Simple Pulse-Width-Modulation (PWM) LED Source for Linearity Testing of DSLR Camera Sensor

Abstract

To create meaningful photometry data knowledge of the linearity performance of the sensor in use (e.g. CCD or CMOS-array) is essential. The emergence of embedded controllers makes it possible – even for the hobbyist – to build fairly low-cost, highly controlled devices with capabilities that can be utilized to make light sources with pulse-width modulated LEDs.
A simple system, comprised of a laptop computer, an embedded controller with an LED and a few additional parts will be shown. Experiences and data regarding linearity testing of the source itself (Part I) and, subsequently, characterization of a Canon DSLR camera with the source (Part II) will be discussed. The technique can easily be extended to other sensors. The camera is currently used to take photometry data of eps Aurigae.
Principle of Pulse Width Modulation (PWM)

Pulse Width Modulation

LED Brightness

0% Duty Cycle – analogWrite(0)

25% Duty Cycle – analogWrite(64)

50% Duty Cycle – analogWrite(127)

75% Duty Cycle – analogWrite(191)

100% Duty Cycle – analogWrite(255)

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"Arduinos" come in multiple flavors open source, hardware and software (see some web links on last page)

"UNO" ($30.00)

"BoArduino" (from $17.50)

"One Chip"

"Diavolino" (Kit, from $13.00)
Part I: Building the PWM LED Source

Basically 3 hardware parts:
1) Arduino
2) LED (green)
3) Resistor (< 200 Ohm)

(diagrams from “Fritzing”)

Simple PWM program

R < 200 Ohm

LED
Part I: Testing the PWM LED Source

Set-up to test linearity of LED source
Part I: Testing the PWM LED Source

Laptop screen: (right) Simple script to define light output of LED (PWM)  
(left) Serial monitor displaying PWM setting steps
Part I:
Testing the PWM LED Source: How “Linear” is its Performance?

LED Intensity as Function of PWM-Value

Residuals (Line Fit)

Measured LED data for 3 independent test runs.

Residuals – linear fit - for 3 test runs. 
**Note** the magnified “Intensity” scale (x 100) compared to the measured LED data.
Part II:
DSLR Canon 300D:  How to Test its Linearity?

Type: Digital SLR  
Sensor: CMOS, Bayer matrix  
Size: 22.7 x 15.1 mm  
Pixels: 6.3 M  
ADC: 12-bit

Figure 6.3 This low-level light source (L³S) provides a stable, faint source of light for advanced CCD testing. A circuit-stabilized LED emits light that is diffused by an opal-glass or milk plastic diffuser. The variable aperture controls how much light goes to the second diffuser and reaches the CCD.

Part II:
DSLR Canon 300D: How to Test its Linearity?
Part II: DSLR Canon 300D: How to Test its Linearity?

- “Ramp” the LED intensity up and down, take images at each setting
- Extract GREEN channel of “raw” images with gamma = 1
- Analyze each image center region (with AIP4WIN: “Measure - Pixel Tool”)
- Plot Mean, Standard Deviation etc. of center region
Part II:
DSLR Canon 300D @ 400 ASA, 2 s Exposure Time

- 3 independent test runs were performed (all @ 400 ASA, 2 s exposure time)
- Top: Mean values of the sample center region as a function of PWM setting
- Bottom: Standard Deviation values for each run as function of PWM setting

(Note the scale change top/bottom factor 100)
Part II: DSLR Testing - Conclusion

Canon 300D (400 ASA, 2 s exp.)
[12 bit CMOS, i.e. 4096 max. ADUs]
- green channel is linear for ADUs < 3500
- no automatic dark frame subtraction (good!)

background = dark frame level

Mean, Linear Fit and Residuals as function of PWM settings
Summary

- A linear PWM LED light source can be built for ~ $20.00
- The LED source can be used very well to test linearity of CMOS and CCD cameras (example Canon 300D shown)
- Test set-up with embedded controller can be *completely automated*
- Test set-up can easily be *extended* to test linearity of red and blue channels of DSLRs (e.g., use of a R-G-B tricolor LED)
A few web links – to get you started…

Arduino “environment” home page, open source hard- and software:

http://www.arduino.cc/

Buying Arduino “Uno”, “BoArduino”, “Diavolino” (and other) hardware:

http://www.adafruit.com/index.php?main_page=index&cPath=17

http://www.sparkfun.com/commerce/categories.php

http://www.evilmadscientist.com/article.php/diavolino

Fritzing:

http://fritzing.org/