LED Flasher

Here is a LED Flasher circuit. It operates by building current in the inductor through a saturated transistor, and then cutting the transistor off and letting the *flyback* current flow through the LED. Normally, a three volt source could not light a white LED, but using the inductor as an energy conversion device, we can.

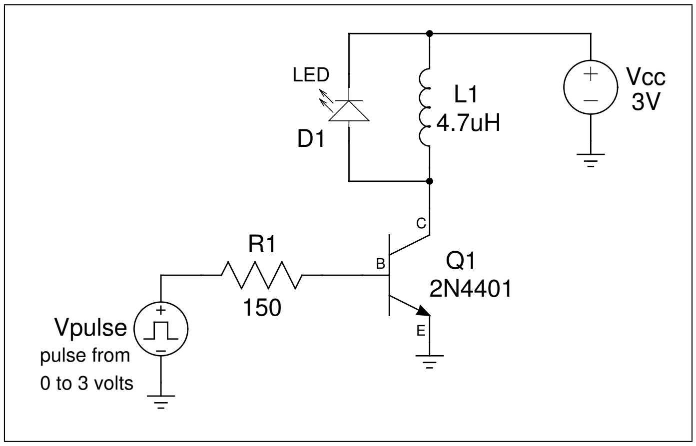

Figure 1: LED Flasher Circuit

Analysis:

- When V_{pulse} is at zero volts, Q1 is off, and the LED has no voltage across it.
- When V_{pulse} is at three volts, Q1 saturates. For as long as Q1 is saturated, the current continues to linerly build through L1 as given by the relationship: $\frac{di}{dt} = \frac{V_{src}}{L}$

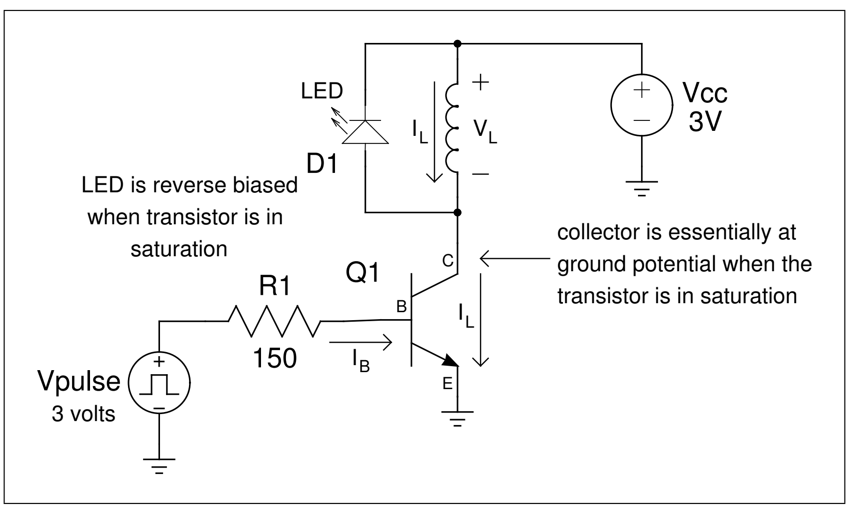

Figure 2: LED Flasher Circuit with Q1 Saturated

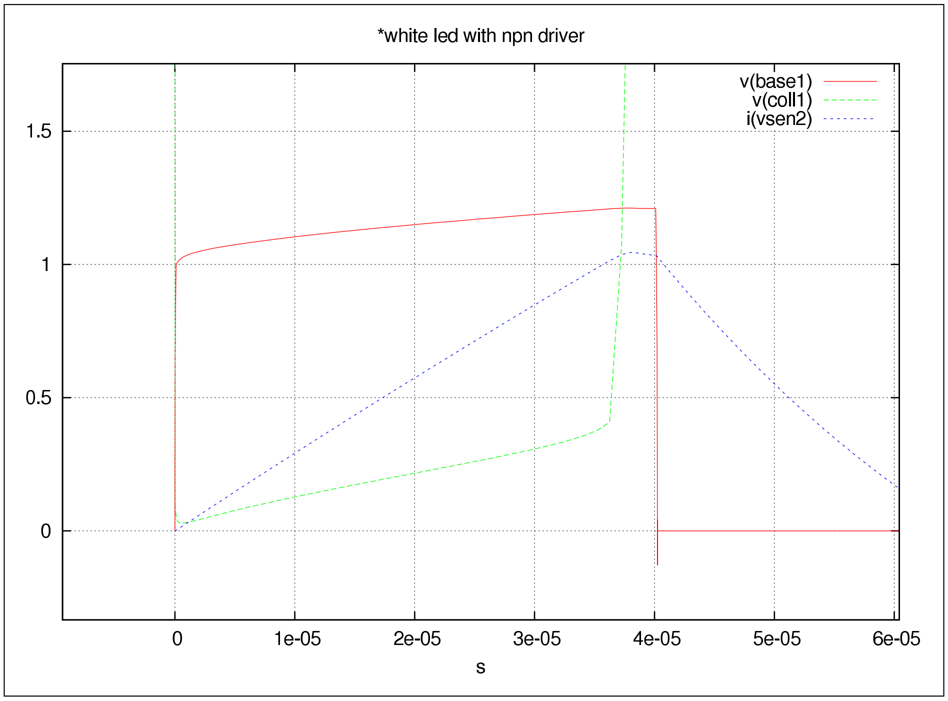

Figure 3: Flasher Circuit with Q1 in Saturation

- Referring to figure 3, we clearly see the saturation of Q1 once V_{pulse} transitions to 3 volts at time zero. Note that the base-emitter voltage on Q1 (V_{base1}) rises to roughly one volt. This tells us that the emitter-base diode is on very *hard*. Also note that when V_{pulse} transitions to 3 volts, Q1's collector voltage, (V_{coll1}) drops to nearly zero volts. With $V_{ce(sat)}$ well less than 0.2 volts, Q1 is clearly deep into the saturation region.
- As the current through L1, $i(vsen2)$, builds, it exceeds the ability of Q1 to remain in saturation. As such, we see Q1's collector begin to rise to 0.4 volts, just outside of saturation. This action requires that we limit the width of the pulse from V_{src} so Q1 does not go further out of saturation. If it did so, it would begin to dissipate a great deal of power.
- Note that while Q1 is on, the voltage across the inductor and the parallel connected LED, keeps it in reverse bias and *off*.

In figure 4 we have the circuit after V_{pulse} has transitioned back to zero volts.

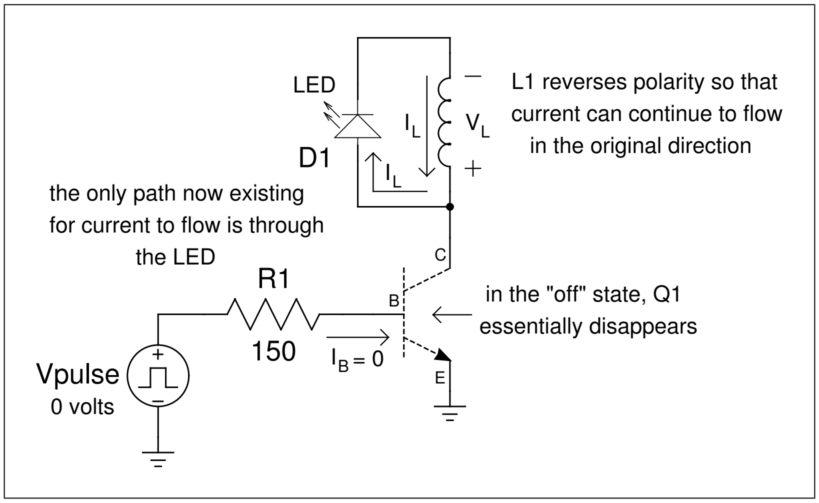

Figure 4: Flasher Circuit after Vpulse Transitions back to Zero Volts

- Referring to figure 4, when V_{pulse} returns to zero volts, Q1 cuts off. While not instantaneous, the removal of current is very fast. Prior to Q1 cutting off, roughly 1 amp of current was flowing through L1. Just after Q1 cuts off, L1 reverses its polarity and rises its terminal voltage enough to maintain its current at 1 amp. For as long as its magnetic field is colapsing, L1 releases its stored energy to the LED.
- The *flyback* voltage created when Q1 turns off is seen at the collector of Q1 in figure 5.

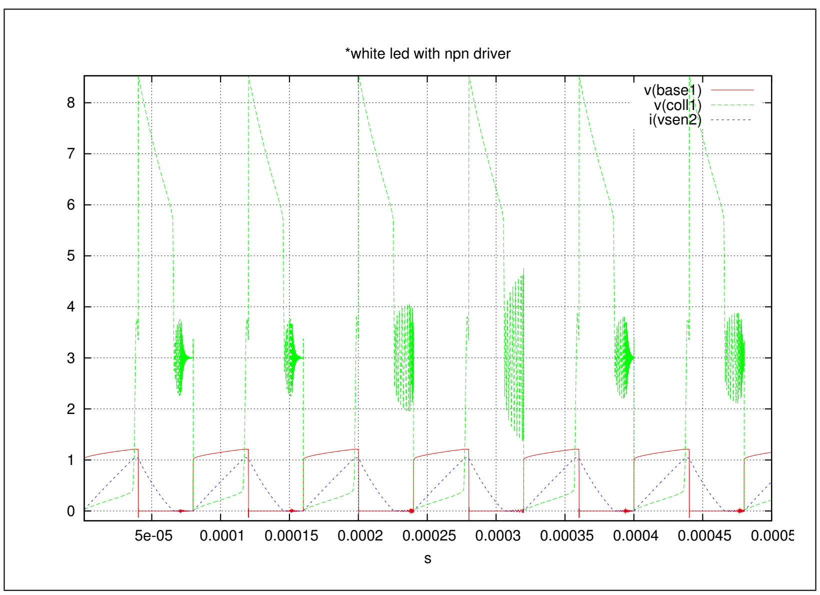

Figure 5: LED Flasher Circuit with Q1 off

- When L1 has reversed its polarity, the only current path is through the LED which illuminates it. As the LED consumes the energy from L1, the current through L1 drops exponentially. If the LED was not present, the voltage at Q1 collector rises to about 1.1kV! This would be far in excess of what Q1 can withstand. With nothing to dissiplate the energy created by the inductor, Q1 would be destroyed in short order.
- The LED stays illuminated for as long as L1 can sustain enough current to maintain 4 volts across its terminals; the *on* voltage for a white LED.

Below is a ngspice netlist for the LED flasher circuit.

```
*White LED with NPN driver

*transistor model
.MODEL t2N3904   NPN(IS=1E-14 VAF=100 Bf=300 IKF=0.4 XTB=1.5 BR=4 CJC=4E-12 CJE=8E-12
+                RB=20 RC=0.1 RE=0.1 TR=250E-9 TF=350E-12 ITF=1 VTF=2 XTF=3 Vceo=40

*White LED model - LUXEON Midpower 5630 binned at 100mA
.model white_led D (Is=2.3275e-19 Rs=2.4475 N=2.7088)

Vsup   vcc       gnd           3.0v ;power supply
*input pulse source
Vosc vpulse gnd  3.0 PULSE(0 3.0 1n 100n 100n 40e-6 80e-6)

q1     coll1    base1   gnd    t2N3904  ; collector base emitter
r5     vpulse   base1          150
l1     coll1    tie2           100uH
vsen2   vcc     tie2           0 ; to sense inductor current
d1     coll1    tie            white_led
vsen   tie      vcc            0 ; to sense LED current

.control
  set hcopydevtype=postscript
  set hcopypscolor=true
  set color0 = rgb:f/f/f
  set color1 = rgb:0/0/0
  tran 1us  0.5ms
  plot  i(vsen) V(base1) V(coll1) i(vsen2) xl 1us 0.5ms
*  gnuplot led_flasher  V(base1) V(coll1) i(vsen2) xl 1us 0.5ms ;make plot for latex
.endc
```