The LIN Bus in Modern Automotive Headlamp Systems

Bart De Cock, AMI Semiconductor BVBA, Belgium

Abstract

AMI Semiconductor have been supplying mixed signal integrated circuits for automotive lighting systems for over a decade. High-volume products include lamp-failure detection, contact-less sensor interfaces, HID (High Intensity discharge) ballast drivers and stepper motor drivers. Modern automotive headlamp systems will rely heavily on the use of sensors and actuators in the near future. These remote sensors and actuators are connected to an electronic control unit via a bus network. Various types of bus networks are feasible, this paper will concentrate on the cost and performance advantages when using the LIN (Local Interconnect Network) bus network in a headlamp application. Various solutions will be presented providing an insight into the different LIN bus architectures available. The integration of a stepper motor driver with LIN interface is demonstrated as an example. In conclusion, the LIN bus provides superior performance when combined with the appropriate system architecture for cost sensitive applications.

1 Introduction: Headlamp Actuator Wiring Architecture and Elements

Figure 1 shows the basic components used throughout this text. The signals of chassis sensors (suspension, turn indicator, steering wheel, car speed, rain sensor and other) are connected through individual wiring or by means of a multiplex bus to the “Light Control Unit” (or LCU). This unit contains - amongst other functions - the intelligence to process the sensor information and to drive small actuators in the headlamp according to the regulations.

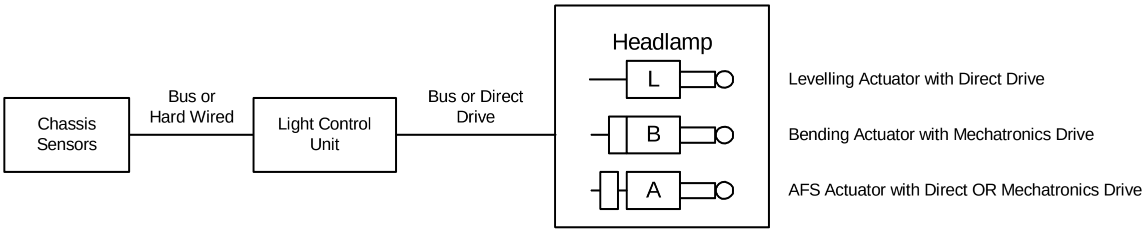


Figure 1: Basic Wiring Elements

The headlamp actuators are controlled by means of dedicated wiring (so-called “Direct Drive”) or using again a multiplex bus. A multiplex bus is ideally suited when used together with mechatronic modules. Mechatronic modules are compact assemblies of an actuator together with its drivers (typically power electronics). The wires connected to mechatronic modules carry (besides the supply lines) low-power control signals of the bus, while the wiring of “Direct Drive” carries the PWM chopped current of the individual motor phases and some diagnostics or sensor feed-back signals. From these differences, it is clear that “Direct Drive” has a negative impact on technical aspects (EMC, cabling dimensions and routing), cost (number of wires, connectors, non-modularity) and finally time-to-market (LCU hardware and cabling variations depending on lighting options require re-qualifications).

2 LIN Basics

A small introduction to LIN will aid understanding of the remaining chapters. LIN is essentially a low-cost network (or multiplex bus) with one master control unit and one or more slave control units. The LIN master initiates communication by sending the “Header”. The “Data Fields” are send by LIN master or a LIN slave. Only one slave will respond to a given header.

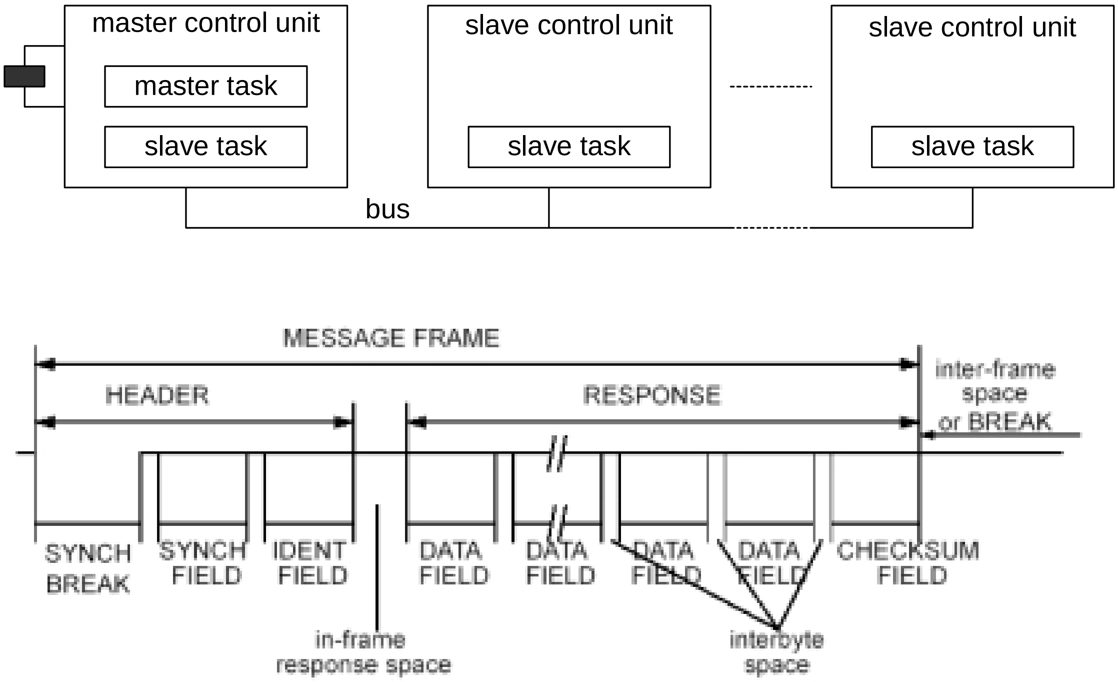


Figure 2: LIN basic network and message frame

The slave nodes cannot initiate communication : they only respond if triggered by specific identifier fields. The maximum communication speed on a LIN bus is 19200 baud. The LIN nodes can therefore send/receive a full 8-byte command every 10ms. Shorter commands can even run every 5ms. This bandwidth is large enough to drive leveling, bending, AFS (Adaptive Front lighting System) and ballast functions of a single headlamp and it also provides high-quality diagnostics feed-back. Please refer to lin-subbus.org website for more information on LIN.

3 Headlamp Wiring Architecture Classification

The proposed classification is based on the headlamp type, wiring of the sensors, the physical location of LCU's, the types of the actuators and their wiring. This yields six variables with about 100 possible combinations. Taking into account the constraints mentioned in the last column of Table 1, 37 cases remain. These cases can then be categorized into five halogen architectures and six HID wiring types.

The drawings in the discussions below are simplified and oriented towards the position of the LCU and the actuator connections : the exact number of wires is not detailed, supply-, diagnostics and bulb wires are not taken into account.

Variable	Value	Subtype	Name	Comments & Constraints
Headlamp type	halogen	leveling	H1	actual standard is S1, C1, L2
		leveling + bending	H2	C3 too expensive L1 not standard if C1 or C2 -> only 1 out of (L1,B1)
	HID	leveling	H3	actual standard is S1, C1, L1
		leveling + bending	H4	if C1 or C2 -> only 1 out of (L1,B1)
		leveling + bending + afs	H5	
Sensor signals		wired	S1	not with C3 and (C2 combined with H4 or H5)
		bus	S2	
Control Unit	single	car interior	C1	S variable not relevant
		car front	C2	
	dual	1 per headlamp	C3	
Leveling actuator	direct drive		L1	
	multiplex		L2	
Bending actuator	direct drive		B1	variable not relevant for H1, H3
	multiplex		B2	
AFS actuator	direct drive		A1	variable not relevant for H1, H2, H3, H4
	multiplex		A2	

Table 1: Headlamp wiring classification

4 Halogen Wiring Architectures

4.1 Cabin Location of Halogen LCU

Figure 3 summarizes the possible cases with only one control unit, this being located inside the passenger cabin. This is the standard location used today and allows simple connection of sensor signals to the control unit. Architecture H1 represents the actual standard halogen leveling with manual adjustment using a brushed DC motor in a mechatronic combination. Bending option (architecture H1a) is then a logical extension based on existing HID standard leveling technology (see Table 1). However, from a wiring point of view, architecture H1b is much more compatible with H1. An analog wire is replaced by LIN. On the position of the LCU for halogen bending systems, one solution is the integration within the standard manual adjust unit. A further improvement is to move the halogen LCU inside the dashboard control unit. By means of a standard central display and it’s push-buttons, a manual adjustment is accomplished and at the same time the light control system is right in the vicinity of speed and steering sensor information. This step would require the cooperation of lighting and dashboard tier-1 suppliers.

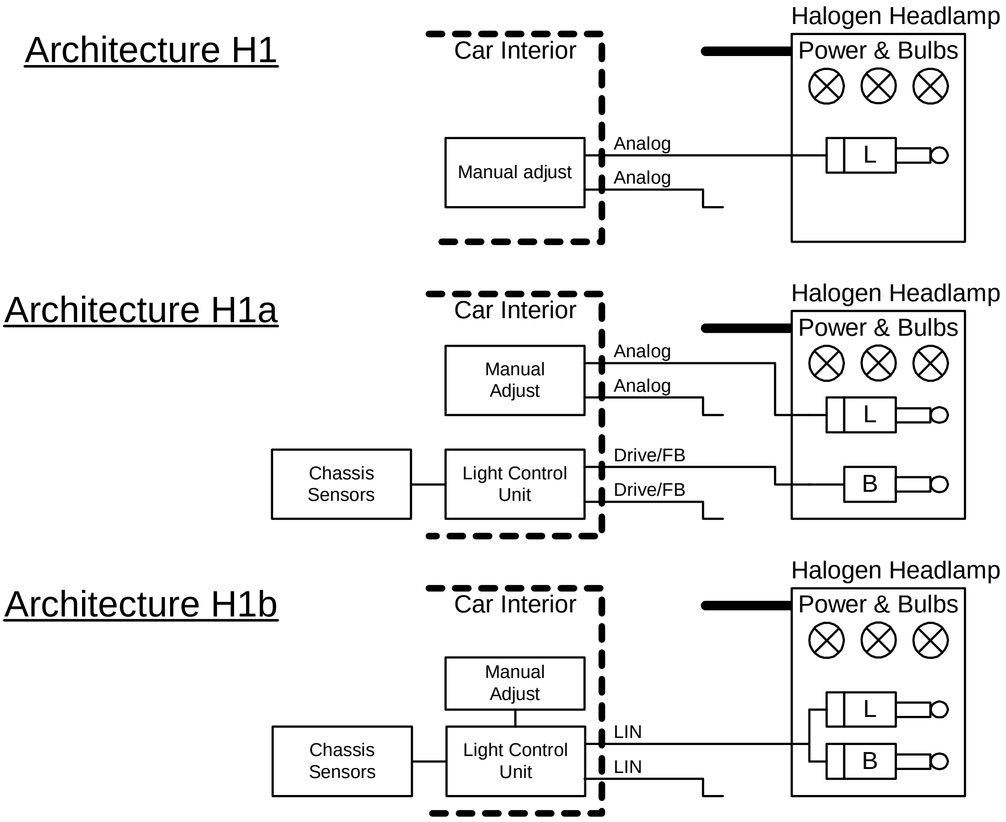


Figure 3: Halogen, cabin location of LCU

4.2 Front Location of Single Halogen LCU

The architectures depicted in Figure 4 have only one control unit, located at the front-module e.g. attached to one headlamp only. Headlamps are by nature not symmetrical, so this asymmetric mounting would not impact stock costs, but there might be objections against this architecture related to crash-sensitivity of lighting functions and system FMEA. Architecture H2a is based on re-use of existing building blocks (standard halogen and HID leveling technology). In H2b, the wiring is made simpler and will not change when bending function is added or removed (bending function is true add-on).

Architectures H2a and H2b would require an interface from standard manual leveling to PWM (or bus) in addition to a front-LCU and this may prove too expensive in a low-cost halogen market. It is reasonable to believe that architectures H1 and H1b are more attractive for the large cost optimized halogen market.

Alternatively, if sensor signals are available on a bus or PWM, then architectures H2a and H2b show interesting wiring compatibility with HID systems (see chapters below).

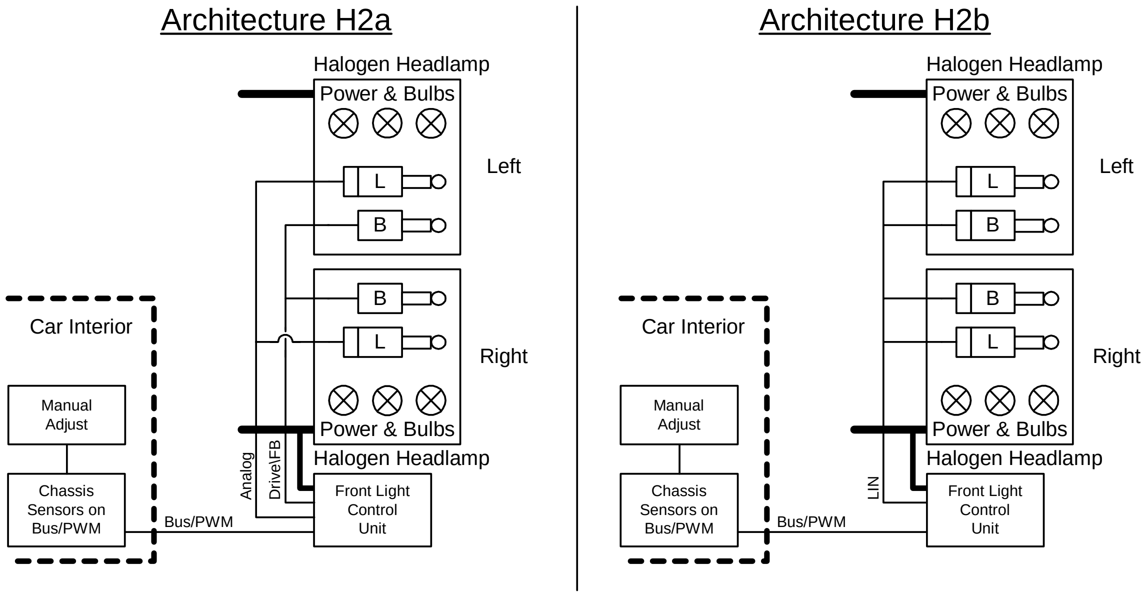


Figure 4: Halogen, front location of LCU

5 HID wiring Architectures

5.1 Cabin Location of HID LCU

Currently, the passenger cabin is the standard location of HID leveling LCU, because it is in the vicinity of the chassis sensors. These sensors are not required to be on a bus system (PWM is also ok). In both cases (see Figure 5), adopting the LIN bus minimizes cost-additions for bending- and AFS functionality. Architecture X1a suffers from high-complexity wiring where direct drive is used for more than one actuator, while X1b reduces wiring and the impact of varying lighting options is reduced to an absolute minimum : all actuators are driven through LIN-mechatronic modules. An interesting item is the connection of the Xenon ballast to LIN for diagnostics and, for example, the control of light output. Architecture X1b is highly compatible with the H1b architecture discussed above, this is important for car platforms that need both bending halogen and HID headlamp options.

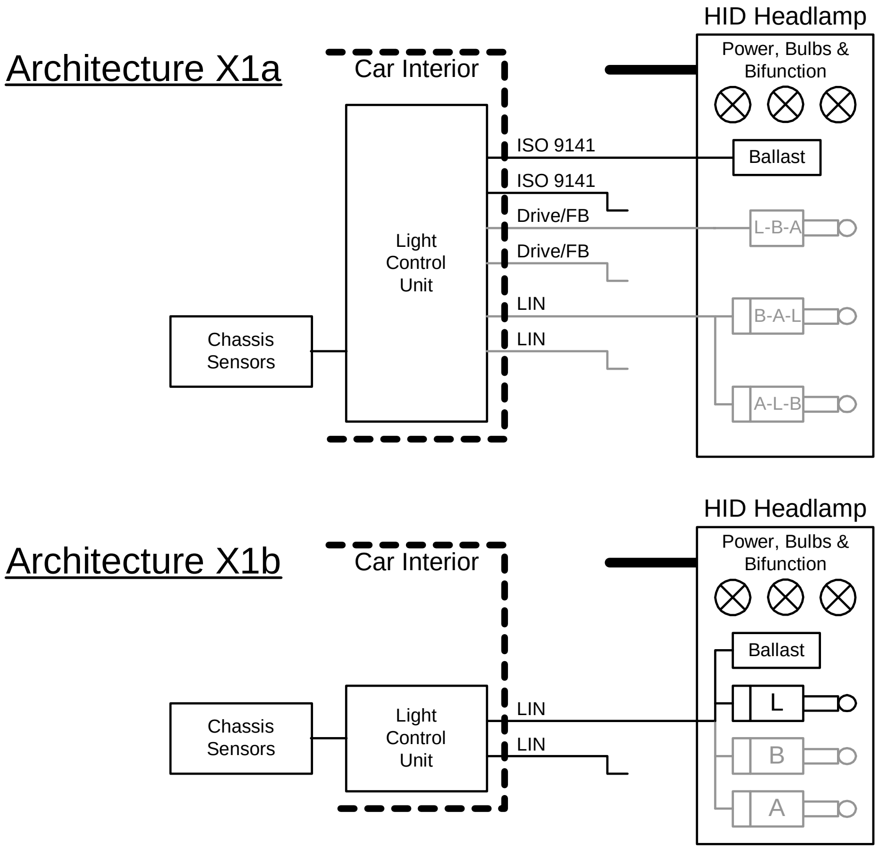
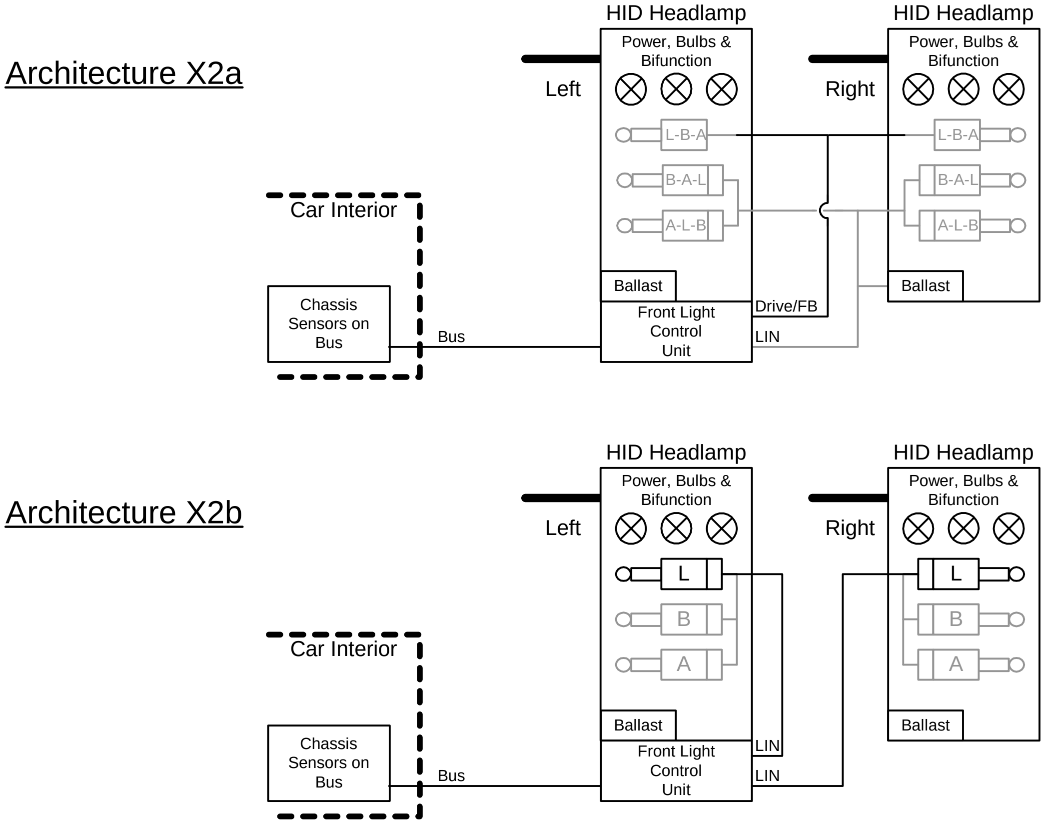


Figure 5: HID, cabin location of LCU

5.2 Front Location of Single HID LCU

Figure 6 shows an asymmetric headlamp configuration with the possibility to mount the LCU directly on the ballast unit. Architectures X2a and X2b are highly compatible with the H1a and H1b proposals, with potential differences in the sensor bus topology : CAN or LIN, depending on the amount of sensor data needed for AFS systems and on-board-diagnostics requirements. A bus carrying sensor signals is preferred for HID systems as the wiring architecture does not need to change with variations in the number of attached sensors (number of sensor signals increase from leveling to bending to AFS) and the bus can be re-used for diagnostic purposes of the LCU and the headlamps. The advantage of LIN for front-mounted HID LCU's is again the modularity and the reduction of wiring complexity in the front-module.


Architecture X2a

Architecture X2b

Figure 6: HID, front location of single LCU

5.3 Front Location of Dual HID LCU

The architectures depicted in Figure 7 require one LCU per headlamp. The sensor-bus is again re-used for diagnostics. In X3a, the electronics board of the LCU contains the leveling drivers, together with bus mastering for the other options like bending and AFS. This is then combined with software to master the regulatory requirements. X3b also shows the leveling performed through LIN. Drawbacks of both architectures are the relatively high-cost and incompatibility with halogen architectures. The advantage of LIN for X3a and X3b is again the modularity and the reduction of wiring complexity in and around the headlamp itself.

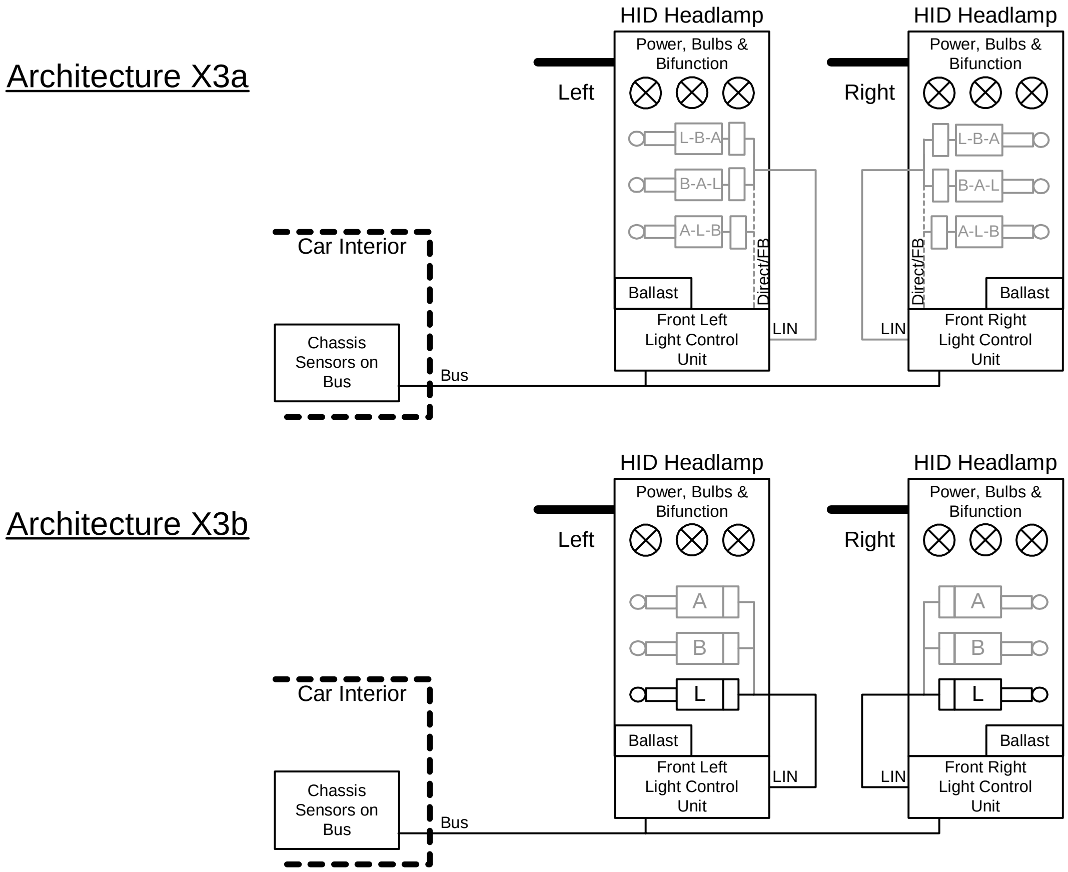


Figure 7: HID, front location of Dual LCU

6 Discussion on Architectures

Considering the simplicity of wiring, architectures H1b and X1b are candidates to become “the architectures of choice” in headlamp systems for the coming years. The driving force would be the high potential of bending light in a cost-sensitive halogen market. Both architectures are compatible with the two types of sensor wiring (bus and PWM) and are compatible with standard halogen and HID leveling systems to date.

Architectures H2 and X2 offer possibilities for high-end car-platforms that still have a substantial halogen penetration. The advantage is the removal of the LCU outside the passenger compartment (space requirements).

Architecture X3 seems to be an expensive solution, but will certainly be important for high-end car platforms with nearly no halogen penetration.

In any case, the architecture of choice will be made by the OEM's and the Tier-1 headlamp suppliers and is related to the penetration rate of halogen/HID in the car type and the forecasted headlamp options (leveling, bending, AFS).

7 LIN Motor Driver for Headlamp Mechatronic Applications

With the exception of halogen leveling, the motors used in headlamps are stepper motors. AMIS has developed LIN solutions to support mechatronic applications utilizing stepper motors. The AMIS LIN technology also enables the use of the LIN bus outside the local scope of sub-systems in a car. It is now possible to network modules in the front of the car with LCU's inside the passenger compartment by means of a LIN bus. An example of such a LIN slave product is the AMIS-30621 stepper motor driver, which contains a well-balanced LIN command set, an advanced state-machine to perform positioning tasks and high-power drivers to activate the motor coils. Detailed diagnostics feed-back helps the LIN master (which is situated in the LCU) to obtain all necessary information of the mechatronic module.

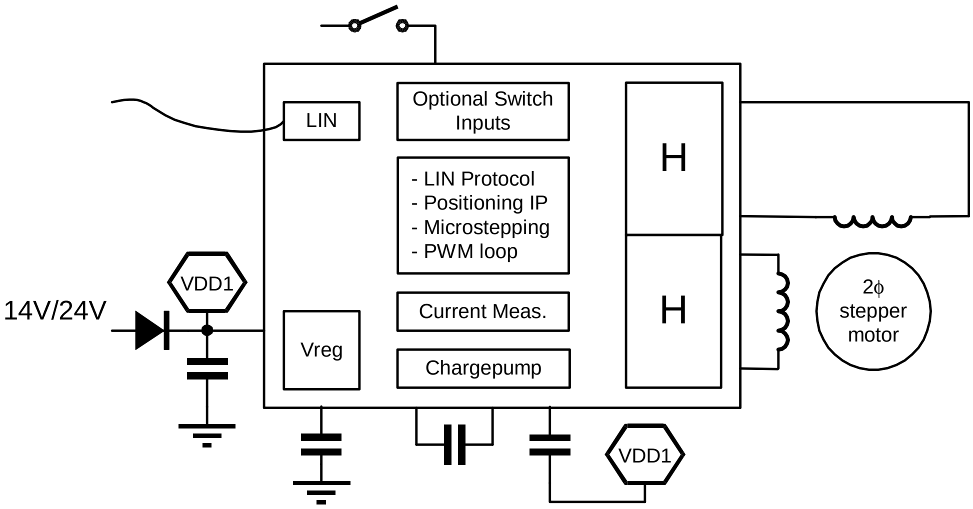


Figure 8: Application diagram LIN stepper motor

Upon LIN wire break or other LIN malfunction, the motor adopts a safety position to meet regulation requirements. Other features of interest are micro-stepping capability and stall detection. Figure 8 shows an indicative application diagram, more information is available in the literature.

8 Conclusion

A classification of wiring architectures of headlamp actuator systems was discussed. It is shown that in all discussed architectures, LIN offers increased modularity, reduced complexity and variation of wiring harness and reduced EMC emissions. This results in system cost reduction, increased performance and shorter time-to-market. AMIS has the right technology and products available to support headlamp system developers with LIN mechatronic solutions.

9 References

http://www.lin-subbus.org

Gerd Bahnmueller, “Headlamp Development-Reduced Time to Market”, PAL 2001 Symposium, Darmstadt University of Technology.

Alexis Dubrovin, “Optimised Lighting Systems Architecture”, PAL 2001 Symposium, Darmstadt University of Technology.

Michael Hamm, “System Strategies for Adaptive Lighting Systems”, PAL 2001 Symposium, Darmstadt University of Technology.

Geert Vandensande, “System-on-Chip Slave Nodes”, paper presented at 1st International LIN Conference, September 2002, Ludwigsburg.

John V. DeNuto et al., “LIN Bus and its Potential for use in Distributed Multiplex Applications”, SAE Technical Paper 2001-01-0072.

http://www.amis.com

This Paper is Published in "Proceedings of the 5th International Symposium on Progress in Automobile Lighting, Darmstadt University of Technology, Laboratory of Lighting Technology, in the Series "Darmstädter Lichttechnik".