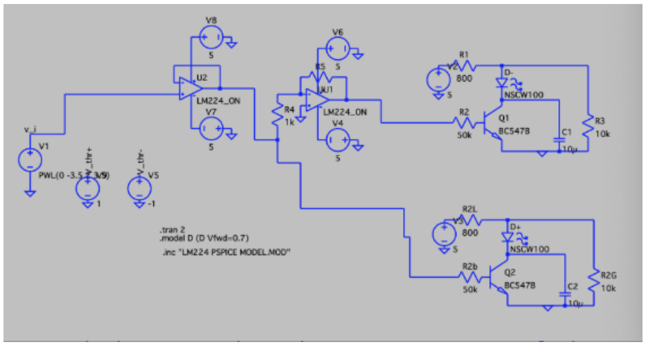
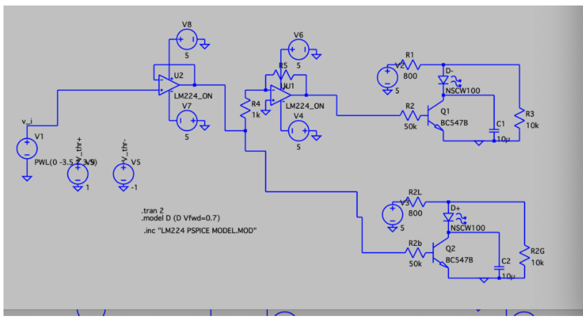
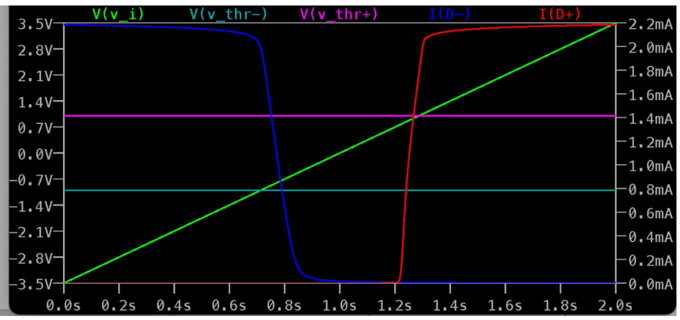
LED interface

Current design



Question : why is the threshold slope different in positive ? (May 16,17)





Apr 25, 2022

LED operating current : 10~30mA

Color	Forward voltage	Required additional resistance for 5V supply : $R = \frac{5 - V_f}{30e^{-6}}$
	1.8V	1067 Ohm
	3.5V	533 Ohm
	3.6V	500 Ohm

So the resistance will be chosen as 1.1k, 600, 600 Ohm

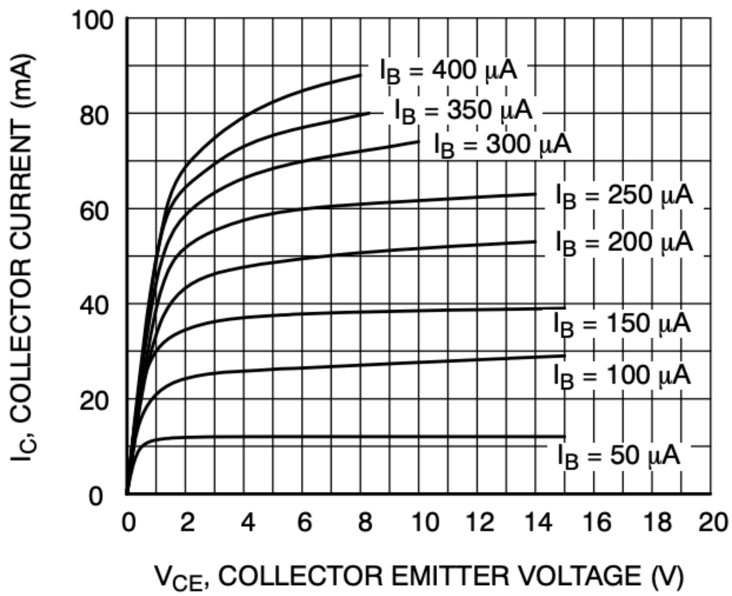


Figure 1. Static Characteristic

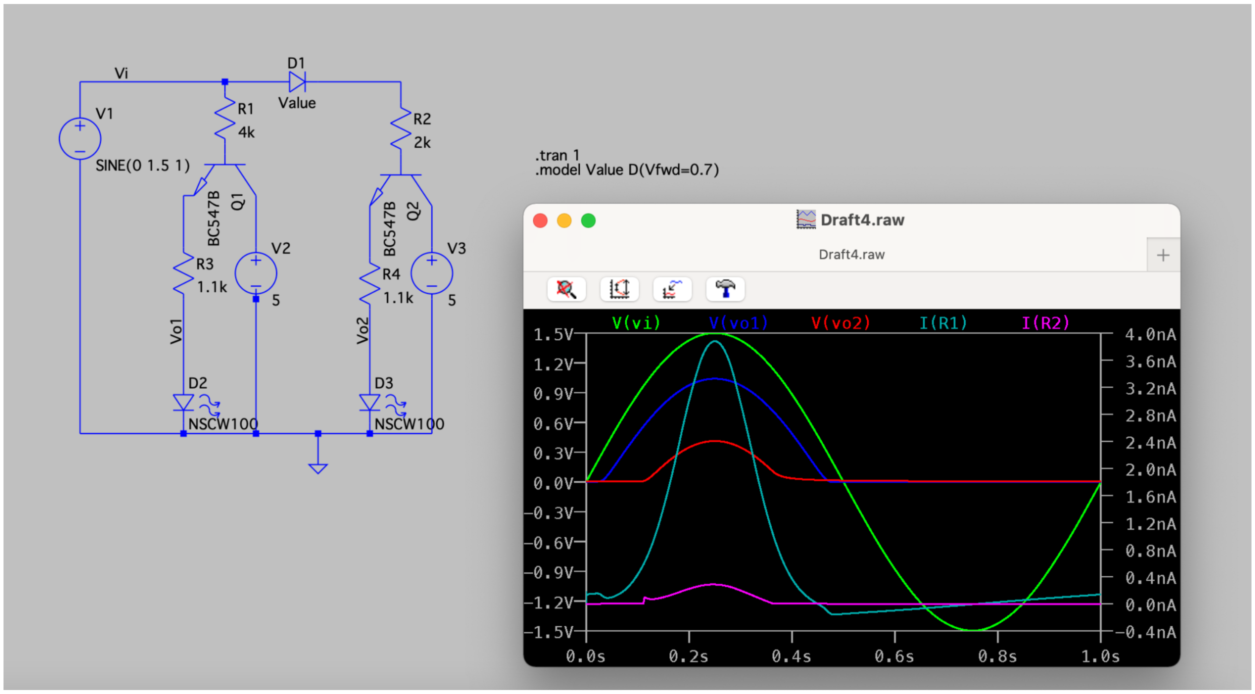
When VCE = 5V, we want the base current to be under 300 uA
For red LED,

$$300 * 10^{-6} = \frac{1.5}{1.1 * 10^3 + R_1}$$

$$R_1 = \frac{1.5}{300 * 10^{-6}} - 1.1 * 10^3 = 3900$$

A 4k Ohm resistor may suffice

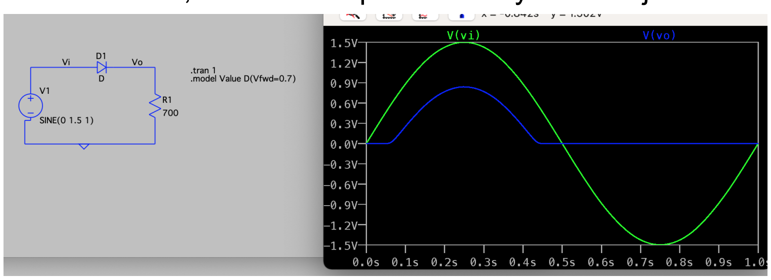
The strategy:
Make LED shine the more we look towards a certain direction. Another LED shines only when a certain threshold is crossed. For convenience, we use 0.7 for now.
Result : Not how I imagined. The Diode does not threshold the Vi by 0.7V, the base current is not calculated by Vi divided by total resistance from base to emitter to ground. Several checks are required :



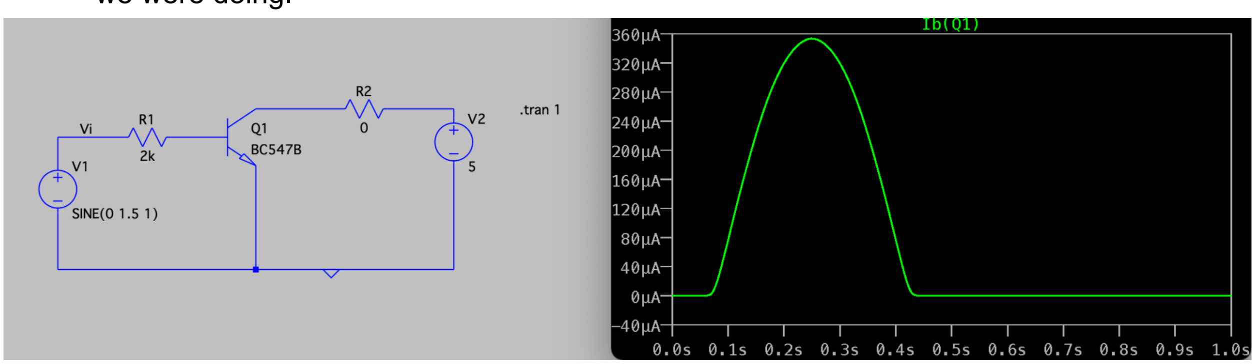
1. Check that diode does reduce the input voltage by 0.7
2. Find ways to determine base current

Answers:

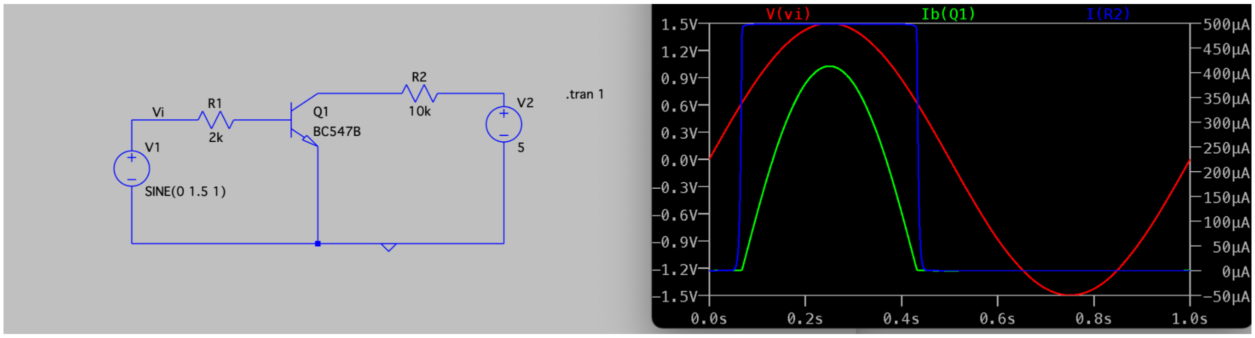
1. It does, so the main problem may be the bjts



2. By experimenting in LTSpice, the resistor at base is the main determinant of the base current. Resistance at the emitter will affect the current highly, but if the resistance is placed at the collector, the effect is minimal, and the current can be well predicted. P.S., in hindsight, we have done that in workshops already and that is the same circuit we were doing.



Step 1 : Pick an R1 so that the Ib falls in the operating region



Step 2 : Placing R2 at the collector side, the current over R2 can simply be obtained by V2/R2. From what we are seeing, there is a readily thresholding from the bjt. So we could use this to do the thresholding for us, and use other circuits to detect the lower gaze angles.

New UI

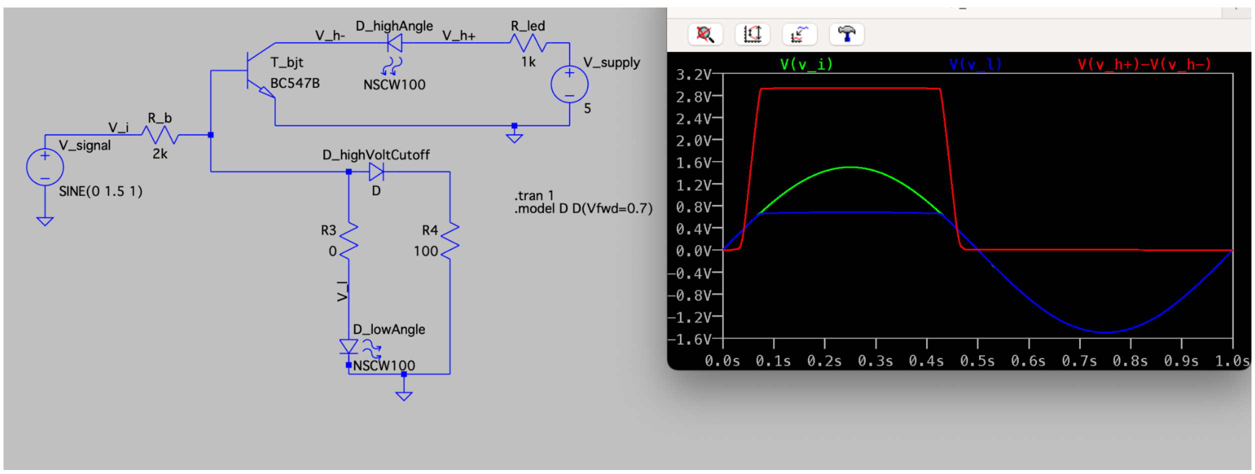


Fig : LEDUI_1 (Top circuit) Lights when gaze angle surpasses certain threshold. (Bottom circuit) Lights when gaze angle below threshold

Though the resistors are arbitrarily chosen except for R_b , it sure is off for a good start.
Issues:

1. V_l may not be enough to light the LED for low angle
2. The threshold for V_h can be increased, but simply adding another diode reduces the voltage by too much.

May 1, 2022

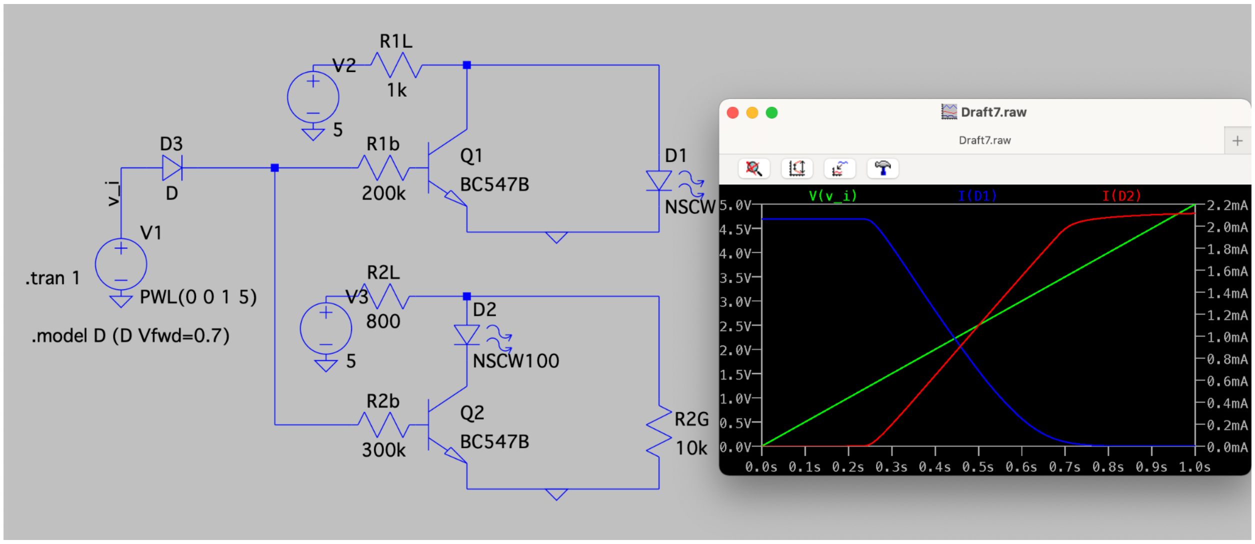


Fig : LEDUI_2 (top) low pass (bottom) high pass

A new scheme is used
Now LED D1 shines at low gaze angle, while LED D2 at high angle.
We could make D1 band pass, rising up only at a certain voltage, but that would increase the number of transistors required, which we only have 4 in total, so I did not implement that.

Rbs can use adjustable resistors to tune the threshold of the rise/fall of LED current.

NEW ISSUE:
Signal voltage changed from 1.5V to 5V, since 1.5V can't even pass through a diode without dropping half of the signal magnitude. New gain will have to adapt to provide a 5V signal.

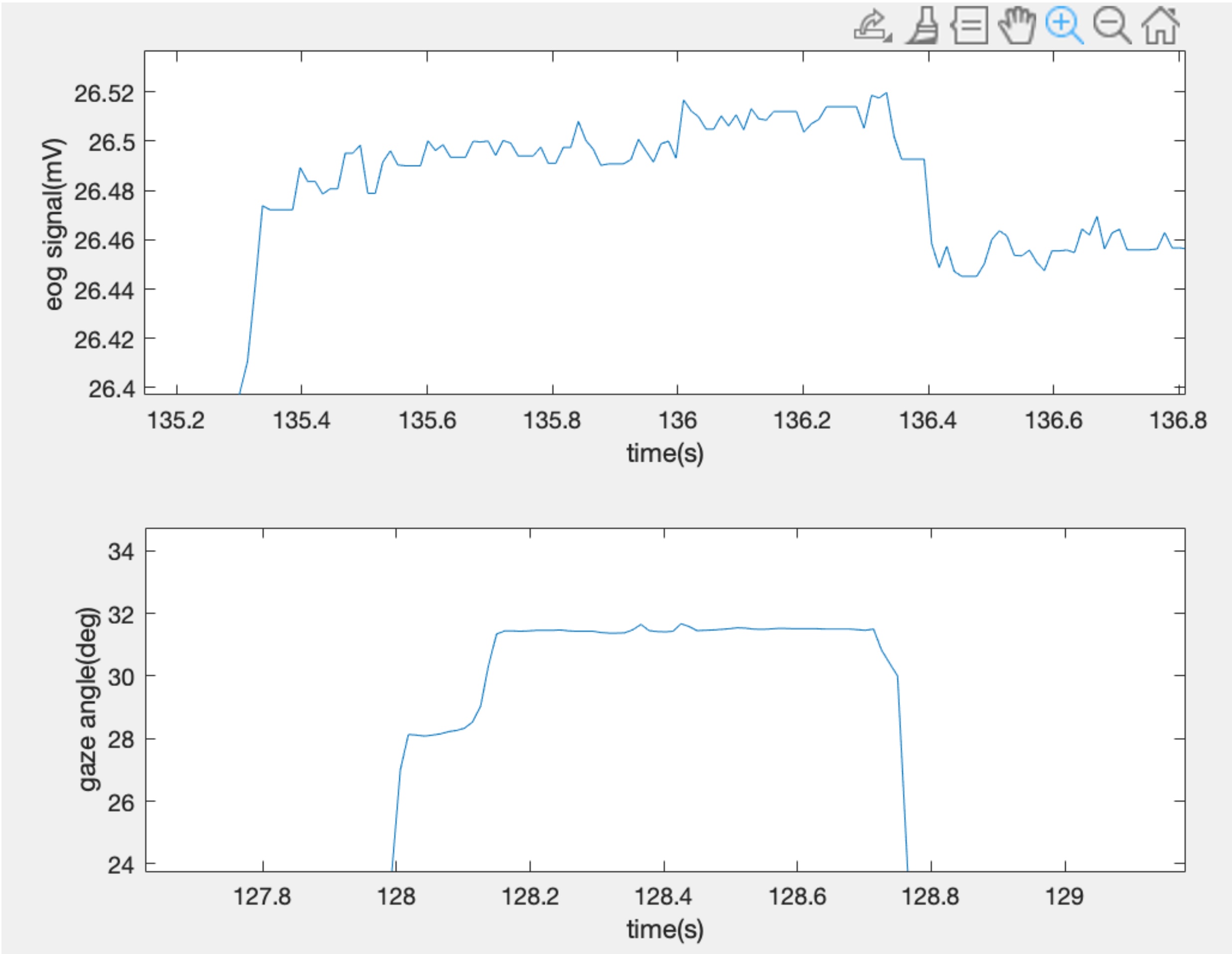
May 16, 2022

New Purpose:

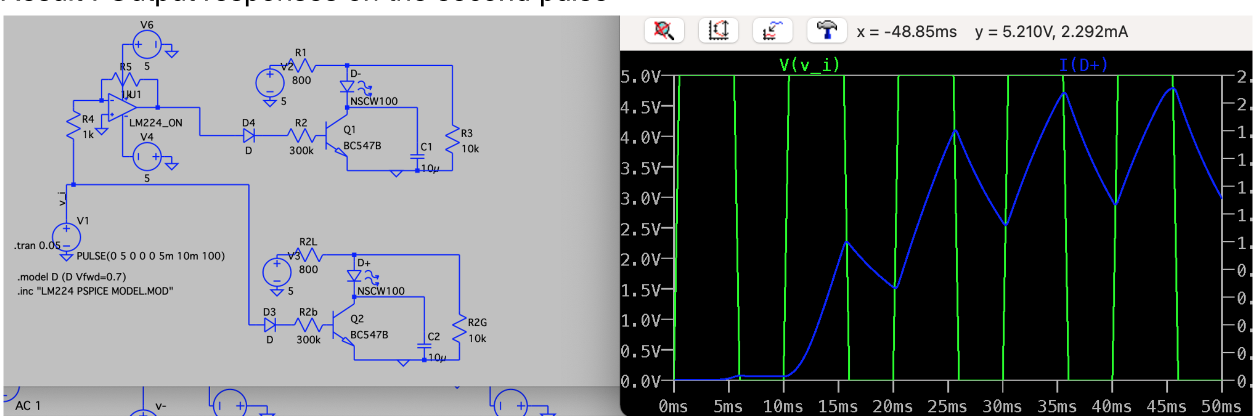
Detect threshold crossing, one for positive, one for negative
Apply smoothing to the signal

Smoothing

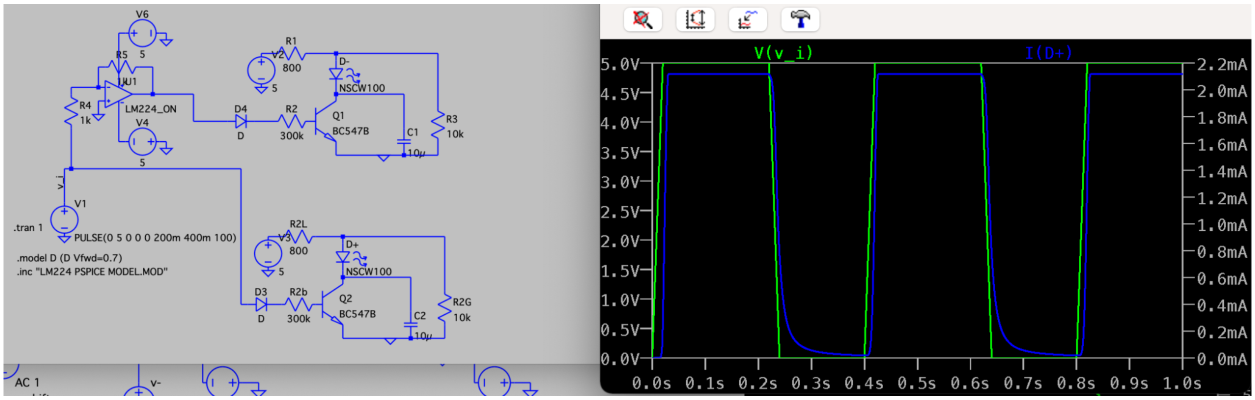
Prevent switching on/off rapidly when signal is near the threshold
From my dataset, the eyegaze lasts for around 0.8s. So I may want it to respond to gazes that last over 0.4s. On the other hand, the fluctuations in the signal have a period of around 10ms. By simple trial and error (Can't calculate time constant due to the diode, which I don't know how to determine the resistance), I have chose a capacitance around 10uF that makes the switch not respond to 1 single pulse of the fluctuations(T = 10ms), and is still able to respond to the signal changes.



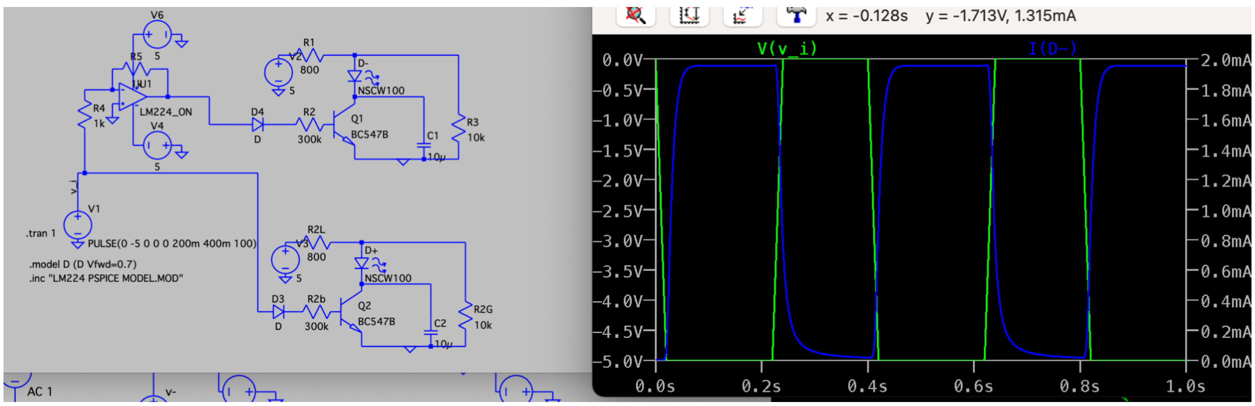
Test : square wave of T = 10ms
Result : Output responses on the second pulse

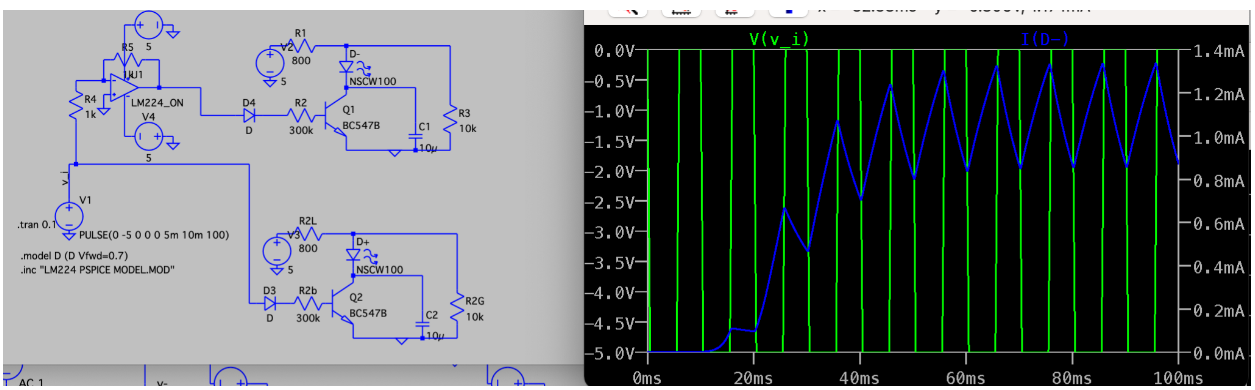


Test : square wave of T = 10ms
Result : Output is able response to a single pulse



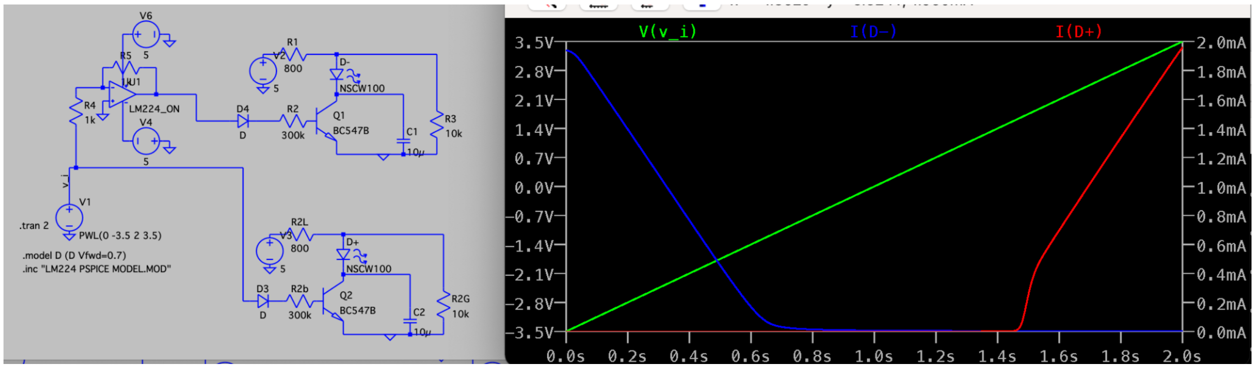
Similarly checking on the top circuit (negative side)

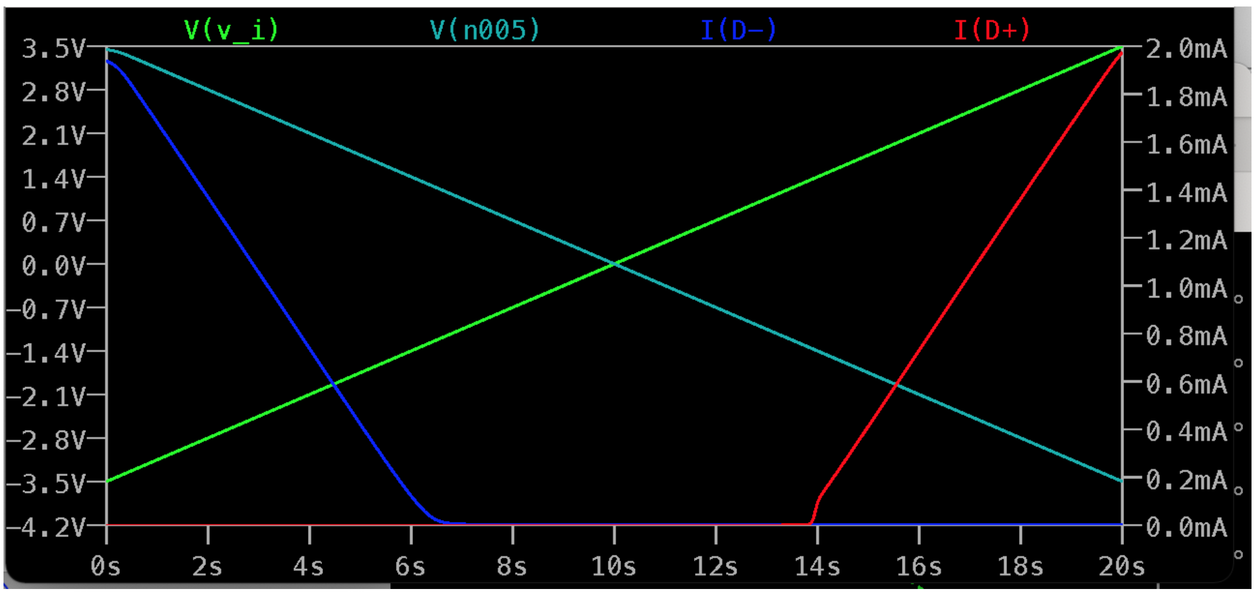


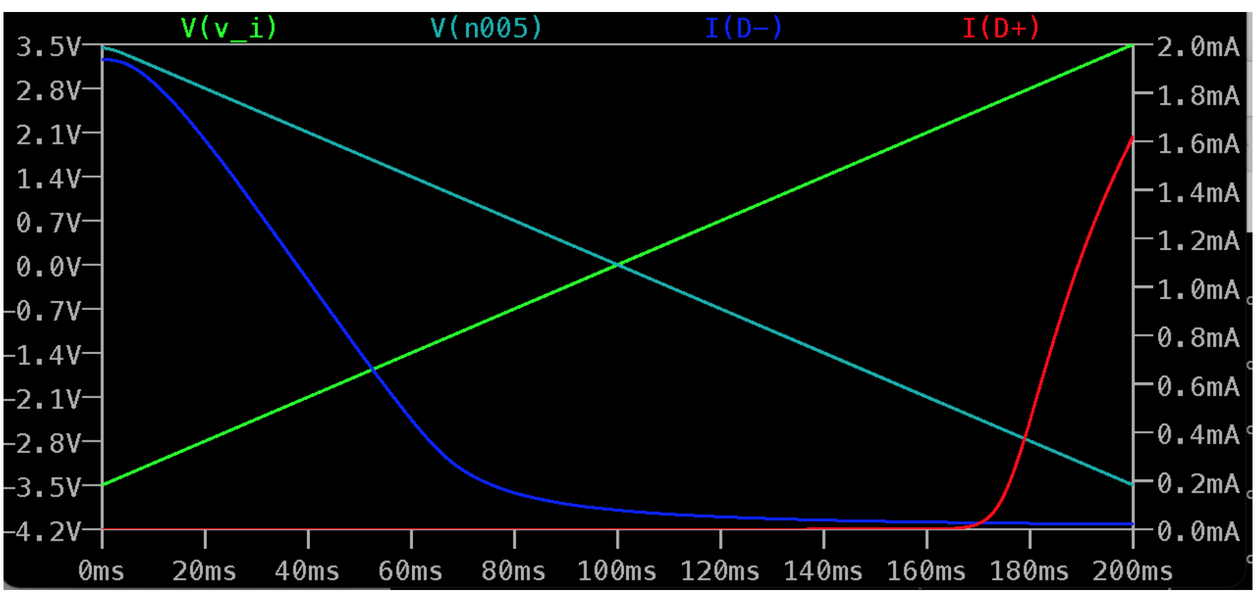


Thresholding

Currently with this setup, the threshold is at ∓1.4V, which is pretty good. Interestingly, although both positive and negative have the same slope and threshold, the shape at the threshold voltage is cutoff in the positive voltage. Interestingly, this is temporal response, as we can see that the output is altered depending on the input slope. Why does introducing an inverter mitigates the issue? I have no idea, probably the internal components are doing some filtering. Nevertheless, if the effect is significant to the actual circuit, we will introduce a voltage follower to the positive end.

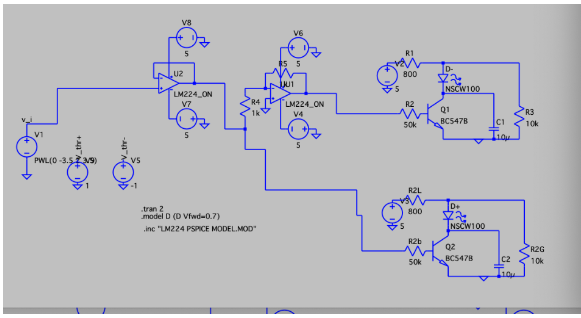

V(v_i)
I(D-)
I(D+)
.tran 2
PWL(0 -3.5 2 3.5)
.model D (D Vfwd=0.7)
.inc "LM224 PSPICE MODEL.MOD"
LM224_ON
NSCW100
BC547B

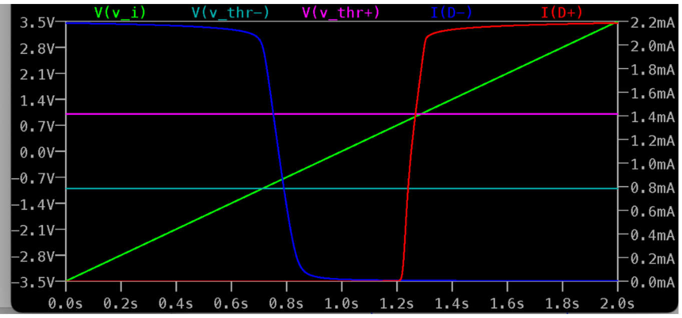

V(v_i)
V(n005)
I(D-)
I(D+)
3.5V
2.8V
2.1V
1.4V
0.7V
0.0V
-0.7V
-1.4V
-2.1V
-2.8V
-3.5V
-4.2V
2.0mA
1.8mA
1.6mA
1.4mA
1.2mA
1.0mA
0.8mA
0.6mA
0.4mA
0.2mA
0.0mA
0s
2s
4s
6s
8s
10s
12s
14s
16s
18s
20s


V(v_i)
V(n005)
I(D-)
I(D+)
3.5V
2.8V
2.1V
1.4V
0.7V
0.0V
-0.7V
-1.4V
-2.1V
-2.8V
-3.5V
-4.2V
2.0mA
1.8mA
1.6mA
1.4mA
1.2mA
1.0mA
0.8mA
0.6mA
0.4mA
0.2mA
0.0mA
0ms
20ms
40ms
60ms
80ms
100ms
120ms
140ms
160ms
180ms
200ms

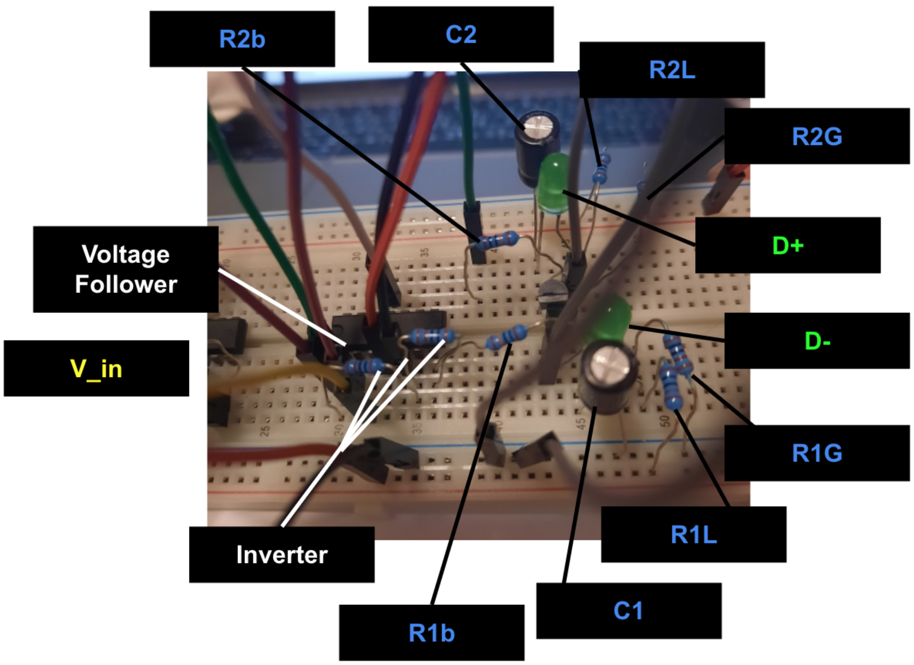
May 17, 2022

The threshold voltage is now set at 1V, i.e., make the signal saturate at 1V.

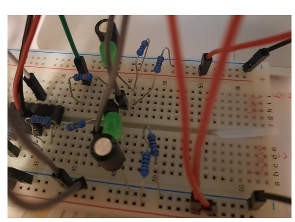


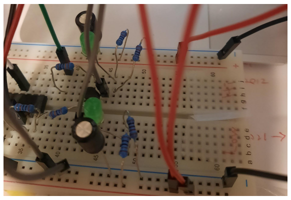
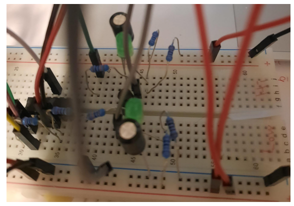
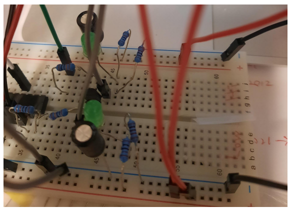
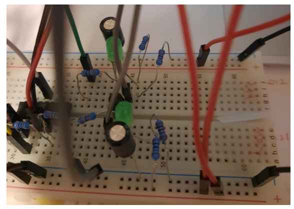
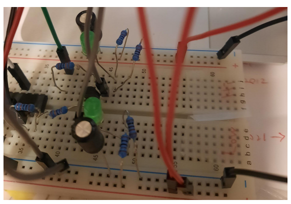
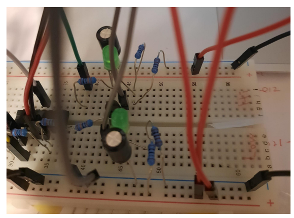
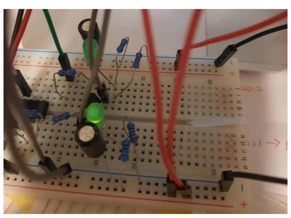
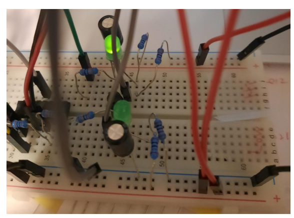
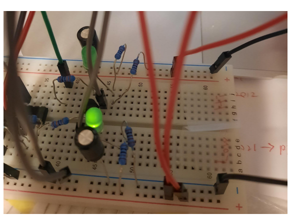
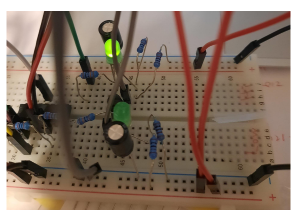
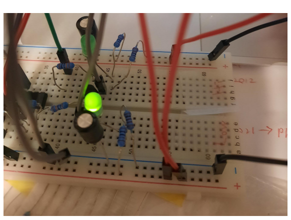
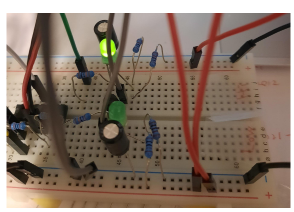
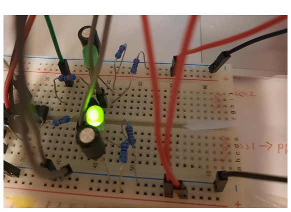
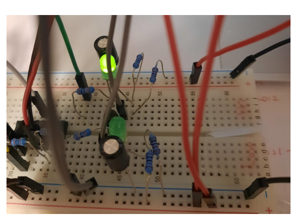


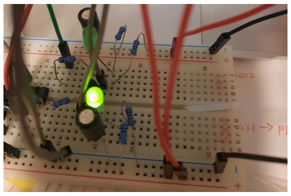
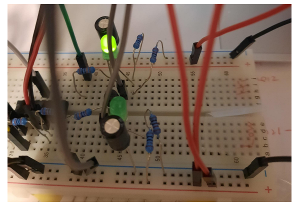
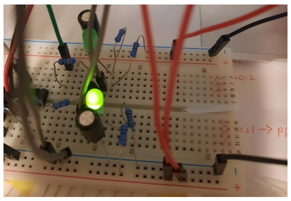
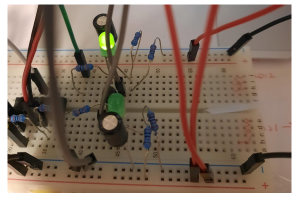
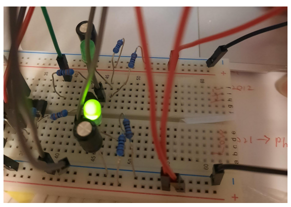
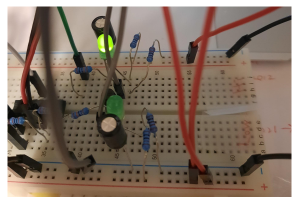
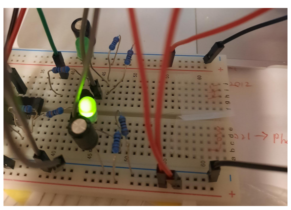
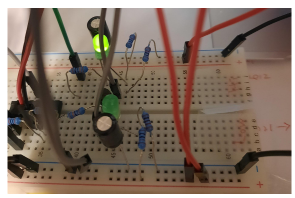
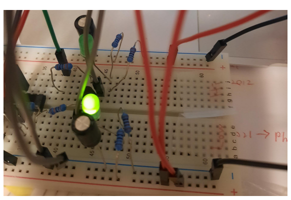
The diodes were removed to reduce the threshold, but a voltage follower is added to prevent backflow and loadings to the circuit input.



Circuit was built, and tested with DC signals, the lights do show thresholding behavior at around ∓1V. As in the simulation, the positive saturation slope is steeper than the negative one, making the led shine brighter +0.8V, while being equally dim at ∓0.6V.
The following table shows the testing results.

0	

-0.2V		+0.2V	
-0.4		+0.4	
-0.6		+0.6	
-0.8		+0.8	
-1		+1	
-1.2		+1.2	
-1.4		+1.4	

-1.6		+1.6	
-1.8		+1.8	
-2		+2	
-2.5		+2.5	
-3.5		+3.5