Indian Institute of Technology Hyderabad

Analog Electronics and Integrated Circuits

Designing an LED Blinker for Neuromodulation Lab

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1 Problem Statement

We are tasked with designing an LED blinker for the Neuromodulation lab. The LED should blink every time a pulse is generated by the SoC (System on Chip), and the blinking signal must be captured by a camera placed 15 feet away.

2 Defining Initial Parameters

The power ratings of the GPIO (General Purpose Input Output Pin) are as follows:

- Power: 100 mW
- Voltage Rating: 5 V
- Maximum Current: 20 mA

For each LED, the voltage rating is given by:

$$1.8\,\mathrm{V} < v < 2.2\,\mathrm{V} \tag{1}$$

The current rating for each LED is within the range:

$$10\,\mathrm{mA} < i < 30\,\mathrm{mA} \tag{2}$$

For eight LEDs, the total current required will be:

$$80\,\mathrm{mA} < i_t < 240\,\mathrm{mA} \tag{3}$$

For eight LEDs, the total power required will be:

$$144\,\mathrm{mW} < P_t < 480\,\mathrm{mW} \tag{4}$$

The Resistance of each LED can be approximated as:

$$R_{LED} = 100\,\Omega \tag{5}$$

It's observed that the power source, i.e., the GPIO pin, cannot power all eight LEDs; therefore, an amplifier must be used.

3 Modelling Using Linear Elements

- GPIO pin is abstracted as an Ideal Voltage Source(That switches on and off at regular intervals)
- Jumper wires can be abstracted as ideal conductors.
- Each LED can be abstracted as an ideal resistor, even though their V-I characteristics are exponential.
- The LEDs are connected in parallel so that in case one LED stops working the other will continue to work

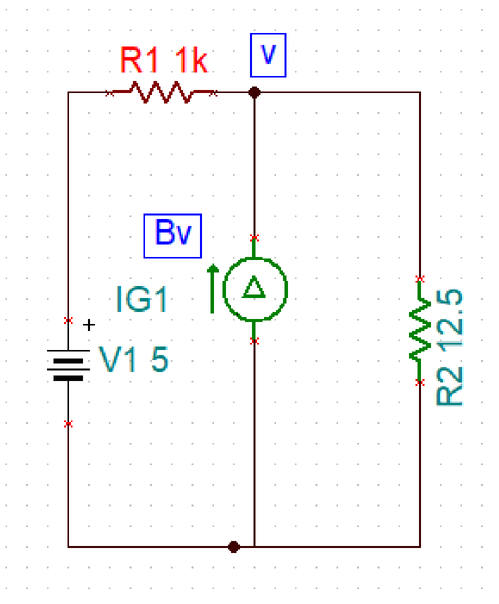


Figure 1: Modeling the Circuit using linear and ideal elements

The eight LEDs in parallel are modeled as a single equivalent resistor with resistance:

$$R_{eq} = \frac{100\,\Omega}{8} = 12.5\,\Omega \tag{6}$$

Now, to solve for the value of β with the constraint:

$$1.8\,\mathrm{V} < v < 2.2\,\mathrm{V} \tag{7}$$

Let us assume $v = 2V$ Applying KCL at Node v:

$$\frac{5-2}{100} + 2\beta = \frac{2}{12.5} \tag{8}$$

On solving we get:

$$\beta = 78.5\,\frac{mA}{V} \tag{9}$$

Total Current through the LED is 160 mA Which satisfies the equation

$$80\,\mathrm{mA} < i_t < 240\,\mathrm{mA} \tag{10}$$

4 Limitations in Design

One limitation of this design is that it can provide a maximum current of 160 mA at a voltage of 2 V. As a result, the LEDs may not reach their maximum brightness.

Another potential issue is that due to heating, the initial values of the resistor and dependent source may change, thereby deviating from the linear and ideal properties upon which they were modeled.

5 Powering the SoC

There are several options for powering the Arduino-based SoC:

- **USB Power:** Most Arduino boards can be powered via a USB connection from a computer or a USB wall adapter. The board has an onboard voltage regulator that steps down the USB voltage to the required voltage.
- **Battery Power:** You can power an Arduino using batteries, such as AA or AAA batteries, through the onboard voltage regulator or directly, depending on the Arduino model.

6 Powering the LED

As previously established, the GPIO pin of the Arduino cannot source enough power to light all eight LEDs simultaneously.Therefore, we have employed a Voltage Dependant Current source.

Additionally, a current-limiting resistor must be added to maintain the potential difference between the LEDs within the valid range.

The total power provided to the LEDs in this model is 320 mW, which falls within the acceptable range:

$$144\,\mathrm{mW} < P_t < 480\,\mathrm{mW} \tag{11}$$

7 Adapting the model

When the model will be built the dependent souce will be replaced by a mosfet or BJT which will act as current sources

8 Lab Work

In case of the actual implementation the Ideal Voltage source will be replaced by a function generator and a Arduino with an Elvis board

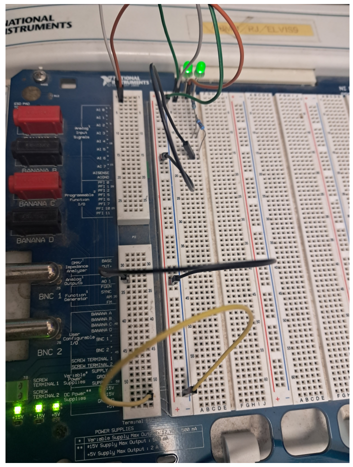


Figure 2: Circuit Diagram

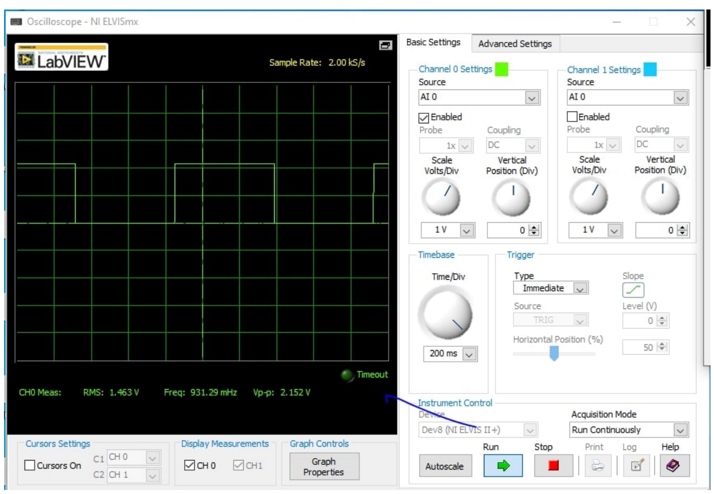


Figure 3: Output Reading of Oscilloscope

9 Mosfet Implementation

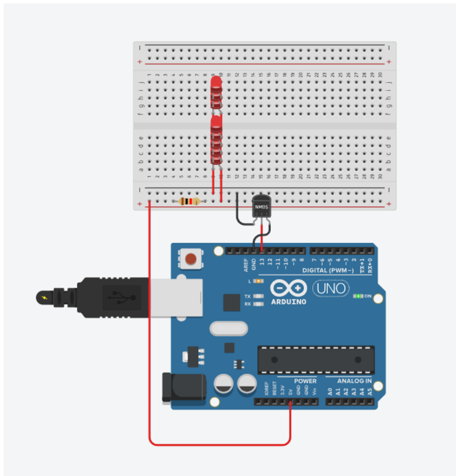
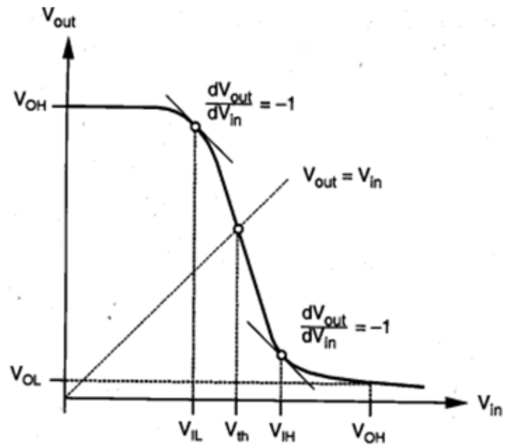


Figure 4: Using Mosfet as a Current Source

- The Gate of the mosfet is connected to the pin
- The Source is connected to the ground
- The Drain is connected to the common anode of the LED
- The Cathode is conected to the ground via a resistor to limit voltage

Link of the simulation:https://www.tinkercad.com/things/2LTKCZsnDGy-tinkercad/editel

10 Mosfet Characteristics



Typical voltage transfer characteristic (VTC) of a realistic nMOS inverter.

Figure 5: Voltage Transfer Characteristics of a Mosfet

As we can observe from the graph, the minimum value of V_{in} is V_{th}, and the maximum value of V_{in} is $V_{th} + \frac{-1+\sqrt{1+2V_s kR}}{kR}$ for the Mosfet to operate in the saturation zone. The value of V_s and R must be taken such that V_{gs} lies within the range of V_o.

The overall benefit of using this system over directly connecting the LEDs is direct control over i_{ds} by changing the gate voltage.

the forward voltage of the LED is between 1.2 to 3.6 V, and the forward current is between 10 to 30 mA. 80 mA ¡ I$_d = \frac{k}{2}(V_{gs} - V_t)^2 < 240\,mA$