Driving RGB LEDs for interior lighting applications

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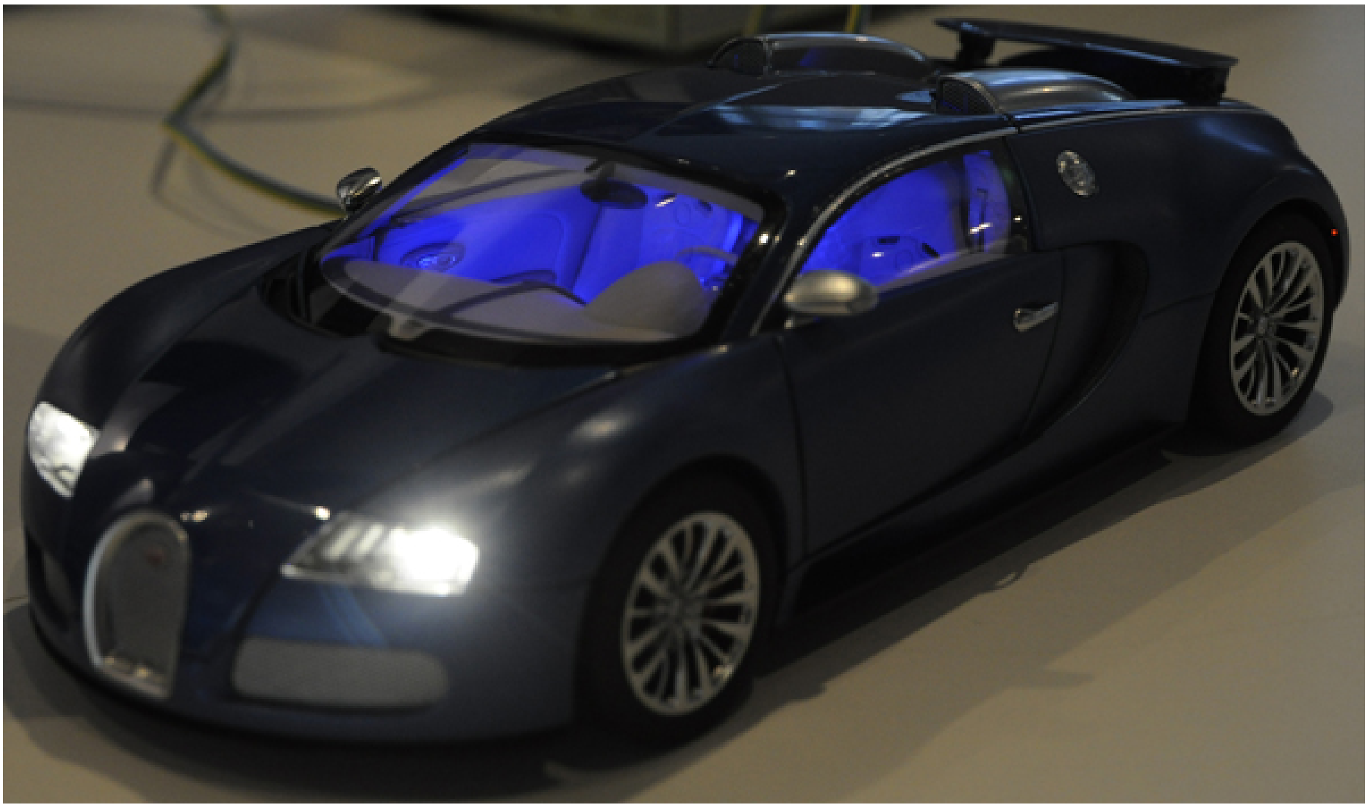
RGB LEDs are becoming increasingly popular for applications inside vehicles. For reasons of style and personalisation, as well as driver comfort and safety, they present an exciting opportunity for interior designers at major car makers. As multiple light points are required inside the vehicle in order to achieve the implementation of an effective solution, the individual nodes that incorporate the light source, driver, LIN communication and processing must be small. This article looks at the growing trend for interior RGB lighting and discusses single-chip solutions that will help make them a reality.

Ambient RGB interior lighting is a major contributor to the recent steep increase in the demand for adding an individual touch to homes and offices using light emitting diodes (LEDs). Car owners spend much more time inside a car than outside, thus styling and personalization of a car's interior is becoming increasingly important. In addition, there are studies that demonstrate the benefits of interior lighting on comfort and safety. We can also recognize this in the acceptance of the ambient RGB interior lighting option by car-buyers. Where the option is offered, we see high uptake on RGB LEDs for vehicle interior lighting, and the inclusion of this type of lighting is on the roadmap of most major car manufacturers.



Use of RGB LEDs and drawbacks
In interior lighting applications, many light points are distributed throughout the car and RGB LEDs are used for generating colored light. These devices consist of three individual LED chips assembled together in the same package with a transparent cover. While these RGB LEDs have many advantages, such as their small size along with the possibility to generate multiple colors by adding different amounts of RGB light, there are a couple of drawbacks to using RGB LEDs that must be considered.

To understand these drawbacks, it is important to have a closer look at the physics involved in LEDs. A Light Emitting Diode is a semiconductor component which emits light when current is flowing through its junction. The process of emitting light is through radiative electron-hole recombination. Recombination is a process by which a conduction band electron loses energy and re-occupies the energy state of an electron hole in the valence band. In the case of radiative recombination, a photon is emitted in this recombination process.

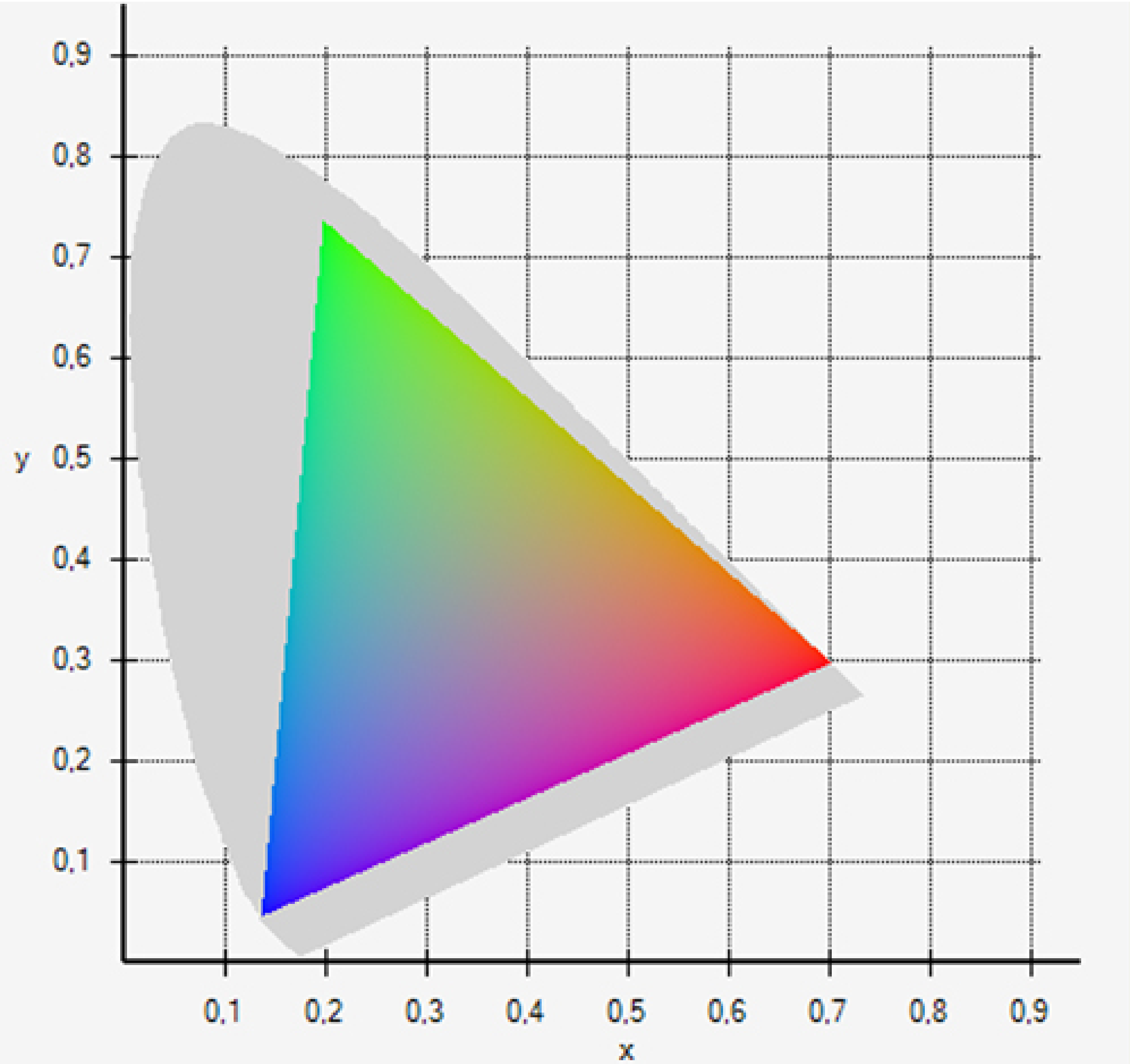
Using the energy conservation law, we can deduct that the photon energy should be given by the difference between the electron energy and the hole energy that take part in that process. This energy is approximately equal to the bandgap energy at reasonably low temperatures. The frequency (and its inverse the wavelength) of the emitted light are linked with the photon energy through Planck’s constant. The desired emission wavelength of an LED can hence be attained by choosing a semiconductor material with the appropriate bandgap energy.

Choosing the semiconductor material comes down to putting materials together in different fractions. The inherent process spread in manufacturing these semiconductors results in a spread in the emission peak-wavelength and intensity over different LED modules. Not only the difference in light output of the primary colors is playing, but when combining the light of two or three LEDs, differences in intensity are also automatically translated in perceived color differences.

Since different light points in the car are relatively near each other and expected to be able to display the same color, some adjustment step is needed. Several methods can be used, the most straightforward is to select only a few colors and store the needed outputs to obtain these colors. Another possibility is to use the linear properties of the human vision system and of the color mixing.

The calibration process goes as follows:
* A “reference” - red, green, blue is defined. These reference primary colors remain the same for the entire production of LED modules. In the CIE (Commission Internationale de L'Éclairage or International Commission on Illumination) colorspace, these reference color points make the largest triangle that can be inscribed in the color triangles of all the possible produced color sets.
* The red, green, blue LED color coordinates are measured with a color meter.
* Correction factors are calculated that map the incoming data to the “reference” values red, green, blue.
* This information is stored in the memory of the module.

During operation, incoming RGB data that is referred to the reference colors is converted into outgoing RGB data, taking the specific colors of the module into account. Thanks to the linear properties of the human vision and additive color combination, the whole calibration process can be done using elementary matrix calculations.



A second item that requires some consideration is the behaviour of the LEDs over temperature. LEDs of different colors have a different material composition to create different bandgaps for selecting the correct peak wavelength of the emitted light. The differing material composition results in different temperature behavior. Particularly on the red channel, we see a significant drop in light output with increasing LED die temperature. When mixing colors, for example when making yellow out of a combination of red and green, this difference can become apparent under certain conditions, therefore some temperature compensation might be required. To accomplish this, one could think of measuring the emitted light in some way and compensating for the light changes using a closed loop.

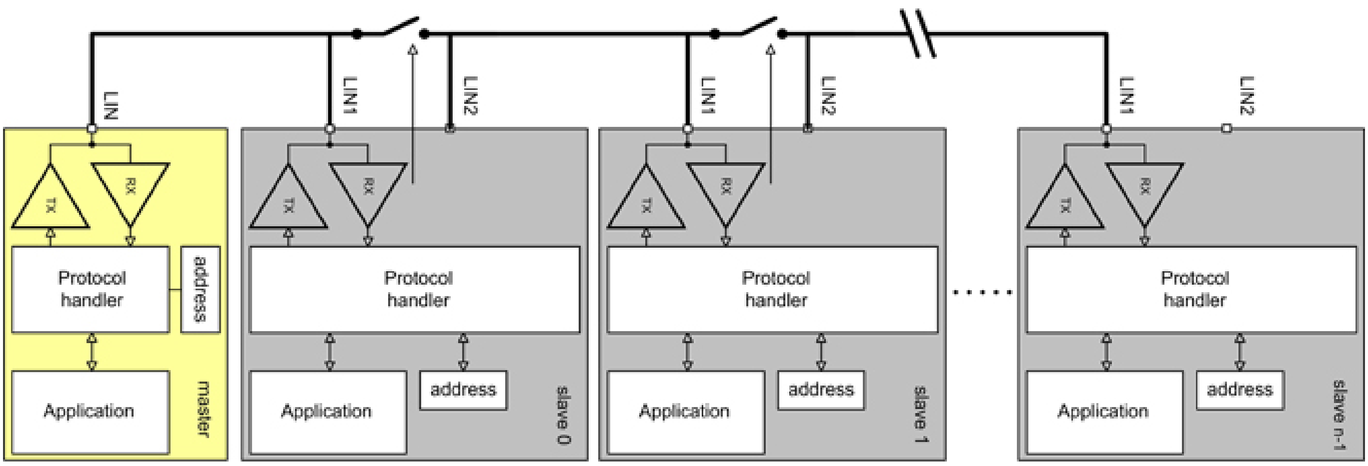
Different methods can be used to find an approximation of the temperature of the LED die. The temperature on the board can be measured by a temperature dependant element such as a NTC/PTC resistor, a junction diode, etc. Some refinement can take into account the dissipated power (known from the level of light displayed), the thermal coupling between different LEDs, etc. Going closer to the LED, we could look for properties of the LED that are dependant on temperature. One such characteristic is the forward voltage of the LED. An LED is a

Light Emitting Diode, so in addition to it's light emitter properties, it also has diode properties. The forward voltage of a diode is dependent on the temperature, and this parameter can then be used to determine the LED temperature.

LIN for cost reduction

For a more complete experience, individual light points need to be commanded. An important contributor to the cost of a system is the cable cost. To reduce the cable costs, a bus structure with addressable nodes such as the Local Interconnect Network (LIN) protocol is a good solution. Only a LIN wire is needed together with a power line (battery) and ground (GND). Thanks to the bus-structure, all nodes can be connected in a daisy chain.

The LIN protocol uses a master-slave approach. This communication scheme is well suited for this application. The LIN master is located in a central ECU and the individual light points are seen as slaves. When the master sends a message, the LIN slave checks if it is the intended addressee of the message, if so, it executes a command such as putting the light on.



Addressing

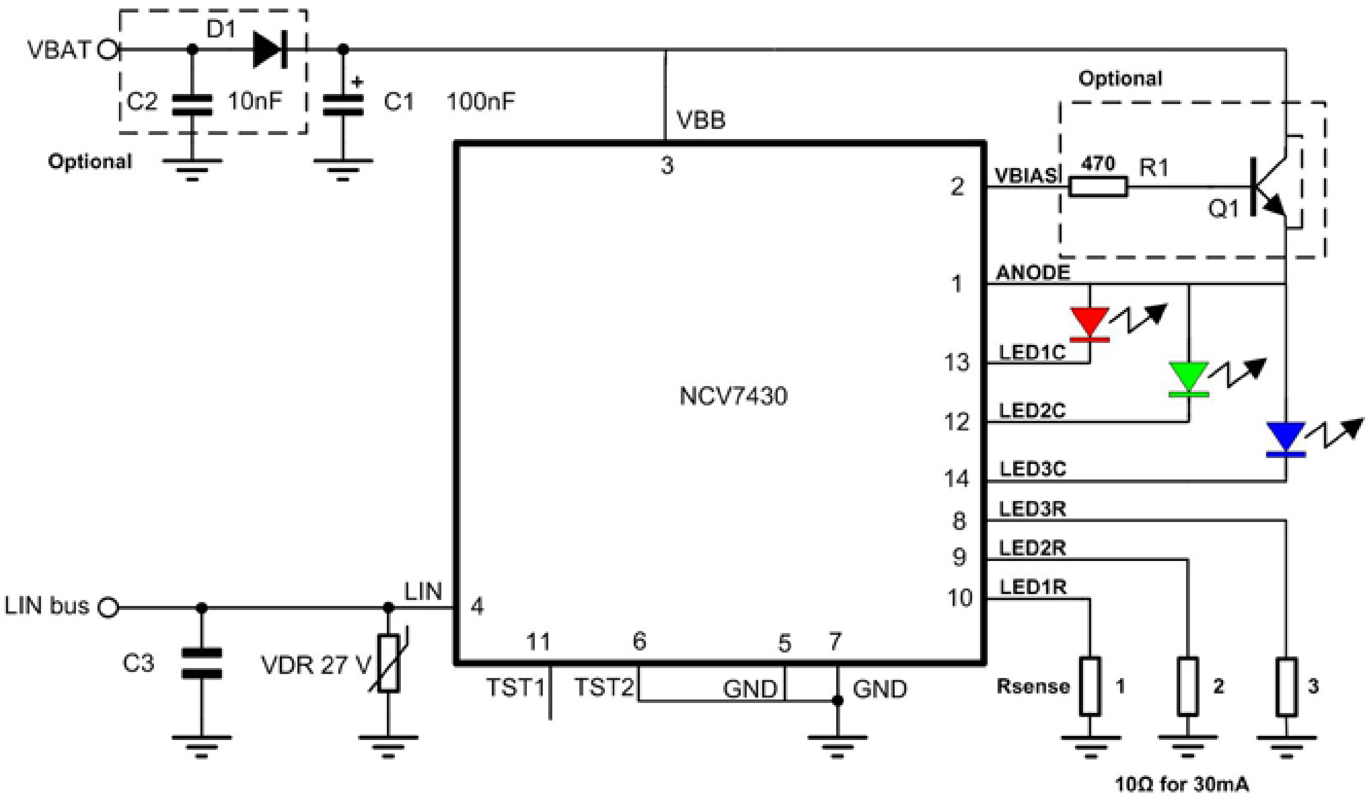
How does a module know its address? To this end, several possibilities are used: modules can be pre-programmed with an address before they are assembled in a part of the car. For example cup holders with RGB lighting get address 1, left doors get address 2 etc. A more flexible but also more expensive method uses auto-addressing. At start-up of the network the LIN nodes get an address based on Node Position Detection (NPD): the node finds its position in the network and gets an address. A well-known technique for NPD is the so-called ‘extra wire daisy chain’. In this technique, an additional wire is put between two modules that are connected after each other in the chain. Each module has an input port (D1) for such a wire and an output port (D2). All nodes are consecutively turned “on” by changing the level on the wire. This method is not popular in interior lighting, because the extra wire increases the cost and introduces some further constraints on the (already congested) holes where the different cables have to pass through. More popular approaches avoid the extra wire as they use the LIN bus line to determine the position of the slaves. Bus Shunt Method is one of them, another one is the so-called LIN switch method.

Space requirements

In order to be able to fit in multiple places in the vehicle interior, the nodes typically use boards with a very small area. On this small area, all the functions of the RGB LED module need to be present: an RGB LED, a LIN transceiver, light processing, an LED driver, etc. Single chip solutions with integrated LIN communication, processing and driver are clearly a preferred choice for these types of modules.

Related to space are also the requirements on the thickness of cables. The modules can literary be anywhere in a car, the fewer cables are needed to go to these places, the easier it becomes. LIN communication provides the solution for this.

Solutions
In the past the modules for interior RGB lighting usually consisted of three devices: an RGB LED, a system basis chip (SBC) containing a LIN transceiver and a voltage regulator and a micro-controller for the processing. Lately a number of semiconductor suppliers have been introducing devices that integrate the processing together with the LIN transceiver and LED driver. Some have an embedded micro-controller while others have a full hardware solution using a state machine. The NCV7430, recently introduced by ON Semiconductor works on a portfolio of single chip driver solutions for automotive ambient RGB interior lighting. On one single die, the LIN interface is incorporated together with calibration algorithms and different transition features and an EMC reducing LED driving technique. Temperature compensation can be done using the temperature dependency of the junction of a schottky diode on the reference resistors. The device also contains the option to do auto-addressing using the LIN switch method.



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