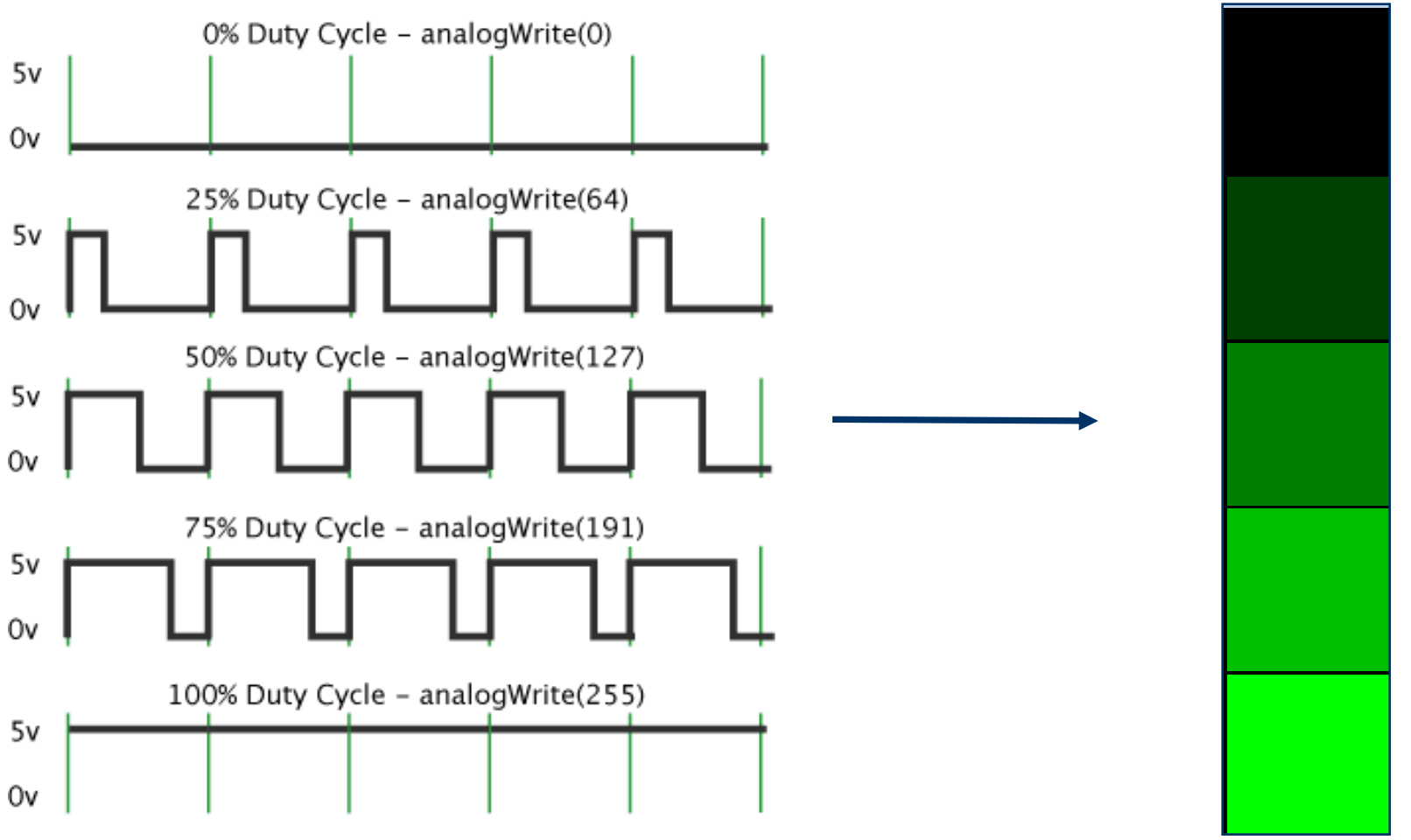
Simple Pulse-Width-Modulation (PWM) LED Source for Linearity Testing of DSLR Camera Sensor

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)

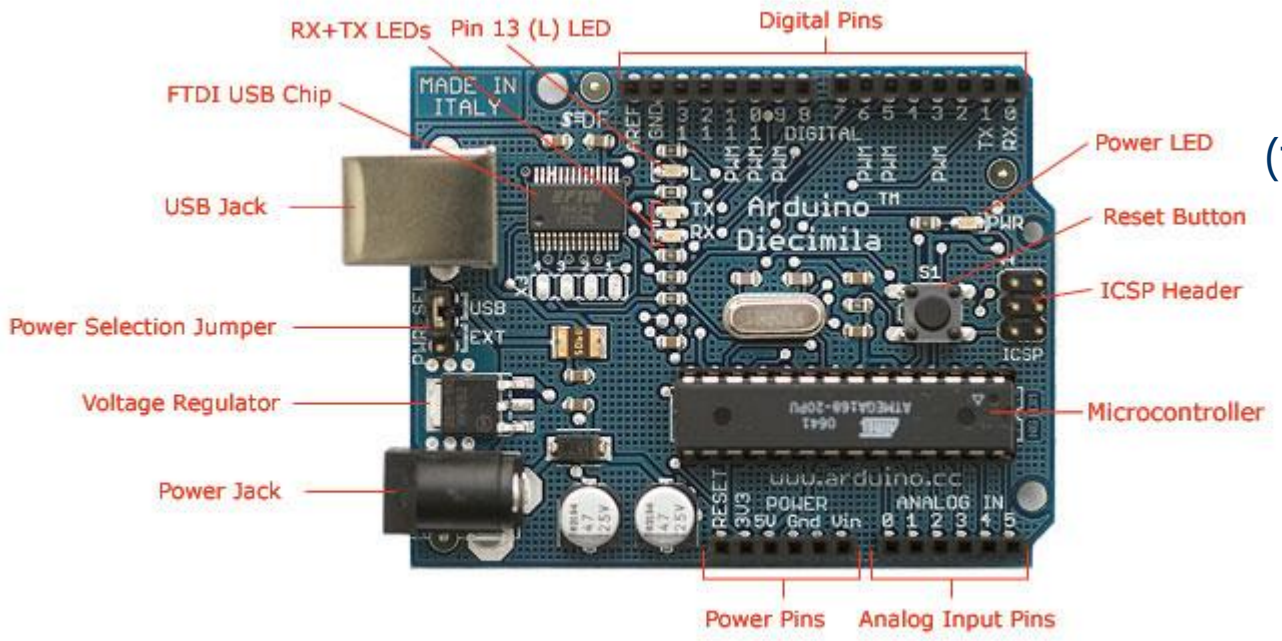


Pulse Width Modulation

LED Brightness

Embedded Controller Example: "Arduino"

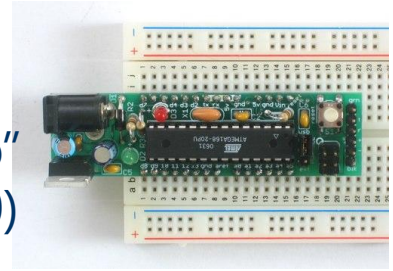
"Arduinos" come in multiple flavors open source, hardware and software (see some web links on last page)



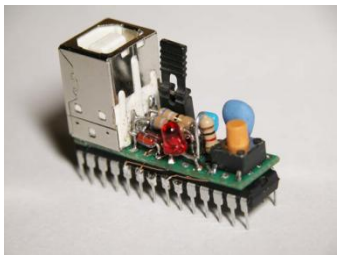
Photograph by SparkFun Electronics. Used under the Creative Commons Attribution Share-Alike 3.0 license.

"UNO"
($30.00)

"BoArduino"
(from $17.50)



"One Chip"

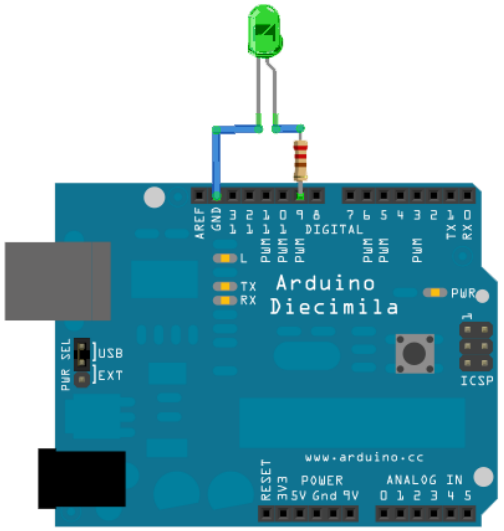


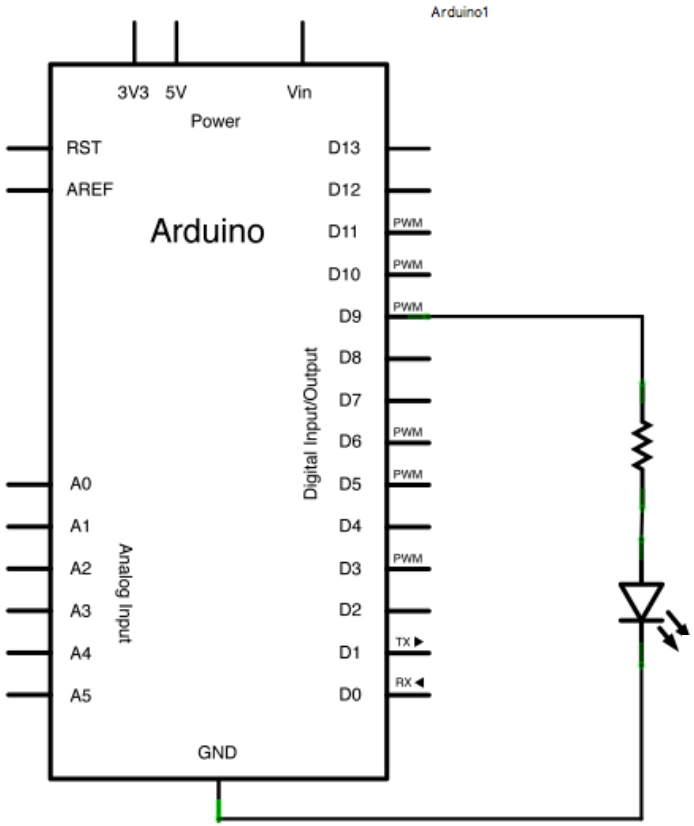
"Diavolino"
(Kit,from $ 13.00)

Part I:
Building the PWM LED Source

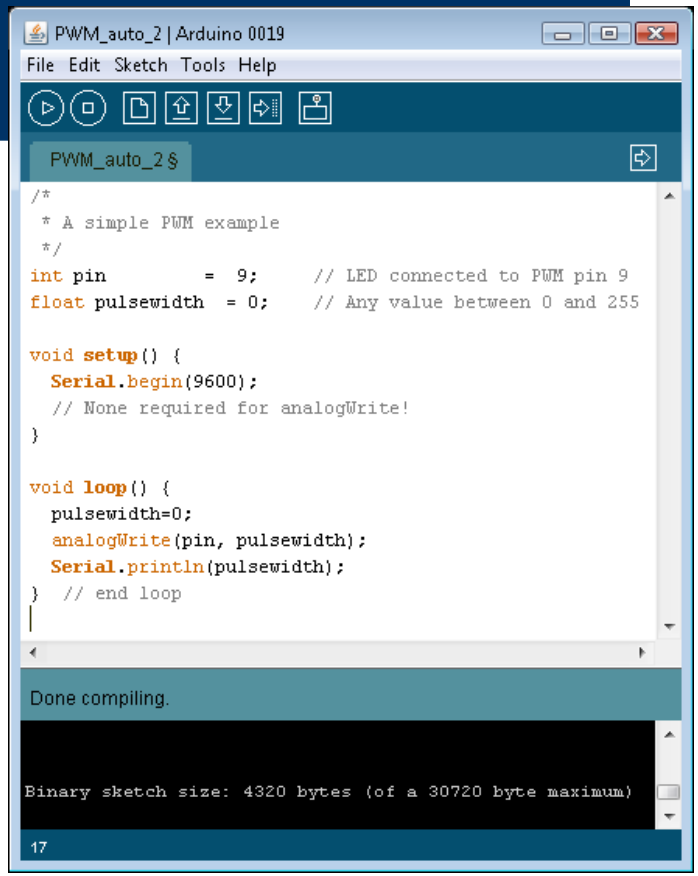
Basically 3 hardware parts:

1) Arduino
2) LED (green)
3) Resistor (< 200 Ohm)



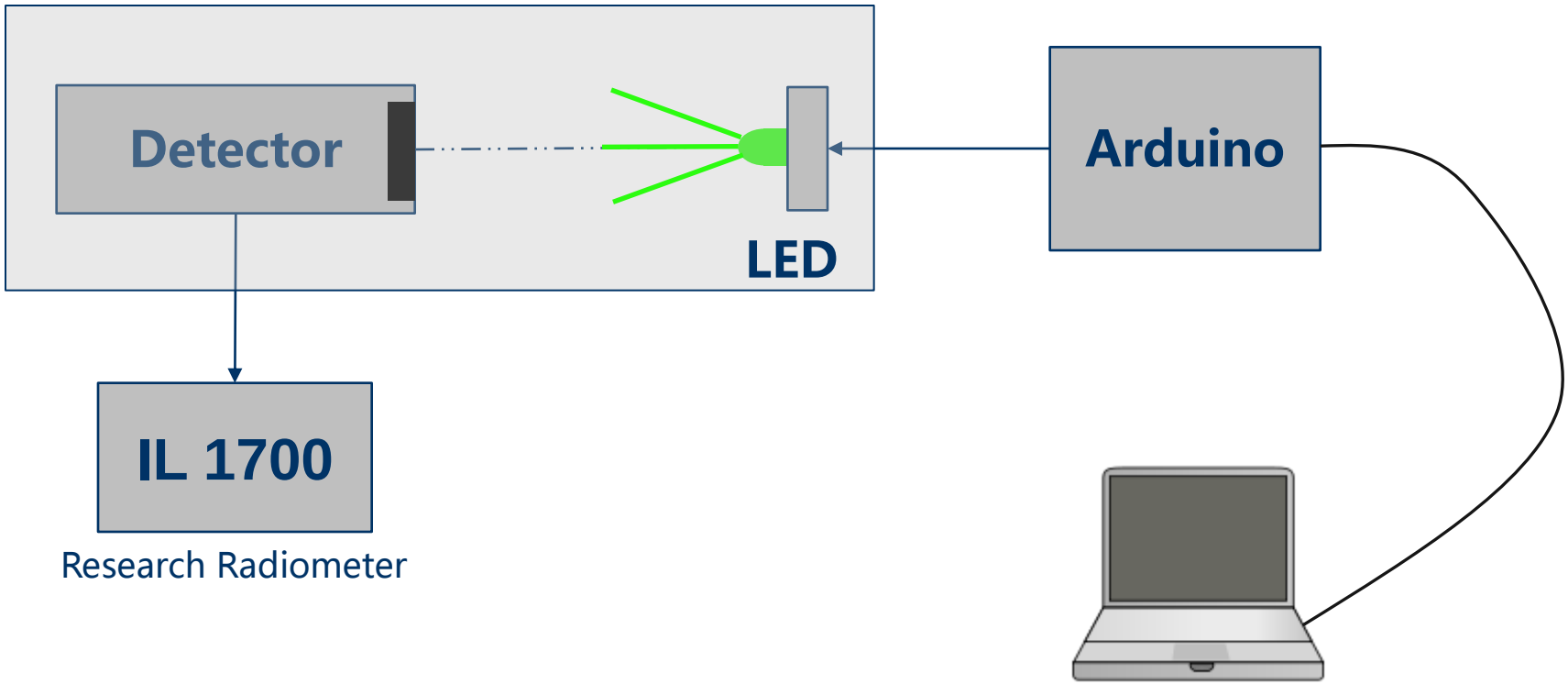


(diagrams from "Fritzing")



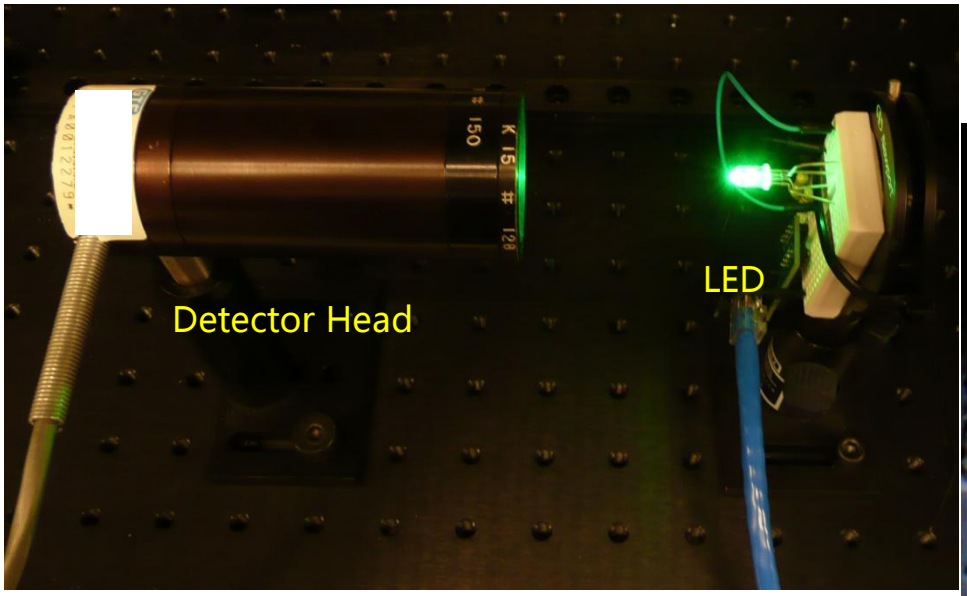
Simple PWM program

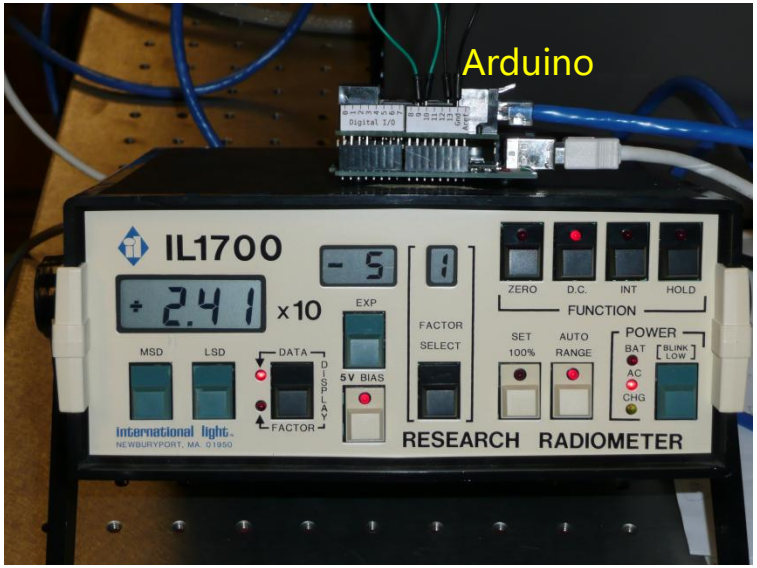
Part I:
Testing the PWM LED Source

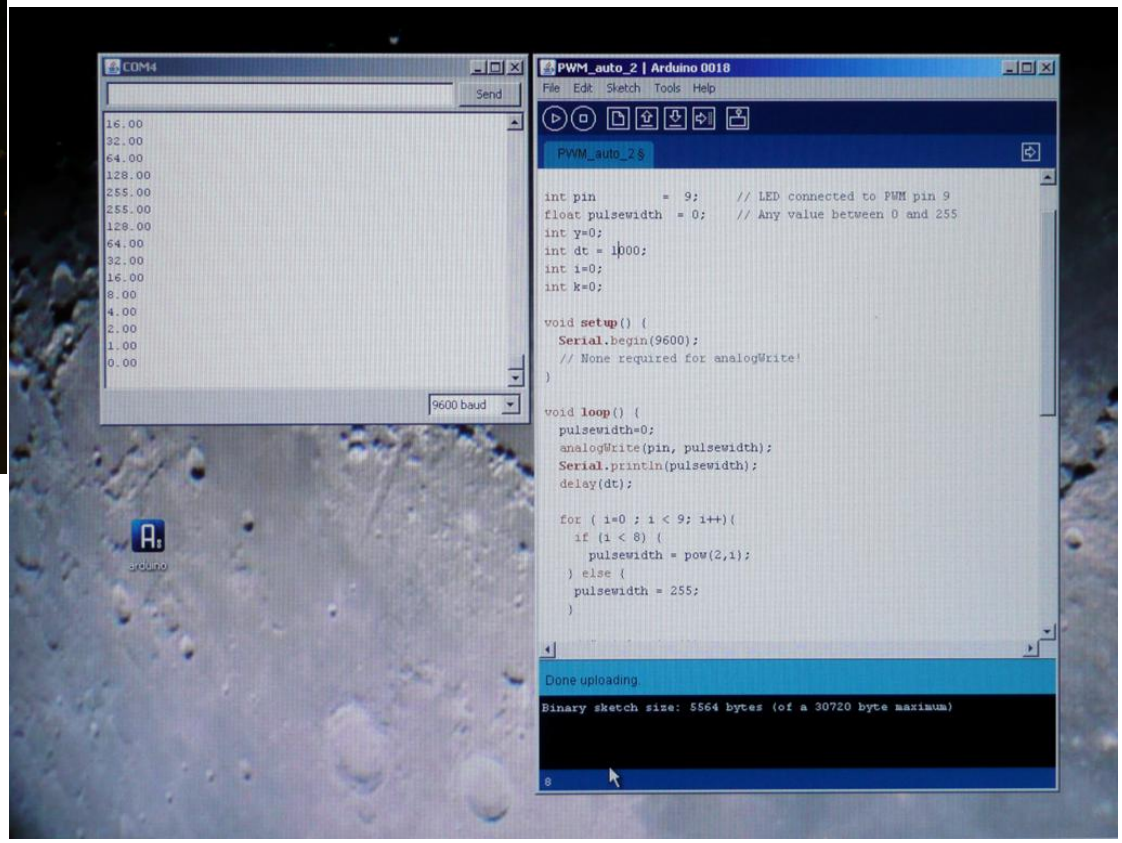


Set-up to test linearity of LED source

Part I:
Testing the PWM LED Source

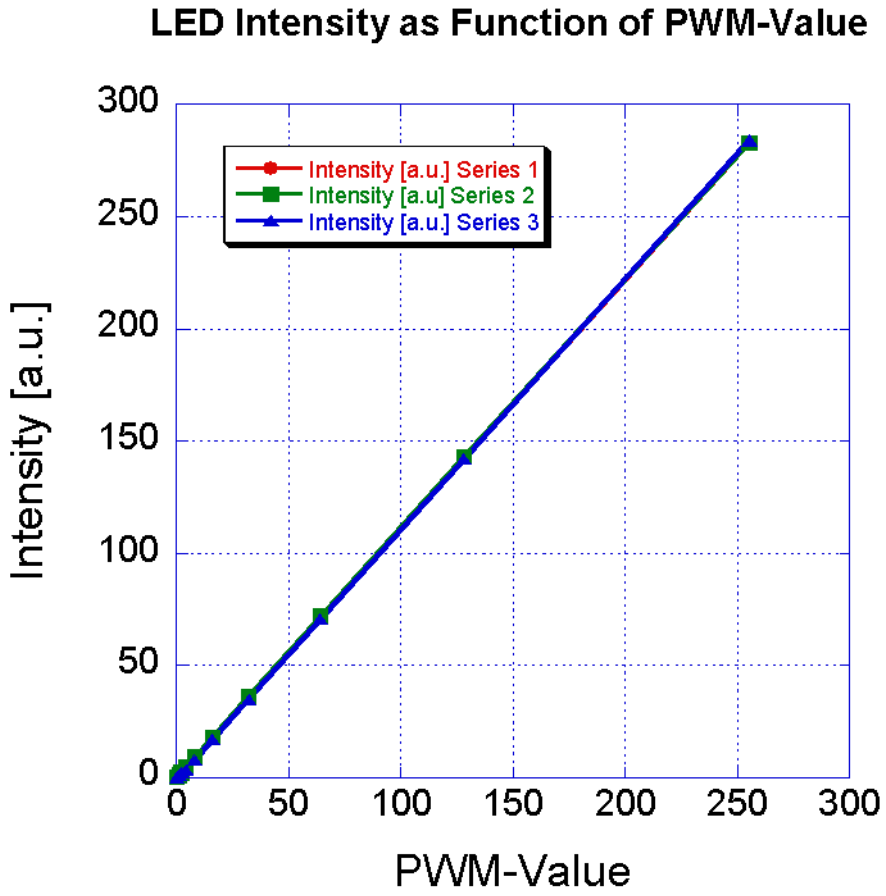




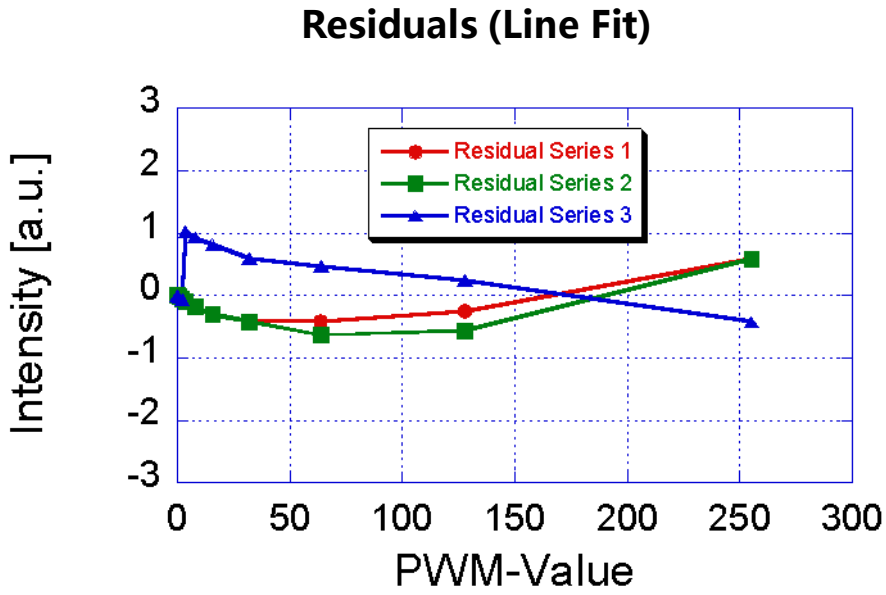


Laptop screen:
(right) Simple script to define light output of LED (PWM)
(left) Serial monitor displaying PWM setting steps

Part I:
Testing the PWM LED Source: How "Linear" is its Performance?



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

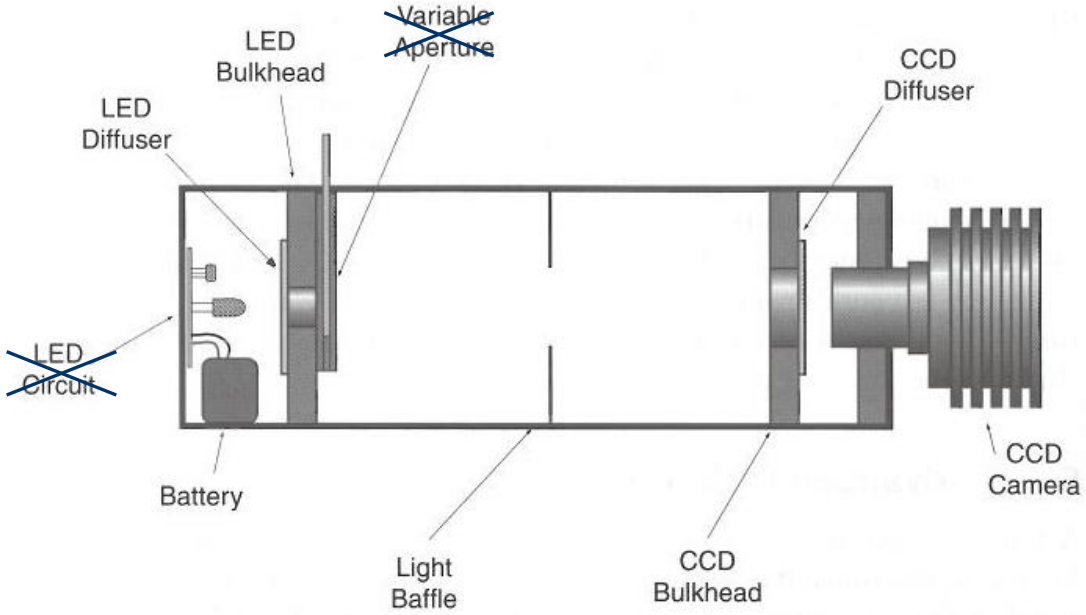
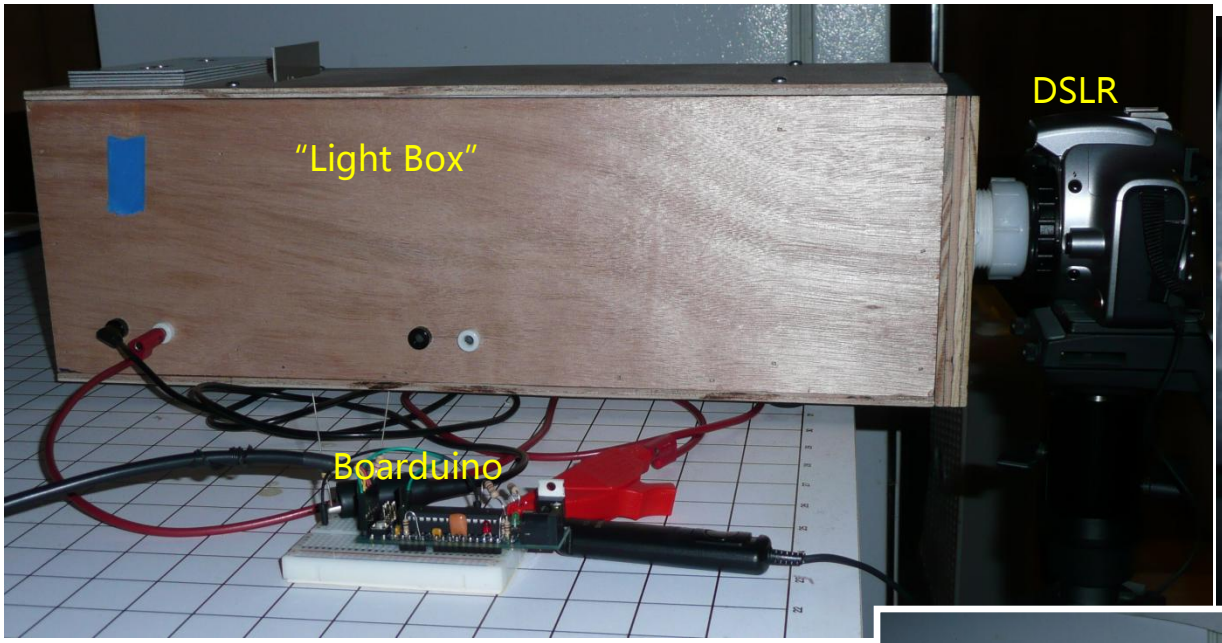
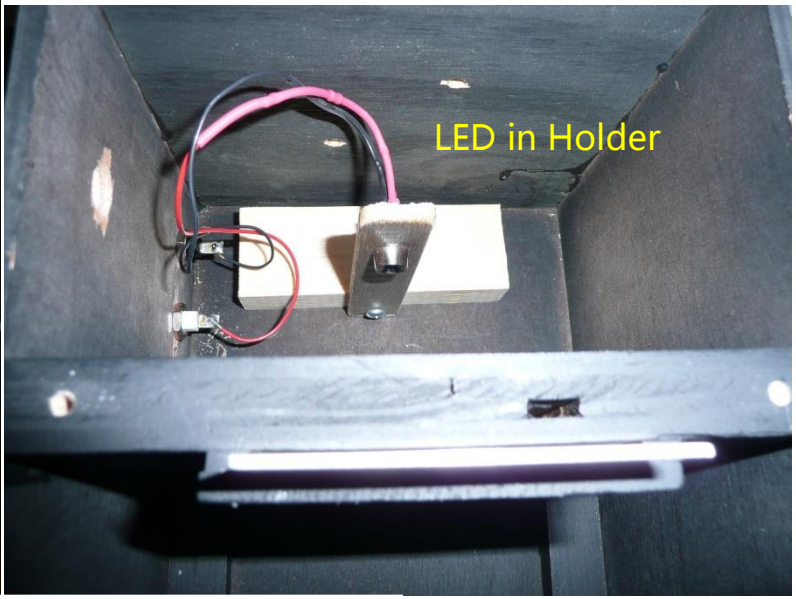


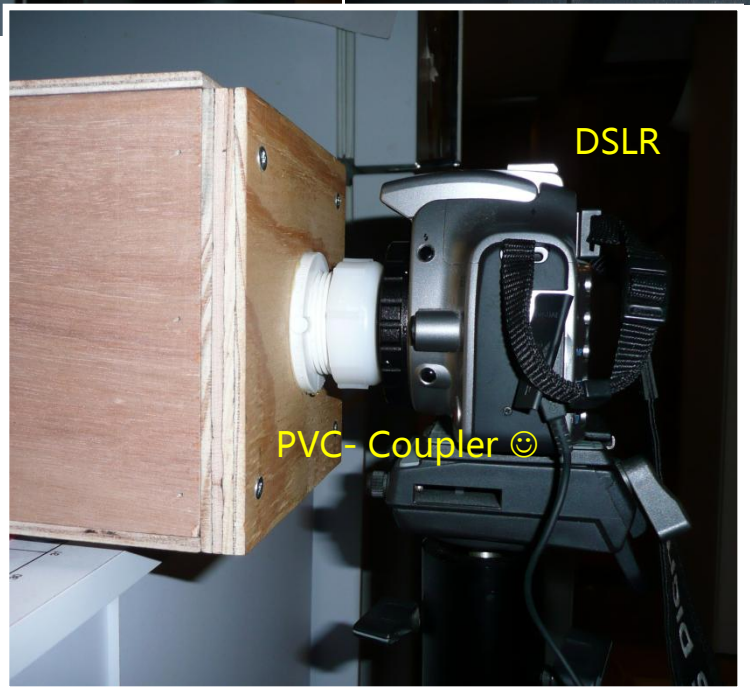
Figure 6.3 This low-level light source (L^3S) provides a stable, faint source of light for advanced CCD testing. A circuit-stabilized LED emits light that is diffused by an opal-glass or milk plastic diffuser. The variable aperture controls how much light goes to the second diffuser and reaches the CCD.

from *The Handbook of Astronomical Image Processing,* Richard Berry & James Burnell, Willman-Bell, Inc.

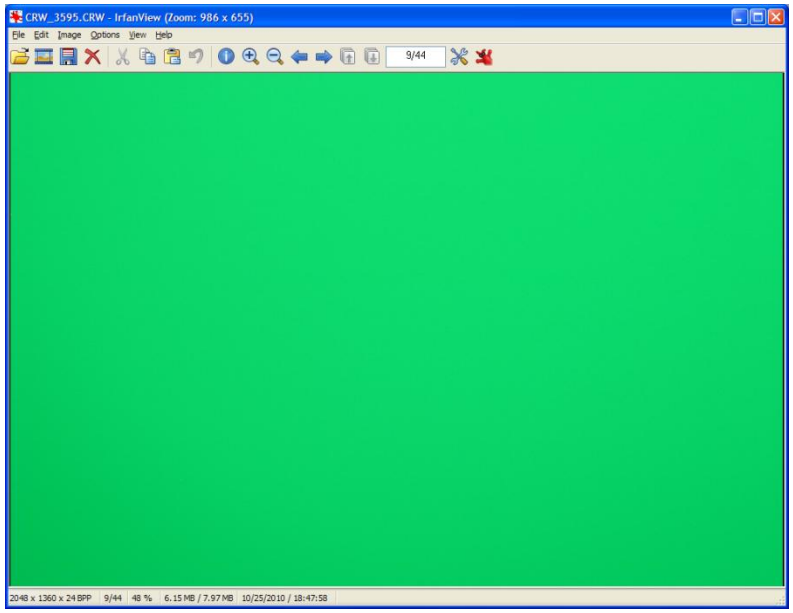
Part II:
DSLR Canon 300D: How to Test its Linearity?



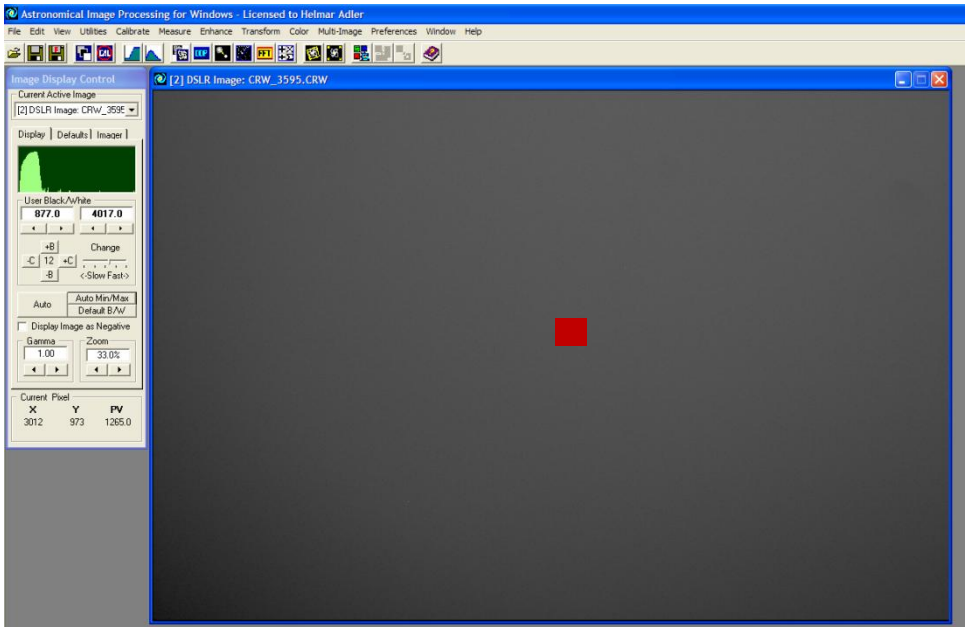




Part II:
DSLR Canon 300D: How to Test its Linearity?



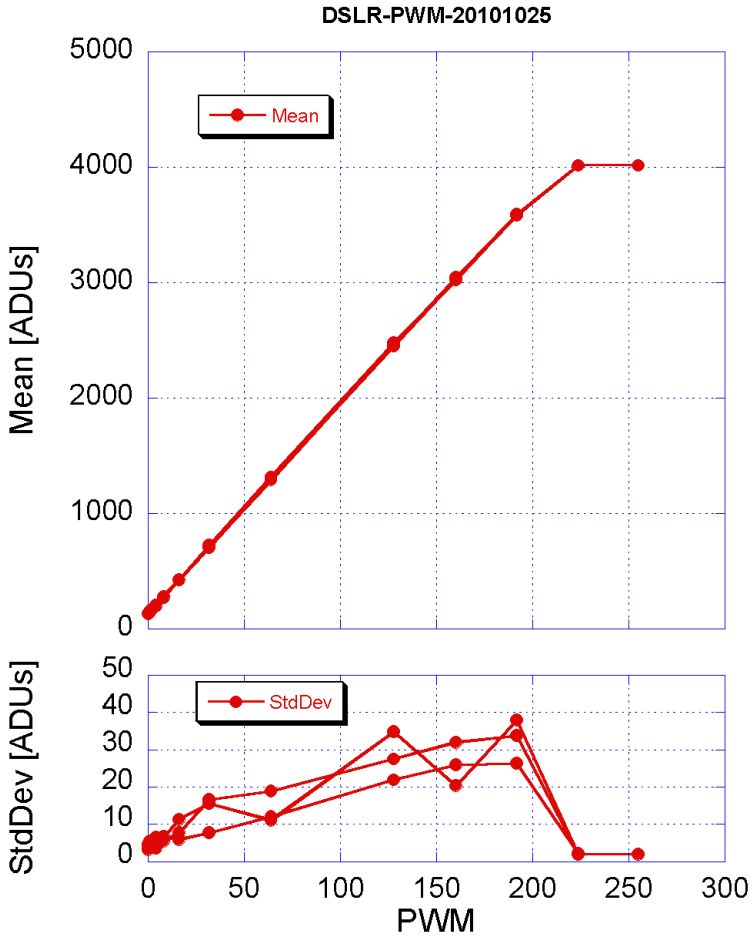
DSLR image of green LED in "light box"



Extracted green channel frame (AIP4WIN)

- "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

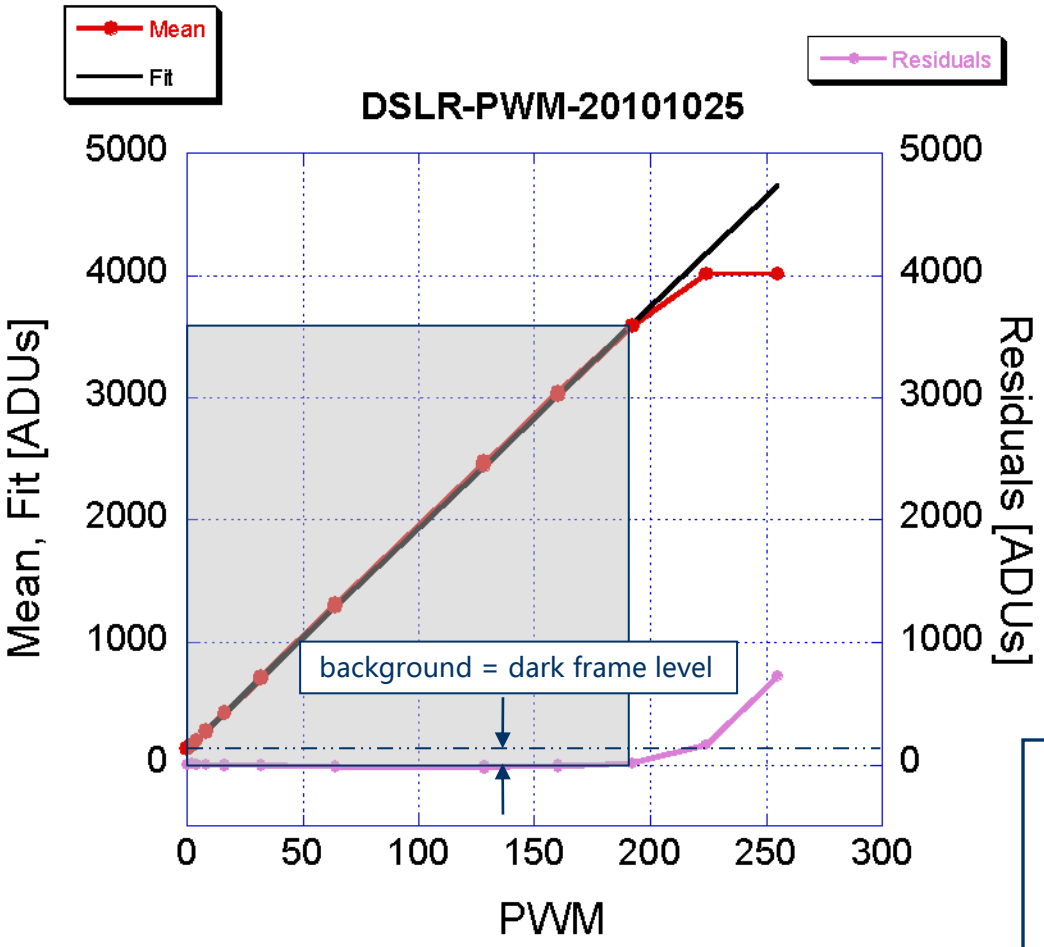
Part II:
DSLR Canon 300D @ 400 ASA, 2 s Exposure Time



- 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



Mean, Linear Fit and Residuals as function of PWM settings

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!)

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/