Embedded Systems
Assignment Week3

Your Name Here

Problem 0.14 — A 3.3V output pin feeds through a 100K resistor into the base of a 2N3904 (NPN) transistor, as shown in Figure 1. Assuming the forward voltage of the base is 0.7V, how much current flows into the base of the transistor?

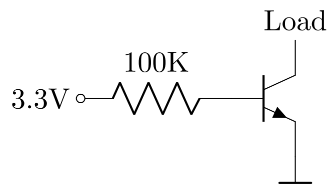


Figure 1: A microcontroller driving a transistor.

Answer: We can use Ohm's Law to find this. 3.3V – 0.7V = $I * 100\text{k}\Omega$. Solving for I, we get 0.026mA.

Problem 0.15 — Assuming the transistor in Exercise 0.14 has a gain between 150 and 200, how much current flows from the collector to the emitter? Is this within the ratings of the 2N3904?

Answer: The amount of current flowing from the collector to the emittor can be as little as $150 \times 0.026\text{mA} = 3.9\text{mA}$ and as much as $200 \times 0.026\text{mA} = 5.2\text{mA}$. This is well below the rating of the 2N3904 of 200mA.

Problem 0.16 — Figure 2 shows a voltage divider made from a potentiometer and a fixed resistor in series. What are the maximum and minimum voltages that can appear on the `out`+ terminal?

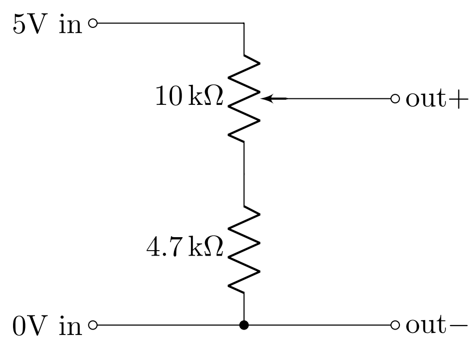


Figure 2: A potentiometer voltage divider.

Answer: To find the maximum and minimum output voltages, we need to consider the resistances values on either side of the potentiometer as it moves from extreme to extreme. The resistance on either side would range from 0Ω and 14.7kΩ to 10kΩ and 4.7kΩ.

We can calculate the minimum and maximum voltages using these four possible resistance values using the formula for a resistance divider.

Max:

$$\Delta V_{out} = \Delta V_{in} * \frac{R_2}{R_1 + R_2}$$
$$\Delta V_{out} = 5\text{V} * \frac{14.7\text{k}\Omega}{0\Omega + 14.7\text{k}\Omega}$$
$$\Delta V_{out} = 5\text{V}$$

Min:

$$\Delta V_{out} = \Delta V_{in} * \frac{R_2}{R_1 + R_2}$$
$$\Delta V_{out} = 5\text{V} * \frac{4.7\text{k}\Omega}{10\text{k}\Omega + 4.7\text{k}\Omega}$$
$$\Delta V_{out} = 5\text{V} * 0.32$$
$$\Delta V_{out} = 1.6\text{V}$$

Problem 0.18 — Find the current through each resistor and the voltage v_1 (relative to ground) for the circuit in Figure 3.

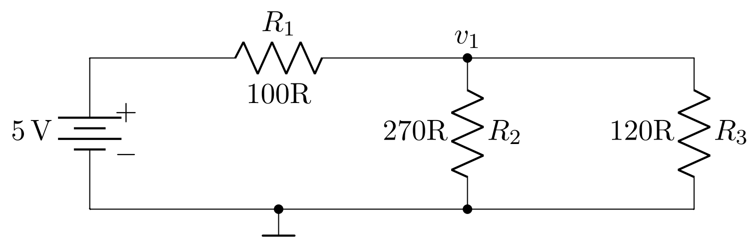


Figure 3: A battery and three resistors.

Answer: We can find the current through each component first by finding the total current. We can calculate this using Ohm's Law, V = IR.

$$V = I * R$$
$$5\text{V} = I * 100\Omega + \frac{1}{\frac{1}{270\Omega} + \frac{1}{120\Omega}}$$
$$5\text{V} = I * 100\Omega + 83.1\Omega$$
$$I = \frac{5\text{V}}{183.1\Omega}$$
$$I = 0.0273\text{A} = 27.3\text{mA}$$

Kirchoff's Current Law means that both the 100Ω resistor and the parallel resistors equal to 83.1Ω have 27.3mA running through them. We can find the current through each parallel resistor, each will be a fraction of the total 27.3mA, inversily proportional to how much resistance they from the pair. The 120Ω resistor would have 18.8mA of current through it and the 270Ω resistor would have 8.38mA.

v_1 can be found using Ohm's Law.

$$V = 0.0273\text{A} * 100\Omega$$
$$V = 2.73\text{V}$$

This is the total voltage drop through the resistor, so relative to ground v_1 would be $5\text{V} - 2.73\text{V} = 2.27\text{V}$.

Problem 0.21 — A 0.33µF capacitor and a 0.47µF capacitor are placed in parallel. What is the equivalent capacitance?

Answer: The capacitance of two capacitors wired in parallel is equivalent to the sum of the two individual capacitances. So we can calculate 0.33µF + 0.47µF = 0.8µF.

Problem 0.22 — A 0.33µF capacitor and a 0.47µF capacitor are placed in series. What is the equivalent capacitance?

Answer: Two capacitors placed in series have a combind capacitance of:

$$C = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2}}$$

Thus we can calculate the capacitance as such:

$$C = \frac{1}{\frac{1}{0.33\mu\text{F}} + \frac{1}{0.47\mu\text{F}}}$$
$$C = \frac{1}{5.15\mu\text{F}}$$
$$C = 0.194\mu\text{F}$$

Problem 0.23 — A 1pF capacitor and a 470nF capacitor are placed in parallel. What is the equivalent capacitance?

Answer: To calculate, we should conver 470nF into 470,000pF. Thus, the combind capacitance, since they are in parallel, is 1pF + 470,000pF = 470,000pF.

Problem 0.24 — A 1pF capacitor and a 470nF capacitor are placed in series. What is the equivalent capacitance?

Answer: Just like the previous question, we should convert 470nF into 470,000pF. Then we can calculate the combind capacitance as such:

$$C = \frac{1}{\frac{1}{1\text{pF}} + \frac{1}{470{,}000\text{pF}}}$$
$$C = \frac{1}{1.00000212\mu\text{F}}$$
$$C = 0.99999787\text{pF}$$

Problem 0.25 — A 0.22µH inductor and a 0.47µH inductor are placed in parallel. What is the equivalent inductance?

Answer: We can calculate to combined inductance using the formula:

$$L = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2}}$$

Thus we can calculate the inductance as such:

$$L = \frac{1}{\frac{1}{0.22\text{µH}} + \frac{1}{0.47\text{µH}}}$$
$$L = \frac{1}{6.67\text{µH}}$$
$$L = 0.15\text{µH}$$

Problem 0.26 — A 0.22µH inductor and a 0.47µH inductor are placed in series. What is the equivalent inductance?

Answer: We can calculate the combind inductance simply by summing the individual inductances. So a 0.22µH inductor and a 0.47µH conductor combined are 0.69µH.

Problem 0.27 — A 1nH inductor and a 33mH inductor are placed in parallel. What is the equivalent inductance?

Answer: To find the inductance, we first should convert 33mH to 33,000,000nH. We can calculate the combined inductance using the formula:

$$L = \frac{1}{\frac{1}{L_1} + \frac{1}{L_2}}$$

Thus we can calculate the inductance as such:

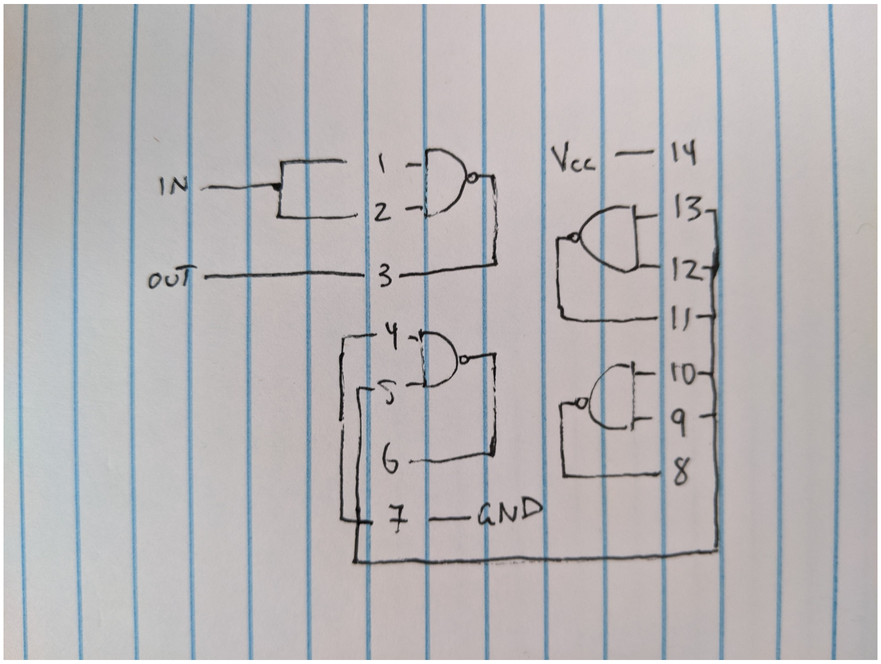
$$L = \frac{1}{\frac{1}{1\text{nH}} + \frac{1}{33{,}000{,}000\text{nH}}}$$
$$L = \frac{1}{1.00000003\text{nH}}$$
$$L = 0.99999997\text{nH}$$

Problem 0.28 — A 1nH inductor and a 33mH inductor are placed in series. What is the equivalent inductance?

Answer: We can calculate the combined inductance by simply summing the individual inductances, but first we should convert 33mH to 33,000,000nH. Thus, our combined inductance is 1nH + 33,000,000nH = 33,000,001nH.

Problem 0.29 — Draw a circuit using the quad NAND gate in Figure 0.38(b) on page 28 of the text that implements the NOT logic function. Clearly mark on your circuit where the `in` (input) signal is attached and where the `out` (output) signal emerges. Also indicate where power and ground are attached. Attach any unused inputs to ground.

Answer: We can implement a NOT gate using a NAND gate by passing the same input to both inputs of the gate.



Problem 0.34 — What is the maximum frequency of an ATmega328P when operating with $\mathsf{V_{CC}} = 1.8\text{V}$? (Consult the datasheet.)

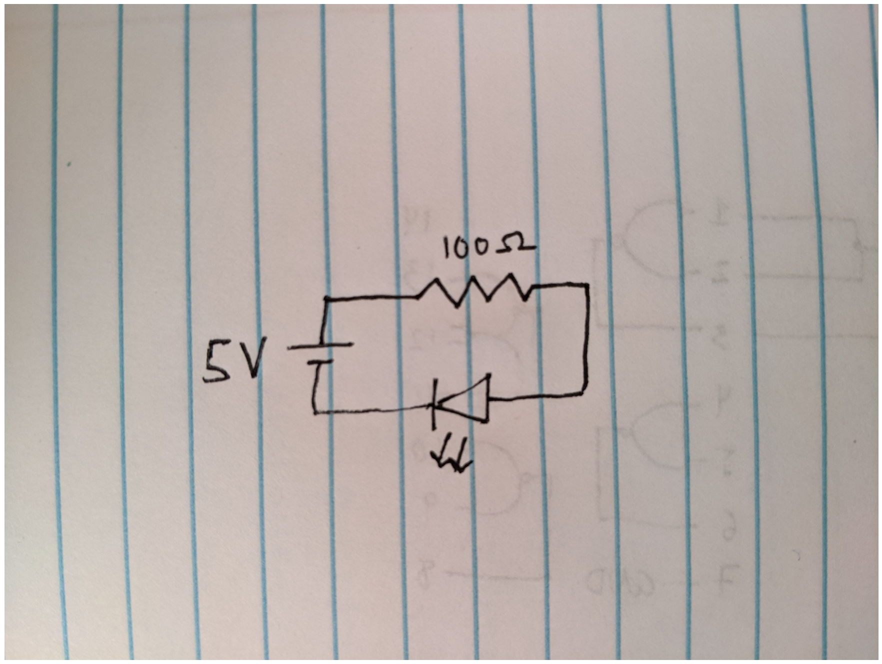
Answer: Found in section 29.4.3 Table 29-10 of the ATmega328P datasheet, the maximum frequency is 4MHz.

Problem 0.37 — Consult a datasheet to find the forward voltage of a red LED at 20mA. If we intend to drive that LED from a 5V output pin of an ATmega microcontroller, what size E12 resistor should we use in series with the LED to limit the current to 20mA or less? Draw a picture of the circuit.

Answer: The datasheet I found had 1.8V as the forward voltage for a red LED. We need at least a 90ohm resistor to limit the LED to 20mA.

$$
\begin{aligned}
1.8\text{V} &= 0.02\text{A} * R \\
R &= \frac{1.8\text{V}}{0.02\text{A}} \\
R &= 90\Omega
\end{aligned}
$$

The closest E12 resistor that guarantees 90Ω is a 100Ω resistor. Here is it implemented in a circuit:


100Ω
5V