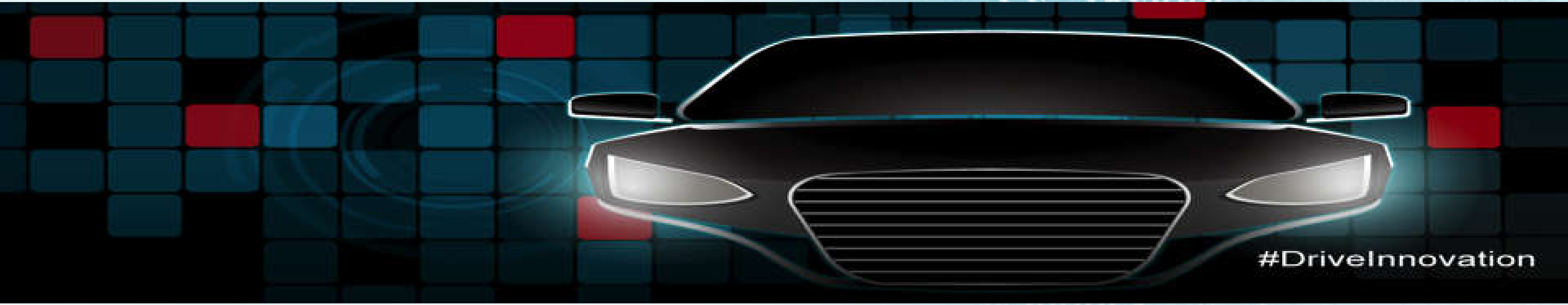
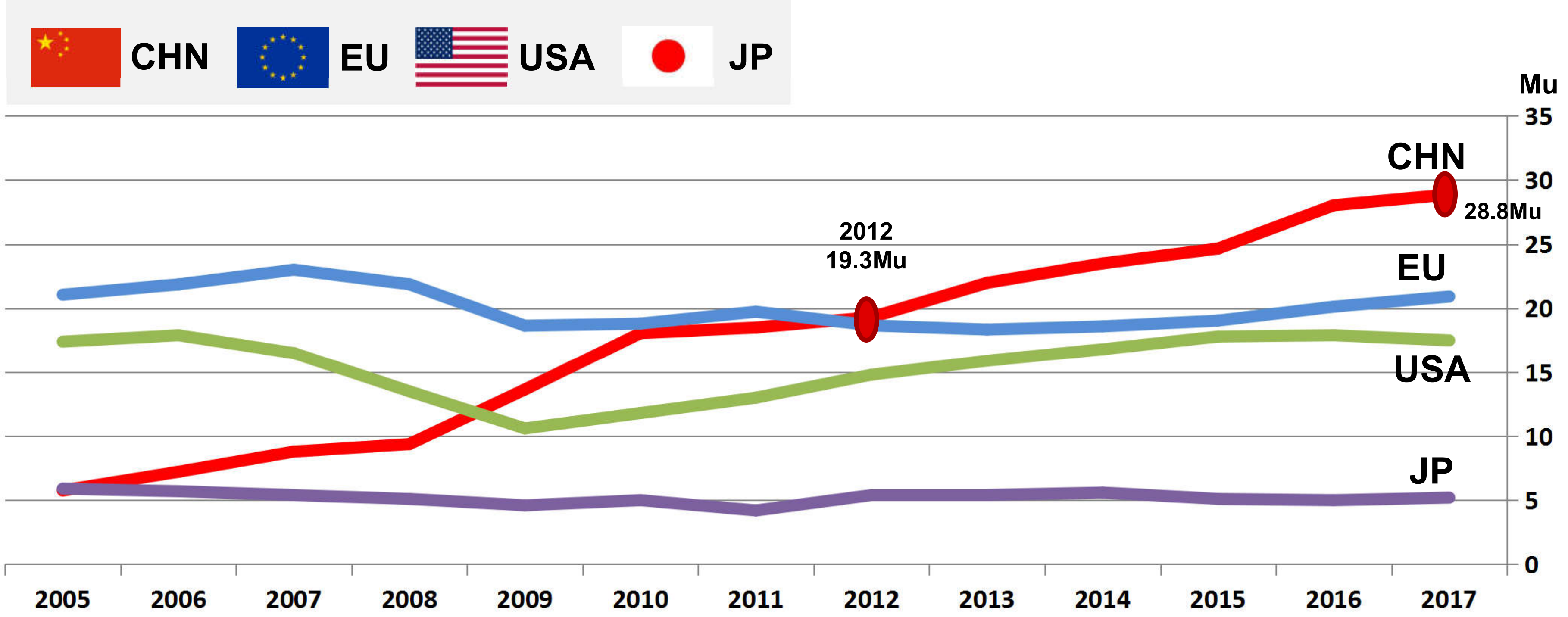
Accelerate Automotive Growth



Zhicheng Yao

Sep, 2018

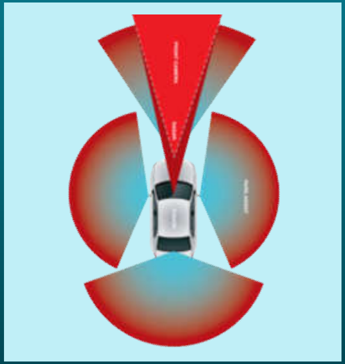
WW Automotive Market



- ❑ China automotive achieves 12.6% 10Yr CAGR from 2007 to 2017
- ❑ China automotive shipment becomes WW No. 1 in 2012

TI Innovation Focuses on Four Application Sectors

Advanced driver assistance systems



Adaptive cruise control
Night vision
Blindspot detection
Lane departure warning

Safer driving environment

Infotainment & cluster

Entertainment system
Head-up display
Navigation system
eCall

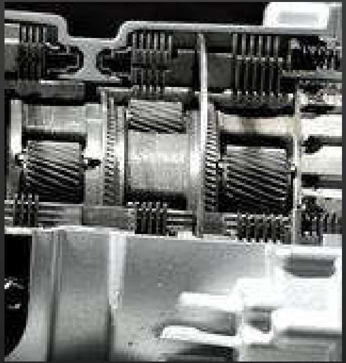
Connected driving experience

Body electronics & lighting

Security system
Seat position control
Remote keyless entry
Lighting

Differentiation in lighting and body electronics

Hybrid/electric and powertrain systems



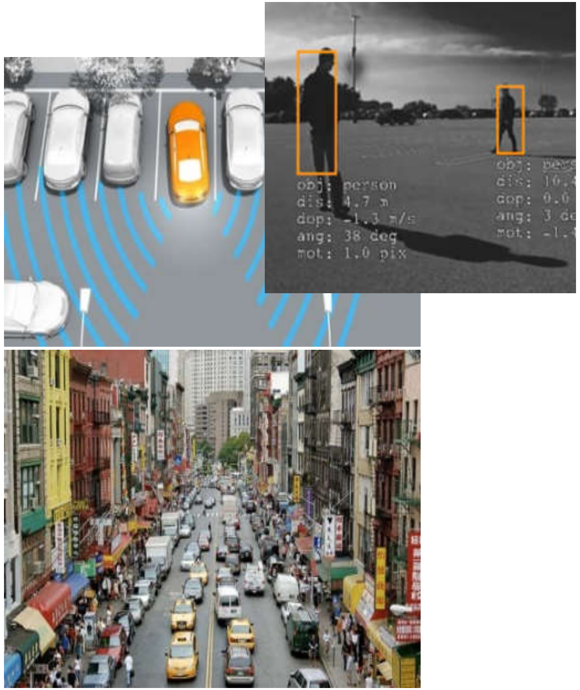
Automatic start/stop
Battery management
Electric power steering
Engine and transmission control

Electrification of vehicles

and more…

Fun & Safe in Infotainment & ADAS

Infotainment
Touch display, Navigation, Media Hub



Head-Up Display
DLP solution, high visual angle

Second Display
Remote Display, Premium Audio, Touch Pad

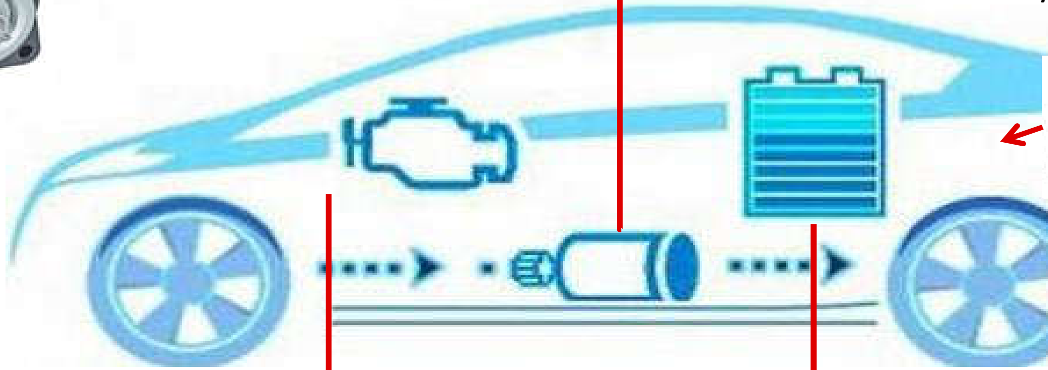
ADAS Radar
LRR, MRR, SRR , Pedestrian Detection
Parking, BSD, LCA, LKA, etc

3D TOF
3D TOF, Gesture Controlled Dashboard

Green Transportation in HEV/EV

Traction Motor

Functional Safety, ASIL C/D



On Board Charge

Analog & EP solution

Bi-Directional DCDC

400V-12V, 48V-12V DC/DC

HV BMS

HV/LV BMS, ASIL C/D BMS

TI’s Innovative Automotive Lighting Solution

DLP Headlight Chipset
Glare-free Adaptive High Beam

Dynamic LED driver
Adaptive High Beam / Low Beam

Switching LED Driver
Daytime Running Light
High Beam / Low Beam
Fog Light

Linear LED Driver
Stop / Tail Light
Turn Light
Reverse Light

Multi-channel LED Driver
Cluster Tell-Tale
Dashboard Backlight

Automotive LED Lighting Application

Successful Story in Lamp

Expand to More Automotive LED EEs









Signal Lighting – Safety Relevant

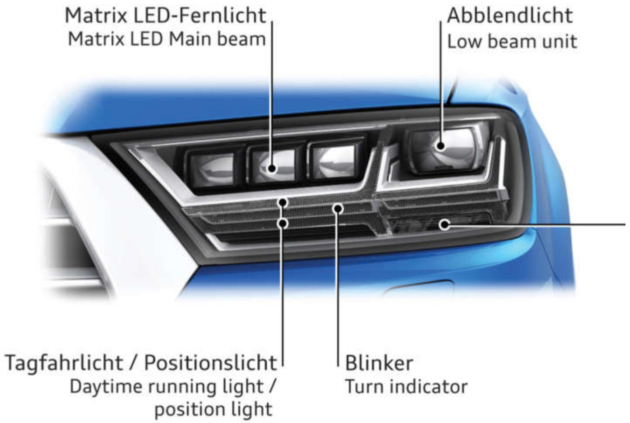
- LED Drivers needed per car
  - Turn Indicators (8 pcs), RCL Lamp (8pcs), License plate(1pc)
  - CHMSL(2pcs), Side Marker(2 pcs), Mirror Indicator(2pcs)
  - EV/HEV Charger Indicator(1pc)
- Key Care-abouts
  - Diagnostics of LED open/short failure with low fault current
  - Single LED Short Diagnostics is key competitive feature.
  - Mid current range 70 – 200mA per string

Convenience Lighting – Cost Driven

- LED Drivers needed per car
  - Door handler(4 pcs), Welcome (2pcs), Emblem (1pc)
  - Dome (2pcs), Rearseat Overhead(2 pcs)
  - Glove box(1pc), Sunshade (2pcs)
- Key Care-abouts
  - Low cost
  - Current accuracy for homogeneity

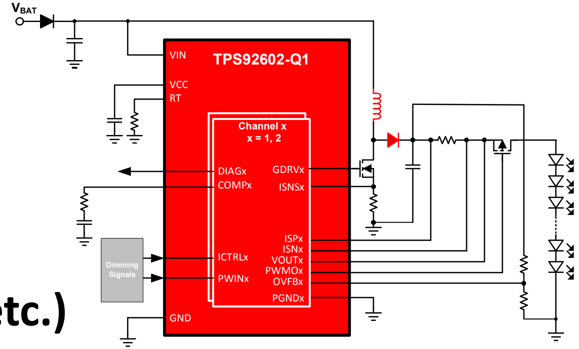
Exterior LED Application

- Front
  - Lowbeam & Highbeam
  - DRL
  - Turn Indicator
  - Front Fog
- Rear
  - Stop
  - Tail
  - Turn Indicator
  - Front Fog
  - Reverse/Back up
- Misc: mirror, side marker, etc.

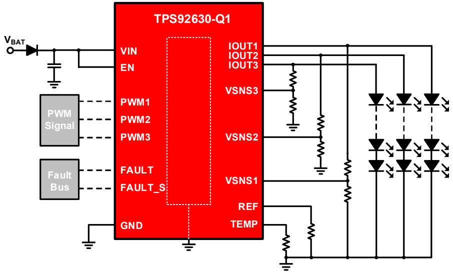


LED Driving Topology

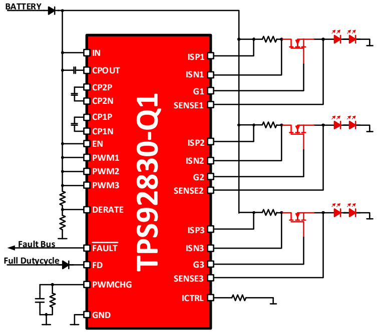
DC/DC
(Buck, Boost,
Buck/Boost,
Sepic, Flyback, etc.)



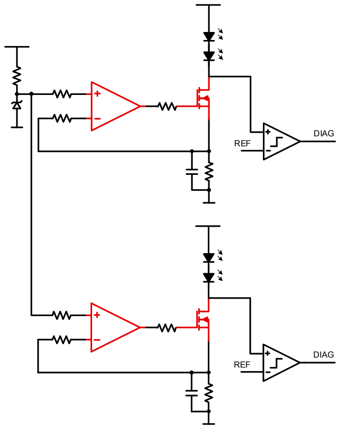
Linear
Integrated



Linear
Controller

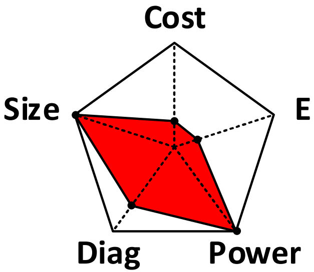


Discrete

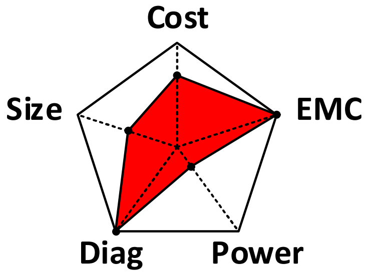


Existing Design Challenge

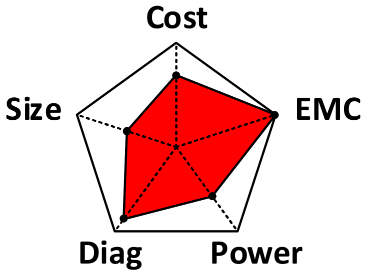
- Cost
- EMC/EMI
- High Power / Thermal
- Diagnostics
- Size



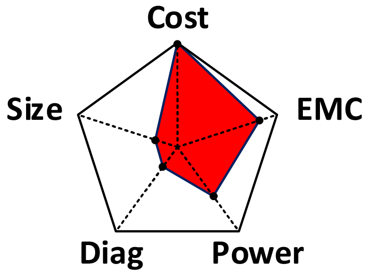
DC/DC



Linear
Integrated

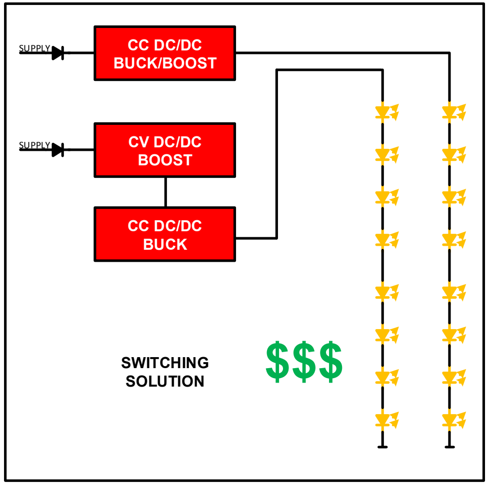


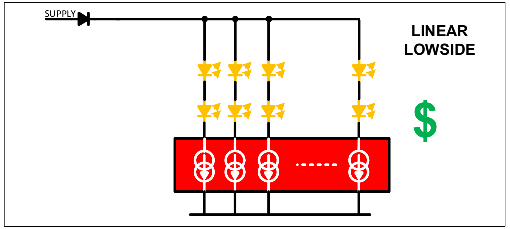
Linear
Controller

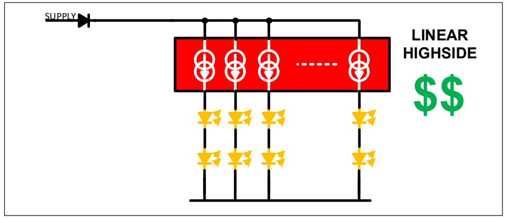


Discrete

Homogeneity



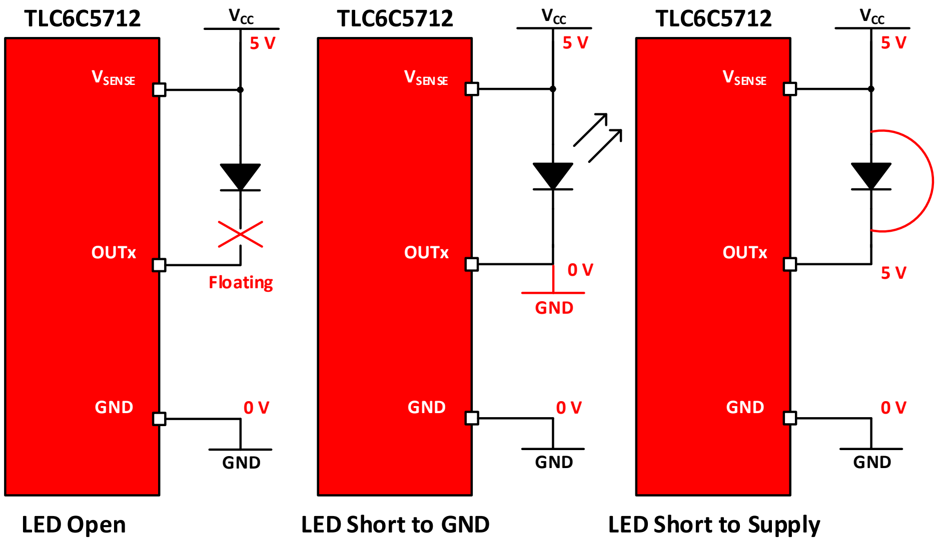


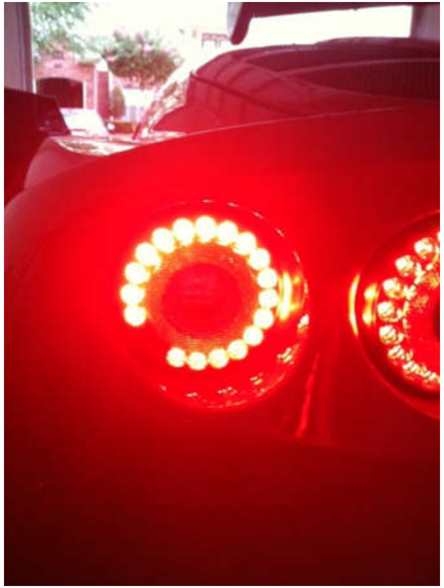


- LED-LED varies on forward voltage, color temperature and brightness, etc.
- Common solution is
  1. Use pre-selected LEDs, (Binned LED)
  2. Adjust output current per batch requirement
  3. Serial LEDs to avoid current source variation.

$$$

Diagnostics – LED Failure Modes



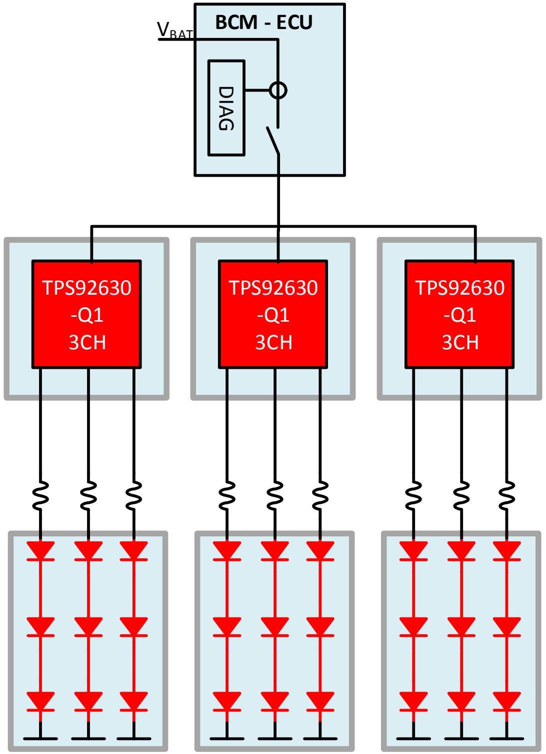


- Common LED faults includes LED **Open**, LED **Short**, LED Short to GND, LED Short to Supply

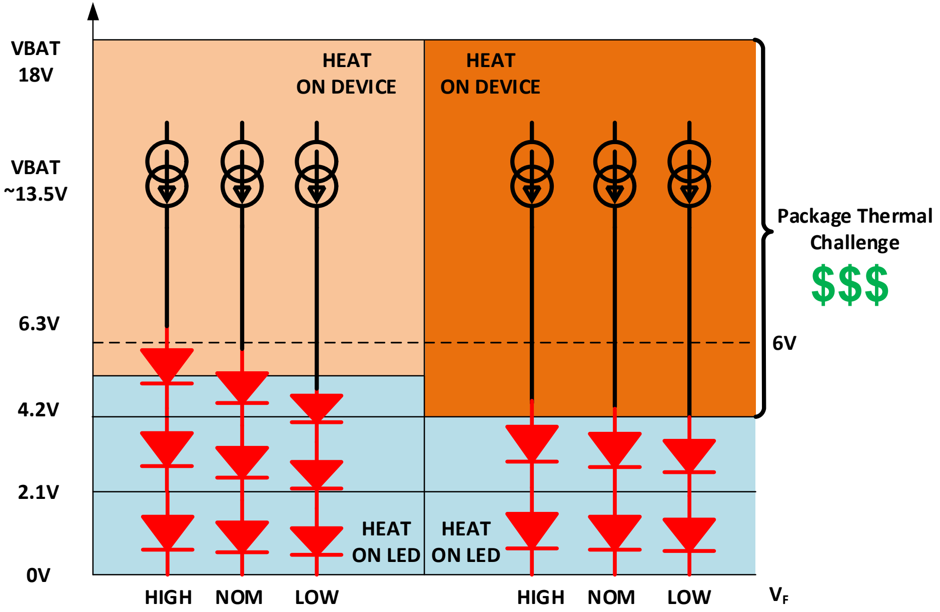
Detect & Distinguish

BCM Diagnostics – 1 wire for EACH function

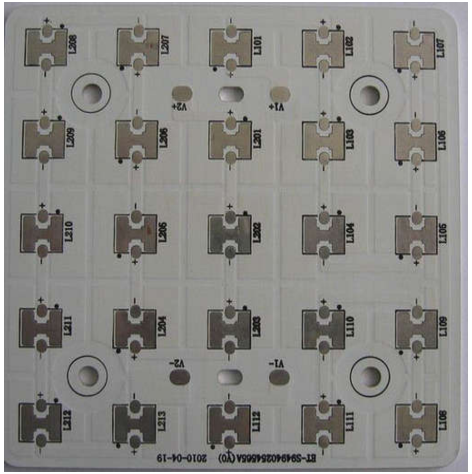
- Highside driver current sense in BCM
- Commonly supports both Bulb and LED.
- Due to low accuracy of existing BCM highside driver current sensing, some European OEM requires LED driver:
  - Consume **more** than 50mA when fully functional
  - Consume **less** than 10mA when fault is detected and turn off all LEDs for this function **(One-Fail-All-Fail)**



Thermal – it's all about cost



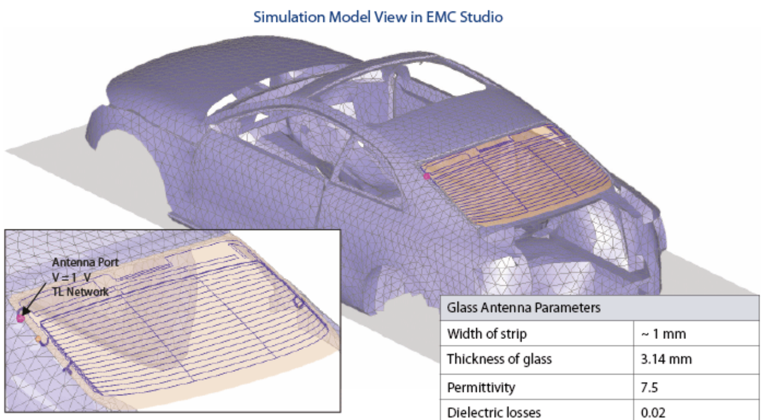
Aluminum Based PCB $$$



- Moving to 6V crank condition will increase system level power dissipation by at least 50%. $$$
- Only selected rear light function(e.g. turn indicator in VW) requires warm cranking at this moment. Some low cost customer in Japan even puts 4 LEDs in a string.

EMC

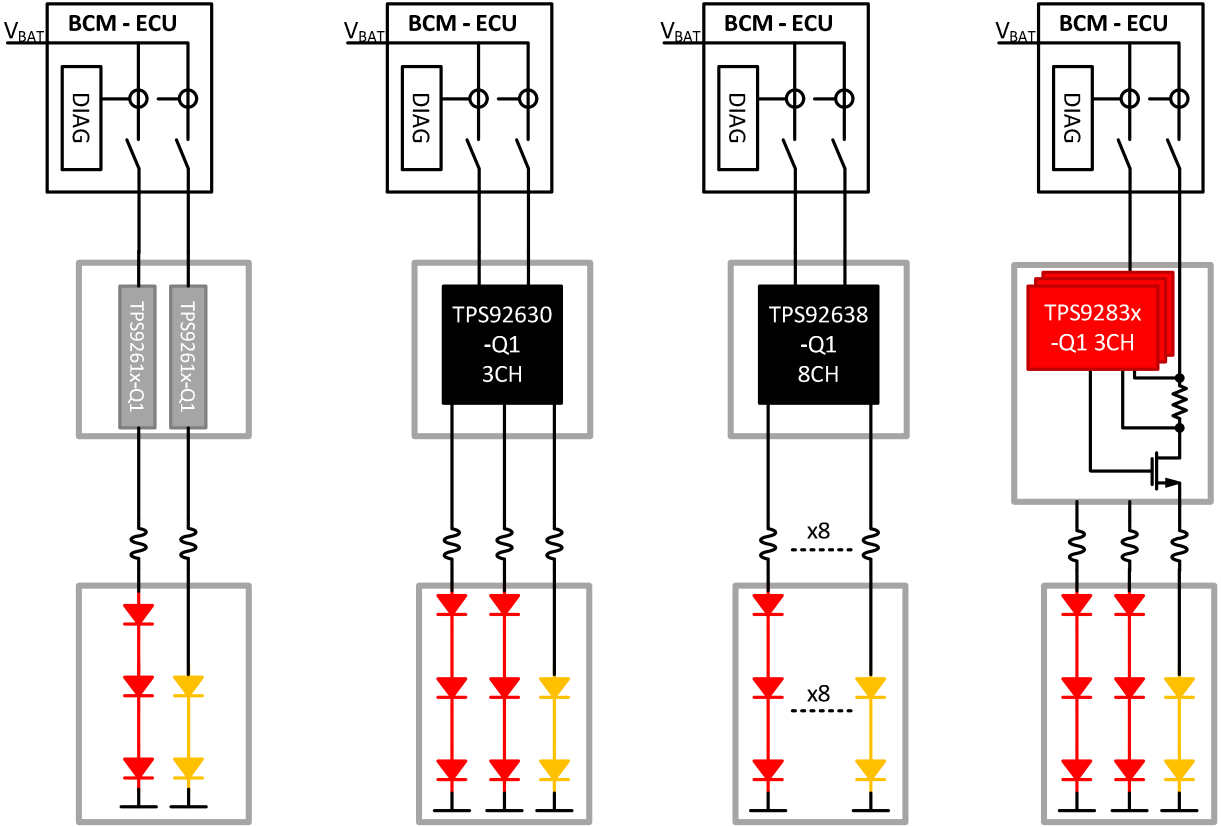
- Traditional rear light makers' only electrical component is Bulb.
- EMC is a extremely difficult topic for most rear light customers.



Glass Antenna Parameters	
Width of strip	~ 1 mm
Thickness of glass	3.14 mm
Permittivity	7.5
Dielectric losses	0.02
Real Ground Parameters	
Permittivity	13
Conductivity, [S/m]	5e-3

- Many cars use rear window defogger as antenna
- Other cars placed closed to trunk/roof
- Most OEMs have stringent requirement of EMC for rear light

Linear LED Driver Topology



Automotive LED Driver Demo

Rear Combination Lamp

Full LED Cluster

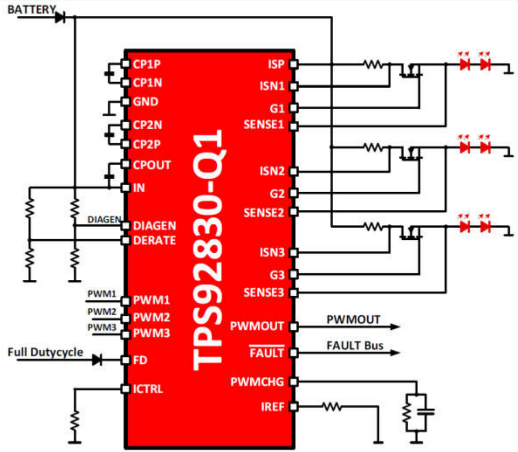
TPS92830-Q1

Features

- AEC-Q100 Qualified for Automotive Applications
- Wide voltage input range from **5 - 40V**
- **3-CH high side current driving and sensing**
  - Channel independent current setting
  - Channel independent PWM inputs with 1000:1 dimming ratio
  - PWM dimming via either PWM inputs or power supply
  - Optimized slew rate for better EMC
- **High Precision LED Driving**
  - Precision current regulation with external **NMOS FET (Max. 3% tolerance)**
  - 20:1 analog dimming profile with off-board bin resistor support
  - Precision on-chip PWM Generator with Full Duty-Cycle mask **(Max. 2% tolerance)** & Open drain PWM output for synchronization
- **Protection and Diagnostics**
  - **Output Current Derating** with adjustable input voltage threshold for external MOSFET thermal protection
  - **Diagnostics** for LED string Open Circuit or Short Circuit with auto recovery
  - **Diagnostics Enable with adjustable threshold** for low voltage operation
  - **Fault bus** up to 15 devices, configurable as either **One-Fail-All-Fail** or only failed-channel off
  - **Low quiescent current** in fault mode (<2mA per device)
- TSSOP 28 Package (PW)
- Operating Junction Temperature Range: -40 C to +150 C

Benefits

- Complete high side architecture supports off-board LED driving and LED bin capability
- Linear LED driving for easy EMI/EMC design
- High precision local PWM generation saves external components
- Built-in diagnostics and protection for automotive lighting
- Multiple devices standalone operation with One-Fail-All-Fail



Applications

- Rear Light – Tail/Stop Light, Fog Light, Reverse Light, Turn Indicator
- Front Light – Position Light, Daytime Running Light, Fog Light, Turn Indicator

Key Parameter Overview

Output Channel	3	
VIN Operating Voltage	5 ~ 40	V
Current Regulation Accuracy	3	%
On-chip PWM Generator Accuracy	2	%

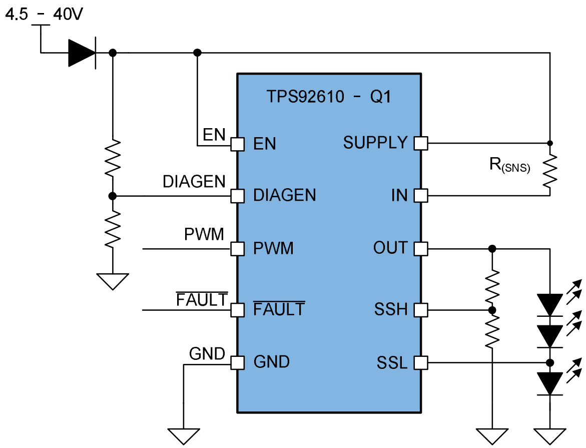
TPS92610-Q1

Features

- AEC-Q100 Qualified for Automotive Applications
- Wide voltage input range from 4.5 - 40V
- **Single channel high side current driving and sensing**
  - Constant Current output up to 450mA
  - Analog current setting via external resistor
  - Output Current expansion via external NPN or resistors
  - PWM dimming by PWM input or SUPPLY
  - Optimized slew rate for better EMC
  - Max Dropout Voltage (-40 ~ 125 C) 700mV @ 150mA
- **High Precision LED Driving**
  - Current accuracy <4.5% (-40 ~ 125C)
  - 100mV Reference Resistor Headroom
- **Protection and Diagnostics**
  - **Single LED Short detection**
  - **LED Open detection with low dropout mode**
  - **LED Short detection and protection**
  - **Fault bus** and **One-Fails-All-Fail**
  - **Auto Retry** from any failures
  - Thermal Shutdown protection
- HTSSOP-14 package (52.4C/W)
- Operating Junction Temperature Range: -40 C to +150 C

Benefits

- Full Diagnostics and Protection with Auto Retry to meet Automotive Safety requirements
- Single LED Short Detection to meet Car OEMs most advanced requests when using LED string
- Complete high side architecture supports off-board LED driving and LED bin capability
- Current Expansion with NPN and resistors helps to achieve low cost high current solution



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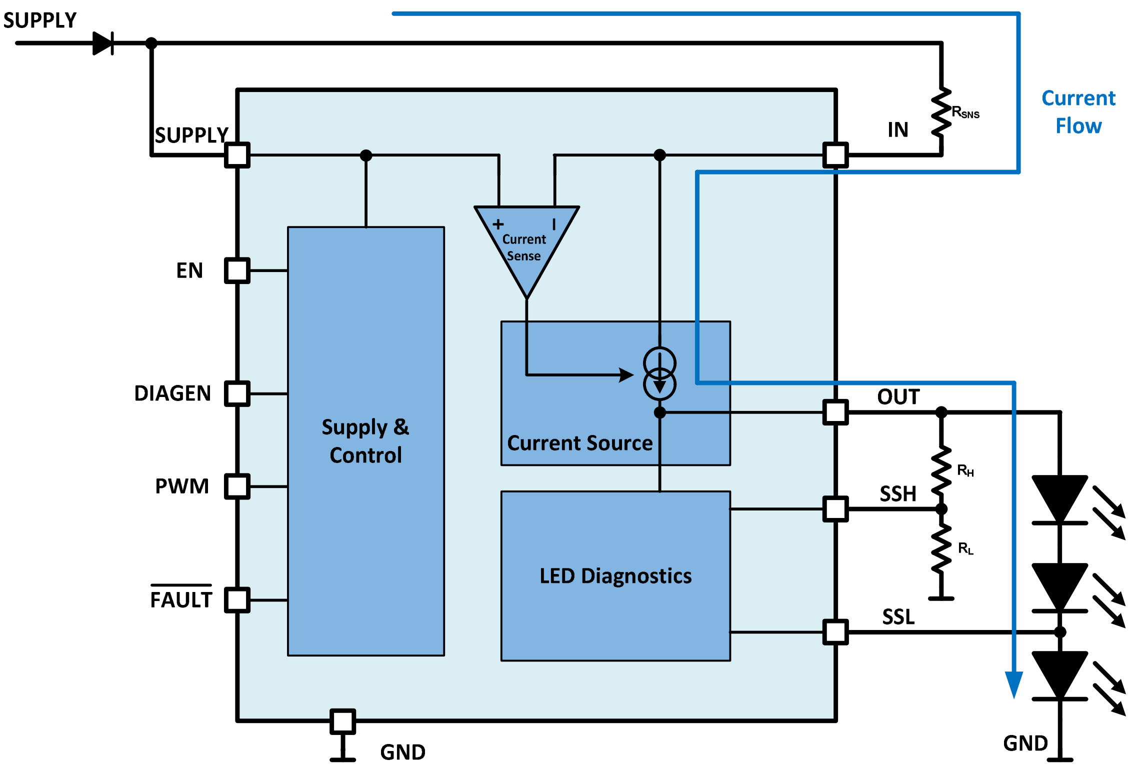
Applications

- Rear Light – Tail/Stop Light, Turn Light, Fog Light, Reverse Light
- Interior Light – Dome Lamp, Glove Box Lamp
- Side Marker, Mirror Indicator, EV Charger Indicator

Key Parameter Overview

Output Channel	1	
VIN Operating Voltage	4.5 ~ 40	V
Per Channel Max. Output Current	450	mA
Output Current Accuracy	4.5	%

TPS9261x-Q1 Functional Block Diagram



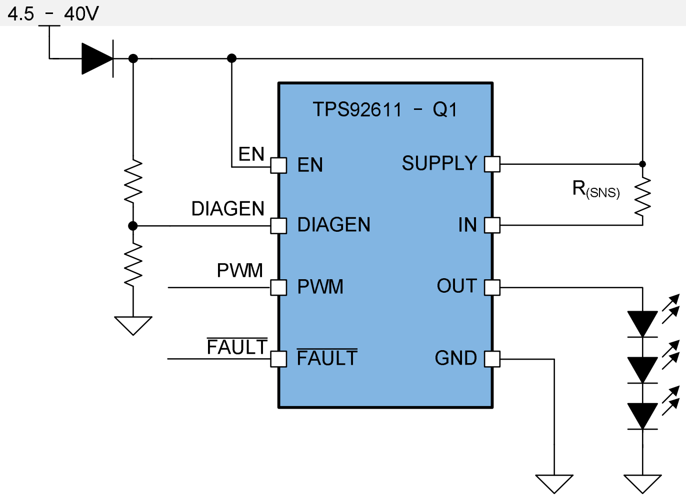
TPS92611-Q1

Features

- AEC-Q100 Qualified for Automotive Applications
- Wide voltage input range from 4.5 - 40V
- **Single channel high side current driving and sensing**
  - Constant Current output up to 300mA
  - Analog current setting via external resistor
  - Output Current expansion via external NPN or resistors
  - PWM dimming by PWM input or SUPPLY
  - Optimized slew rate for better EMC
  - Max Dropout Voltage (-40 ~ 125 C) 400mV @ 70mA
- **High Precision LED Driving**
  - Current accuracy <4.5% (-40 ~ 125C)
  - 100mV Reference Resistor Headroom
- **Protection and Diagnostics**
  - **LED Open detection with low dropout mode**
  - **LED Short detection and protection**
  - **Fault bus** and **One-Fails-All-Fail**
  - **Auto Retry** from any failures
  - Thermal Shutdown protection
- MSOP-8 package (60.0 C/W)
- Operating Junction Temperature Range: -40 C to +150 C

Benefits

- Full Diagnostics and Protection with Auto Retry to meet Automotive Safety requirements
- Complete high side architecture supports off-board LED driving and LED bin capability
- Current Expansion with NPN and resistors helps to achieve low cost high current solution



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Applications

- Rear Light – Tail/Stop Light, Turn Light, Fog Light, Reverse Light
- Interior Light – Dome Lamp, Glove Box Lamp
- Side Marker, Mirror Indicator, EV Charger Indicator

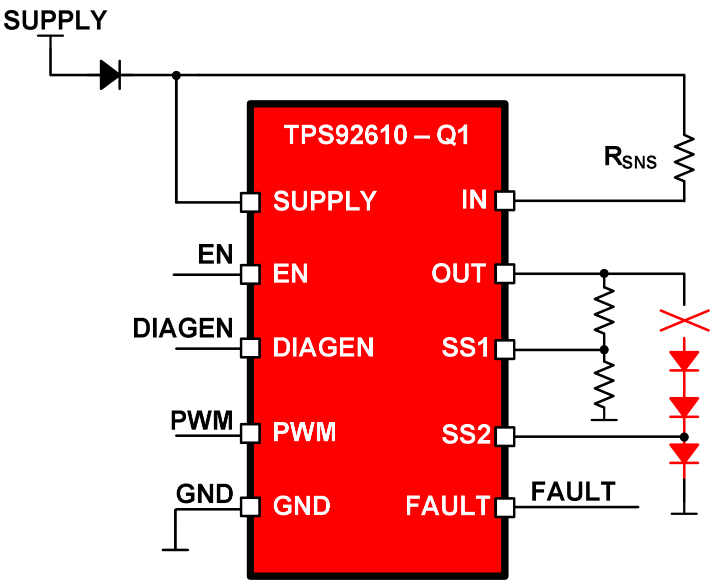
Key Parameter Overview

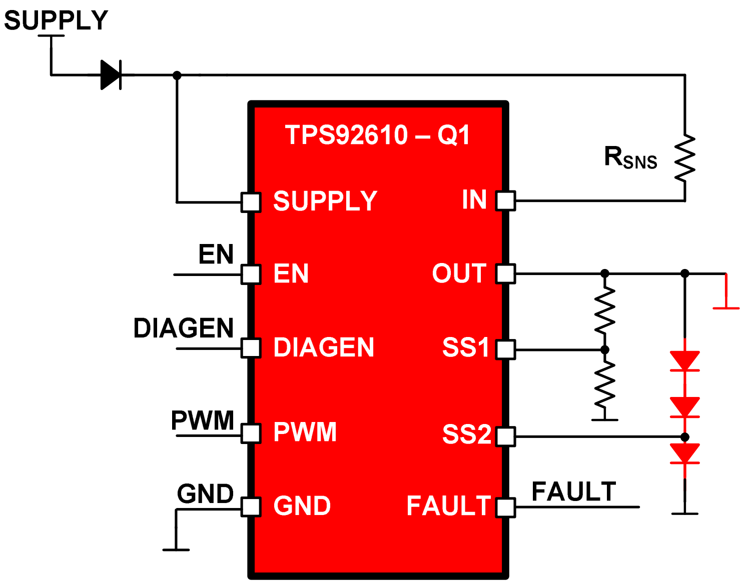
Output Channel	1	
VIN Operating Voltage	4.5 ~ 40	V
Per Channel Max. Output Current	300	mA
Output Current Accuracy	4.5	%

Value Proposition

Feature	Benefits
Low cost	Save customers' cost with device family
Support Current Extension by Bipolar or Resistors	Save customers' solution cost
Thermal Protection	Protect from thermal breakdown, saves cost of extra package for reliability
PWM Dimming	Integrated PWM dimming and saves discrete cost
LED Diagnostics (Open/Short Detection, Single LED Detection, One-Fails-All-Fail)	Fulfill diagnostics requirement without additional cost

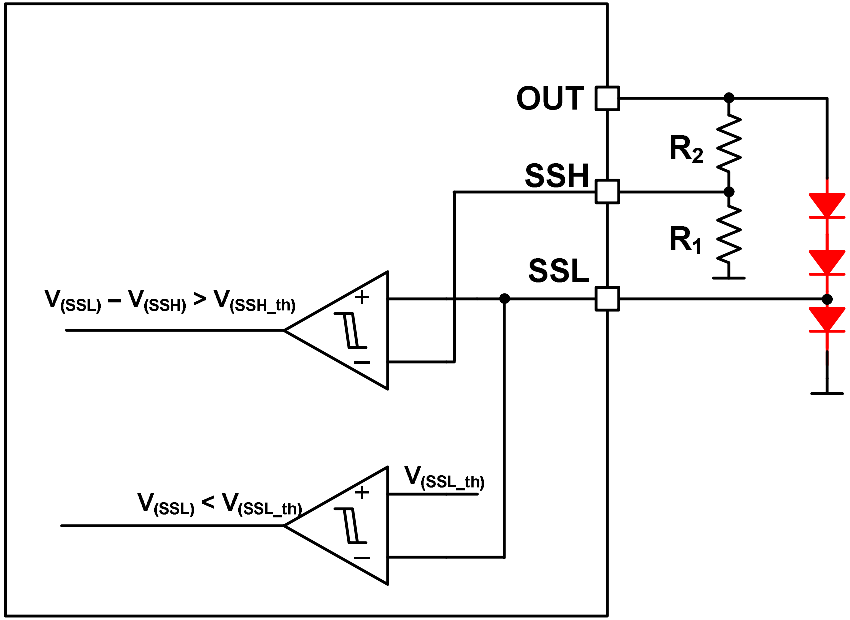
Protected LED Failure Mode





- Full Diagnostic and FAULT pin reports Open, Short to GND and Thermal Shutdown
- Auto Recovery after removing Fault condition (no overshoot current upon recovery from Open)

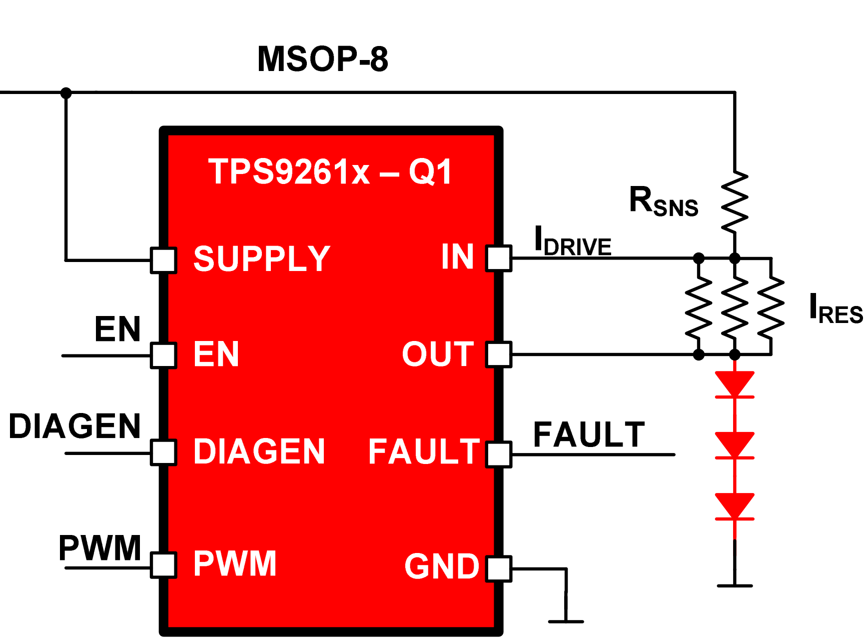
Single LED Short Detection



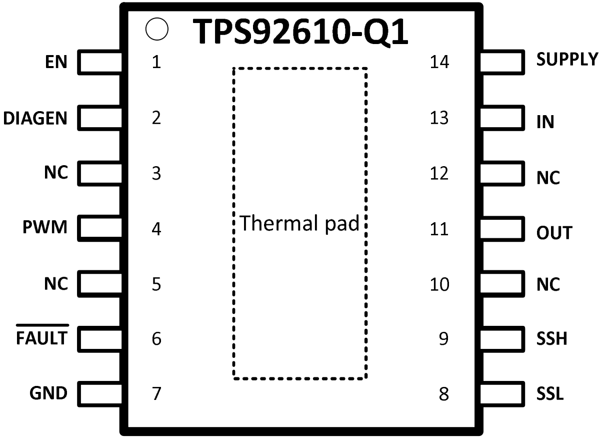
- Use Bottom LED Forward Voltage as reference
- At least 5 LEDs per string, also good for DC/DC + Linear hybrid topology
- Auto-retry and one-fail-all-fail fault bus

Current Expansion with External Resistors

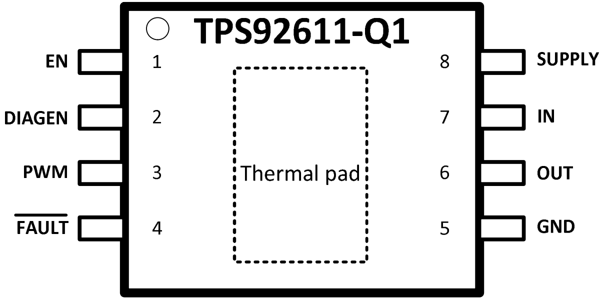
- Total current is set by R_{SNS}
- I_{RES} varies with SUPPLY voltage
- I_{TOTAL} achieves ~2x of I_{DRIVE}
- Supported by all TPS9261x-Q1
- With LED Open Fault Detection



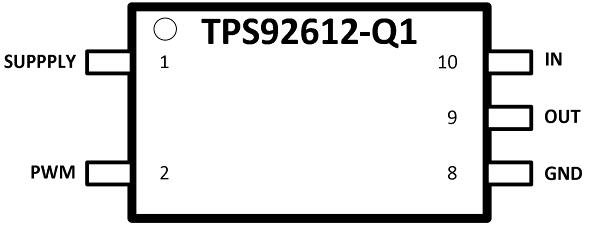
TPS9261x-Q1 Package and Pin Assignment



HTSSOP-14
Size 6.4*5*1.2
Pitch: 0.65



MSOP-8
Size :4.9*3*1.1
Pitch: 0.65



Size :2.9*2.8*1.45
Pitch: 0.95

Thanks!

大联大控股
A Member of WPG Holdings
世 平 集 团
World Peace Industrial Group

车用照明(大灯与矩阵灯电源)功能叙述与应用

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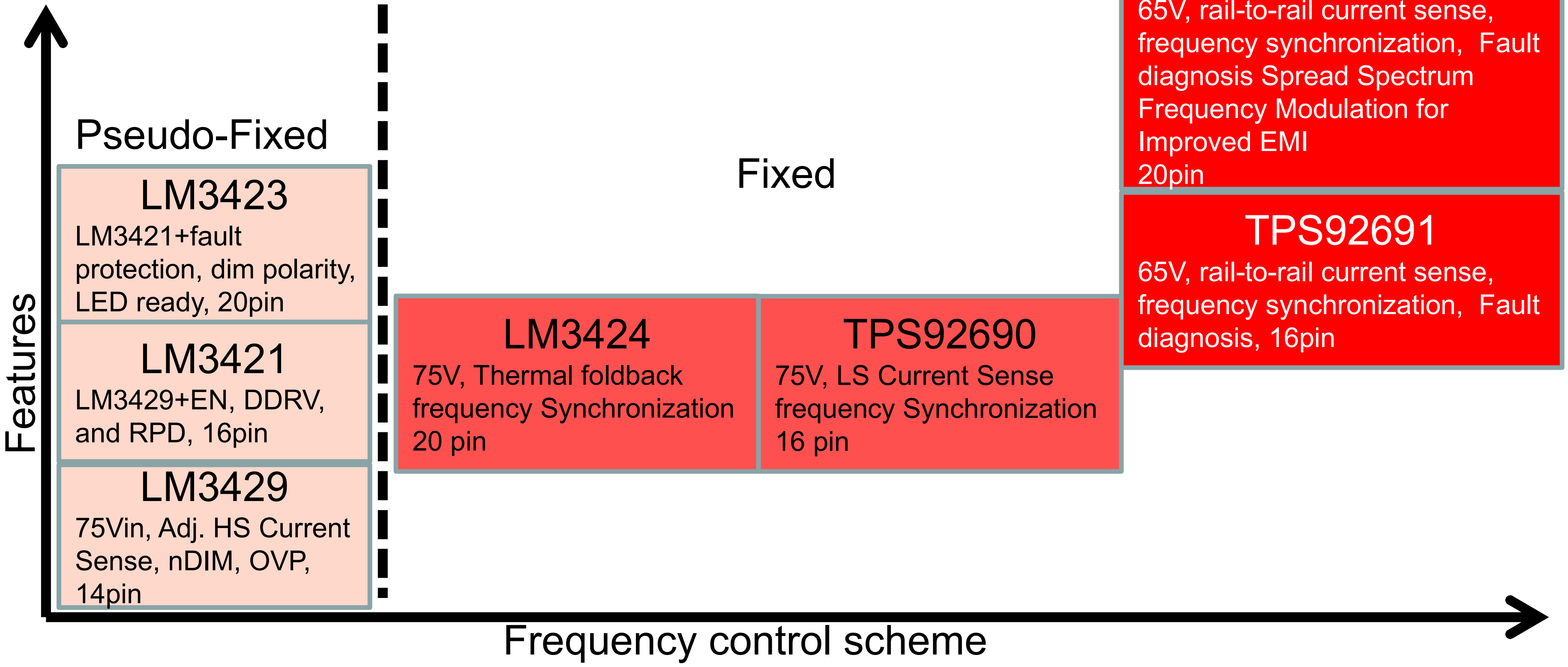
Agenda

- TI N-Ch MOSFET Controller for LED Lighting Family
- TPS92691 Overview
- How To Design SPEIC
- EMI & Layout Placement
- LED Matrix Manager
- Customer Collateral

TI N-Channel MOSFET Controller for LED Lighting Portfolio



TPS92691 Multi-Topology LED Driver with Rail-to-Rail Current Sense Amplifier

Features (特征)

- Input Voltage Range: 4.5 V to 65 V multi-topology configurable
- Rail-to-rail current sense amplifier (Product Folder: TPS92691)
- Better than +/-3% LED Current Accuracy
- Analog and PWM Dimming
- Switching Frequency Adjustable 80K~700KHz and up to 1MHz with Sync option
- Continuous LED status monitoring output
- VCC UVLO, Over-Current, and Over-Temperature Protection
- Packages: HTTSOP-16, AEC-Q100 Grade 1

Applications (应用)

- Appliances
- LED lighting applications requiring Current Monitoring
- LED lighting applications requiring high currents or large LED

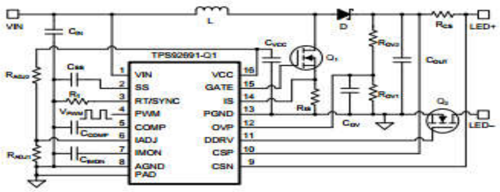
Tools & Resources (工具与资源)

- **EVMs:**
  - TPS92691 SEPIC LED Driver Evaluation Board
  - TPS92691-Q1 Boost and Boost-to-Battery LED Driver Evaluation Board

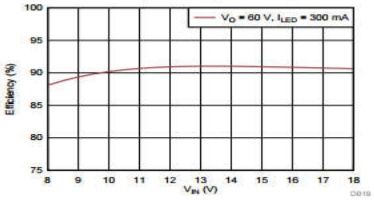
Benefits (效益)

- Supports Boost, Buck, Buck-boost, Cuk, Flyback and SEPIC topologies
- Supports output voltage from 2V to 65V and either high-side or low-side current sense
- Linear input range from 140mV to 2.2V for analog dimming and over 1,000:1 series FET PWM dimming
- Optimize for Efficiency, Size, or LED Ripple Current
- System Fault detection and diagnoses
- Protects Against Faults and Abnormal Operating Conditions

Typical Boost LED Driver Application Schematic

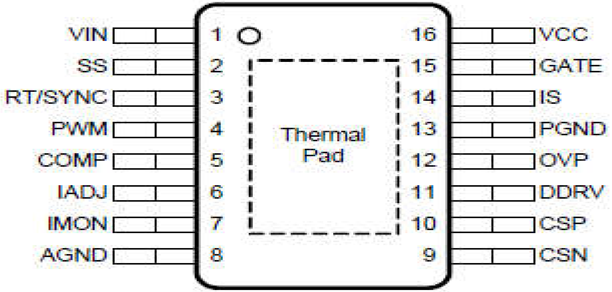


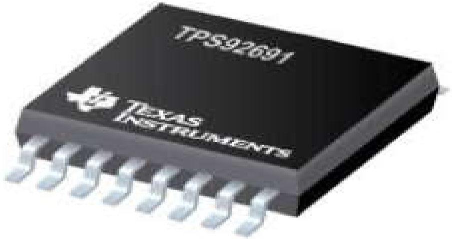
Efficiency vs Output Voltage



HTTSOP-16

TPS92691/-Q1 Pin Description

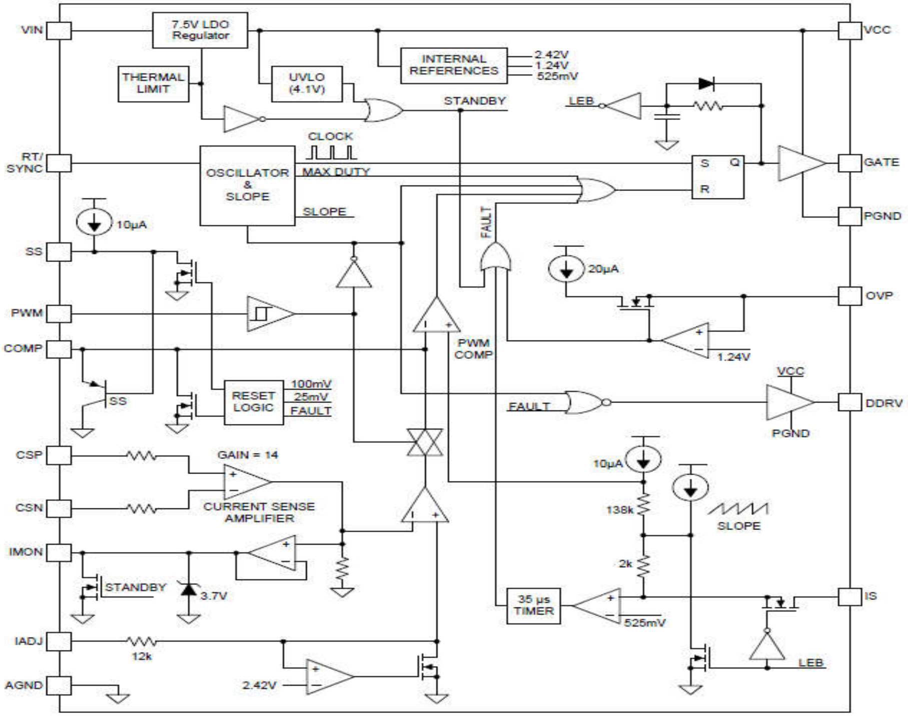




HTSSOP 16
(PWP16)

	NAME	DESCRIPTION
1	VIN	Input supply for the internal VCC regulator. Bypass with 100-nF capacitor to GND located close to the controller.
2	SS	Soft-start programming pin. Connect a capacitor to AGND to extend the start-up time. Switching can be disabled by shorting the pin to GND.
3	RT/SYNC	Oscillator frequency programming pin. Connect a resistor to AGND to set the switching frequency. The internal oscillator can be synchronized by coupling an external clock pulse through 100-nF series capacitor.
4	PWM	PWM dimming input. Driving the pin below 2.3 V (typ), turns off switching, idles the oscillator, disconnects the COMP pin, and sets DDRV output to ground. The input signal duty cycle controls the average LED current through PWM dimming operation. Connect to VCC when not used for PWM dimming.
5	COMP	Transconductance error amplifier output. Connect compensation network to achieve desired closed-loop response.
6	IADJ	LED current reference input. Connecting pin to VCC with 100-kΩ series resistor sets internal reference voltage to 2.42 V and the current sense threshold, $V_{(CSP-CSN)}$ to 172 mV. The pin can be modulated by external voltage source from 0 V to 2.25 V to implement analog dimming.
7	IMON	LED current report pin. The LED current sensed by CSP/CSN input is reported as $V_{IMON} = 14 \times I_{LED} \times R_{CS}$. Bypass with a 1-nF ceramic capacitor to AGND.
8	AGND	Analog ground.
9	CSN	Current sense amplifier negative input (–). Connect directly to the negative node of LED current sense resistor (R_{CS}).
10	CSP	Current sense amplifier positive input (+). Connect directly to the positive node of LED current sense resistor (R_{CS}).
11	DDRV	Series dimming FET gate driver output. Connect to gate of external N-channel MOSFET or a level-shift circuit with P-channel MOSFET to implement series FET PWM dimming.
12	OVP	Hysteretic overvoltage protection input. Connect resistor divider from output voltage to set OVP threshold and hysteresis.
13	PGND	Power ground connection pin for internal N-channel MOSFET gate drivers.
14	IS	Switch current sense input. Connected to the switch current sense resistor, RIS, in the source of the N- channel MOSFET.
15	GATE	N-channel MOSFET gate driver output. Connect to gate of external switching N-channel MOSFET.
16	VCC	VCC bias supply pin. Locally decouple to PGND using a 2.2-μF to 4.7-μF ceramic capacitor located close to the controller.
PowerPAD		The AGND and PGND pin must be connected to the exposed PowerPAD for proper operation. This PowerPAD must be connected to PCB ground plane using multiple vias.

TPS92691/-Q1 Block Diagram



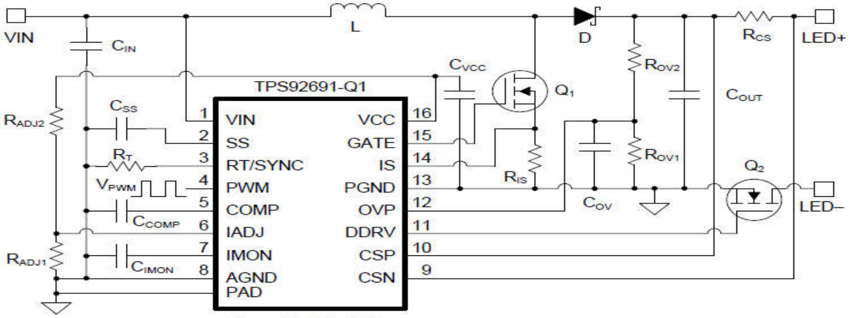
• Fixed Frequency Peak Current Mode Controller
–Rail-to-Rail current sense amplifier feedback
–Internal slope compensation
–Max duty cycle limit: 92%

• PWM Dimming
–Fast dimming transient response
–Integrated series N-ch FET driver for high contrast application
–Simple enable/disable operation for low contrast application

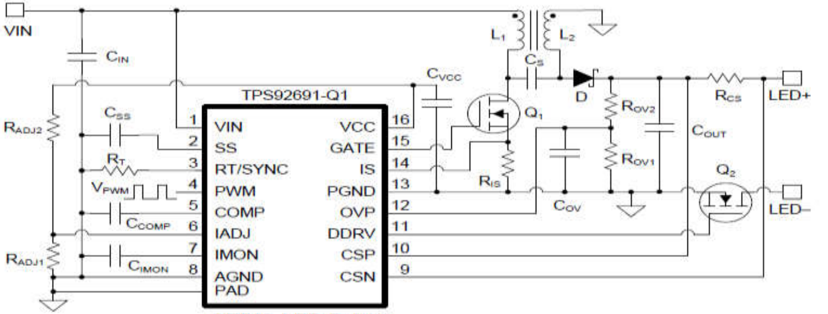
• Analog Adjust
–Fixed internal reference: 2.42V
–Linear range:140mV to 2.25V

•Current Reporting Output
•Comprehensive fault protection with default auto-restart mode of operation

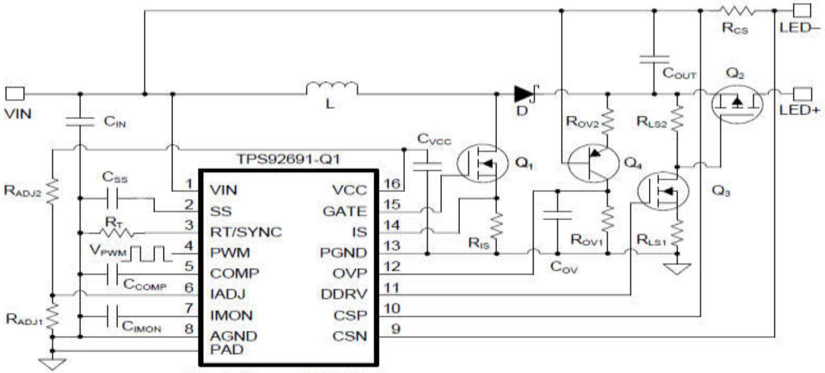
Topology



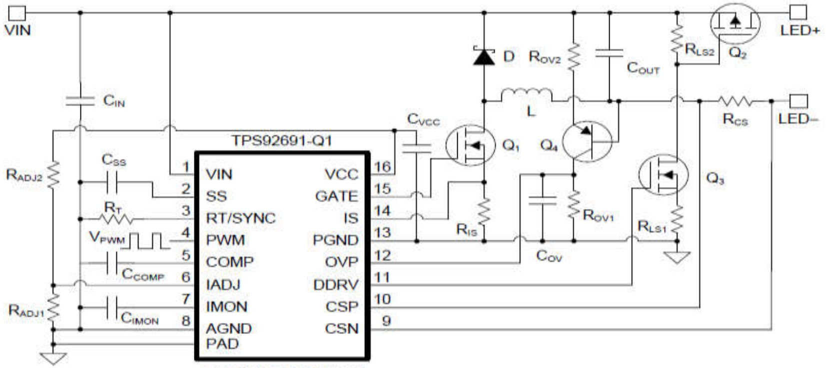
Boost LED Driver



SEPIC LED Driver



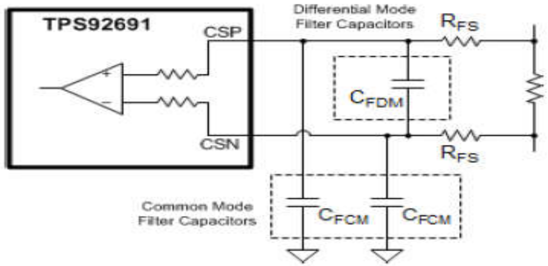
Buck-Boost LED Driver



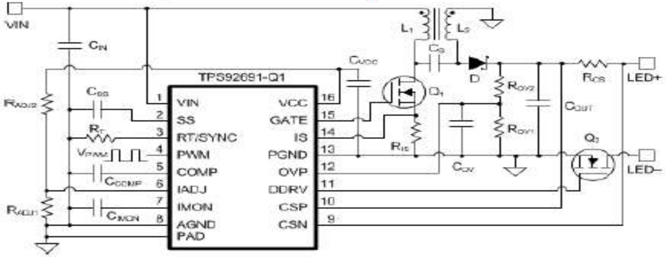
Buck LED Driver

Rail-to-rail Current Sense Amplifier

- **Common-mode range of CSP,CSN runs from 0 V to 65 V**

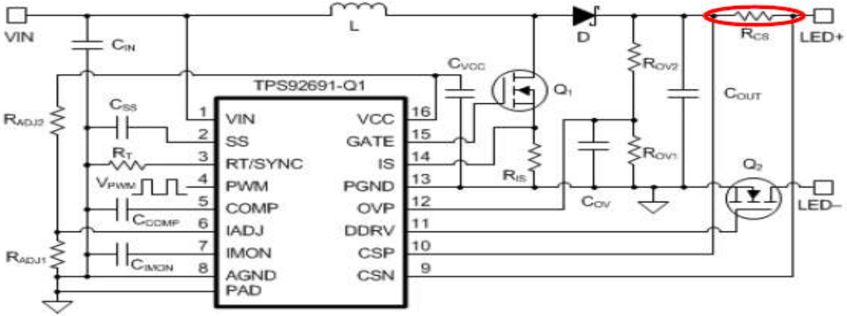


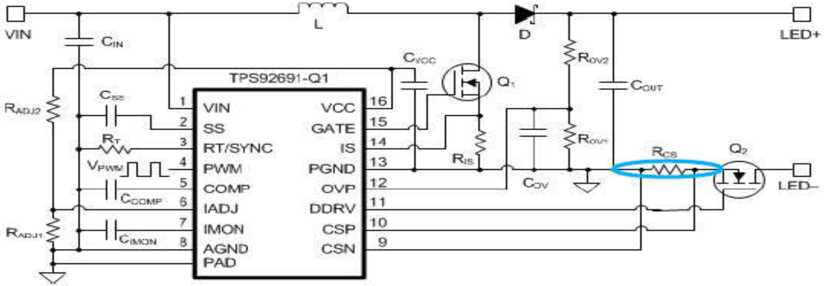
- **Provides accurate current regulation with single LED output**



- **E.g. SEPIC from VIN from 7 – 16 V, VLED = 2 V for Red LED**

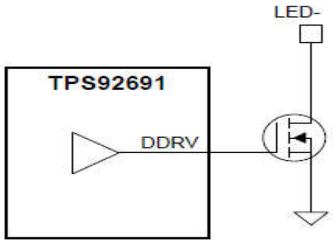
- **Flexibility on sensing resistor position: either high-side or low-side**

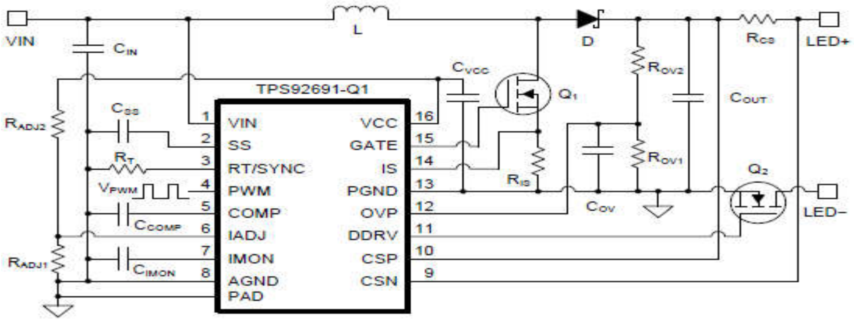


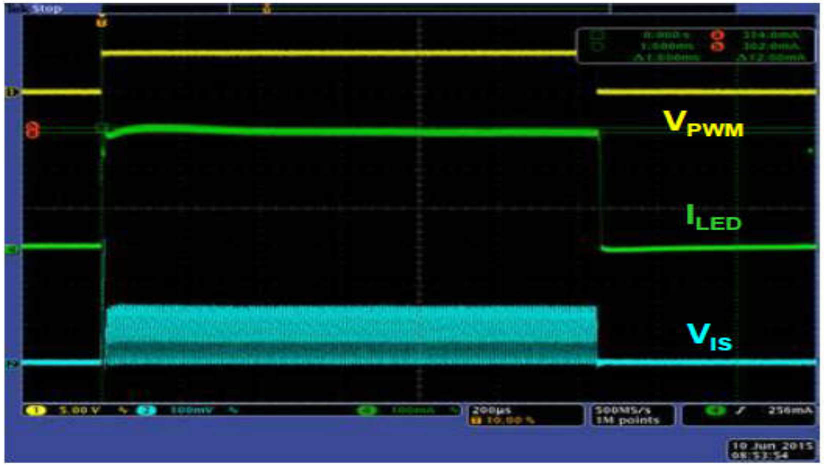


PWM Dimming Using Series N-MOSFET

- DDRV output designed to directly drive low-side N-ch MOSFET
- Linear and monotonic behavior with over 100:1 contrast ratio for dimming frequency up to 400 Hz
- Recommended for SEPIC, Cuk and Flyback LED driver topologies



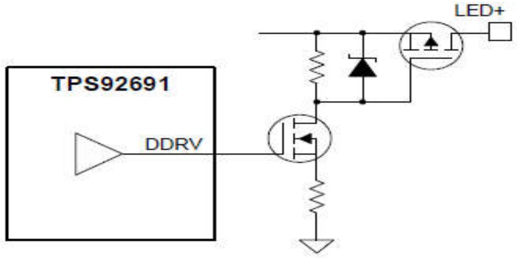


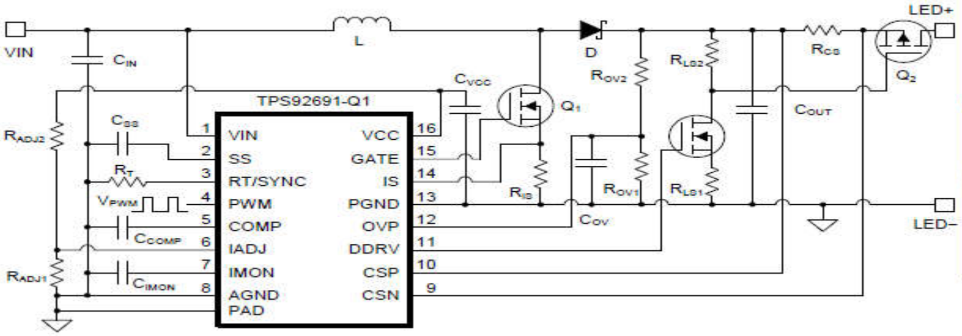


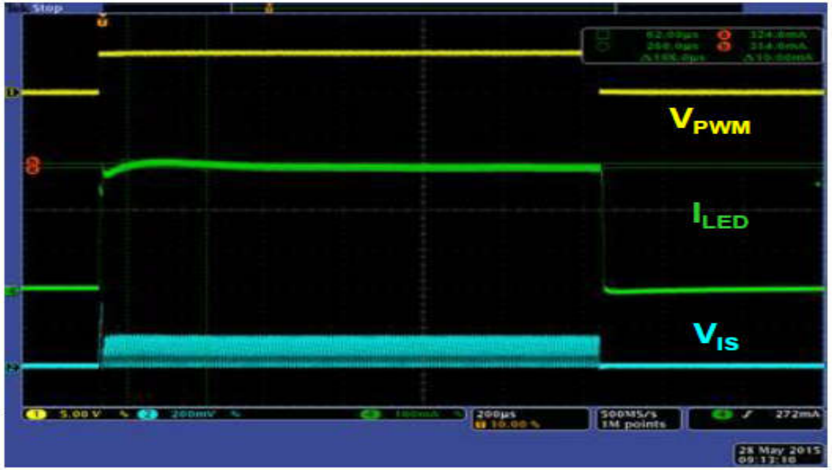
V_{IN} = 14V, 18 LEDs, V_{IADJ} = 420mV, R_{CS} = 0.1Ω, f_{PWM} = 400Hz

PWM Dimming Using Series P- MOSFET

- DDRV output with external level-shift circuit used to drive high-side P-ch MOSFET
- Linear and monotonic behavior with over 100:1 contrast ratio for dimming frequency up to 400 Hz
- Recommended for Boost, Buck-Boost and Buck LED driver topologies

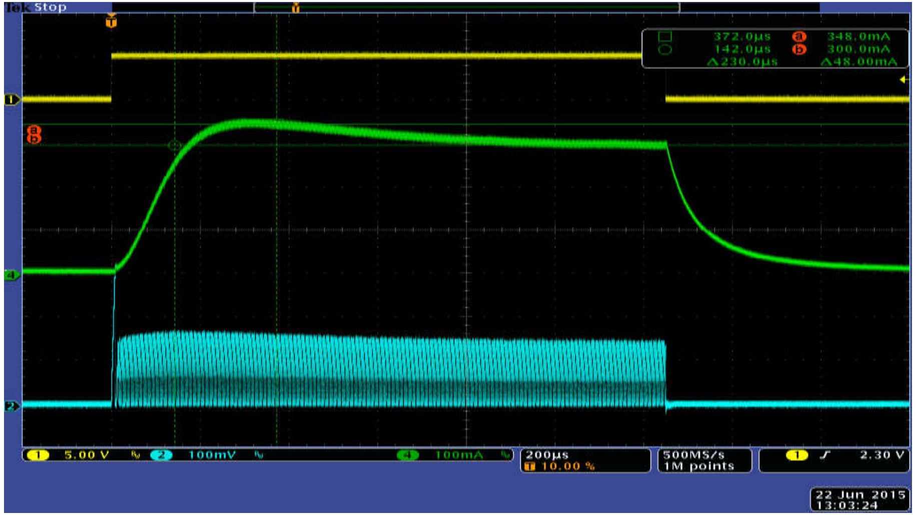






V_{IN} = 14V, 18 LEDs, V_{IADJ} = 420mV,
R_{CS} = 0.1Ω, f_{PWM} = 400Hz

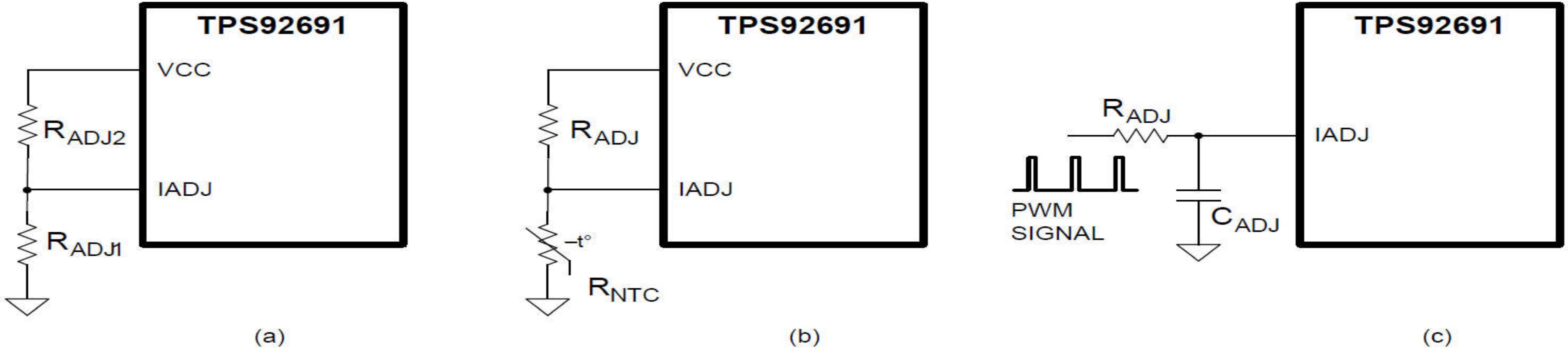
PWM Dimming: Enable/Disable Mode



VIN = 14V, 18 LEDs, VIADJ = 420mV, RCS = 0.1Ω, fPWM = 400Hz

- LED current controlled by PWM input
- –Dimming achieved by turning on and off switching operation (GATE drive)
- –No series FET required
- •Suitable for low contrast dimming application (10:1)
- •LED current response and overshoot controlled by tuning compensation network

Analog Adjust Input



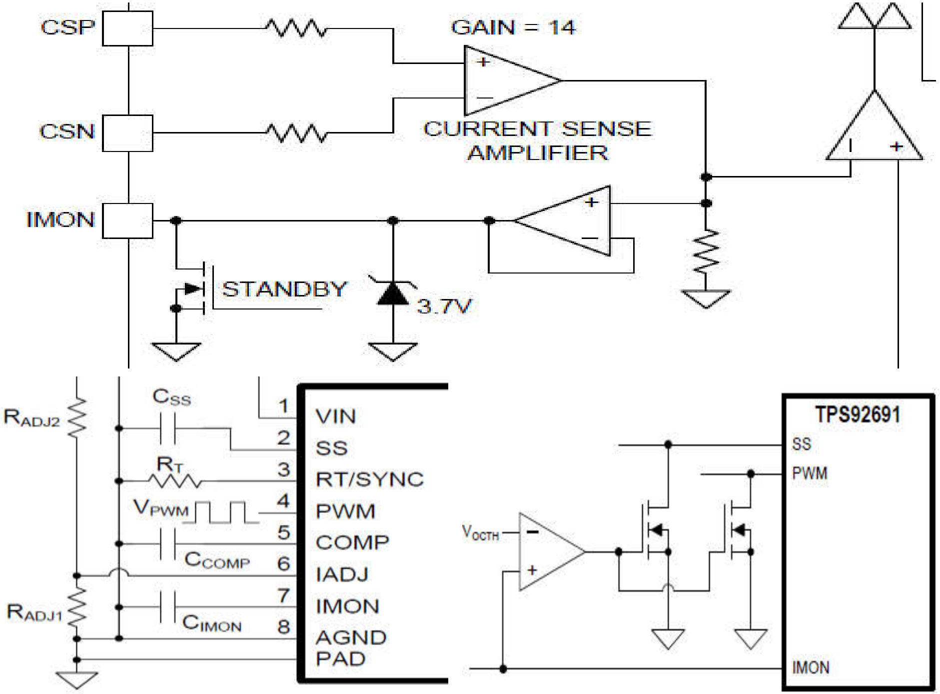
a. Static reference setting resistor divider from VCC
b. Thermal fold-back circuit using external NTC resistor
c. Analog dimming achieved by low-pass filtering external PWM signal

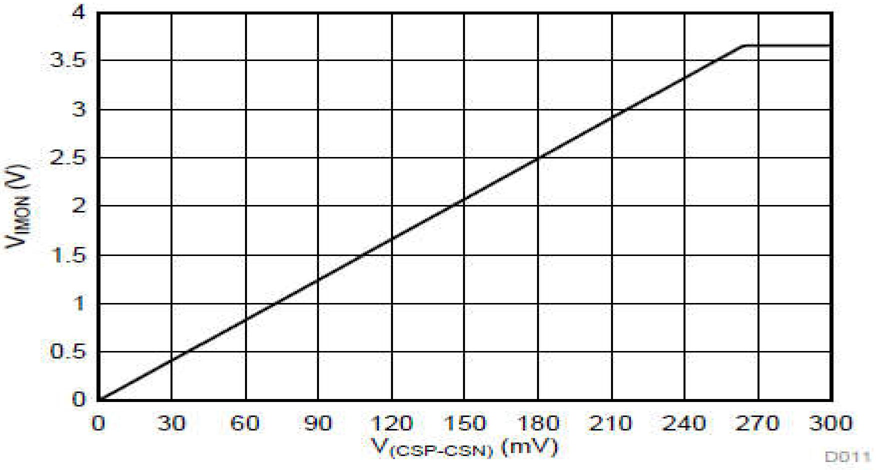
Startup Behavior: Soft Start

VIN = 14V, 7 LEDs, VIADJ = 420mV, RCS = 0.1Ω, tSS = 8ms
Ch1 : Input Voltage, Ch2 : Soft start, Ch3 : Input current, Ch4 : LED current

- Soft-start time programmed by connected a capacitor from SS pin to GND
- COMP voltage clamped to SS ramp by a diode during start-up
- Switching can disabled by driving SS below 25mV threshold

IMON



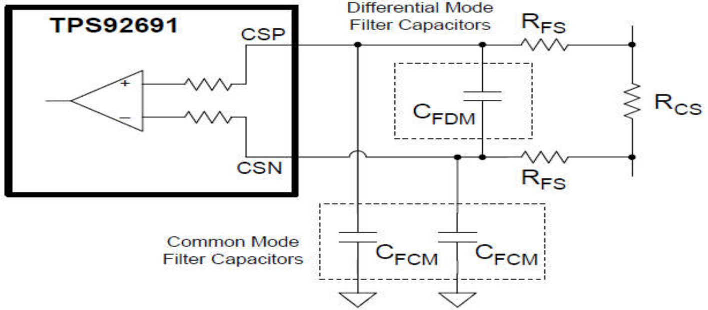


V_{IMON} vs $V_{(CSP-CSN)}$

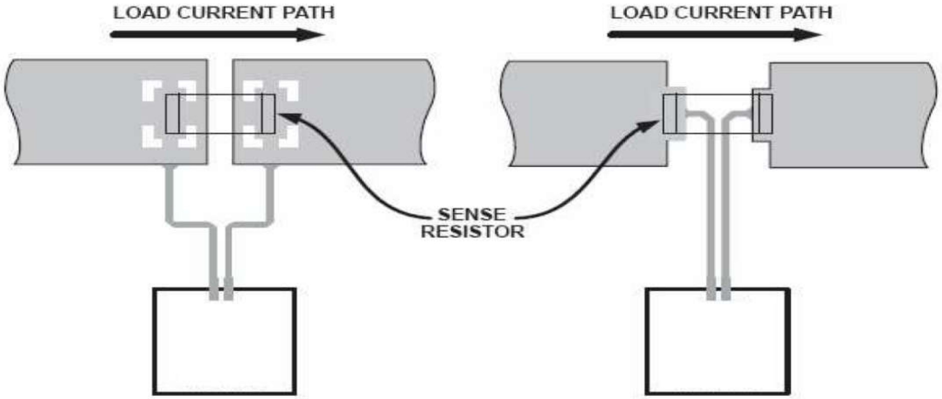
Rail to Rail AMP

Current Capacity PCB Etch

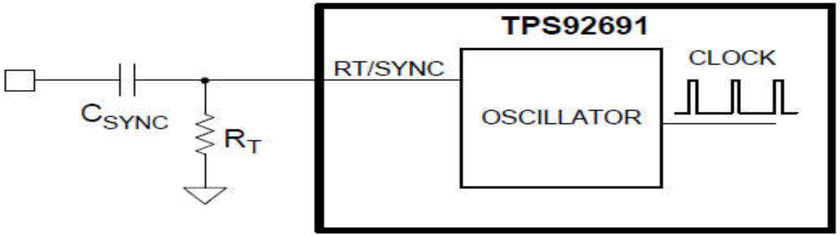
WIDTH	CURRENT CAPACITY
0.010"	0.8 A
0.015"	1.2 A
0.020"	1.5 A
0.050"	3.2 A
0.100"	6.0 A



Current Sense Amplifier Input Filter Options



Oscillator



Oscillator Synchronization Through AC Coupling

$$R_T = \frac{1.432 \times 10^{10}}{(f_{SW})^{1.047}} \ (\Omega)$$

TI recommends a switching frequency setting between 80 kHz and 700 kHz for optimal performance over input and output voltage operating range and for best efficiency.

Operation at higher switching frequencies requires careful selection of N-channel MOSFET characteristics and should take into consideration additional switching losses and junction temperature rise.

TPS92692/-Q1 High Accuracy LED Controller With Spread Spectrum Frequency Modulation and Internal PWM Generator

Features

- Wide Input Voltage: 4.5V to 65V
- Better than ± 4% LED Current Accuracy over Temperature with Low Input Offset Rail-to-Rail Current Sense Amplifier
- Spread Spectrum Frequency Modulation for Improved EMI
- Internal Analog-to-PWM Conversion for Stand-Alone Dimming Operation
  Analog LED Current Adjust Input (IADJ) with over 15:1 Contrast Ratio
  Integrated P-Channel Driver to enable Series FET Dimming and LED Protection
- Advanced Fault Protections and Reporting:
  - Open Drain FAULT Indicator
  - Continuous Output Current Monitoring
- AEC-Q100 Grade 1 Qualified (T_{JMAX} = 150°C) in HTSSOP-20

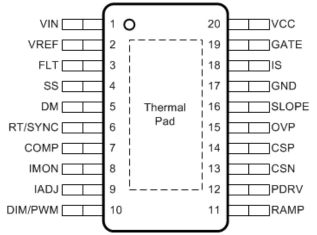
Applications

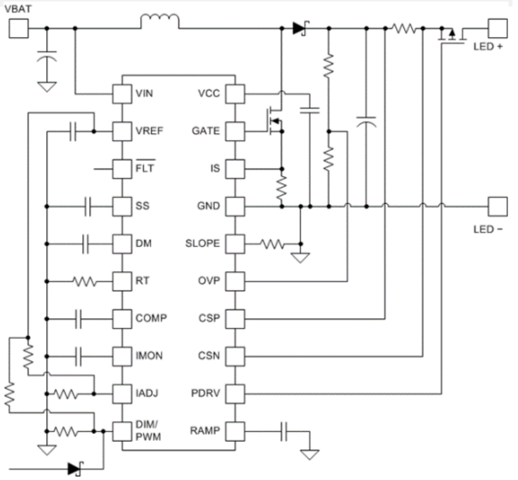
- Automotive Front Lighting: DRL, High Beam/Low Beam, Turn Indicator, Position, Fog
- Emergency Industrial Lighting Signs
- Portable Industrial Lighting

- **EVM:** TPS92692EVM-880
- **Tools:** PSpice Transient Model, Spreadsheet Design Calculator
- **TI Reference Design :** ***TIDA-01581***
  http://www.ti.com/tool/TIDA-01581

Benefits

- Supports Boost, Buck-Boost, SEPIC and Cuk LED Driver Topologies
- Reduced BOM Count While Maintaining Homogeneity in Light Output Across System; No Need to Overdesign to Meet Lumen Specifications
- Prevent System Damage and Increase Life of LEDs
- Meets Automotive Requirements Specified by OEMs





TPS92692/-Q1 High Accuracy LED Controller With Spread Spectrum Frequency Modulation and Internal PWM Generator

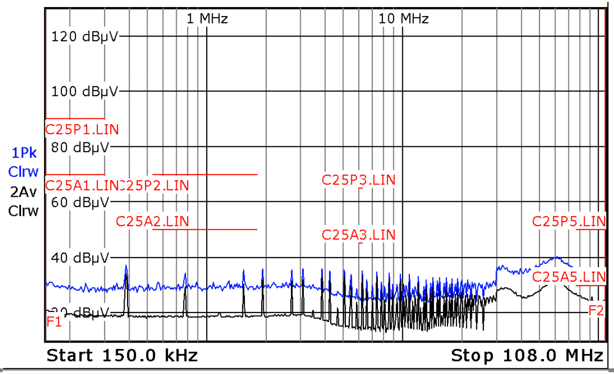
*"Easier to **meet EMI standards**"*

- What is Spread Spectrum Frequency Modulation (SSFM)?
  - Switching LED Drivers generate conducted and radiated EMI. SSFM improves this EMI by not allowing emitted energy to stay in any one receiver band for a significant amount of time

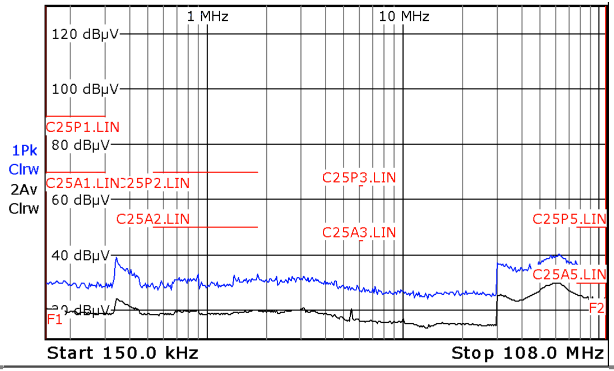
- TPS92692's SSFM characteristics:
  - Modulation method: Triangular wave
  - Modulation spread, Δf : ± 15%
  - Modulation Frequency, f_m: Adjustable 100Hz to 12Khz
  - Spread Spectrum Disable function

$$f_m = \frac{16.67 \times 10^{-6}}{C_{DM}} \text{(Hz)}$$

EMI Scan with SSFM disabled

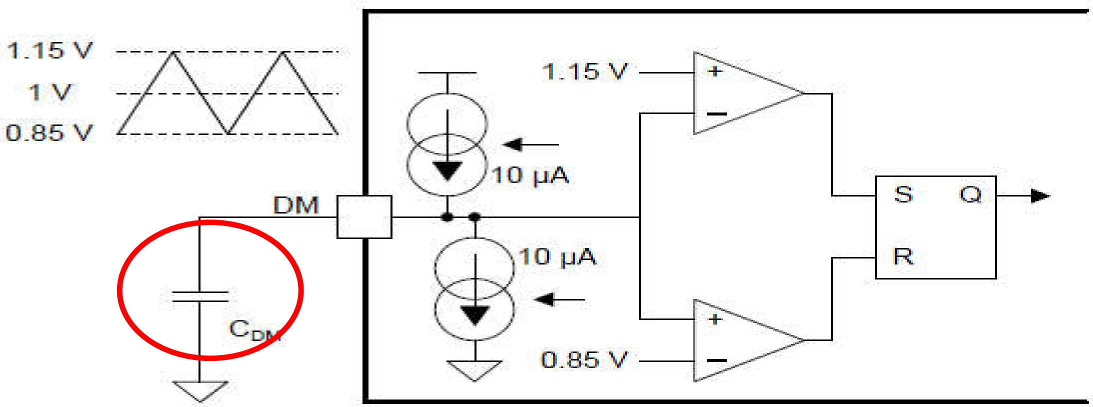


EMI Scan with SSFM enabled



TPS92692-Q1 Spread Spectrum Frequency Modulation

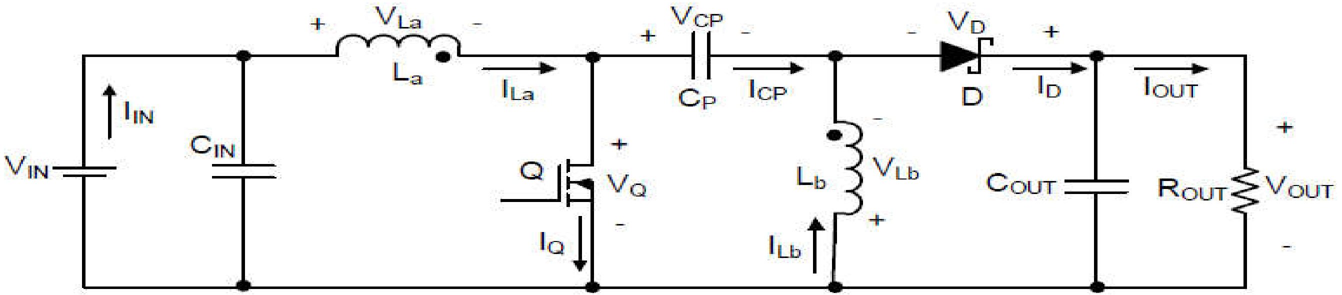
TPS92692-Q1设备提供了一种频率抖动选项，该选项通过将电容器从DM引脚连接到GND来实现。在CDM电容器上产生以1 V为中心的三角形波形。三角形波形将振荡器频率调制为外部定时电阻RT设置的标称频率的±15%。CDM电容值设置低频调制的速率。在100至1.2千赫的范围内实现平均EMI扫描设置调制频率的最大衰减。低调制频率对准峰值EMI扫描影响不大。将调制频率设置为10 kHz或更高，以实现对准峰值EMI测量的衰减。高于9kHz接收机分辨率带宽(RBW)的调制频率仅影响准峰值EMI扫描，对平均测量影响不大。该装置通过提供调节调谐的手段来简化EMI柔顺性。基于测量的EMI签名的频率。下列方程式计算设置调制频率FMOD（Hz）所需的CDM介电常数。将DM引脚连接到GND以禁用频率抖动电路操作。

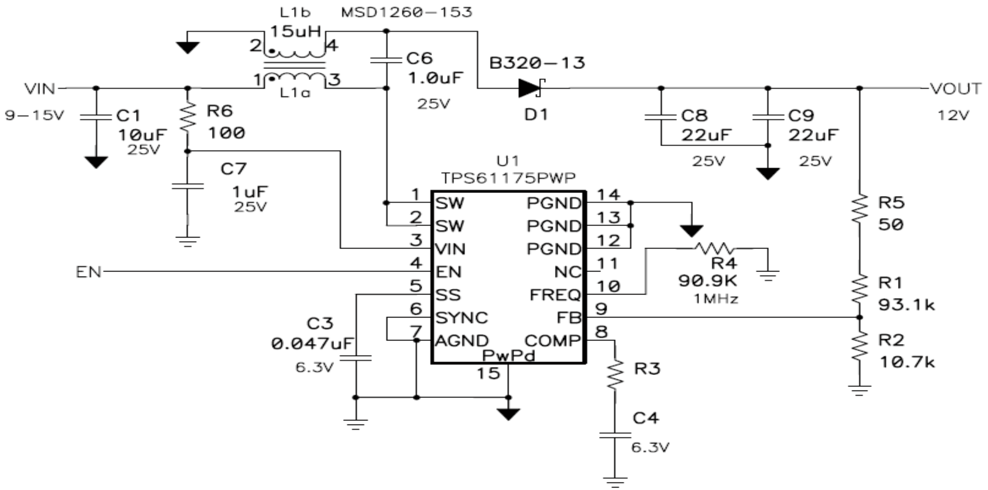


$$C_{DM} = \frac{10\ \mu A}{2 \times f_{MOD} \times 0.3\ V}\ (F)$$

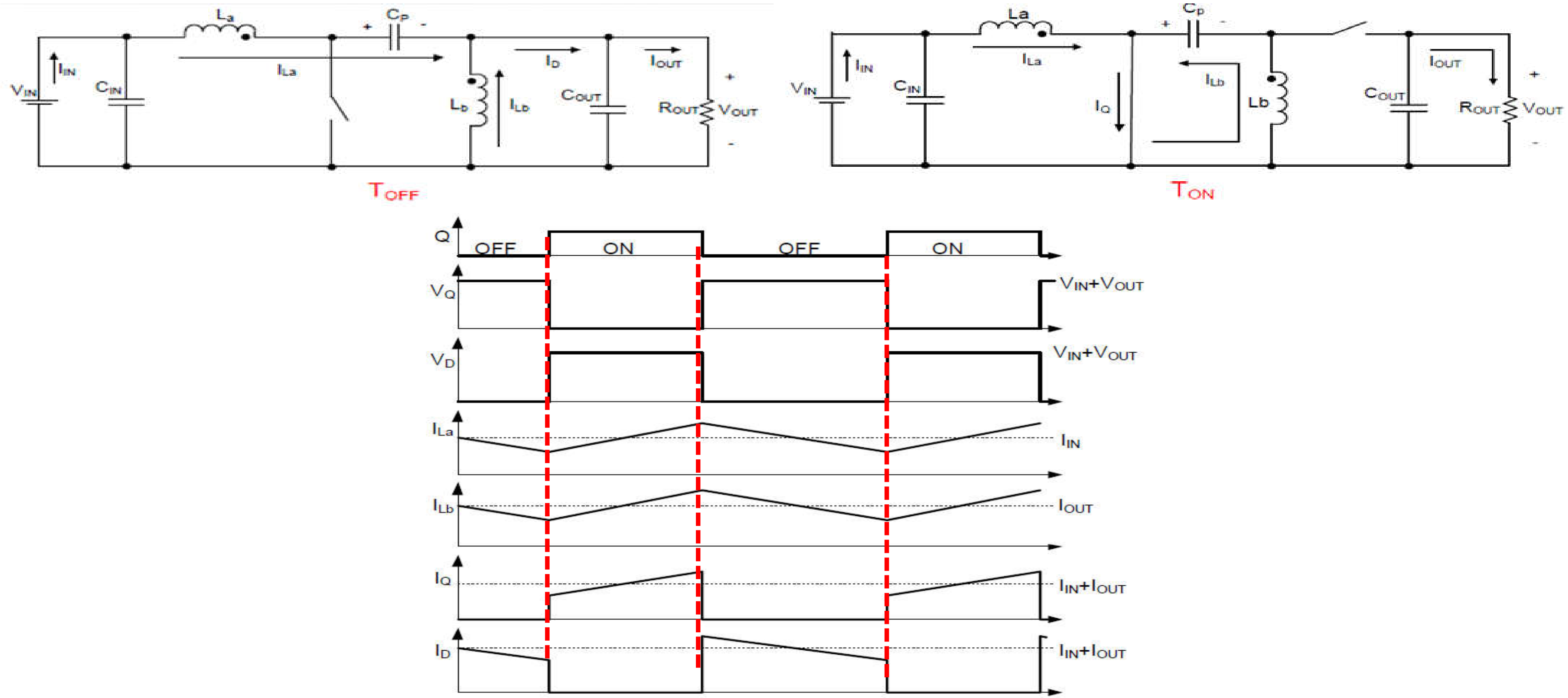
SEPIC DESIGN

SEPIC Circuit





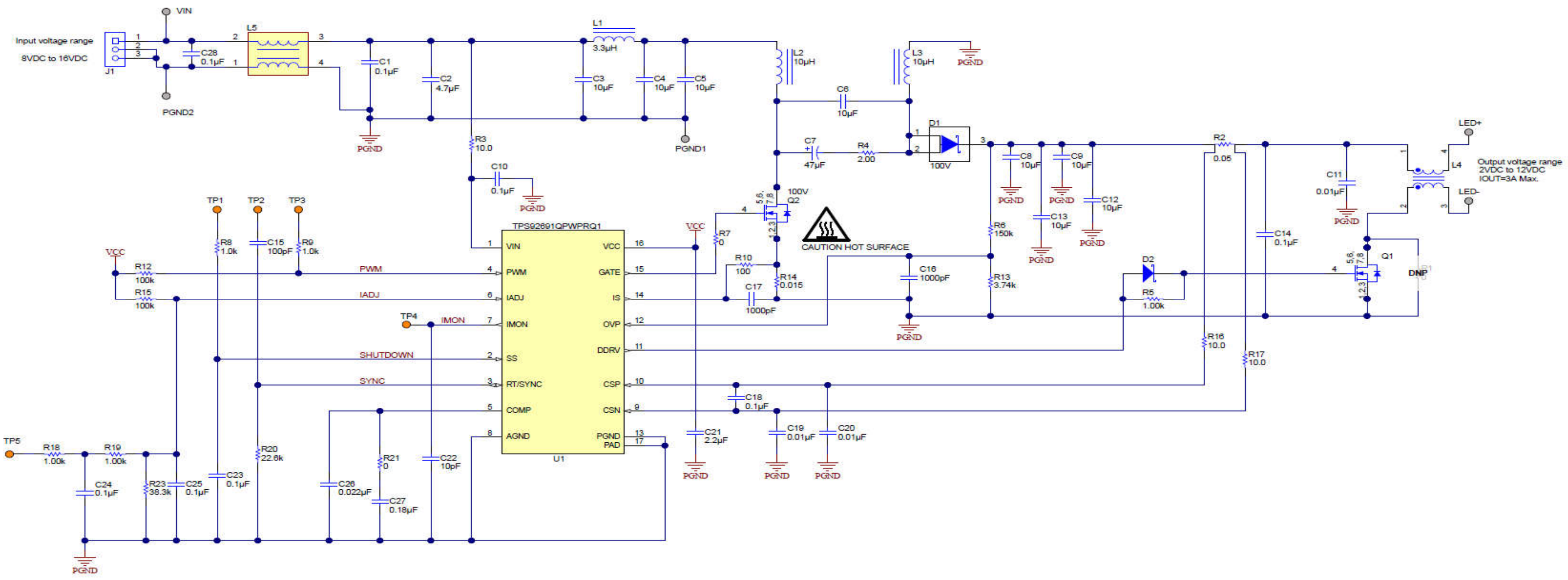
Voltage and Current Waveforms in a SEPIC



TPS92691/-Q1 SEPIC Spec Details

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
INPUT CHARACTERISTICS					
V_{IN} input voltage (nominal)	—	8	13	16	V
V_{IN} input voltage (min or max)	Warm crank or load dump	7	—	42	V
V_{IN} undervoltage lockout	—	—	4.4	—	V
OUTPUT CHARACTERISTICS					
LED forward voltage	—	—	2	—	V
Number of LED in series	—	1	—	6	—
V_{LED} output voltage	LED+ to LED–	—	—	12	V
I_{LED} output current	V_{IADJ} = 0.1 to 2.1 V, six LEDs	0.33	1.5	3	A
Output power	—	—	18	36	W
PWM dimming range	60 Hz, six LEDs	—	900:1	—	—
SYSTEM CHARACTERISTICS					
Output overvoltage protection level	—	—	51	—	V
Overvoltage hysteresis	—	—	3	—	V
f_{SW} switching frequency		—	350	—	kHz
Efficiency	V_{IN} = 13 V, six LEDs at 1.5 A	—	87	—	%
	V_{IN} = 13 V, six LEDs at 3 A	—	84	—	
EMI (conducted)	—	CISPR-25 Class 3			
BASE BOARD CHARACTERISTICS					
Form factor	—	3.3"L × 2.5"W			
Number of layers	—	4			
Height	—	0.4"			

TPS92691/-Q1 SEPIC EVM Circuit



Design Detail

$$D = \frac{V_{OUT} + V_D}{V_{IN} + V_{OUT} + V_D}$$

Duty_Min	Vout	Vd	Vin_Max
43.86	12	0.5	16

Duty_Max	Vout	Vd	Vin_min
60.98	12	0.5	8

DMAX = 60.98% occurs at VIN(MIN)= 8 V and DMIN=43.86 occurs at VIN(MAX)=16V

$$I_{IN(DC)} = \frac{I_{OUT}}{\eta_{EST}} \times \frac{V_{OUT} + V_D}{V_{IN}}$$

Iin(DC)	Iout	Vout	Vd	Efficiency	Vin
2.60	1.5	12	0.5	90	8

$$L_{1a} = L_{1b} \geq \frac{1}{2} \times \frac{V_{IN(max)} \times D_{(min)}}{\Delta I_{L(15V_{IN})} \times f_S}$$

L1a=L1b	Delta_IL	Fsw(K)	Vin	Dmin
9.62	1.041667	350	16	43.86

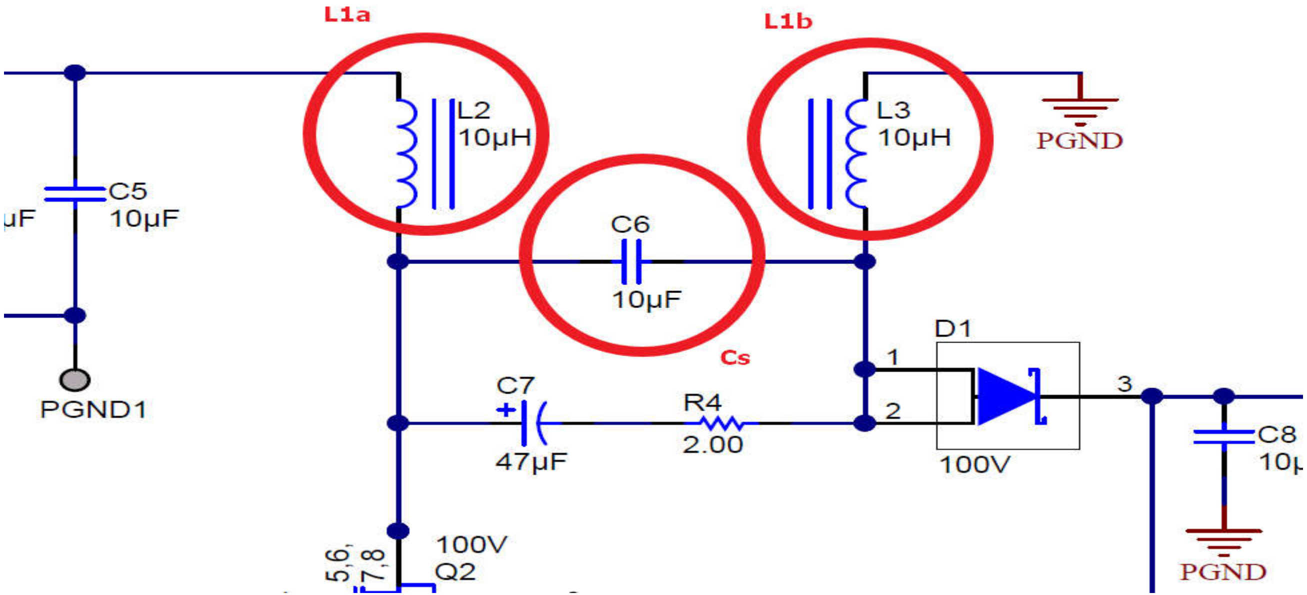
L1a=L1b=10uH

$$C_S = \frac{I_{LED(MAX)} \times D_{MAX}}{f_{SW} \times \Delta V_C}$$

Cs	ILED_Max	Dmax	Fsw	Delta_Vc
6.53	3	60.98	350	0.8

Cs=10uF

Choose Inductor and Cs



Cin/Cout/MOSFET/Diode Design

$$C_{OUT} = \frac{I_{LED} \times D_{MAX}}{f_{SW} \times r_D \times \Delta i_{LED(PP)}}$$

Cout	Iout	Dmax	Delta_Vrpl	Fsw(K)	C_ESR
34.8457143	3	60.98	50	350	3

$$I_L = \frac{P_{OUT(MAX)}}{V_{IN(MIN)} \times \eta}$$

IL	Pout	Vin_min	Efficiency
6.62	36	8	85

$$\Delta I_{L(PP\,MAX)} = \frac{V_{IN(MIN)} \times D_{MIN}}{L \times f_{SW}}$$

Delta_IL(ppmax)	Vin_max	Fsw	Duty_Min	Choose L1a
2.01	16	350	43.86	10

$$C_{IN} = \frac{I_{L(PPMAX)}}{f_{SW} \times \Delta v_{IN(PP)} \times 8}$$

Cin	IL(ppmax)	Fsw	Vin_ripple
14.36	2.01	350	50

$$V_{DS} = 1.2 \times \left(V_{O(OV)} + V_{IN(MAX)}\right)$$

Vds	Vo(ov)	Vin_max
80.40	51	16

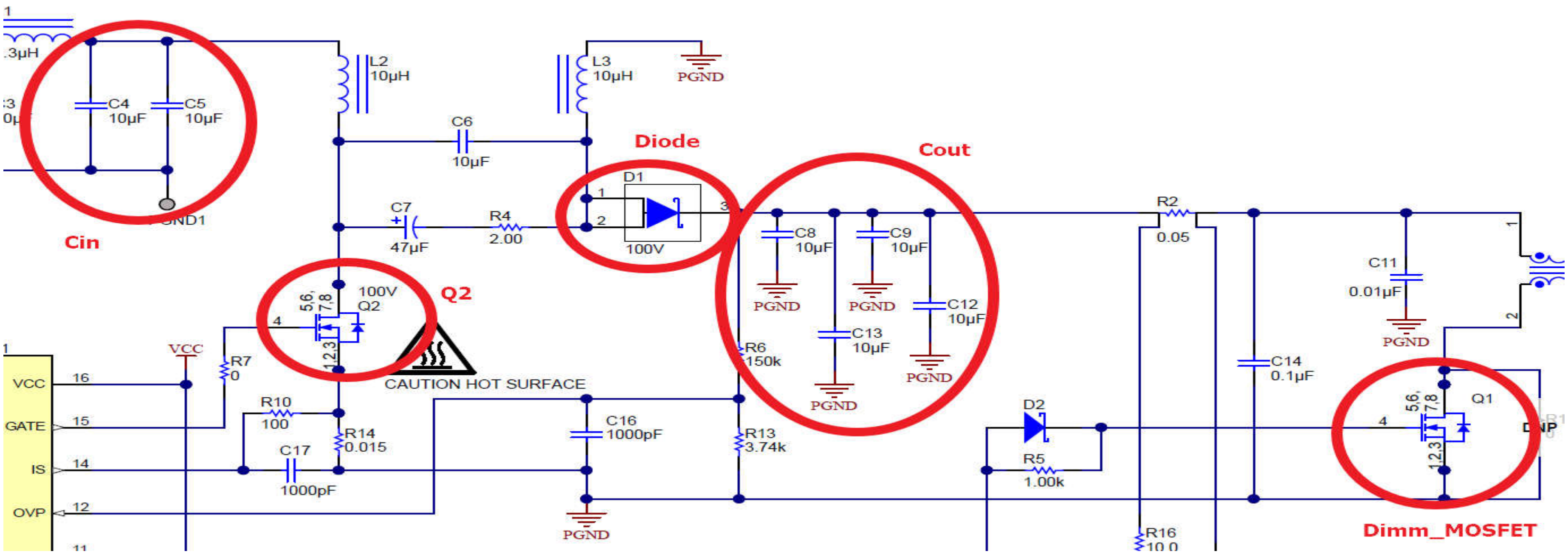
$$I_Q = I_{LED} + I_L$$

IQ_peak	I_LED	IL
8.62	3	5.62

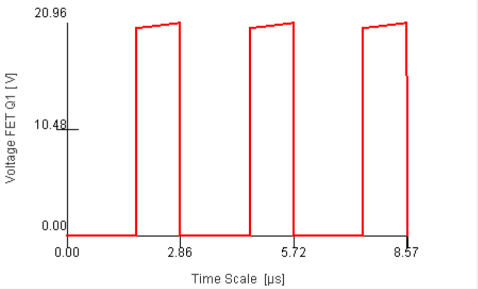
$$I_{Q1rms} = \frac{V_{OUT} \times I_{OUT}}{V_{INmin} \times \eta \times \sqrt{D_{max}}}$$

IQ1rms	Vout	Iout	Vin_min	Efficiecny	D_max
6.78	12	3	8	85	60.98

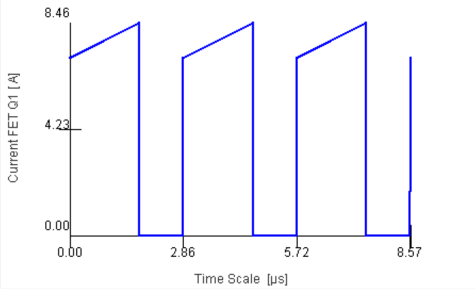
Choose Cin/Cout/MOSFET/Diode



MOSFET Vds/Ids Waveform



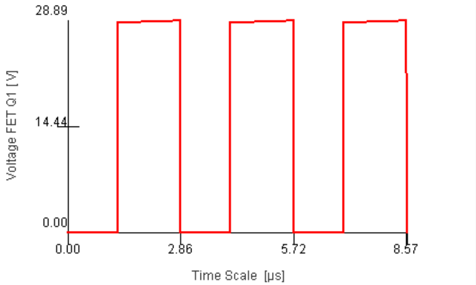
Min. Voltage FET Q1: 0.00 V
Max. Voltage FET Q1: 20.96 V



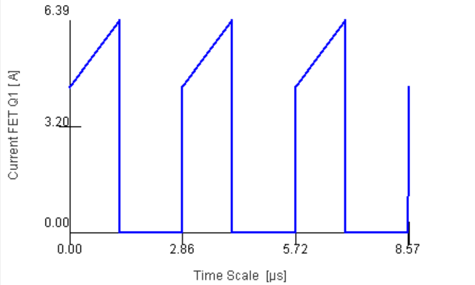
Min. Current FET Q1: 7.06 A
Max. Current FET Q1: 8.46 A
RMS Current FET Q1: 6.09 A
Avg. Current FET Q1: 4.76 A
AC Current FET Q1: 3.79 A

Input Voltage: 8.00 V

8.00 12.00 16.00



Min. Voltage FET Q1: 0.00 V
Max. Voltage FET Q1: 28.89 V

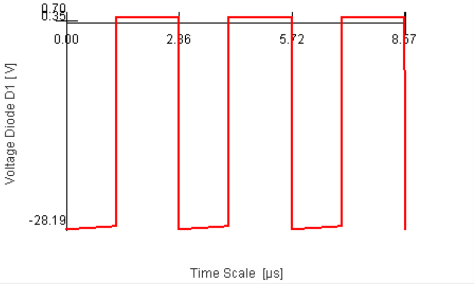


Min. Current FET Q1: 4.37 A
Max. Current FET Q1: 6.39 A
RMS Current FET Q1: 3.60 A
Avg. Current FET Q1: 2.38 A
AC Current FET Q1: 2.70 A

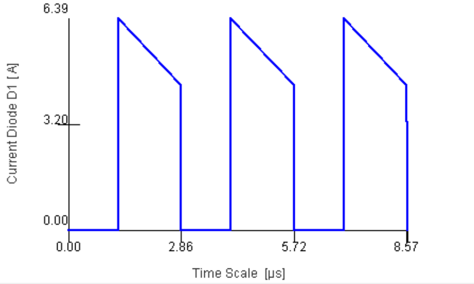
Input Voltage: 16.00 V

8.00 12.00 16.00

Diode Vf/If Waveform



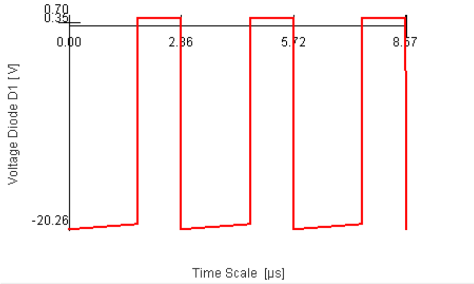
Min. Voltage Diode D1: -28.19 V
Max. Voltage Diode D1: 0.70 V



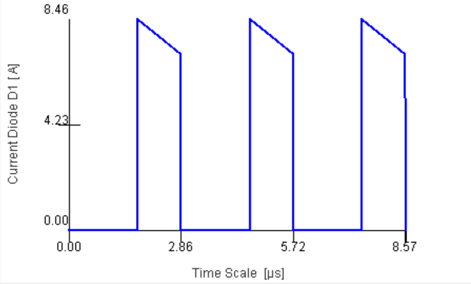
Min. Current Diode D1: 4.37 A
Max. Current Diode D1: 6.39 A
RMS Current Diode D1: 4.04 A
Avg. Current Diode D1: 3.00 A
AC Current Diode D1: 2.71 A

Input Voltage: 16.00 V

8.00 12.00 16.00



Min. Voltage Diode D1: -20.26 V
Max. Voltage Diode D1: 0.70 V

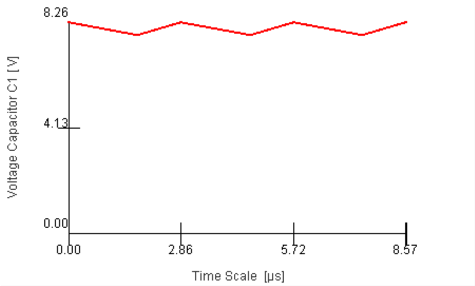


Min. Current Diode D1: 7.06 A
Max. Current Diode D1: 8.46 A
RMS Current Diode D1: 4.83 A
Avg. Current Diode D1: 3.00 A
AC Current Diode D1: 3.79 A

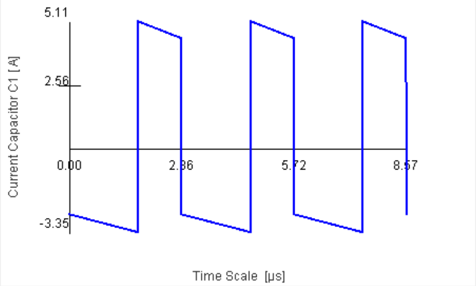
Input Voltage: 8.00 V

8.00 12.00 16.00

Cs Voltage And Current Waveform



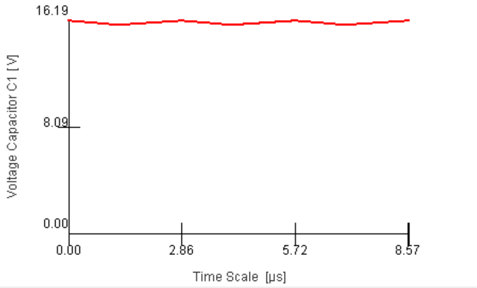
Min. Voltage Capacitor C1: 7.74 V
Max. Voltage Capacitor C1: 8.26 V



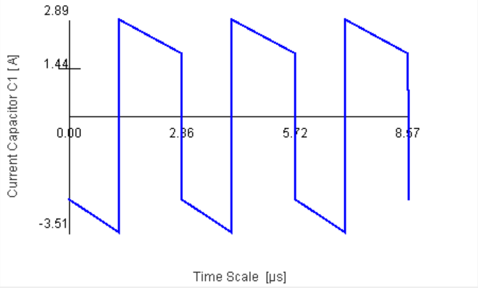
Min. Current Capacitor C1: -3.35 A
Max. Current Capacitor C1: 5.11 A
RMS Current Capacitor C1: 3.79 A
Avg. Current Capacitor C1: 0.00 A
AC Current Capacitor C1: 3.79 A

Input Voltage: 8.00 V

8.00 12.00 16.00



Min. Voltage Capacitor C1: 15.81 V
Max. Voltage Capacitor C1: 16.19 V



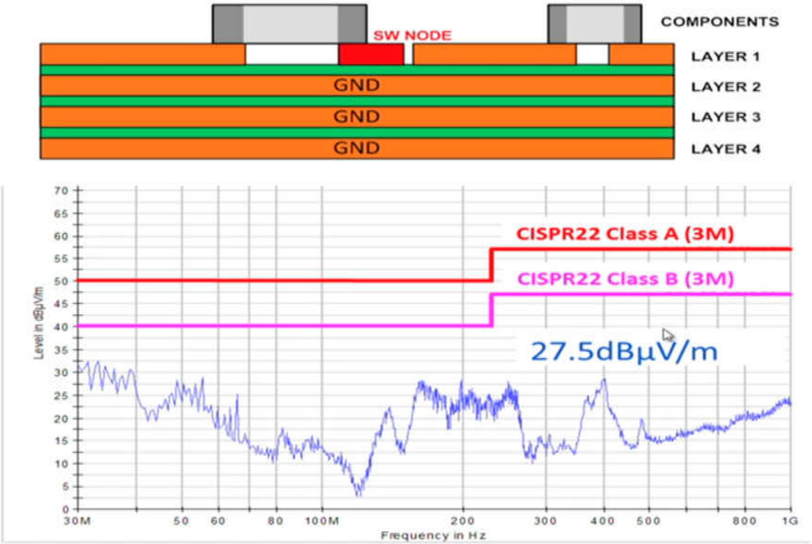
Min. Current Capacitor C1: -3.51 A
Max. Current Capacitor C1: 2.89 A
RMS Current Capacitor C1: 2.69 A
Avg. Current Capacitor C1: 0.00 A
AC Current Capacitor C1: 2.69 A

Input Voltage: 16.00 V

8.00 12.00 16.00

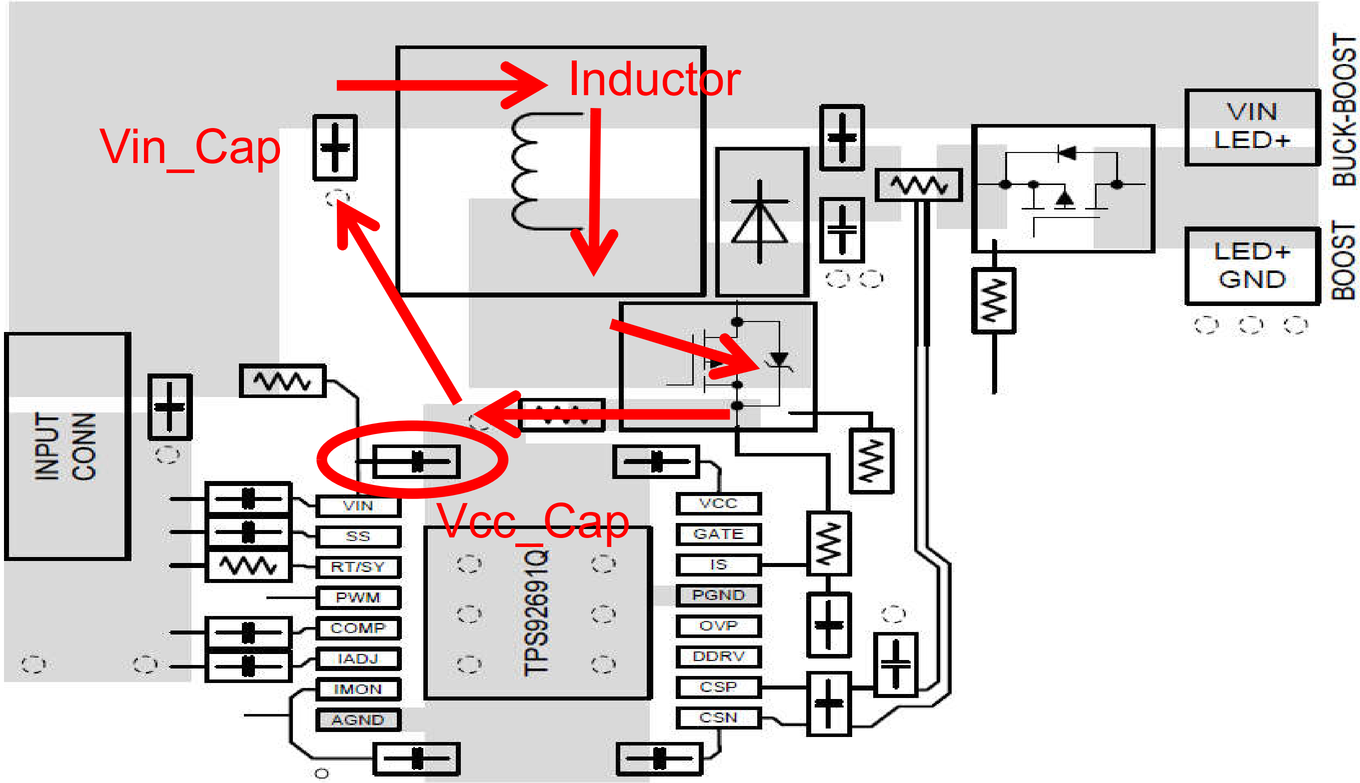
EMI & Layout Placement

Shielding – Using GND or PWR Planes

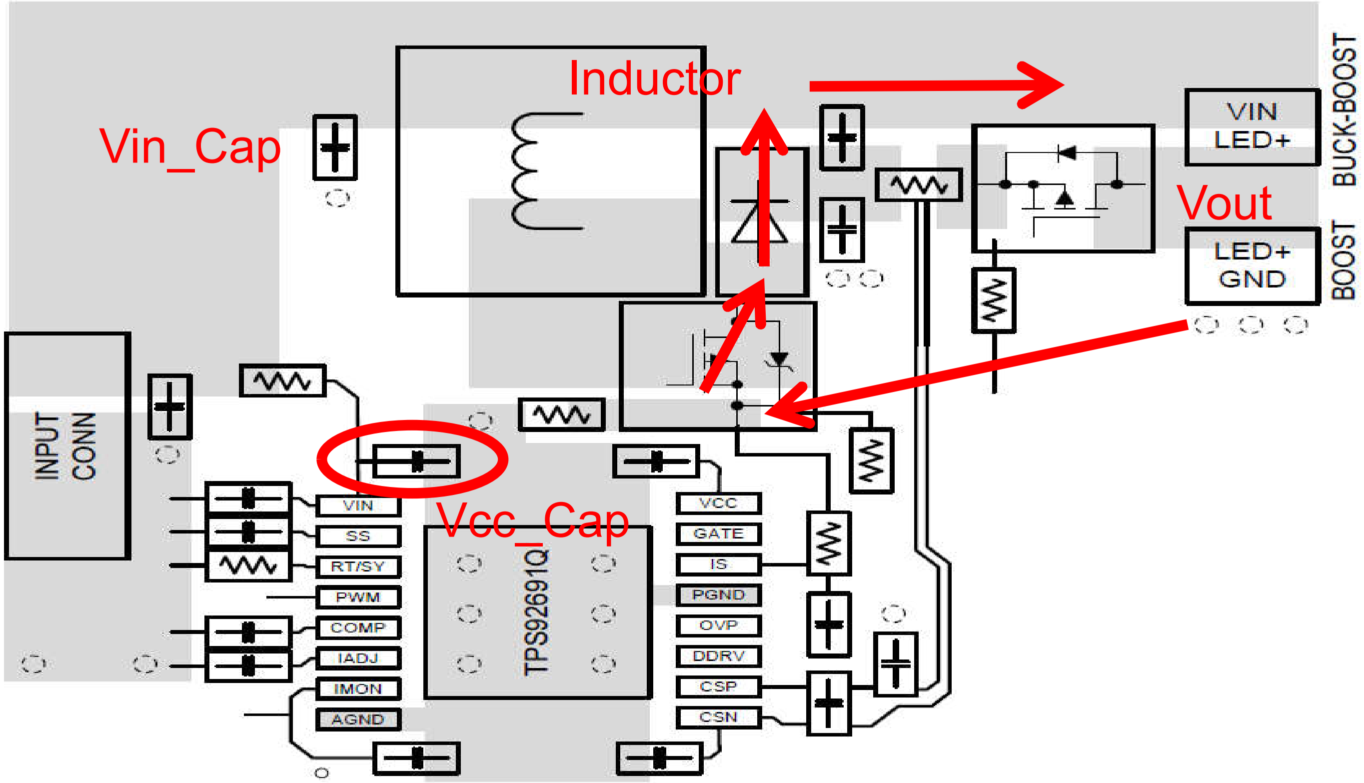


Two Layer (one GND layer) : 32.5 dBuV/m
Multi layer GND shielding : 27.5 dBuV/m

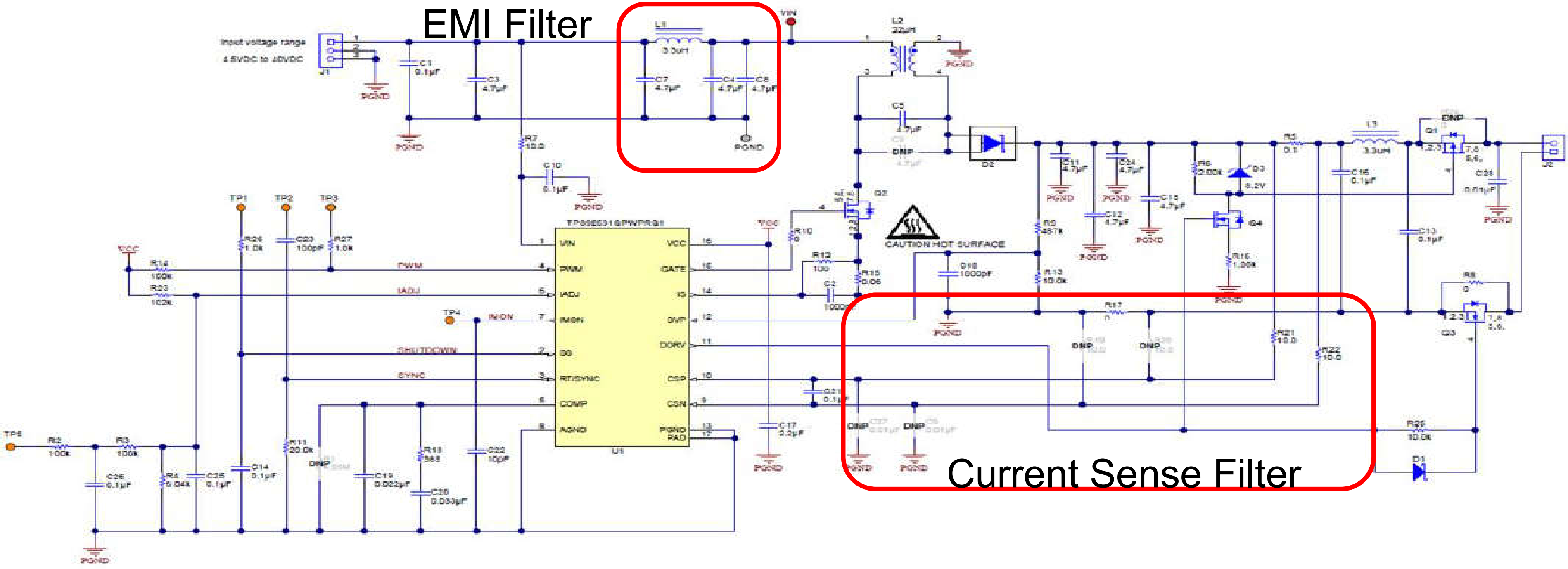
TPS92691 – Layout Placement



TPS92691 – Layout Placement



Filter

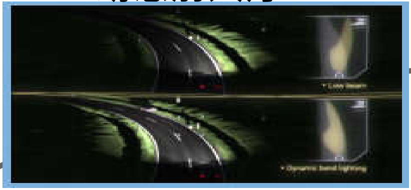


TPS92661Q
LED Matrix Manager

High-brightness LED Matrix Manager for Automotive Headlight Systems

一、 Matrix Lighting 的应用介绍

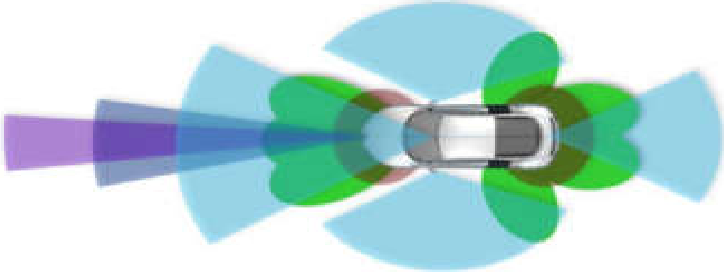
动态前大灯



行人标识

无眩光远光灯

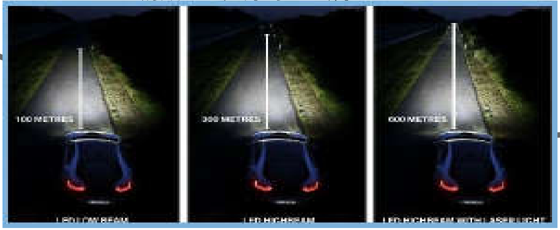
车道线标识



自动驾驶人机接口

动态（扫动）
转弯指示器

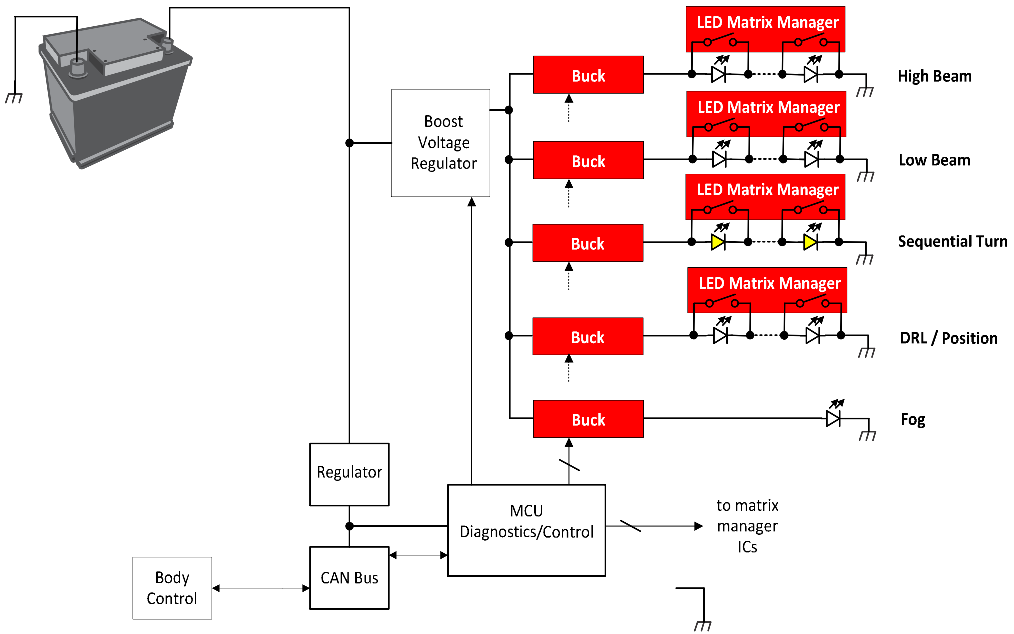
激光及高电流 LED



动态尾灯

Architectures for Automotive Front Lighting

- **Matrix headlight**
  - LED Matrix Manager dynamically controls individual LED brightness
  - Fast-response constant current buck LED drivers are required to support fast-changing pixels and not causing LED damage
  - Matrix headlight improves road safety if working together with ADAS system, e.g. anti-glaring



LED Matrix Manager for Matrix Head-Light

Portfolio Strengths

- **First-to-market matrix manager device**
- **10-bit individual LED brightness control**
- Multiple devices to support high number of pixel matrix head-light
- **UART** interface **enhance noise immunity** for communication
- **Comprehensive LED fault protection and fault report**
- **Work with ADAS system to enhance road safety**

Benefits

- Reduce board space due to discrete implementations
- Realize fine brightness control per individual pixel
- Able to support high resolution matrix head-light applications
- Easy digital communication between MCU and matrix managers
- LED faults be informed immediately
- Enhance road safety such as anti-glaring

Target End Equipment

- Dynamic High beam
- Dynamic Low beam
- Wiping Daytime Running Light / Position Light
- Sequential Turn light

Parts

- **TPS92661-Q1**
  - Max. 12 LEDs in series
  - Max. 1 A LED current support
  - 10-bit individual LED brightness control
  - Max. 96-pixel implementable

- **TPS92662-Q1 (New)**
  - Flexible LEDs in series arrangements
  - High LED current support feasible
  - 10-bit individual LED brightness control
  - Max. 384-pixel implementable

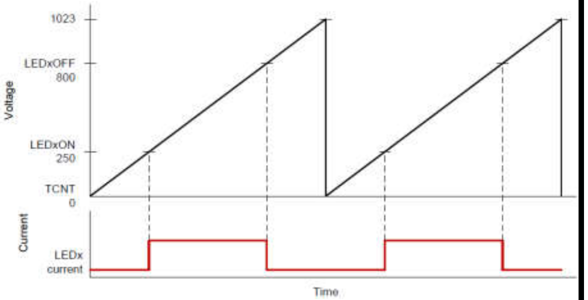
Matrix Lighting 的应用介绍

智能前灯

LED Matrix Manager – TI Advantages

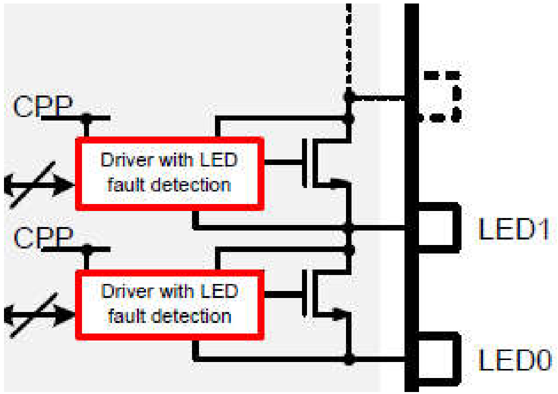
10-bit brightness adjustment

- Adjust brightness by controlling LEDON and LEDOFF registers through UART interface
- Synchronize multiple devices to achieve systematic dynamic head-light beam-forming
- **Work with ADAS cameras for anti-glaring to enhance road-safety**



LED brightness control through LEDON/OFF

Individual LED fault protect & report



LPP's LED Matrix Manager enables convenient LED fault protection and reporting per individual LEDs

Advantages:
- Real-time monitor on LED open / short
- LED open: protect LED through turning-on internal FET and report fault on fault register
- LED short: Report fault on fault register
- Fault information read-back per UART

Diagnostic Registers				
E0h	FAULTL	FAULT[8:1]		00000000
E1h	FAULTH	RESERVED	FAULT[12:9]	00000000

LED Matrix Manager significantly reduces board space for matrix head-light electronics' implementation!

TPS92661-Q1 High Brightness LED Matrix Manager

Features

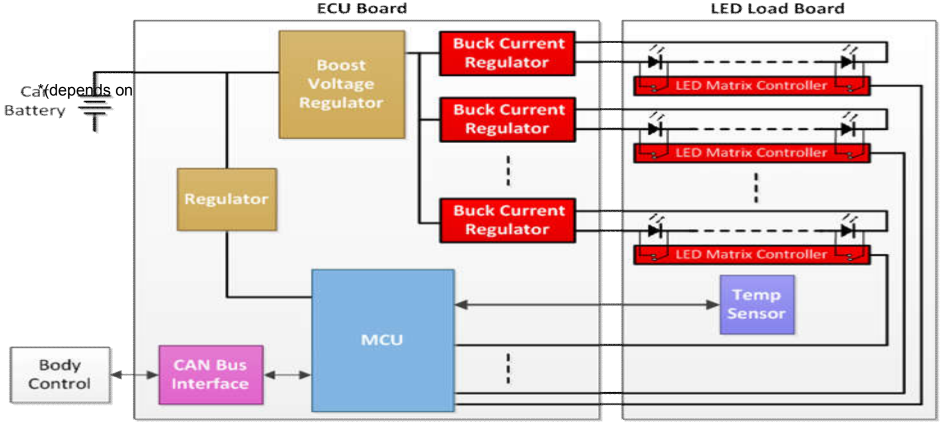
- 12 floating bypass LED switches in series
- Multi-drop UART communication interface
- Programmable 10-bit PWM dimming
- Individual turn-on / off time per switch
- Inherent phase-shift capability
- Device-to-device synchronizations
- LED open protection, short detection and fault diagnostic / reporting
- Q100 Grade 1 qualified
- Package: 48-pin TQFP exposed PAD package

Applications

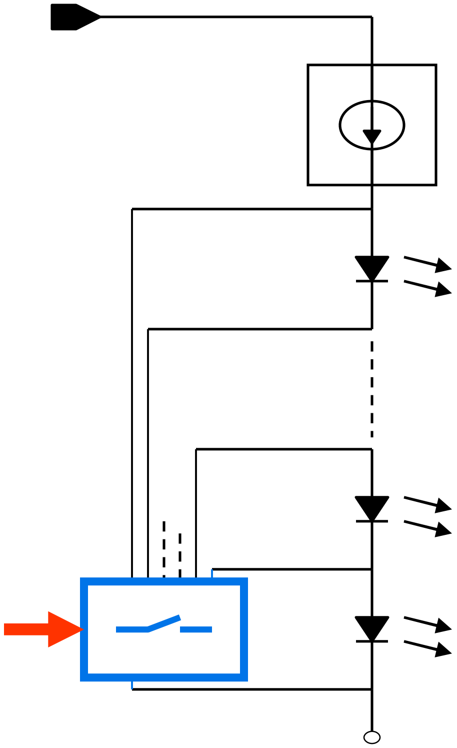
- Matrix head-light
- Factory Automation
- Applications requiring individual LED brightness control

Benefits

- Instantaneous beam forming / shaping for advanced automotive headlight systems
- IC can control ON/OFF times for each LED individually
- Simplifies control algorithm for the LMMs
- Seamless communication with system MCUs
- Feasible to support LED current running at above 1 A *
- Individual LED fault diagnostics and status reporting
- Cost effective routing with single layer metal-core PCB
- Small form factor with good thermal performance



LMM1 System Architecture



System configuration

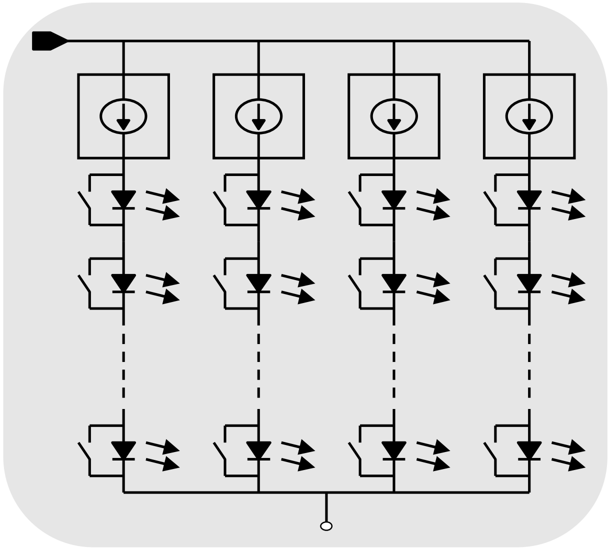
- 12 LEDs per string
- Current source for each string
- 8 string max per communication line

Individual control of switches

- Separate PWM control of each
- 10 bit dimming resolution
- Individual fault detection/protection

Other system features

- UART based communication architecture
- Minimized complexity, part count, signal routing
- 3.3V or 5V communication compatible
- Up to 65V LED stack voltage



Competitive Summary

	TPS92661Q	Discrete-built
Compactness	Excellent	[redacted]
EMI performance	Good	Fair
Control easiness	Easy	Fair
Number of components	Minimal	[redacted]
Solution Cost	Medium	High
System reliability	High	Low

LMM in Dynamic Turn Signaling

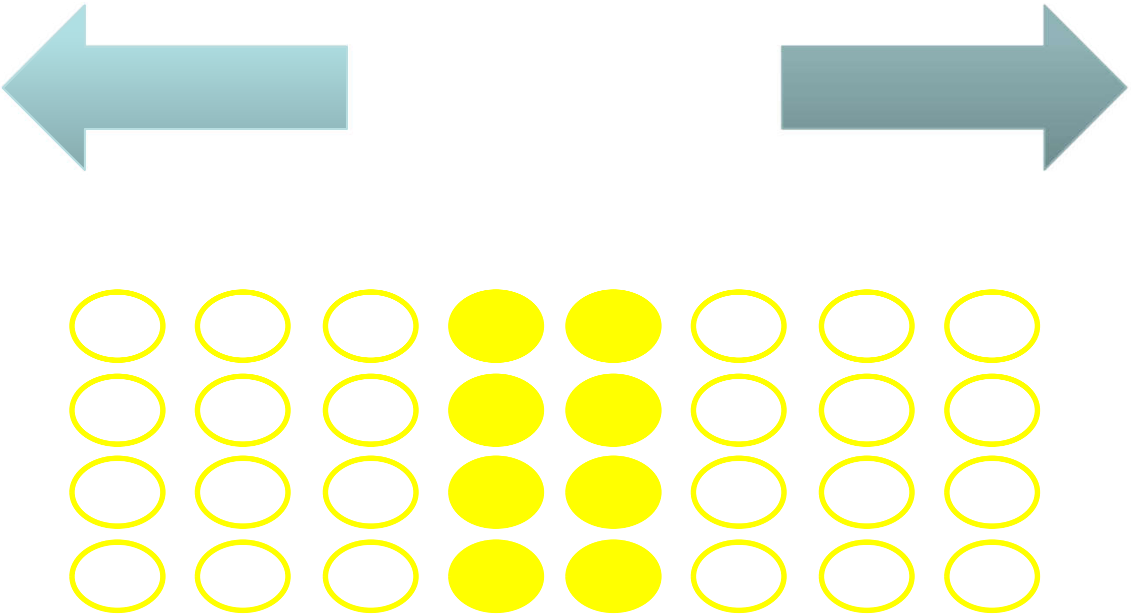
LMM in Dynamic Turn Signaling

LMM in Dynamic Turn Signaling

LMM in Dynamic Turn Signaling

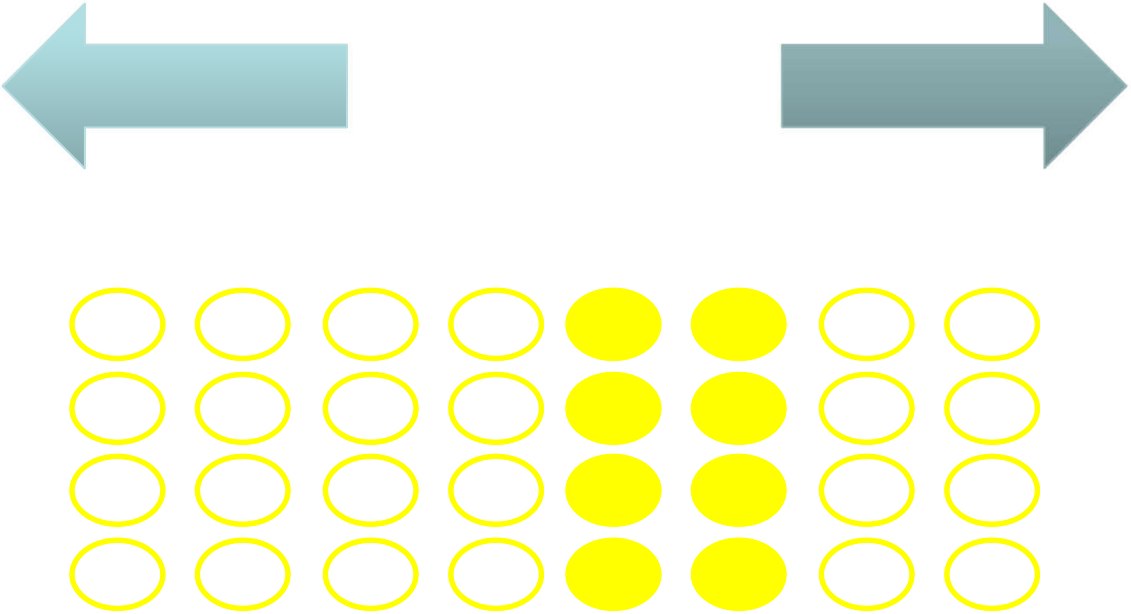
Replay dynamic turn

LMM in Directional Beaming



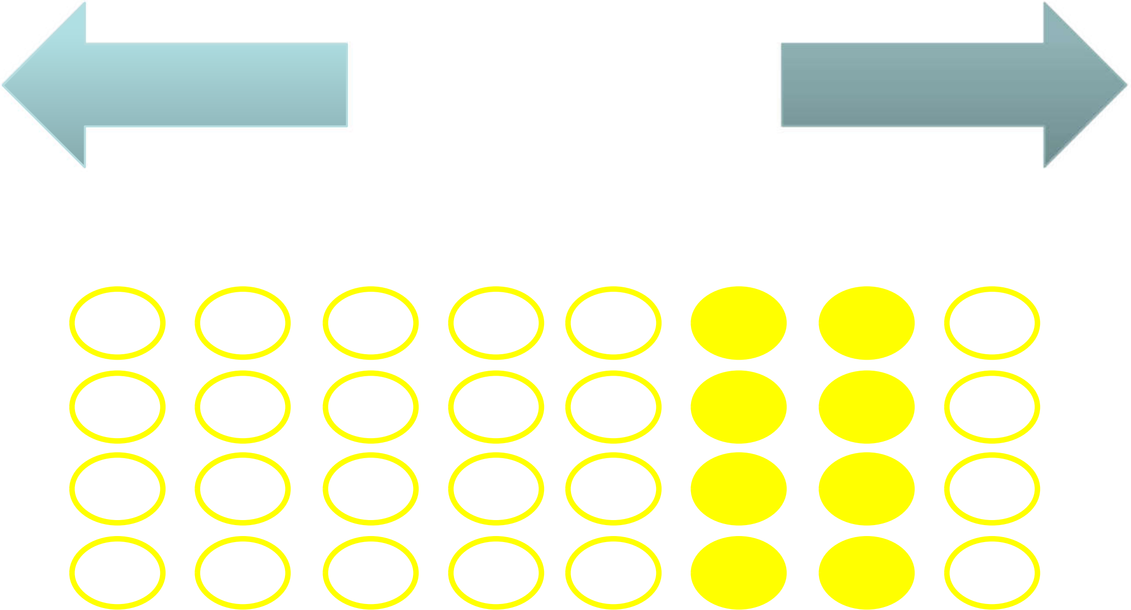
Anti-glaring feature

LMM in Directional Beaming



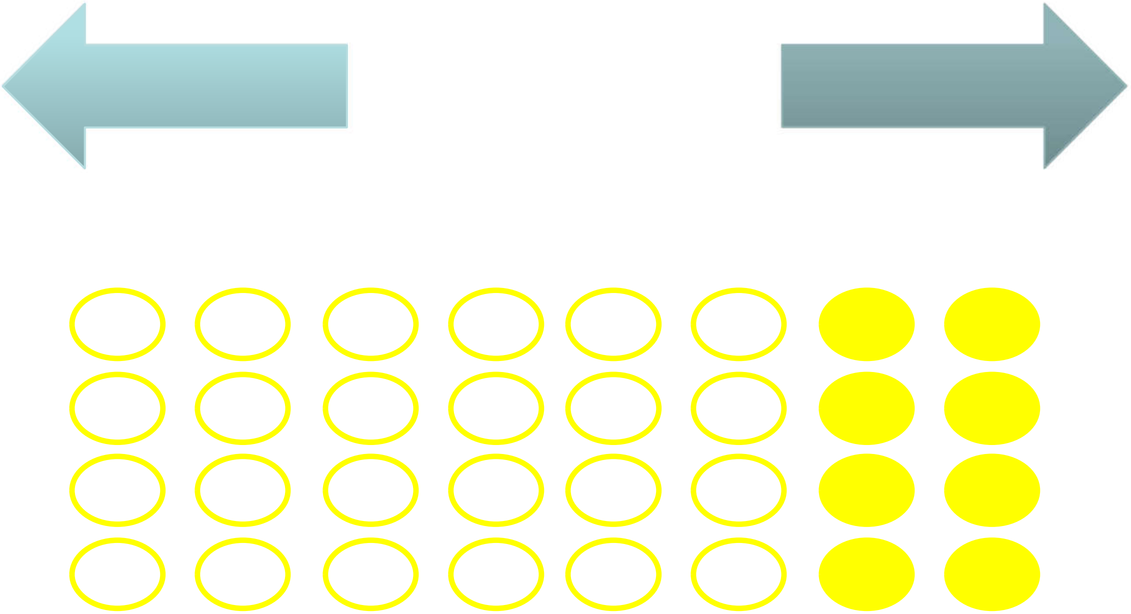
Anti-glaring feature

LMM in Directional Beaming



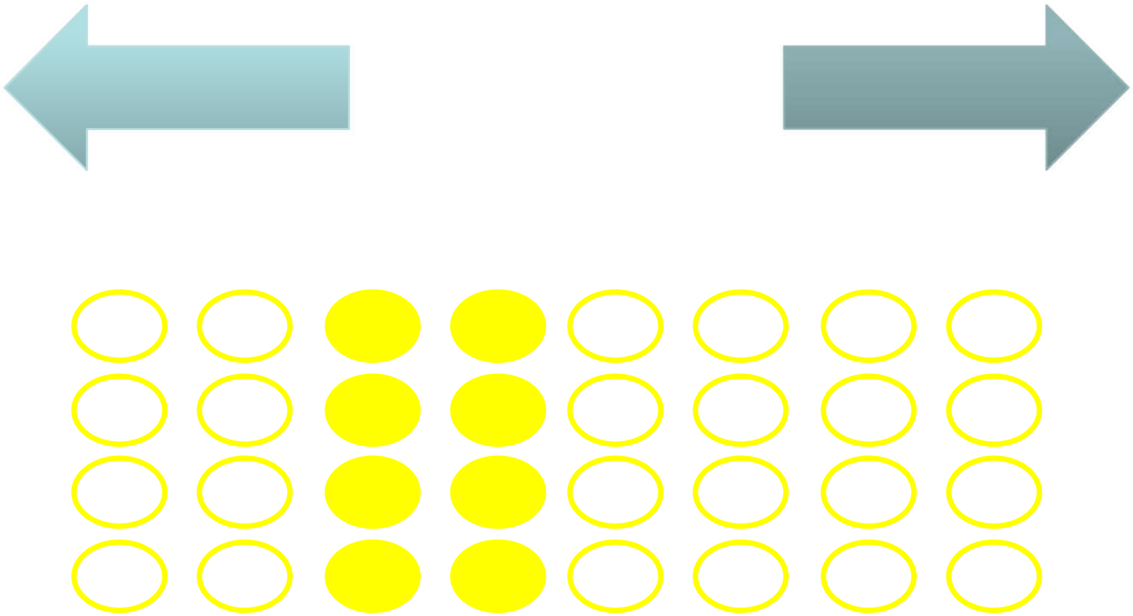
Anti-glaring feature

LMM in Directional Beaming



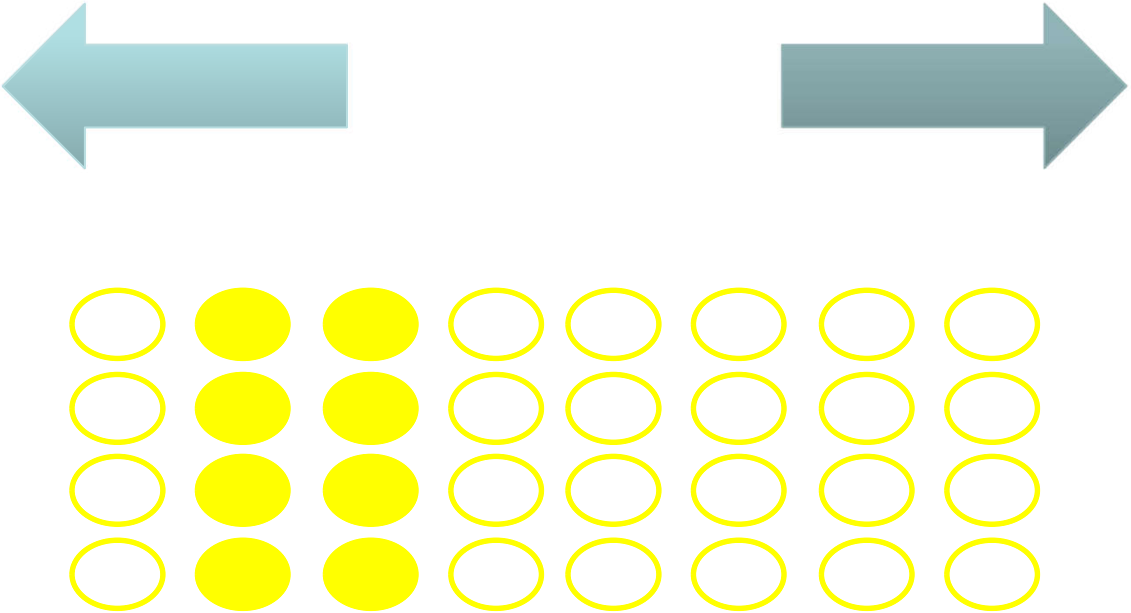
Anti-glaring feature

LMM in Directional Beaming



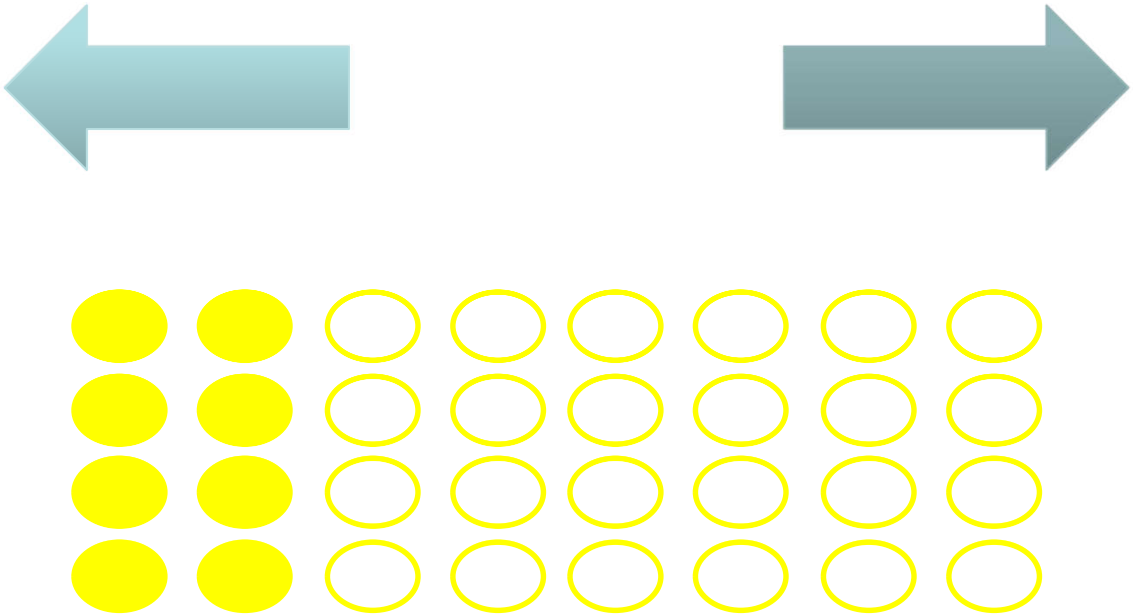
Anti-glaring feature

LMM in Directional Beaming



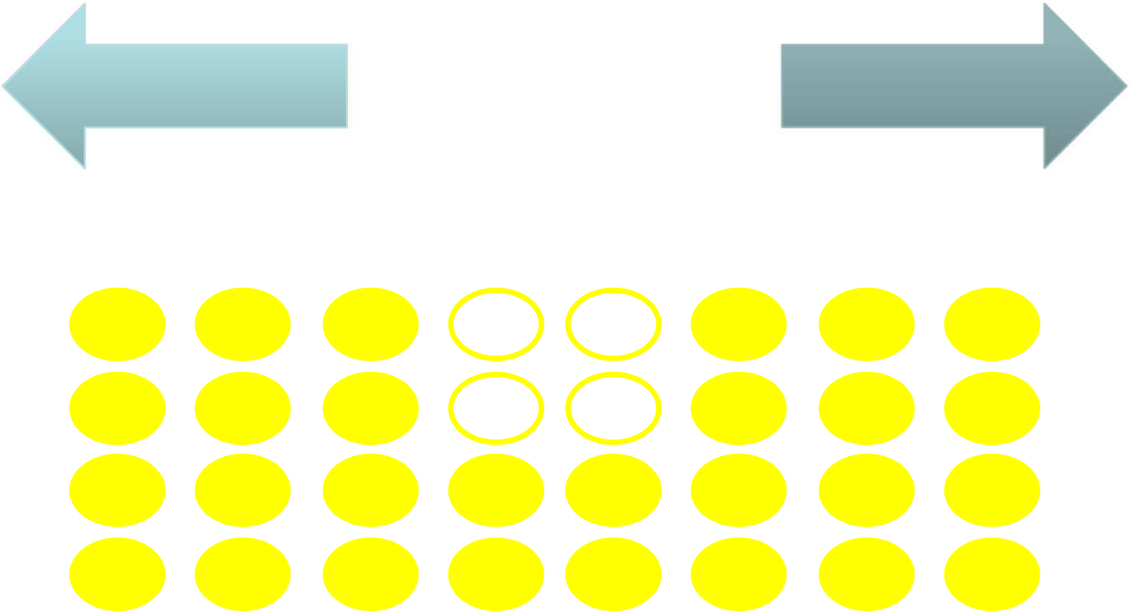
Anti-glaring feature

LMM in Directional Beaming



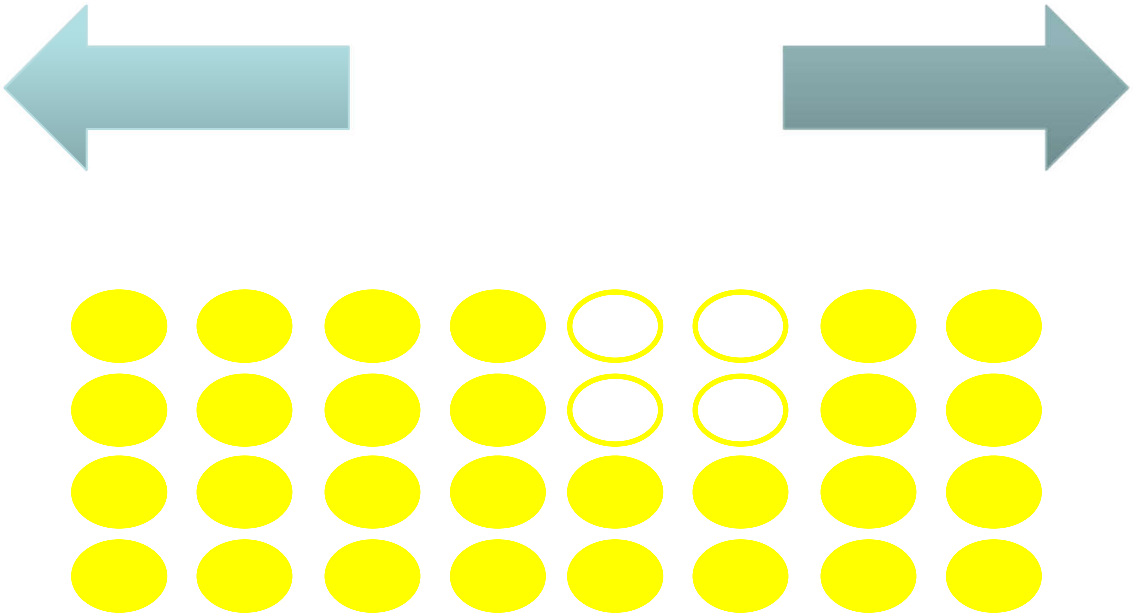
Anti-glaring feature

LMM in Anti-Glaring Feature



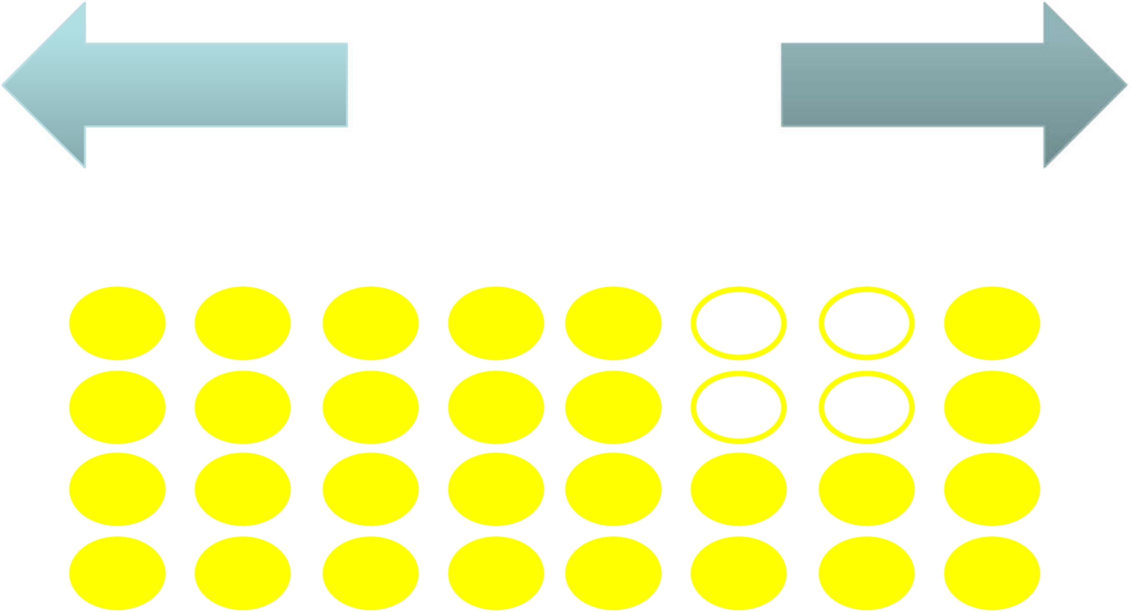
Directional beaming FAQ

LMM in Anti-Glaring Feature



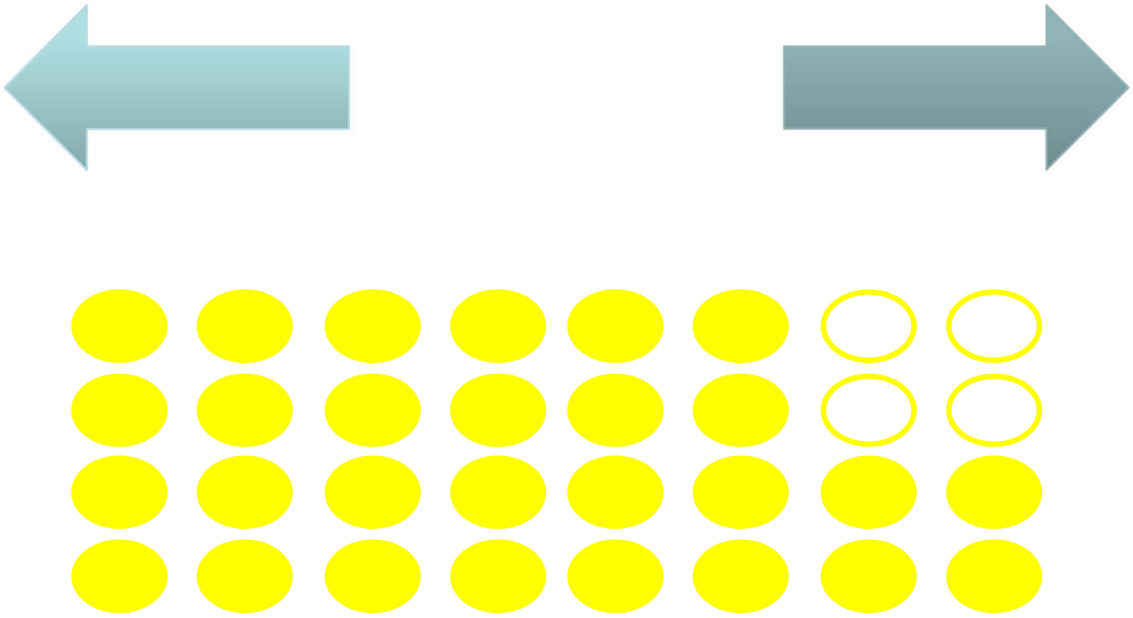
Directional beaming **FAQ**

LMM in Anti-Glaring Feature



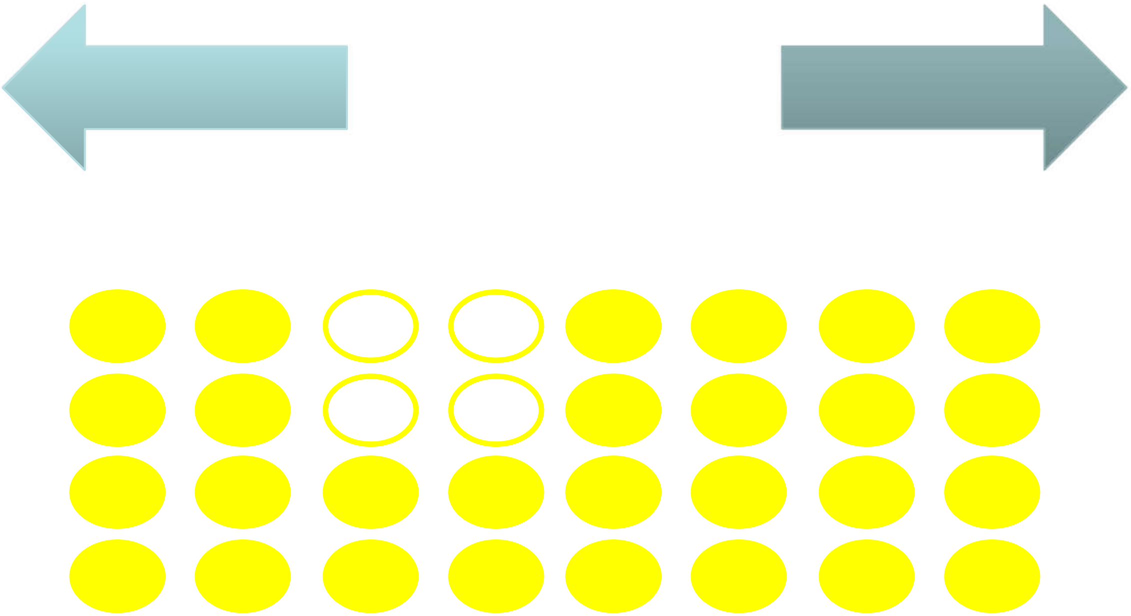
Directional beaming FAQ

LMM in Anti-Glaring Feature



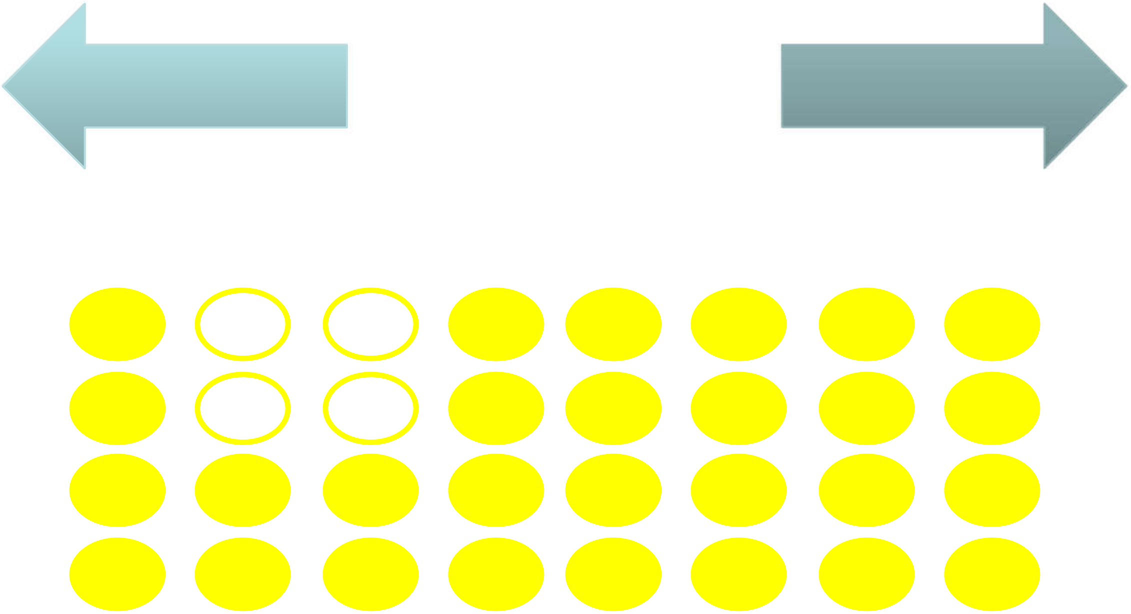
Directional beaming FAQ

LMM in Anti-Glaring Feature



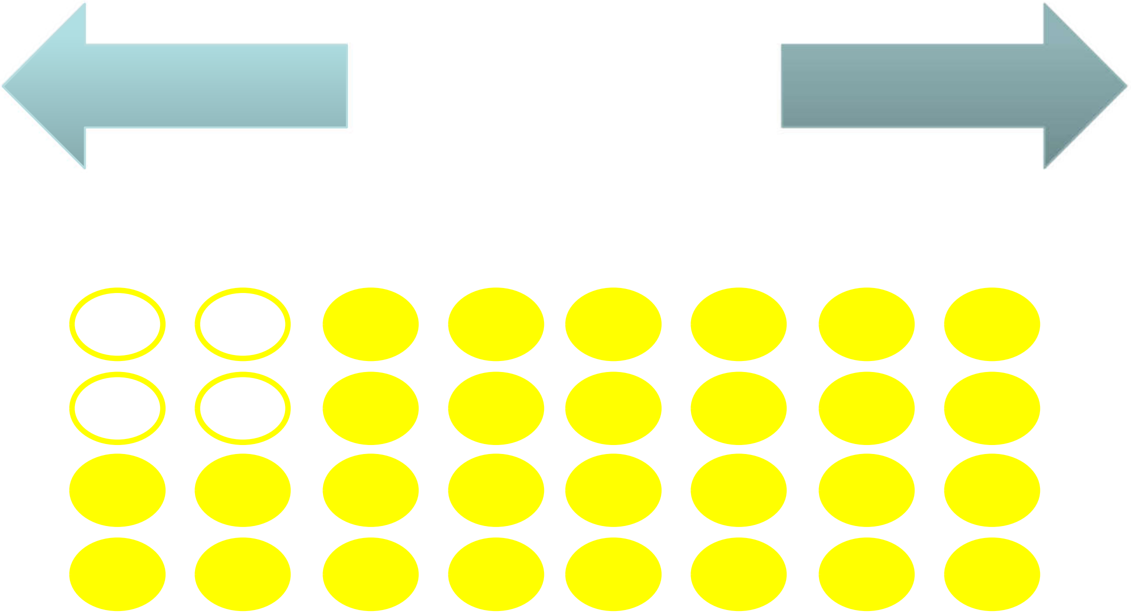
Directional beaming FAQ

LMM in Anti-Glaring Feature



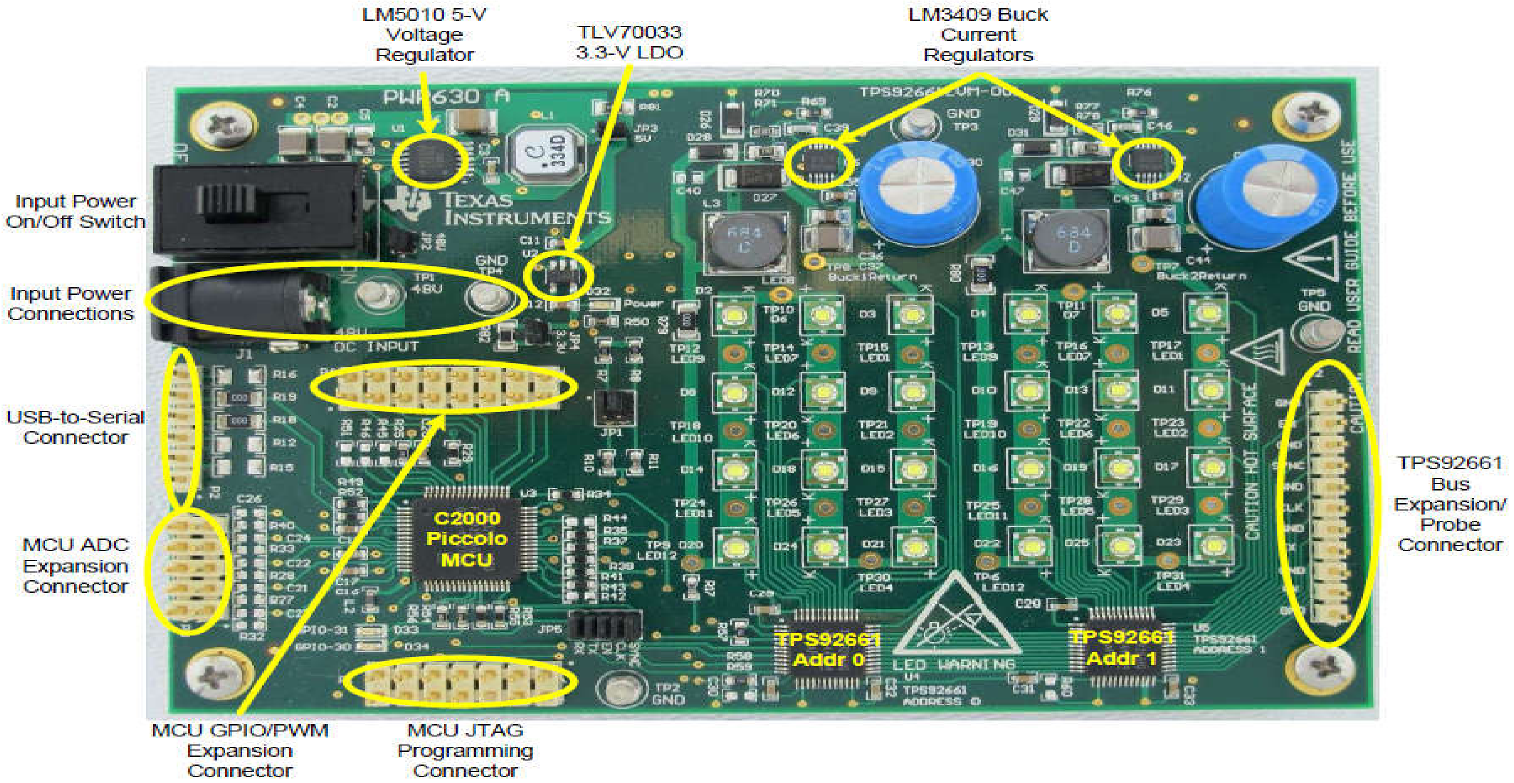
Directional beaming FAQ

LMM in Anti-Glaring Feature



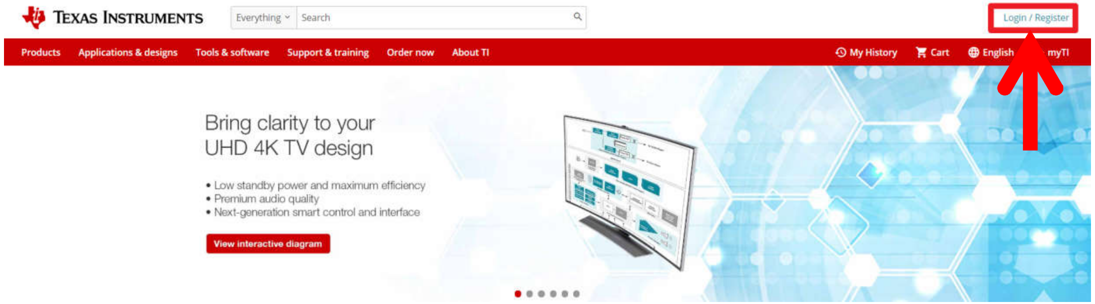
Directional beaming FAQ

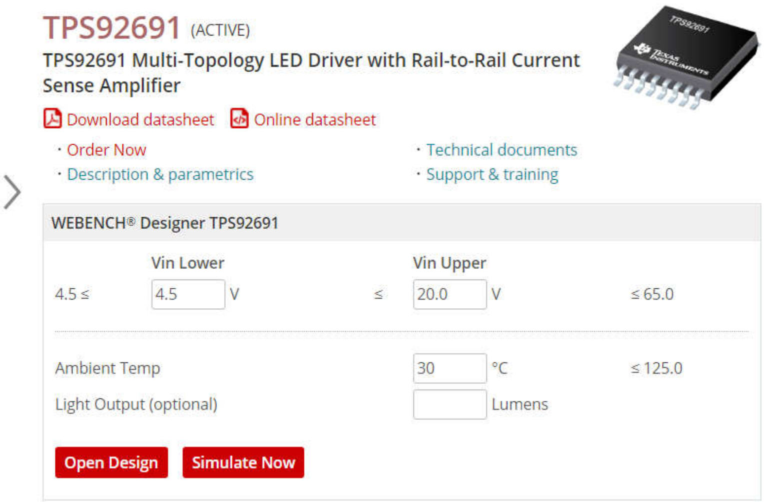
TI Matrix LED Lighting EVM

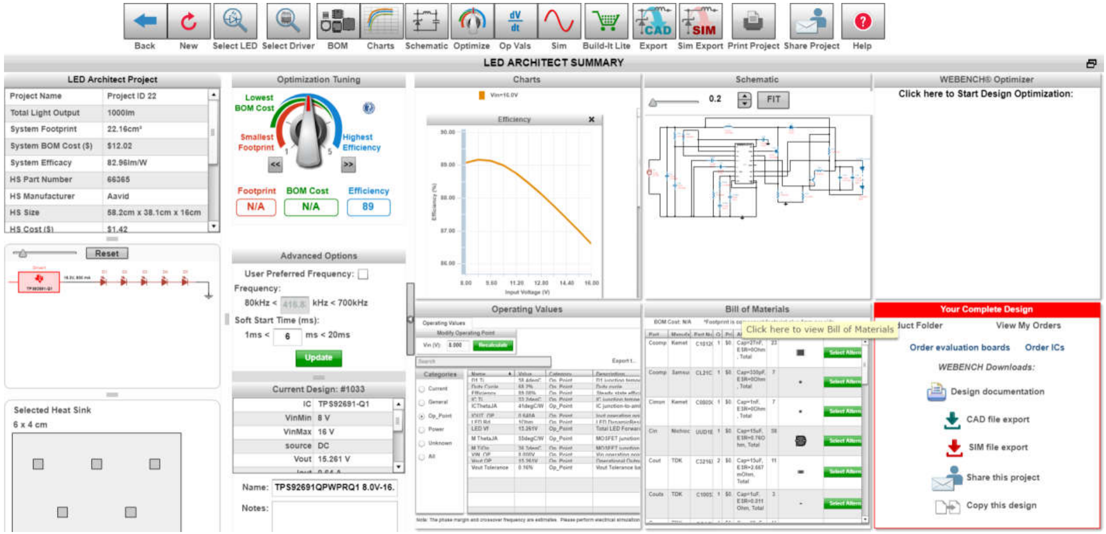


Demo EVM Board

Webench – 地上最强的线上Simulation软件







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Thank you

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