Functional Safety in Automotive Lighting Systems and Implications on IC Development

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SECURE CONNECTIONS FOR A SMARTER WORLD

Agenda

- Trends in Automotive LED Lighting applications
- NXP Multichannel Automotive LED Driver portfolio
- NXP Automotive Matrix LED Controller
- Functional Safety Support
- Design Enablement kits
- Summary

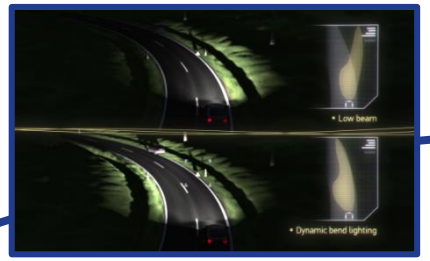
Trends in Automotive LED Lighting Applications

Advanced Driver Assistance with LED Lighting

New use cases improving safety and driver experience

Glare-free High Beam

Dynamic Front Lighting



Pedestrian Marker

Lane Marker

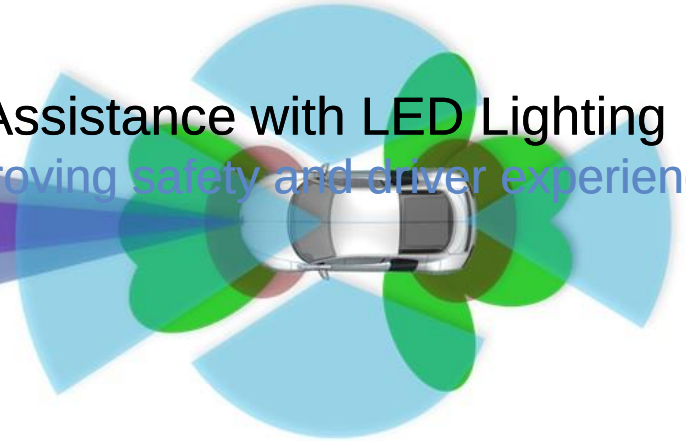
Pedestrian Communication

Dynamic (sweeping) Turn Indicator

Laser and High Current LED Spot

Dynamic Rear Lighting

HMI in Autonomous Drive



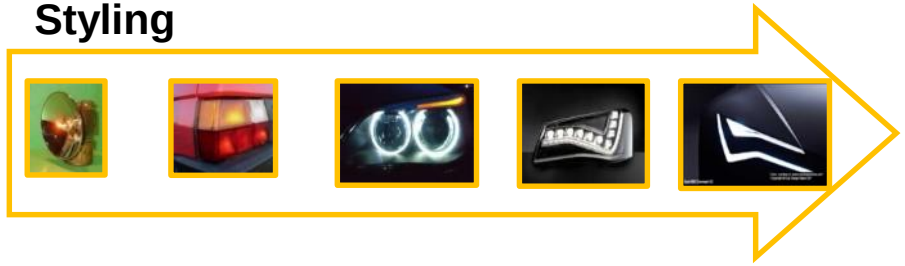
Advanced Driver Assistance with LED Lighting
New use cases improving safety and driver experience

Automotive LED Lighting

Emerging market driven by design, efficiency and innovation

Growth Drivers

Styling



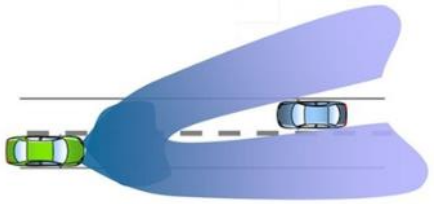
Improved efficiency

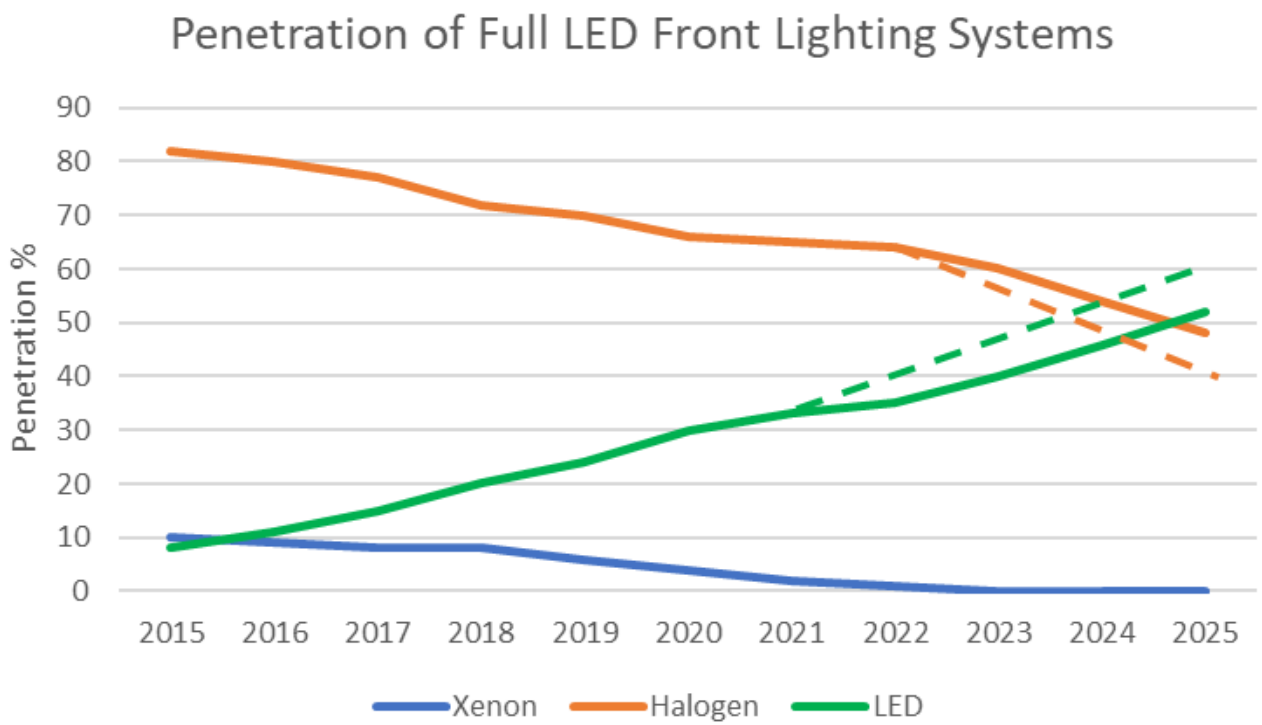
Energy Consumption*	DRL – LED	DRL – Bulb
Energy Consumption	2 x 11.4W	45.8W
CO2 – emission	**0.58g** CO2/km	**1.2g** CO2/km

50% reduction in CO_2 emissions by using LEDs*

* Source: University Of Michigan Transportation Res. Inst.

Advanced lighting options (ADAS-ADB)

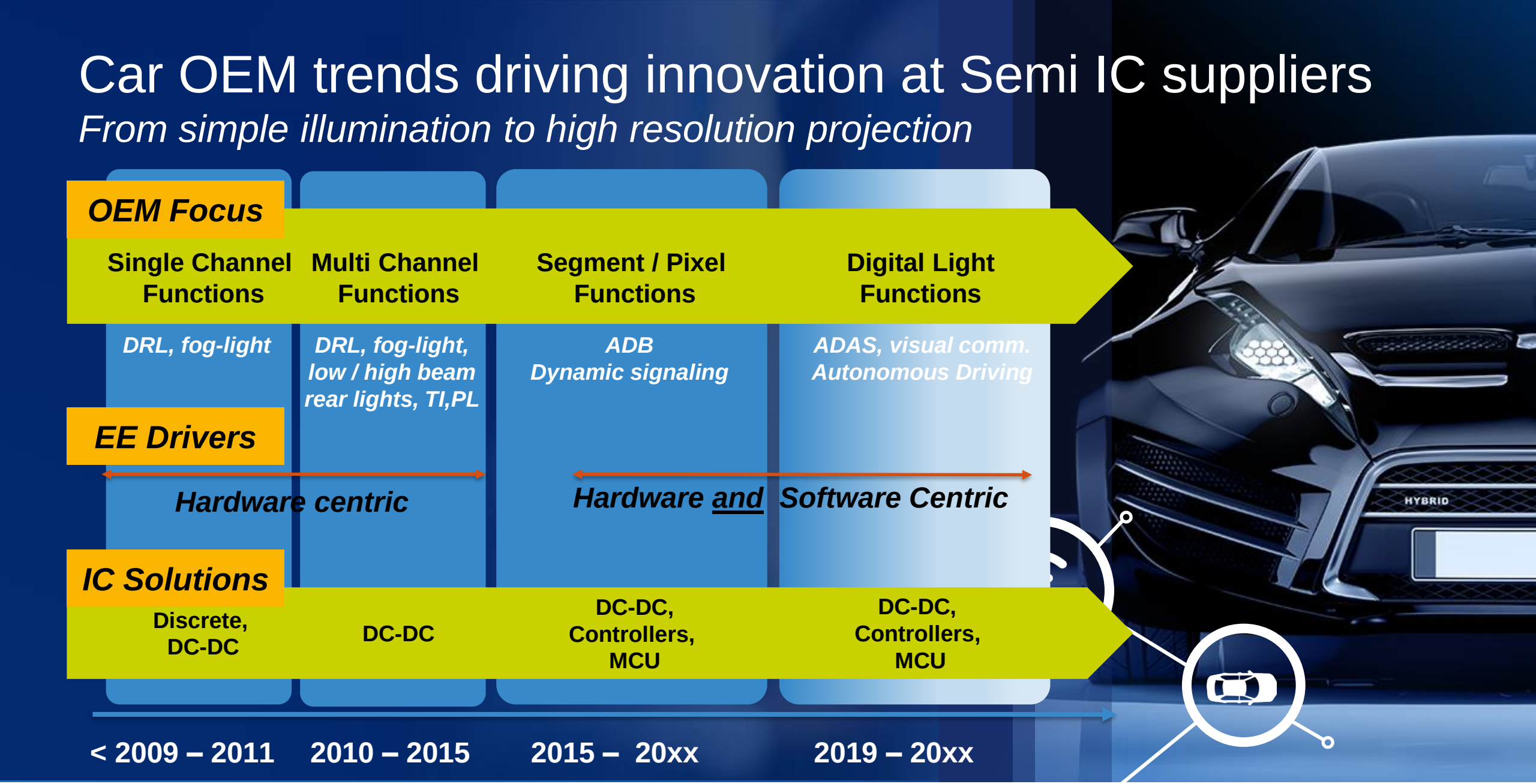




Source: Driving Vision News 2019

Car OEM trends driving innovation at Semi IC suppliers

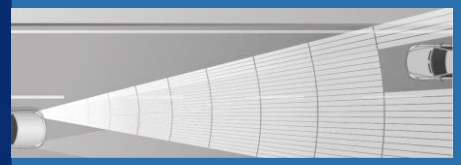
From simple illumination to high resolution projection



See push for increasing Front Lighting Beam Resolution

APPLICATIONS	MATRIX	PIXEL	*Fuzzy Space*	DIGITAL LIGHT
# LED SEGMENTS	8 – 24	80 – 120	120 – 30K	> 30K
TECHNOLOGY	SEGMENT	LED HD	µAFS	LCD, DLP + Pixel lighting
MAX CURRENT	1.5 A	800 mA		3 A, 6 A
COMM. B/W	+	++		+++
DIAGNOSTICS	+/-	++		+++
		Basic projection possible		

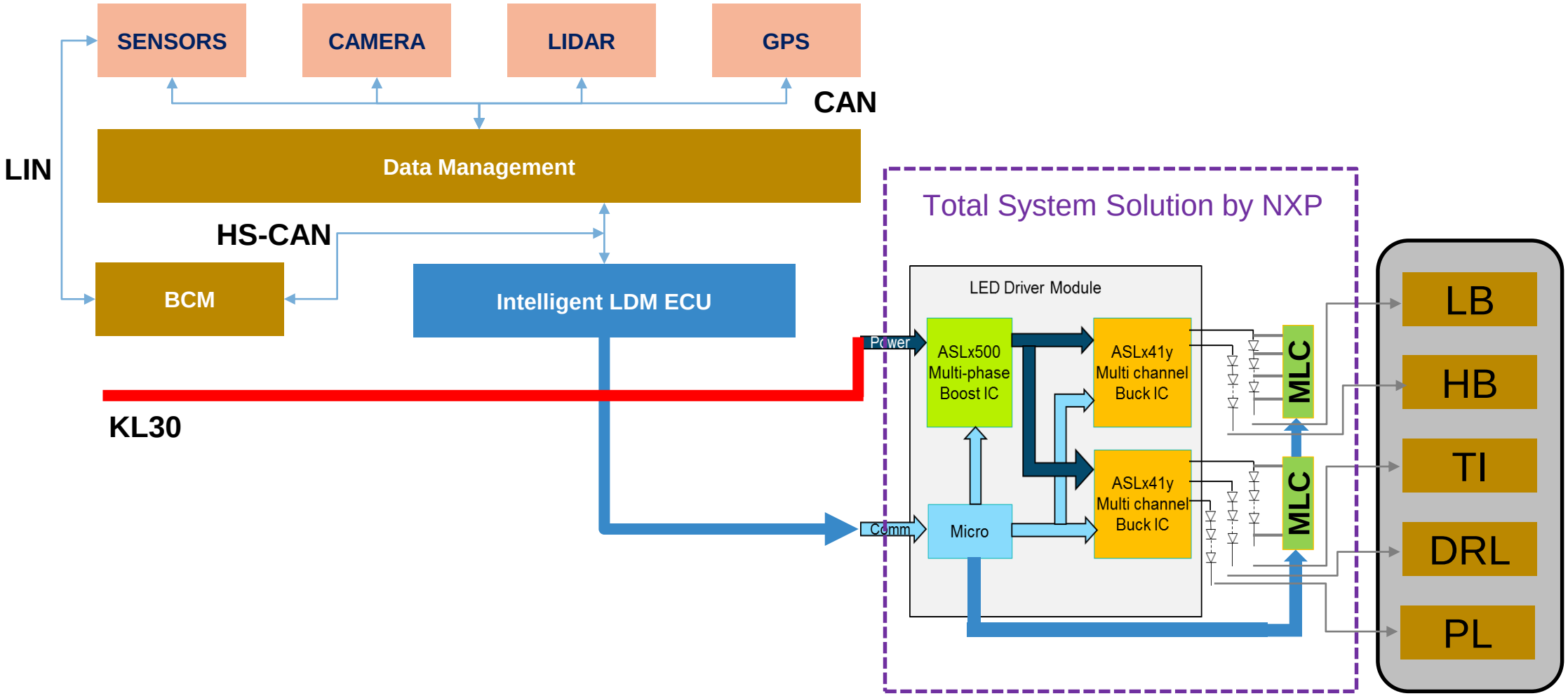
Compact / Medium
Example: Opel Astra



Premium
Example: E-Class

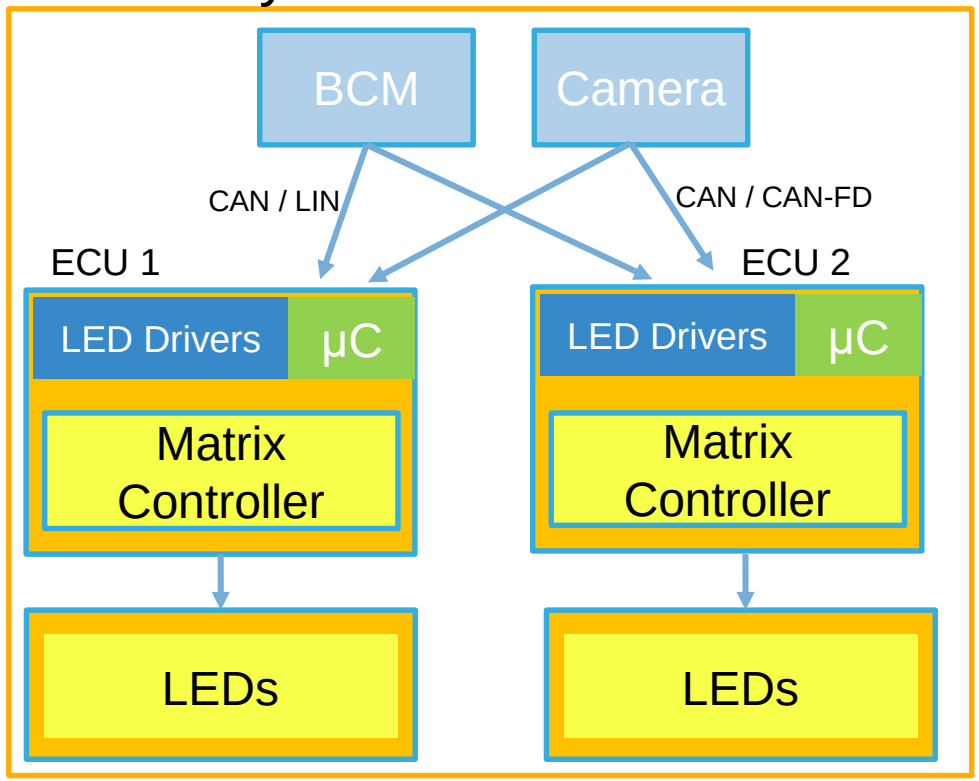
Premium
2025+

Typical system architecture for Advanced Dynamic Beam

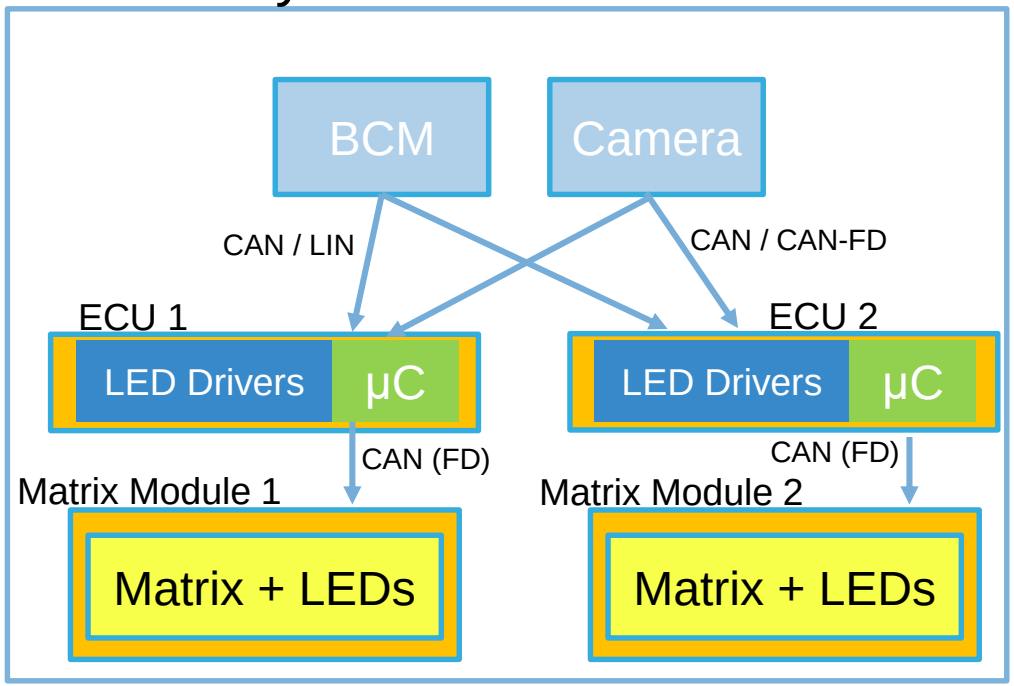


Most Common Lighting System Architecture

System Architecture 1

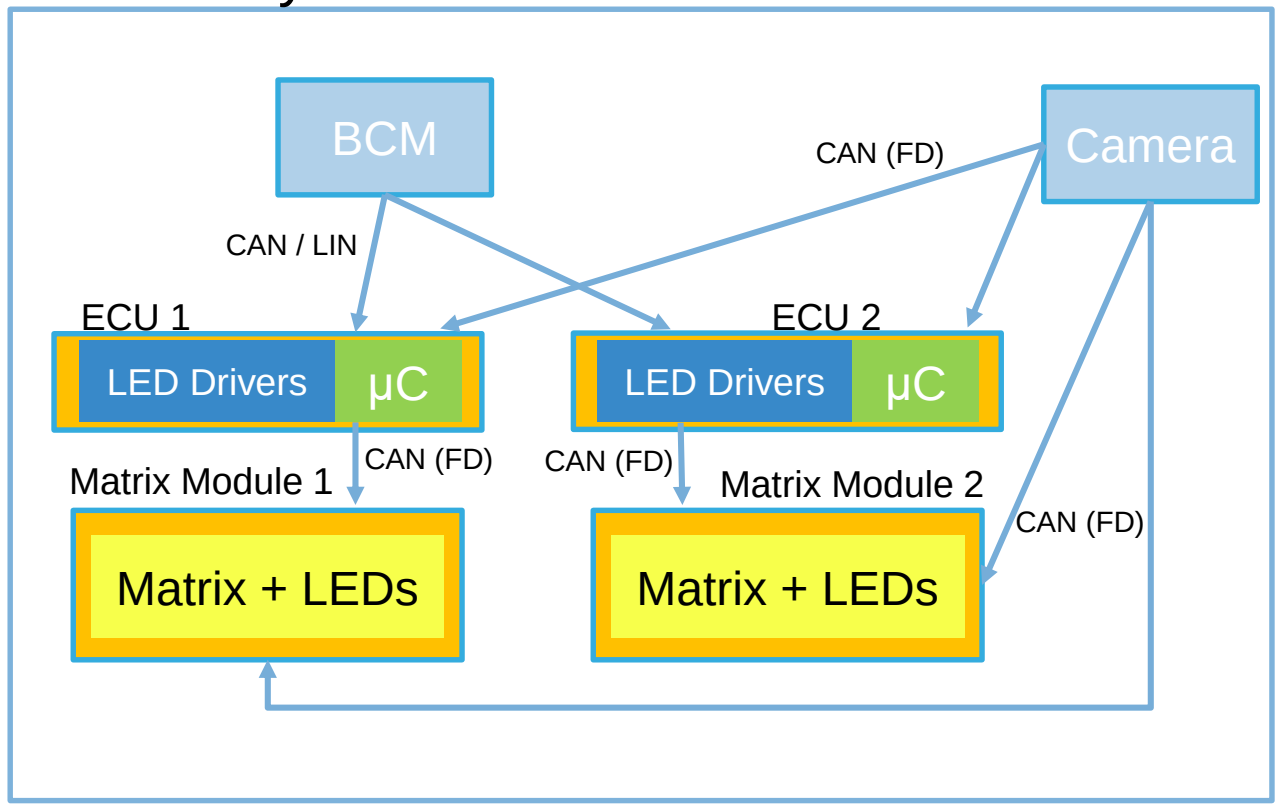


System Architecture 2



Multi Master Lighting System Architecture

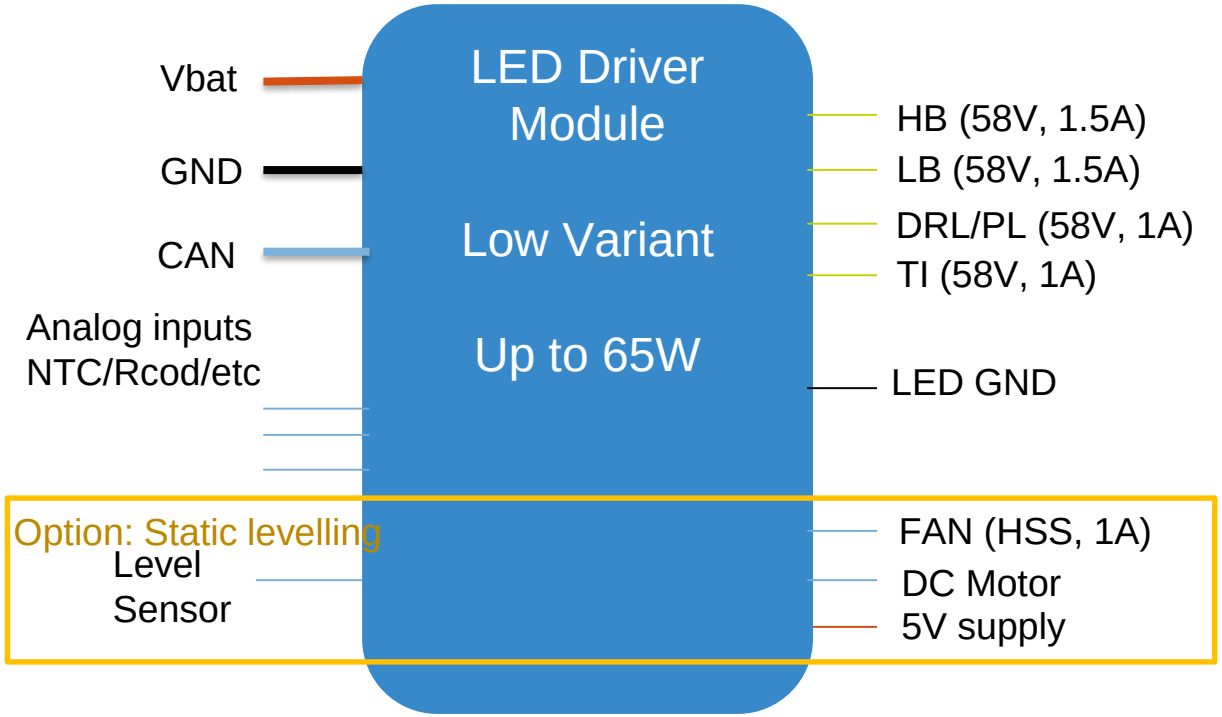
System Architecture 3

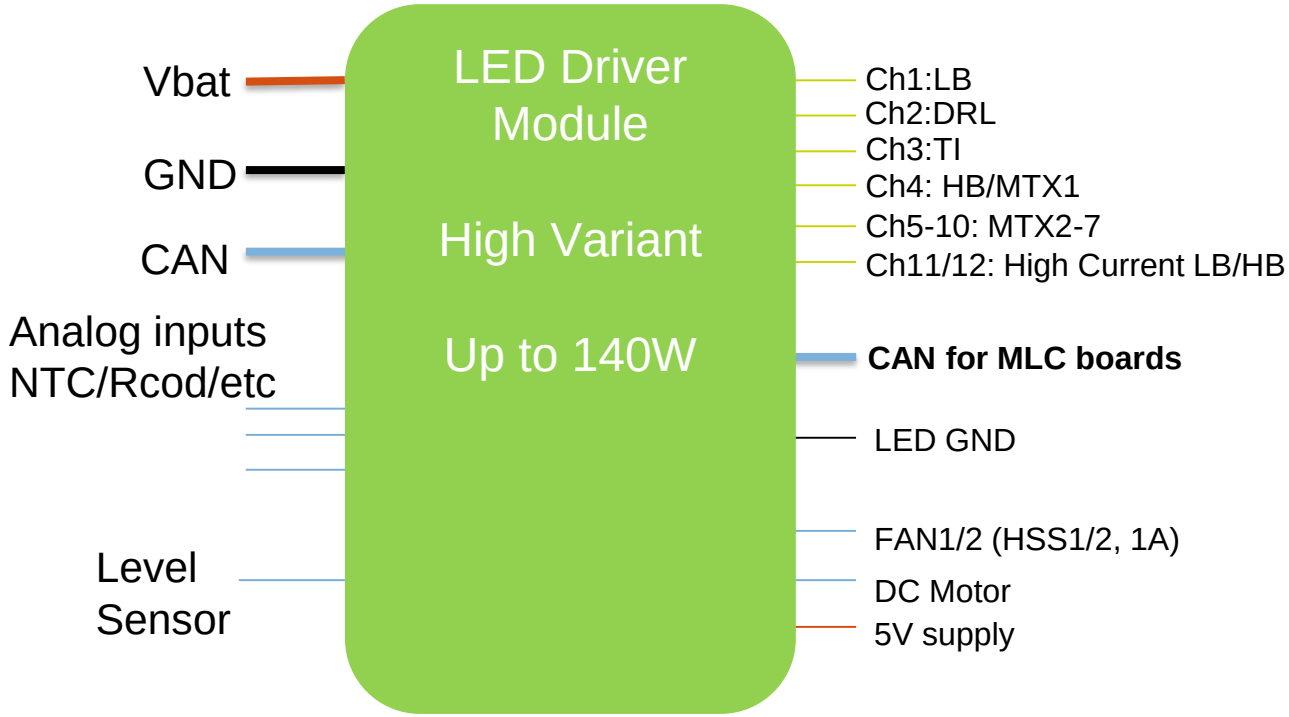


- The Matrix module is controlled by multi-masters
- The camera module not only detects the target but also control the Matrix LED controller
- Lighting ECU continue driving the diagnosis and safety requirements
- Lighting ECU also drives LHM functionality together with NXP MLC
- NXP MLC has a built in CAN controller, no extra components are required
- NXP MLC's CAN controller is ISO compliant, accepts multi-master and has a built in buss off recovery for CAN fault confinement.

General LED Driver Module Architectures

- Most car OEMs are adopting a platform approach with a high and low variant
  - The Low variant is providing basic LED functionality
  - The High variant is providing full LED functionality including ADB, Matrix, high current
- Efficiency is key for both variants due to the power range 60 – 140W





NXP Multi-Channel Auto LED drivers with Matrix Controller

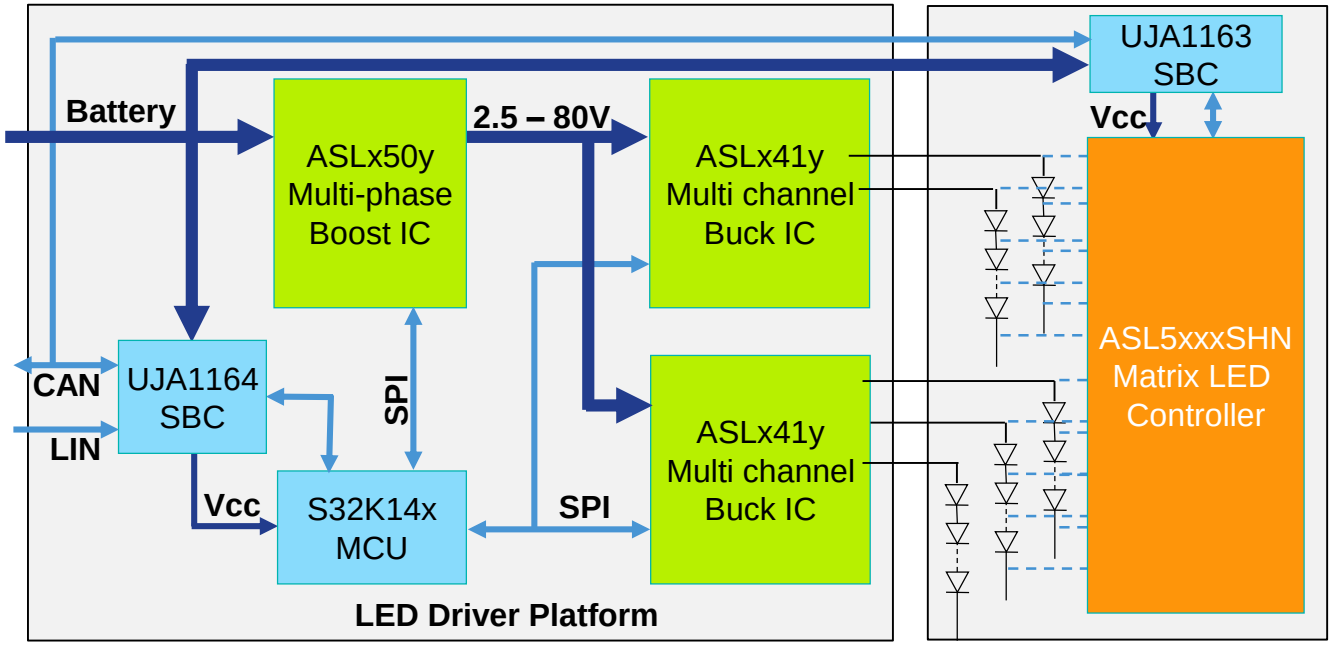
Flexible, scalable and high efficiency 70V multi-channel boost / buck LED driver platform with >1.5A per channel drive capability and thermally efficient matrix control

Differentiation

- >1.5A LED current drive per channel
- Dual voltage, multi-phase 80V boost
  - Low ripple, low system cost and high efficiency
- >87% system efficiency
- Thermally efficient, highly integrated matrix control
- 12b matrix resolution for flicker-free PWM dimming

Features

- 2.5V – 70V buck outputs
- Drives 2 – 12+ LED channels with 30 – 140W
- Flexibility to drive external FETs
  - Thermal, power, and EMC optimization
- SPI Interface for configurability, control & diagnostics
- Supports segment and matrix switching



Typical Application

6-channel headlamp

NXP Multichannel Automotive LED Driver Portfolio

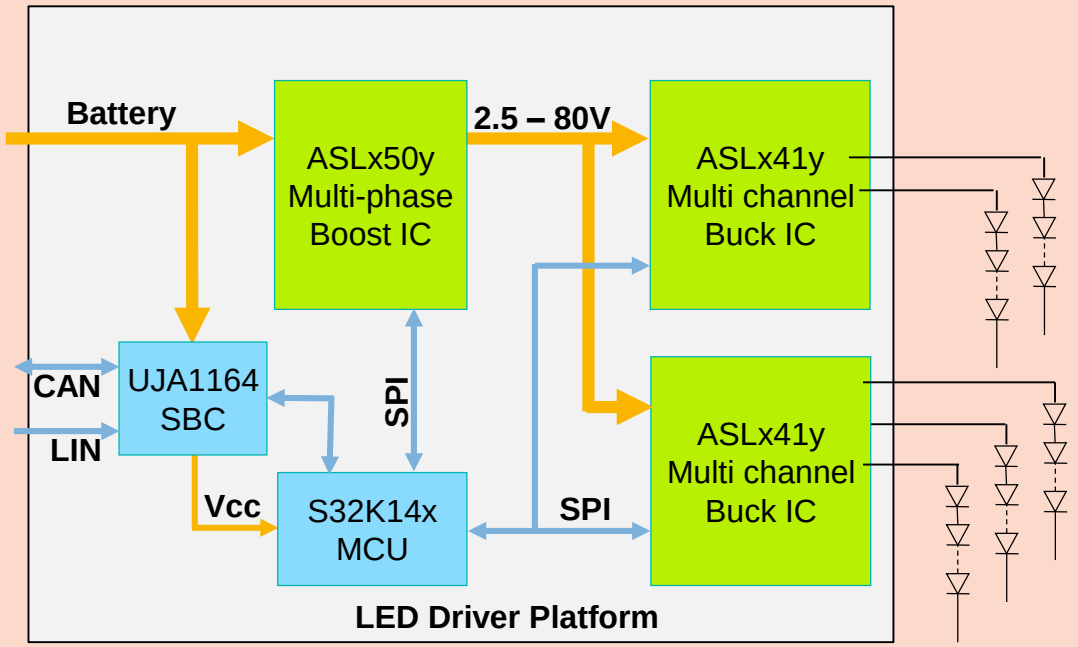
NXP Multi Channel Automotive LED drivers: Key Features

Cost effective architecture for multi-channel LED platform

Key Benefits to Customer

- **Provides Flexibility using a common architecture**
  - Drives all LED string configurations including matrix
  - SPI Interface for configurability, control and diagnostics
- **Enables Scalability with a common architecture**
  - Drives 2 – 12+ LED channels and 30 to 140W output power
  - Buck Outputs – 2.5V – 70V
  - Pin2Pin footprint compatibility including SW registers
- **Multi-phase boost stage**
  - Ensures lower ripple on battery line by adjusting output phases
  - Enables lower system cost by optimizing size of boost stage
- **2 output voltages** from boost stage
  - Optimizes system efficiency by matching output voltage to load
- Drive **>1.5A LED current** per channel
- **External FETs**
  - Enables better thermal management, EMC optimization
- **>87% overall system efficiency**

Boost followed by Buck with External FETs



ASL1500/2500/4500 – Boost Converter

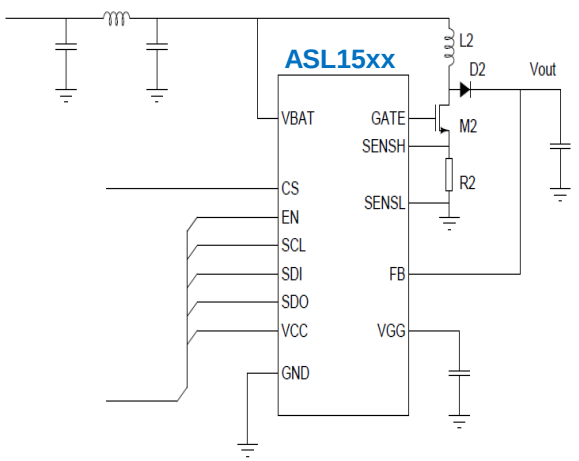
Multiphase boost converter IC with integrated SPI

- Highly integrated boost converter
- 2 independently controlled output voltages with 3% accuracy
- Programmable control loop compensation
- 5V SPI interface for control & diagnostic communication with external micro.
- Adjustable DC/DC converter frequency
- Optimize cost, efficiency, EMC performance and LED ripple current

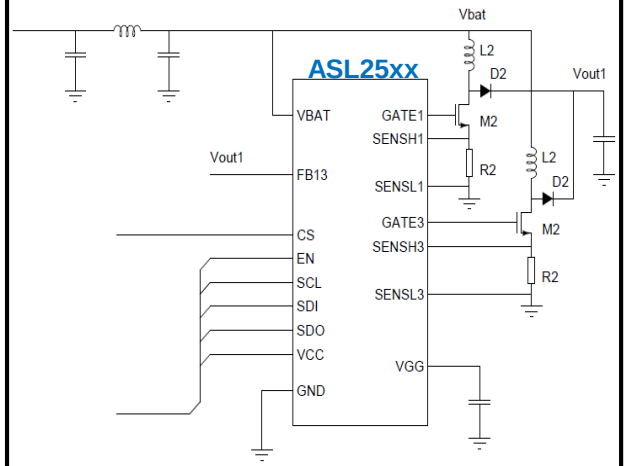
Boost Converter Portfolio

- ASL1500SHN: 1-phase Boost Converter
- ASL2500SHN: 2-phase Boost Converter
- ASL4500/1SHN: 4-phase Boost Converter
- ASL1507SHN: 1-phase Boost Converter with Limp Home Mode
- ASL2507SHN: 2-phase Boost Converter with Limp Home Mode

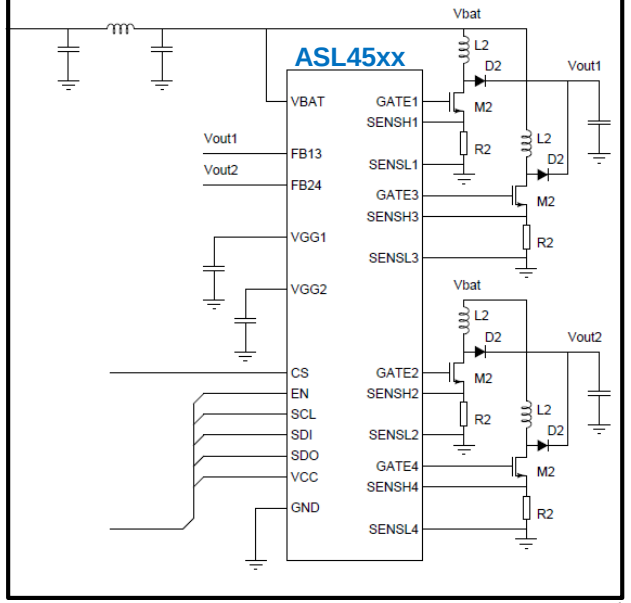
ASL15xx: 1 phase Boost converter



ASL25xx: 2 phase Boost converter



ASL45xx: 4 phase Boost converter



Released

ASL2416SHN/3416SHN – Buck Converter

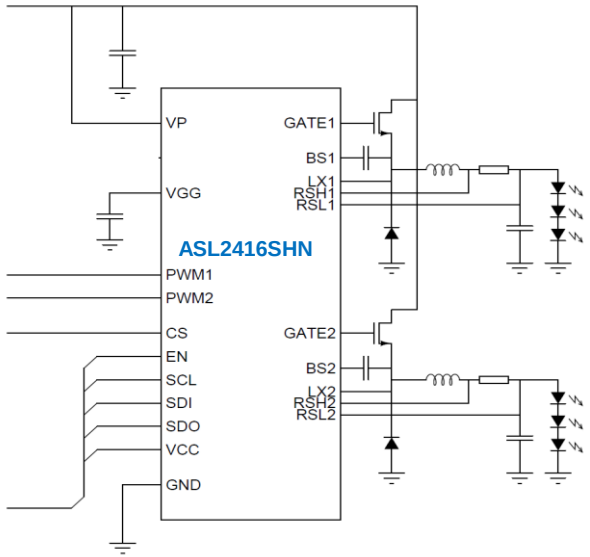
Multi-Channel Buck Mode LED drivers with integrated SPI

- A programmable hysteretic constant current buck converter
- 5V SPI interface for control & diagnostics
- Programmable LED current from 120mA to >1.5A with 5% accuracy
- PWM dimming from 0 to 100%, 0.1% resolution
- LED open and short-to-ground fault detection.

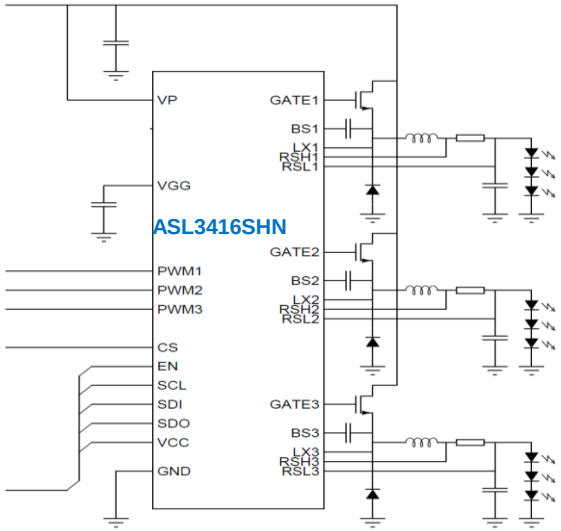
Buck LED Driver Portfolio

- ASL2416SHN: 2-channel Buck LED driver
- ASL3416SHN: 3-channel Buck LED driver
- ASL2417SHN: 2-channel Buck LED driver with Limp Home Mode
- ASL3417SHN: 3-channel Buck LED driver with Limp Home Mode

ASL2416SHN: 2 channel buck LED driver



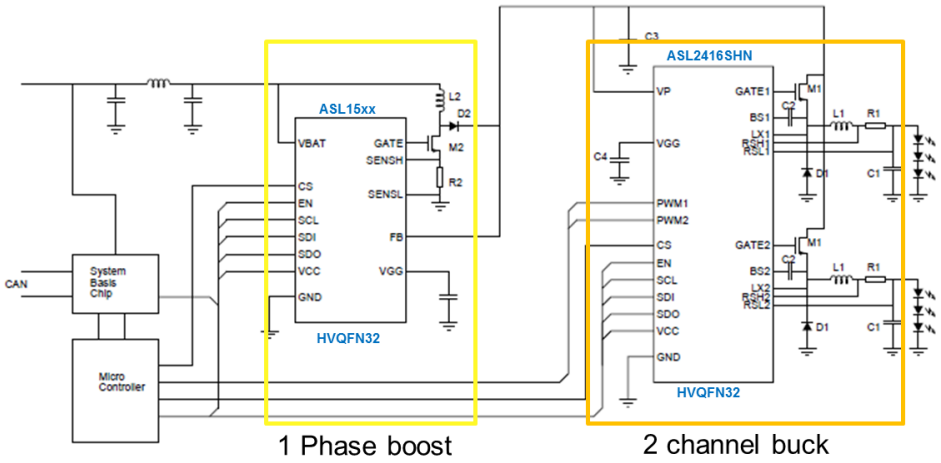
ASL3416SHN: 3 channel buck LED driver



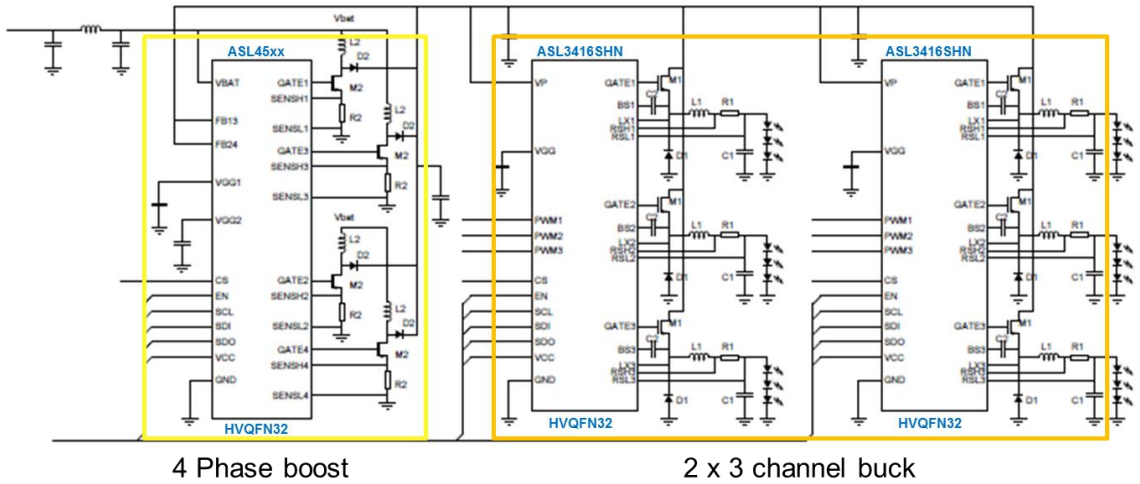
Released

NXP's Scalable Multi-channel Architecture

Typical schematic for 2 channel system ……easily scalable to 6 channel system



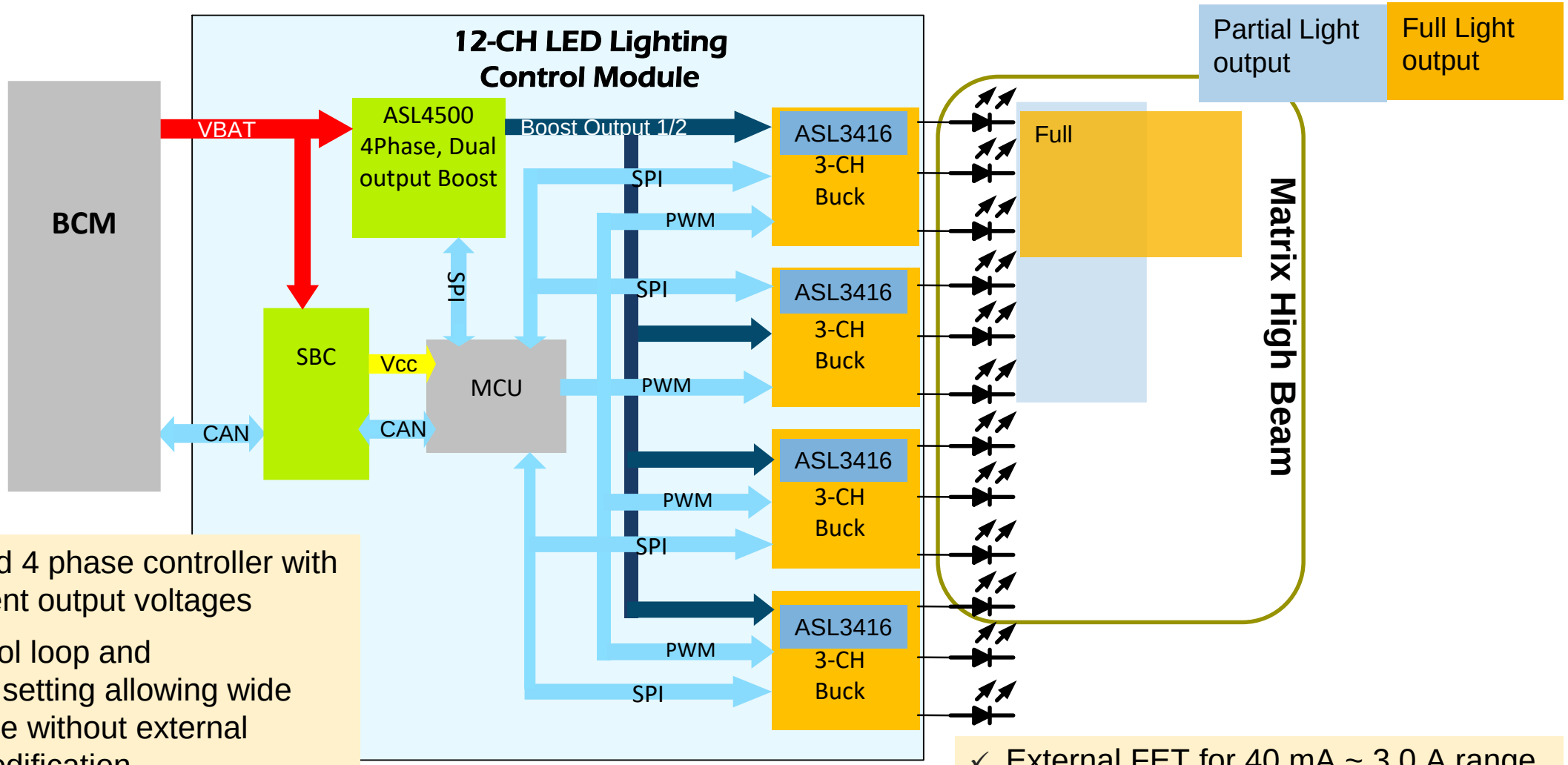
1 Phase boost 2 channel buck



4 Phase boost 2 x 3 channel buck

Achieving High Flexibility With a Common Architecture

Driving Matrix or Segment Switching (Dynamic Power Distribution)



- ✓ Fully integrated 4 phase controller with two independent output voltages
- ✓ Digitized control loop and compensation setting allowing wide operating range without external component modification

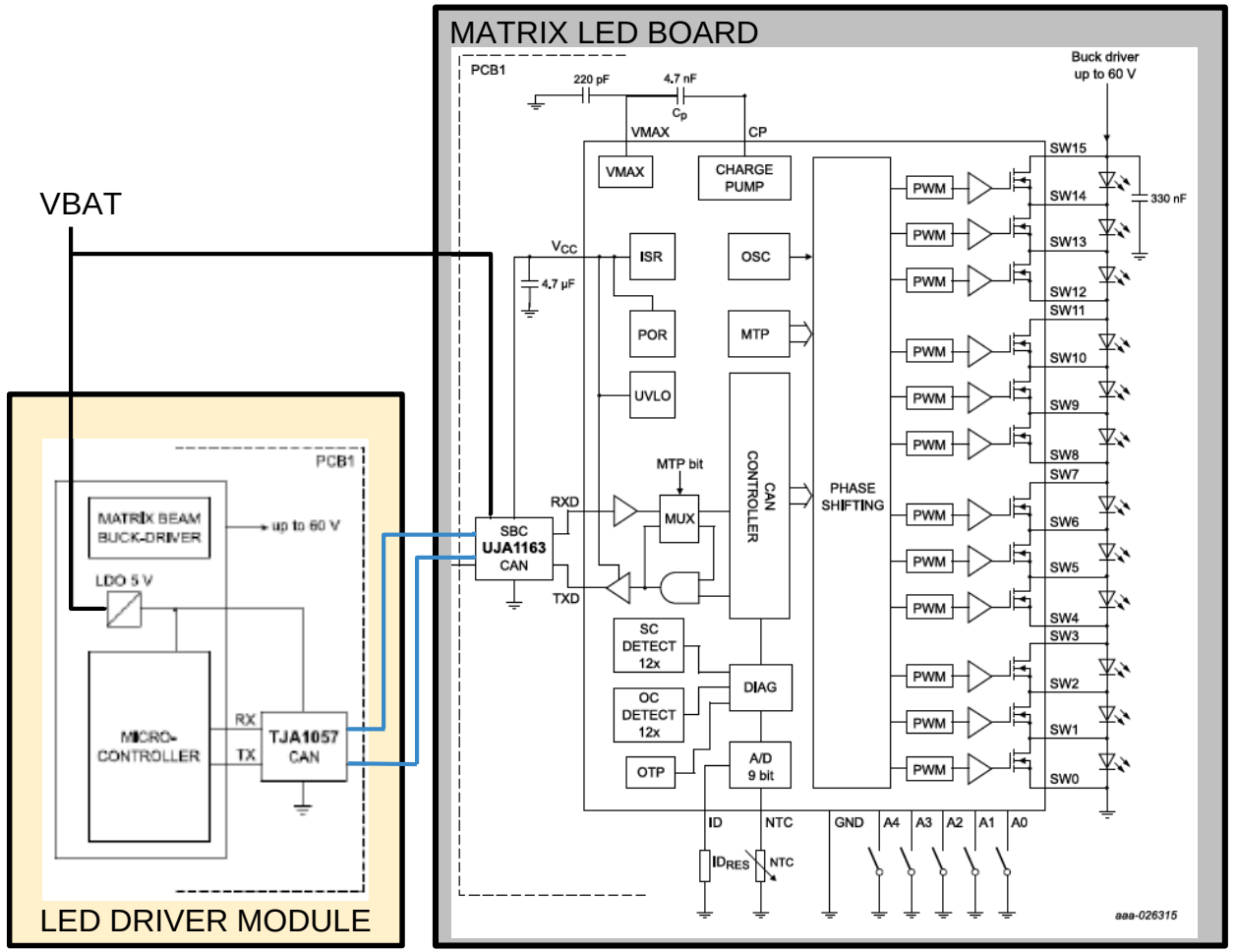
- ✓ External FET for 40 mA ~ 3.0 A range
- ✓ Asynchronous channels

NXP Automotive Matrix LED Controller

NXP Matrix LED Controller (MLC): ASL5x15 / ASL5x08

Key Features and Block Diagram

- **12 switches**, 4 floating blocks of 3 switches (individual or segments)
- **1.5A max. per Switch** (in parallel up to 6.0A) – ASL5x15SHN
- 0.8A max. per Switch (in parallel up to 3.2A) – ASL5x08SHN
- **SMART & Direct PWM** options available
- **12 bit resolution PWM** at 244Hz/488Hz allowing smooth dimming
- **Phase shifted of PWM** to avoid large peak currents when switching
- Single LED open/short detection and diagnostics with bypass feature
- Direct NTC and PCB binning resistor input
- **CAN interface** (optionally CAN FD available)
- Integrated **200MHz Oscillator**
- **Limp Home Mode** in case of communication failure
- 5 Address pins connecting up to 32 MLCs
- 5V Vcc supply and current consumption < 10mA
- **Small package outline** HVQFN36 (6x6 mm2) with wettable flanks (Optionally 48-pin QFP package variant available)

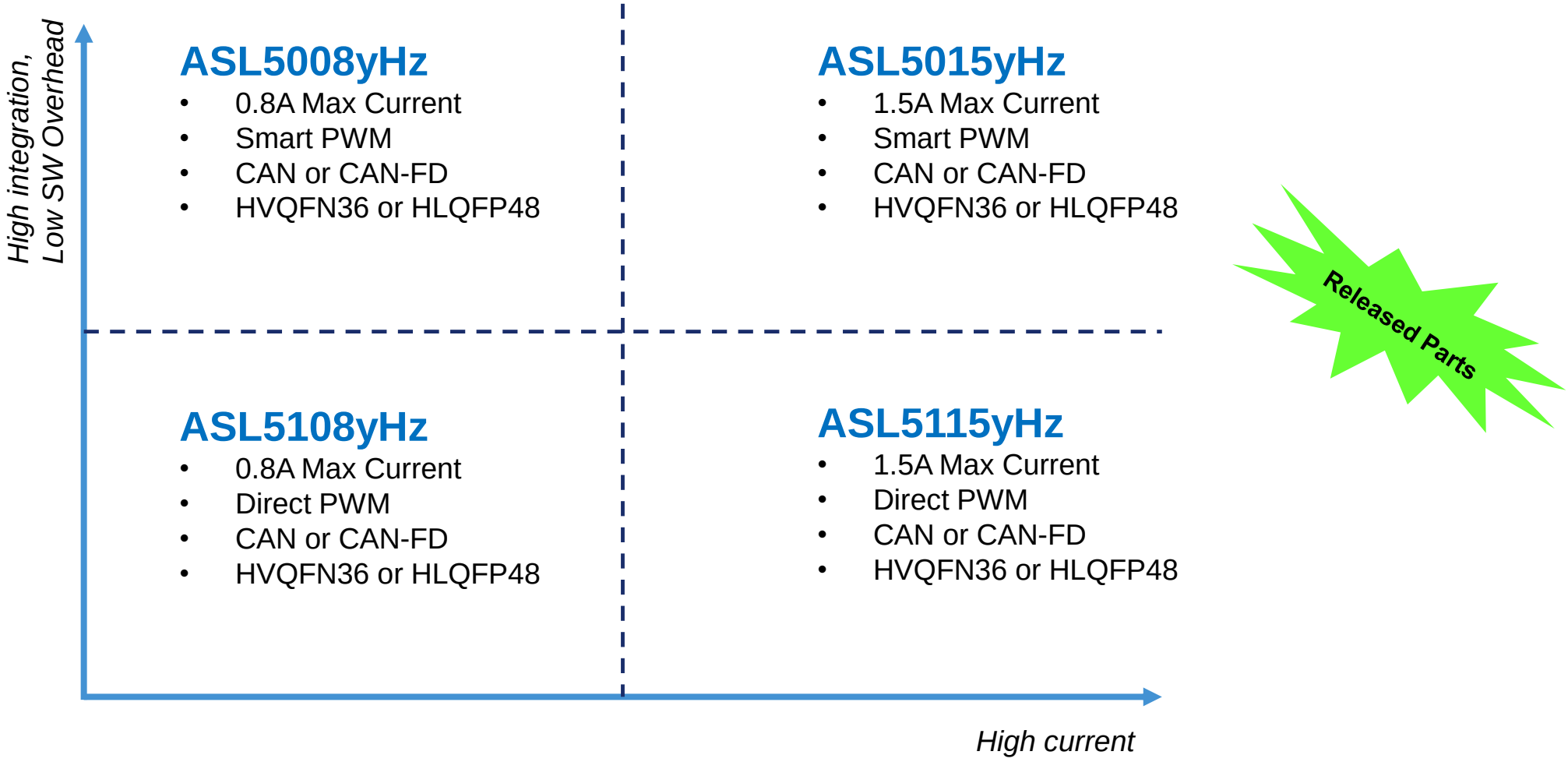


NXP Matrix LED Controller Key Benefits to Customer

Key Feature	NXP	Benefit to customer
Scalability	Integrated HW/SW	Pin2Pin compatibility and SW register maps reduces R&D effort
Oscillator	Integrated IP	BOM cost saving, no external synchronization line, improves EMC
Communication	CAN	Robust, reliable automotive communication (future proof CAN-FD)
Data Storage	embedded non-volatile memory	BOM cost saving, ease of use, highly configurable
Charge Pump	1x ext. Cap	BOM cost saving, higher FIT, increased reliability
Limp Home	Full functionality	Avoids SW work-arounds at start up
Diagnosis	Full System	Built in diagnosis, avoids external components
Slew Rate Ctrl	16x settings	Optimized EMC performance, LED string protection
Tj (Max)	175 °C	Allows maximum 1.5A LED current without triggering shut down
RDSON	100mΩ	Very low power dissipation at 1.5A, reduces cost of heat sink
QFN package Rth	2.1 K/W	Better thermal management
Ext. Components	Few	BOM cost saving

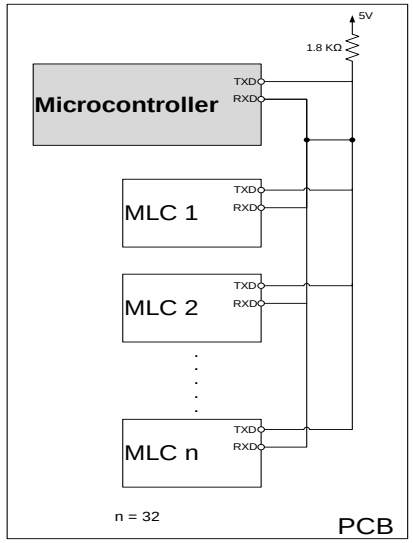
NXP MLC solutions for different ADB applications

Product matrix addressing wide range of use cases

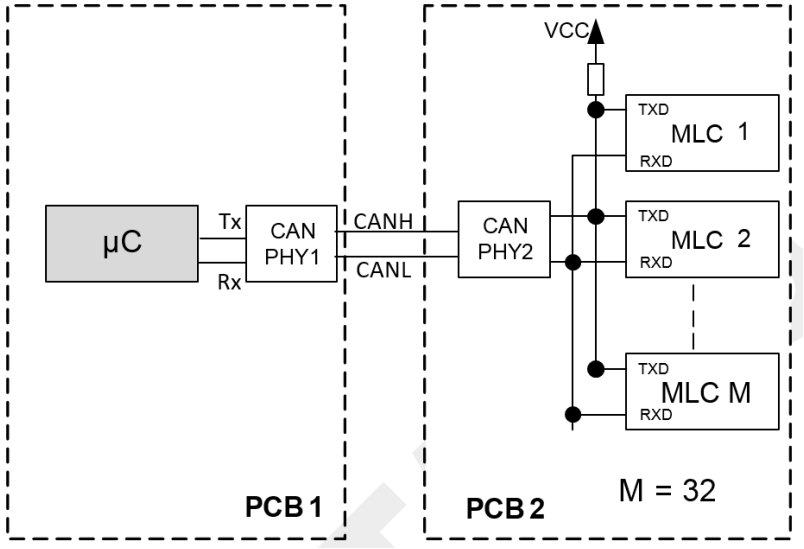


Communication interface configuration options

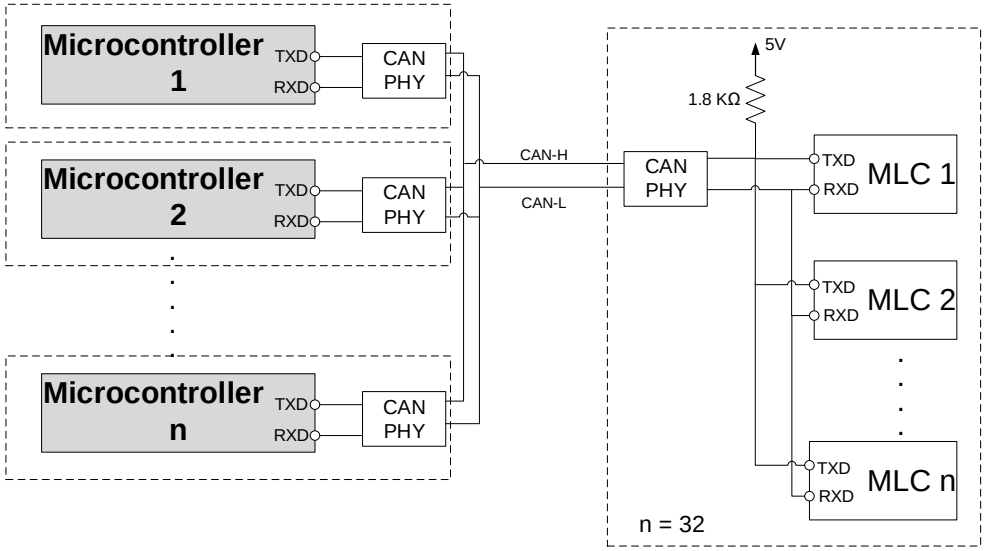
Flexible for On Board or Off Board Microcontroller



On-Board configuration



Off-Board configuration

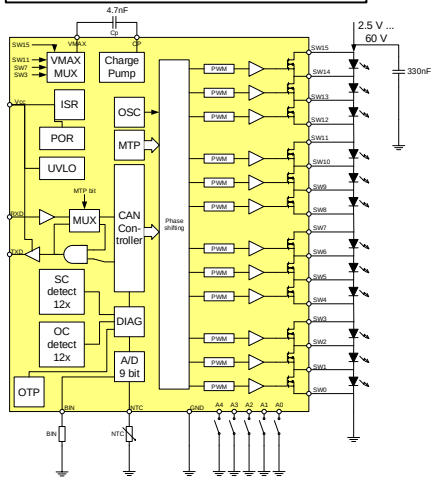


Multi-Master configuration

LED String Configurations allowing scalability

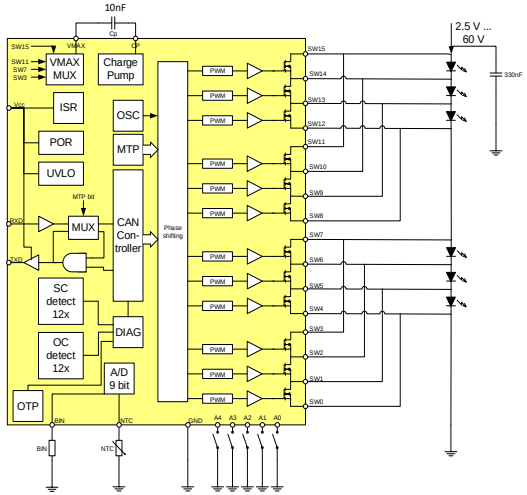
Serial vs Parallel

Serial configuration

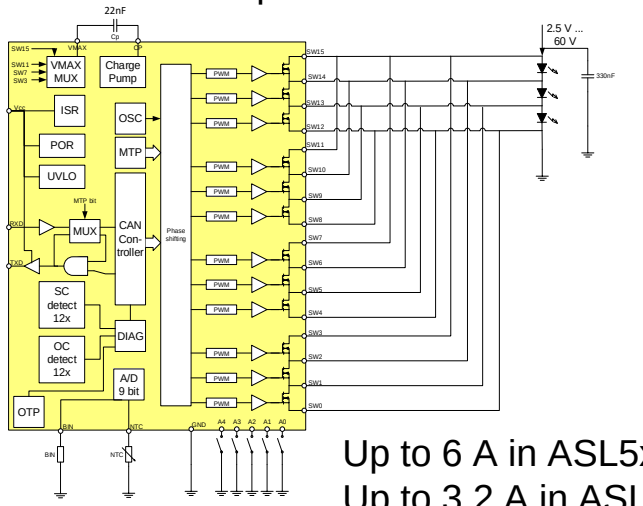


Up to 1.5 A in ASL5x15SHN
Up to 0.8 A in ASL5x08SHN

Parallel configuration

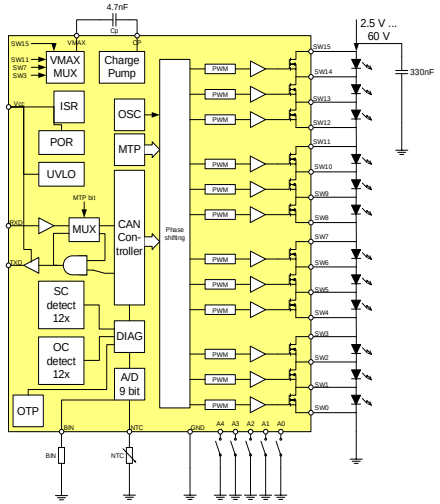


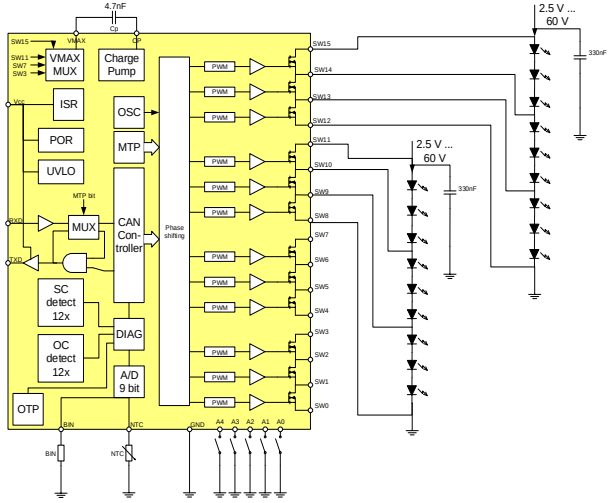
Up to 3 A in ASL5x15SHN
Up to 1.6 A in ASL5x08SHN



Up to 6 A in ASL5x15SHN
Up to 3.2 A in ASL5x08SHN

Single LED vs Segments driving





Executive Summary

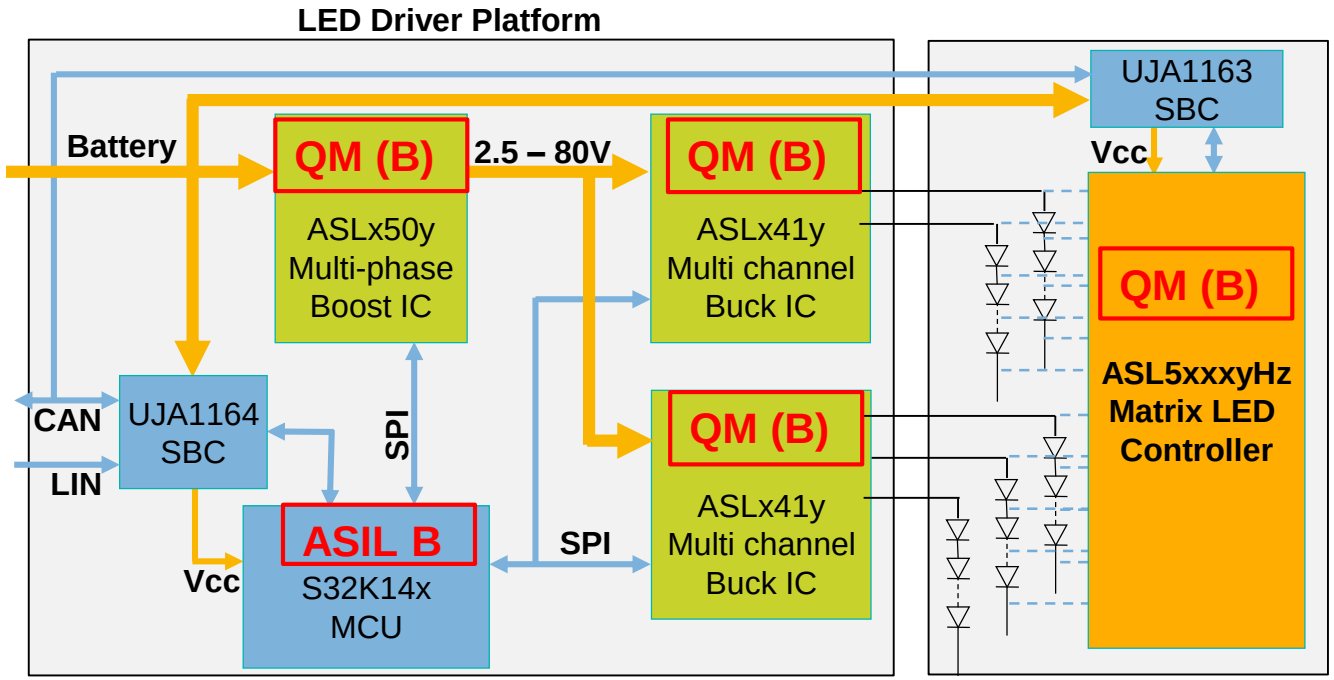
- NXP Matrix Controller offers **superior performance**, **optimized BOM** and **small** form factor
- Using **CAN(FD)** communication, we offer a **robust and fully reliable** automotive communication protocol that solves many challenges faced with UART protocols
- With a **very low Rdson**, NXP Matrix Controller offers **best in class thermal behavior** for high temperature operation
- NXP Matrix Controller offers a **12-bit resolution PWM** with < 2% bus bandwidth consumption with **SMART PWM**
- An embedded non-volatile memory **(MTP)** allows a **permanent Limp Home Mode** configuration
- **Full system diagnostic** (LEDs, IC and external components) and functional safety documentation supports **achieving ASIL-B at system level**
- NXP Matrix Controller is offered in p2p compatible, multiple current variants for **scalability**

Functional Safety Support

Functional Safety in Lighting

ASIL allocation on lighting functions:

- Low beam (with or without Matrix function)→ ASIL B
- Turn Indicator → ASIL B
- High Beam without ADB functionality → QM (Quality Managed)
- High Beam with ADB functionality → ASIL A/B



Quantify A Risk: ASIL definition – Example on lighting system

S= Severity E= Exposure C= Controllability

		C1 – SIMPLE	C2 – NORMAL	C3 – DIFFICULT
S1 LIGHT		QM	QM	QM
	E2 (low)	QM	QM	QM
	E3 (medium)	QM	QM	A
	E4 (high)	QM	A	B
S2 SEVERE		QM	QM	QM
	E2 (low)	QM	QM	A
	E3 (medium)	QM	A	B
	E4 (high)	A	B	C
S3 FATAL		QM	QM	A
	E2 (low)	QM	A	B
	E3 (medium)	A	B	C
	E4 (high)	B	C	D

(QM: "quality managed" → no requirements from standard applied explicitly)

S3: If light is not available during night driving, the result might be fatal
E2: The hazardous situation is only during night time
C2: More than 90% of driver should be able to control the situation (Redundancy = 2 HL)

Reduce The Risk: Track And Understand The Failures

Car OEM

SET SYSTEM **RISK CRITICITY** (HAZARD ANALYSIS) ASIL A, B, C or D
DEFINE **SAFETY GOALS**

Tier1 & NXP

IMPLEMENT M**EASURES** TO **REDUCE RISK OF FAILURE**
ANALYZE DIFFERENT TYPE OF FAILURES (AS MUCH AS POSSIBLE)

Avoid **SYSTEMATIC FAILURES** during development

- Process
- Safety management
- Best practices
- Lessons learned
- Verification & validation

Reduce, Control **RANDOM FAILURES** during operation

- System safe state
- Safety architecture
- Quantitative & qualitative analysis
- Documentation

Functional safety in lighting – Safety Goals

Safety goals are always applicable at item level (full lighting system) but not all them affect the same sub-systems, ICs or IPs inside our devices.

NOTE: The **A**utomotive **S**afety **I**ntegrity **L**evel (ASIL) is always allocated to functions **NOT** to ICs.

ASSUMED SAFETY GOALS ON LED DRIVING MODULE (LDM)

SG001 Avoid wrong light intensity when the light function is on
SG002 Avoid light output when the light function is off
SG003 Allow fast system availability. The light sources shall be turned on and off fast enough
SG004 A fail of the turn indicator shall be detected

ASSUMED SAFETY GOALS ON MATRIX MODULE (MLC module)

SG001 Avoid Light sources (LED or segment) are unintendedly bypassed or unintendedly released

How is NXP supporting functional safety in lighting?

FMEDA

Support documentation for QM (B):

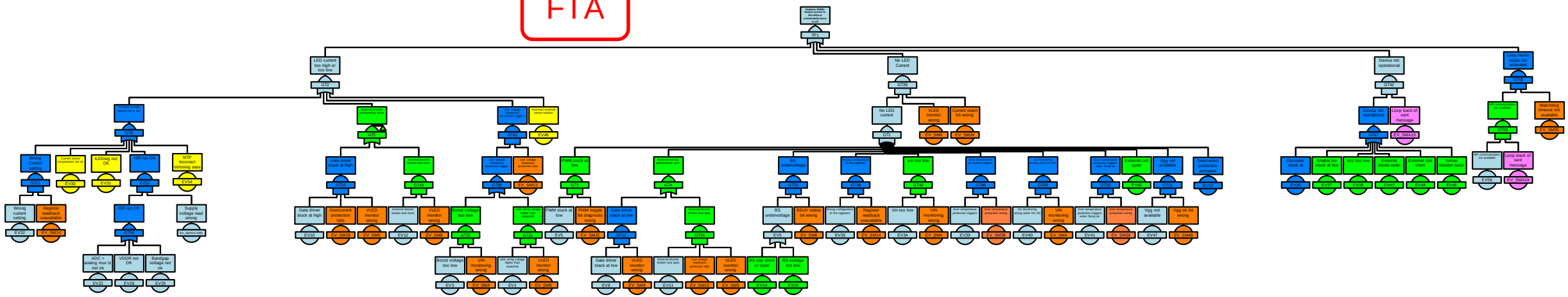
- FMEDA
- FTA
- DFA
- Safety Application notes *
- FIT rate calculation *

* Available in DocStore for LED drivers and MLC

λ	Failure mode	Failure mode that has the potential to violate the safety goal in absence of safety mechanism?	Failure rate distribution	Failure mode rate	Applicable Safety mechanism	Safety Mechanism(s) allowing to prevent the failure mode from violating the safety goals	ISO 26262	Failure mode coverage wrt. violation of safety goals	SPFM = 93,22% Residual of single point fault failure rate/FIT
0,018	Voltage reference too high	Yes	25,0%	0,004	SM5 + SMA21	Input voltage measurement on VIN voltage	D.2.1.1 Mechanisms of input-voltage or current Technique + D.2.1.2 Mechanisms of output-voltage or current Technique	90%	0,0004
0,018	Voltage reference too low	Yes	25,0%	0,004	SM5 + SMA21	Input voltage measurement on VIN voltage	D.2.1.1 Mechanisms of input-voltage or current Technique + D.2.1.2 Mechanisms of output-voltage or current Technique	90%	0,0004
0,018	Voltage reference oscillation inside reference range (noise)	No	25,0%	0,004		#N/A	#n/a	#N/A	0,0000
0,018	Voltage reference oscillation outside reference range (noise)	No	25,0%	0,004		#N/A	#n/a	#N/A	0,0000
0,174	ADC output data stuck at full scale value	Yes	20,0%	0,035	SMA19	Loop back of sent SPI messages (External SM)	D.2.7.9 Read back of sent message	90%	0,0035
0,174	ADC output data stuck at 0 value	Yes	20,0%	0,035	SM5 + SMA21	Input voltage measurement on VIN voltage	D.2.1.1 Mechanisms of input-voltage or current Technique + D.2.1.2 Mechanisms of output-voltage or current Technique	90%	0,0035
0,174	Wrong Conversion	Yes	20,0%	0,035	SM5 + SMA21	Input voltage measurement on VIN voltage	D.2.1.1 Mechanisms of input-voltage or current Technique + D.2.1.2 Mechanisms of output-voltage or current Technique	90%	0,0035
0,174	Conversion inaccurate (offset)	Yes	20,0%	0,035	SM5 + SMA21	Input voltage measurement on VIN voltage	D.2.1.1 Mechanisms of input-voltage or current Technique + D.2.1.2 Mechanisms of output-voltage or current Technique	90%	0,0035
0,174	Conversion time too long	No	20,0%	0,035		#N/A	#n/a	#N/A	0,0000
0,076	Regulated Output in overvoltage	Yes	16,7%	0,013	SM5 + SMA21	Input voltage measurement on VIN voltage	D.2.1.1 Mechanisms of input-voltage or current Technique + D.2.1.2 Mechanisms of output-voltage or current Technique	90%	0,0013
0,076	Regulated Output in under voltage	Yes	16,7%	0,013	SM5 + SMA21	Input voltage measurement on VIN voltage	D.2.1.1 Mechanisms of input-voltage or current Technique + D.2.1.2 Mechanisms of output-voltage or current Technique	90%	0,0013
0,076	Regulated Output affected by spikes	No	16,7%	0,013		#N/A	#n/a	#N/A	0,0000
0,076	Incorrect start-up time	No	16,7%	0,013		#N/A	#n/a	#N/A	0,0000
0,076	Regulated Output Oscillation inside regulation range	No	16,7%	0,013		#N/A	#n/a	#N/A	0,0000
0,076	Regulated Output Oscillation outside regulation range (incl. drift)	No	16,7%	0,013		#N/A	#n/a	#N/A	0,0000

Safety Goal or Requirement | System Assumptions | Block Failure Rate | FMEDA | Function_FailureMode_Catalog | Metrics_summary | Safety Mechanisms

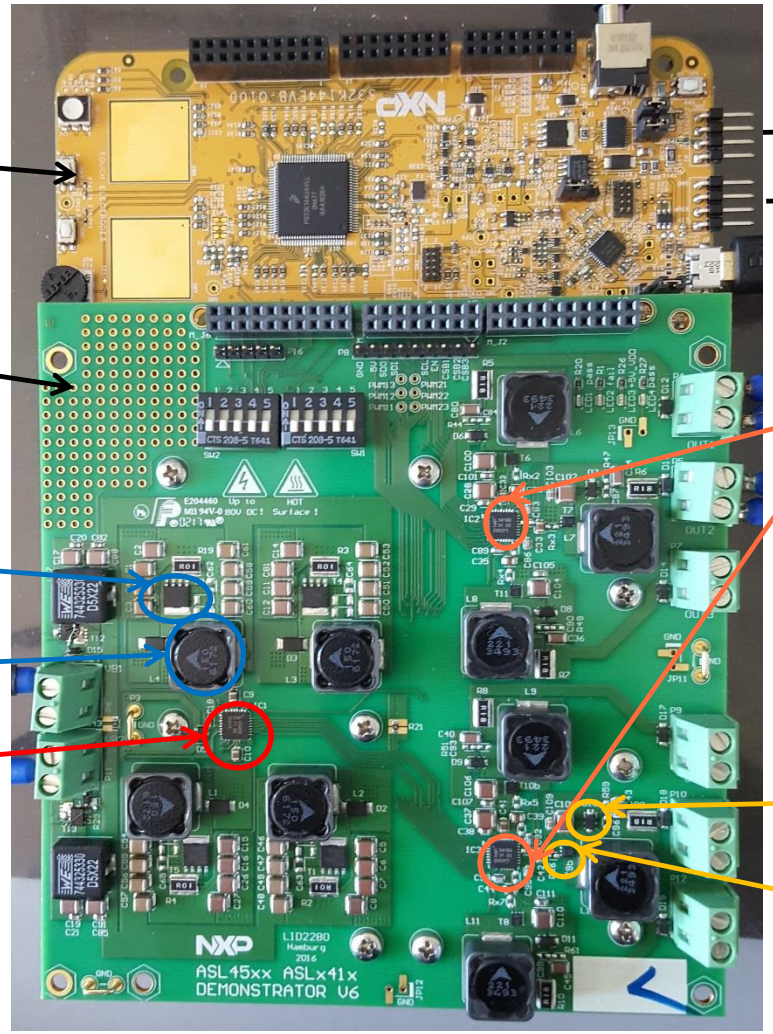
FTA



Design Enablement Kits

NXP Multi-channel Driver Evaluation Board

Complete system solution from NXP

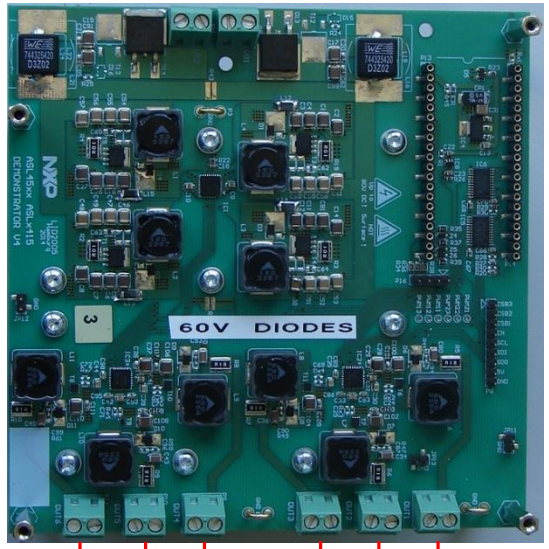


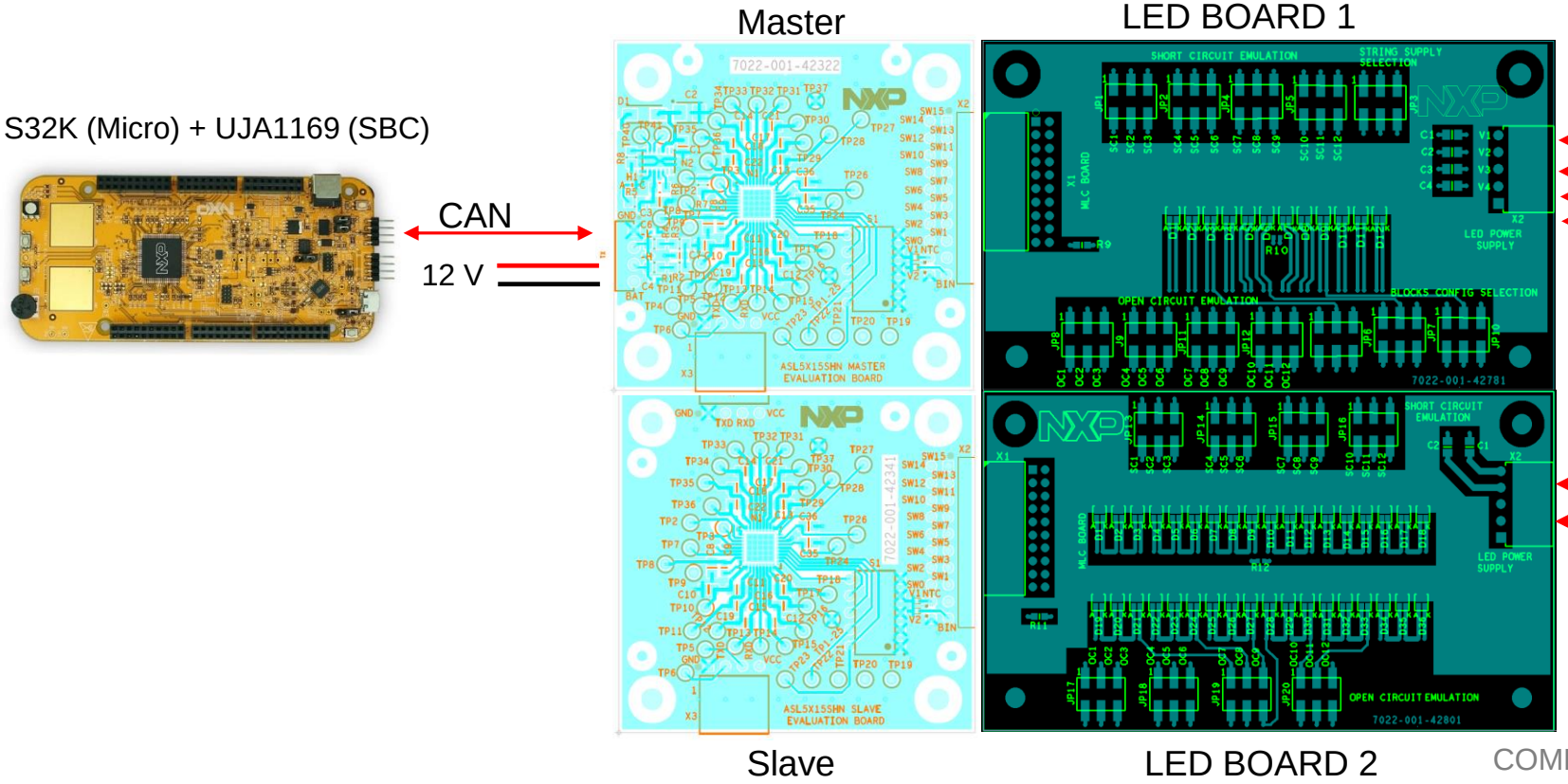
Complete System Solution from NXP enabling easy design in

- Reference design based on
  - 6-channel / 120W LED driver board
  - Master / Slave Matrix LED driver board
  - S32K MCU, SBC, LEDS
- Basic SW drivers to run front lighting scenarios

Multichannel LED Driver Evaluation Board

1 x ASL4500SHN
2 x ASL3416SHN





Technical Information and Support Tools

	Availability
• Datasheet	
• Application notes and silicon notes	
• System emulation tools – based on EXCEL	
• DBC file for CAN network simulation	
• CANoe System Emulations	
• Reference HW design	
• Reference software	
• Drivers for our LED drivers and Matrix controllers	
• Libraries for S32K Microcontroller	
• Multichannel LED drivers and Matrix Controllers Evaluation boards	

Summary

NXP Auto SSL Product Portfolio

Key take-away - Key features and benefits

- Multi-channel LED driver solution
  - Scalable & flexible platform solution → low system cost & R&D throughput time
  - External buck FET → Allows >1.5 A per channel, optimized thermal solution
  - Independent & multiphase boost output → improved system efficiency

- Matrix LED Controller
  - 12 switches, 4 floating blocks, 1.5A LED current → better thermal performance
  - 12 bit PWM resolution with SMART PWM option → high configurability
  - CAN (FD) interface with minimum data transmission → fast and reliable communication
  - Emulation board available now, released samples available now!

Summary: NXP Value Proposition as Lighting Solution Partner

- **Global R&D Footprint** to guarantee Automotive Quality, robustness and high volume production
- **Global Support Structure** operating with regional teams to provide outstanding local support
- Highly **flexible** and **scalable** solution suitable for platform design in approach
- Able to drive a **wide operating range** covering multiple applications
  - High current LEDs, OLEDs, Laser diodes, Matrix
- **Low** system cost solution
  - Few external components compared to existing analog solutions
  - Integrated crystal oscillator and embedded non-volatile memory for driving Matrix
- **Total solution** including LED Drivers, Matrix Controller, SBC, Microcontroller.
- Dedicated **Customer Support Team**, SW libraries to ease design in effort

SECURE CONNECTIONS
FOR A SMARTER WORLD