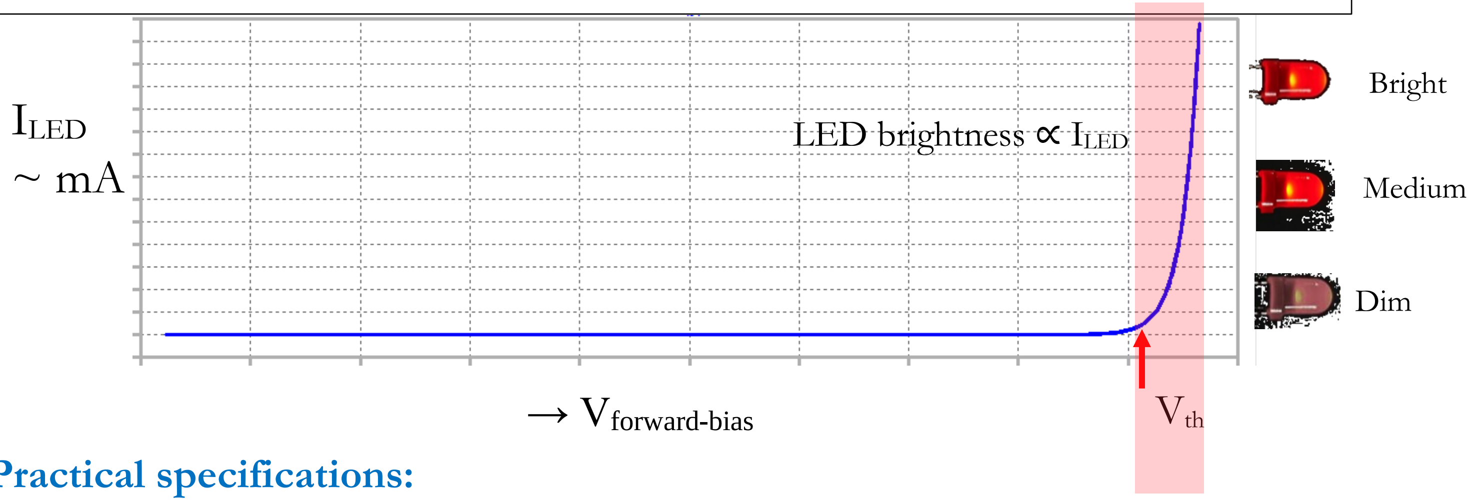
PH233 End-semester exam Module A: Actuator

Objective:

Setup a circuit that gives precise control of current through an LED such that brightness of light emitted by the LED can be precisely controlled.

An LED is a type of diode. As we have learnt, a diode I-V characteristics dictate that once the forward bias voltage across an LED exceeds a threshold voltage V_{th} it starts conducting. The brightness of light from the LED is proportional to the conduction current (we assume the relation is approximately linear for this experiment)

Fig 1: Typical LED I-V characteristic: The turn-on threshold voltage will vary depending on Red/Green LED's and may be different for different LED's. Aim of this module is to devise an opamp based LED driving circuit that operates in the shaded red band – I_{LED} is directly controlled, without caring about V_{th}



Practical specifications:

In earlier labs, we were mostly concerned with turning an LED ON or OFF, and putting a safety limit on the forward current with a series current limiting resistor.

<u>Our goal is *different* in this experiment</u>. We want to control the brightness of the LED which is (approximately) proportional to I_{LED} in forward bias after turn on.
We will be working with voltage levels between modules of the overall feedback system. So we don't want to waste V_{th} (~1.8V for red LED) simply to turn it on and then have a very narrow band of voltage control highlighted in red in Fig 1 to control its current.

Use the following ingredients to design and build an actuator module that controls the brightness of a red LED by precisely controlling the current I_{LED} in the red band highlighted in Fig 1. i.e. I_{LED} is directly controlled (not V_{LED})

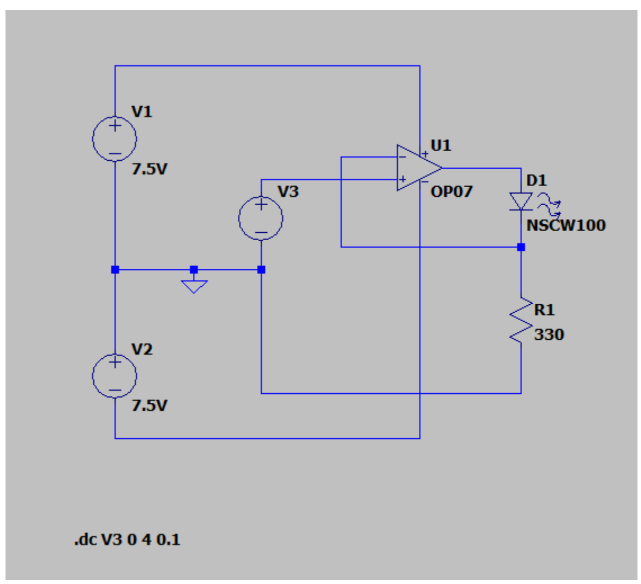
Design ingredients for actuator:

1. Single Opamp LM741 must be used
2. Input voltage to the circuit $V_{in|actuator}$ must span 0V to 4V. LED must turn on immediately when $V_{in|actuator}$ rises above 0V and its brightness ($\propto I_{LED}$) must increase approximately linearly up to $V_{in|actuator} = 4V$
   (i.e. V_{th} of the I-V characteristic must not be supplied directly from V_{CC}
3. HINT: This can be done by including the LED in your opamp feedback loop. Figure out how and why this works.

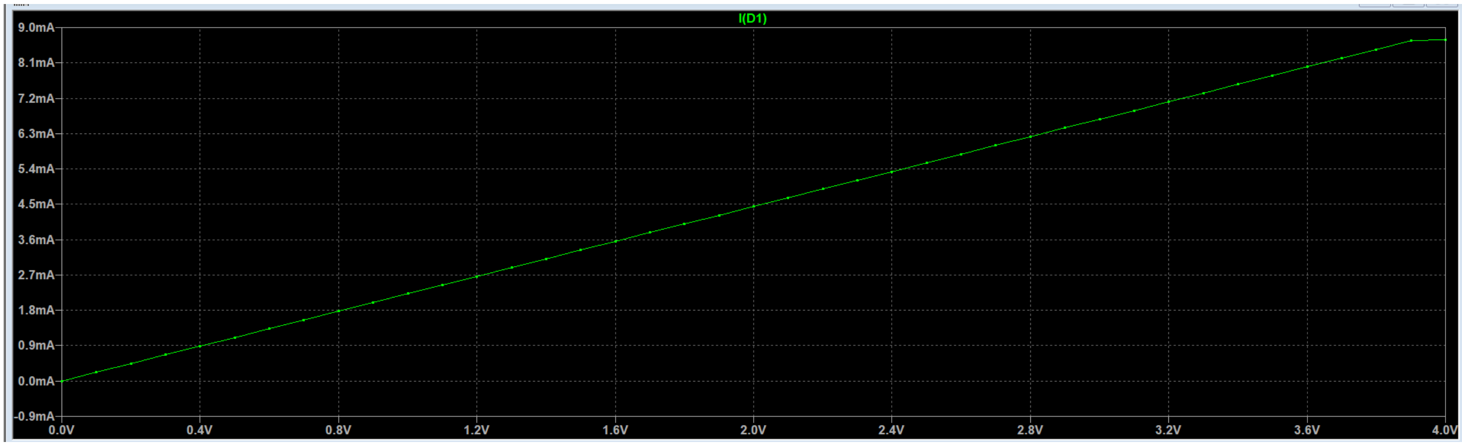
Simulation: 5

Draw your LTSpice simulation circuit design here. Provide a simulation plot of I_{LED} v/s $V_{in|actuator}$ validating the control range of your circuit.

Use component values such that $I_{LED|max} \sim 10$ mA to avoid saturation of the photo-transistor and to remain well within the maximum current that can be supplied by the opamp. Measure the voltage across a suitably connected resistor to probe I_{LED} when you build the circuit.



NOTE: Voltage source of 7.5V has been used instead of the usual 9V due to my actual battery source draining out after a lot of usage.



Demo **5**

Build your circuit as per the above design. Use a 10kΩ potentiometer to vary DC voltage input $V_{in|actuator}$ to your circuit. Measure $V_{in|actuator}$ and $I_{LED}=V_{shunt}/R_{shunt}$ with DMM

Fill the following table listing your measurements for a few settings between 0V and 4V

$V_{in|actuator}$ = 0V I_{LED} = 0mA

$V_{in|actuator}$ = 1V I_{LED} = 2.1mA (as V_{shunt} = 1V)

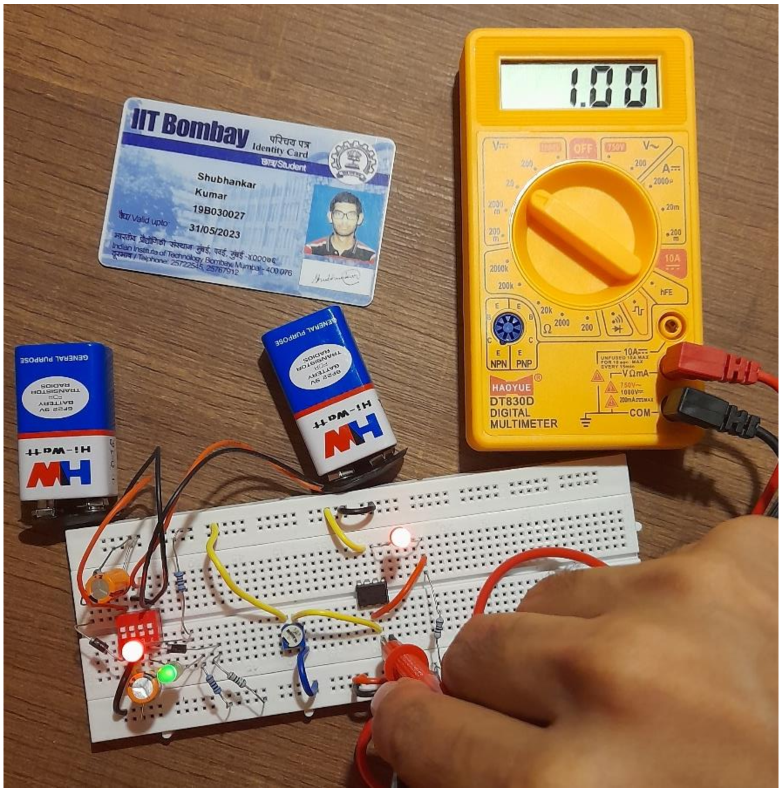
$V_{in|actuator}$ = 2V I_{LED} = 4.2mA (as V_{shunt} = 2V)

$V_{in|actuator}$ = 3V I_{LED} = 6.4mA

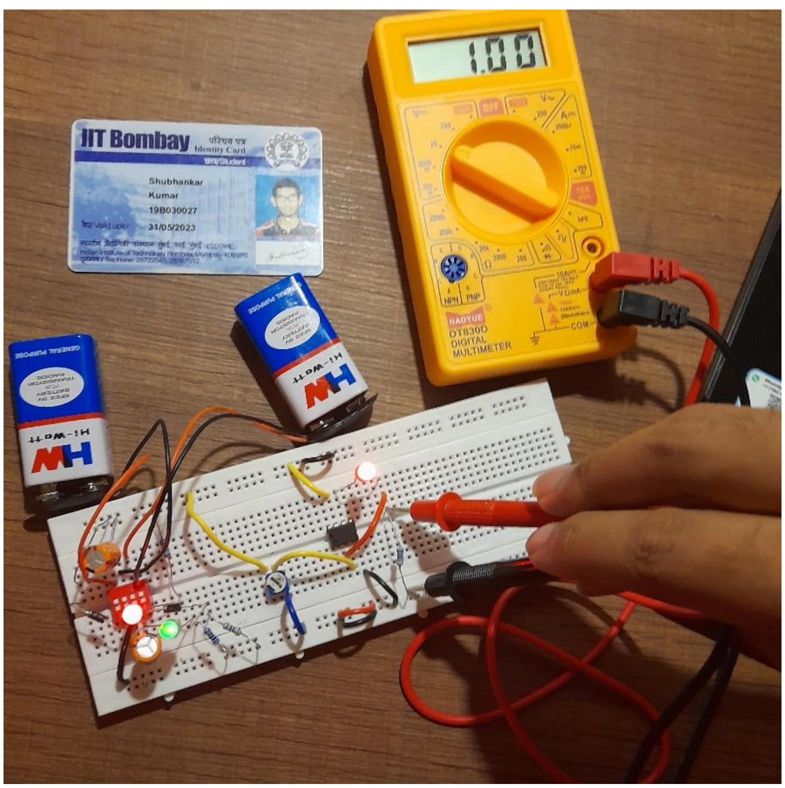
$V_{in|actuator}$ = 4V I_{LED} = 10mA

Post a sequence of photos for a few of the above measurements, indicating $V_{in|actuator}$ applied (measured with DMM), and the corresponding I_{LED} measured as voltage V_{shunt} by DMM across the shunt resistor

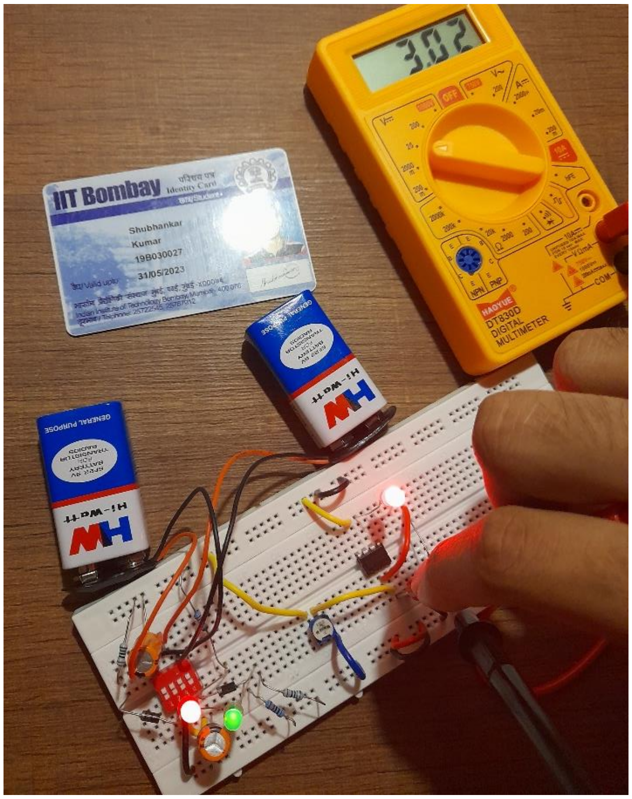
Does I_{LED} vary approximately linearly with $V_{in|actuator}$?



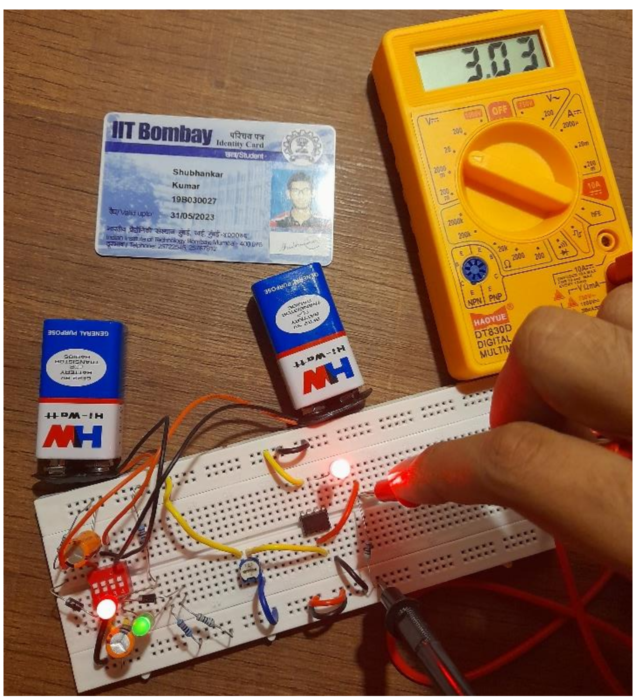
V_{IN} = 1V



V_{shunt} = 1V



$V_{IN} = 3V$



V_{shunt}