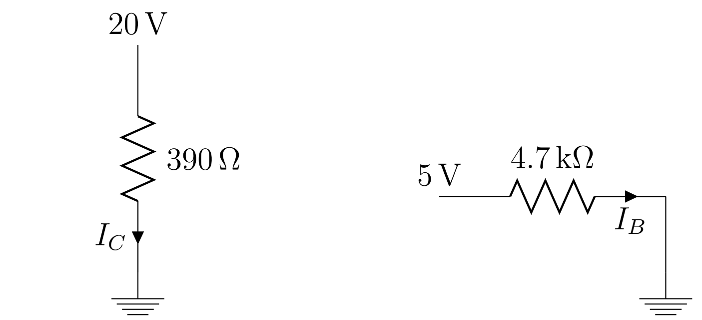
Task 1

Task 1.a

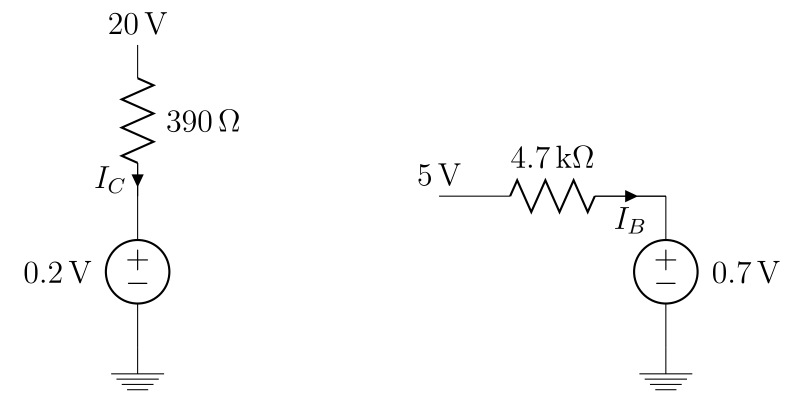


(a) Resistor circuit A (b) Resistor circuit B

Figure 1: Resistor circuits

Show that $I_B \approx \frac{I_C}{50}$ in Figure 1.

Task 1.b



(a) Resistor circuit A (b) Resistor circuit B

Figure 2: Resistor circuits

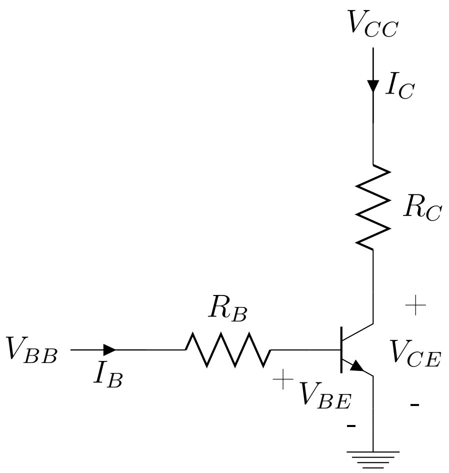
Show that $I_B \geq \frac{I_C}{100}$ in Figure 2.

Task 1.c

Using Figure 3 find the ratio $\frac{R_B}{R_C}$. Comment on the ratio given V_{CC}, V_{BB} and β in the saturated (on) state.

Task 1.d

Show that the transistor in Figure 3 is on.



(a)

Symbol	Value
R_B	$4.7\,\mathrm{k\Omega}$
R_C	$390\,\Omega$
V_{BB}	$5\,\mathrm{V}$
V_{CC}	$20\,\mathrm{V}$
V_{BE}	$0.7\,\mathrm{V}$
V_{CE}	$0.2\,\mathrm{V}$
β	100

(b) Values in saturated state

Figure 3: Transistor circuit

Task 1 Solution

Task 1.a Solution

Circuit A:

$$V_C = R_C I_C \Rightarrow I_C = \frac{V_B}{R_B}$$
$$I_C = \frac{20\,\mathrm{V}}{390\,\Omega} \approx 51\,\mathrm{mA}$$

Circuit B:

$$V_B = R_B I_B \Rightarrow I_B = \frac{V_B}{R_B}$$
$$I_B = \frac{5\,\mathrm{V}}{4.7\,\mathrm{k\Omega}} \approx 1\,\mathrm{mA}$$

We see that $I_C \approx 50 I_B \Rightarrow \underline{\underline{I_B \approx \frac{I_C}{50}}}$.

Task 1.b Solution

$$V_{R_B} = V_B - 0.7\,\mathrm{V}$$
$$I_B = \frac{V_{R_B}}{R_B} = \frac{V_B - 0.7\,\mathrm{V}}{R_B} = \frac{4.3\,\mathrm{V}}{4.7\,\mathrm{k\Omega}} = 915\,\mathrm{\mu A}$$

$$V_{R_C} = V_C - 0.2\,\mathrm{V}$$
$$I_C = \frac{V_{R_C}}{R_C} = \frac{V_C - 0.2\,\mathrm{V}}{R_C} = \frac{19.8\,\mathrm{V}}{390\,\Omega} = 51\,\mathrm{mA} \Rightarrow \underline{\underline{I_B \geq \frac{I_C}{100}}}$$

Task 1.c Solution

$$\frac{R_B}{R_C} = \frac{4.7\,\mathrm{k\Omega}}{390\,\Omega} \approx 12.05$$

The transistor is saturated when

$$I_B \geq \frac{I_C}{\beta}$$
$$\frac{V_{BB} - V_{BE}}{R_B} \geq \frac{V_{CC} - V_{CE}}{R_C}\frac{1}{\beta}$$
$$\frac{V_{BB} - V_{BE}}{V_{CC} - V_{CE}}\beta \geq \frac{R_B}{R_C}$$
$$\frac{R_B}{R_C} \leq \frac{4.3\,\mathrm{V}}{19.8\,\mathrm{V}}100 \approx 21.7$$

Task 1.d Solution

In order for the transistor to be saturated, then $I_B \geq \frac{I_C}{100}$. This also means that $\frac{R_B}{R_C} \leq 21.7$. Since $\frac{R_B}{R_C} \approx 12.05$, the transistor is on.

Task 2

Task 2.a

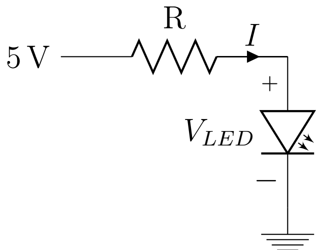


Figure 4: LED circuit

Suppose that the voltage over the LED in Figure 4 is $V_{LED} = 2\,\mathrm{V}$ when the LED is conducting current and lighting up. It is given that the current should not exceed 10 mA or the LED will blow up. The intensity of the LED increases when the current increases.

According to the textbook: "Usually a 330 Ω resistor is included in series with a LED when used in digital (5 V) designs."

What is the resulting current I when $R = 330\,\Omega$? Does this make sense?

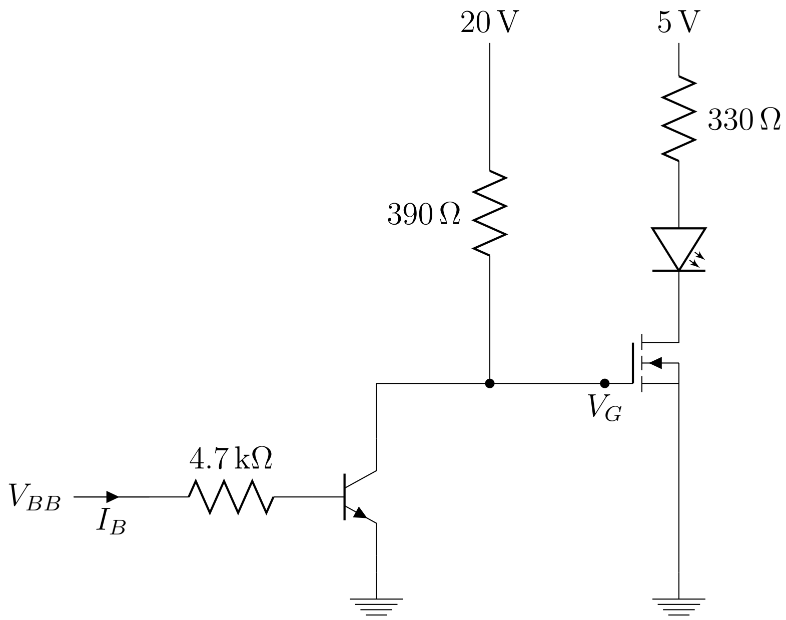


Figure 5: LED circuit

Task 2.b

Suppose that the MOSFET in Figure 5 is switched on when $V_G > 12\,\mathrm{V}$, and off when $V_G \leq 12\,\mathrm{V}$. Using the circuit in Figure 5 assume $V_{BB} = 0\,\mathrm{V}$. Will the LED light up?

Task 2.c

Using the circuit in Figure 5 assume $V_{BB} = 5\,\mathrm{V}$. Will the LED light up?

Task 2 Solution

Task 2.a Solution

$$5\,\mathrm{V} = V_R + V_{LED} \Rightarrow V_R = 5\,\mathrm{V} - 2\,\mathrm{V} = 3\,\mathrm{V} V_R = IR \Rightarrow I = \frac{V_R}{R} = \frac{3\,\mathrm{V}}{330\,\Omega} \approx \underline{\underline{9.1\,\mathrm{mA} < 10\,\mathrm{mA}}}$$

Since LEDs usually use 2 V, then a resistor with 330 Ω will give less then the max current, while almost giving max intensity in a digital design. You could use 300 Ω to get max intensity, but then a small increase in voltage will blow up the LED. The next standard size in resistors is 330 Ω

Task 2.b Solution

Since $V_{BB} = 0\,\mathrm{V}$, the transistor is off. V_G is not connected to ground and will therefore receive 20 V. $V_G > 12\,\mathrm{V}$ and the MOSFET is therefore on. This means that the LED is connected ground, and the LED will light up.

Task 2.c Solution

Since $V_{BB} = 5\,\text{V}$, the transistor is on. V_G is connected to ground, and will therefore be $0\,\text{V}$. The MOSFET is off, and therefore the LED not connected to ground, and will not light up.

Task 3

Task 3.a

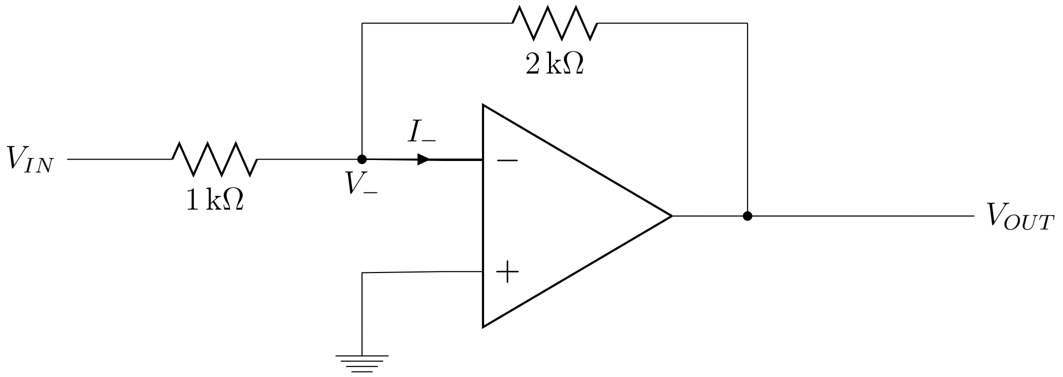


Figure 6: Inverted amplifier

What is V_- in Figure 6? What is I_-? Find $\frac{V_{OUT}}{V_{IN}}$.

Task 3.b

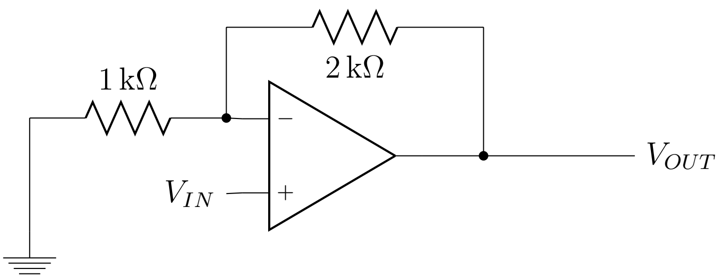


Figure 7: Non-Inverted Amplifier

Find $\frac{V_{OUT}}{V_{IN}}$ for Figure 7.

Task 3.c

Find $\frac{V_{OUT}}{V_{IN}}$ for Figure 8. What is I_{IN}?

Task 3.d

What is V_{OUT} in Figure 9?

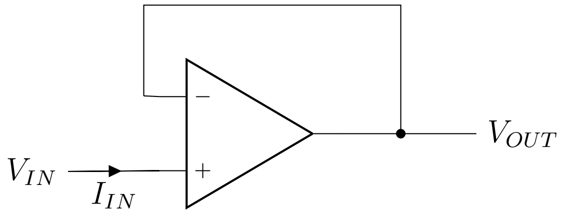


Figure 8: Voltage follower

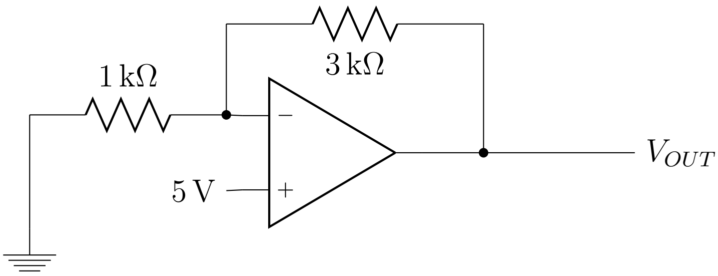


Figure 9: Non-Inverted Amplifier

Task 3.e

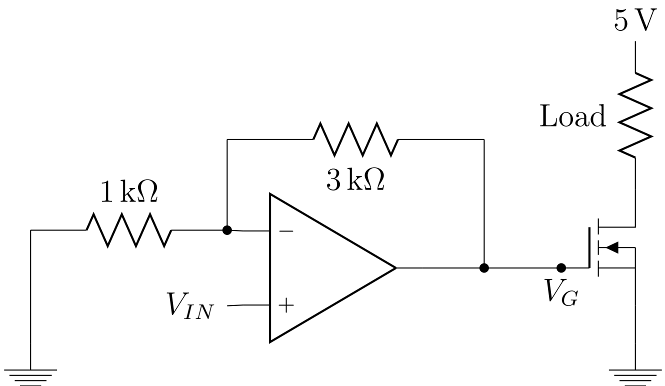


Figure 10: MOSFET circuit

Suppose that the MOSFET in Figure 10 is switched on when $V_G > 12\,\mathrm{V}$ and switched off when $V_G \leq 12\,\mathrm{V}$.

Suppose $V_{IN} = 0\,\mathrm{V}$. Is the MOSFET on?

Suppose $V_{IN} = 5\,\mathrm{V}$. Is the MOSFET on?

Task 3 Solution

Task 3.a Solution

I_- is always 0. There will never go any current into the amplifier from the IN pins. Since the amplifier has a feedback loop, then $V_- = V_+$. Since V_+ is connected to ground, then $V_- = 0\,\mathrm{V}$.

Task 3.b Solution

We call the 1 kΩ resistor R_1, and the 1 kΩ resistor R_1.

Since there is no current going through the amplifier, the resistors will be equal to a voltage divider, where the divided voltage is V_{IN}. This gives the relationship

$$V_{IN} = \frac{R_1}{R_1 + R_2} V_{OUT}$$
$$\Rightarrow \frac{V_{OUT}}{V_{IN}} = \frac{R_1 + R2}{R1} = 1 + \frac{R2}{R1} = \underline{\underline{4}}$$

Task 3.c Solution

Since there is a feedback loop from OUT to IN-, then $V_{IN-} = V_{IN+} = V_{IN}$. There is no component between IN- and OUT, so $V_{IN-} = V_{OUT}$ and $\underline{\underline{\frac{V_{OUT}}{V_{IN}} = 1}}$

The current I_{IN} is going into the amplifier and is therefore 0.

Task 3.d Solution

$$V_{OUT} = (1 + \frac{3\,\mathrm{k\Omega}}{1\,\mathrm{k\Omega}}) 5\,\mathrm{V} = \underline{\underline{20\,\mathrm{V}}}$$

Task 3.e Solution

If $V_{IN} = 0\,\mathrm{V}$, then $V_{OUT} = V_G = 0\,\mathrm{V}$, and the MOSFET is off.

If $V_{IN} = 5\,\mathrm{V}$, then $V_{OUT} = V_G = 20\,\mathrm{V}$, and the MOSFET is on.