Sensorless LED temperature protection

by NUCON.DE R&D in Germany

The junction on LED chips can usually not exceed a certain temperature limit such as 150°C to prevent damage to the LED.

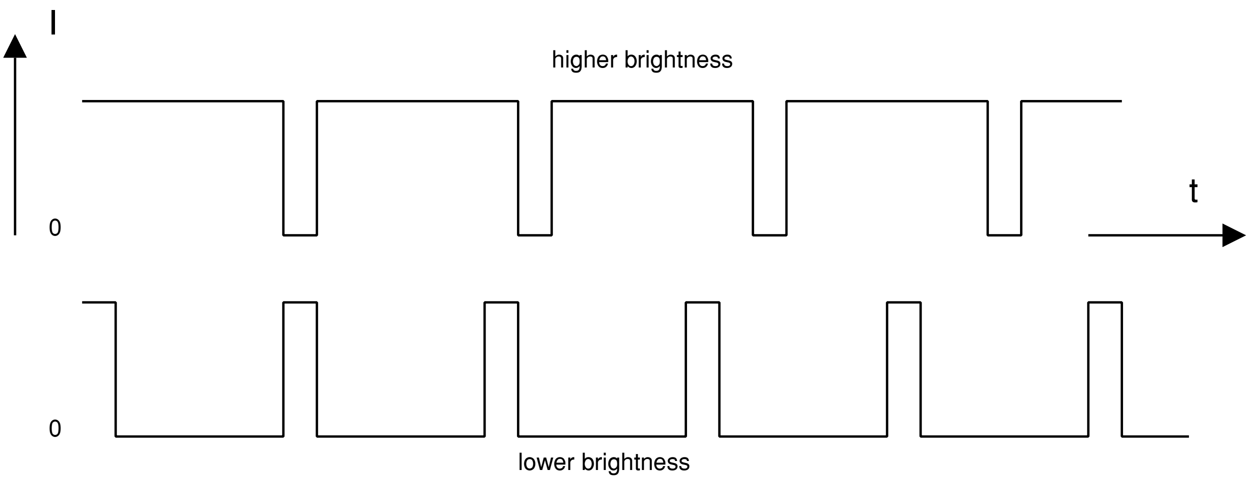
The electric energy to light conversion is not perfect , about 60% of input power is converted into heat.

A good heat transfer to ambient is required in order to keep the LED chip below its temperature limit. However, cooling efficiency and ambient temperature are not constant and are also influenced by application, tolerances, system contamination, aging, et cetera.

The best protection of an LED against overheating is a direct temperature measurement on the chip itself, without any other influence.

Cost savings are substantial due to the absence of sensors along with their cabling, connectors, space requirements and additional parts. The on-chip temperature can be determined without any special fixtures, for example in LED strings.

LEDs can be turned ON and OFF so fast that a pulsed operation (pulse width modulation or PWM) used for dimming or an occasional very brief off phase are not visible. The light of an LED will generally still appear smooth and without visible flicker yet the current of an LED may have the following wave form:

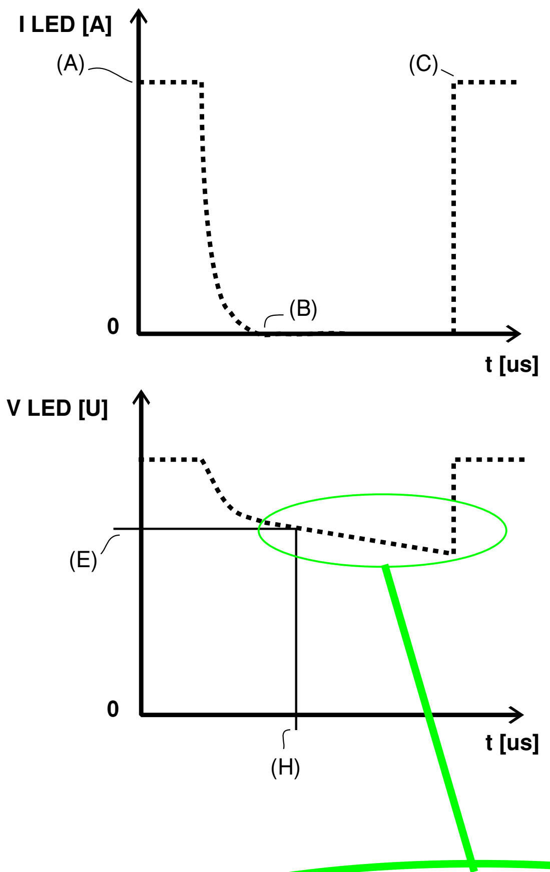


Interruptions in LED current can be used for analyzing the condition of the LED. Nucon has developed a new and very simple method to monitor the voltage drop of the LED when it is turned OFF.

This voltage drop is being characterized to obtain reproducible measurement data depending only on the junction temperature of the LEDs.

The simple but effective new idea is to use only a brief discharge cycle of a capacitor connected in parallel to the LEDs.

The state of the art is to toggle the LED current between two current levels, the normal LED operating current and a very small probing current. For accurate temperature measurements this requires an additional low current source which adds circuit complexity and cost.



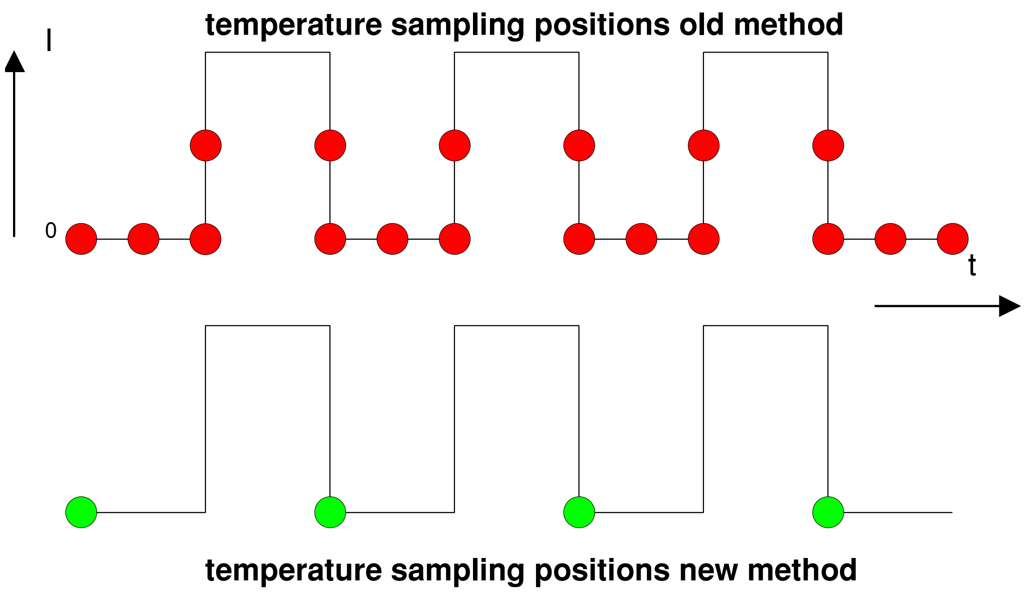
The graph on the left demonstrates the new method. When the LEDs are turned OFF the high current through an LED will very quickly drop to a very low level. After a short time the capacitor discharge current over the LED provides a slow linearly falling voltage ramp. This timing behavior remains the same no matter what the temperature level inside the LEDs might be. The starting voltage level (E) of the voltage ramp (H) is the parameter revealing the temperature.

Capturing the voltage level (E) while maintaining a constant delay (H) will result in an accurate measurement of the temperature of the LED chip (junction). Maintaining precise and repeatable time delays and thus sampling positions is easy using simple digital circuitry or a micro controller.

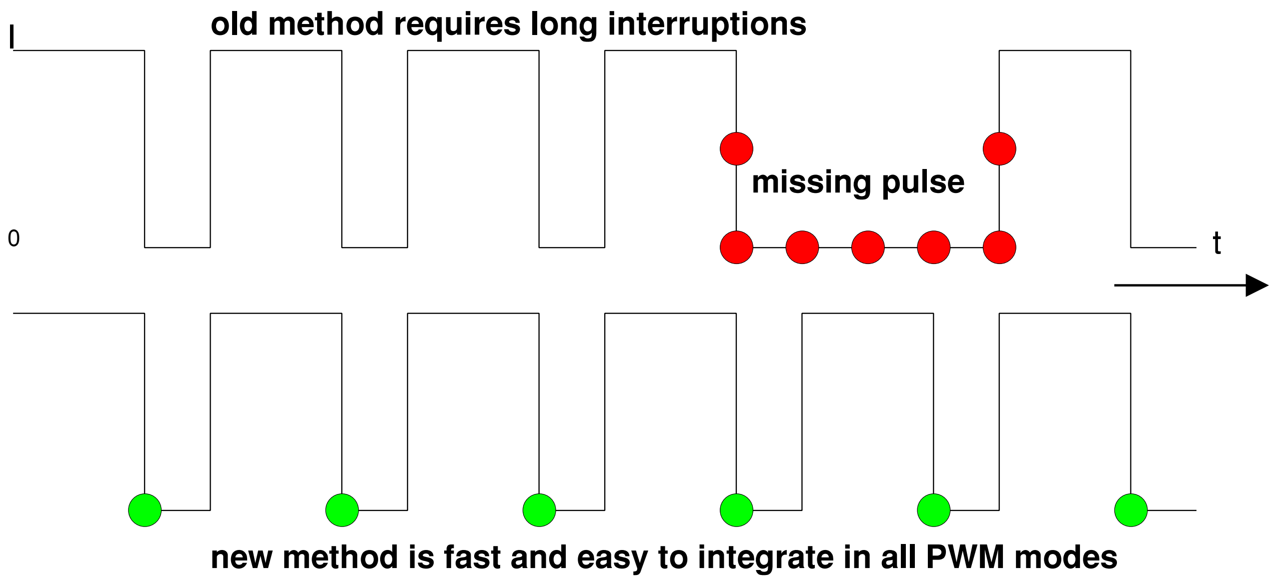
An averaging for a basic standard linear approximation is performed. The calculations can also be done by a low cost micro controller that is often already present in a system.

the voltage decrease over time is proportionate to the capacitance connected in parallel to the LEDs

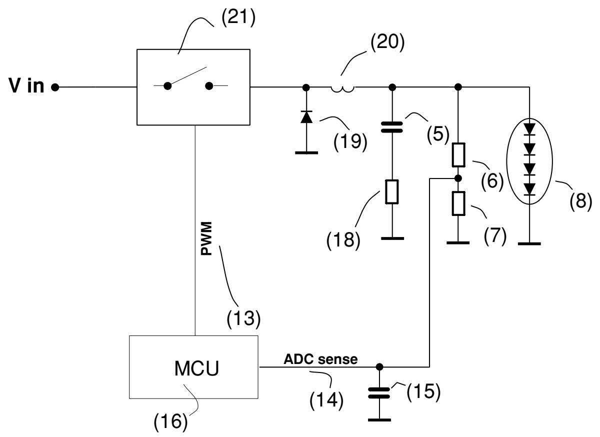
Advantages of our method compared to the state of the art



Less statistics: The new method is pre selecting the correct sample positions and is reducing the statistical load for calculating the temperature following thereafter. Lower numbers of components and involved tolerances are further reducing possible errors for the result.



Low interference: The new method is using single samples and requires a minimum current interruption in the range of 10-15 micro seconds. That is about **100** times faster than the old method. This is very important to avoid possible flicker for the human eye caused by missing pulses when operating LEDs at high frequency and high duty cycles. The new method makes it very easy to integrate in a firmware of an LED system.



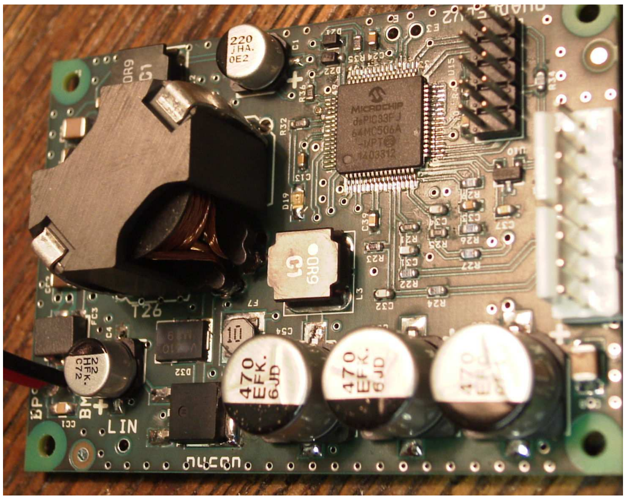
The schematic on the left shows the new method in conjunction with a buck regulator. ADC sensing of the LED voltage is used for two different tasks: It is regulating the buck when the LEDs are ON and it is used for the sensorless temperature measurement by capturing the voltage drop over time during interruptions in LED current.

The new sensorless temperature sensing and protection does not require costly additional components when a micro controller is used for controlling the LEDs.

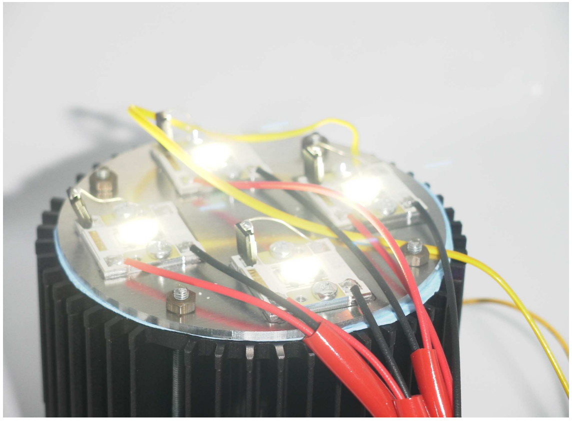
BUCK regulator based on PIC 18F

The software regulator is also able to change and control the drive current of the LEDs.

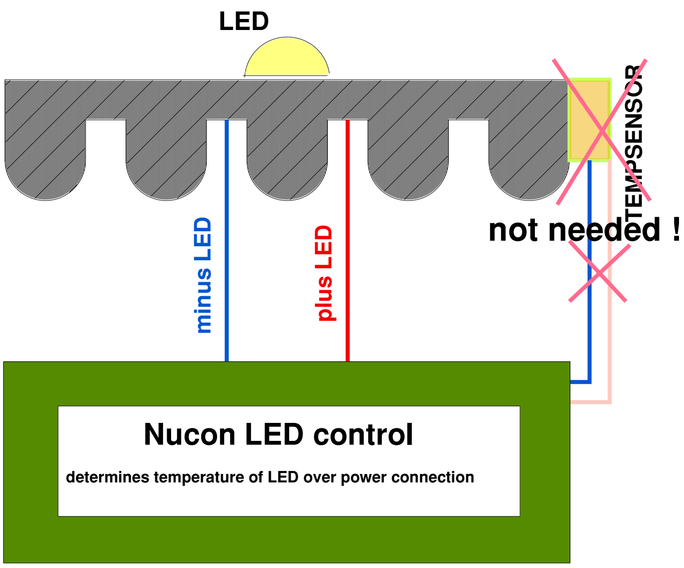
The main dimming does not have to be performed by PWM only, it can also be a combination of analog dimming (drive current) and PWM. If dimming is performed by drive current only, very short periodic interruptions for temperature measurements are required allowing up to 99% duty cycle.



Prototyp for four automotive OSTAR LEDs with a RM8 flyback converter based on a DSPIC.



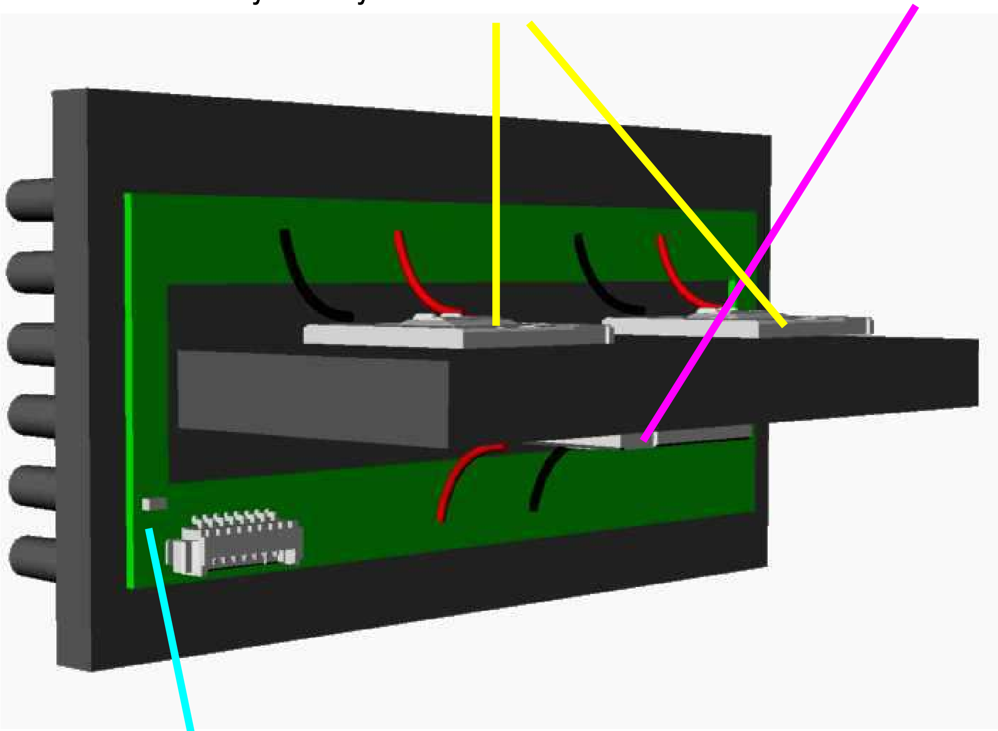
Four OSTAR LEDs mounted with graphene foil on a common cooling block to develop and prove a system based on four independent controlled LED channels.
In automotive headlights 500Hz is currently used but 1kHz dimming is supported by the prototype.



The LEDs can be operated and temperature-protected just over the common supply harness. Long supply cables are possible.

Save costs and making sense:

Automotive headlights do have more than only one LED. When using powerful cluster LEDs you may have two LEDs for low beam and a third one for the high beam on a heat sink as the example is showing according to an existing design.



Connector and cables are expensive. They have a space requirement for the full plugged connection and cable outlet. The space at the LEDs itself is very limited because they are to be integrated into an optic system with an effective cooling to the back side. Having several LEDs on a heat sink simply every LED can not contain it's own NTC sensor otherwise the costs and space requirement would be simply too high. The more cables involved the higher the costs also at the side of the control unit.

So the number of cable connections should be kept as low as possible and the above light head has just one NTC placed at the corner close to the connector for all three LEDs. The NTC sensor senses an average temperature at the heat sink which is relatively slow in response and can not judge the seperate LEDs. The green mounting PCB must be connected to the heat sink in a way to dissipate the heat to the thermal sensor.

Using sensorless temperature sensing lets you monitor all three main driving LEDs at the same time, prolonging their life time and saving costs for the not required NTC cable assembly and special mounting.

Sensorless temperature sensing can be applied prolonging life time for LED strings also at other applications like tail lights where sensors can not be applied because of a non existing heat sink or are not allowed to be used because of involved higher costs.