Automotive LIN Bus Driving Sensor Applications

Dr. Stephan Hartmann

Today´s cars contain, on average, more than 50 different sensors to monitor various physical variables. This number is growing, driven mainly by the proliferation of actuators, which require sensors to deliver the relevant input values. In addition, requirements for signal systems are now increasing, and analog data transfer techniques are showing their limitations. The engineer now faces the challenge of transforming the sensor area into an efficient, high-performance digital subsystem.

LIN bus driving sensor technology enables efficient management of digital data, combining the benefits of existing voltage modulation and current modulation approaches. Atmel® provides all necessary products independent of the integration level of LIN applications.

Sensor systems differ in many respects from other electronic components of the car. The most important difference is that sensors are mostly located outside the vehicle in harsh environments where they are subject to changes in humidity, temperature or pressure. In most cases, sensors also have to be mounted in areas with very limited space and are connected with a 2- or 3-wire harness.

The Applications for Sensors are as Diverse as the Application Areas Themselves:

- **In the comfort area:**
  - Temperature sensors
  - Solar altitude sensors
  - Light sensors
  - Humidity sensors
  - Dew point sensors
- **In the powertrain area:**
  - Position sensors
  - Speed sensors
  - Pressure sensors
  - Knock sensors
- **In the body control area:**
  - Pressure sensors
  - Gyro sensors

A typical sensor node contains the sensing element itself, a microcontroller for signal conditioning, and a transceiver for signal transmission. As the length of the data line is often more than 1m, the data transfer is dominated by analog signal conditioning which has a portion of about 90%.

Analog signal conditioning does have some advantages. It is compatible with previously existing mechanical or electromechanical detection systems, and is also easy to use and to plug in. Analog data can be provided in a voltage range of, for example, 0 to 5V and the sensor can then be monitored by an ADC port on a microcontroller which converts the data into the digital domain. Generally, however, requirements for sensor systems are increasing, making analog signal conditioning less attractive. With ADC resolutions up to 10 Bit, and the ability to indicate two different types of failure modes by clamping the signal voltage either to the lowest or to the highest voltage levels, analog techniques have already reached the limits of their performance and will be replaced by different types of digital data transfer.

Digital data transfer can be managed either by voltage modulation or current modulation. Both types have advantages and disadvantages. Simple current modulation allows a very cost-efficient design of the ECU as well as of the wiring harness. Inside the ECU, the different current levels can be transferred into voltage levels using a single pull-up resistor. For the connection to the sensor, a 2-wire connection is used. Disadvantages include thermal power dissipation in the sensor module, as well as a limited data rate dominated by the pull-up resistor. Other current-based transfer methods, such as Manchester-coded protocols, require dedicated transceiver ICs, driving system costs up.

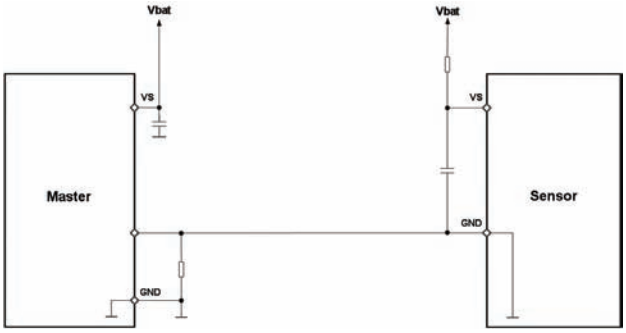

Figure 1. Basic Current Interface Set-up

Voltage modulation has the advantage of allowing a variety of protocols, beginning with simple PWM and moving to more complex versions like SENT, which have higher data rates than current modulation. Additionally, the ECU input can be designed as a capture compare unit on a timer basis. The main drawback of voltage modulation is that a wiring harness with a 3-wire connection is mandatory. Further issues may arise at EMC testing because most PWM drivers do not include a slope rate control. Additionally, ESD protection is low.

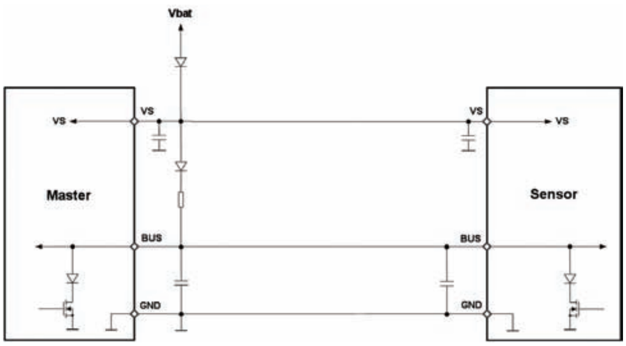

Figure 2. Basic Voltage Interface Set-up

The LIN bus protocol combines all advantages described above. As a two-wire interface, LIN helps save cost in the wiring harness. LIN's slew rate control in the transceiver ICs supports excellent EMC performance, while LIN's ESD protection features allow robust system designs suitable for harsh environments. Finally, the high production volumes for LIN bus transceivers lead to very cost-efficient designs compared to other protocols requiring transceiver ICs (e.g., current-based transfer protocols).

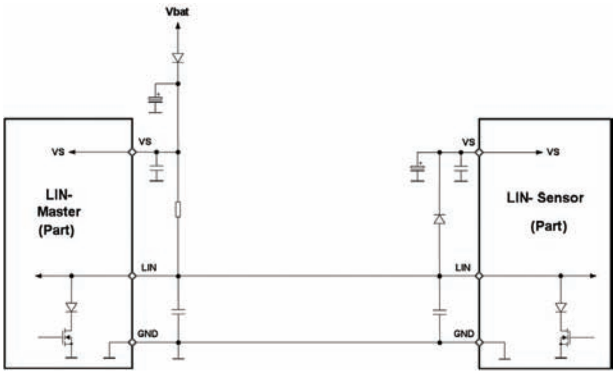

Figure 3. LIN Interface Set-up Modified to Support the Current Supply of the LIN Sensor Slave

The concept for the system design specifies a pull-up resistor at the ECU level. This is required to control the current supply for the LIN slave sensor through the data line. At the LIN slave sensor, only a buffer capacitor is required. Depending on the capacitor value, the data rate can be chosen up to 100 kbit/s. Supply voltage reduction provides an additional option for influencing the data transmission speed. As the dominant and recessive levels are referenced to the supply voltage, a reduction of the supply voltage directly reduces the gap between bus low and high level (the delta) to reach the correspondent levels. A 2V supply voltage reduction leads to an increase in the data transmission rate of roughly 15%.

Unfortunately, the supply voltage cannot be lowered in all cases. The time portion of the bus-dominant level must also be considered, as this state discharges the buffer capacity of the LIN slave sensor

Sensor system design using LIN can be viewed as a three-step process. First approaches to a discrete slave-node design include a sensing element, a LIN system basis chip,

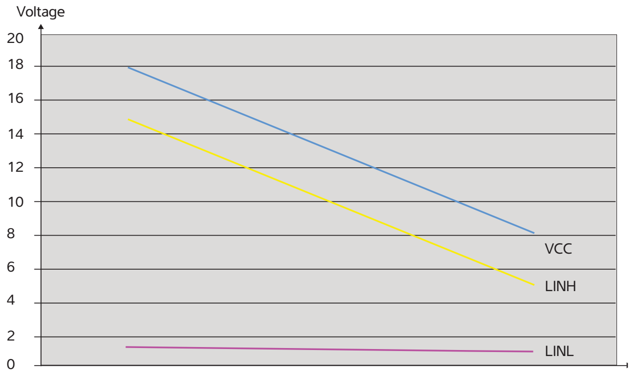

Figure 4. Bus Level States Bus Level States Depending on the Supply Voltage

and a microcontroller for signal conditioning and protocol handling. Atmel® serves all integration levels with LIN transceivers, LIN system basis chips (SBCs), and LIN system-in-package (SiP) devices. With SiP, the customer benefits from the ultra low-power designs of Atmel AVR® microcontrollers with Atmel picoPower® technology. As a second step, the designs can be converted into single-chip, multi-die SiP designs. This saves PCB space and allows the engineer to include all electronics in the connector of the sensor element. Finally, by integrating the sensor element into the chip, and by implementing an intelligent state machine, the engineer takes a further step toward advanced, single-chip LIN sensor node designs.

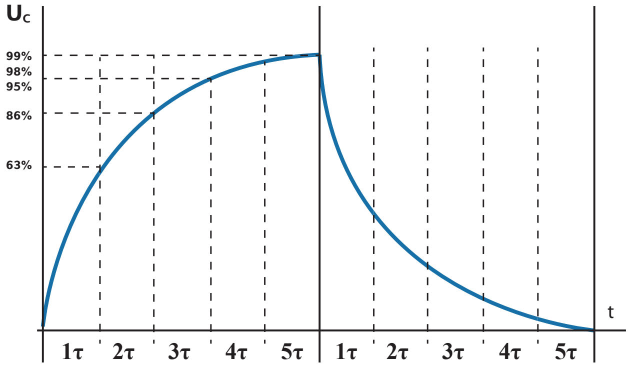

Figure 5. Capacity Discharge Depending on the Bus-dominant State Time

In summary, LIN not only enhances the driving of cars from the in-vehicle networking point of view, it also allows the rumble change of the sensor area to a cost-efficient and high-performing digital sub-system. Atmel offers all necessary products regardless of the integration level of LIN applications. To support low-power designs, the AVR microcontroller with picoPower technology is key. In addition, engineers can design the most robust and EMV-tolerant systems with the leading-edge EMC and ESD performance of LIN transceivers and SBCs from Atmel.

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