CENTRALISED SOFTWARE AND ZONAL ARCHITECTURES
FOR FUTURE INNOVATIVE AMBIENT LIGHTING
ENABLED BY E\(^2\)B 10BASE-T1S
BMW & ANALOG DEVICES

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IEEE AUTOMOTIVE ETHERNET & IP TECH DAY
AGENDA.

1. Ambient Lighting future needs
2. Solving the system challenges
3. Measurement results and summary
STRATEGY FOR FUTURE INNOVATIVE AMBIENT LIGHTING

THE NEXT LEVEL EXPERIENCE ENABLED BY LIGHT FUNCTIONS

- INTELLIGENT
- LIVE
- DYNAMIC
- MODERN

- CUSTOMER EXPECTATION FOR LIGHT SYSTEMS ARE INSPIRED BY HOME AND BUILDING ARCHITECTURES
STATE OF THE ART SP2021

OVERVIEW

- Distributed & heterogeneous System (Synchronisation)
  - Complex integration of different technologies
    - Software (LIN Hubs/LIN RGBs/ Central ECU)
  - Static, dynamic and functional light (5 LINs)
- Limited System
  - Limited animation and appearances due to LIN
  - Fixed number of LEDs in the whole system
  - Maximum number of LEDs in a strip 63
- Not aligned to zonal architecture
- Difficult to update

TOPICS FOR 2025 ARCHITECTURE

- Investigation of other Bus technologies (CAN/Flexray ...)
- SW partitioning (AUTOSAR vs. LINUX)
- Synchronisation of the whole System
- 20ms update of each LED (jitter)
BENEFITS OF INTERIOR LIGHT ARCHITECTURE E/E SYSTEM 25

FUNCTIONAL BENEFITS
- “Realtime” light functions
- Dynamic projection
- Multi-dimensional lighting experience (2D effects)
- Interaction with customer / personalisation
- Dynamic light functions responding to real-time input
- Synchronous control of all lighting components
- Central logic (also advantages for Function on Demand, Always fresh)

COMPONENT BENEFITS
- Wiring Harness optimization
- Elimination of wiring harness splices
- Zonal architecture
- Elimination of SW (only HW components)
COMPONENTS AND SCALING E/E SYSTEM 25 - OVERVIEW

- E2B Hub (10BASE-T1S to ILoS)
- Ambient interior light
- Functional interior light
OVERVIEW INTERIOR LIGHT ZONAL ARCHITECTURE

ZONAL ARCHITECTURE

- E2B Hubs all hardware implemntation which communicates over 10BASE-T1S Ethernet and translate the signals to ILaS
- ILaS is offered in different zones (e.g. dashboard)
- Power supply is provided by zonal ECUs and looped through by the components
- ILaS is looped through the light components
- For small cars one E2B hub is sufficient
- For fully equipped cars additional E2B hubs can also be added
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APPLICATION AND SYSTEM CHALLENGES CREATE OPPORTUNITIES TO INNOVATE

- ADI engaged early with BMW to understand upcoming system requirements and address the following key challenges:

  - **Software Defined**
    - Upgradable, Flexible and Adaptable Lighting System

  - **Zonal Architecture**
    - Align to Zonal Architecture

  - **System Optimization**
    - Enable an optimized edge node implementation

  - **Synchronized Animation**
    - Provide cross-lighting and cross application Synchronisation

- The advanced requirements of the BMW’s Ambient Lighting solution drove a different approach and opportunity for system level innovations utilising the latest available technologies
RESULT – COMPLETELY NEW, INNOVATIVE SYSTEM APPROACH

**Software Defined**
- All *software* (Application layer to edge node driver) is **centralized**

**Zonal Architecture Support**
- Ethernet-based switch ECUs

**System Optimization**
- 10BASE-T1S-based Hardware only
  - Edge node
- ILaS interface to LED

**Synchronized Animation**
- TSN support
1. SOFTWARE DEFINED: REQUIREMENTS

- Support full **OTA** updates
- Software located in the **User Space**
- Easy to Update and maintain
- Support **advanced animation** routines
- Provide Cross-application synergy
1. SOFTWARE DEFINED: THE SOLUTION

- All lighting software integrated and runs in a single location on Central ECU
- Lighting Master Application
- Lighting Driver
  - ILaS Driver
    - ISELED Light & Sensor Network protocol
- E²B Driver
  - Ethernet to the Edge Protocol

Software from edge nodes removed and centralized in Central ECU
2. ALIGN TO ZONAL ARCHITECTURE: REQUIREMENTS

- Support connectivity to Zonal ECU's
  - Easily **upgradable** network
  - Scalable Network
    - Ability to **easily add nodes**
  - Qualification of Network
    - **Minimum re-qualification** effort when network updates are made
- Reusability of Network
  - Previous designs **reusable** to minimize effort/cost
2. ALIGN TO ZONAL ARCHITECTURE: THE SOLUTION

- Switch based ECUs extending **Ethernet to the Edge to simplify** networking solution
  - Gateways eliminated
  - Ethernet frames handled directly in switch
  - Switch MCU available for other tasks or scaled down
  - Unified solution suite across the network
    - Security, TSN, Routing, Wake/Sleep, etc.
3. OPTIMISED EDGE NODES: REQUIREMENTS

- Ease of implementation
- **Identical performance** across all nodes from multiple suppliers
- **No Software** Qualification
- Synchronisation/Determinism
- Small Form factor
3. OPTIMISED EDGE NODES: THE CONCERN

- Existing Ethernet Based Edge Nodes
  - **Added complexity** for simple edge nodes
    - Examples: Lighting, Body Control, Drive-train, ...
    - Reluctance to adapt Ethernet for these applications
  - Ethernet Software Stack at the edge node requires dedicated MCU
    - Significant overhead of SW qualification
    - Identical performance from multiple suppliers is difficult to achieve
3. OPTIMISED EDGE NODES: THE SOLUTION

- **E²B** provides a highly optimized yet flexible hardware-based Ethernet edge node enabling:
  - **Removal of Software/Software Qual:** Hardware only edge node
  - **Simplified OTA:** No requirement of OTA to edge node
  - **Determinism:** Hardware implementation provides fully deterministic Lighting interface
  - **Diagnostics:** Handled in the central ECU, all connectivity diagnostics enabled in hardware
  - **Security:** Hardware based approach reduces possible attack surfaces
4. SYNCHRONIZED ANIMATION: REQUIREMENTS

- Lighting Animation synchronization
  - Must be **stable** < 1-2ms jitter
  - Must be **accurate** to 20ms of precision
  - Configurable to match lighting strip length

- Cross-application synchronization
  - Delay must be < 150ms for HMI interaction
  - Easily adjustable to **align with other functions**
    - Ambilight Display
    - Hazard indication – safe exit indication
4. SYNCHRONIZED ANIMATION: ERROR SOURCES

- **Zonal architecture**
  - Varied network paths to lighting elements must be equalized

- **Central compute**
  - Lighting drivers run in Linux user space
  - e.g. Linux +/- 40ms accuracy
  - Refresh rate minimum of 50Hz for smooth animation
4. SYNCHRONIZED ANIMATION: THE SOLUTION

- Lighting synchronized via gPTP
  - All nodes **synchronized to gPTP timebase**
  - IEEE 802.1AS
  - Presentation time used to control actuation
  - MAX_TRANSIT time accounts for worst case
  - Software timebase uncertainty
  - Network delay
  - Fixed deterministic latency of E2B end node guarantees accuracy to endpoint (e.g. LED)

- Cross-application solution
  - Timebase shared with all Ethernet nodes
  - Synchronized orchestration of all sensor/actuators
  - Easier to achieve/maintain.scale than with legacy network technologies
4. SYNCHRONIZED ANIMATION: THE SOLUTION

- Direct drive from 'User Space' will not achieve required animation accuracy
- Embed *animation presentation time* in updates
  - gPTP time based
  - Synchronized actuation at edge nodes
  - Animation time incremented to achieve desired refresh rate
- Lighting application can *schedule multiple animation updates*
  - Animation updates queued in the HW FIFOs on Edge Nodes
- Edge nodes *actuate updates* at embedded animation time
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MEASUREMENT SET-UP AND RESULTS

MEASUREMENT SET-UP

- E2B nodes
- Supply
- ISELED strip
- Master ECU
- Switch ECU 1
- Switch ECU 2

MEASUREMENT RESULTS

- Update of each ISELED = 19,960 ms + 40 μs = 20 ms == 50 Hz
10BASE-T1S E²B – EXCELLENT FIT FOR BROAD RANGE OF APPLICATIONS

And many more.....
SUMMARY

- Ambient lighting is undergoing a significant change
- Leveraging the Ethernet Ecosystem (switches/TSN etc) simplified the system implementation
- The availability of 10BASE-T1S further eased the system design bringing Ethernet to the edge
- Use of E2B, enabling an all hardware edge node, further reduced the complexity of the edge node and enabled centralisation of the software
- 10BASE-T1S is ready for production rollout