Quality Engineering Tools Focused on Designing Remote Temperature Measurements for Inaccessible Locations by Using Light Components Parameterization of the Heated Materials

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Abstract. This paper is focused on research dedicated to measure the bucket wheel bearing temperature of the bucket wheel excavator (BWE). It proposes a measurement method for heating friction materials because is difficult to detect the temperature variation in the bearing. The major issue is to detect the generated infrared light according to the material detection. The temperature is considered the major signal of the wheel reliability and a remotely temperature detection method is proposed and because the sleeve bearing is a crucial part of the excavator a predictive measurements system for buckled wheel axis system was designed.

1. Introduction
In lighting design they are two large efforts: one is dedicated by the lamps producers, researchers and users in order to realize efficient lighting systems based on semiconductor devices [1]; second development direction is dedicated to correct lighting from the eye sensitivity point of view [1']. On the other hand, power LED lighting systems are more suitable, and more convenient for automation, lighting scattering managing, with intelligent implementations. A very important demand of LED lighting applications, out of indoor or outdoor lighting is the correctly render of the colors [2, 3]. According to [2, 3], if the demands are satisfied, the tendencies of practical implementations are:

- good color rendering for material analyzing,
- good color rendering for safety,
- high reliability devices and simple commanded devices,
- smart lighting (Adaptive Environment Lighting - AEL),
- energy efficiency and fast light switching.

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2. Typical switch mode power supply (SMPS) topologies

The implementation of LED lighting has some requirements and the effort of performing these requirements driven the industry toward smaller, lighter and more efficient electronics, development of the Switch Mode Power Supply (SMPS) is an issue. A very good synthesis of topologies commonly used to implement SMPS is presented in [4] and [5]. Although certain topology may be used in many applications, there is for any application a best suited topology. The choice of the best topology must take into account [4] several factors, like: the relation between input and output voltage, number of outputs, requirement for electric isolation, values for input/output voltages and currents and the maximum duty cycle.

1.1. Transitory regime analysis of the designed boost-up module with TPS55340

For the paper purpose, in this section we are proposing two issues to be solved. One issue is related to transient analysis, and second issue is related to the components related thermal stress. There are several ways for running such designing simulation scenarios as the Spice model which is available on the TI sites can be exported as other tools, but also can be used in the web simulation tools of TI called WEBench [6-12]. Running WEBench designer with many solutions, based on our criteria, the circuit diagram is shown in figure 1. The simulation interface of the WEBench uses four designing areas (A- schematic designing, B- menu area, C- simulation tools, D- thermal evaluation), which are available on entire session simulation. For the simulation, based on the TPS55340 datasheet, the block diagram for parameters controlling is shown in figure 2.

![Figure 1. The graphical interface of WEBench designer with main facilities.](image1)

![Figure 2. The block diagram of the TPS55340 for parameters controlling.](image2)

At simulation start-up, based on our input parameters (Vin = 12V, Vout =37V, Iout =1 A), the WEBench offer some recommended values for the major requirements [Uout, Iout] = f [Uin, Iin], but they are many other possibilities to control some output parameters according to some local conditions.
input values (operational temperature, switching frequency, duty cycle). By analyzing some simulation reports, they are some critical points inside to circuit diagram. They are shown in figure 3.

![Circuit Diagram](image)

**Figure 3.** TPS55340 connected into a power supply boost-up circuit.

Some other stressing signal variations are inductor current ($I_{\text{Inductor}}$), and output capacitor current ($I_{\text{Cout}}$). First, as figure 3 suggests, we are simulating the transitory output voltage simulation according to the input supplying.

![Simulation Diagrams](image)

**Figure 4.** a) The first simulation diagram: the output voltage according to the input voltage, with default setting up parameters; b) The output current runs similar with output voltage.

1.2. **Measuring visible and infrared radiation with micro sensor TLS2561**

The measuring method is based on two integrating analog-to-digital converters (ADC) that integrate currents from two photodiodes. Integration of both channels occurs simultaneously. Upon completion of the conversion cycle, the conversion result is transferred to the Channel 0 and Channel 1 data registers, respectively. The transfers are double-buffered to ensure that the integrity of the data is maintained. After the transfer, the device automatically begins the next integration cycle.

It combines one broadband photodiode (visible plus infrared) and one infrared-responding photodiode on a single CMOS integrated circuit capable of providing a near-photopic response over an effective 20-bit dynamic range (16-bit resolution).
Two integrating ADCs convert the photodiode currents to a digital output that represents the irradiance measured on each channel.

1.3. Measuring visible color, with infrared filter using TCS3472

The TCS3472 device provides a digital return of red, green, blue (RGB), and clear light sensing values. An IR blocking filter, integrated on-chip and localized to the color sensing photodiodes, minimizes the IR spectral component of the incoming light and allows color measurements to be made accurately. The high sensitivity, wide dynamic range, and IR blocking filter make the TCS3472 an ideal color sensor solution for use under varying lighting conditions and through attenuating materials. The TCS3472 color sensor has a wide range of applications including RGB LED backlight control, solid-state lighting, health/fitness products, industrial process controls and medical diagnostic equipment. In addition, the IR blocking filter enables the TCS3472 to perform ambient light sensing (ALS). Ambient light sensing is widely used in display-based products such as cell phones, notebooks, and TVs to sense the lighting environment and enable automatic display brightness for optimal viewing and power savings. The TCS3472, itself, can enter a lower-power wait state between light sensing measurements to further reduce the average power consumption.

The four integrating ADCs simultaneously convert the amplified photodiode currents to a 16-bit digital value. Upon completion of a conversion cycle, the results are transferred to the data registers, which are double-buffered to ensure the integrity of the data. All of the internal timing, as well as the low-power wait state, is controlled by the state machine. Communication of the TCS3472 data is accomplished over a fast, up to 400 kHz, two-wire I2C serial bus. The industry standard I2C bus facilitates easy, direct connection to microcontrollers and embedded processors.

![Diagram](image-url)
1.4. Measuring proximity/UV/ambient light sensor with SI 1145

The Si1145/46/47 is a low-power reflectance-based, infrared proximity, ultraviolet (UV) index, and ambient light sensor with I2C digital interface and programmable event interrupt output. This touchless sensor IC includes an analog-to-digital converter, integrated high-sensitivity visible and infrared photodiodes, digital signal processor, and one, two, or three integrated infrared LED drivers with fifteen selectable drive levels.

The Si1145/46/47 offers excellent performance under a wide dynamic range and a variety of light sources including direct sunlight and can also work under dark glass covers. The photodiode response and associated digital conversion circuitry provide excellent immunity to artificial light flicker noise and natural light flutter noise. With two or more LEDs, the Si1146/47 is capable of supporting multiple-axis proximity motion detection. These devices are provided in a 10-lead 2x2 mm QFN package and are capable of operation from 1.71 to 3.6 V over the –40 to +85 °C temperature range.

The UV Index is a number linearly related to the intensity of sunlight reaching the earth and is weighted according to the CIE Erythemal Action Spectrum and has been standardized by the WHO and includes a simplified consumer UV exposure level as shown in figure 8. This weighting is a standardized measure of human skin response to different wavelengths of sunlight from UVB to UVA.

![Figure 7. Measuring proximity/UV/ambient light sensor with SI 1145.](image)

![Figure 8. UV Index characteristic and consumer UV exposure level.](image)
When the calibration parameters are recovered they show up at I2C registers 0x22 to 0x2D. These are the same registers used to report the VIS, IR, PS1, PS2, PS3, and AUX measurements. Once the calibration parameters have been recovered the routine Si114x_set_ucoef is used to modify the default values that go into the UCOEF0 to UCOEF3 UV configuration registers to remove normal part-to-part variation. The typical calibrated UV sensor response vs. calculated ideal UV Index is shown in figure 11 for a large database of sunlight spectra from cloudy to sunny days and at various angles of the sun/time of day.

3. Designing remote temperature device for inaccessible locations
One urge required action is to measure the bucket wheel bearing temperature of the bucket wheel excavator (BWE). The issue is related to the BWE maintenance. The temperature is considered the major signal of the wheel reliability [1,2], but at this moment there almost impossible to detect the temperature variation in the bearing. We propose here a remotely temperature detection method. We are starting with general approach for infrared detection [3], where the major issue is to detect the generated infrared light according to the material detection. The authors of [3] underline the major factors that influence the temperature remote measurements. In this paper we are developing our research related to the external light that influences the measurements. Next figure shows the detection principle we are taking into account.

![Figure 9. a) The sensors module detects the entire radiated energy; b) Hardware software architecture of the lab parameterization system.](image)

The sensors module captures the entire radiation: infrared radiation as a material temperature estimation, and reflected temperature when the material is variable illuminated. Because the sensors detect kmol m⁻²s⁻¹, (quantic model of the light) it is required to extract RGB content from the measured light signal. In order to implement this method, we switch now to the frequency model of the light that means that we are using the addition and subtraction method of the beams of lights.

According to this method, we can subtract part of the lights if they have equal intensity. It means that each primary color of light has a secondary color of light as its complement. In order to manipulate this method we have design hardware- software architecture and the block diagram of this architecture is shown is presented in figure 9. The sensors module captures the entire radiation: infrared radiation as a material temperature estimation, and reflected temperature when the material is variable illuminated.

In order to create this measuring and discrimination system we have implemented the microcontroller- based architecture around an 8 bit system, that communicate with the software on a PC for data processing. The main way of components dialog is shown next:
After the embedded software handshake (ports communication pairing and synchronization), during the execution data from a processing software is send as RGB parameters to the execution software. The upper figure shows the data exchange between two components. The interfaces for manual control during calibration process are shown next.

In both figure there is a handling facility to control/ manipulate every single component of the RGB high power driver.

4. Testing and results
The laboratory testing intended to discriminate the light components. For our experiment we have used a laboratory calibration device Fluke 712B with PTH100 (385) temperature probe. Next figure shows capture screen of the Fluke device during calibration process.
The upper figure shows the processing application for light components discrimination, which is used to subtract the RGB components of the captured light by the sensors module. The results are shown in next table, where the values are in Celsius degrees.

| Region                  | a  | b  | c  | d  | e  | f  | g  | h  |
|-------------------------|----|----|----|----|----|----|----|----|
| After RGB subtraction   | 290| 310| 300| 170| 145| 135| 110| 110|
| FLUKE measured          | 310| 310| 310| 170| 170| 170| 120| 120|
| Infrared termal camera  | 350| 350| 350| 140| 130| 130| 130| 130|

The comparative graph representation is shown next.

Figure 14. The comparative representation of the temperature measured values using three methods.

5. Conclusions

We have developed a hardware-software system for remote temperature measurement with RGB errors compensation. The system uses a driver for high power LED in order to ensure controlled light spectrum.

The system is tested by comparing a calibration method with our implemented method and one consecrated measuring method. If we consider the calibration method as reference, we can conclude
that the infrared camera is not sensitive (the error exceed 20%). Our implemented method offers one possibility to detect border situation. Our method offers a measuring solution in 16 bits resolution, and in an error range of 5%.

The method must be tested also taking into account the errors introduced by the measuring distance.

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