AUTOMOTIVE LIGHTING
Rear Lamp Development and Production

Università degli Studi di Padova – SSIE 2015

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Audi R8 LMX Laser based Headlamp Application
World Premiere 2014

Audi R8: 3 Generations of Pioneering New Technology

2008 – Audi R8
World first Full-LED headlamp

2012 – Audi R8 FL
Facelift Full-LED headlamp

2014 – Audi R8 LMX
World Premier Laser Headlamp

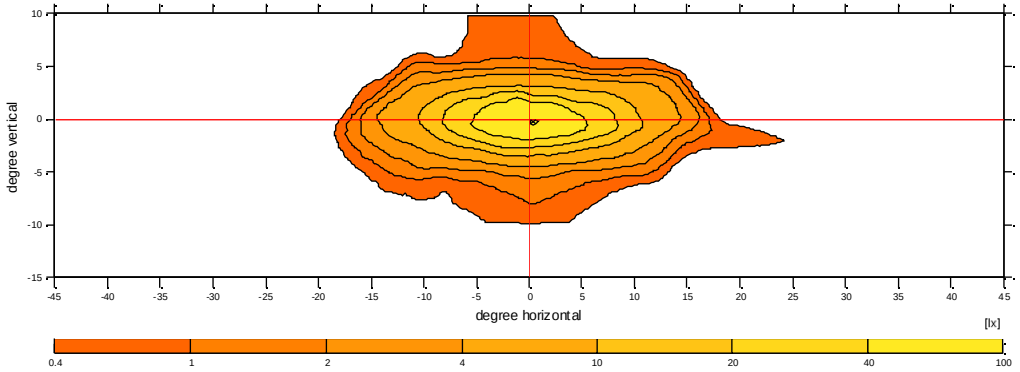
Laser Headlamp Audi R8 LMX

Official Presentation Audi R8 LMX

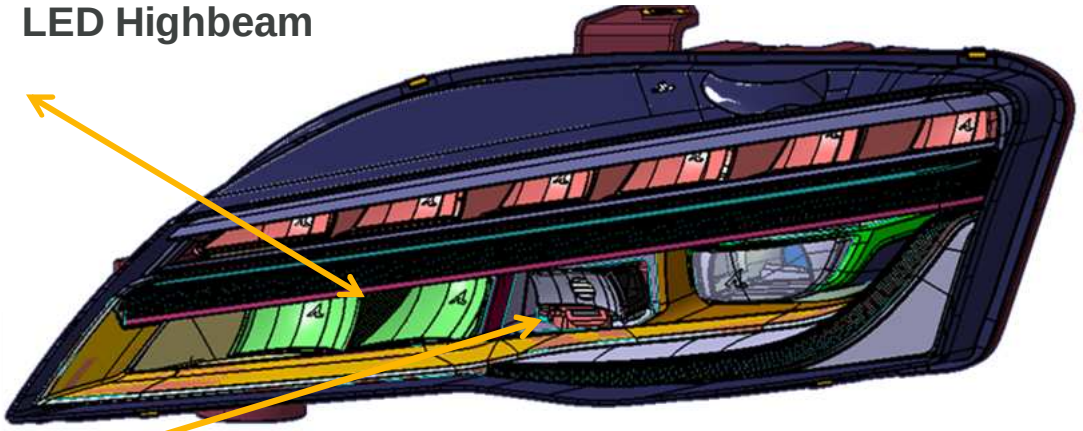
LeMans, June 13, 2014

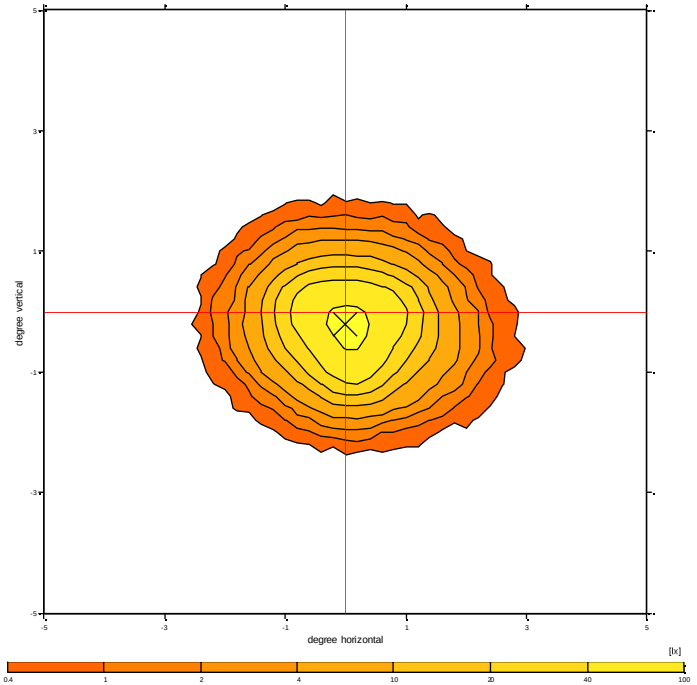
Laser Headlamp Presentation LeMans June 13, 2014

Audi R8 LMX
Laser Reflexion System as additional High Beam Boost



LED Highbeam

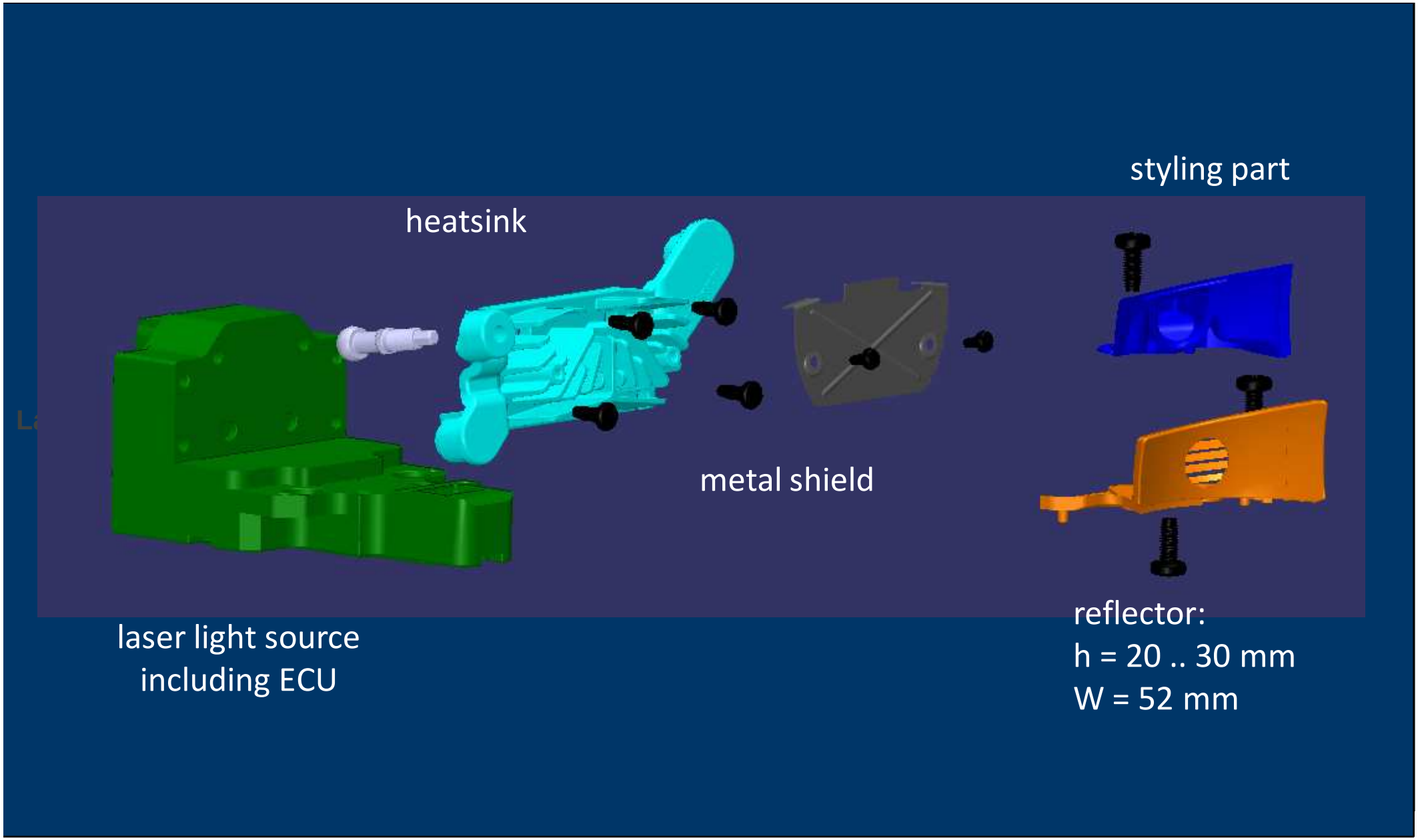




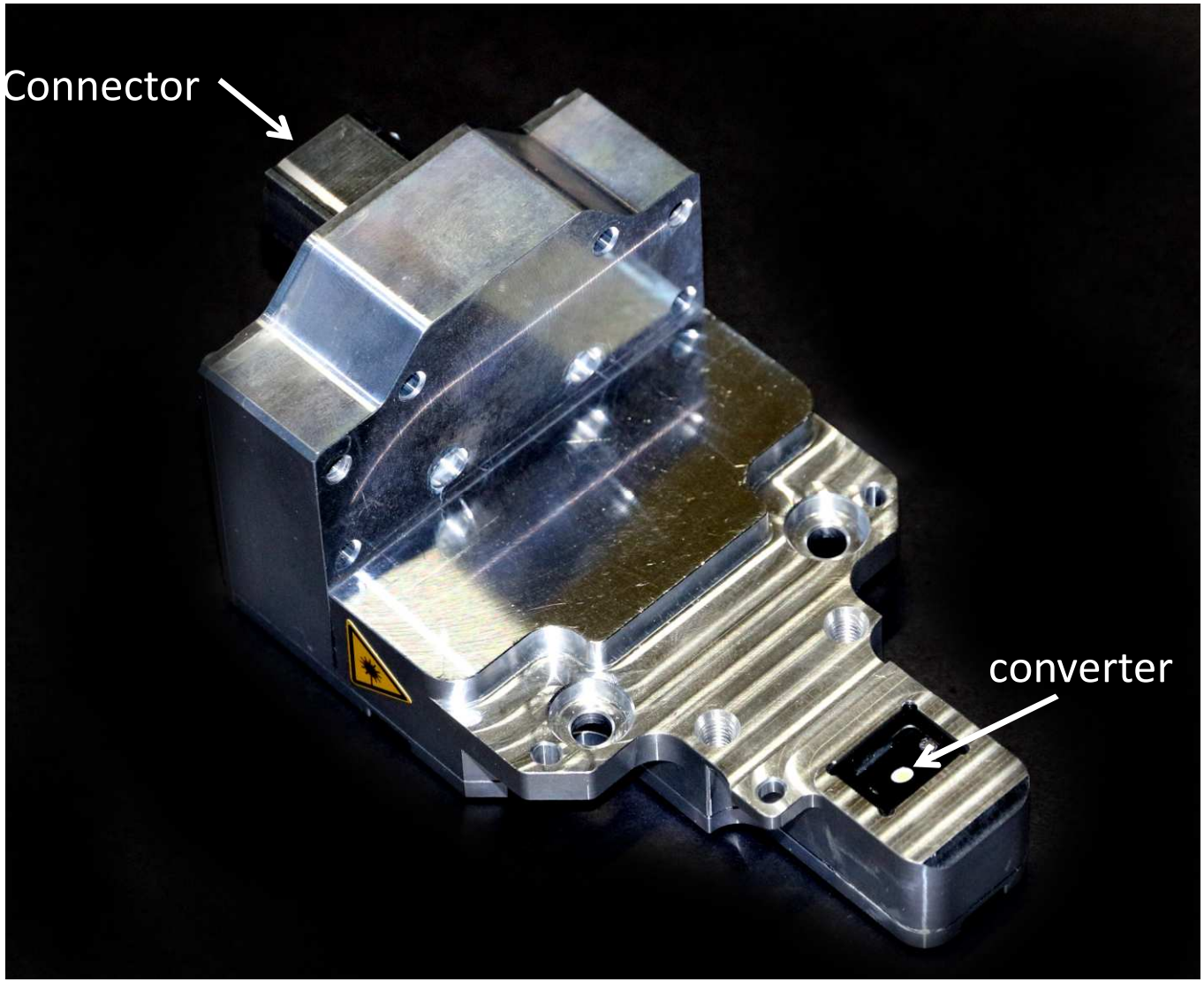
Laser high beam boost

Configuration	E_{Max}
LED Highbeam	121 lx
Laser Highbeam	200 lx
LED Highbeam + Laser	>300 lx

Audi R8 LMX: Optical Laser System



LASER Light Sources for Headlamp Applications



Most important Safety Features:

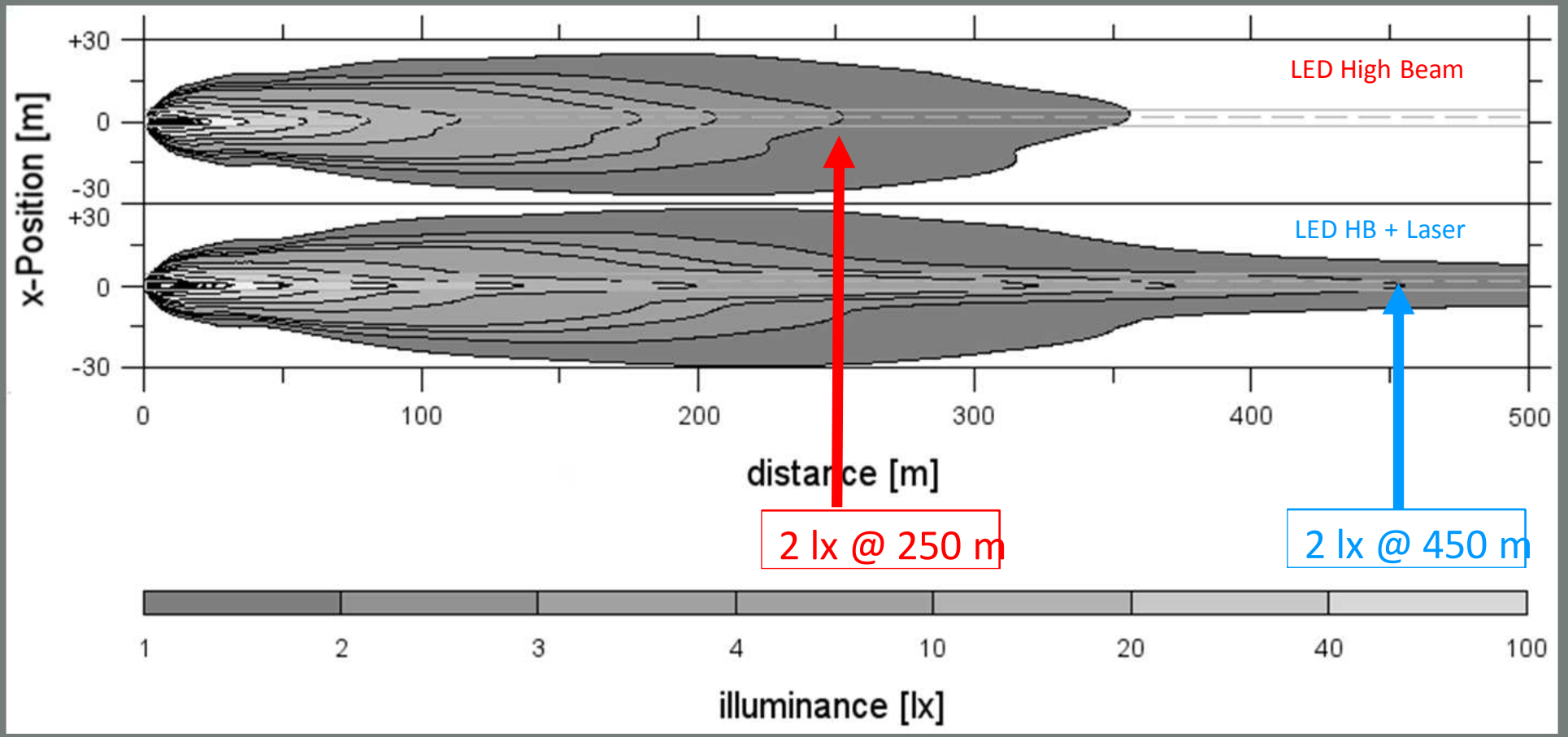
ECU integrated in laser light source:
- self diagnosis and safety deactivation

Vehicle speed controlled system (v > 60 km/h)

Camera controlled activation

Trap in optical system for coherent blue light in case of a failure

Audi R8 LMX: Bird's Eye View High Beam



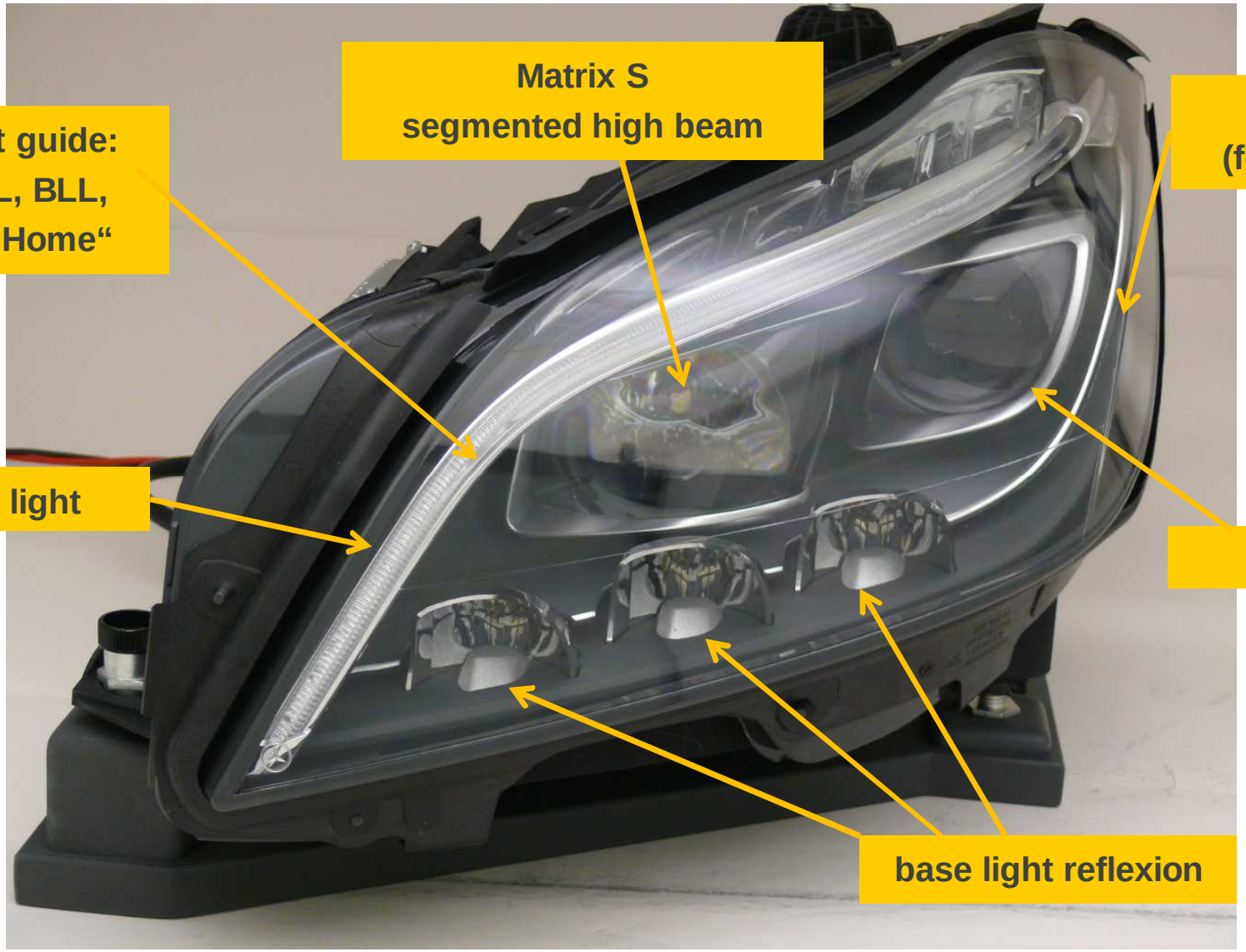
AL Matrix-Beam Solutions

Audi TT3 Reflexion System

Mercedes CLS facelift

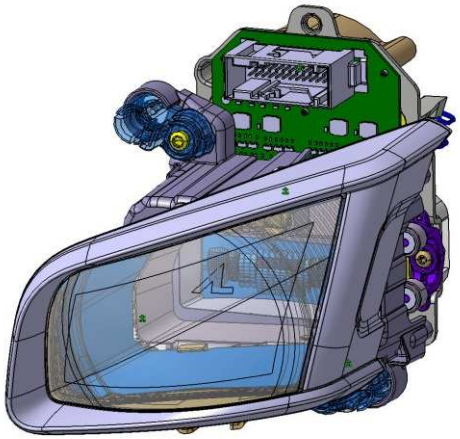
Mercedes CLS – Matrix Beam Version

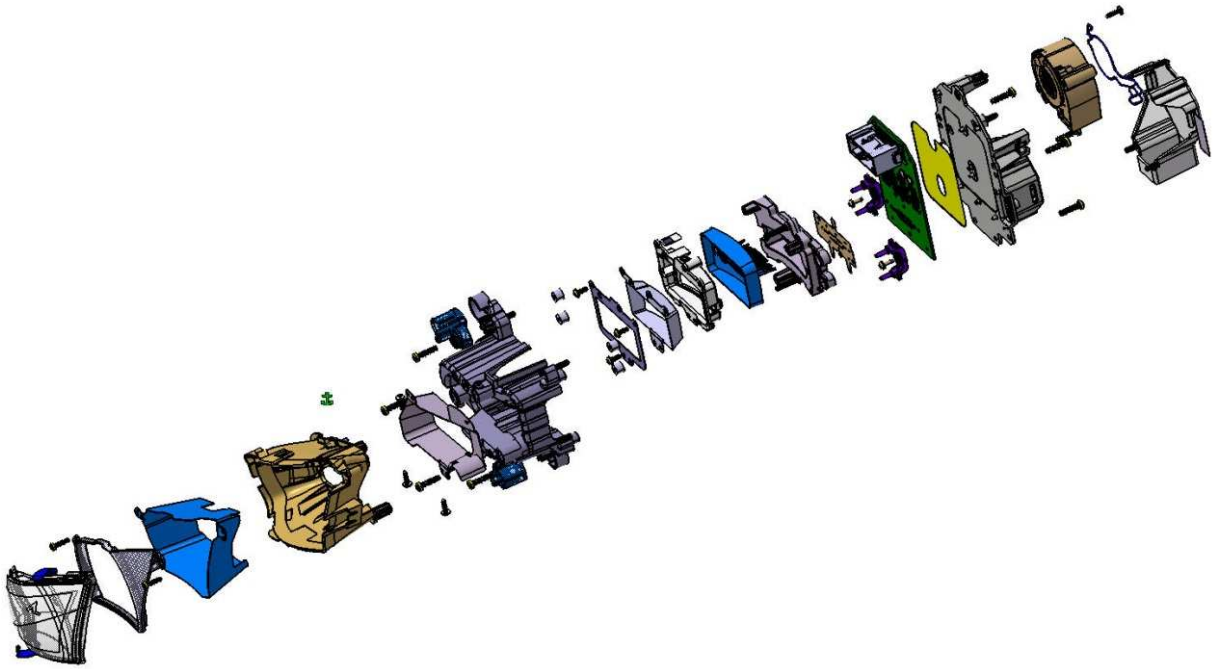
Functional scope



Mercedes CLS – complex headlamp design

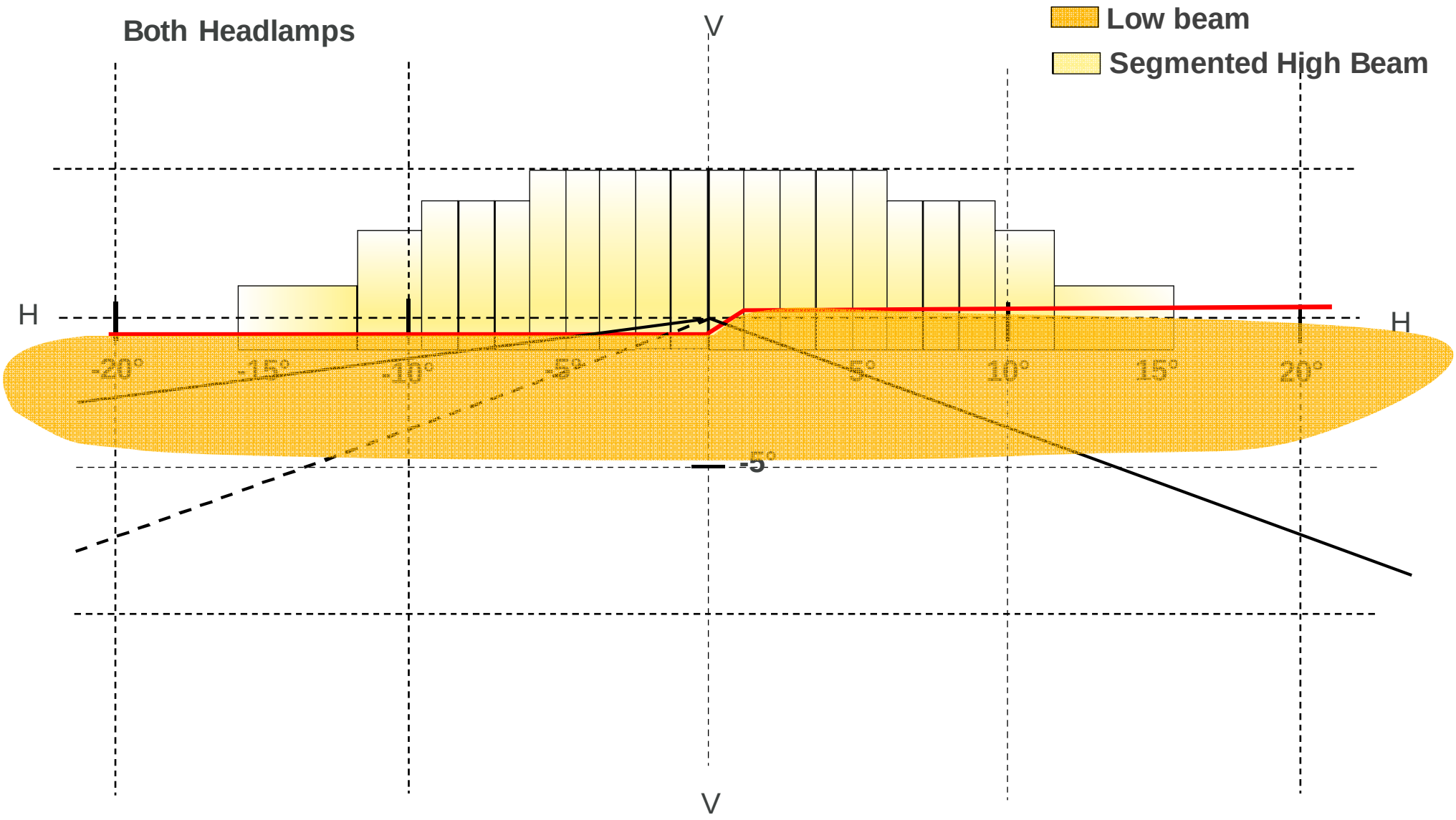
Matrix Beam S module



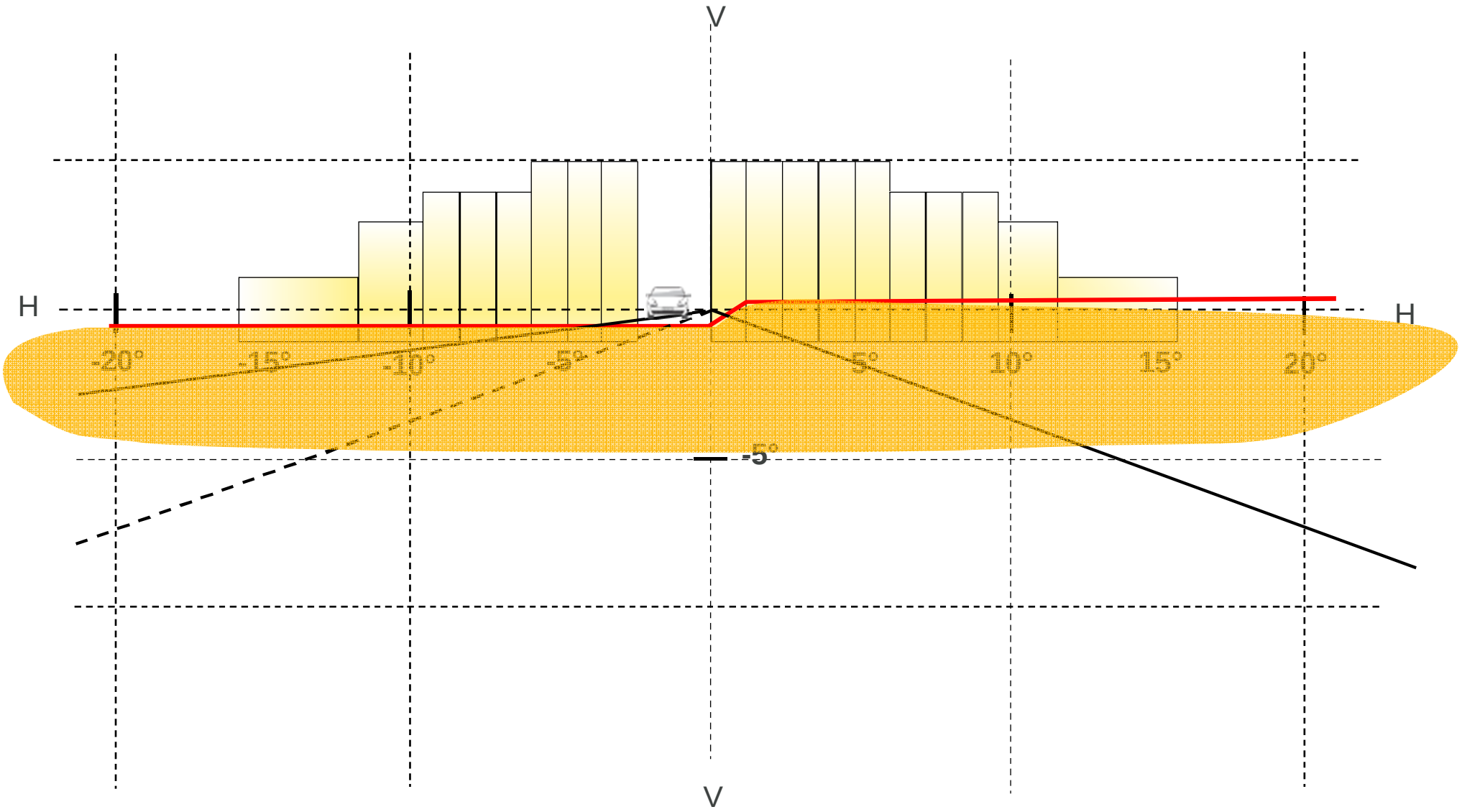


- 24 Osram Oslon Compact CM (½ mm² LEDs)
- 18 vertical segments
- Primary optic out of Silicon (ultra-tranparent)
- Passive thermal management
- Single plastic projection lens (3-layer type)

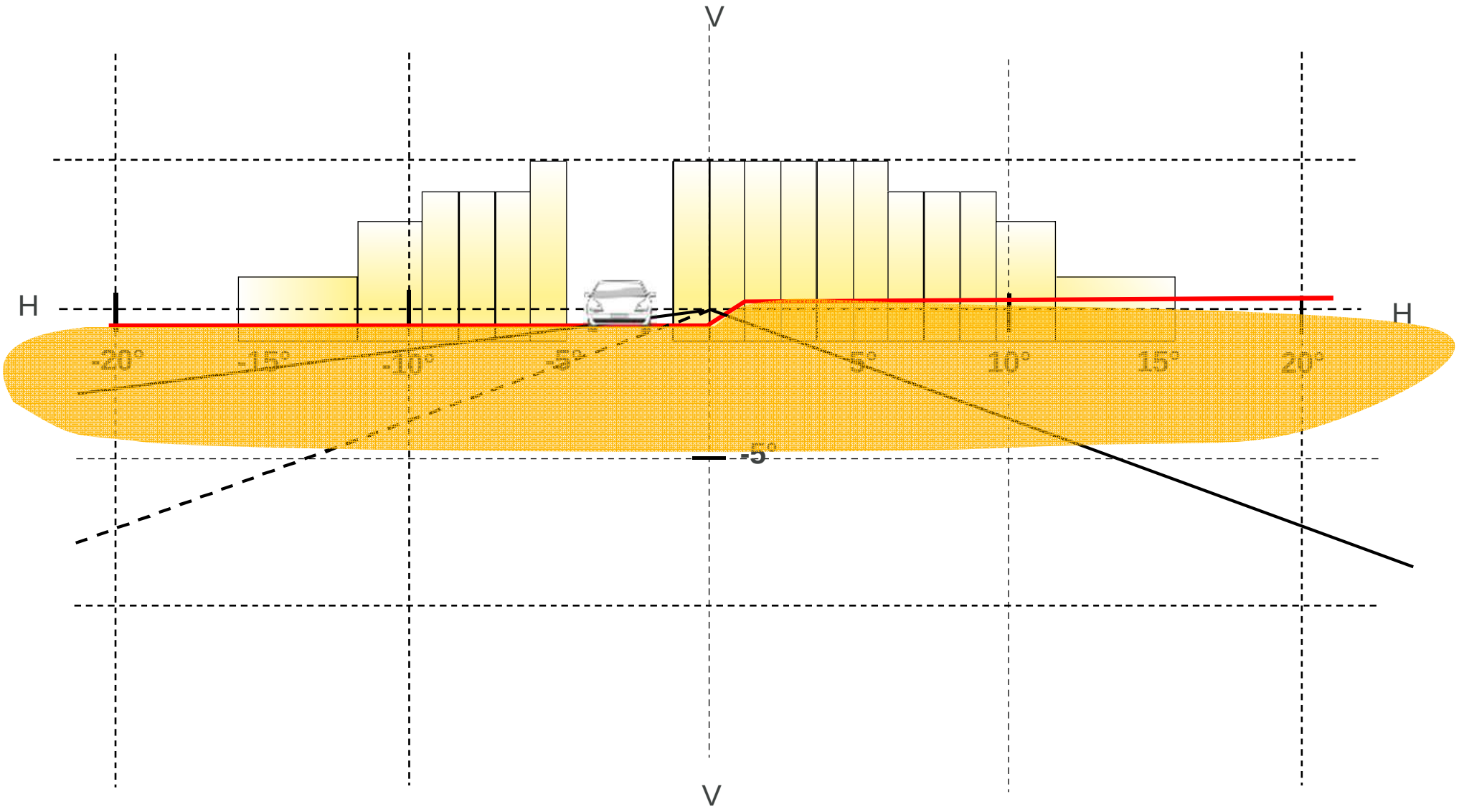
Matrix Beam: Segmented High Beam



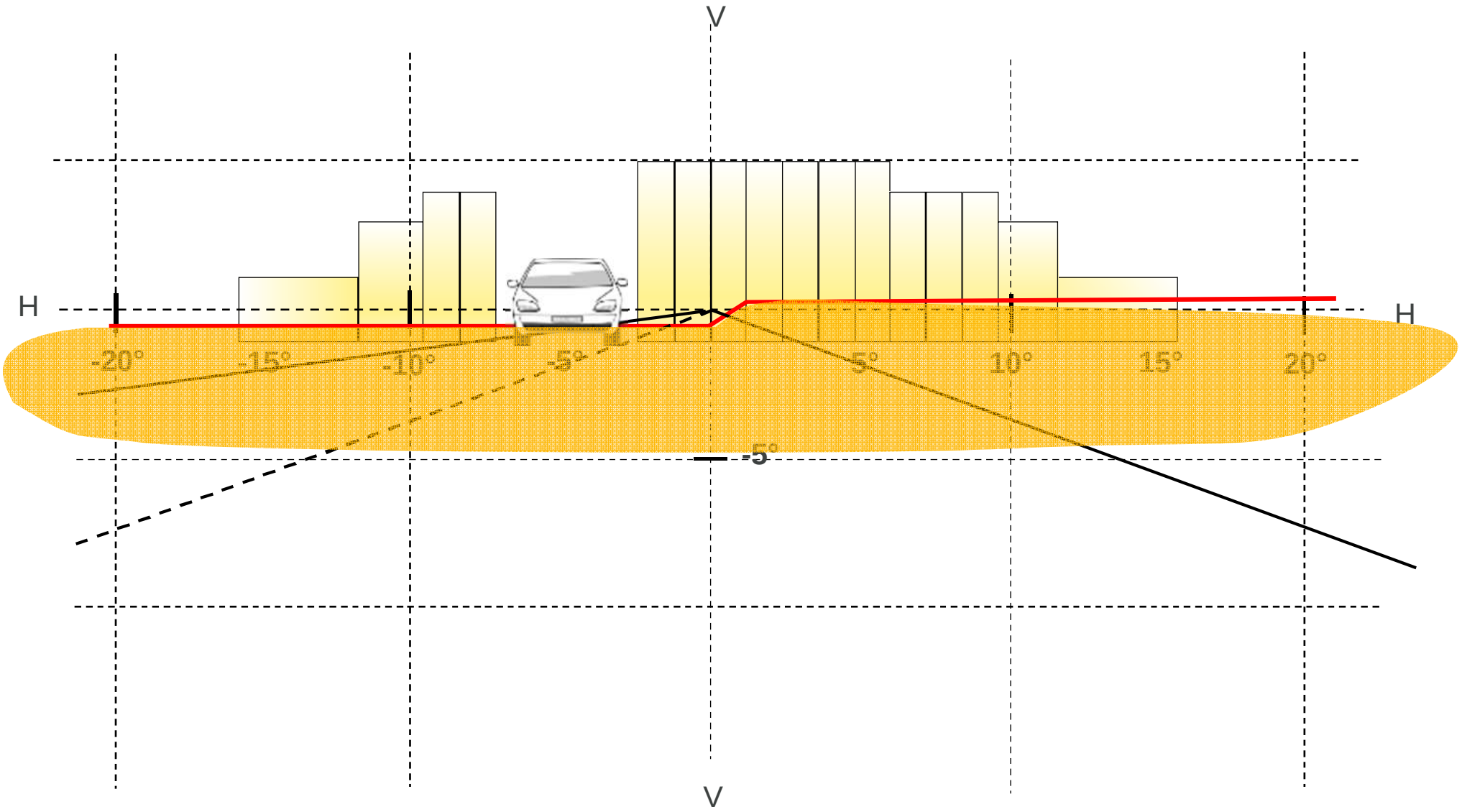
Matrix Beam: Segmented High Beam



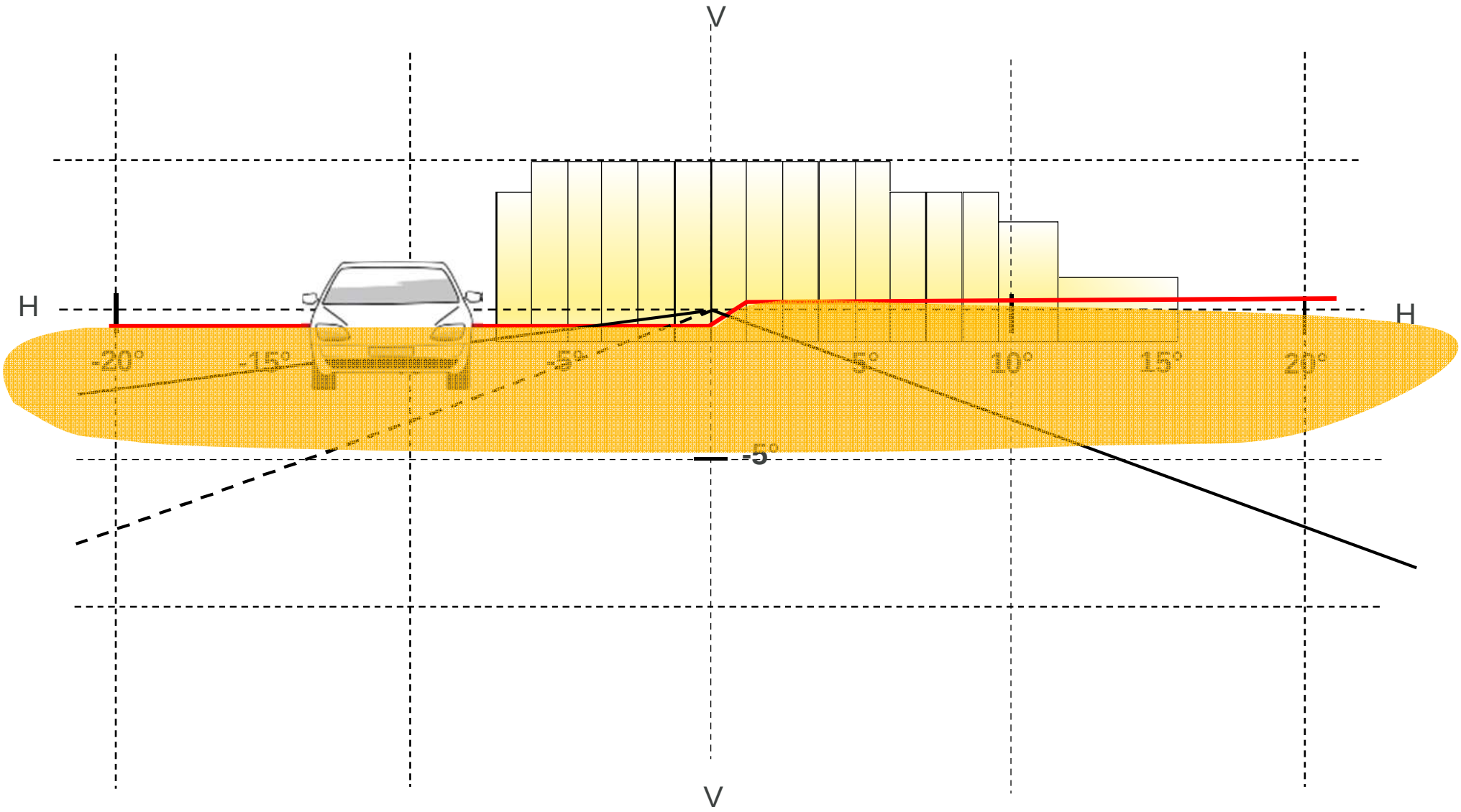
Matrix Beam: Segmented High Beam



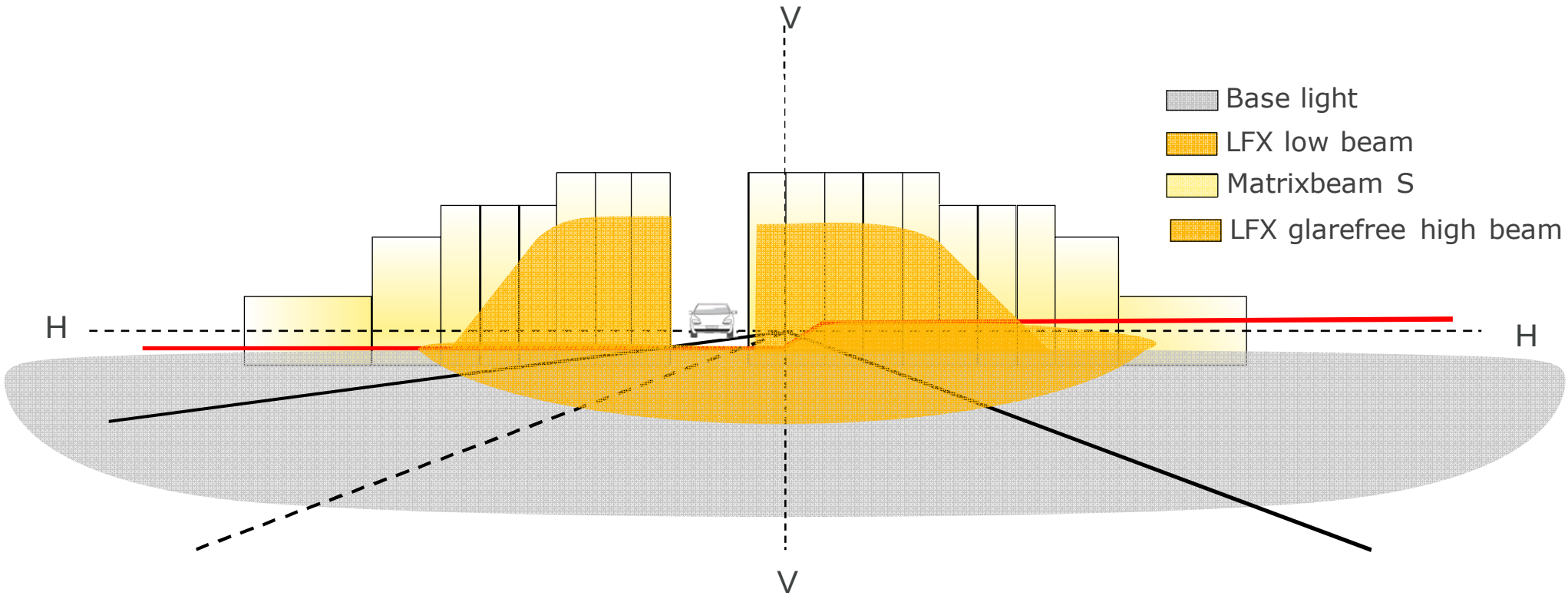
Matrix Beam: Segmented High Beam



Matrix Beam: Segmented High Beam

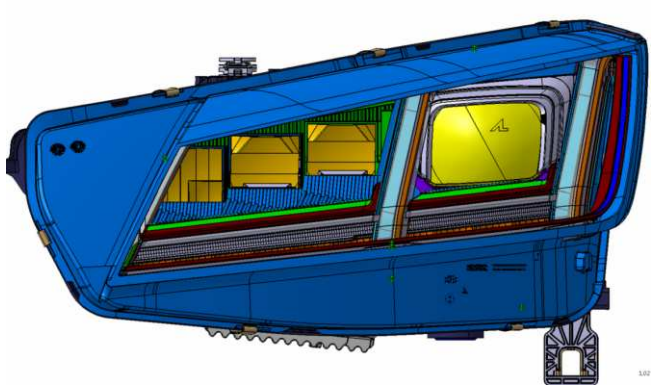


Mercedes CLS: Matrix Beam S Module + LFX



Matrix Beam S : An extension to the conventional partial high beam (LFX in Mercedes S-class)

AUDI TTS - SOP 2014



Segmented High Beam

Segmented High Beam

Segmented High Beam

EEG Office

What does EEG mean?

E = Entwicklung - Development

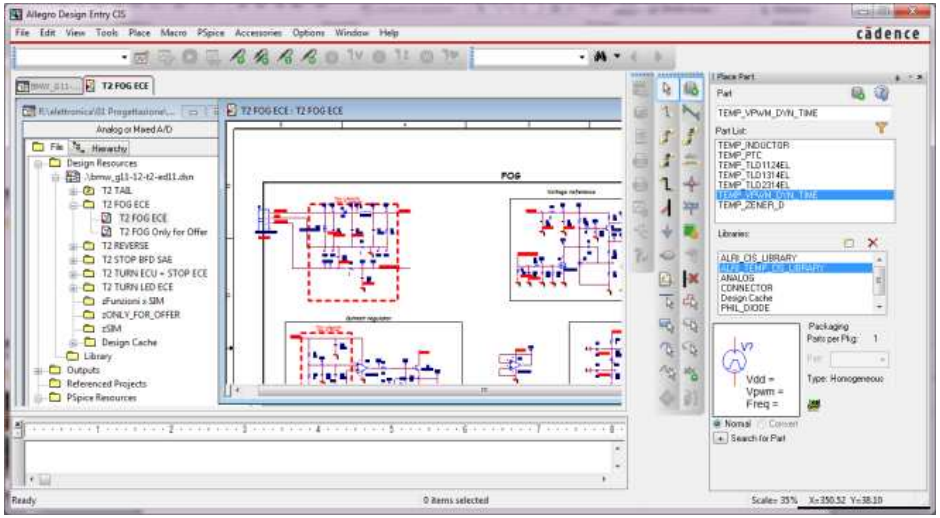
E = Elektronik - Electronic

G = Gerät - Device

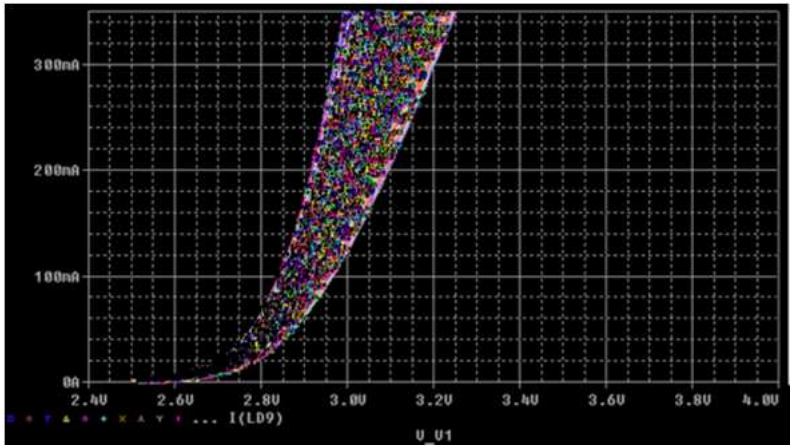
EEG office: competence and tools

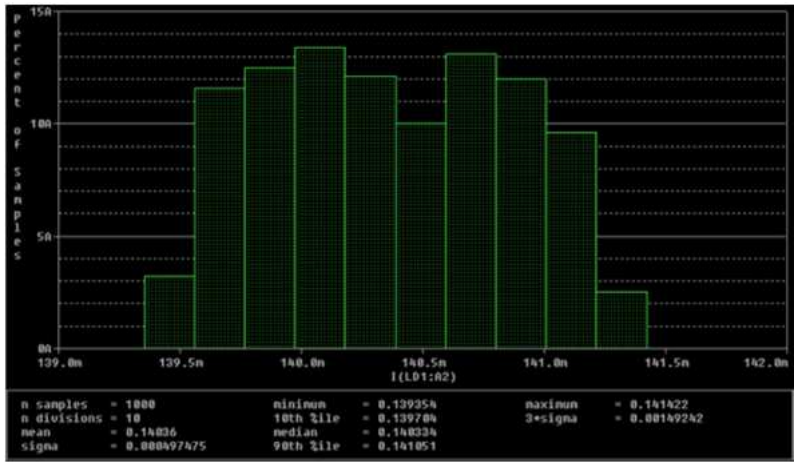
- **HW design**
  - Analog design
  - Digital design

Cadence Allegro Design CIS



Electronic design based on customer requirements



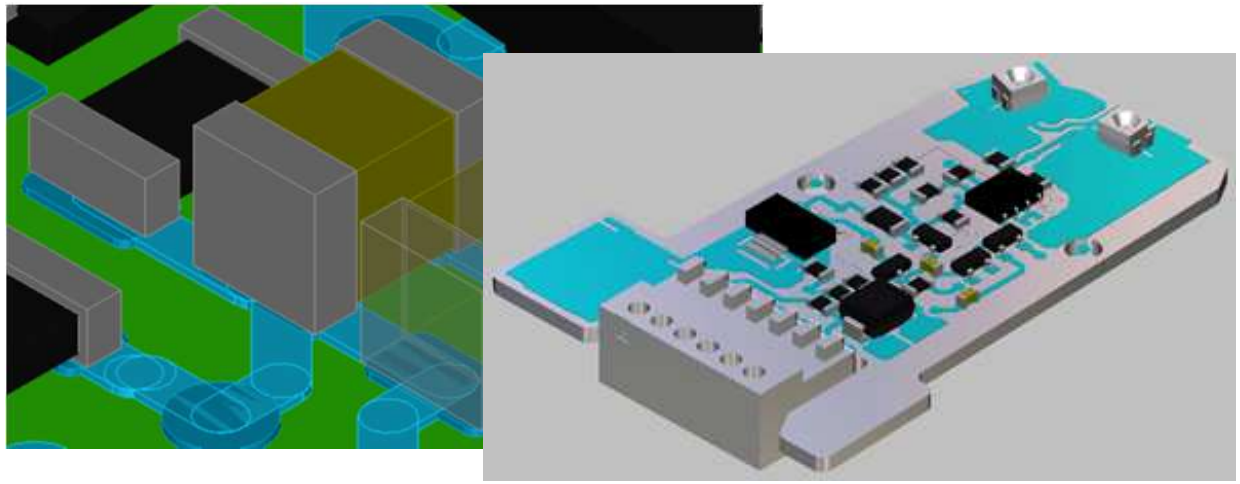


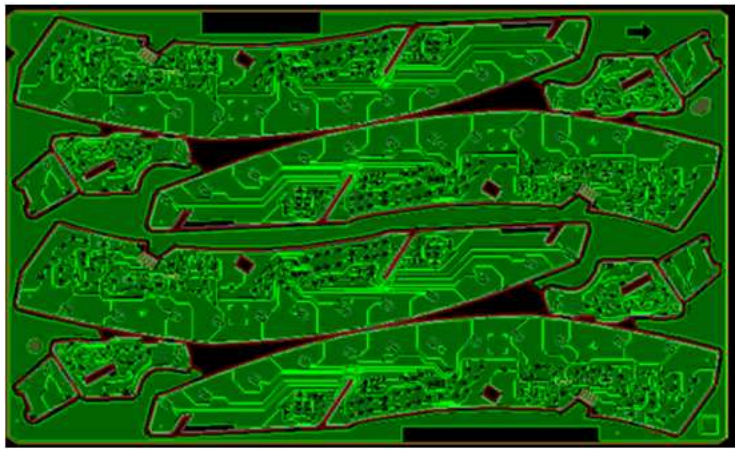
Electronic simulations: Bias, Sweep, time domain, Montecarlo analysis ecc…

EEG office: competence and tools

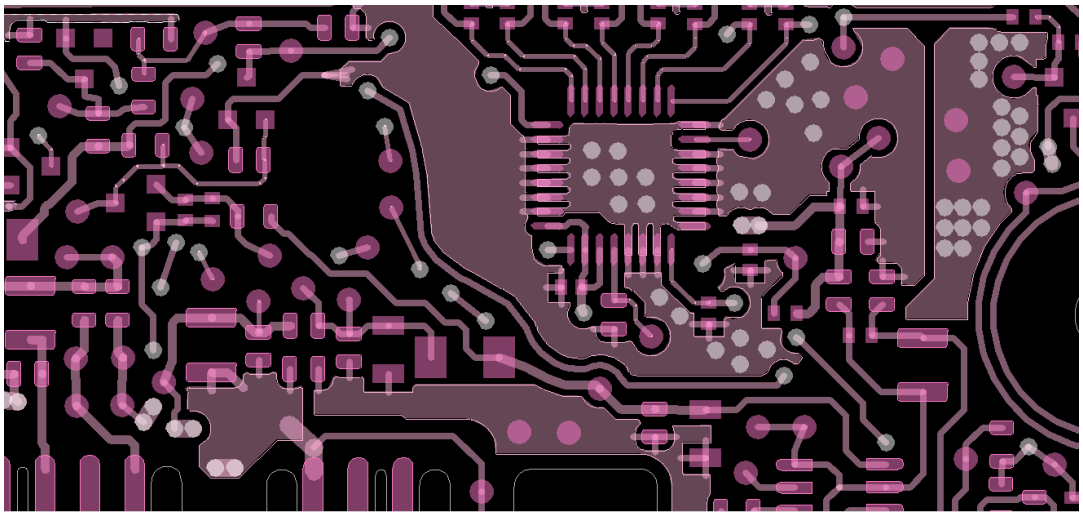
- **Layout design**
  - PCB design
  - FPC design
  - Panel design
  - EMC design oriented
- **Industrialization design**
  - Manufacturing constrains
  - Cost optimization

Cadence Allegro PCB Design





PCB and Pannel Layout design



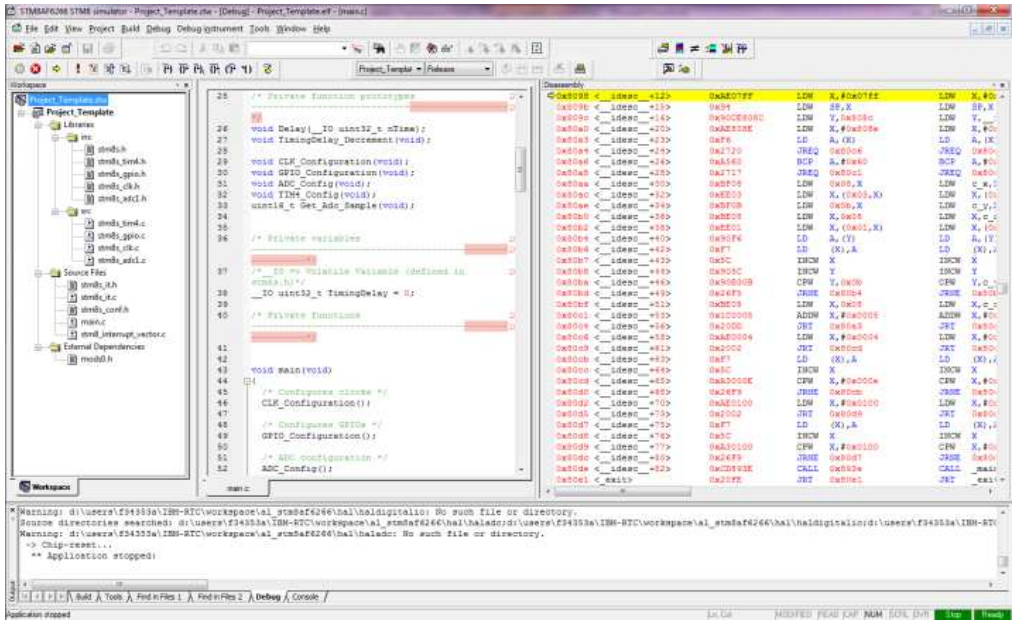
EEG office: competence and tools

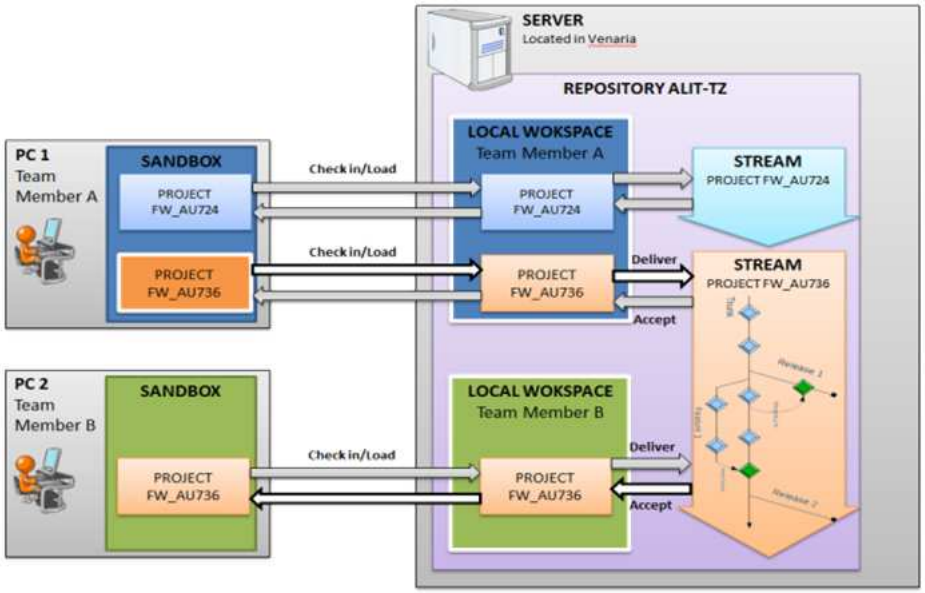
- **SW design & testing**

Development tools: ST IDE, Microsoft Visual Studio, Freescale Codewarrior

Configuration management: IBM RTC

Testing and Validation: Gimpel PC-LINT, NI CompactRIO





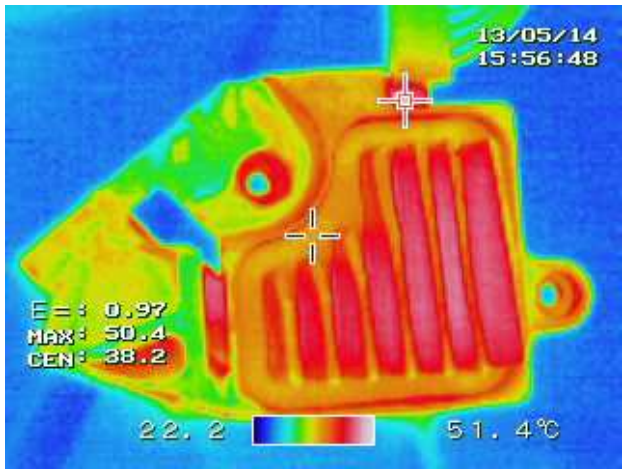
Software design based on the customer requirements

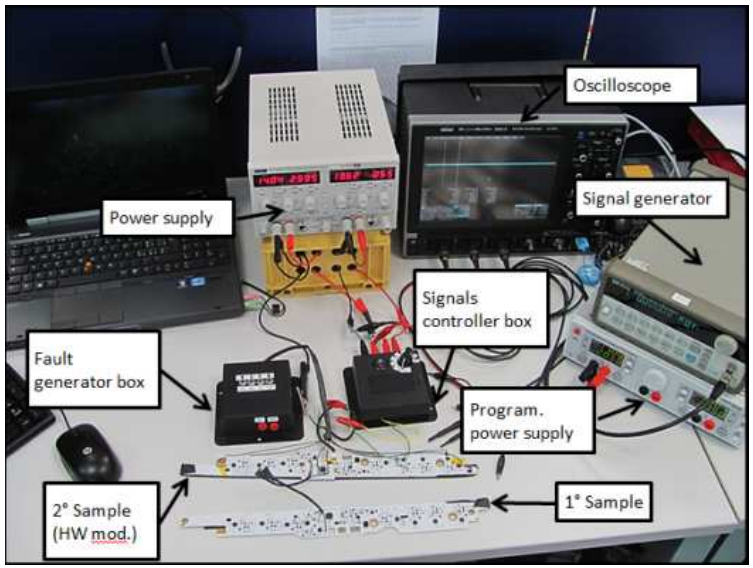
EEG office: competence and tools

- **Testing & Validation**
  - Electrical
  - EMC
  - Thermal
  - Optical

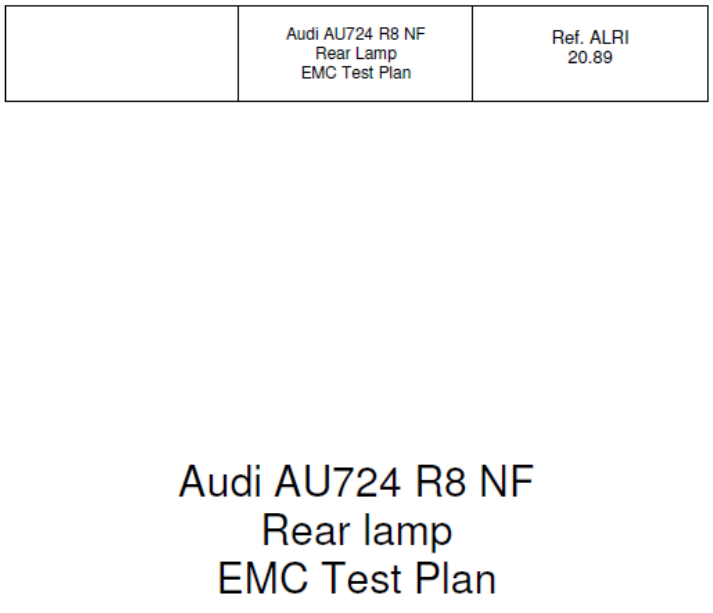
Proprietary tools

Standard & proprietary equipment





EEG laboratories: EMC tests



	Audi AU724 R8 NF Rear Lamp EMC Test Plan	Ref. ALRI 20.89

Audi AU724 R8 NF
Rear lamp
EMC Test Plan

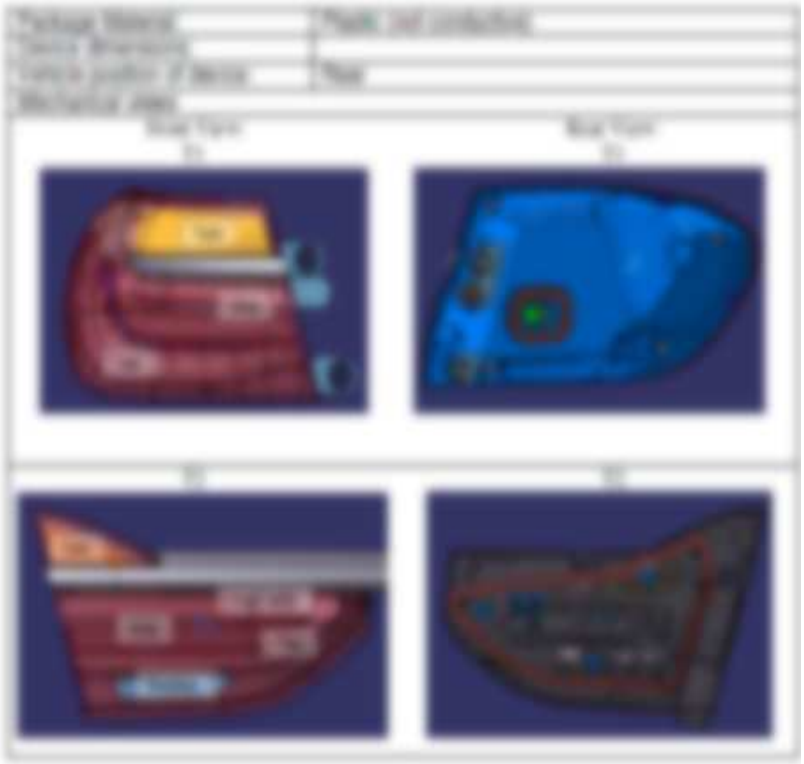
Issue Date: 10th March, 2014

Edition: 01

Contents:

- ✓ Functional and electrical description of DUT
- ✓ Test Setup
- ✓ Operative modes
- ✓ List of Test
- ✓ Parameters to be verified

EEG laboratories: EMC tests



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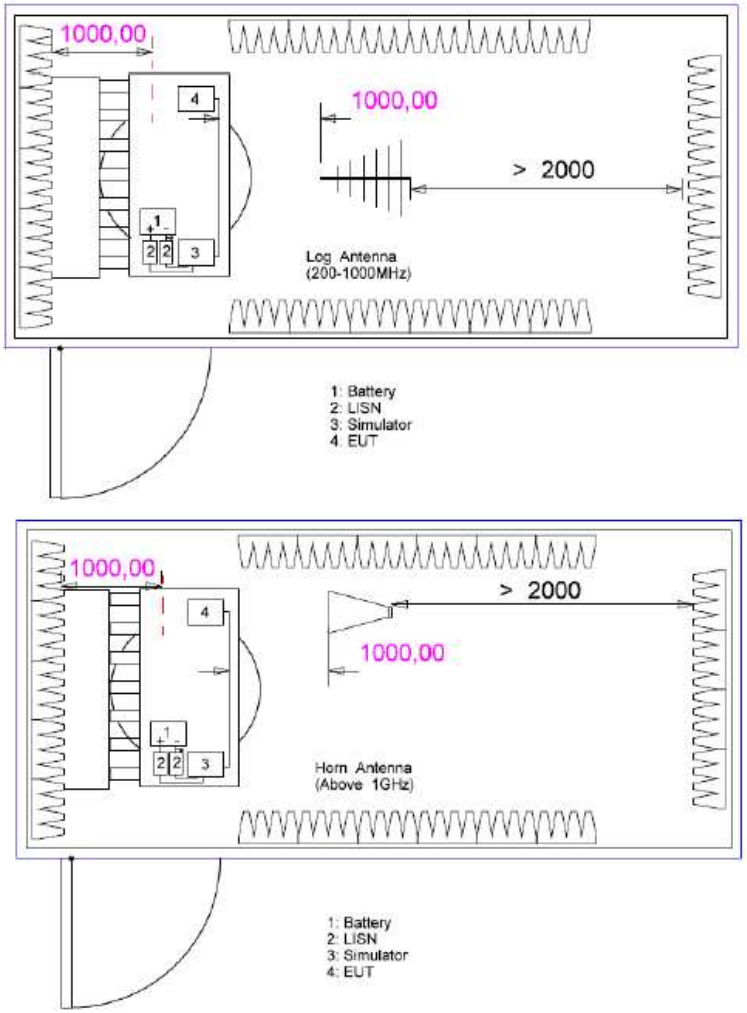
EEG laboratories: EMC tests



Contents:

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- ✓ Test Setup
- ✓ Operative modes
- ✓ List of Test
- ✓ Parameters to be verified

EEG laboratories: EMC tests

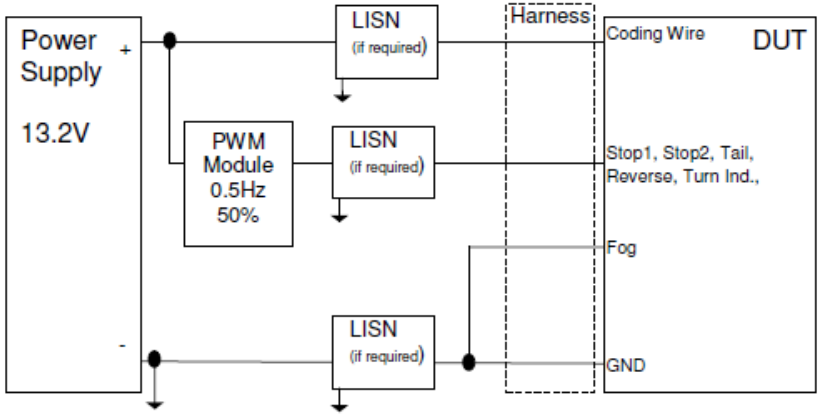
4. Operating information

Typical test block diagram:

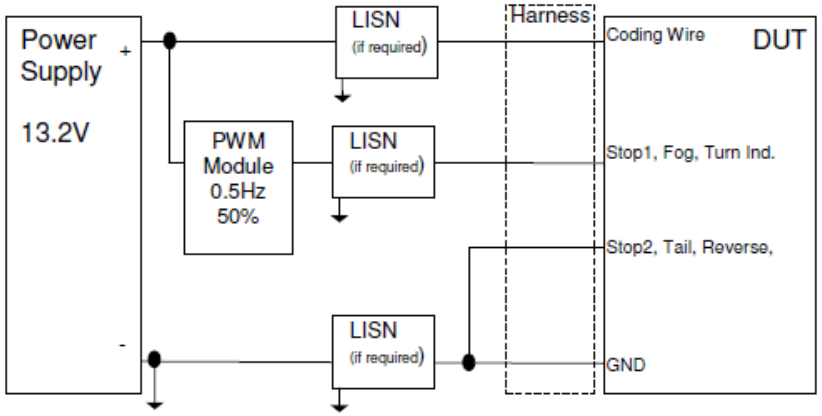
ECE version:

WARNING!
ECE Lamp shall be activated following the sequence of connection at page 14.

ON_PWM_Fog_OFF mode:



ON_PWM_Fog_ON mode:



Contents:

- ✓ Functional and electrical description of DUT
- ✓ Test Setup
- ✓ Operative modes
- ✓ List of Test
- ✓ Parameters to be verified

EEG laboratories: EMC tests

Test shall be performed according to the table below with the same order sequence:

Test Description	Func. Status / Test Severity	Interface to be tested	S/C[1]	Operating Mode(s)	B-samples Sets[2]			C-samples Sets[2]		
					1	2	3	1	2	3
TL 82466 - Immunity to Electrostatic Discharge (ESD)	Category 3	Electrical Functionality After test	S	UNPLUGGED, ON_DC	Y[3]	Y[3]		Y	Y	
TL 820 66 - Conducted Interference - § 5 Interference immunity verification test	Status C for pulse 1, Status A for pulses 2a, 3a, 3b, 6	Light Output, Electrical Functionality after test		ON_DC	Y	Y		Y	Y	
TL 82166 - Radiated Interferences - §6.1 BCI Test	Category 3	Light Output, Electrical Functionality after test	S	ON_PWM_Fog_ON, ON_PWM_Fog_OFF	Y	Y		Y	Y	
TL 82166 - Radiated Interferences - §6.2 Antenna method	Category 3	Light Output, Electrical Functionality after test	S	ON_PWM_Fog_ON, ON_PWM_Fog_OFF	Y	Y		Y	Y	
TL 965 - Interference Emission - §5.1 HF emissions – measurement at the artificial network (AN test)	Class 5	Noise generated		ON_DC	Y	Y		Y	Y	
TL 965 - Interference Emission - §5.3 HF emissions – measurements with antennas (ALSE test)	Class 5	Noise generated		ON_PWM_Fog_ON, ON_PWM_Fog_OFF	Y	Y		Y	Y	
LAH.DUM.000.M - Zusätzliche ESD Prüfungen an Scheinwerfern und Heckleuchten		Electrical Functionality after test		GROUND_PLUGGED	Y[3]	Y[3]		Y	Y	Y

1. Indicate specific DUT operating modes that the test applies to.
   C (Combined): The operating modes are to be tested simultaneously.
   S (Separate): The operating modes are to be tested separately
2. "Y" means test to be done
3. ESD test to be performed only in case the samples have definitive plastic body. Anyhow ESD test on pins has to be done.

Set	Description	Notes
1	1 lamp ECE Left Hand, 1 lamp ECE Right Hand	
2	1 lamp SAE Left Hand, 1 lamp SAE Right Hand	
3	1 lamp ECE Left Hand, 1 lamp ECE Right Hand	

Contents:

- ✓ Functional and electrical description of DUT
- ✓ Test Setup
- ✓ Operative modes
- ✓ List of Test
- ✓ Parameters to be verified

EEG laboratories: EMC tests

Contents:

- ✓ Functional and electrical description of DUT
- ✓ Test Setup
- ✓ Operative modes
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- ✓ Parameters to be verified

Functional status Description:

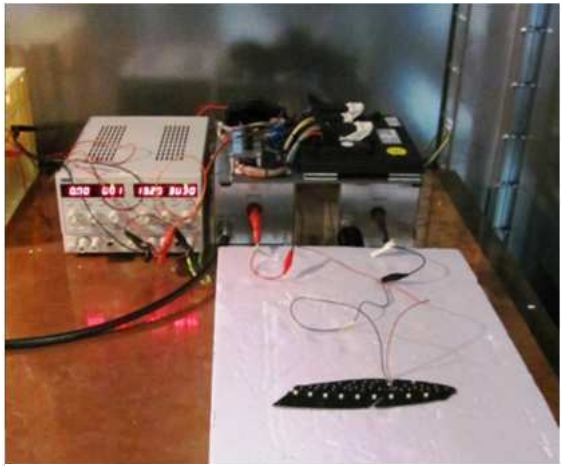
Functional status A: All device/system functions perform as specified during and after exposure to the disturbance.

Functional status B: All device/system functions perform as specified during exposure. However, one or more functions may be outside the specified limit deviation. All functions automatically return to the specified limits once exposure has ended.

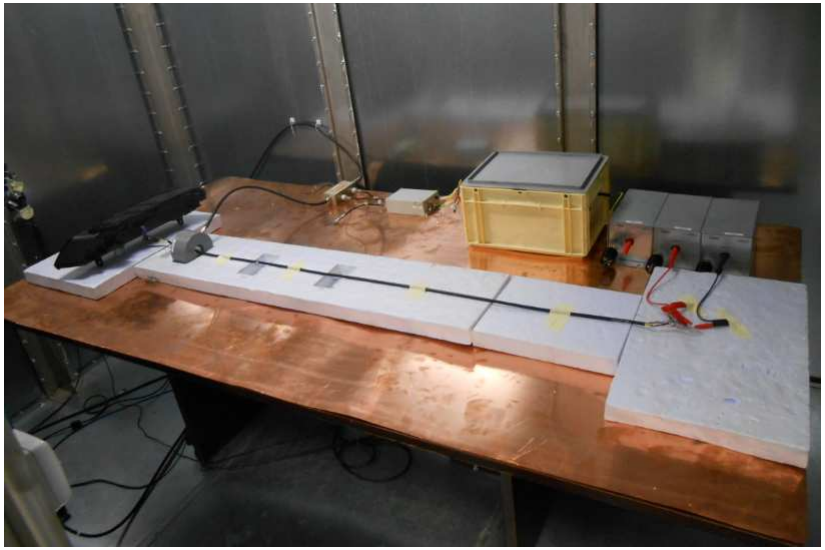
Functional status C: One or more device/system functions do not perform as specified during exposure, but return to normal operation once exposure has ended.

EEG laboratories – EMC/EMI tools

Shielded chamber for EMC testing



Conducted emission

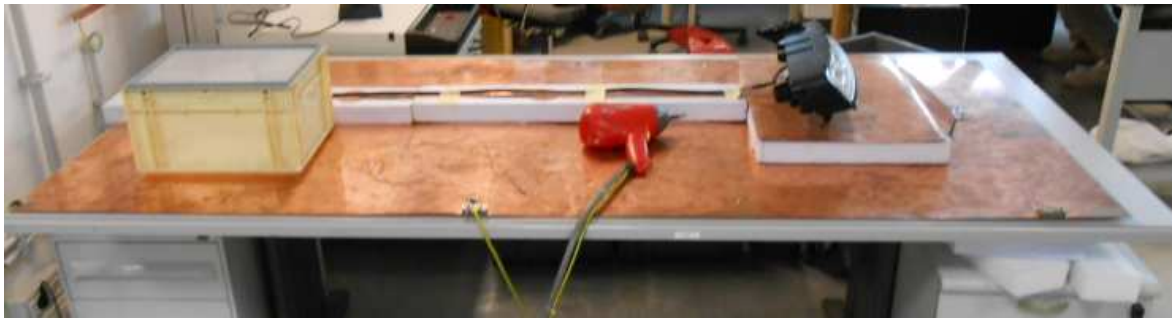


Bulk Current Injection

EMI receiver and RF signal generator

EEG laboratories – ESD and pulses tools

Pulses

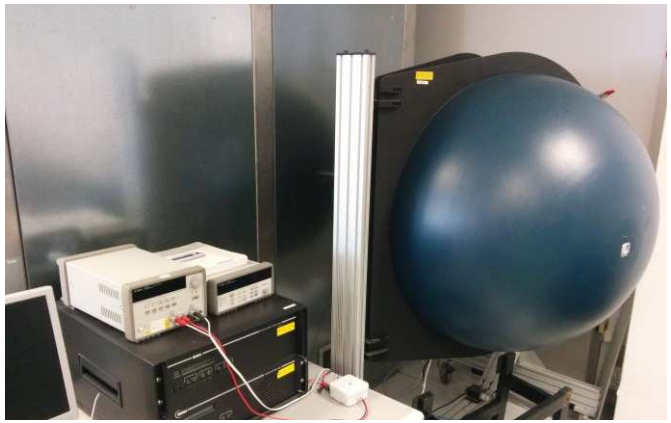


ESD Test

EEG laboratories – optical tools

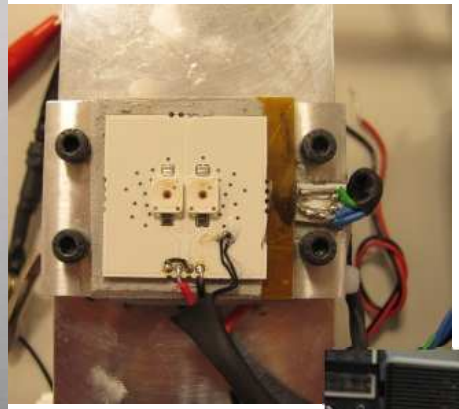
Scanner 3D

Microscope

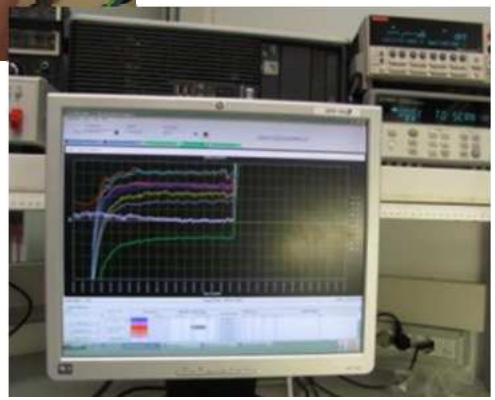


Integrating spheres for optical simulation

EEG laboratories – thermal analysis tools



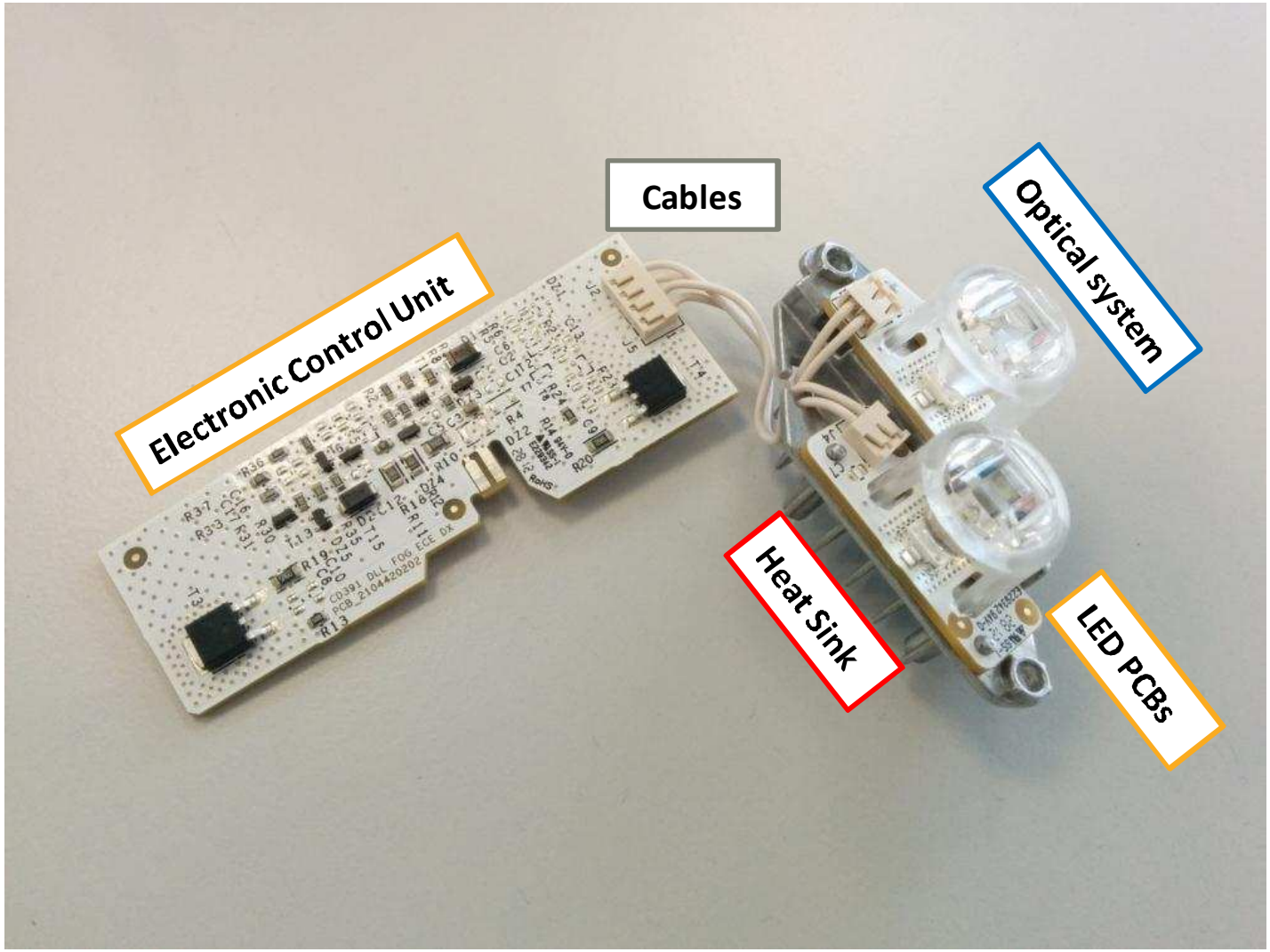
Integrating spheres for optical simulation



Thermal simulation and analysis

Electronics inside rear lamp

Assembled electronics: complete lighting system



Implemented functionalities in rear lamp circuits

- Current regulation
- Over Temperature protection
- Over Voltage Protection
- LED Open Load Diagnostic 

- LED Short Circuit Diagnostic 

- Dynamic LED Matrix for higher power efficiency 

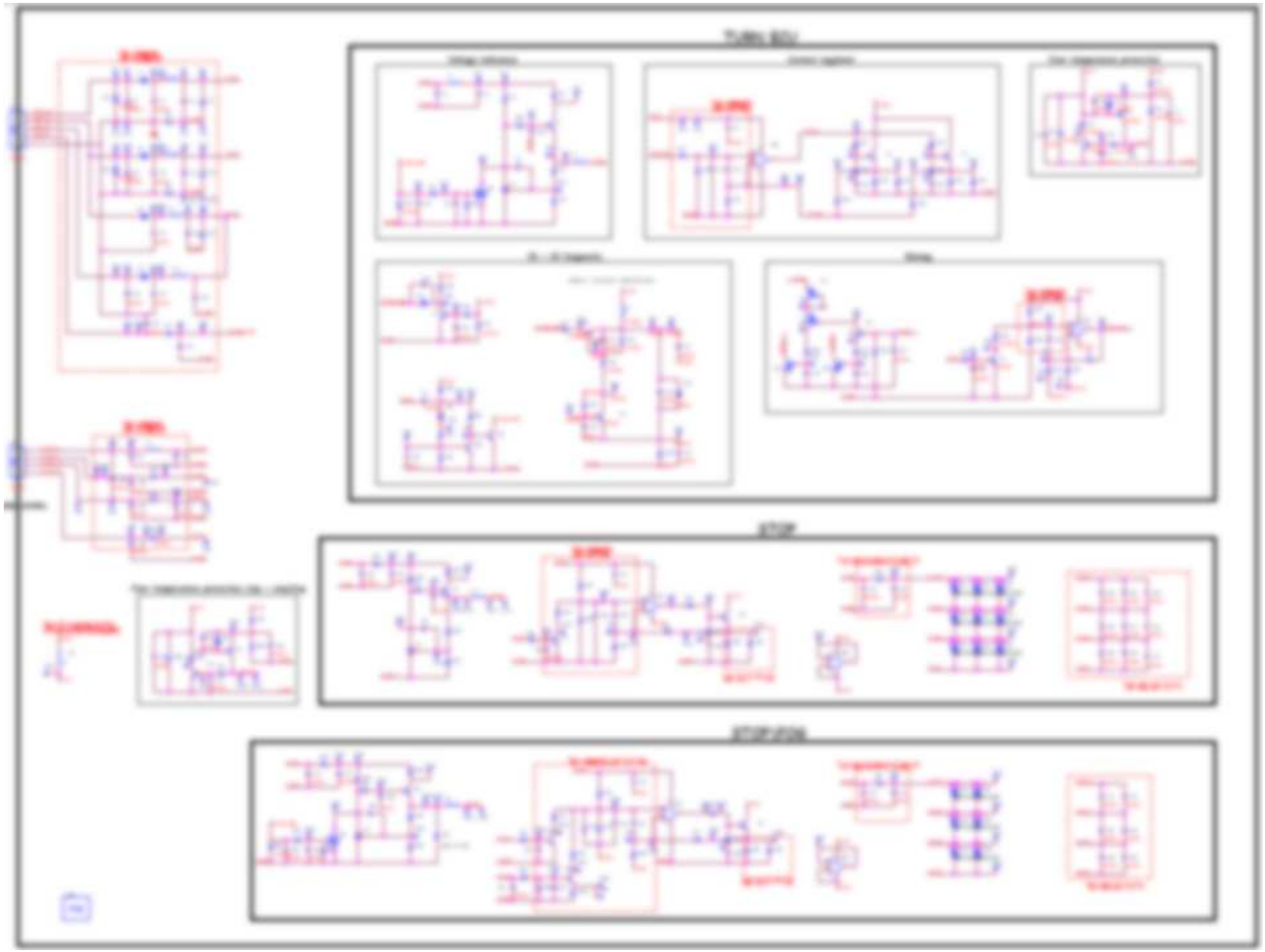
- Multilevel Coding of LED binning 

- LED Luminous Flux Decay Compensation with NTC 

- uC based application (animations, PWM generation, diagnosys) 

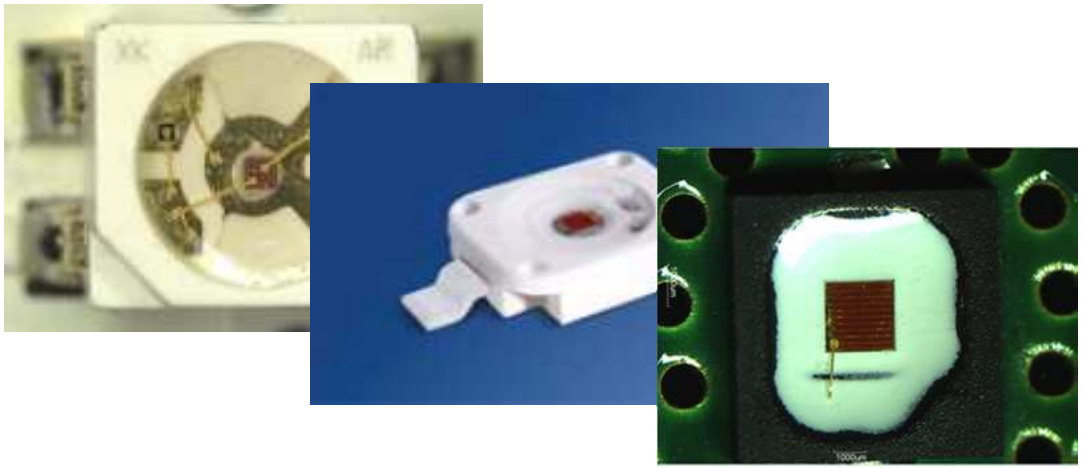
- ASIC and ASSP co-design 

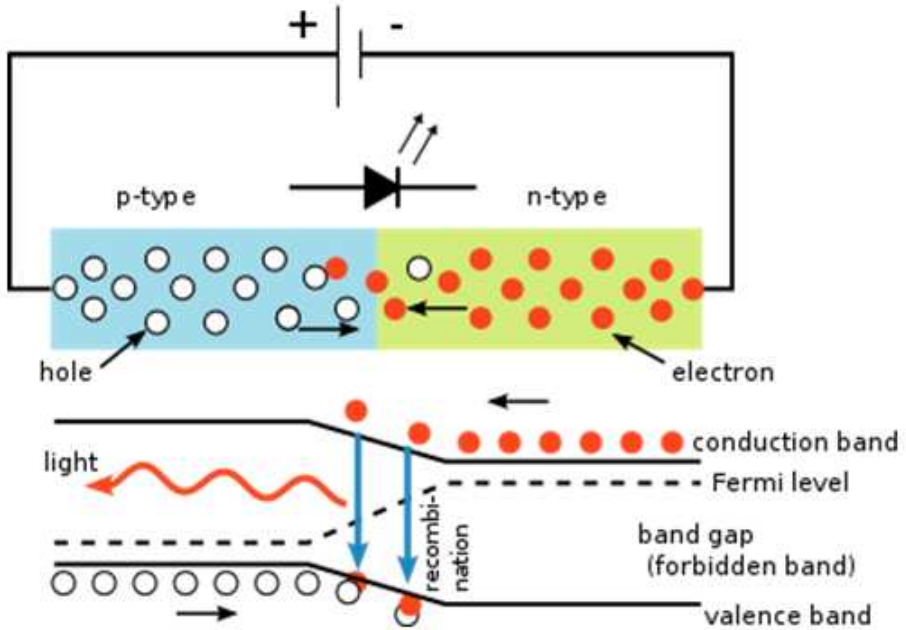
From customer requirements to electronic circuits…

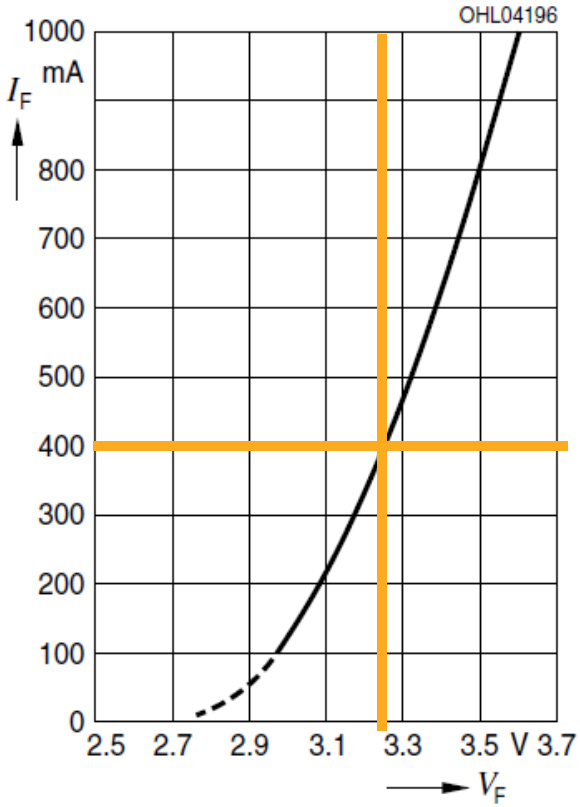


Electronic architectures for LED current driving

LED functionality







Example datasheet

Power TOPLED
Enhanced thin film LED
Lead (Pb) Free Product - RoHS Compliant

LA E67F, LO E67F, LY E67F

Released

Besondere Merkmale

- **Gehäusetyp:** weißes P-LCC-4 Gehäuse, farbloser klarer Verguss
- **Besonderheit des Bauteils:** mehr Licht durch erhöhten optischen Wirkungsgrad
- **Wellenlänge:** 617 nm (amber), 606 nm (orange), 590 nm (gelb)
- **Abstrahlwinkel:** Lambertscher Strahler (120°)
- **Technologie:** InGaAlP
- **optischer Wirkungsgrad:** 62 lm/W (amber), 79 lm/W (orange), 47 lm/W (yellow)
- **Gruppierungsparameter:** Lichtstärke, Durchflussspannung, Wellenlänge
- **Verarbeitungsmethode:** für alle SMT-Bestücktechniken geeignet
- **Lötmethode:** Reflow Löten und Wellenlöten (TTW)
- **Vorbehandlung:** nach JEDEC Level 2
- **Gurtung:** 8 mm Gurt mit 2000/Rolle, ø180 mm oder 8000/Rolle, ø330 mm
- **ESD-Festigkeit:** ESD-sicher bis 2 kV nach JESD22-A114-D
- **Erweiterte Korrosionsfestigkeit:** Details siehe **Seite 9**

Features

- **package:** white P-LCC-4 package, colorless clear resin
- **feature of the device:** more light due to higher optical efficiency
- **wavelength:** 617 nm (amber), 606 nm (orange), 590 nm (yellow)
- **viewing angle:** Lambertian Emitter (120°)
- **technology:** InGaAlP
- **optical efficiency:** 62 lm/W (amber), 79 lm/W (orange), 47 lm/W (yellow)
- **grouping parameter:** luminous intensity, forward voltage, wavelength
- **assembly methods:** suitable for all SMT assembly methods
- **soldering methods:** reflow soldering and TTW soldering
- **preconditioning:** acc. to JEDEC Level 2
- **taping:** 8 mm tape with 2000/reel, ø180 mm or 8000/reel, ø330 mm
- **ESD-withstand voltage:** up to 2 kV acc. to JESD22-A114-D
- **Superior Corrosion Robustness:** details see **page 9**

Example datasheet

Durchlassspannungsgruppen [6] *Seite 16*
Forward Voltage Groups [6] *page 16*

Gruppe Group	amber		orange		yellow		Einheit Unit
	min.	max.	min.	max.	min.	max.	
3A	1.90	2.05	1.90	2.05			V
3B	2.05	2.20	2.05	2.20	2.05	2.20	V
4A	2.20	2.35	2.20	2.35	2.20	2.35	V
4B	2.35	2.50	2.35	2.50	2.35	2.50	V
5A	2.50	2.65			2.50	2.65	V

Helligkeits-Gruppierungsschema
Brightness Groups

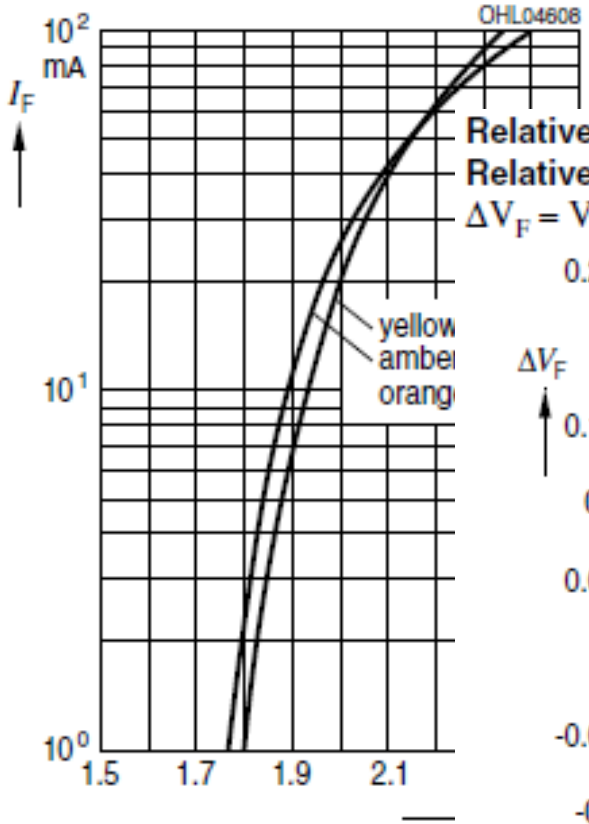
Helligkeitsgruppe Brightness Group	Lichtstärke[1] *Seite 16* Luminous Intensity[1] *page 16* I_V (mcd)	Lichtstrom[2] *Seite 16* Luminous Flux[2] *page 16* Φ_V (mlm)
AA	1120 ... 1400	3700 (typ.)
AB	1400 ... 1800	4800 (typ.)
BA	1800 ... 2240	6050 (typ.)
BB	2240 ... 2800	7550 (typ.)
CA	2800 ... 3550	9500 (typ.)
CB	3550 ... 4500	12000 (typ.)
DA	4500 ... 5600	15100 (typ.)

Anm.: Die Standardlieferform von Serientypen beinhaltet eine Familiengruppe. Diese besteht aus wenigen Helligkeitsgruppen. Einzelne Helligkeitsgruppen sind nicht bestellbar.

Note: The standard shipping format for serial types includes a family group of only a few individual brightness groups. Individual brightness groups cannot be ordered.

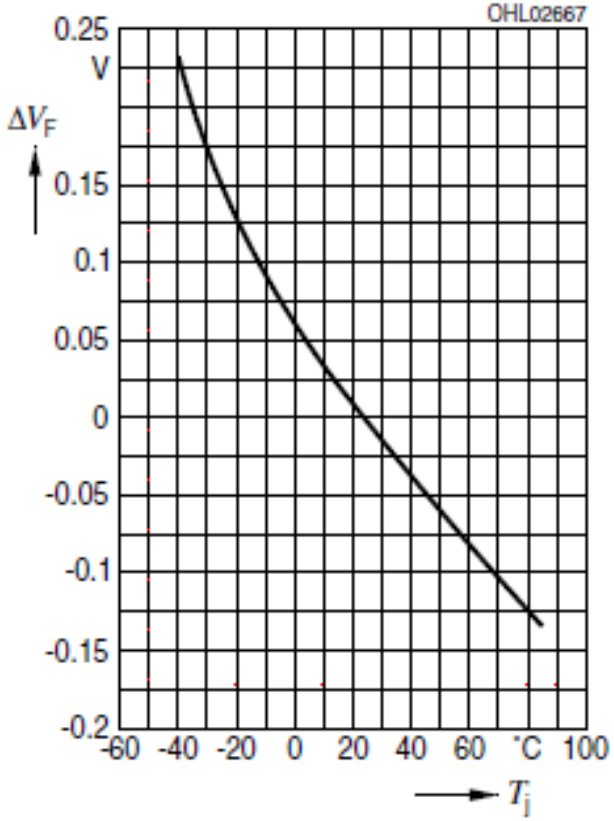
Example datasheet

Durchlassstrom[2] *Seite 16*
Forward Current[2] *page 16*
$I_F = f(V_F)$; $T_S = 25$ °C

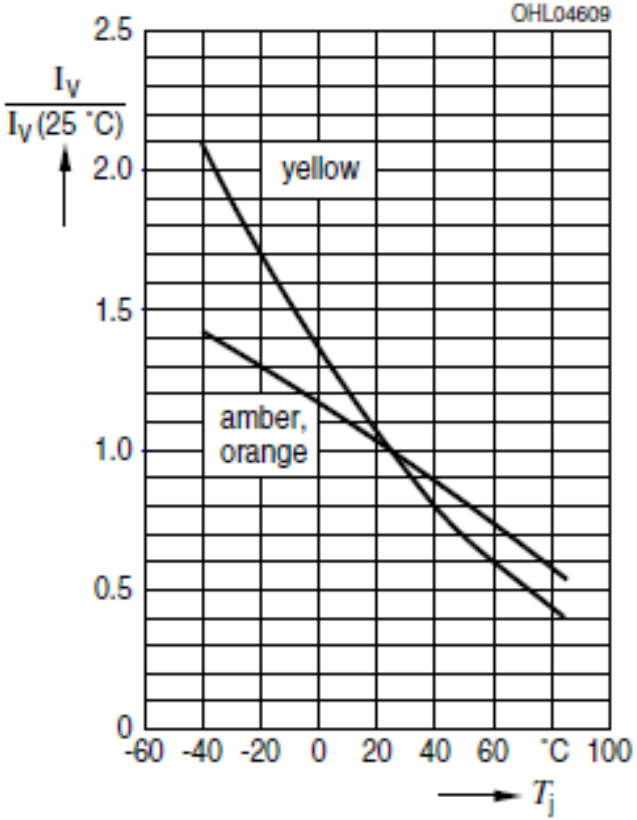


Relative Lichtstärke[2] 7) *Seite 16*
Relative Luminous Intensity[2] 7) *page 16*
$I_V/I_V(50\ mA) = f(I_F)$; $T_S = 25$ °C

Relative Vorwärtsspannung[2] *Seite 16*
Relative Forward Voltage[2] *page 16*
$\Delta V_F = V_F - V_F(25\ °C) = f(T_j)$; $I_F = 50$ mA



Relative Lichtstärke[2] *Seite 16*
Relative Luminous Intensity[2] *page 16*
$I_V/I_V(25\ °C) = f(T_j)$; $I_F = 50$ mA



Example datasheet

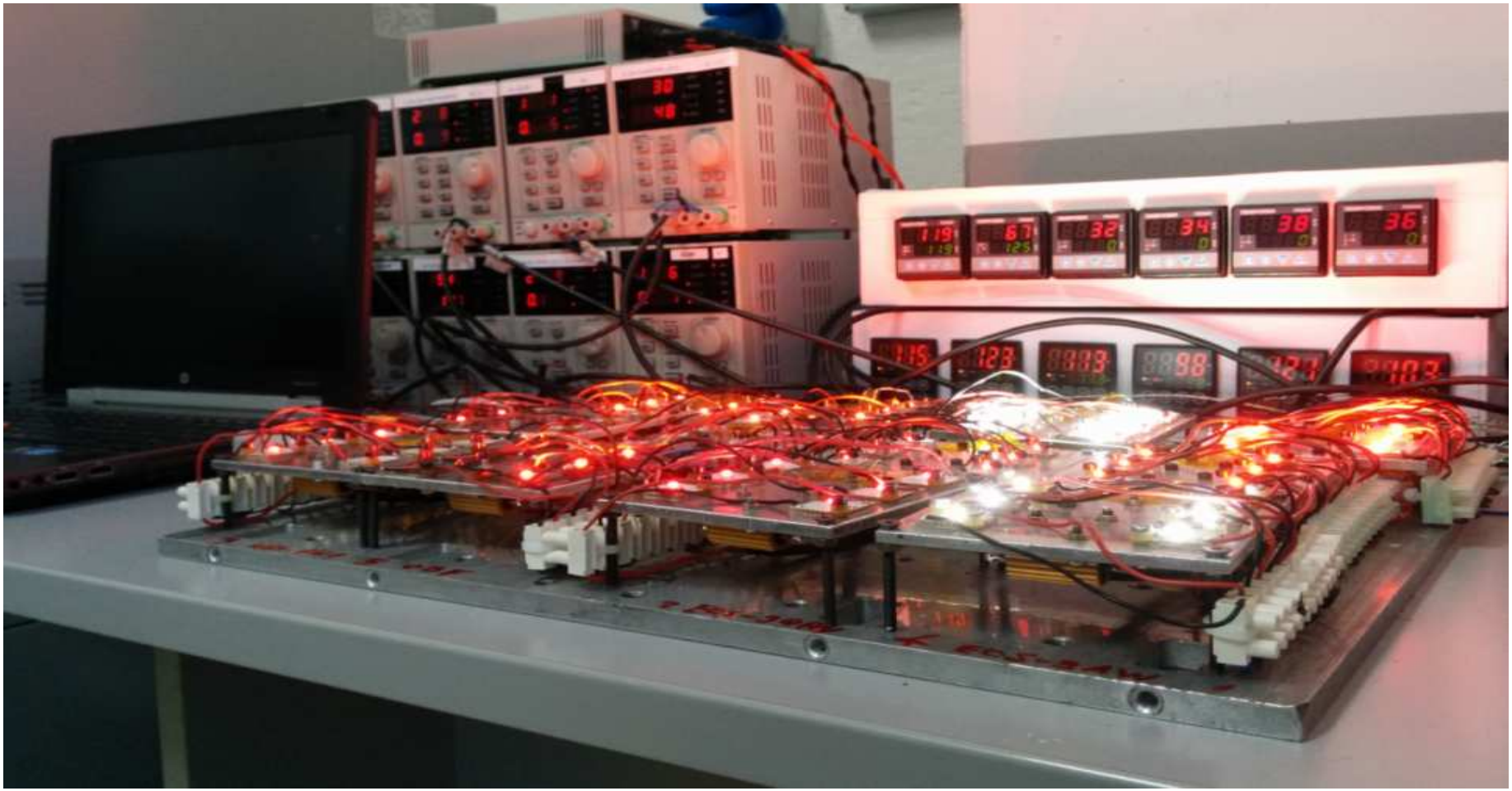
Kennwerte
Characteristics
(T_S = 25 °C)

Bezeichnung Parameter		Symbol Symbol	Wert Value			Einheit Unit
			LA	LO	LY	
Durchlassspannung[6] *Seite 16* Forward voltage[6] *page 16* I_F = 50 mA	(min.) (typ.) (max.)	V_F V_F V_F	1.90* 2.15 2.65	1.90* 2.15 2.5	2.05* 2.30 2.65	V V V
Sperrstrom Reverse current V_R = 12 V	(typ.) (max.)	I_R I_R	0.2 10	0.2 10	0.2 10	µA µA
Temperaturkoeffizient von λ_{peak} Temperature coefficient of λ_{peak} I_F = 50 mA; –10°C ≤ T ≤ 100°C	(typ.)	$TC_{\lambda peak}$	0.14	0.12	0.12	nm/K
Temperaturkoeffizient von λ_{dom} Temperature coefficient of λ_{dom} I_F = 50 mA; –10°C ≤ T ≤ 100°C	(typ.)	$TC_{\lambda dom}$	0.07	0.10	0.10	nm/K
Wärmewiderstand Thermal resistance Sperrschicht/Umgebung[4] *Seite 16* Junction/ambient[4] *page 16*		$R_{th\ JA}$		300**		K/W
Sperrschicht/Lötpad Junction/soldering point		$R_{th\ JS}$		130**		K/W

* Einzelgruppen siehe Seite 5
Individual groups on page 5

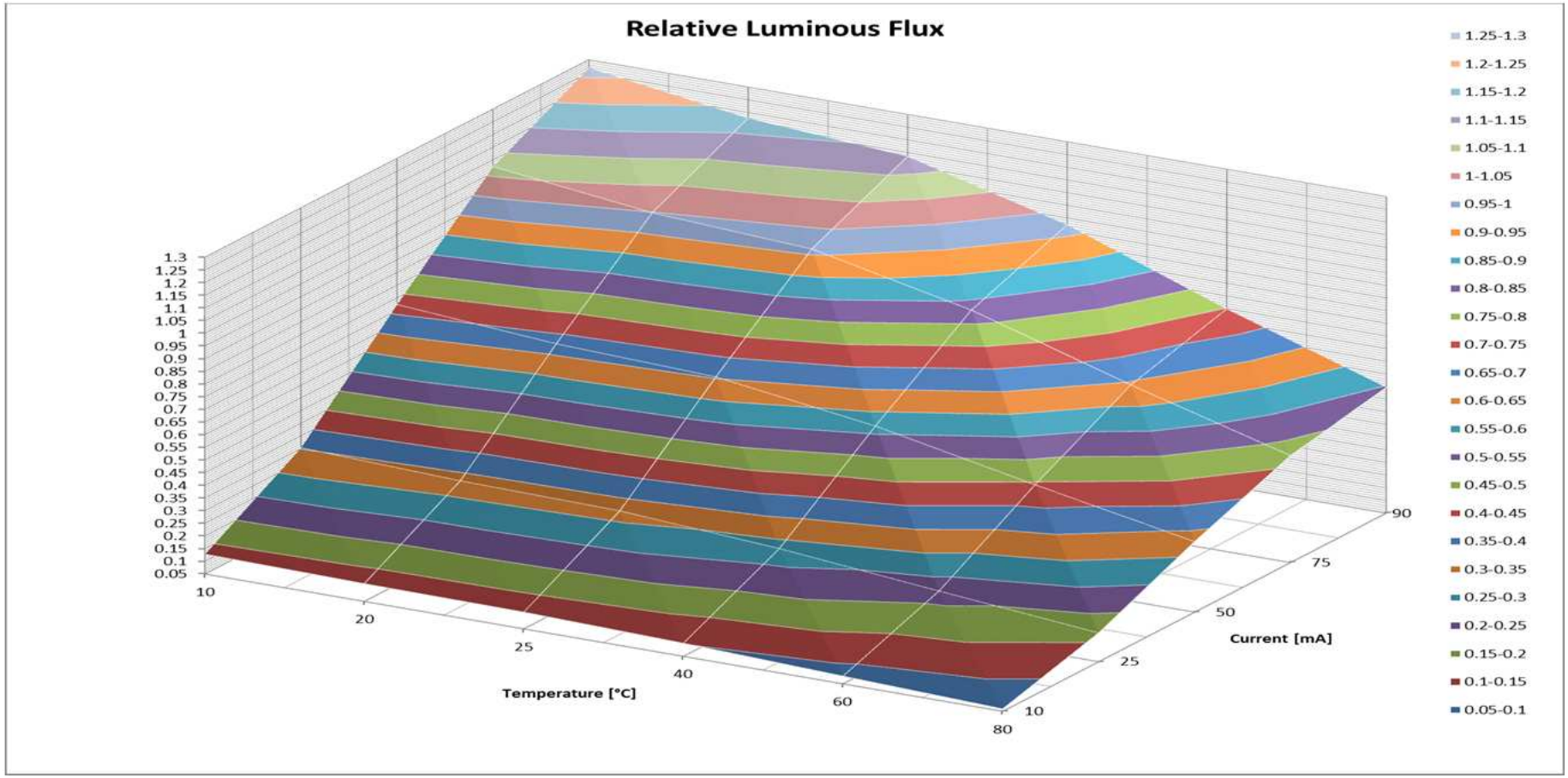
**R_{th}(max) basiert auf statistischen Werten
R_{th}(max) is based on statistic values

LED validation



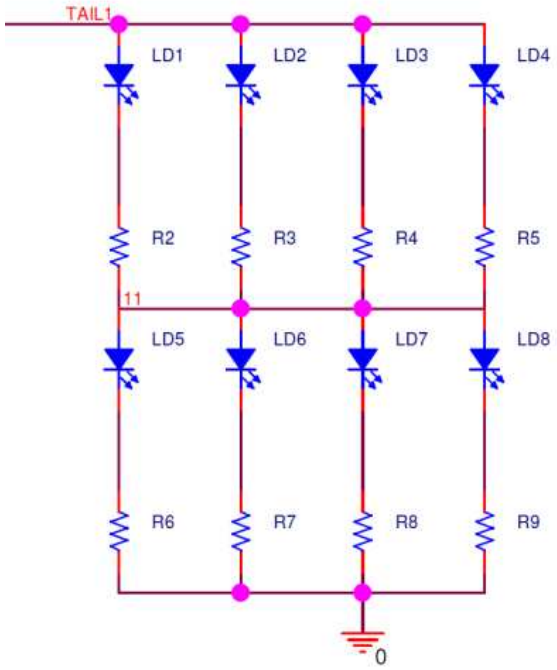
Several optical and thermal tests, life cycle simulations, quality..

LED validation



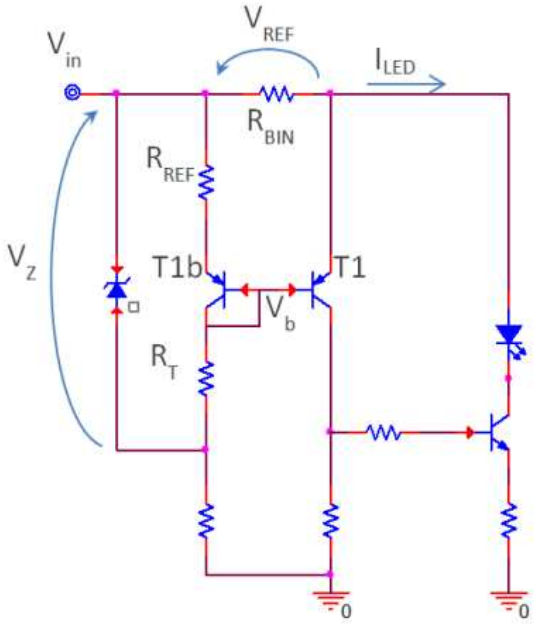
Performances analysis,
result comparison,
best devices selections

How to drive a LED: main architectures



LED and resistors

Current regulation with transistors



$$V_{REF} = V_{in} - V_b + V_{be}$$

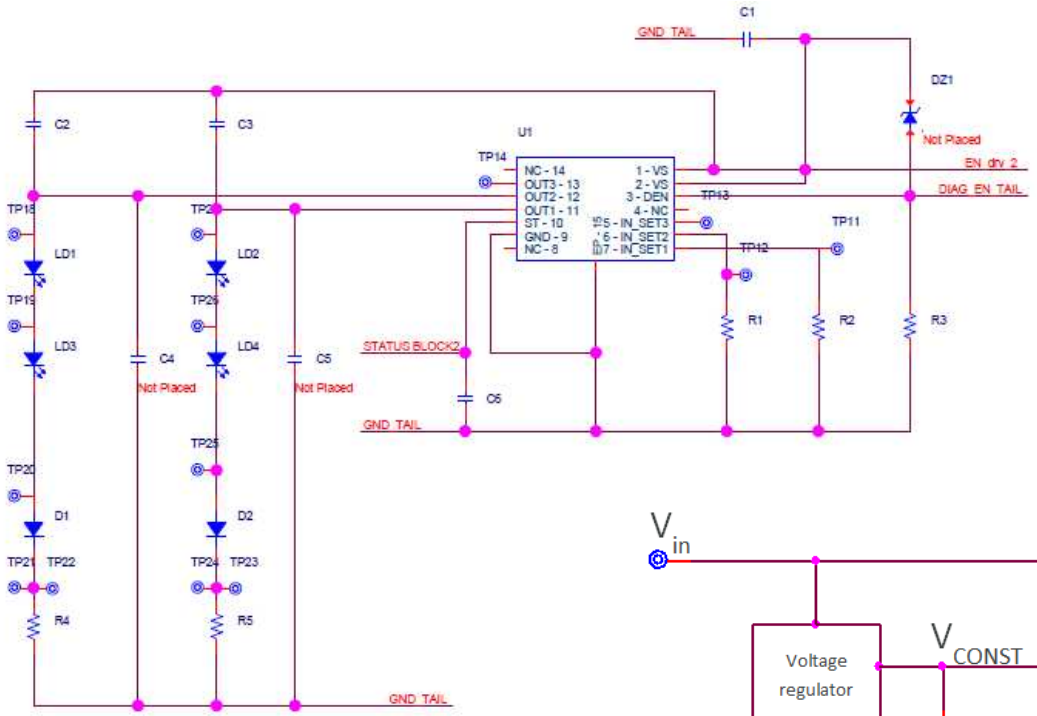
$$V_b \approx V_{in} - \frac{(V_Z - V_{be})}{R_{REF} + R_2} * R_{REF} - V_{be}$$

$$V_{REF} \approx \frac{(V_Z - V_{be})}{R_{REF} + R_T} * R_{REF} \approx \frac{V_{const}}{R_{REF} + R_T} * R_{REF}$$

$$I_{LED} \approx \frac{V_{REF}}{R_{BIN}}$$

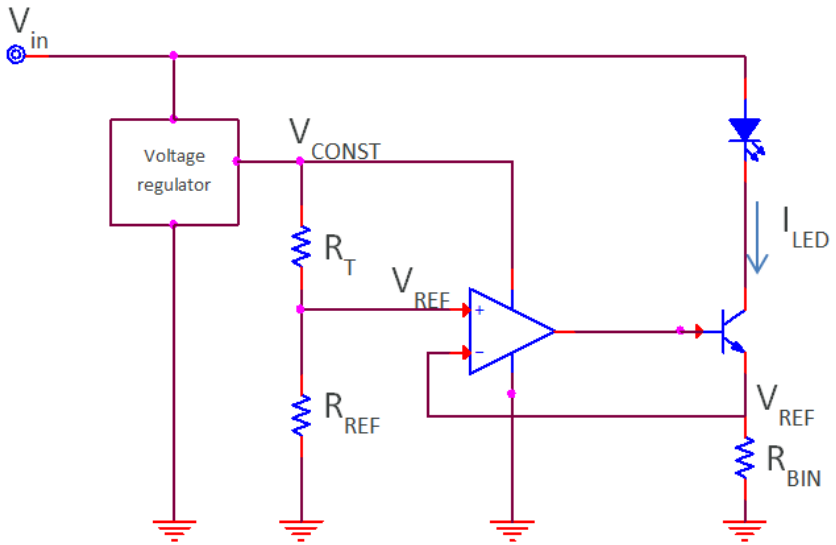
$$I_{LED} \approx \frac{V_{const}}{R_{REF} + R_T} * \frac{R_{REF}}{R_{BIN}}$$

How to drive a LED: main architectures



Current regulation with IC LED Driver

Current regulation with Op-Amp

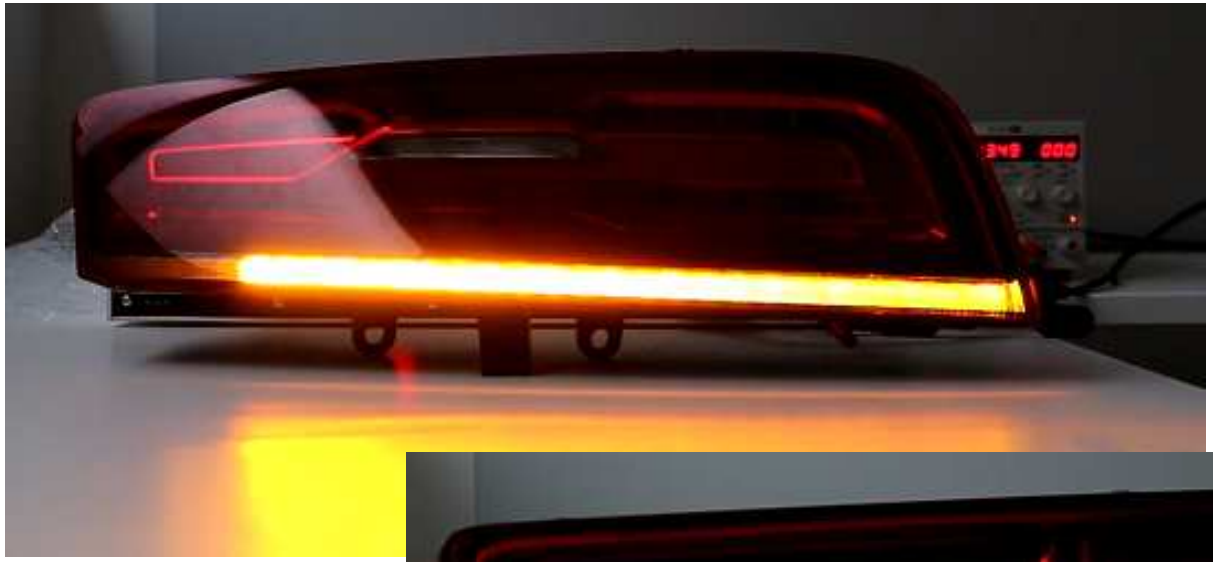


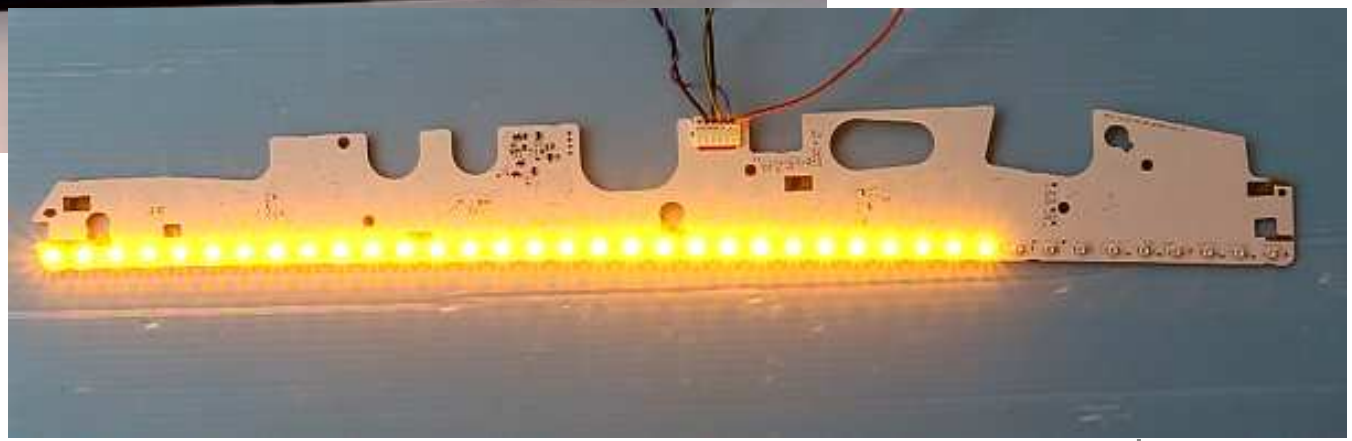
$$V_{REF} = \frac{V_{CONST}}{R_{REF} + R_T} * R_{REF}$$

$$I_{LED} = \frac{V_{REF}}{R_{BIN}}$$

Software design

Turn Wiping



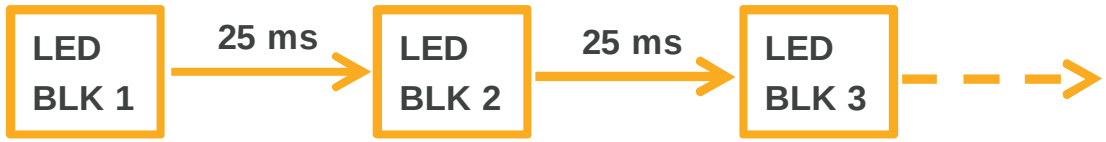


Turn Wiping

WHY IS NECESSARY TO INTRODUCE SOFTWARE?

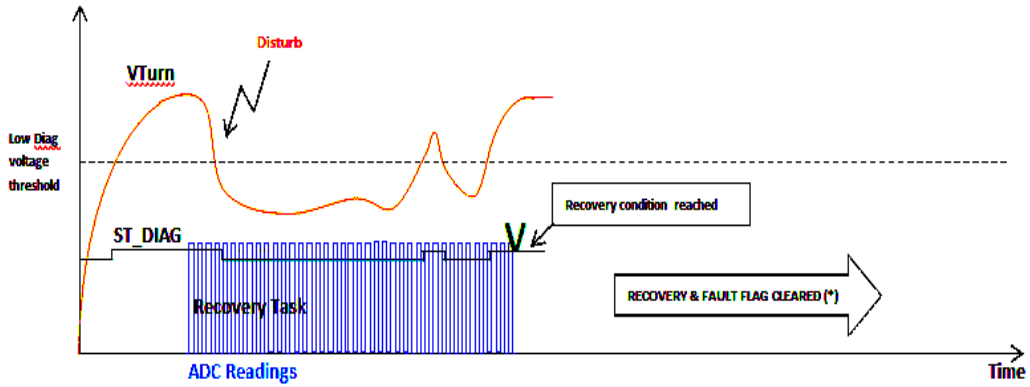
Wiping effect could be obtained also introducing simple HW delays on the several LED branch switches on…

So, why SW is necessary?



Robustness

- In case of glitch on the input voltage, the sequence must not be interrupted;
- Fault recovery;
- Robust readings (SW filtering) on the signals

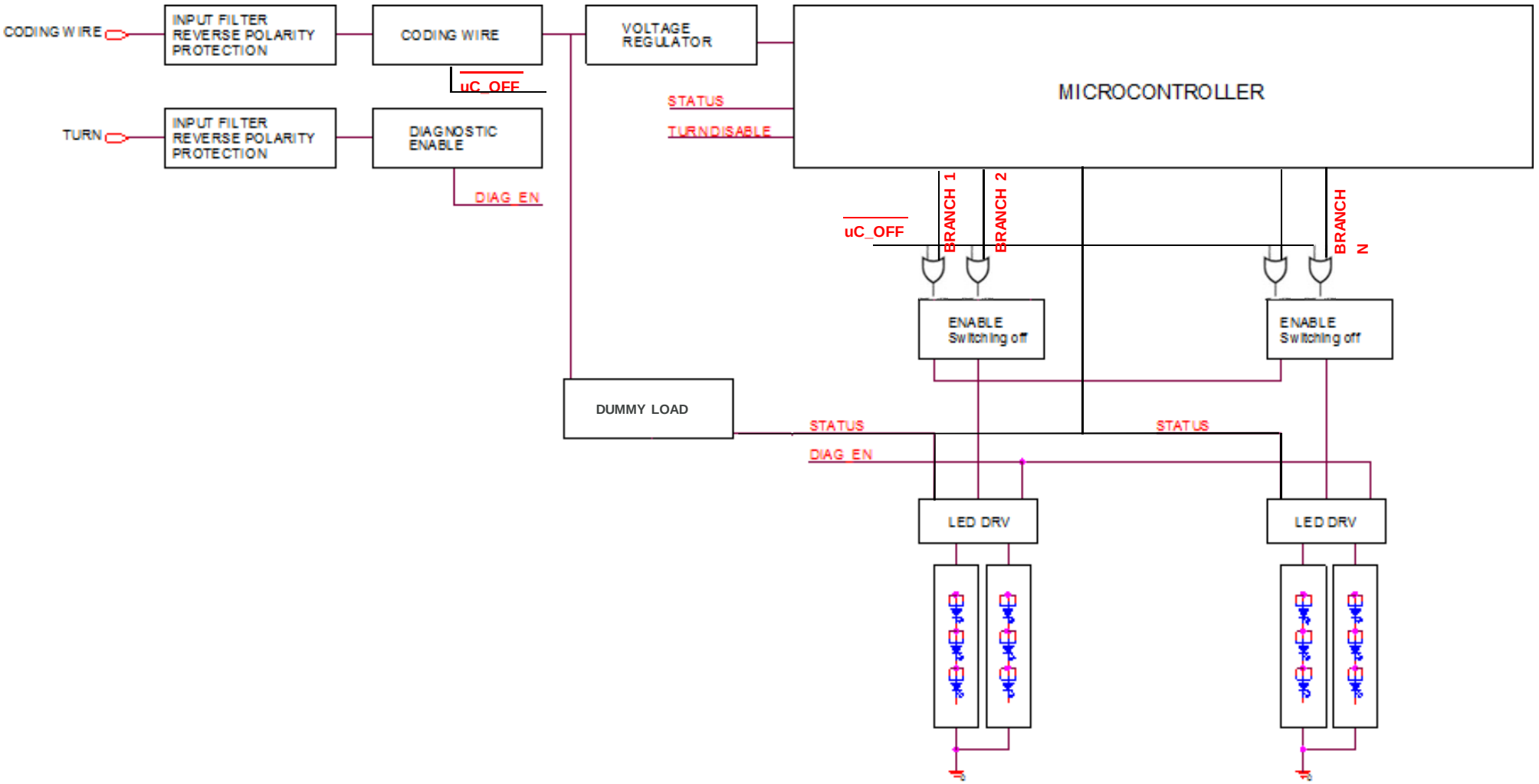


Flexible design on the animation

Function behavior during fault

- If a LED is faulty, the system memorizes the fault condition in the internal memory, in order to stay switched off and avoid aesthetical defects and to communicate the fault to the car's body computer.

Software architecture design: HW/SW partitioning

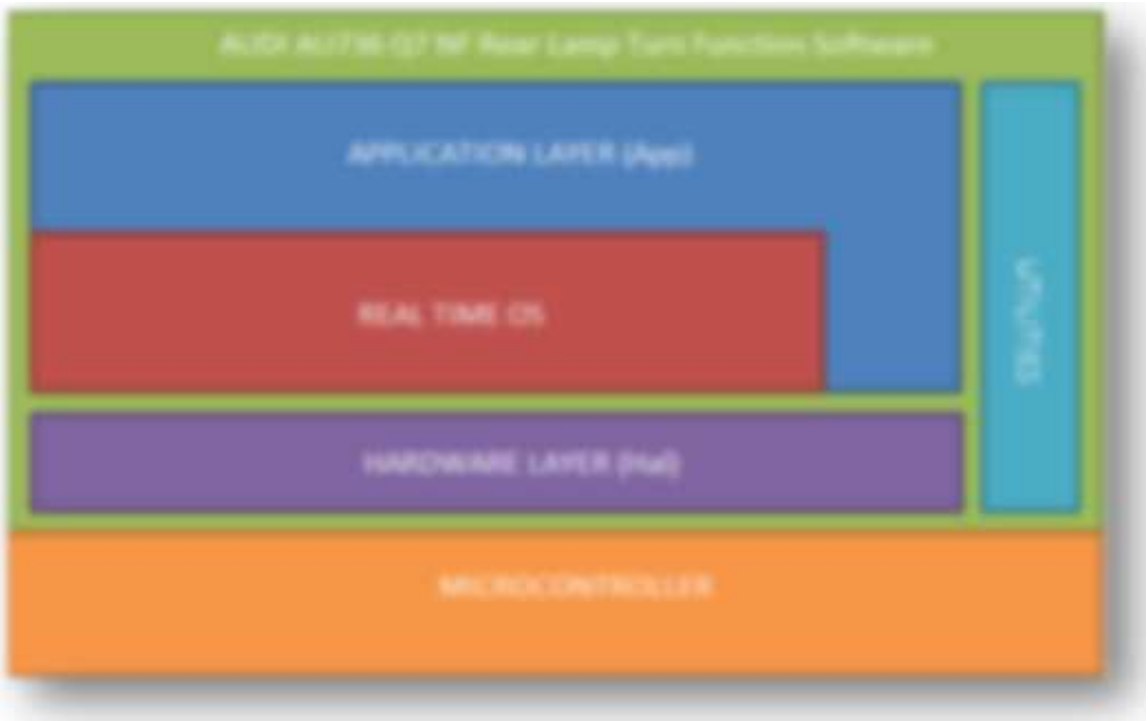


Modular design and software architecture

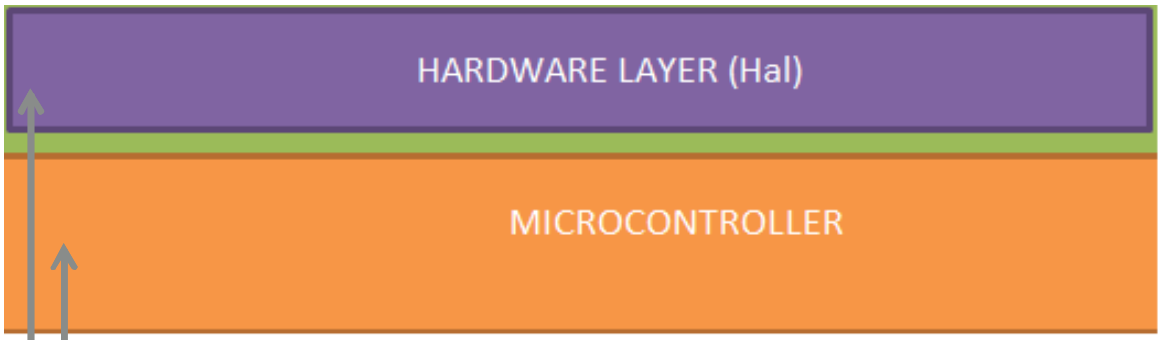
Modular software design allow us to achieve

- flexibility of design
- efficiency of implementation
- clean distribution within the architecture
- ⇨ separation of the software modules in several layers such as low-level drivers (Pwm, Adc), and high level functions

Software decomposition in layers and modules



Software design: layers



Microcontroller

- Platform based on 8 bit ST microcontroller
- uC family contains many memory/package sizes options
- Used also in headlamp projects → high volumes

Hardware layer

- Contains all the low-level drivers to access the uC peripherals with standard functions interfaces
- If uC platform is changed, only the hardware layer needs to be adapted → **portable solution**

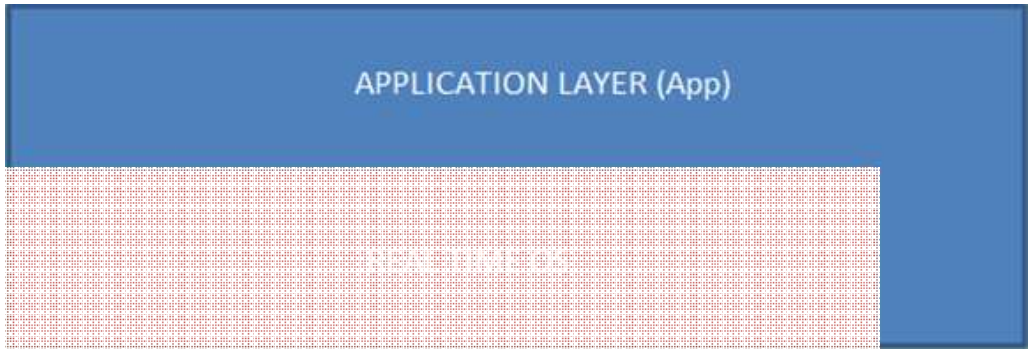
Software design: layers

REAL TIME OS

Real time operating system

- Schedules task execution with definition of 1 ms
- Assure task timing execution
- Manage task priority if multiple tasks occurs in one time slice
- Provides a common framework for modular software design on the application layer
- Provide mid-level services (error logging, watchdog and stack overflow management)
- Can be reused in different project

Software design: layers



Application layer

- Contains all the application specific functionalities
- It's the only part that need to be modified in a project that use the standard HW platform and Real Time OS
- It's based on the standard design pattern concept of state machine
- Each state of the system contains a different set of real time scheduled tasks that implement all the system state functionalities

MISRA C compliancy

Guideline Example: MISRA

Improvements:

- code robustness
- avoids misunderstandings between developers
- problems / failures are recognized sooner
- improved porting and maintenance of code

Example:

MISRA-C:2004 Rule 12.7:

no bitwise operation on signed data

(position of sign bit is compiler specific!)

```
signed int8 MyModule_nWhatever;

// Wrong
if ( MyModule_nWhatever & 0x80u ) {…}
// OK
if ( (UINT8) MyModule_nWhatever & 0x80u) {…}
```

MISRA C compliancy

```
//-------------------------------------------------------------------
/// \file   main.c
/// \brief  This file contains the main function definition
/// \author Guiotto A., ALRI-TI/EEG
/// \note   TODO
//-------------------------------------------------------------------

//-------------------------------------------------------------------
// Includes
//-------------------------------------------------------------------
#include "stmBs.h"
#include "UtilType.h"
#include "HalInit.h"
#include "Os.h"
#include "StateInterface.h"
#include "AppDefines.h"
#include "AppTaskList.h"
#include "UtilDbg.h"
#include <stdio.h>

int _fotopy(char name);

#pragma section const (version)
const char  ver[10] = "TI_v1.1.0";
#pragma section const ()

//-------------------------------------------------------------------
// Main function
//-------------------------------------------------------------------
void main(void)
{
  /* Call the _fotopy() function with the first ex
   *_fotopy('F');*  for a manual copy of the decla
   (FLASH_CODE) in RAM before execution*/
  _fotopy('F');

  MCU_init(); // Call Device Initialization

  OsStartOs(); // Start OS and never return
```

MISRA C is a set of guidelines for the development of code in C language. It increases the safety, the portability and the reliability of the code in embedded systems.

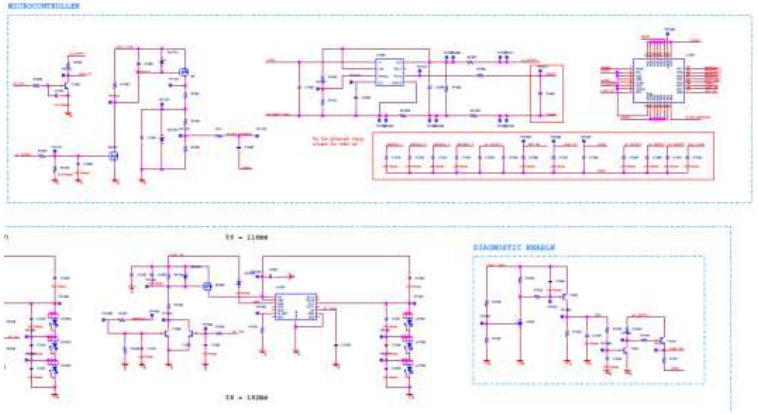
File Name	Rc	C	Code	Message
C:\Users\Admin\workspaceLNT\PsPv	25	0	Warning 659	Nothing follows '}' on line terminating struct/union/enum definition
C:\Users\Admin\workspaceLNT\PsPv	61	4	Warning 525	Negative indentation from line 60
C:\Users\Admin\workspaceLNT\PsPv	63	6	Warning 525	Negative indentation from line 60
C:\Users\Admin\workspaceLNT\PsPv	66	###	Note 9027	Unpermitted operand to operator '!' [MISRA 2012 Rule 10.1, required]
C:\Users\Admin\workspaceLNT\PsPv	81	4	Warning 525	Negative indentation from line 60
C:\Users\Admin\workspaceLNT\PsPv	###	16	Note 9012	sub-statement should be a compound statement [MISRA 2012 Rule 15.6, required]
C:\Users\Admin\workspaceLNT\PsPv	###	16	Note 904	Return statement before end of function 'OsPushTaskScheduler(function_type, function_type, MTIMER, MTIMER)' [MISRA 2012 Rule 15.5, advisory]
C:\Users\Admin\workspaceLNT\PsPv	###	24	Note 9012	sub-statement should be a compound statement [MISRA 2012 Rule 15.6, required]
C:\Users\Admin\workspaceLNT\PsPv	###	24	Note 904	Return statement before end of function 'OsInitTask(task_id_t, MTIMER)' [MISRA 2012 Rule 15.5, advisory]
C:\Users\Admin\workspaceLNT\PsPv	###	41	Warning 661	Possible access of out-of-bounds pointer (1 beyond end of data) by operator '[' [Reference: file C:\Users\Admin\workspaceLNT\PsPwm_Module\AL_RTSvA\
C:\Users\Admin\workspaceLNT\PsPv	###	51	Warning 661	Possible access of out-of-bounds pointer (1 beyond end of data) by operator '[' [Reference: file C:\Users\Admin\workspaceLNT\PsPwm_Module\AL_RTSvA\
C:\Users\Admin\workspaceLNT\PsPv	###	24	Note 9012	sub-statement should be a compound statement [MISRA 2012 Rule 15.6, required]
C:\Users\Admin\workspaceLNT\PsPv	###	53	Warning 661	Possible access of out-of-bounds pointer (1 beyond end of data) by operator '[' [Reference: file C:\Users\Admin\workspaceLNT\PsPwm_Module\AL_RTSvA\
C:\Users\Admin\workspaceLNT\PsPv	###	89	Warning 661	Possible access of out-of-bounds pointer (1 beyond end of data) by operator '[' [Reference: file C:\Users\Admin\workspaceLNT\PsPwm_Module\AL_RTSvA\
C:\Users\Admin\workspaceLNT\PsPv	###	89	Warning 661	Possible access of out-of-bounds pointer (1 beyond end of data) by operator '[' [Reference: file C:\Users\Admin\workspaceLNT\PsPwm_Module\AL_RTSvA\
C:\Users\Admin\workspaceLNT\PsPv	###	51	Warning 661	Possible access of out-of-bounds pointer (1 beyond end of data) by operator '[' [Reference: file C:\Users\Admin\workspaceLNT\PsPwm_Module\AL_RTSvA\
C:\Users\Admin\workspaceLNT\PsPv	###	16	Note 904	Return statement before end of function 'OsInitTask(task_id_t, MTIMER)' [MISRA 2012 Rule 15.5, advisory]
C:\Users\Admin\workspaceLNT\PsPv	###	8	Note 9077	missing unconditional break from final switch case [MISRA 2012 Rule 16.1, required], [MISRA 2012 Rule 16.3, required]
C:\Users\Admin\workspaceLNT\PsPv	###	50	Warning 661	Possible access of out-of-bounds pointer (1 beyond end of data) by operator '[' [Reference: file C:\Users\Admin\workspaceLNT\PsPwm_Module\AL_RTSvA\
C:\Users\Admin\workspaceLNT\PsPv	###	16	Note 9012	sub-statement should be a compound statement [MISRA 2012 Rule 15.6, required]
C:\Users\Admin\workspaceLNT\PsPv	###	16	Note 904	Return statement before end of function 'OsStartTask(task_id_t)' [MISRA 2012 Rule 15.5, advisory]
C:\Users\Admin\workspaceLNT\PsPv	###	41	Warning 661	Possible access of out-of-bounds pointer (1 beyond end of data) by operator '[' [Reference: file C:\Users\Admin\workspaceLNT\PsPwm_Module\AL_RTSvA\
C:\Users\Admin\workspaceLNT\PsPv	###	53	Warning 661	Possible access of out-of-bounds pointer (1 beyond end of data) by operator '[' [Reference: file C:\Users\Admin\workspaceLNT\PsPwm_Module\AL_RTSvA\
C:\Users\Admin\workspaceLNT\PsPv	###	16	Note 904	Return statement before end of function 'OsStartTask(task_id_t)' [MISRA 2012 Rule 15.5, advisory]
C:\Users\Admin\workspaceLNT\PsPv	###	8	Note 9077	missing unconditional break from final switch case [MISRA 2012 Rule 16.1, required], [MISRA 2012 Rule 16.3, required]
C:\Users\Admin\workspaceLNT\PsPv	###	50	Warning 661	Possible access of out-of-bounds pointer (1 beyond end of data) by operator '[' [Reference: file C:\Users\Admin\workspaceLNT\PsPwm_Module\AL_RTSvA\

ANALYSIS RESULT

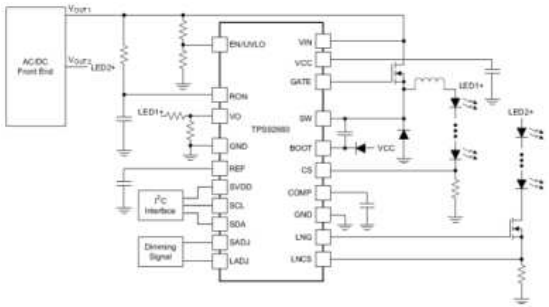
Continuous platform optimization

- **uC scouting to improve the function integration, bus communication and cost reduction**

- **HW/SW optimization, to improve cost and robustness**



- **Research on new implementation**



NCV7683

Product Preview

Enhanced 100mA Linear Current Regulator and Controller for Automotive LED Rear Combination Lamps

The NCV7683 consists of eight linear programmable constant current sources. The part is designed for use in the regulation and control of LED based Rear Combination Lamps for automotive applications. System design with the NCV76xx allows for two programmed levels for stop (100% Duty Cycle) and tail illumination (programmable Duty Cycle), or an optional external PWM control can be implemented.

Discrete LED brightness levels are easily programmed (stop is programmed to the absolute current value, tail is programmed to the duty cycle) with two external resistors. The use of an optional external ballast FET allows for power distribution on designs requiring high currents. Set back power limit reduces the drive current during overvoltage conditions. This is most useful for low power applications when no external FET is used. Over temperature conditions also use the set back power feature.

Enhanced features of this device include better thermal performance, a global enable function, and display sequencing.

The device is available in SSOP-24 package with exposed pad.

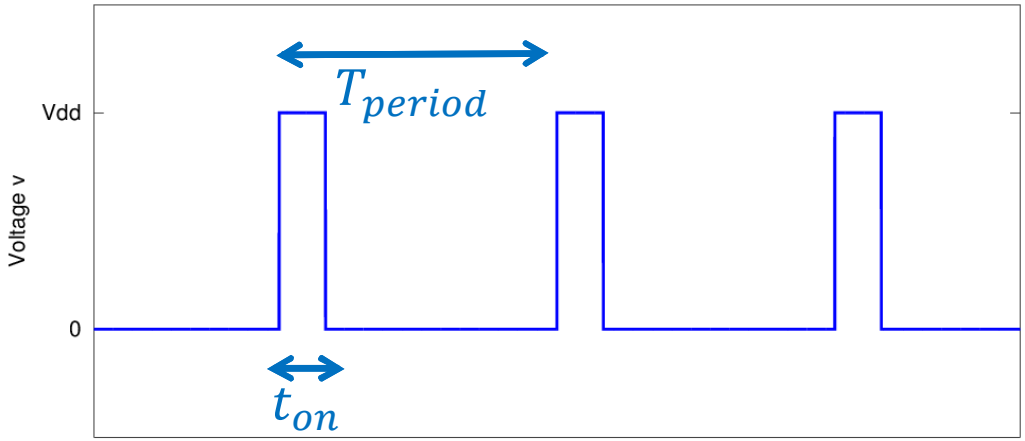
ON Semiconductor®
http://onsemi.com

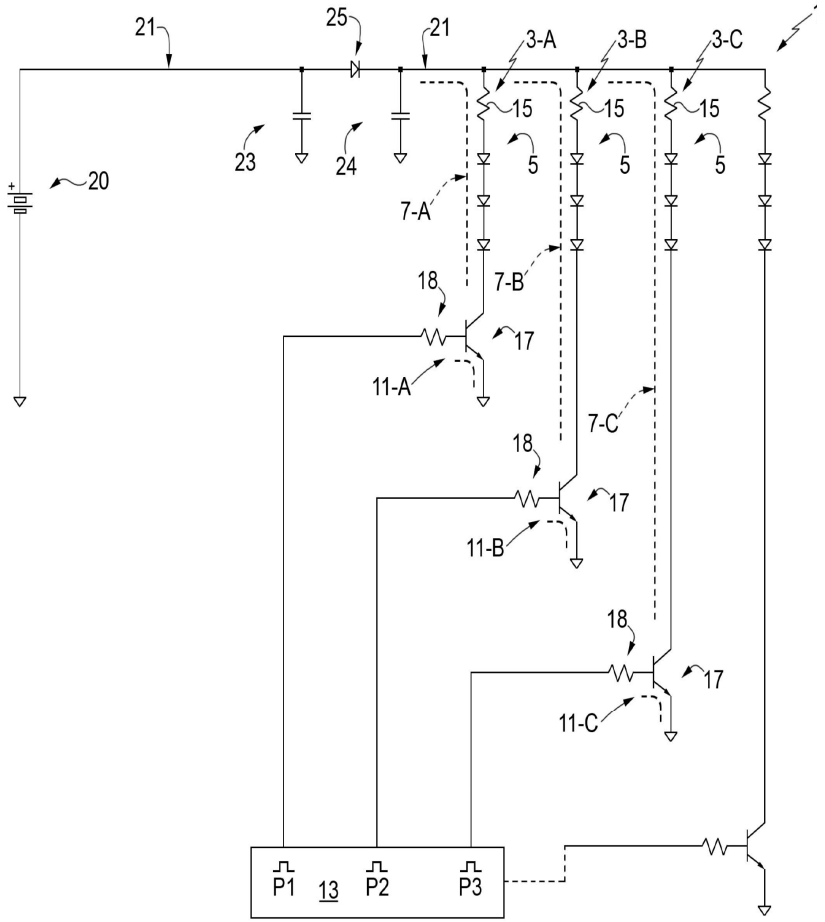
SSOP–24
CASE 565AL

Case study: PWM generation

Why PWM?

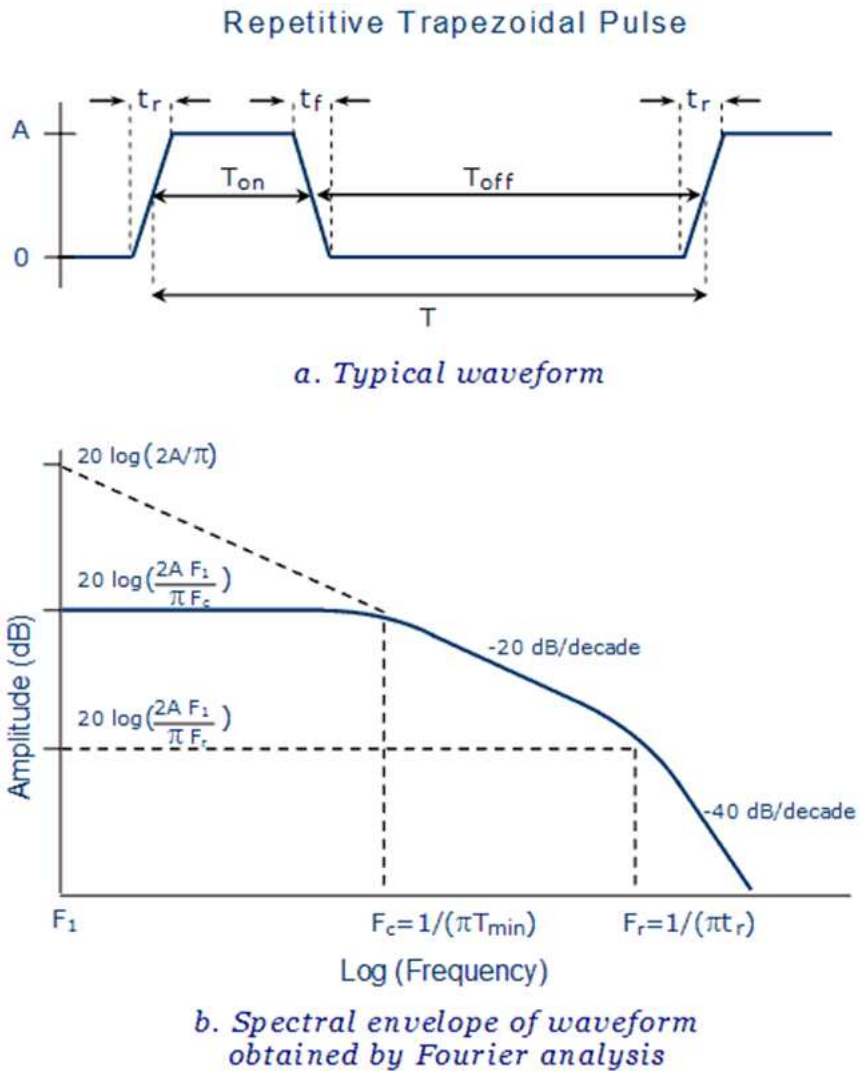
- Customer and market requests for **dimmed luminosity**:
  - *Background light* during wiping in *SAE* market;
  - *Smooth wiping*;
  - *Welcome effects*.
- **P**ulse **W**idth **M**odulation:
  - Simple control of LED branches;
  - Mean LED branch current:
    - $I_{mean} = I_{max} \frac{t_{on}}{T_{period}}$.
  - Generated by µController.





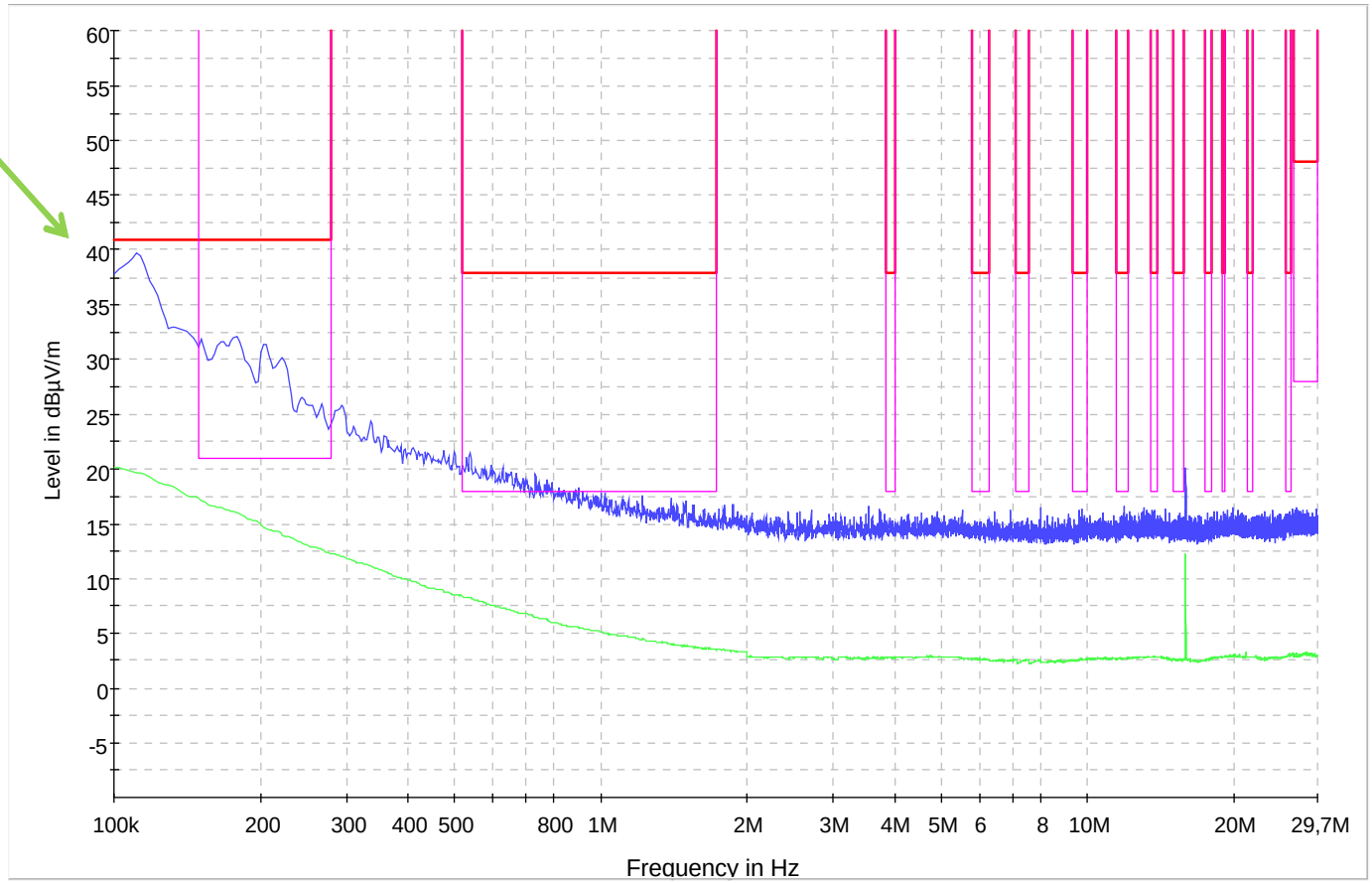
Not a good news for EMC…

- *Spurious harmonics* introduced;
  - **Integer multiples of** $f_{Period} = \frac{1}{T_{period}}$;
- *First pole* at $F_c = 1/(\pi T_{min})$;
  - $T_{min} = \min(t_{on}, t_{off})$;
  - Low luminosity requires small t_{on};
  - **Very high cut-off frequency**!
- *Second pole* at $F_r = 1/(\pi t_r)$;
  - t_r rise time of the signal;
  - t_r **should be quite fast**.



Not a good news for EMC…

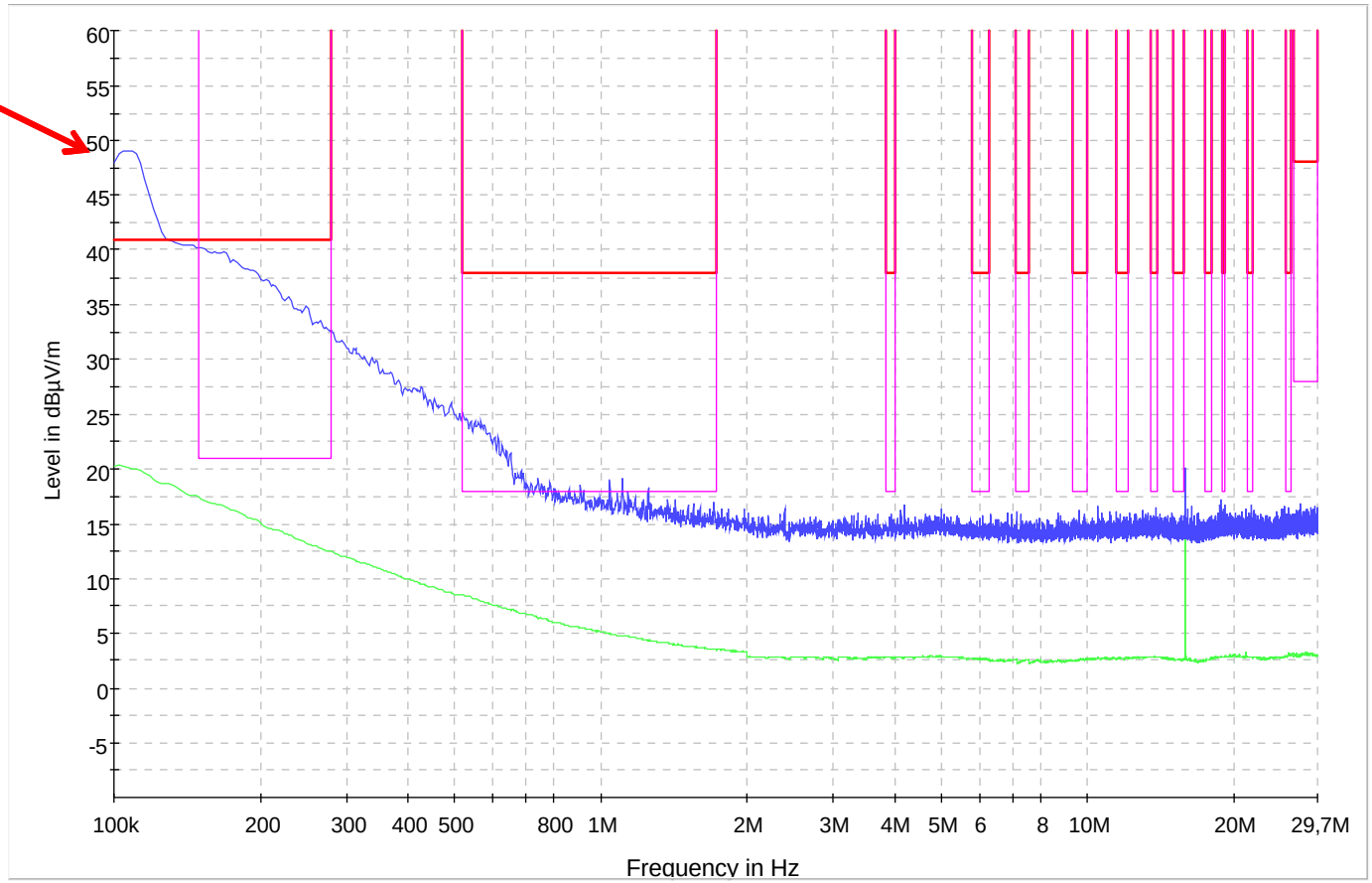
OK



no PWM

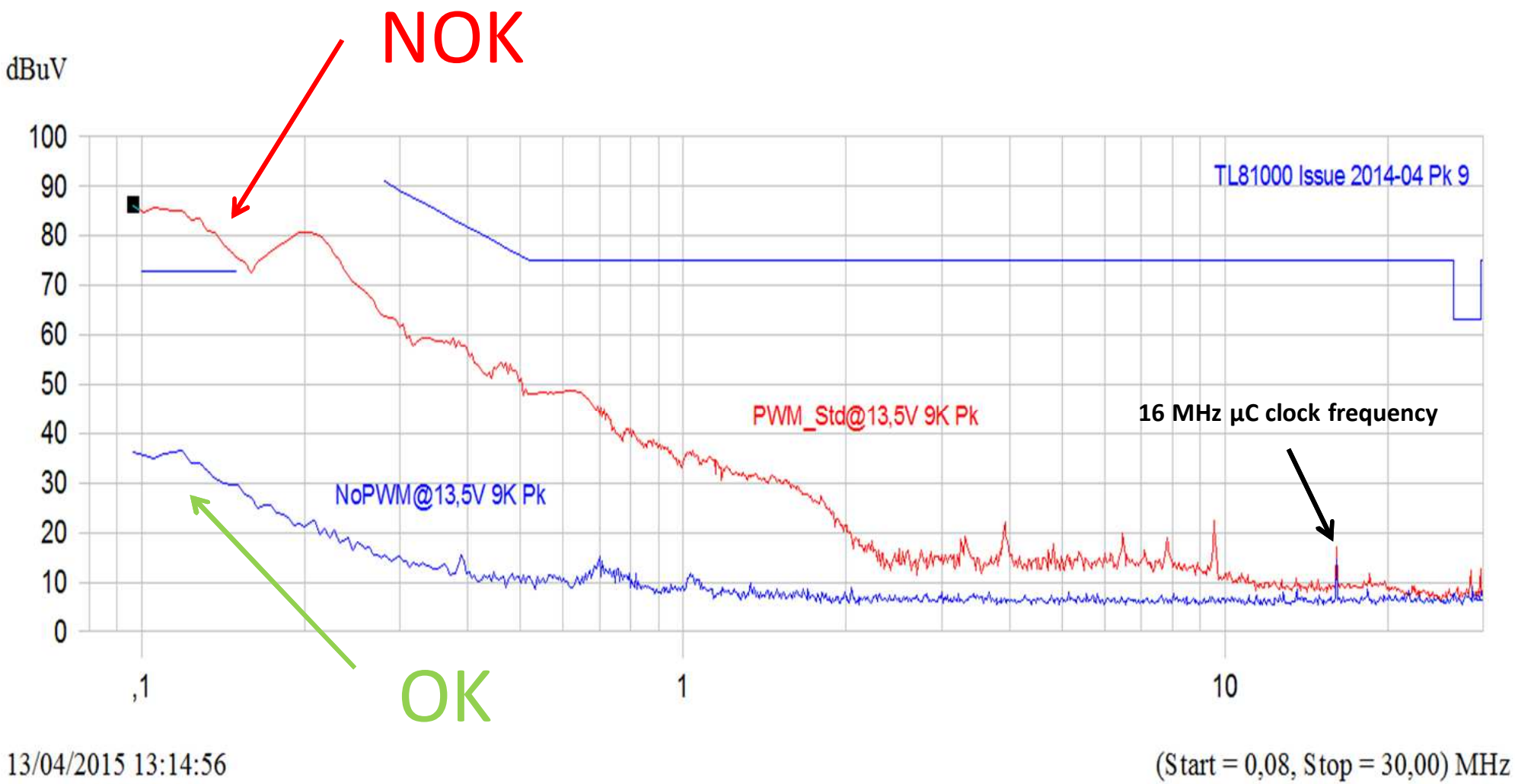
Not a good news for EMC…

NOK



with PWM

Not a good news for EMC…

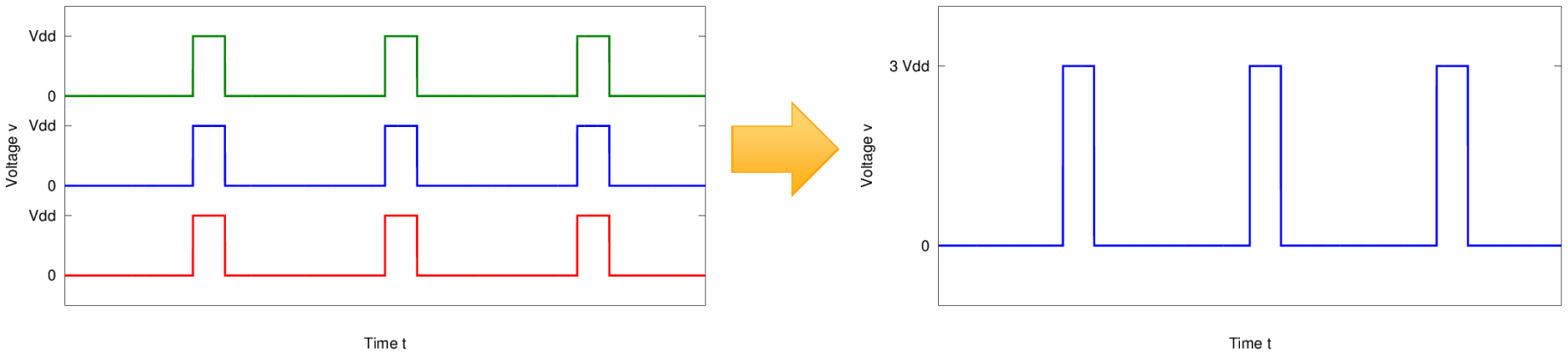


6 LED branches, **without PWM** and **with 2% PWM**

Phase Shift PWM

How to reduce PWM harmonics?

- Generally, *multiple LED branches* controlled by the same t_{on};
- All the signal harmonics sum with the *same phase*;
  - PWM disturbances are *emphasized*;
- Possible solution: **phase shift** among the signals;
  - It can be easily *done by µC*;
  - Aim: *destructive interference* between the frequency spectra.
- How to choose phase shifts?
  - Simple solution: *uniform phase shift*;
    - $\delta = T_{period}/N$;
    - N number of LED branches.



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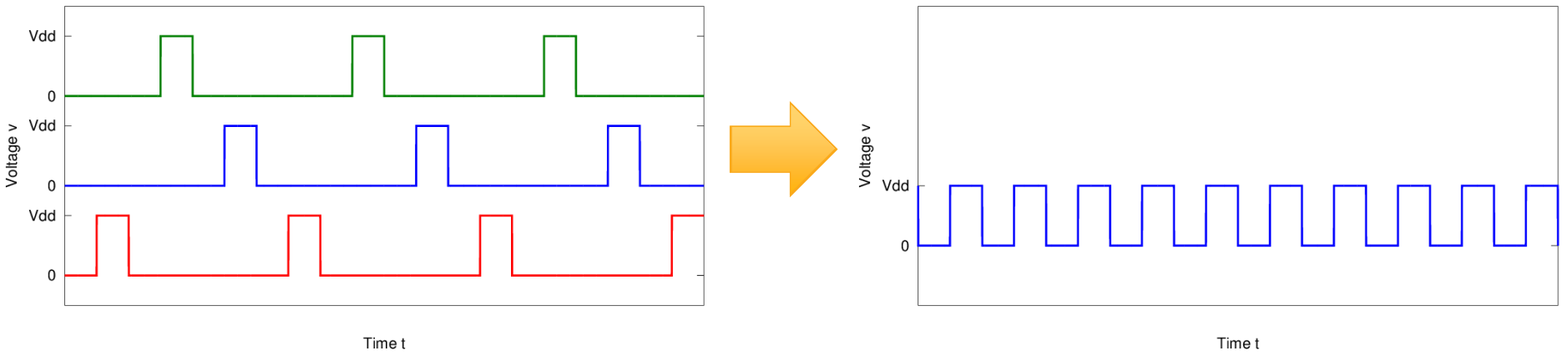
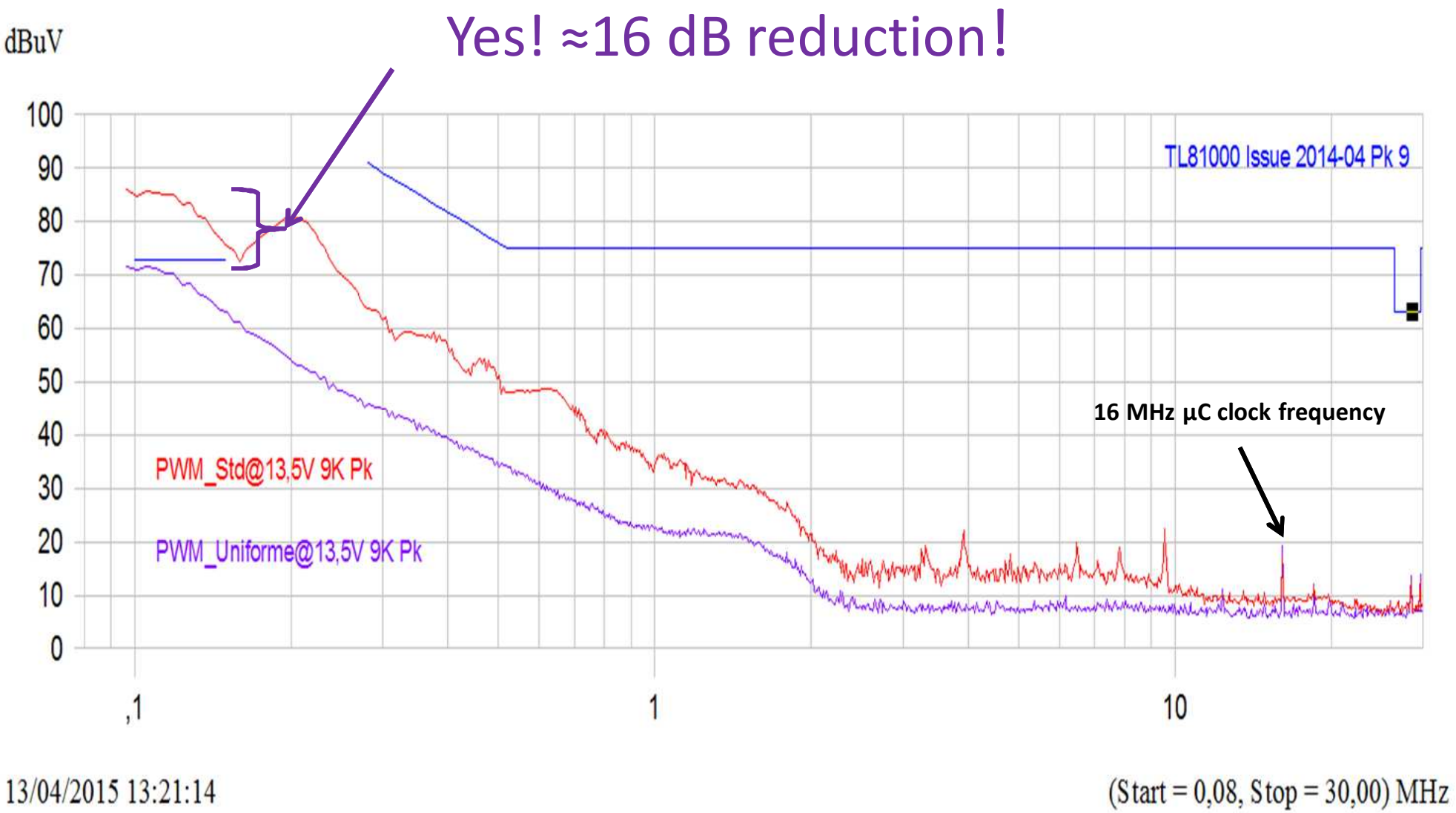


Does it works?



6 LED branches, 2% PWM ***without*** *and* ***with phase shift***

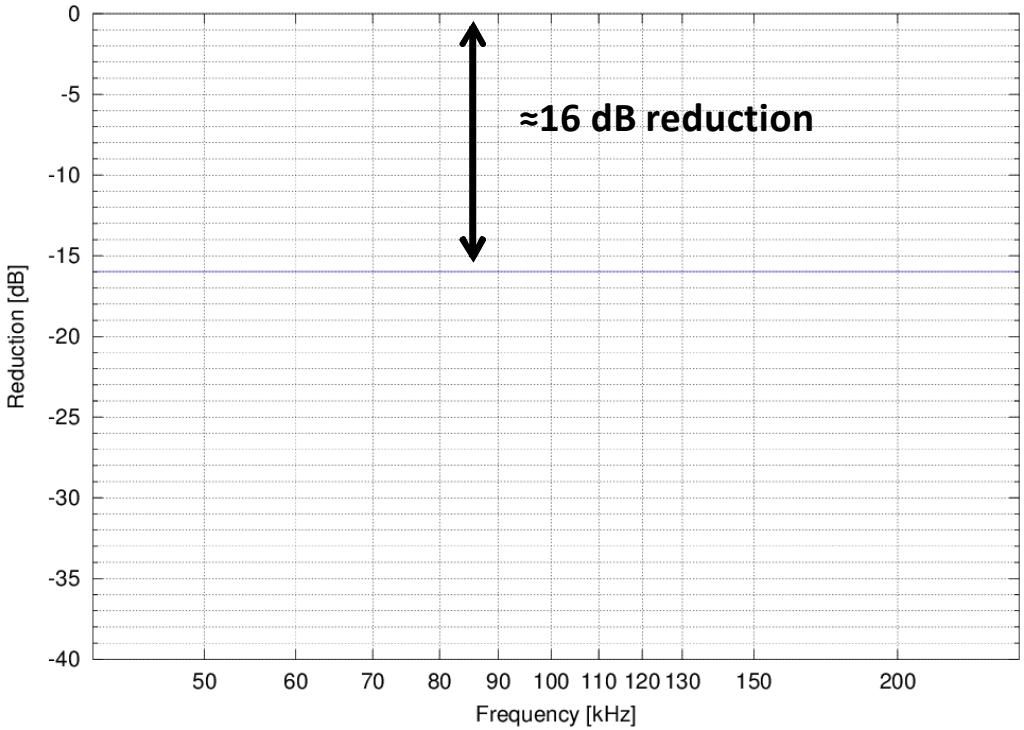
Optimization of the PWM Phase Shifts

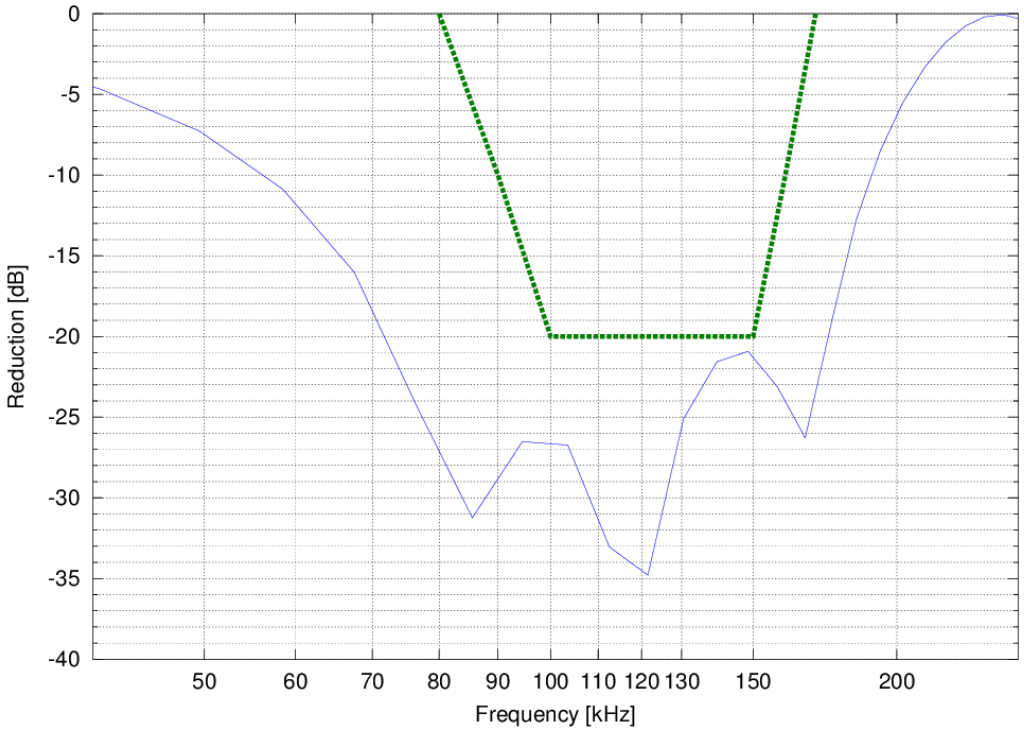
Can we do it even better?

- Are different choices for phase shifts better?
- Uniform phase shift solution is not "*customizable*";
  - Very small margin in some areas and very large in others;
- We want to "**shape**" EMC frequency spectrum.

Can we do it even better?

- Reduction given by uniform phase:
  - Fixed: $20\ \log_{10}(1/N)$, N number of LED branches;
  - Constant in frequency.
- We want to shape the spectrum with an user-supplied mask;
  - To gain margin in a particular frequency range.





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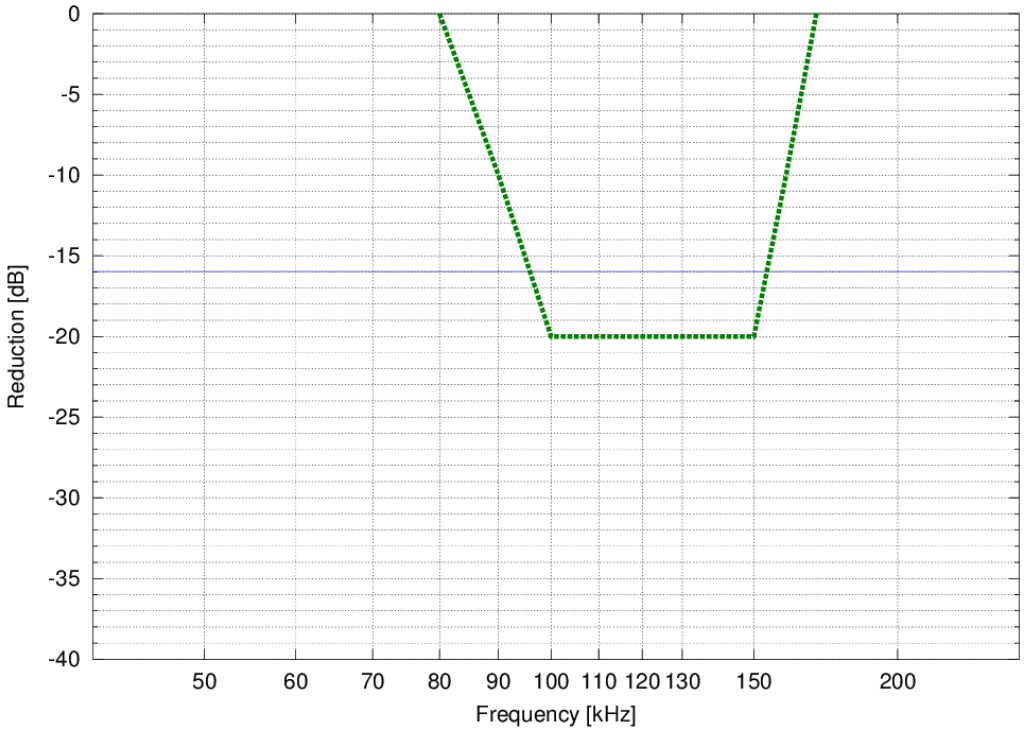
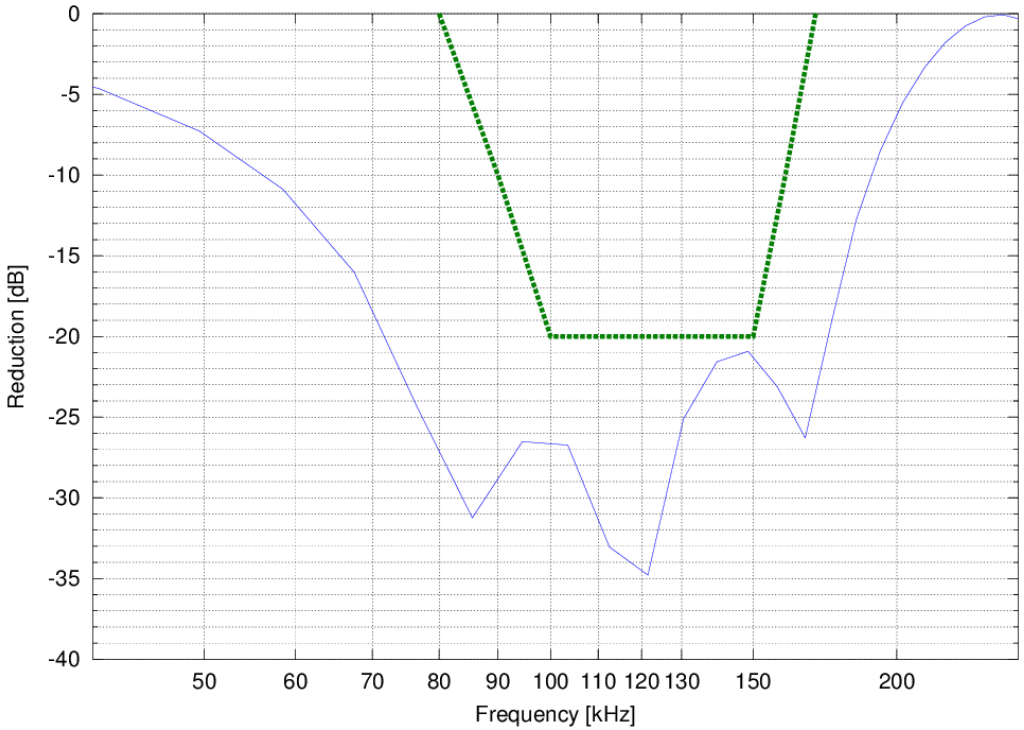




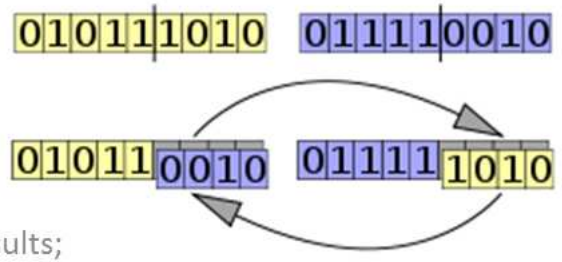
Phase Shift Optimization

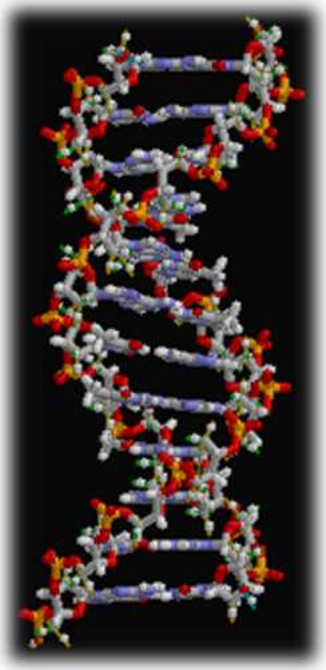
- We have to consider the **sum of the PWM signals**:
  - $A(t) = x_{PWM}(t) + x_{PWM}(t + \delta_1) + \cdots + x_{PWM}(t + \delta_{N-1})$
    - $x_{PWM}(t)$ is the **PWM signal**;
    - N is the **number of LED branches** to be controlled by PWM;
    - $\delta_1, \ldots, \delta_{N-1}$ are the $N - 1$ **relative delays**.
- The **Fourier transform** is:
  - $A(f) = X_{PWM}(f) + X_{PWM}(f)e^{i2\pi f \delta_1} + \cdots + X_{PWM}(f)e^{i2\pi f \delta_{N-1}} = \\ = X_{PWM}(f) \cdot (1 + e^{i2\pi f \delta_1} + \cdots + e^{i2\pi f \delta_{N-1}})$
    - $X_{PWM}(f)$ is the **spectrum of the PWM signal**;
      - We can hardly change it, since it depends on t_{on} and t_r;
    - We can optimize the delays $\delta_1, \ldots, \delta_{N-1}$.
- **Patent pending method**.
- Problem: how to choose the best delays?
  - *"Brute-force" algorithms* not feasible (too time-consuming).

Genetic Algorithm

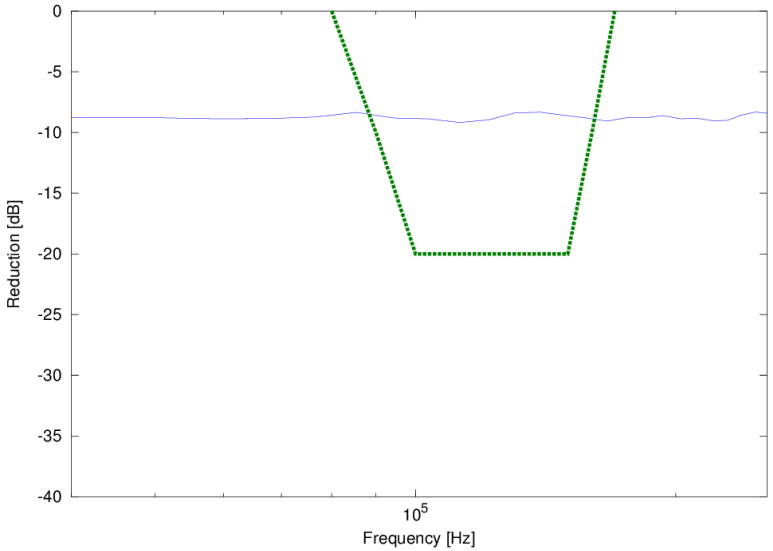
- **Heuristic numerical optimization** method;
- Mimics **biological life evolution**:
  1. *Random generation* of possible solutions;
     - Random set of phase shifts;
  2. Solutions *fitness computation*;
     - Distance to a particular frequency mask;
  3. *Cross-over*;
     - Mixing together solutions can give you better results;
  4. Random *mutation*;
     - Exploration of new possible solutions.
- Implementation in **Visual Studio C++.**

Iterate

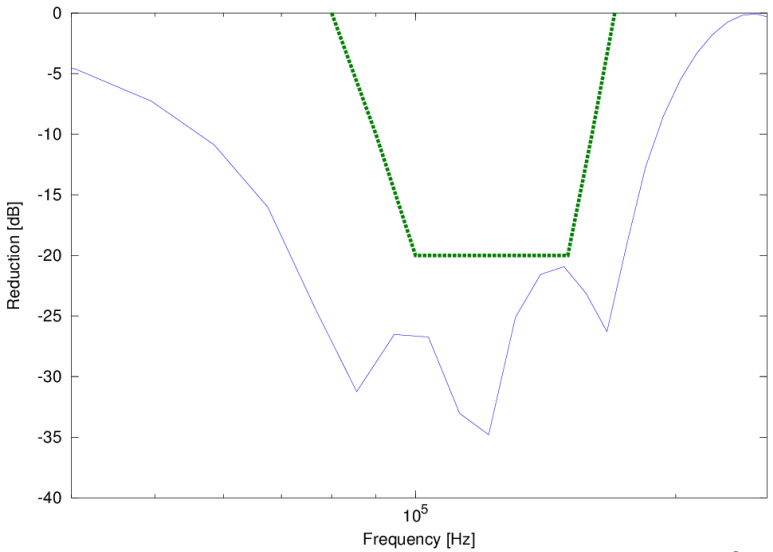




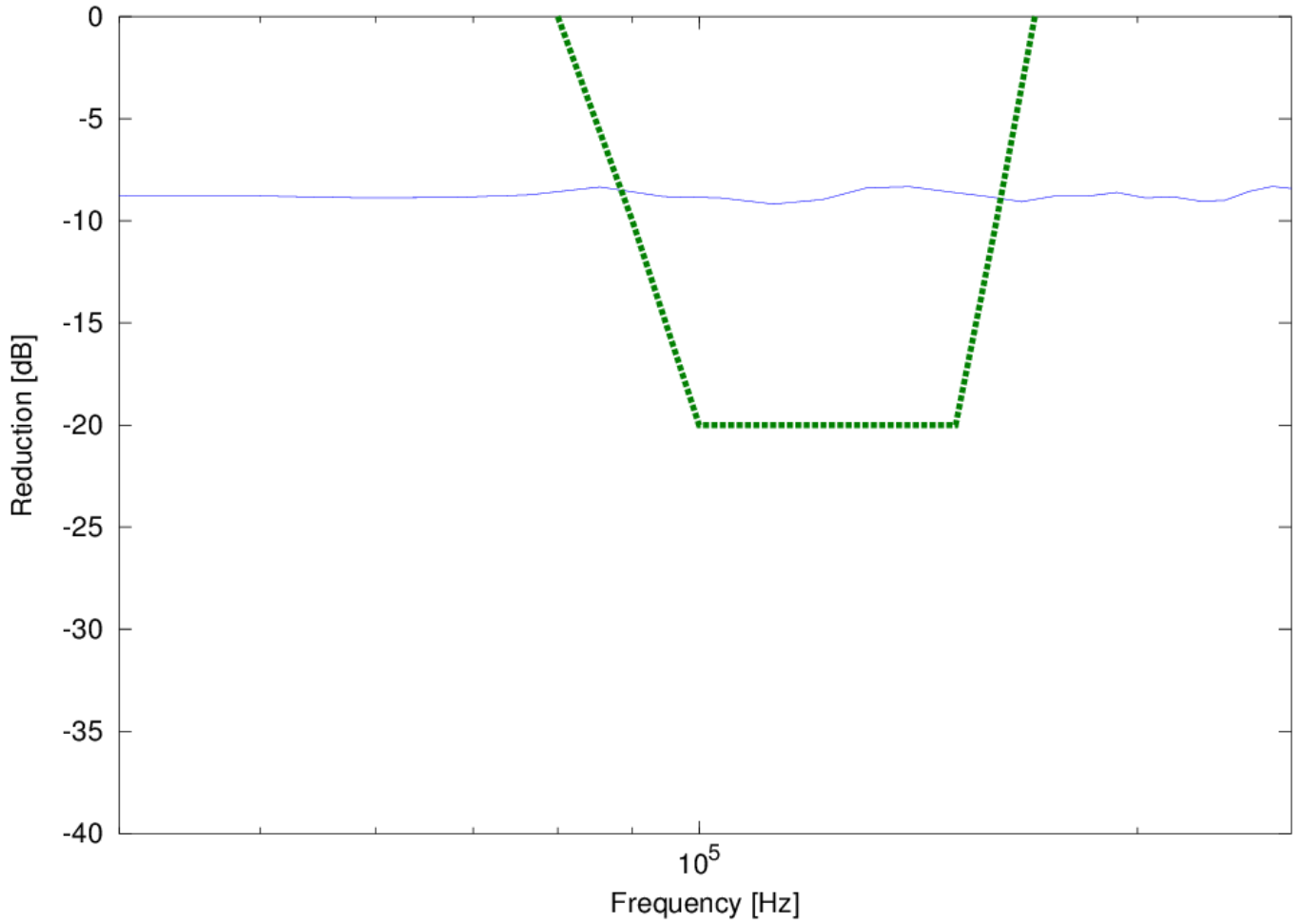
Low fitness



High fitness

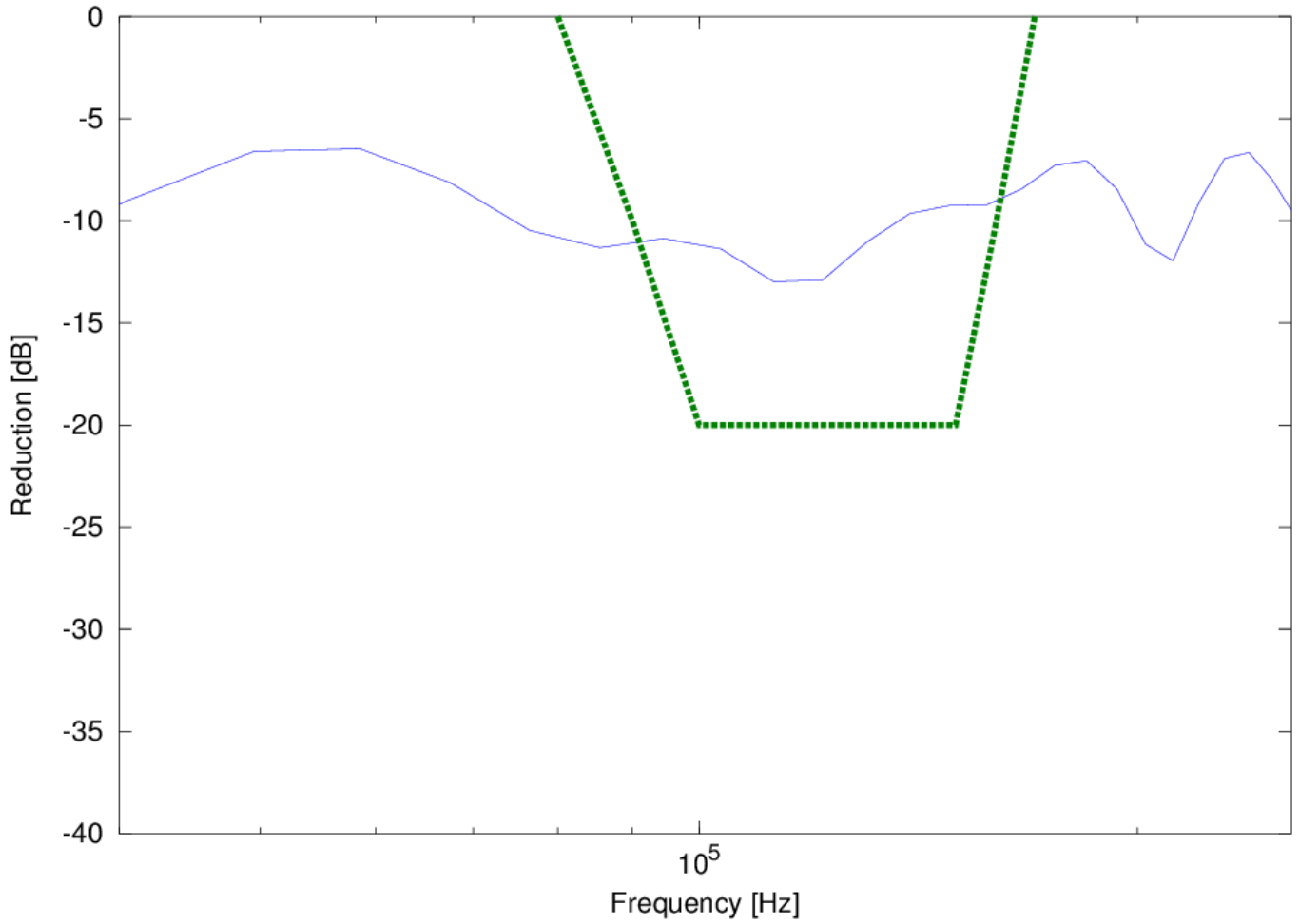


Example of Optimization



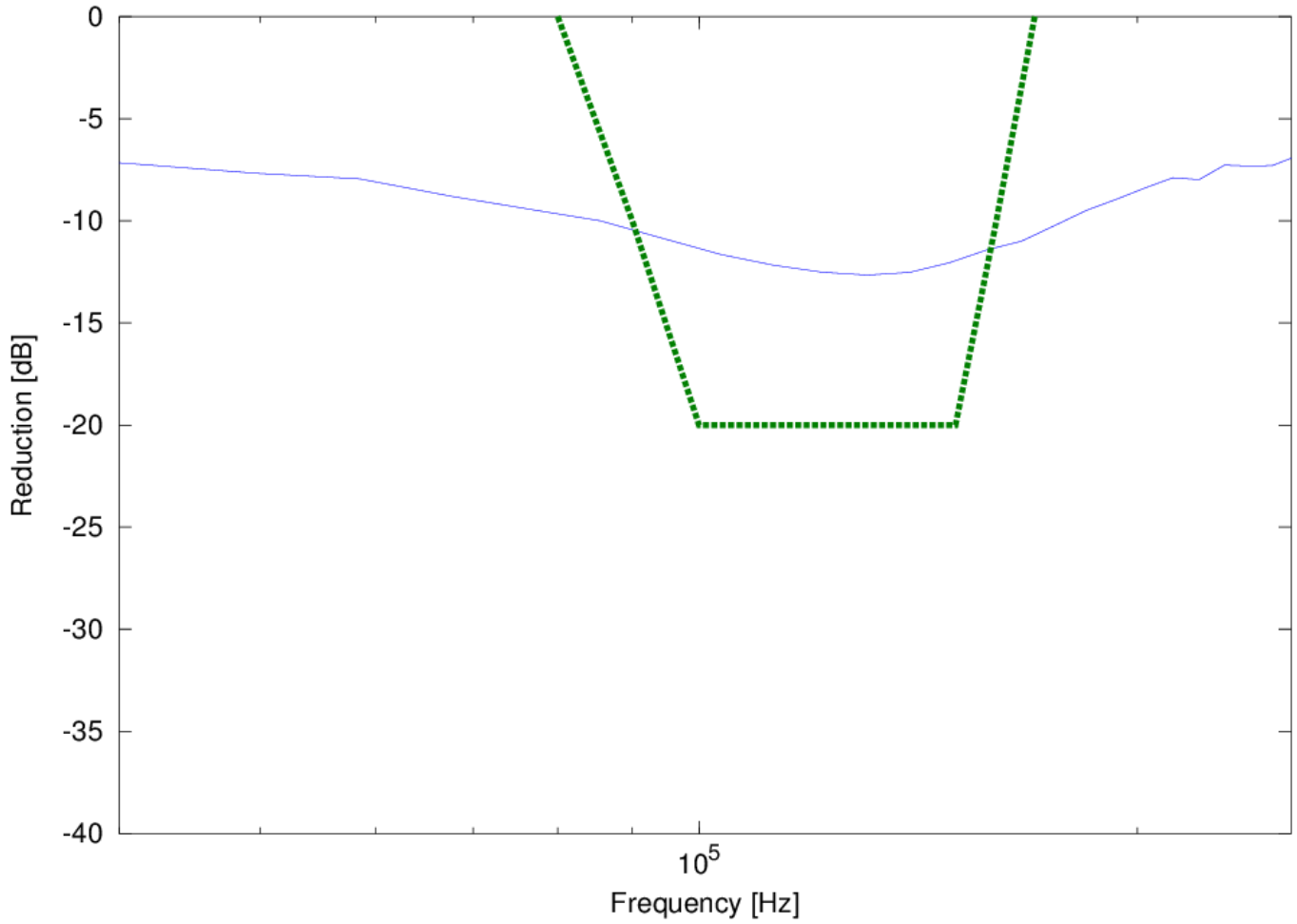
Initial solution, *15.7% fitness*.

Example of Optimization



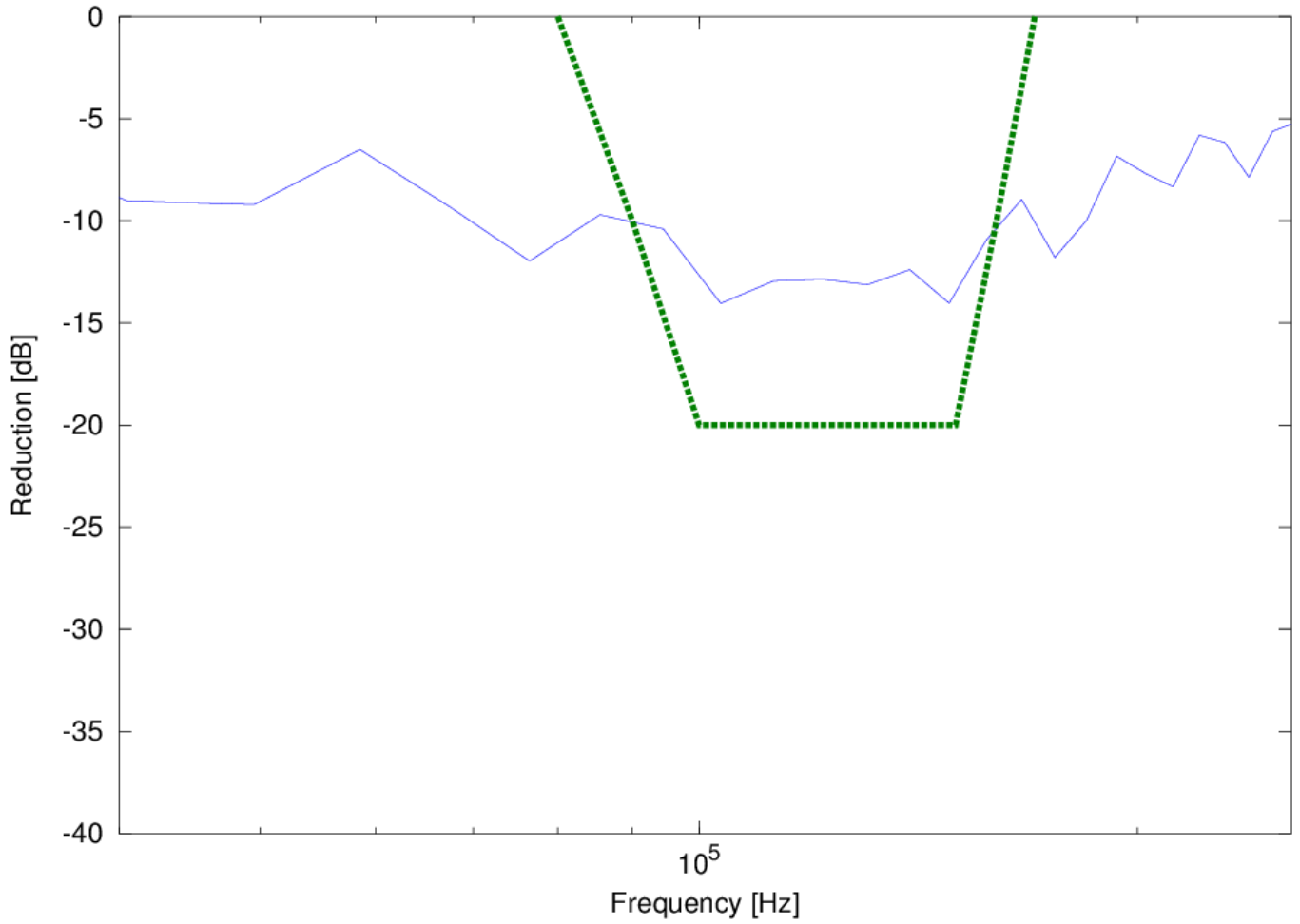
After *one iteration, 24.4% fitness*.

Example of Optimization



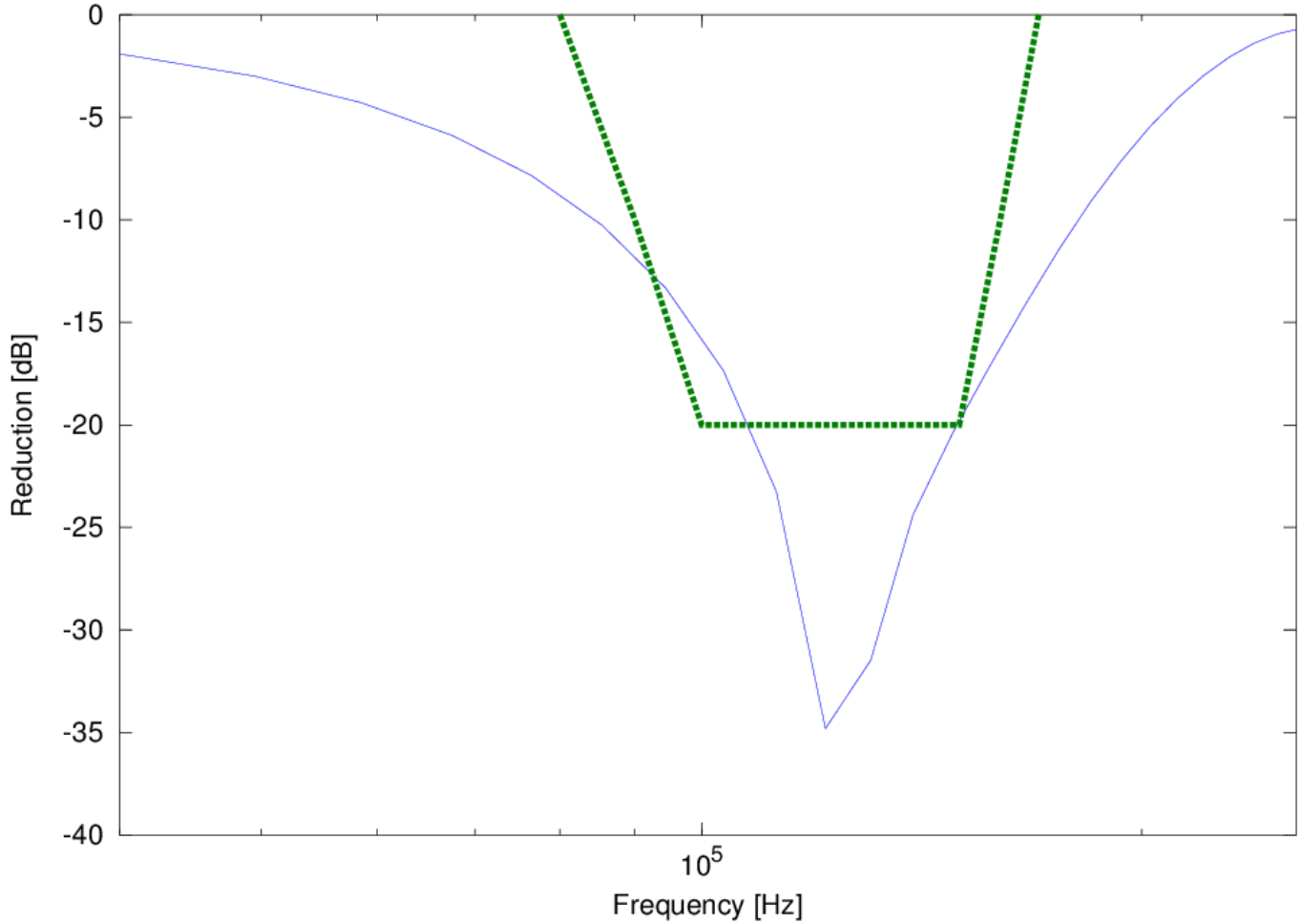
After *10 iterations, 29.3% fitness*.

Example of Optimization



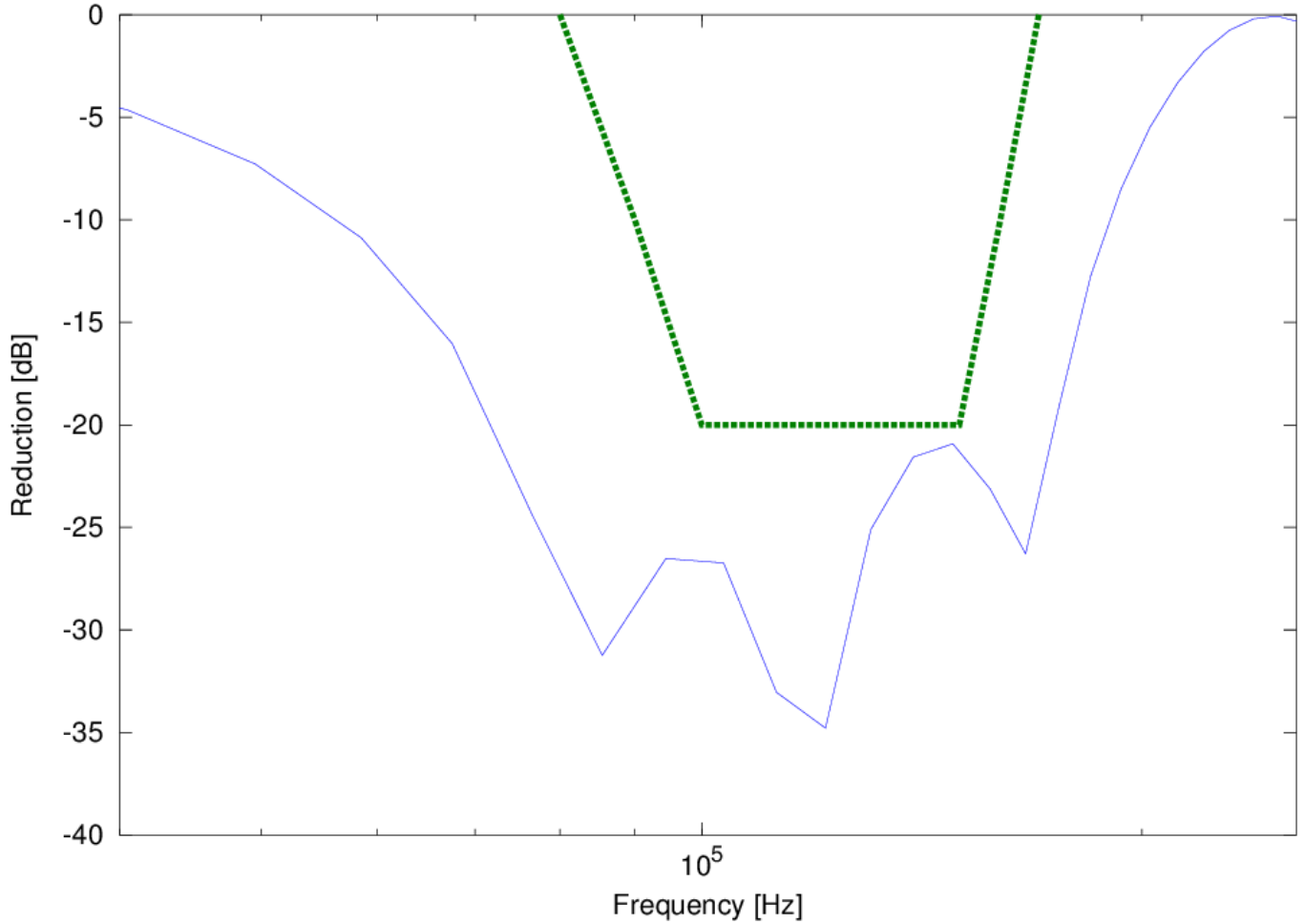
After *40 iterations, 33.9% fitness*.

Example of Optimization



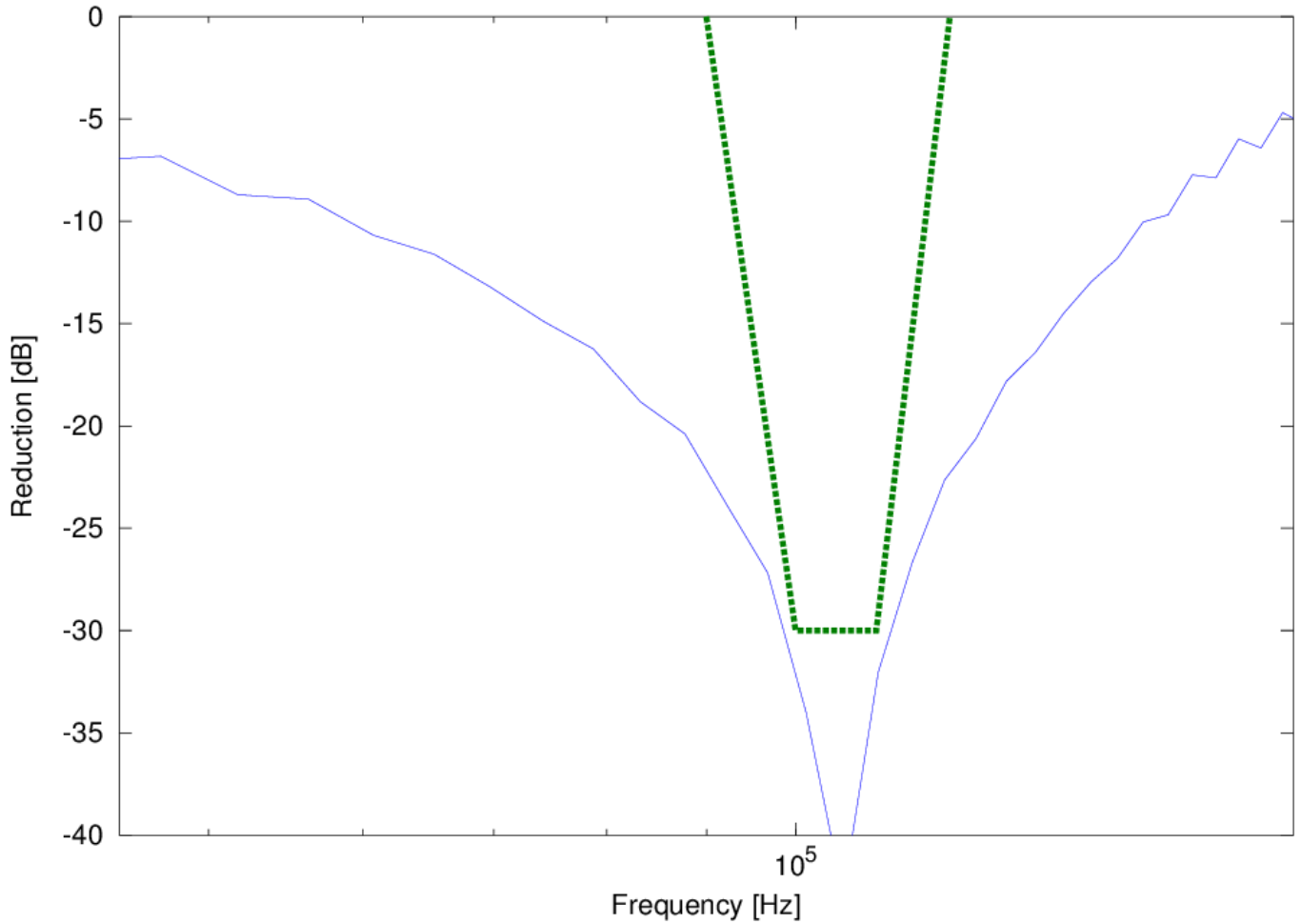
After *140 iterations, 72.1% fitness*.

Example of Optimization



Final solution after *160 iterations*, *100% fitness*.

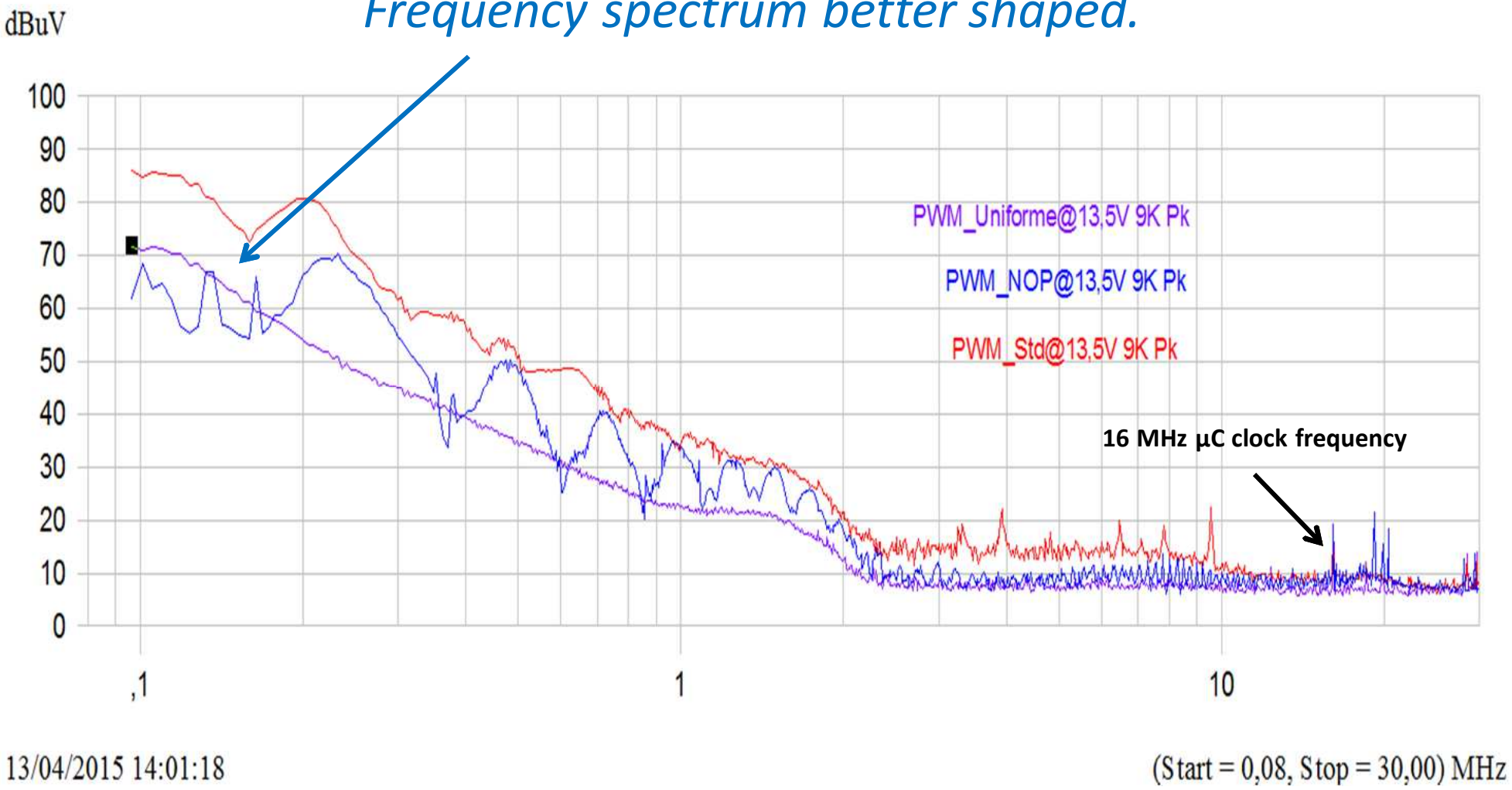
Another Example



30 dB reduction in a shorter frequency range.

Comparison of different optimizations

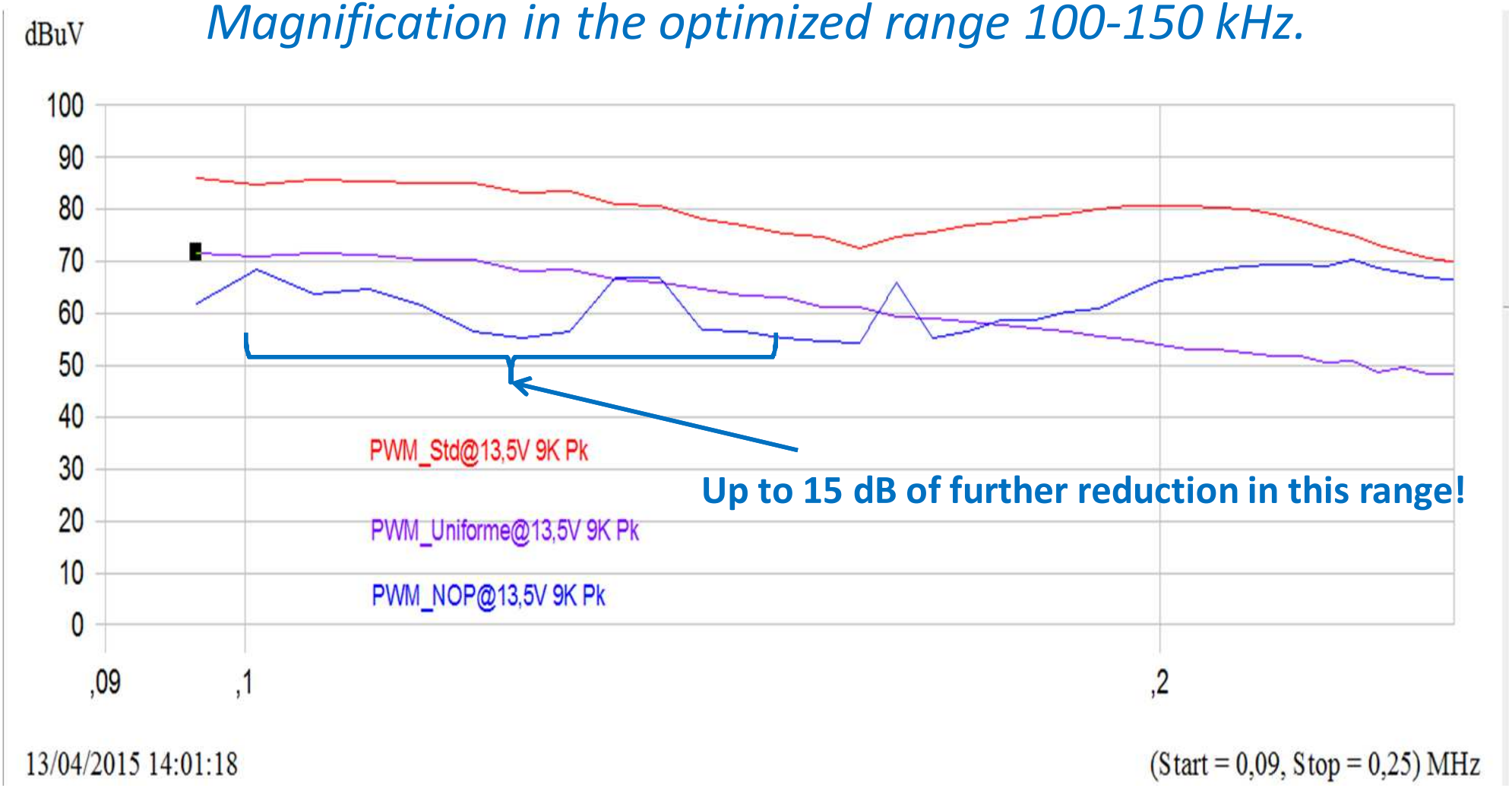
Frequency spectrum better shaped.



*6 LED branches, 2% PWM **without phase shift**, with **uniform phase shift** and with **optimized phase shift***

Comparison of different optimizations

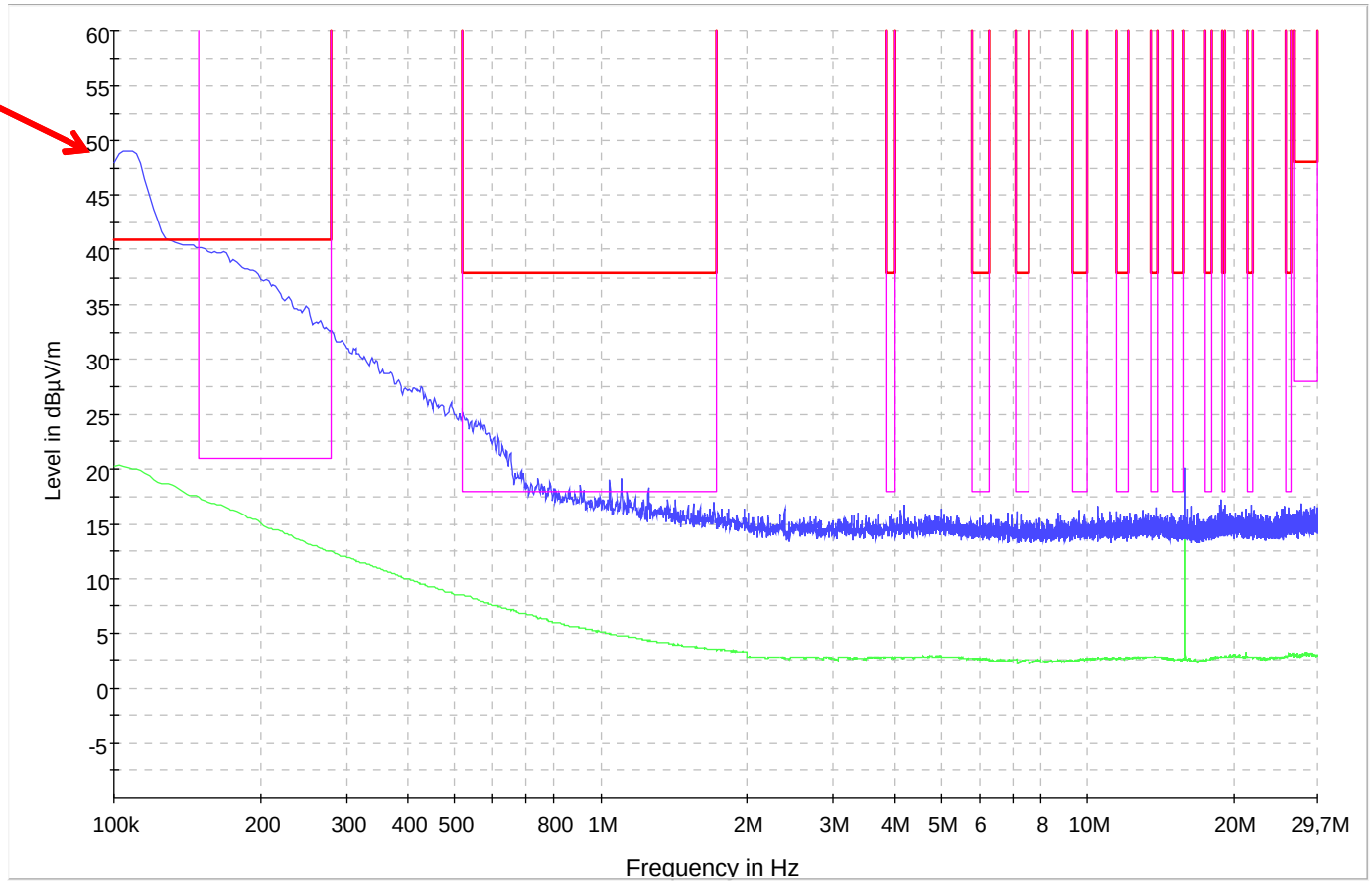
Magnification in the optimized range 100-150 kHz.



*6 LED branches, 2% PWM **without phase shift**, with **uniform phase shift** and with **optimized phase shift***

Further results

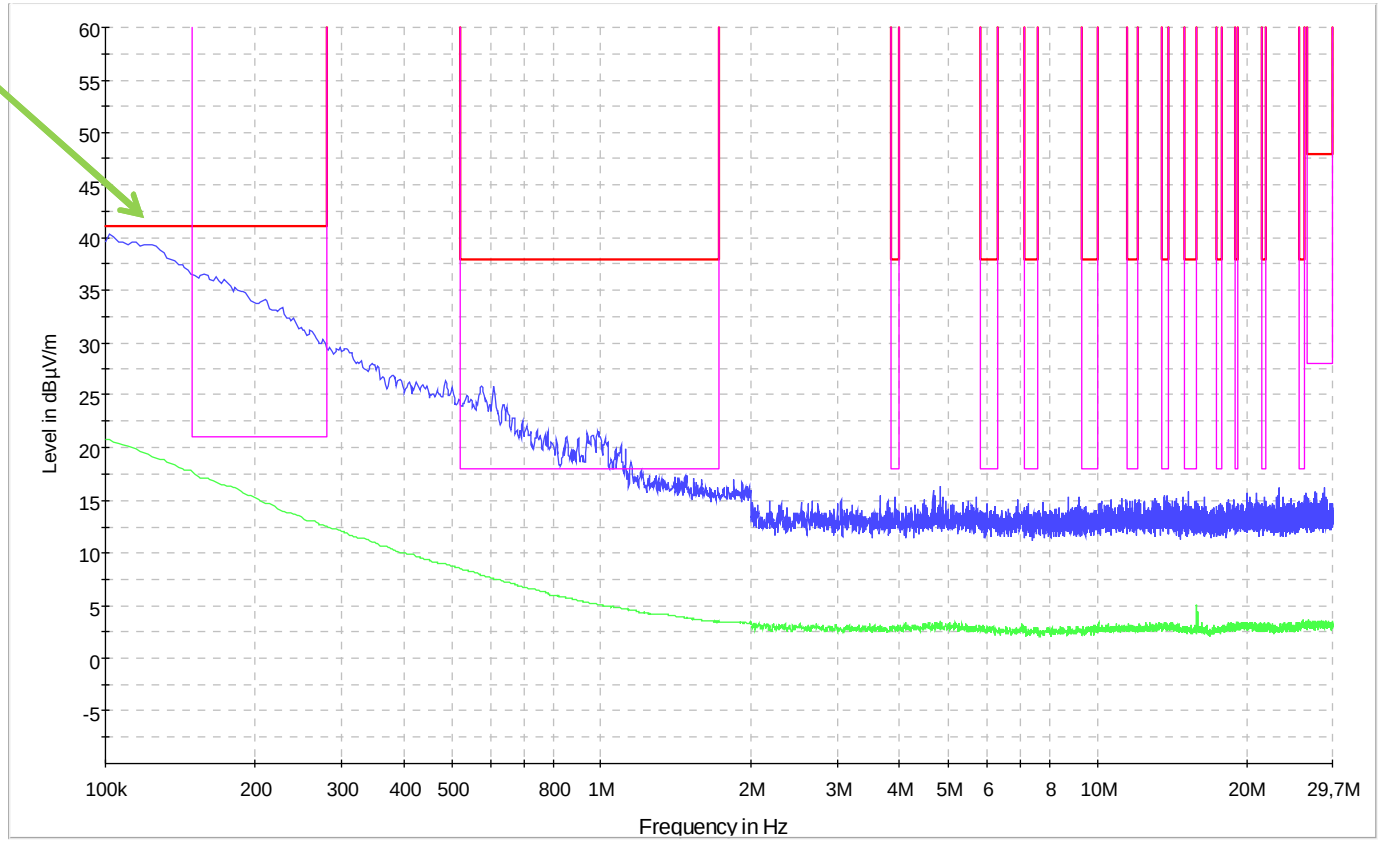
NOK



with PWM

Further results

OK



shifted PWM

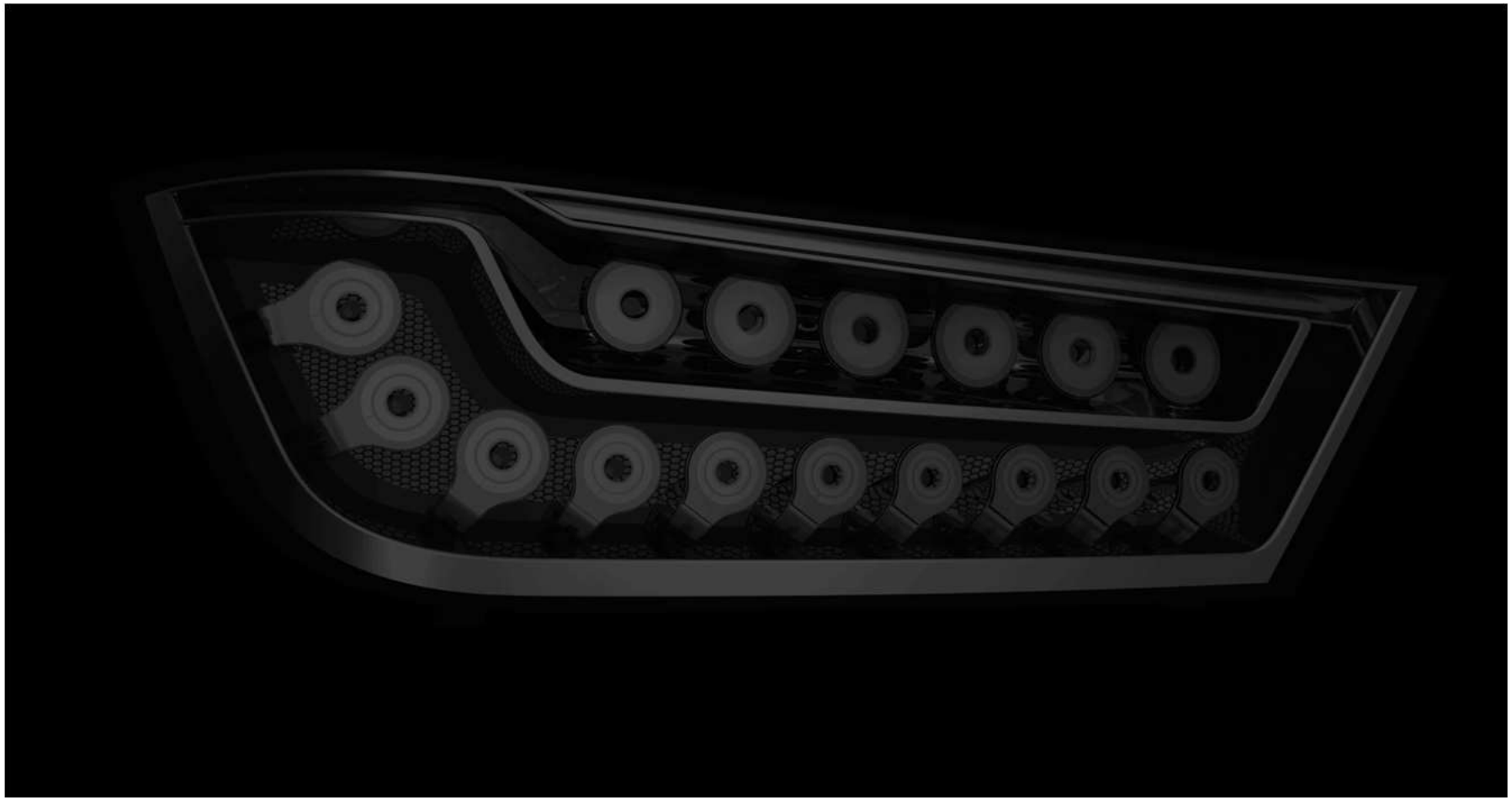
Conclusions

Conclusions

- **PWM modulation** generated **internally** by the rear lamp is **required**;
- PWM signals may lead to **EMC issues**;
- **Phase shift** of PWM signals done by **µC** reduces spurious harmonics;
- **Uniform phase shifts** give simple and effective solution;
- **Numerical optimization** of the **phase shifts** permits to further “shape” the frequency spectrum if required.

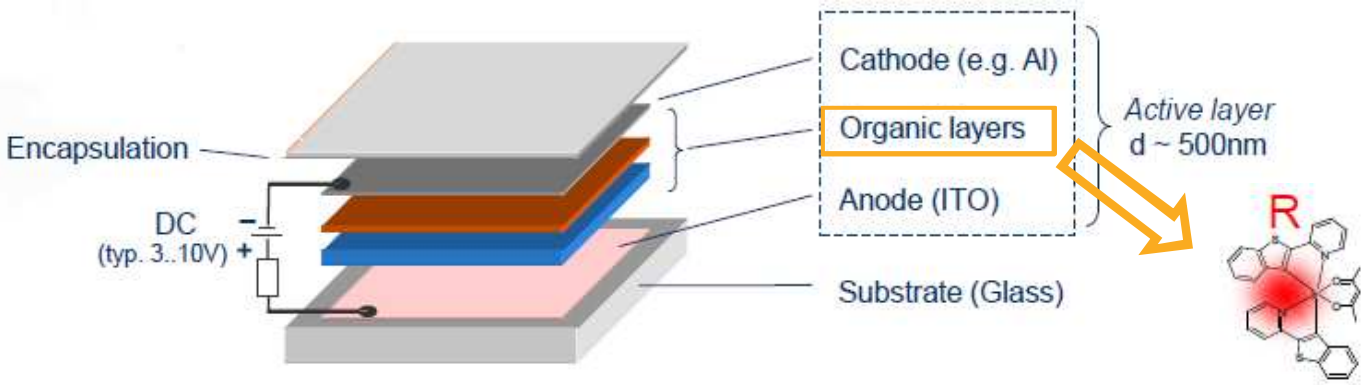
Innovation topics

OLED

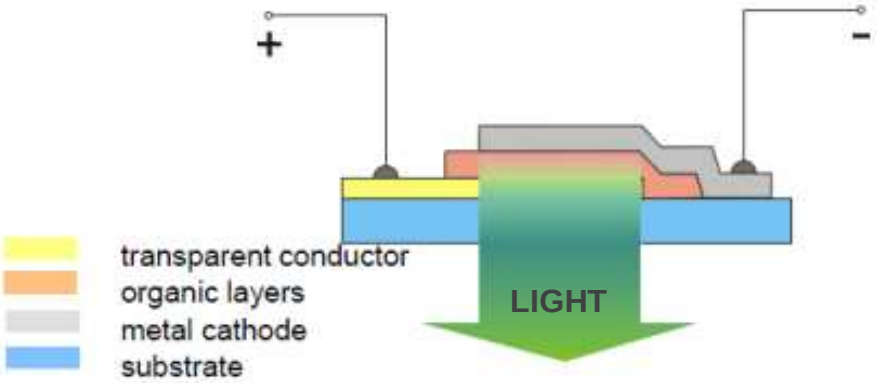


OLED

OLED is a light emitting diodes composed with organic electroluminescent layers.



Small molecule OLED deposited through evaporation in vacuum chambers



<u>Red</u> layer reaches monochromatic radiation up to 630nm

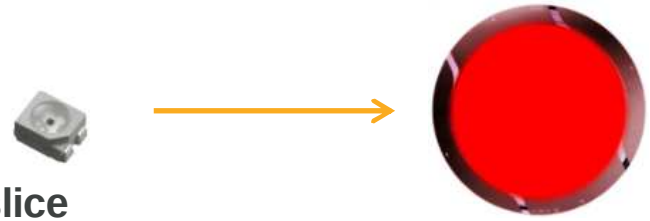
<u>Yellow</u> layer monochromatic radiation working @ 591nm

White light can be achieved depositing in the same device the 3 RGB layers

OLED

PRO:

Large light emitting area and full homogeneity



Thin slice

OFF Appearance: Transparent, mirroring or milky

Curved shaped pixel

CONS:

Glass substrate for fragility, rigidity

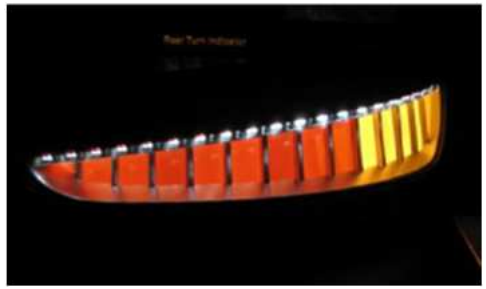
Lifetime at high temperatures/humidity

High Costs

OLED: STYLISTIC INPUT

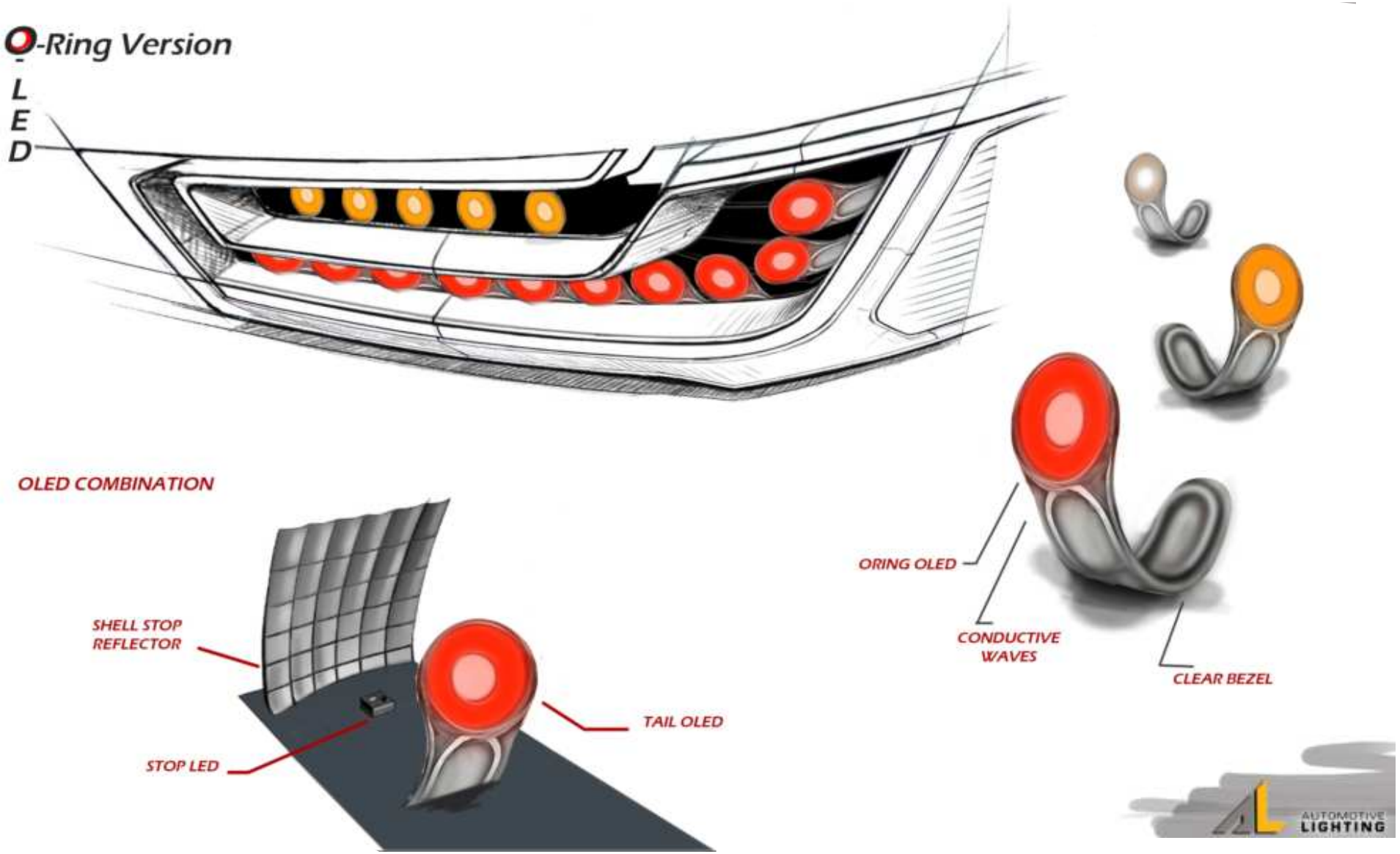





OLED: CONCEPT

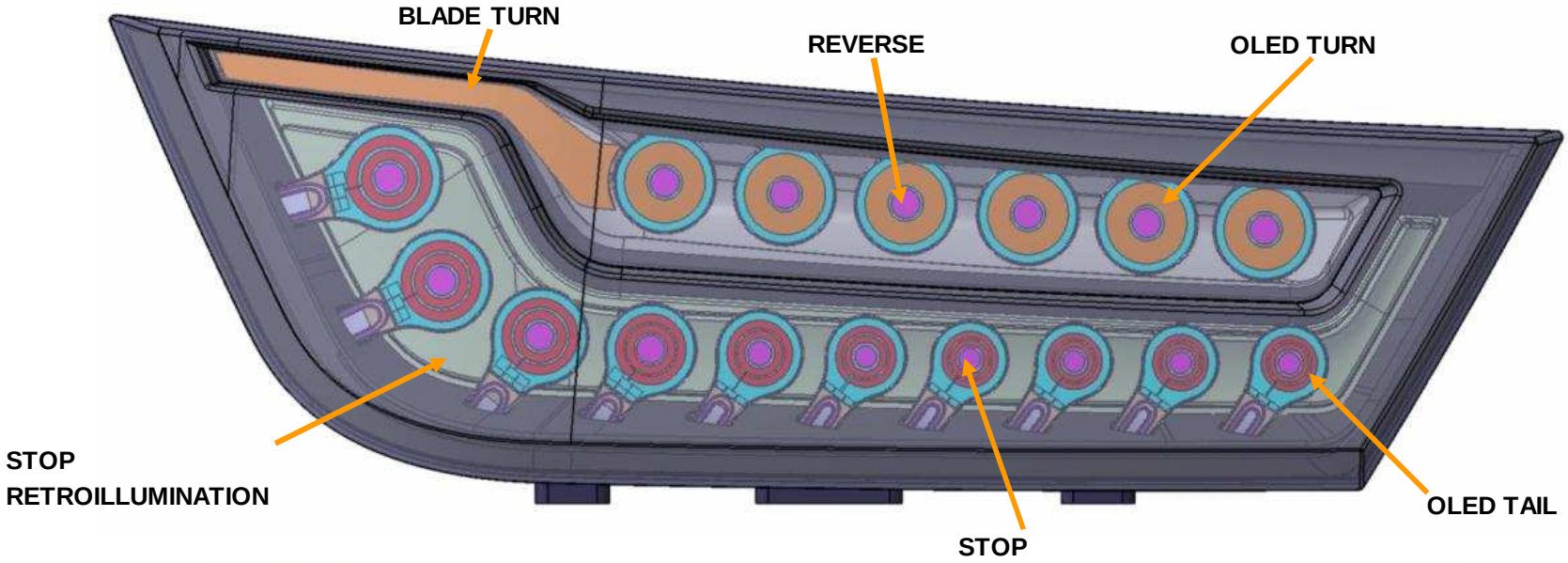
First Internal AL Design - Application on OLED rearlamp



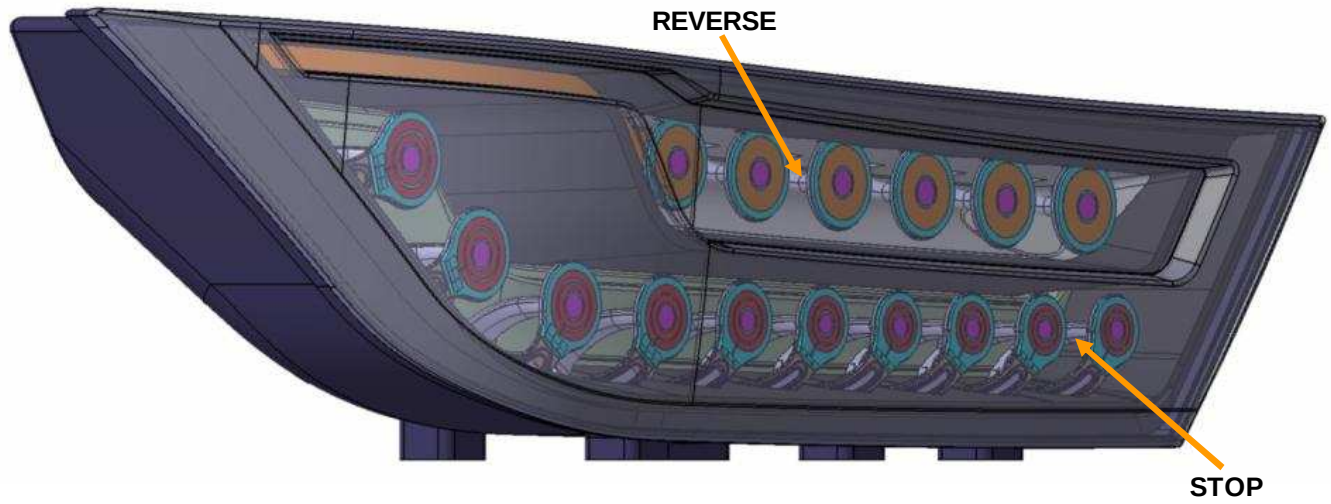
General description of ORING rearlamp

Light functions

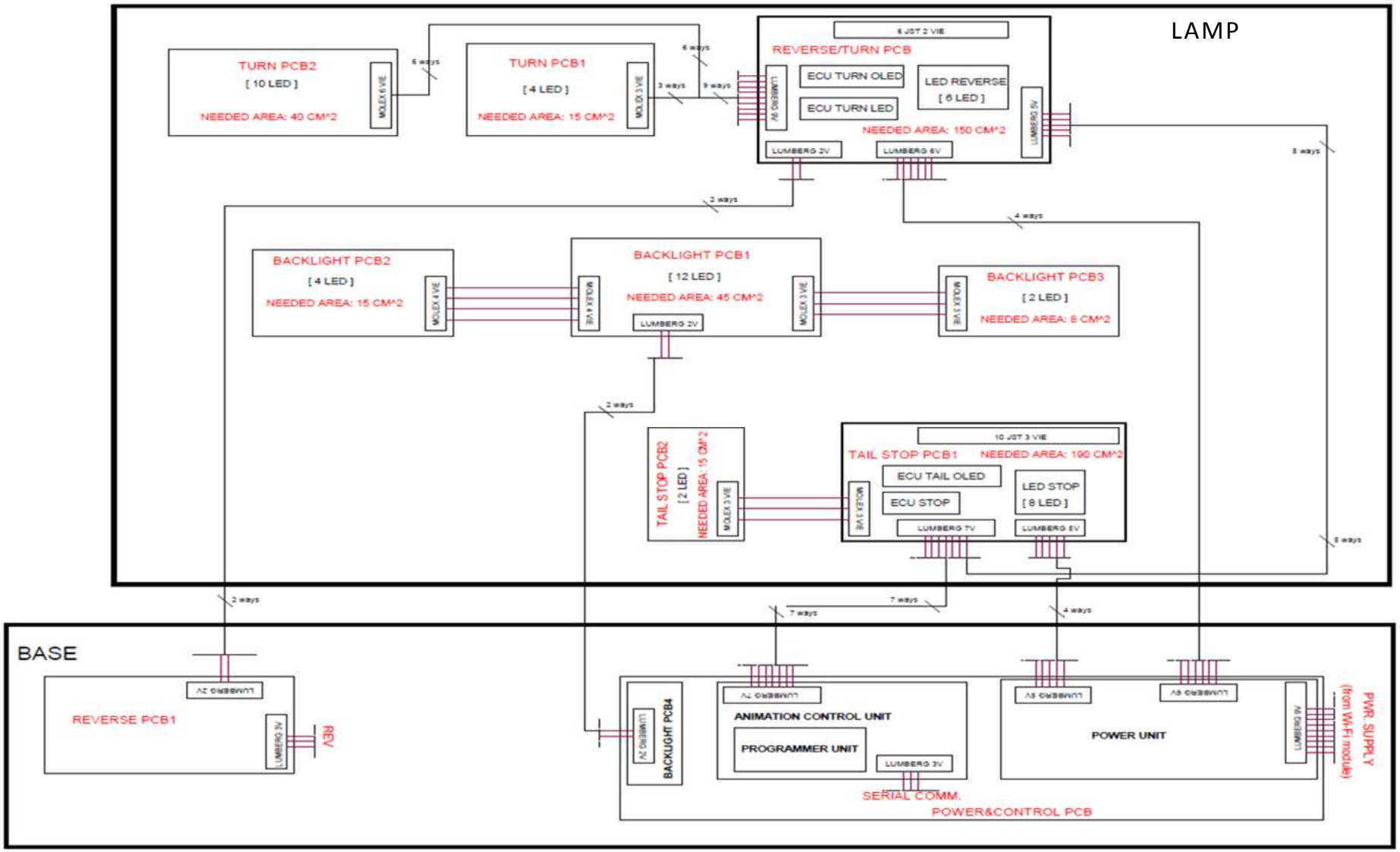
FRONT VIEW



SIDE VIEW



Electronic system



General description of ORING rearlamp

Light functions

Light functions

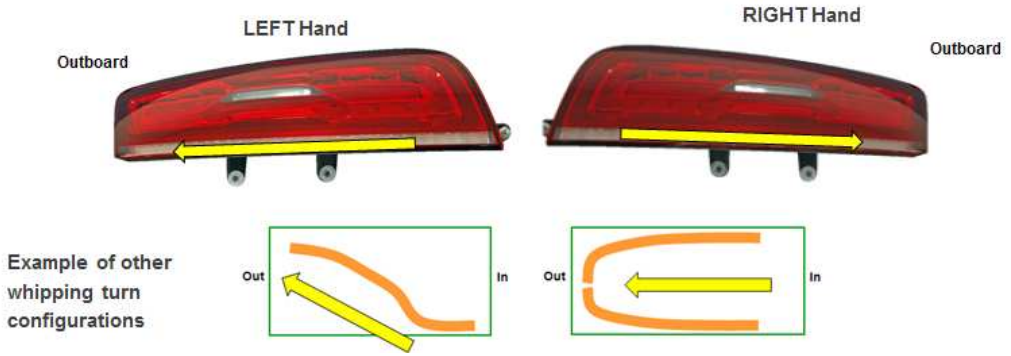
Light functions

Innovation topics

Electronic Control Unit

Electronic architecture evolution

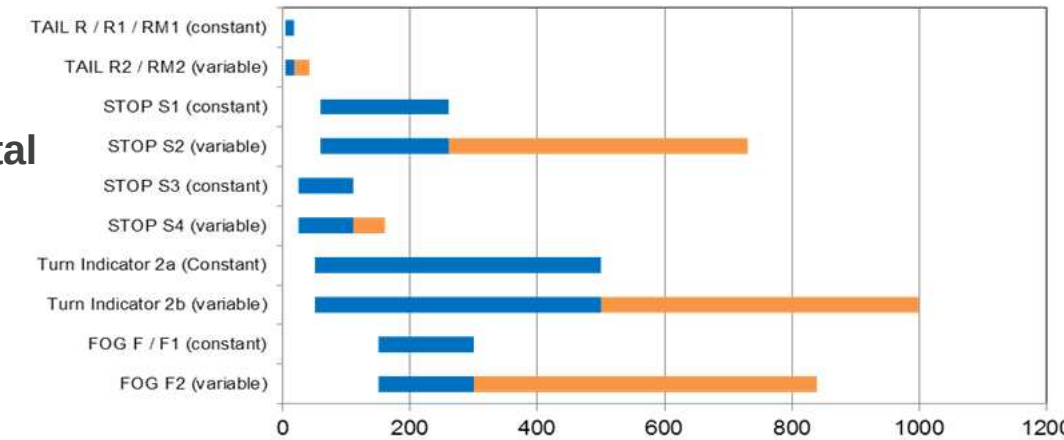
1) Wiping turn



2) ARS

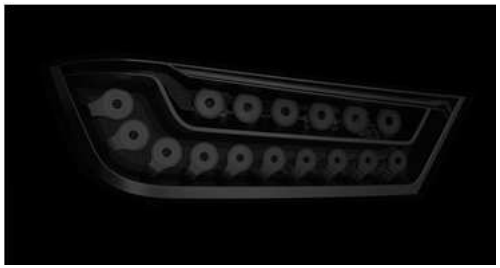
Adaptive light levels according environmental conditions

Daily light
Poor visibility



For system with variable light intensity, the maximum value is increased and could be used in poor visibility condition

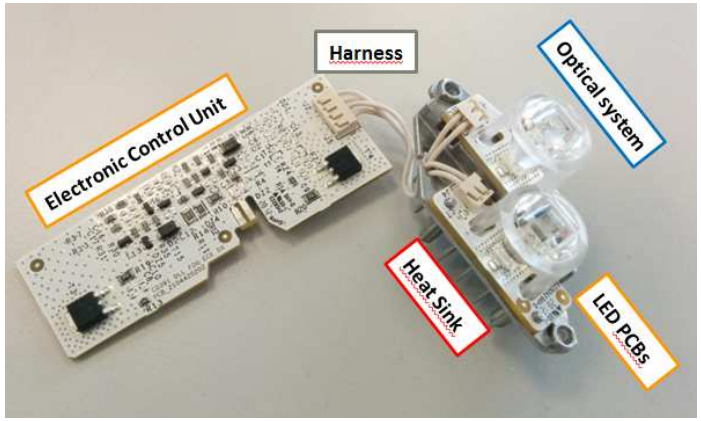
3) Welcome function



Electronic architecture evolution

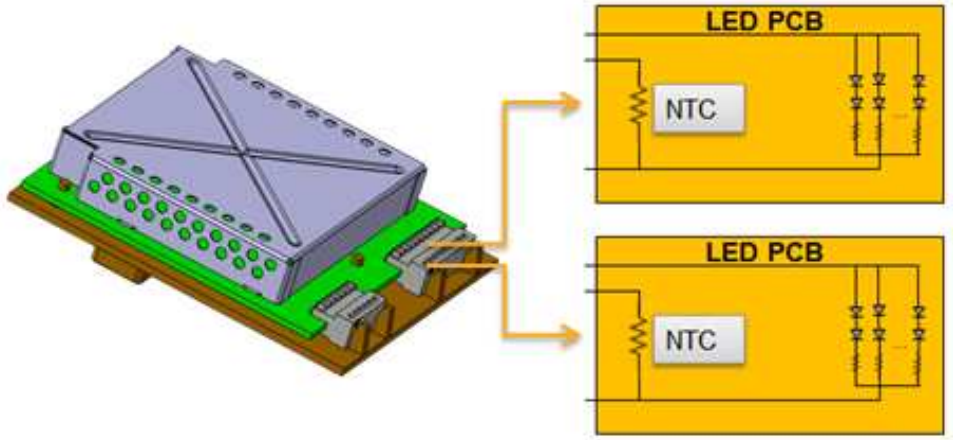
Technology Trend Analysis

Ad hoc control electronics



- One ECU per light function
- Non-standard solution
- Non-standard data communication
- Redundancy between light functions (harness, input filters, regulators, diagnosis, …)

Standard Control Electronic

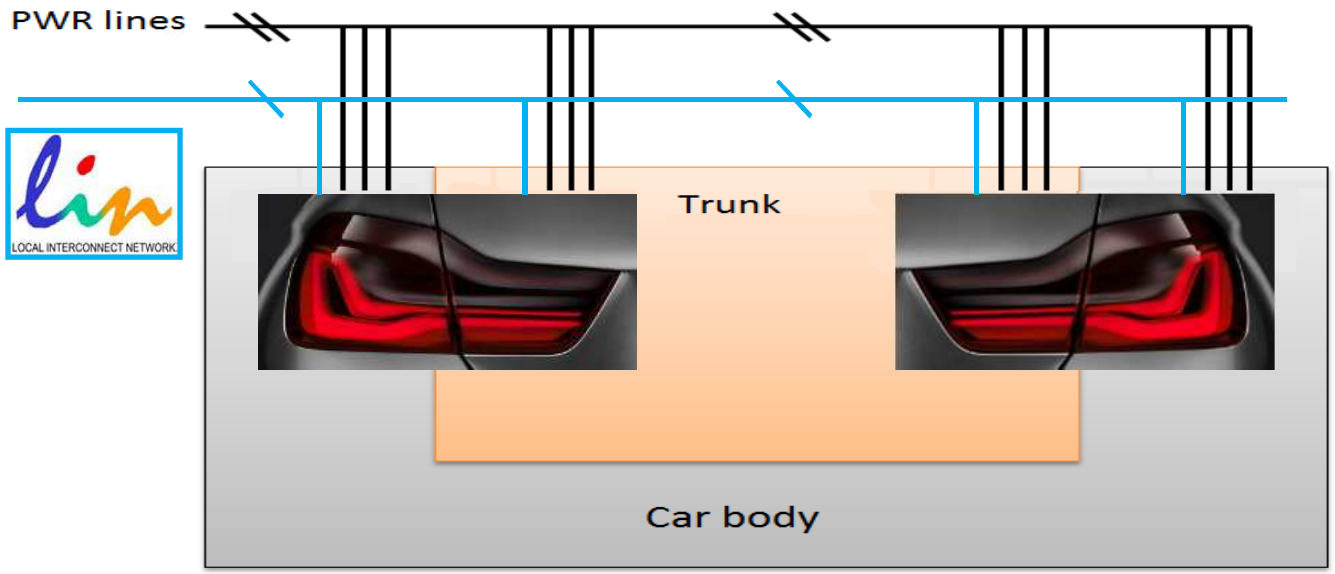


- One standard ECU per rear lamp
- Data bus with body computer
- All advanced features standardized:
  - Diagnosis
  - Car body communication
  - Animations
  - Current regulation

Trend

Electronic architecture evolution

New functionality: ECU with Network interface



Key features of such a ECU

- Standard high speed data communication with car body computer
- Management of advanced functionalities with a single centralized ECU

The integration of an automotive bus network in the rear lamp, will allow the integration of additional functionality thanks to the possibility to exchange information with the car body computer

Management of complex functions in rearlamp will make Intelligent ECU an interesting option for rearlamps.
Functions such as ARS (Adaptive light level), wiping TURN, Welcome functions, Diagnostics, Current control, …., can be managed **without increase of car cables and without requiring the development of a new car body computer**

Thank you for your attention!!