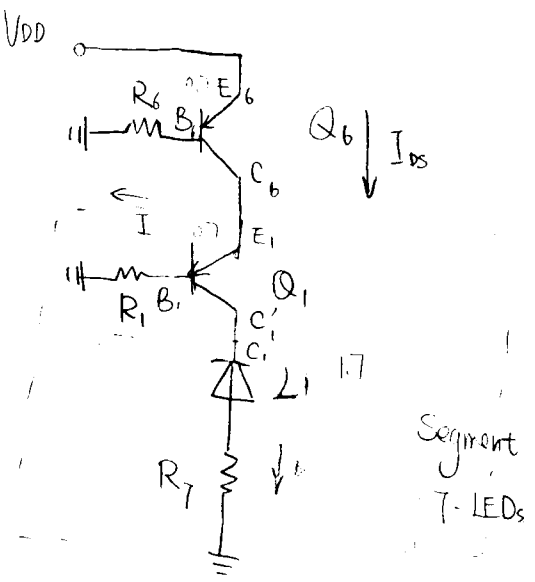

Because the current goes through Q_1, $V_{E6} \rightarrow V_{B6}$ will drop 0.7 V to satisfy saturation. $V_{E1} \rightarrow V_{B1}$ will drop 0.2 V

Given by V_{DD} 5V,

V_{b6} $V_{DD} - V_{be} = 5V - 0.7V = 4.3V$,

V_{C6} $V_{DD} - V_{ce} = 5V - 0.2V = 4.8V$

For Q_1,

$V_{b1} = V_{E1} - V_{be} = V_{C6} - V_{be}$ $4.8 - 0.7 = 4.1V$

$V_{C1} = V_{E1} - V_{ce} = V_{C6} - V_{ce}$ $4.8 - 0.2 = 4.6V$

For Q_6

$i_{C6} = \beta i_{b6}$,

For point C_1 there has 8 parallel LED for one 7-segment, $i_C' = 8 i_C$

For point C_6 there has 5 parallel PNP, $i_{C6} = 5 i_{e1}$

$$i_{C1}' = \frac{\beta}{1+\beta} i_{e1} = \frac{\beta}{(1+\beta)5} i_{C6} = \frac{\beta}{5(1+\beta)} i_{b6} \Rightarrow i_{C1}' \approx \frac{\beta}{5} i_{b6} \Rightarrow i_{b6} \approx \frac{5}{\beta} i_{C1}'$$

$$i_{b1} = \frac{i_{e1}}{1+\beta} = \frac{1}{5(1+\beta)} i_{C6} = \frac{\beta}{5(1+\beta)} i_{b6} \Rightarrow i_{b1} \approx \frac{i_{b6}}{5}$$

Assume the max current which goes through LED is 10mA, $\beta = 100$, the voltage drop of L1 is 2V

$$R_7 = \frac{V_{C1} - 2}{i_{C1min}} = \frac{4.6 - 2V}{10mA} = 260\,\Omega.$$ So choose 270 Ω in the circuit for $R_7 - R_{14}$.

$$R_1 = \frac{V_{b1} - 0}{i_{b1}} = \frac{V_{b1}\beta}{i_{C1}} = \frac{4.3 \times 100V}{8 \times 10mA} = 5.125k\Omega,$$ So choose 4.7kΩ for $R_1 \sim R_5$

$$R_5 = \frac{V_{b6} - 0}{i_{b6}} = \frac{V_{b6}\beta}{i_C'} = \frac{4.3 \times 100V}{8 \times 10mA} = 5.125k\Omega$$ choose 4.7kΩ in the circuit.

According to ATmega128 Datasheet, each I/O port can sink 20 mA at $V_{cc} = 5V$. It's more than the current that I design. So, using those resistors for LEDs/ buttons is safe.

Actually measurements:

For LED 1 (7-segment a).

I_a = 23.8 mA

However, the LED a becomes lighter when I test than it enlights in normal. I think the current of LED is influenced by the multimeter, which has power to increase the measuring current I_a. It differs from the value I calculate.

When the value of digit display is more than 1023, it wil subtract 1023 and display the remainder.