Simple and low cost LED current-voltage curve tracer based on a general purpose microcontroller.

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Abstract: A simple and low cost curve tracer which can build by students in their houses is presented. It is based on a microcontroller development board, a PC computer program, and a few generic electronic components. © 2021 The Author(s)

1. Introduction

For several applications it is needed that electronic engineers understand the meaning of the current-voltage characteristic curve of semiconductor devices [1] such as light emitting diodes. For this reason in some electronics undergraduate programmes student take some subjects where the theory related to this relationships and how this impact over the emission spectrum are reviewed. For instance at the University of Guanajuato in Mexico this topic is covered in a subject that involves lectures classes and experimental lab sessions in which they can perform measurements and test the concepts described by the theory. This experience supports the understanding of these theoretical concepts and based on this information students can later implement some more complex circuits, such as current drivers to control the emitted power or color mixing in RGB LEDs. Commonly, for the lab session students have access to basic and even specialized lab equipment which ease the implementation of the experiments. However, due to the COVID-19 in Mexico the lab access have been restricted for students and this represents an impact in the way that these kind of topics are commonly developed. Therefore, in this work a simple and low cost curve tracer which can be built by students in their houses is presented. The system is based on a low cost microcontroller development board linked to a PC computer program, and additionally just a few generic and simple electronic components are required. Finally, it is important to mention that basically with the same components and just changing the connections of the electronic circuit and running different programs students can implement a basic LED current driver.

2. LED current-voltage tracer

The implemented current-voltage curve tracer implemented was based on an Arduino UNO development board [2]. This board does not has analog output ports, however in Mexico it is broadly available and has a quite reduced economical cost. However, any 8 bit microcontroller with at least 2 analog inputs and a UART port can be used for this application. Moreover, the other relevant block of the tracer is a PC interface program, which serially communicates with the Arduino UNO. This PC program can be implemented in different platforms such as MATLAB, LABVIEW, C, and Pyton. The block diagram of the current-voltage tracer it is shown in figure 1, where it can be appreciated that the electronic circuit is quite simple requiring just require 3 resistors, 1 capacitor, 1 BJT and a basic 5 V power supply.

1.1. Principle of operation

The main idea of the tracer is to vary the voltage applied to the LED while the current is measured and afterwards this relationship is displayed graphically. Here, as the Arduino UNO does not have analog outputs, therefore to implement a variable voltage supply a PWM signal was passed through a RC filter. After, this filtered signal was used to feed the base of the BJT to control the collector current. In this way the current and the voltage of the LED under test can be varied by changing the duty cycle of the PWM. Here, we ideally considered that a 100% duty

cycle in the PWM generates a 5 VCD level. The electronic circuit can be easily analyzed by using basic principles [3], and in particular in this design the current of the LED can be described by:

$$I_D = \frac{V_{R2}}{R_2} = \frac{V_E - V_D}{R_2} \tag{1}$$

In order to compute this equation V_C, V_E and V_D were measured and recorded with the Arduino UNO analog inputs A1, A2 and A3 respectively. Later these data were serially sent to the PC, where the interface program received the information and computed equation (1) and finally exhibited the results. Here the maximum current that can be supplied to the LED is determined by a direct relationship of the R_2 and the supply voltage level. In this way students can characterize and visualize the current-voltage curve of different LEDs.
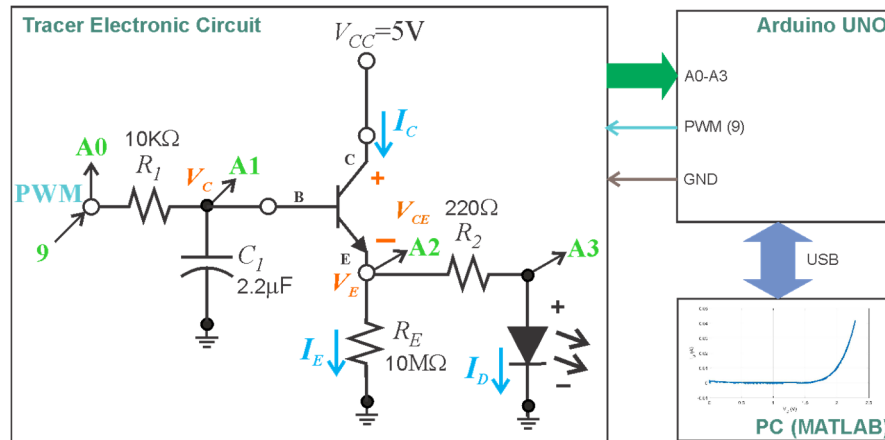

Fig. 1. Block diagram of the LED current-voltage tracer.

3. Results

The tracer can be configured to provide some helpful graphs such as the PWM generated by the microcontroller, and the RC filter output (V_C). Additionally, it can be displayed the voltage level changes on the emitter (V_E), the resistor R_2 (V_{R2}) and the LED (V_D) as the V_C is varied from 0 to 5 V, which is induced by varying the PWM ducty cycle from 0 to 100% respectively. Finally based on these measurements the LED current-voltage curve is calculated and traced.
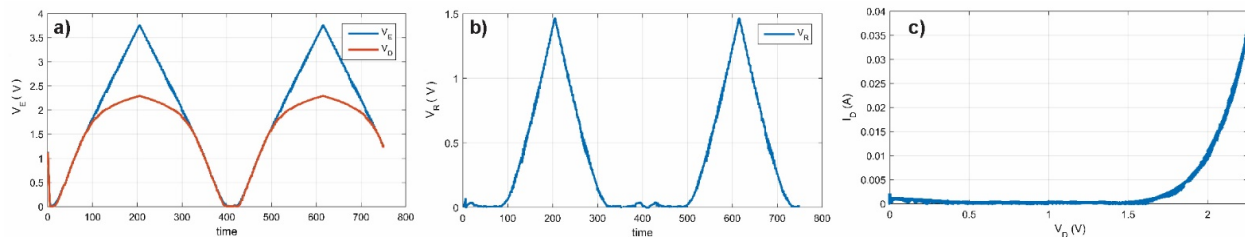

Fig. 2. Examples of graphs generated with the PC interface program of the tracer: changes of a) V_E and V_D and b) V_R as V_C is varied; c) calculated current-voltage curve of the LED.

3. References

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