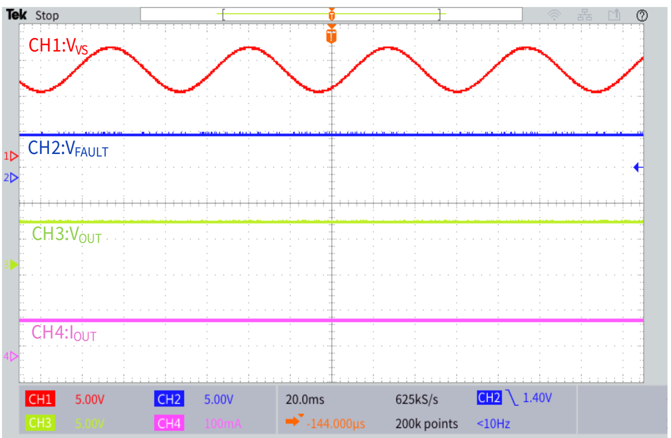


Figure 6.9 Superimposed Alternating Voltage 15Hz

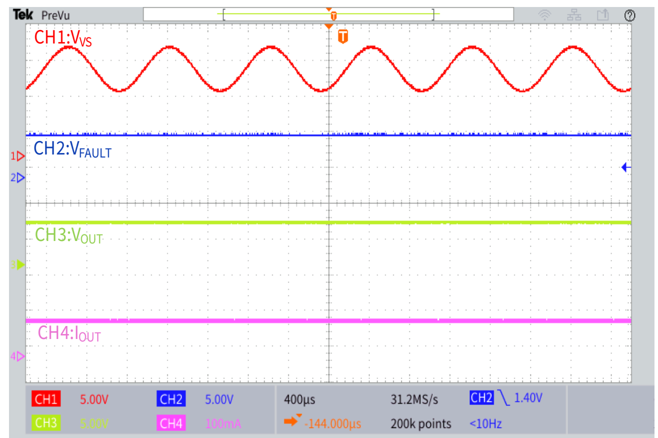


Figure 6.10 Superimposed Alternating Voltage 1kHz

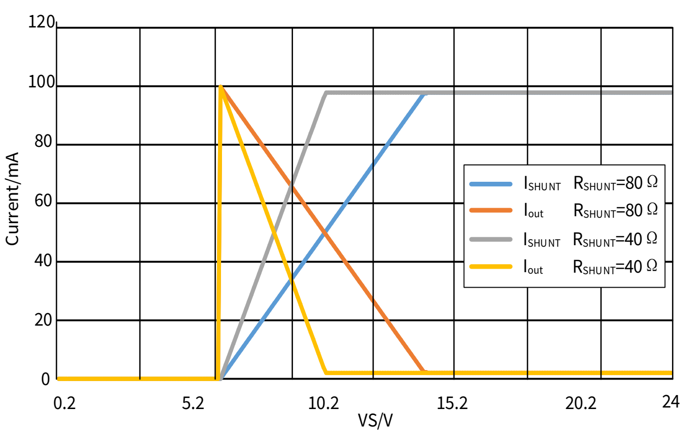


Figure 6.11 Output Current Distribution vs Supply Voltage (I_{set}=99mA)

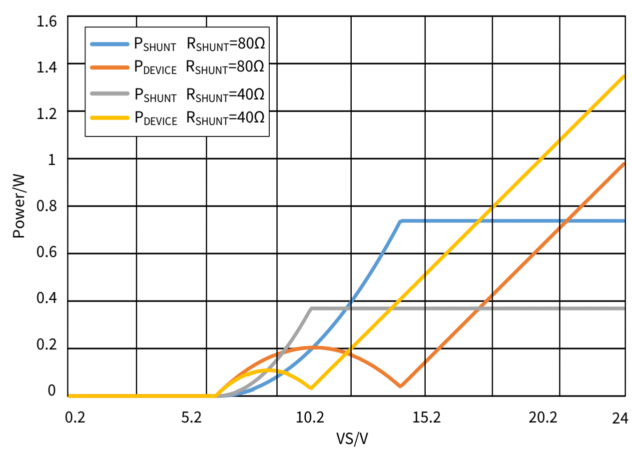


Figure 6.12 Power Dissipation vs Supply Voltage (I_{set}=99mA)

6.3. Parameter Measurement Information

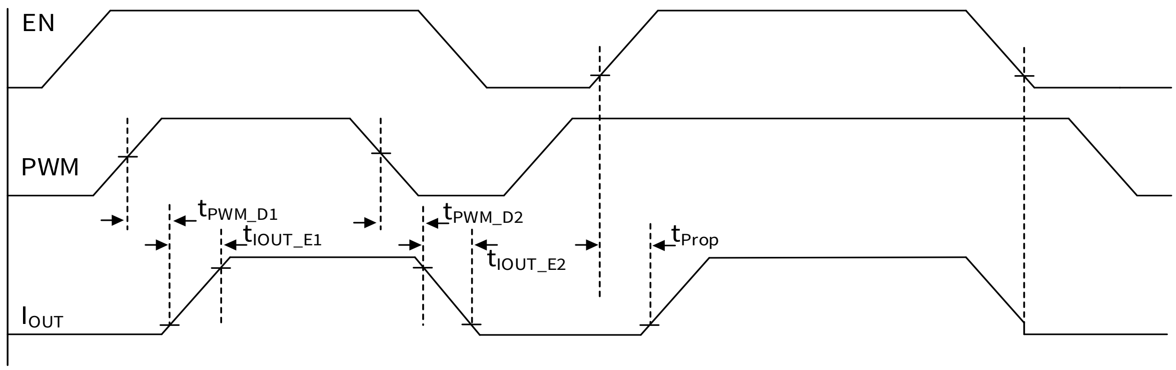


Figure 6.13 Start up sequence & PWM dimming timing

7. Function Description

7.1. Overview

The NSL21610/1 is a linear driver directly powered by automotive batteries with large voltage variations to output full current loads up to 450/300 mA. The NSL21610 single-channel LED driver includes a unique thermal management design to reduce temperature rising on the device. The current output can be set by external R_{ISET} resistor. Current flows through the R_{ISET} into the integrated current regulation circuit and to the LEDs through OUT pin and SHUNT pin (only NSL21610).

The NSL21610/1 device supports both power supply control and PWM control to turn LED ON/OFF. The LED brightness is also adjustable by voltage duty cycle applied on either VS or PWM with frequency above 100 Hz. The NSL21610/1 provides full diagnostics to keep the system operating reliably including LED open/short circuit detection and thermal shutdown protection.

7.2. System Diagram

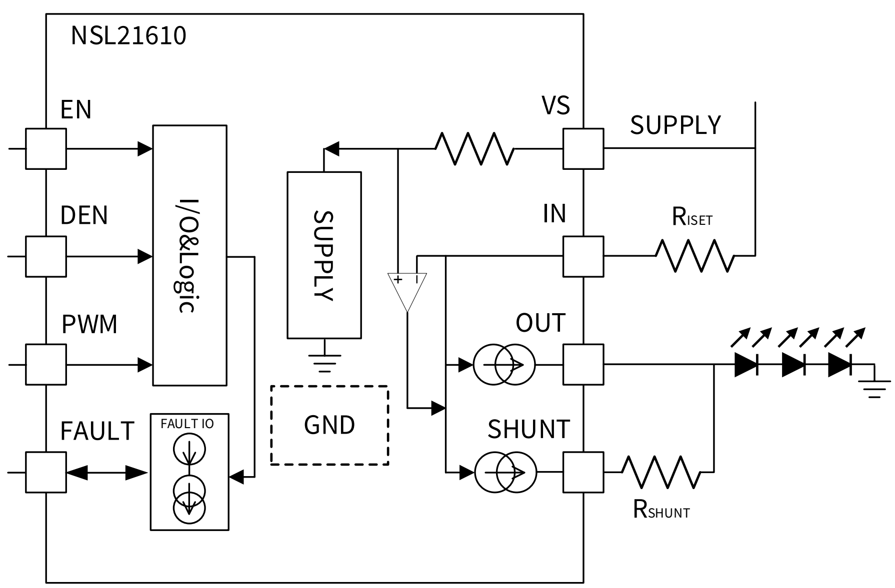


Figure 7.1 NSL21610 Block Diagram

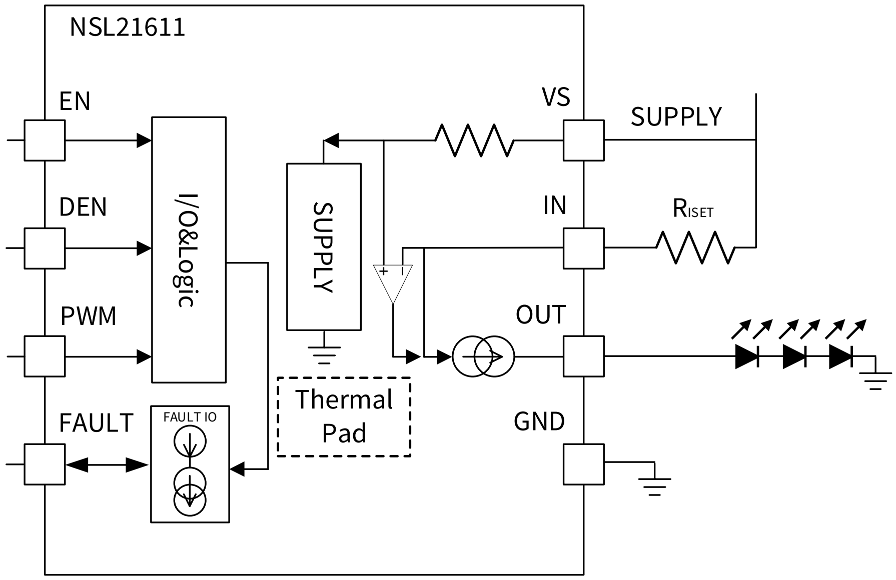


Figure 7.2 NSL21611 Block Diagram

7.3. Feature Description

7.3.1. Power Supply

7.3.1.1. Power On Reset (POR)

The NSL21610/1 device supports wide range from 5V to 40V of supplied voltage. Besides, an internal power on reset(POR) function is provided. When the power supply pin VS is powered by a source, the POR circuit holds the device in reset mode until V_{VS} is higher than Supply voltage POR threshold $V_{VS,TH1}$.

7.3.1.2. On and Off

When the V_{VS} is above $V_{VS,TH1}$ the NSL21610/1 device starts to output. Otherwise, the device turns off the output.

7.3.2. Output Current Setting

The NSL21610/1 device is a high-side current driver for driving LEDs. The device controls each output current through regulating the voltage drop on an external high-side current-sense resistor, R_{ISET} between VS and IN for output channel. An integrated error amplifier drives an internal power transistor to maintain the voltage drop on the current-sense resistor R_{ISET} to V_{ISET}, therefore regulates the current output to target value. When the output current is in regulation, the current value for each channel can be calculated as below:

$$I_{TOTAL}=\frac{V_{ISET}}{R_{ISET}} \qquad (1)$$

Where V_{ISET} is 99mV.

When the supply voltage drops below total LED string forward voltage plus required headroom voltage ($V_{Dropout}$ + V_{ISET}), the NSL21610/1 is not able to deliver enough current output as set by the value of R_{ISET}.

7.3.3. Output Current Thermal Balancing (NSL21610 only)

Two current output paths for each channel are provided by NSL21610. Current can flow to each LED string through both OUT pin and SHUNT pin. The total current output on these two pins is regulated to achieve required current output, and the summed current of OUT and SHUNT is equal to the current through R_{ISET}. Thus it can be calculated as:

$$I_{TOTAL}=\frac{V_{ISET}}{R_{ISET}}=I_{OUT}+I_{SHUNT} \qquad (2)$$

The output current on both OUT and SHUNT output is dynamically adjusted by the integrated current regulation in NSL21610 to maintain the stable total current. In order to reduce the thermal accumulation, the NSL21610 always regulates the current output to the SHUNT pin as much as possible until the SHUNT current path is saturated. Then OUT pin provide the rest of required current. As a result, most of the current to LED flows through the SHUNT pin when the voltage dropout is relatively high between VS and LED total forward voltage. On the contrary, most of the current to LED flows through the OUT pin when the voltage headroom is relatively low.

Note: the shunt resistor is designed according to real application, and it is calculated with many variables including supply voltage, output voltage, output current. So it is difficult to describe clearly by simple description. A design tool can be provided for customers if any questions occur during application. Please contact us for the design tool.

7.3.4. LED Brightness Dimming

7.3.4.1. PWM Control

The NSL21610/1 supports pulse width modulation (PWM) input dimming for LED string. The PWM input also can function as enable. The corresponding output current is enabled when the voltage of the PWM pin is higher than V_{Logic_H}. The output current is disabled with the voltage applied on PWM pin lower than V_{Logic_L}. Besides, the average current output for brightness control can be achieved by setting the frequency of applied PWM signal out of visible range of human eyes. The frequency is suggested higher than 100 Hz.

It has PWM input pin in the NSL21610/1 device to control output channel. The output current for both OUT and SHUNT (only for NSL21610) is controlled by PWM input.

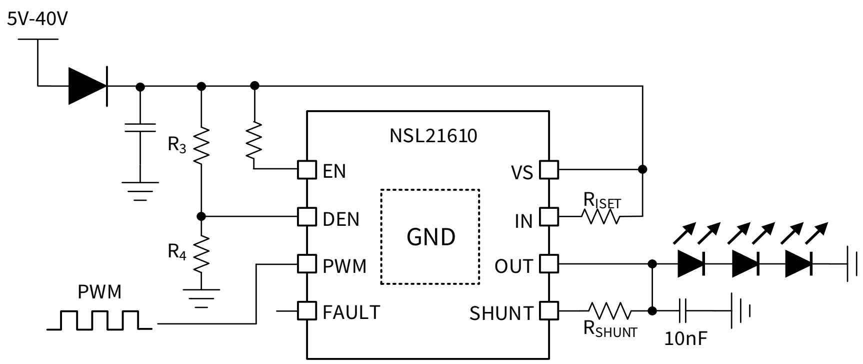


Figure 7.3 NSL21610 PWM Control LED Brightness Dimming

7.3.4.2. Power Supply Control

The power supply of NSL21610/1 also can control the ON and OFF for output current. When the voltage applied on the VS pin is higher than the LED string forward voltage plus needed headroom voltage ($V_{Dropout}$ + V_{ISET}), and the voltage of PWM and EN pins is high, the output current is turned ON and well regulated. When the voltage applied on the VS pin drops below UVLO, the output current is turned OFF. With this feature, the power supply voltage in designed pattern can control the output current ON/OFF. The brightness is adjustable if the ON/OFF frequency is fast enough, which is the same as PWM control.

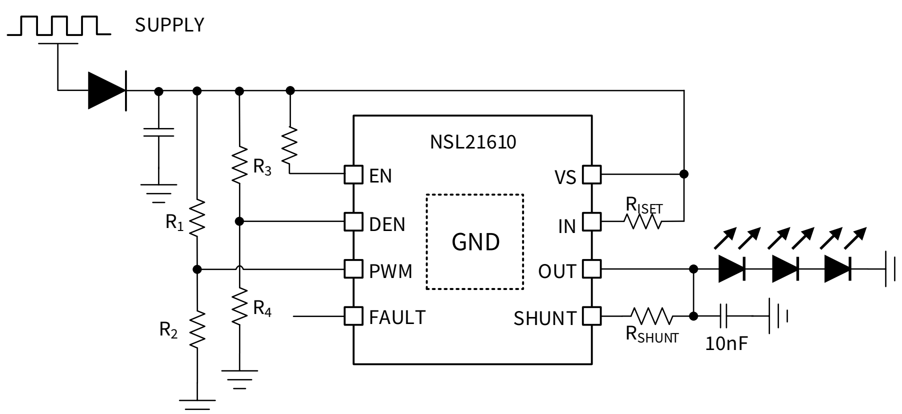


Figure 7.4 NSL21610 Power Supply Control LED Brightness Dimming

- To avoid the output current overshoot during turn-on phase, it is suggested to enable the PWM through resistor as below connection:

$$V_{VS\_PWM\_RISING}=V_{Logic\_H}\times\left(1+\frac{R_1}{R_2}\right) \quad (3)$$

$$V_{VS\_PWM\_RISING}\geq V_{LED\_FWD\_TOT}+V_{Dropout}+V_{ISET} \quad (4)$$

- To avoid the false open-load detection due to low-dropout region operation during turn-on/off phase, it is suggested to enable the DEN through resistor as below connection:

$$V_{VS\_DEN\_FALLING}=V_{Logic\_L}\times\left(1+\frac{R_3}{R_4}\right) \quad (5)$$

$$V_{VS\_DEN\_FALLING}\geq V_{LED\_FWD\_TOT}+V_{OPEN,TH2}+V_{ISET} \quad (6)$$

Where V_{Logic_H} is 1.258V (maximum), V_{Logic_L} is 1.066V (minimum)

7.3.5. Protections and Diagnostics

7.3.5.1. Open-load detection

The device has LED open-load detection. The LED open-load detection monitors the output voltage when the current output is enabled. Only the DEN is HIGH, NSL21610/1 LED open-load detection can be enabled A short-to-battery fault is also detected and recognized as an LED open-load fault. Once a LED open-load failure is detected, the device turns off the faulty channel and retries automatically, regardless of the state of the PWM input. When the retry mechanism detects the removal of the LED open-load fault, the device resumes to normal operation.

When the device operates in normal mode with PWM and EN voltage is high, the NSL21610/1 monitors dropout voltage differences between the VS and OUT pins for LED channel. The voltage difference V_{VS}–V_{OUT} is compared with the internal reference voltage $V_{OPEN,TH2}$ to detect LED open-circuit incident. When V_{OUT} rises causing V_{VS}–V_{OUT} less than the $V_{OPEN,TH2}$ voltage and lasts longer the deglitch time of t_{O/S_Deg}, the device asserts an open-load fault. When DEN input is logic High, Once a LED open-load failure is detected, the internal constant-current sink pulls down the FAULT pin voltage. The device shuts down the output current regulation for the faulty channel. However, the device sources a small current I_{O/S_Retry} from Vs to OUT. The device resumes normal operation and releases the FAULT pin once the fault condition is removed.

7.3.5.2. Short-to-GND detection

In order to ensure the safety of the device and the whole system, LED short-to-GND detection is integrated in NSL21610/1. This function is achieved by monitoring the output voltage when the output current is enabled, and regardless of the state of the DEN input. Once a short-to-GND LED failure is detected, the device turns off the faulty channel and retries automatically, regardless of the state of the PWM input. When the retry mechanism detects the removal of the LED short-to-GND fault, the device resumes to normal operation.

The device monitors the V_{OUT} voltage and V_{SHUNT} voltage of output channel and compares it with the internal reference voltage to detect a short-to-GND failure. Once the V_{OUT} or V_{SHUNT} voltage falls below $V_{SHORT,TH2}$ longer than a deglitch time of t_{O/S_Deg}, the device will be asserts the short-to-GND fault, then pulls low the FAULT pin to assert the fault happen. Once the device has asserted a short-to-GND fault, the device turns off the faulty output channel and retries automatically with a small current, I_{O/S_Retry} from VS to OUT to pull up the LED loads continuously. Once auto-retry detects output voltage rising above $V_{SHORT,TH1}$, it will be considered the fault removed ,and fault will be pull up, the device resumes to normal operation. Please refer to the Fault table 7.1 for details.

7.3.5.3. Thermal Shutdown

The junction temperature is monitored every time by the NSL21610/1 device. The output current will be shutdown if the junction temperature reaches thermal shutdown threshold (T_{SD}). Note that, there is a thermal hysteresis exits, which means only the junction temperature falls below T_{SD}-T_{HYST}, then the device recovers to normal mode. The FAULT pin is pulled low during thermal shutdown.

7.3.5.4. Fault Bus

The state of FAULT pin represents the device state of the device. When any fault scenario occurs, the FAULT pin will be strongly pulled low by the internal pulldown current sink, I_{FAULT_PD}. And the device will report the fault alarm. If no fault scenario occurs, it means the device is operating in normal mode, and the FAULT pin is weakly pulled up by an internal pullup current source, I_{FAULT_PU}. At the same time, the device also monitors the FAULT pin voltage internally. If the FAULT pin is pulled down below V_{FAULT_IL} by external current sink, the current output is turned off even though there is no fault detected on owned outputs.

For multiple NSL21610/1 devices application, one is able to construct a FAULT bus by tying FAULT pins from other devices to achieve fault sharing function as shown in Figure 7.5. It means one device detects any fault and pull down the FAULT pin, then the FAULT bus will turn off all the devices in the bus. Another situation is that one device detects any fault and turn off the fault output pin, but the others will operate normally by connecting all the FAULT pins to the base of an external PNP transistor as illustrated in Figure 7.6.

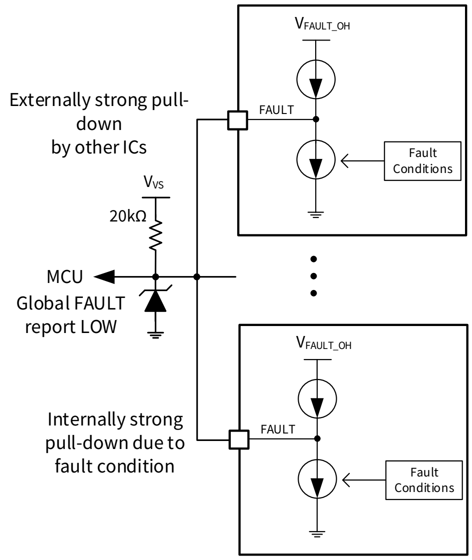


Figure 7.5 All off if one fails application

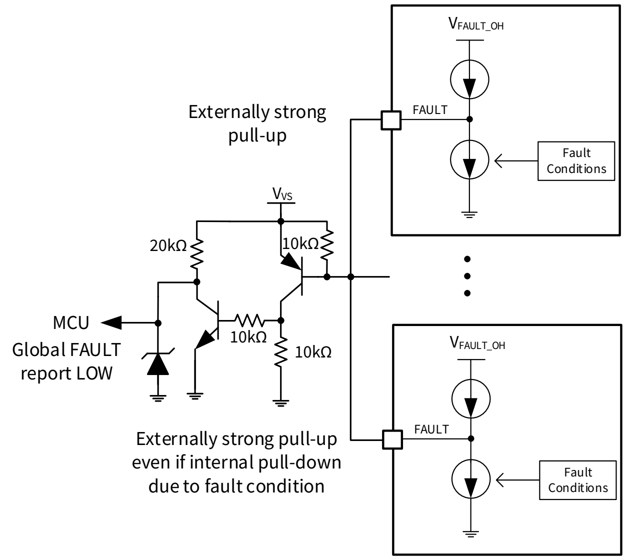


Figure 7.6 Others remain on if one fails application

Table 7.1 Fault table

Fault Bus Status	***Fault Type***	***Detection Mechanism***	***EN Input***	***PWMx Input***	***DEN Input***	***Deglitch Time***	***FAULT Action***	***Device Action***	***Recovery***
FAULT HIGH	Open-load or Short to battery	$V_{VS}-V_{OUT} < V_{OPEN,TH2}$	H	H	H	t_{O/S_Deg}	FAULT internal pulldown current, I_{FAULT_PD}	Device turns failed channel off and retries with I_{O/S_Retry}, ignoring the PWM input.	Auto-recovery
	Short to ground	$V_{OUT}<V_{SHORT,TH2}$ OR $V_{SHUNT} <V_{SHORT,TH2}$	H	H	not care	t_{O/S_Deg}	FAULT internal pulldown current, I_{FAULT_PD}	Device turns failed channel off and retries with I_{O/S_Retry}, ignoring the PWM input.	Auto-recovery
	Thermal shutdown	$T_J>T_{SD}$	H	not care	not care	120us	FAULT internal pulldown current, I_{FAULT_PD}	Device turns all channels off	Auto-recovery
FAULT LOW	Fault detected	Device turns all channels off and keeps auto-retry on failed channels							
	No Fault	Device turns all channels off							

7.4. Device Operation Mode

7.4.1. Normal Operation

With the V_{VS} >$V_{VS,TH1}$, the NSL21610/1 operate in normal mode. The LED string is driven in constant-current with enough voltage drop across Vs and OUT.

7.4.2. Undervoltage Lockout(UVLO)

With the V_{VS} < $V_{VS,TH2}$, All the functions of NSL21610/1 are disabled in this mode. If V_{VS} >$V_{VS,TH1}$, the device will quit this mode.

7.4.3. Low Dropout Operation

When the voltage supply is low and the voltage difference between input and output is less than the open-load detection threshold, the device will report an open load fault. So it is suggested only enabling the open-load detection when the voltage across Vs and out is higher than the maximum voltage of open-load threshold to avoid a false detection.

7.4.4. Fault Operation

The FAULT pin will be pulled down with a constant current if any fault is detected. Then the device operates into a fault mode and consumes a fault current of I_{Q_FAULT}.

8. Application

The fellow parts are not the component specification. The typical application in the fellow parts only helping customers to understand the functions of NSL21610/1, and it also able to provide a design guideline for some applications. By the way, the examples are provided based on NSL21610. For NSL21611, the only difference is the SHUNT pin, and the examples are also suitable by neglecting the SHUNT pin. Customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation to confirm system functionality.

8.1. Typical Application Circuit

8.1.1. Simple Application without MCU

The NSL21610/1 devices can be utilized for automotive single LED string situation without MCU. The Fault pin can be used alone in the floating state or connect to external indication circuit to indicate the fault condition.

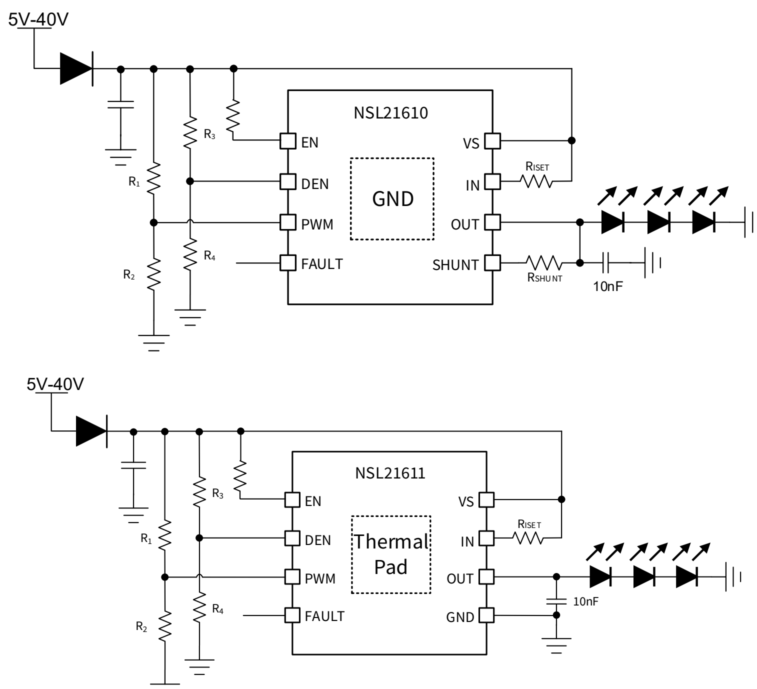


Figure 8.1 Simple Application Without MCU

8.1.1.1. Design Information

The voltage supply for VS is from 9V to 16V, and the dimming method is through power supply on and off. A string with 3 LEDs is driven by a NSL21610 device. each LED forward voltage drop is between 1.9V (V_{LED_min}) to 2.5V (V_{LED_max}). The current flow of every LED is 50mA.

8.1.1.2. Design Procedure

Step 1: calculate R_{ISET} using the equation below:

$$R_{ISET}=\frac{V_{ISET}}{I_{LED}} \tag{7}$$

Where V_{ISET} = 99mV, I_{LED}=50mA.

Due to the required output current for each LED, R_{ISET} =1.96Ω.

Step 2: Calculate the current of I_{OUT} and I_{SHUNT}, and the shunt resistor R_{SHUNT} can be obtained by using Equation 8. The shunt resistor directly decides the current distribution for I_{OUT} path and I_{SHUNT} path. In typical supply voltage application, the current shunt resistor is suggested to consume 50% of the total output current.

$$R_{SHUNT}=\frac{V_{VS}-V_{OUT}}{I_{OUT}\times 0.5} \quad (8)$$

Where V_{VS}=12V(typical), I_{LED}=50mA.

The value of shunt resistor is calculated as 222Ω, when the output voltage is selected as 2.15×3=6.45V.

Step 3: Design the voltage divider resistor value of R_3 and R_4 on DEN pin after design the threshold voltage of supply to enable the open load diagnostics.

Note that, the open-load fault cannot be detected in low dropout operation to avoid unexpected turn off, so headroom between voltage Vs and out must be considered. It means the device must disable open-load detection when the voltage supply is below the maximum LED string forward voltage plus open load threshold $V_{OPEN,TH2}$ and V_{ISET}. The voltage divider R_3 and R_4 can be obtained as Equation 9.

$$R_3=(\frac{V_{OPEN\_TH2}+V_{ISET}+V_{OUT}}{V_{Logic\_L}}-1)\times R_4 \quad (9)$$

Where V_{OPEN_TH2} = 370mV(maximum), V_{ISET} = 99mV, V_{Logic_L} = 1.066V(minimum), R_4=10kΩ(recommended).

When the maximum LED string forward voltage is 2.5V×3=7.5V, R_3=64.75 kΩ is obtained.

Step 4: Calculate the divider resistor of R_1 and R_2 of PWM pin to turn on and off each channel of LED, after the threshold voltage supply is determined.

In order to ensure all the LEDs is operating in normal mode, each LED should be turn off if the voltage supply is lower than LED minimum required forward voltage plus voltage dropout between OUT and Vs. The minimum forward voltage of LED string is calculated as 1.9V×3=5.7V. Thus, the divider resistor R_1 and R_2 can be calculated by Equation 10.

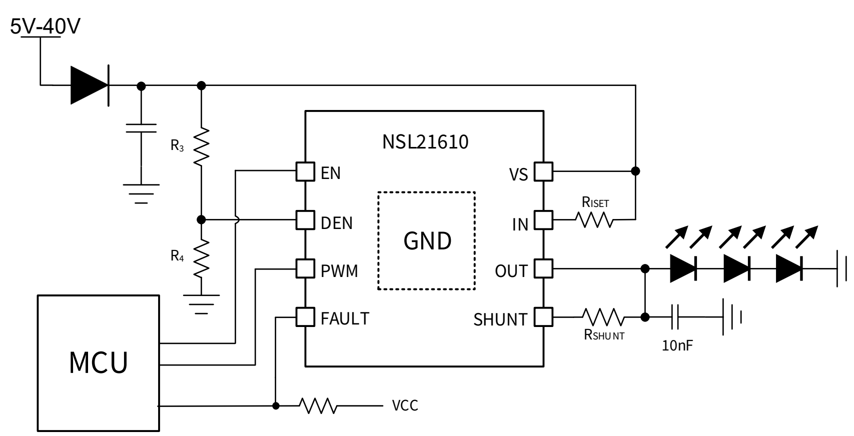
$$R_1=(\frac{V_{Dropout}+V_{ISET}+V_{OUT}}{V_{Logic\_H}}-1)\times R_2 \quad (10)$$

Where $V_{Dropout}$ = 200mV(typical), V_{ISET} = 99mV, V_{Logic_H} = 1.258V(maximum), R_2=10kΩ(recommended).

According to Equation 10, R_1 is 37.68kΩ when the minimum voltage of OUT is 5.7V.

8.1.2. Application with MCU

The NSL21610/1 devices support dimming control by PWM input single which giving by external MCU. The PWM input pin should be connected to MCU out pin to achieve more complex application.



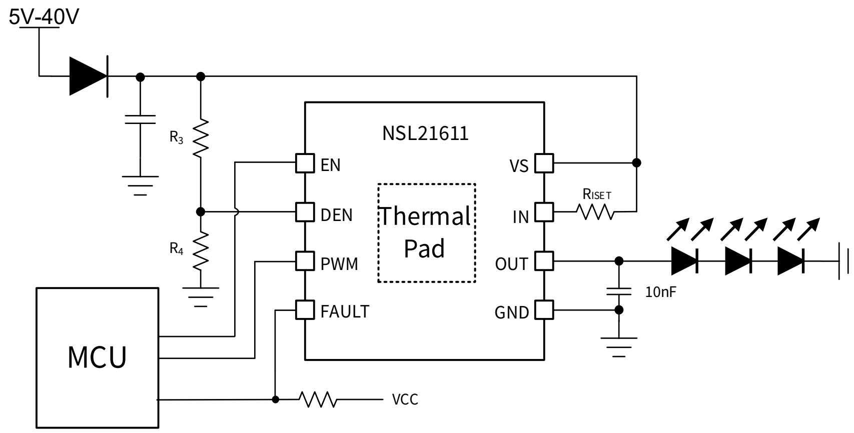


Figure 8.2 Application with MCU

8.1.2.1. Design Information

The voltage supply for VS is from 9V to 16V, and the dimming method is through PWM pin. A string with 3 LEDs is drived by a NSL21610 device. The LED forward voltage drop is between 1.9V(V_{LED_min}) to 2.5V(V_{LED_max}). The current flow of LED is 50mA. External MCU is adopted to give PWM control signal for PWM dimming control as shown in Figure 8.2.

8.1.2.2. Design Procedure

Step 1: calculate R_{ISET} using the equation below

$$R_{ISET}=\frac{V_{ISET}}{I_{LED}} \tag{11}$$

Where V_{ISETX}=99mV, I_{LED}=50mA.

Due to the required output current for each LED, R_{ISET} =1.96Ω.

Step 2: Calculate the current of I_{OUT} and I_{SHUNT}, and the shunt resistor R_{SHUNX} can be obtained by using Equation 12. The shunt resistor directly decides the current distribution for I_{OUT} path and I_{SHUNT} path. In typical supply voltage application, the current shunt resistor is suggested to consume 50% of the total output current.

$$R_{SHUNT}=\frac{V_{VS}-V_{OUT}}{I_{OUT}\times 0.5} \tag{12}$$

Where V_{VS}=12V(typical), I_{LED}=50mA.

The value of shunt resistor is calculated as 216Ω, when the output voltage is selected as 2.2×3=6.6V.

Step 3: This step is same as Step 3 in 8.1.1.2, please refer to it.

9. Layout

9.1. Layout Guidelines

The thermal dissipation must be considered for NSL21610/1 layout.

1: Thermal dissipation area in both top and bottom layers of PCB should be as larger as possible. The thermal pad in the bottom of the device must be reliable welding, and copper pouring in opposite PCB layer or inner layers must be connected to thermal pad directly through multiple thermal vias.

2: The shunt resistors should far away from the device with more than 2cm distance. The large copper pouring area is also required surrounding the R_{SHUNT} resistors for helping thermal dissipating. Other heat source components should be placed away from the device and shunt resistor.

3: NSL21610 EP pad are IC GND pad, and NSL21611 EP pad are thermal pad. In order to ensure the device good GND connection and heat dissipation on the PCB board. We recommend that the PCB stencil thickness is 0.15mm, The EP pads adopted fully opening window to ensure good welding.

Another consideration for the PCB layout is noise immunity.

1: Place decoupling capacitors for VS and out pins as close as possible to the pins.

2: If possible, the GND pin should be connected the housing(metal) with shortest track.

3: The long signal trace is not recommended in the PCB.

4: If possible, the device should be away from high power device with high frequency.

9.2. Layout Example

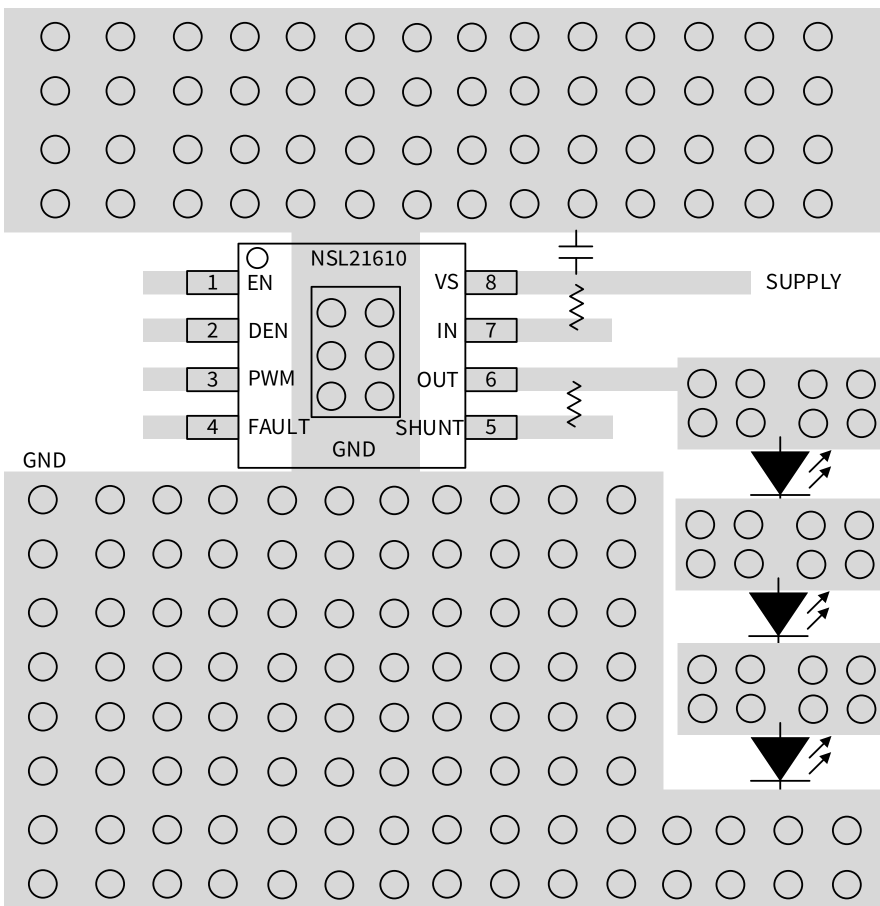


Figure 9.1 Example Layout Diagram for NSL21610

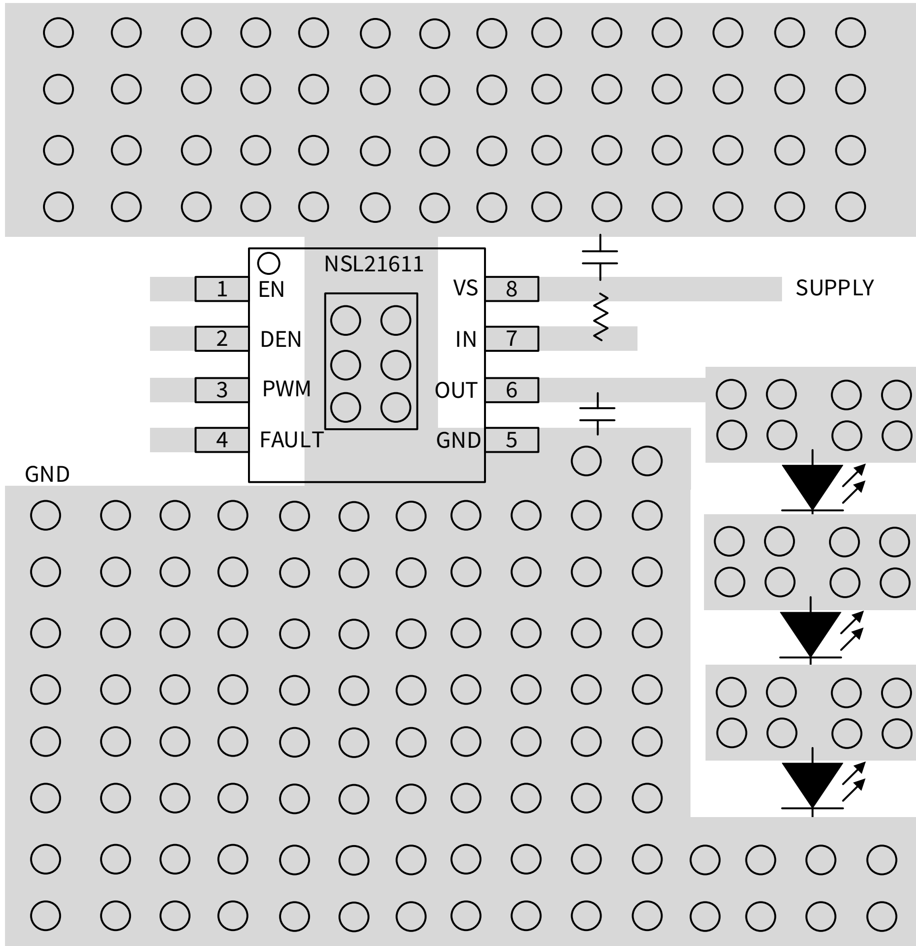


Figure 9.2 Example Layout Diagram for NSL21611

9.3. Recommended Footprint

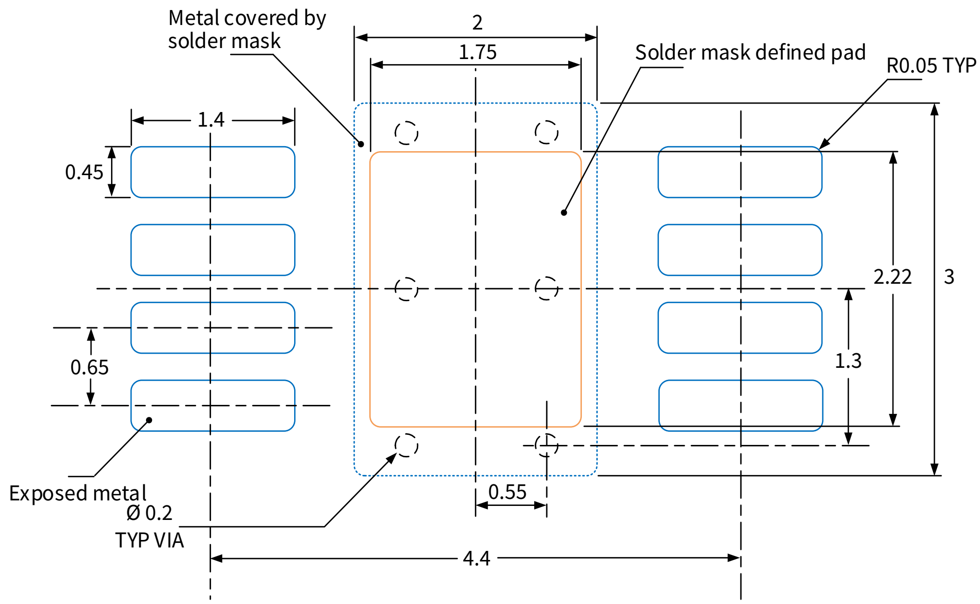


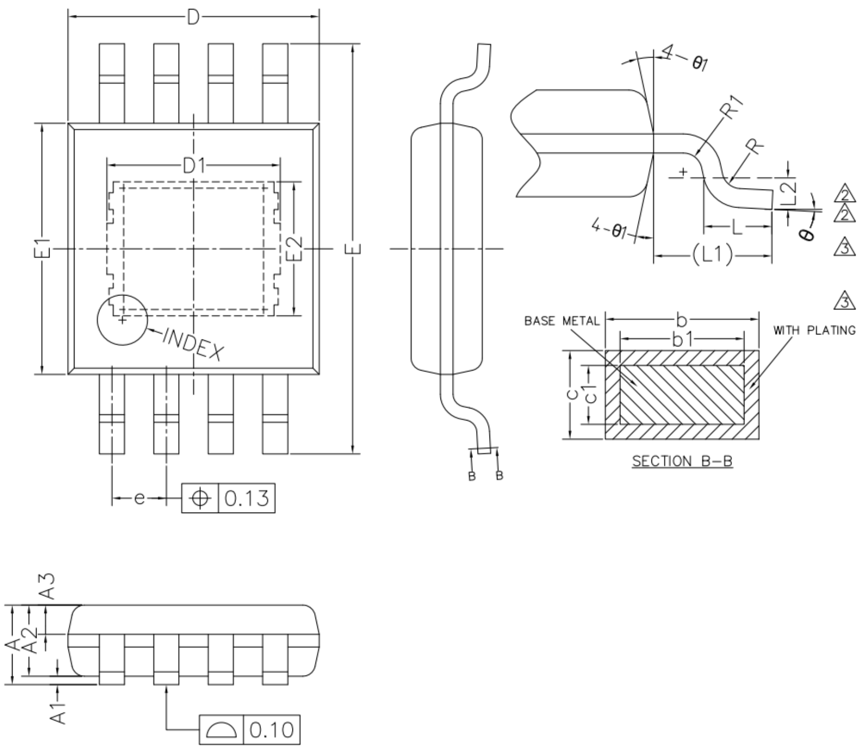
Figure 9.3. Recommended Land Pattern

Notes:

1. Above recommended footprint is based on 0.15mm thick stencil.
2. All dimensions are in millimeters.
3. Drawing is not to scale.

10. Package Information

10.1. HMSOP-8



COMMON DIMENSIONS
(UNITS OF MEASURE=MILLIMETER)

SYMBOL	MIN	NOM	MAX
A	–	–	1.10
A1	0.05	0.10	0.15
A2	0.75	0.85	0.95
A3	0.30	0.35	0.40
b	0.25	–	0.38
b1	0.24	0.30	0.33
c	0.13	–	0.20
c1	0.13	0.15	0.16
D	2.90	3.00	3.10
D1	1.92	2.07	2.22
E	4.75	4.90	5.05
E1	2.90	3.00	3.10
E2	1.45	1.60	1.75
e	0.55	0.65	0.75
L	0.40	0.55	0.70
L1	0.95REF		
L2	0.25BSC		
R	0.07	–	–
R1	0.07	–	–
θ	0°	–	8°
θ1	9°	12°	15°

Figure 10.1 HMSOP-8 Package Shape and Dimension in millimeters

11. Order Information

Part Number	*Output Channel*	*Output Current*	*Thermal Pad*	*Thermal Balance*	*EN*	*MSL*	*MPQ*
NSL21610-Q1HMSR	1	450mA(MAX)	GND	Yes	Yes	3	2500ea/reel
NSL21611-Q1HMSR	1	300mA(MAX)	Suggest connect to GND	No	Yes	3	2500ea/reel
NSL21630-Q1HTPR	3	200mA/per channel(MAX)	Suggest connect to GND	Yes	No	3	4000ea/reel
NSL21631-Q1HTPR	3	200mA/per channel(MAX)	GND	Yes	Yes	3	4000ea/reel

12. Documentation Support

Part Number	*Datasheet*	*Technical Documents*
NSL21630/1-Q1HTPR	Click here	/
NSL21610/1-Q1HMSR	Click here	/

13. Tape and Reel Information

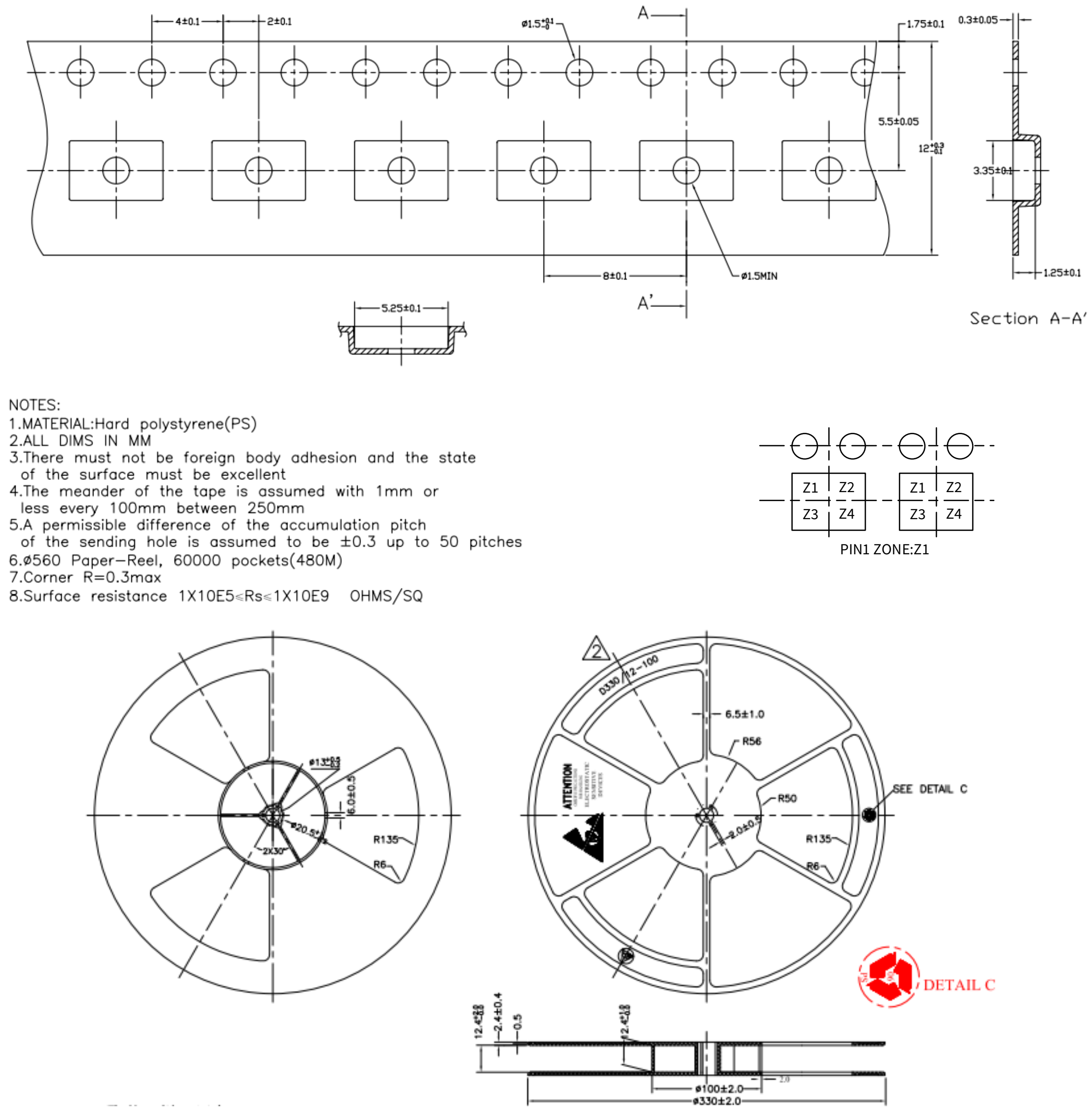


Figure 13.1 Tape and Reel Information

Note: 2500ea/reel.

14. Revision history

Revision	Description	Date
1.0	Change from Advance Information to Production Data	2022/08

IMPORTANT NOTICE

For further information on applications, products and technologies, please contact NOVOSENSE (www.novosns.com).

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