Current Driver for Infrared LED

Week 6: Digital-to-Analog Conversion

ECE 327: *Electronic Devices and Circuits Laboratory I*

Abstract

In the digital-to-analog conversion (DAC) lab, the output of the JK flip–flop used in the analog-to-digital conversion (ADC) lab needs to drive a heavy load. The flip–flop output can only supply 1 mA maximum, but the infrared LED needs to be driven by at least 10 mA and probably will need to operate at 35–50 mA in this lab. So we need to build a current driver. Current drivers can easily be built with with a single NPN or PNP transistor acting as either a current source or sink. Here, we review the prototypical follower and switch circuits that could be used as drivers in this laboratory.

Contents

1 LED Operation

The QEE113 infrared light-emitting diode (LED) should be operated with a current limiting resistor, as shown in Figure 1.1, so that the forward current through the diode is between 10 mA and 50 mA.

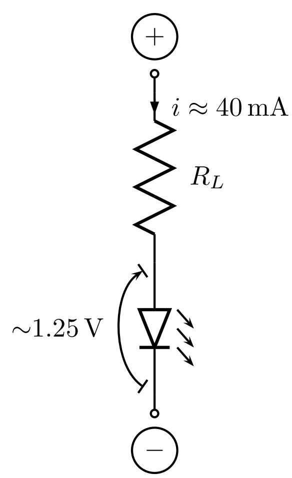


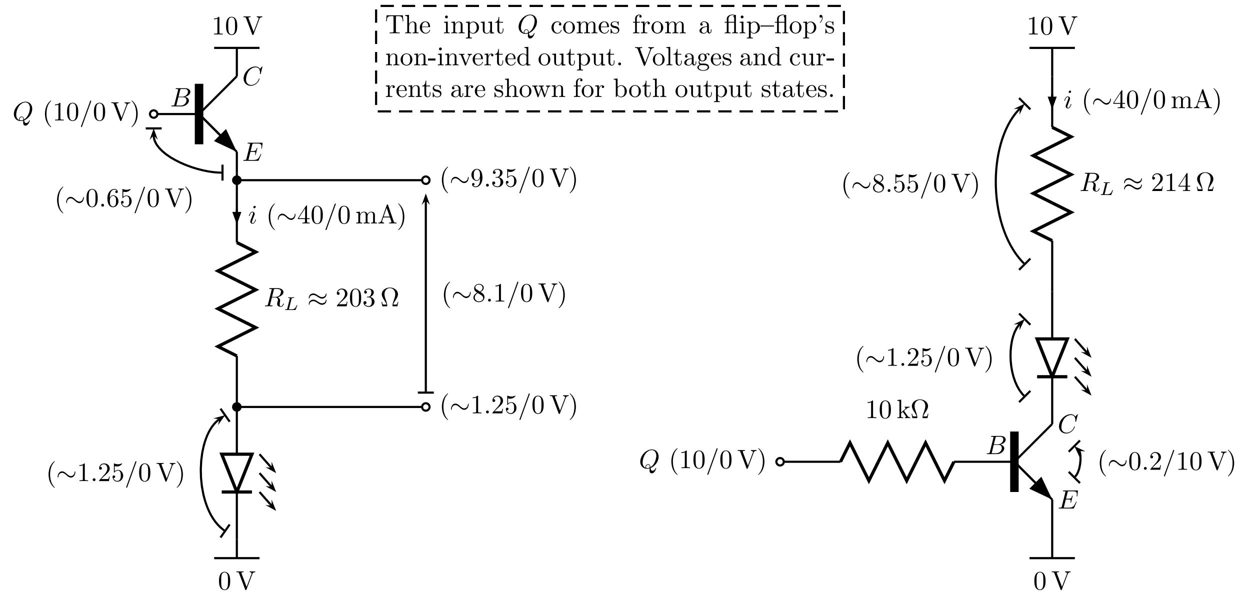
Figure 1.1: Typical operation of QEE113 infrared light-emitting diode (LED).

In this laboratory, a forward current of 40 mA (or less) will be sufficient for eye-to-eye transmission of up to ~0.5 m to a QSE157 receiver. At 40 mA, the potential drop across the LED is 1.25–1.30 V. We use this approximation to derive a nominal value for current-limiting resistor R_L.

In the following, we show four different current driver architectures. In section 2, we show an NPN transistor being used as a current *source* in a follower (i.e., active) configuration and as a current *sink* in a switch (i.e., saturation) configuration. In section 3, we show a PNP transistor being used as a current *source* in a switch (i.e., saturation) configuration and as a current *sink* in a follower (i.e., active) configuration.

2 NPN Current Drivers

In both driver configurations shown in Figure 2.1, the current-limiting resistance R_L must be set to deliver $i \approx 40\,\text{mA}$ to the LED.[1]



(a) NPN follower as current source (b) NPN switch as current sink

Figure 2.1: NPN (2N3904) current drivers for QEE113 infrared LED. The follower configuration in (a) biases the transistor into *active* mode. The switch configuration in (b) biases the transistor into *saturation* mode. Circuit values are shown for both *high* and *low* logic input Q. In the *low* case, transistor current is *cutoff.*

Although R_L can be implemented with a variable resistor (e.g., two adjacent pins of a potentiometer), tuning its value[2] may have less of an impact than tuning the distance between the QEE113 and the QSE157.

NPN Current Source

In Figure 2.1(a), with input Q *high*, the transistor is in *active* mode. A BJT transistor in this mode *dynamically adjusts* its effective collector-emitter resistance so that the base-emitter potential is maintained at approximately 0.65 V. Therefore, the resistor–diode combination is driven by 0 V or 9.35 V depending on whether Q is *low* or *high*, respectively. To make the high current equal to 40 mA, the current-limiting resistor

$$R_L \approx \frac{8.1\,\text{V}}{40\,\text{mA}} = 202.5\,\Omega. \tag{2.1}$$

NPN Current Sink

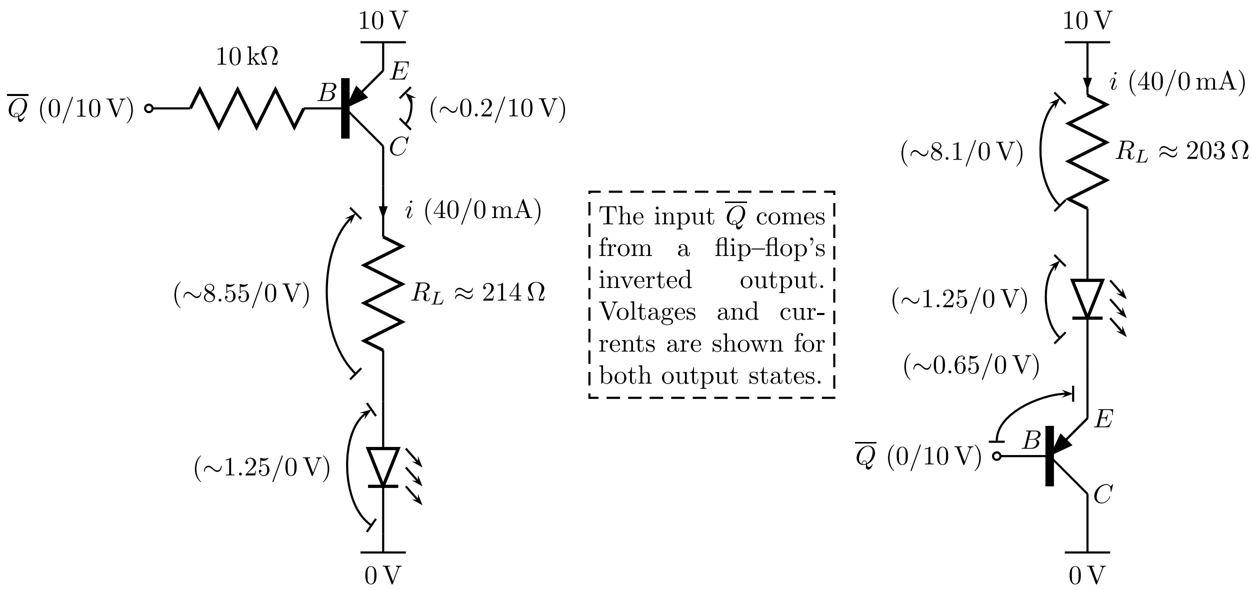
In Figure 2.1(b), with input Q *high*, the transistor is in *saturation* mode. A BJT transistor in this mode is not able to reduce its collector-emitter potential any farther. So it assumes a value of approximately 0.2 V. Therefore, the resistor–diode combination is driven by 0 V or 9.8 V depending on whether Q is *low* or *high*, respectively. To make the high current equal to 40 mA, the current-limiting resistor

$$R_L \approx \frac{8.55\,\text{V}}{40\,\text{mA}} = 213.75\,\Omega. \tag{2.2}$$

[1] Active-mode analysis uses rail-to-rail logic assumption that is untrue for TTL; however, BJT saturation mode is slow.
[2] That is, **increase current** if too little power is received and **decrease current** if the receiver triggers too easily.

3 PNP Current Drivers

In both driver configurations shown in Figure 3.1, the current-limiting resistance R_L must be set to deliver $i \approx 40\,\text{mA}$ to the LED.[3] **NOTE THAT $\overline{Q}$, NOT Q, is used as an input.**



(a) PNP switch as current source

(b) PNP follower as current sink

Figure 3.1: PNP (2N3906) current drivers for QEE113 infrared LED. The switch configuration in (a) biases the transistor into *saturation* mode. The follower configuration in (b) biases the transistor into *active* mode. Circuit values are shown for both *low* and *high* input $\overline{Q}$. In the *high* case, transistor current is *cutoff.*

Although R_L can be implemented with a variable resistor (e.g., two adjacent pins of a potentiometer), tuning its value[4] may have less of an impact than tuning the distance between the QEE113 and the QSE157.

PNP Current Source

In Figure 3.1(b), with input Q *high*, the transistor is in *saturation* mode. A BJT transistor in this mode is not able to reduce its collector-emitter potential any farther. So it assumes a value of approximately 0.2 V. Therefore, the resistor–diode combination is driven by 0 V or 9.8 V depending on whether Q is *low* or *high*, respectively. To make the high current equal to 40 mA, the resistor current-limiting resistor nominally be

$$R_L \approx \frac{8.55\,\text{V}}{40\,\text{mA}} = 213.75\,\Omega. \tag{3.1}$$

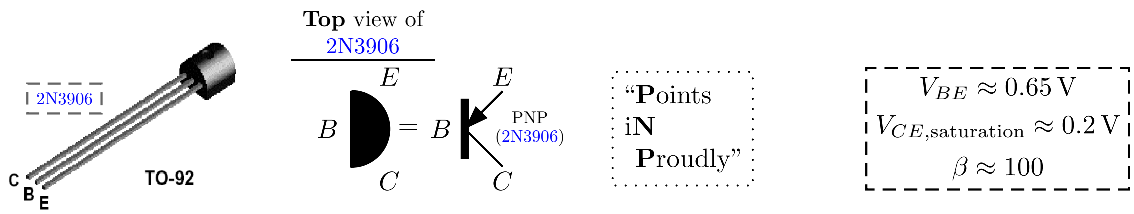
PNP Current Sink

In Figure 3.1(a), with input Q *high*, the transistor is in *active* mode. A BJT transistor in this mode *dynamically adjusts* its effective collector-emitter resistance so that the base-emitter potential is maintained at approximately 0.65 V. Therefore, the resistor–diode combination is driven by 0 V or 9.35 V depending on whether Q is *low* or *high*, respectively. To make the high current equal to 40 mA, the resistor current-limiting resistor nominally be

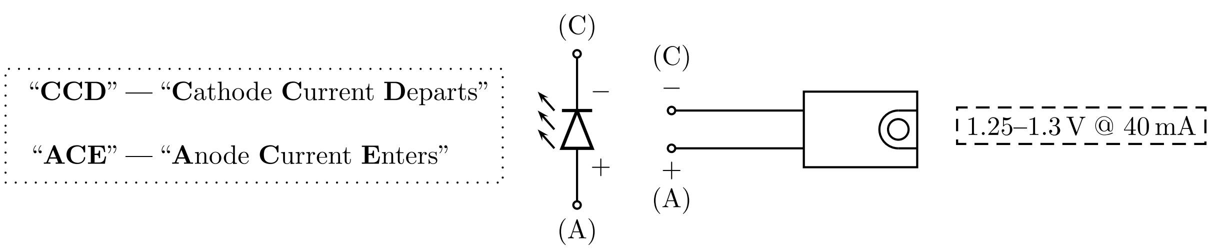
$$R_L \approx \frac{8.1\,\text{V}}{40\,\text{mA}} = 202.5\,\Omega. \tag{3.2}$$

[3] Active-mode analysis uses rail-to-rail logic assumption that is untrue for TTL; however, BJT saturation mode is slow.
[4] That is, **increase current** if too little power is received and **decrease current** if the receiver triggers too easily.

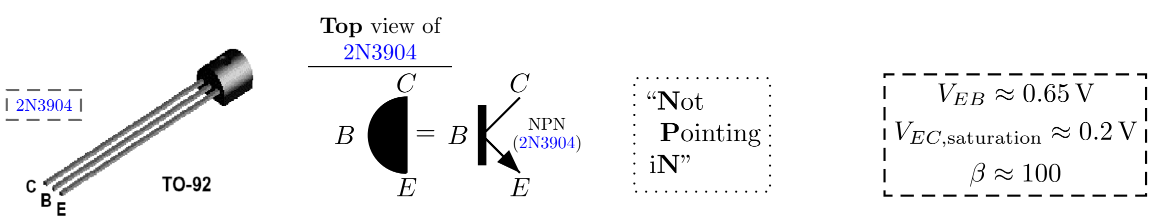
A Parts



(a) 2N3906 PNP BJT transistor



(b) QEE113 infrared LED



(c) 2N3904 NPN BJT transistor

Figure A.1: Part pin-outs.