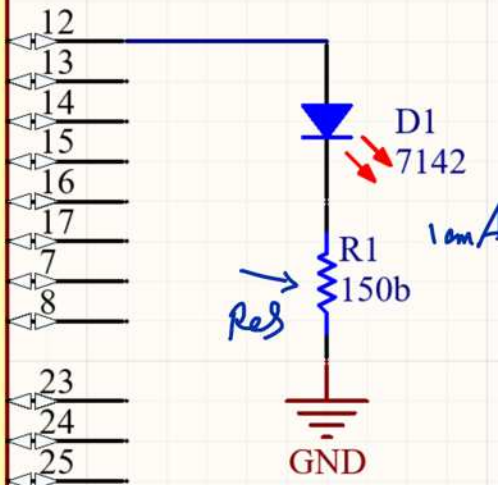
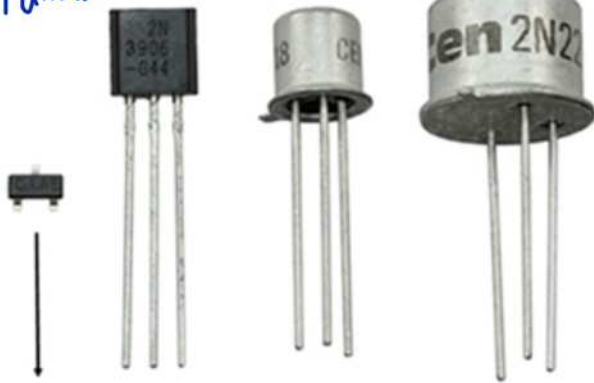


ATmega328

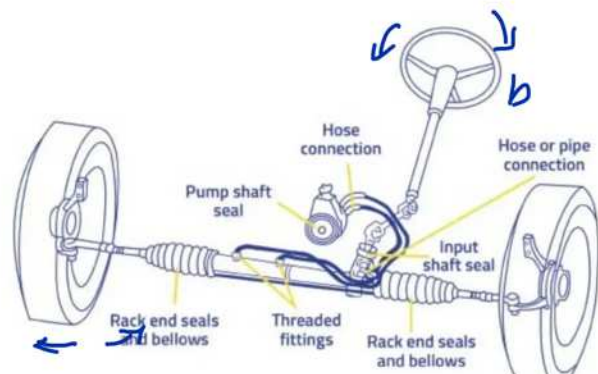
VCC PB0(PCINT0/CLKO/ICP1)
VCC PB1(PCINT1/OC1A)
AVCC PB2(PCINT2/SS/OC1B)
PB3(PCINT3/OC2A/MOSI)
AREF PB4(PCINT4/MISO)
PB5(SCK/PCINT5)
PB6(PCINT6/XTAL1/TOSC1)
PB7(PCINT7/XTAL2/TOSC2)
PC0(ADC0/PCINT8)
PC1(ADC1/PCINT9)
PC2(ADC2/PCINT10)



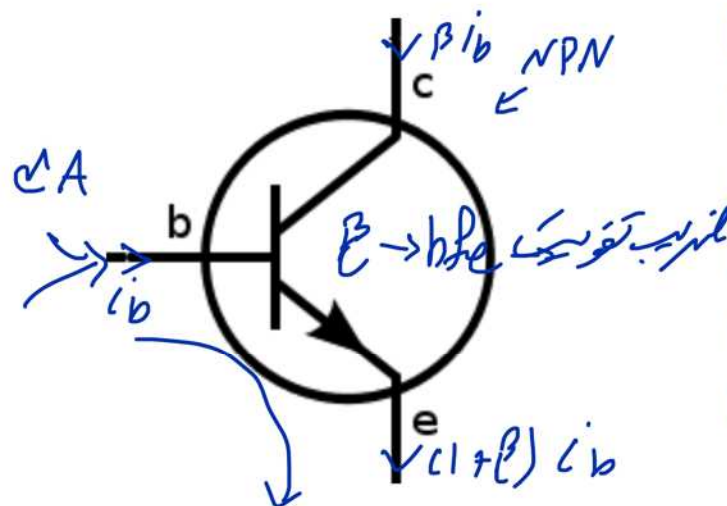
transistor



SOT-23 To-92 TO-18 TO-39



C/E



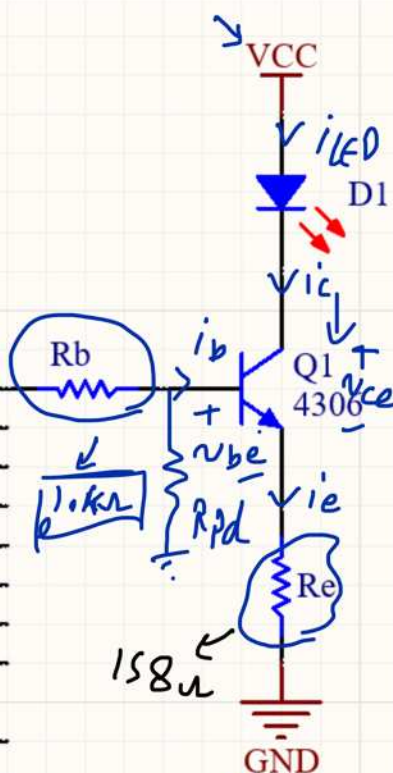
Characteristics	Values	Units
Material	2N2222 NPN	Silicon
Polarity	NPN	--
Collector power dissipation	0.5	W
Collector emitter voltage	30	V
Collector base voltage	60	V
Emitter base voltage	5	V
Collector current	0.8	A
Frequency	250	MHz
Operating temperature	175	°C
Collector capacitance	8	pF
Current transfer ratio	100	hFE

$$\beta_{min} < h_{FE} < \beta_{max}$$

U1

ATmega328

VCC	PB0(PCINT0/CLKO/ICP1)	12
VCC	PB1(PCINT1/OC1A)	13
AVCC	PB2(PCINT2/SS/OC1B)	14
	PB3(PCINT3/OC2A/MOSI)	15
AREF	PB4(PCINT4/MISO)	16
	PB5(SCK/PCINT5)	17
	PB6(PCINT6/XTAL1/TOSC1)	7
	PB7(PCINT7/XTAL2/TOSC2)	8
	PC0(ADC0/PCINT8)	23
	PC1(ADC1/PCINT9)	24



$$\begin{aligned}
 i_c &\approx i_e \\
 i_c &= \beta i_b \\
 i_e &= (1 + \beta) i_b \\
 v_{be} &= 0.7 \text{ V} \\
 h_{fe} = \beta &= 100 \\
 i_{LED} &= 10 \text{ mA} \\
 \Rightarrow i_c &\approx 10 \text{ mA}
 \end{aligned}$$

$$i_b = \frac{i_c}{\beta} = \frac{10 \text{ mA}}{100} \Rightarrow i_b = 100 \mu\text{A}$$

$$\text{I) } -3.3 + R_b i_b + 0.7 + R_e (1 + \beta) i_b = 0$$

$$\Rightarrow -3.3 + 100 \times 10^{-6} R_b + 0.7 + R_e (100 + 1) \times 100 \times 10^{-6} = 0$$

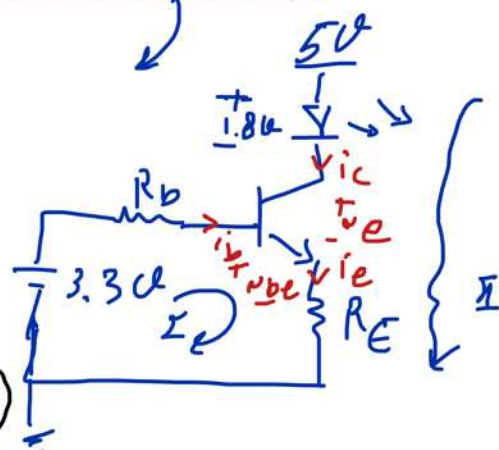
$$\text{II) } -5 + 1.8 + v_{ce} + R_e i_e = 0 \Rightarrow v_{ce} + R_e i_e = 3.2$$

$$\Rightarrow 1.6 + R_e \times (100 + 1) (100 \times 10^{-6}) = 3.2$$

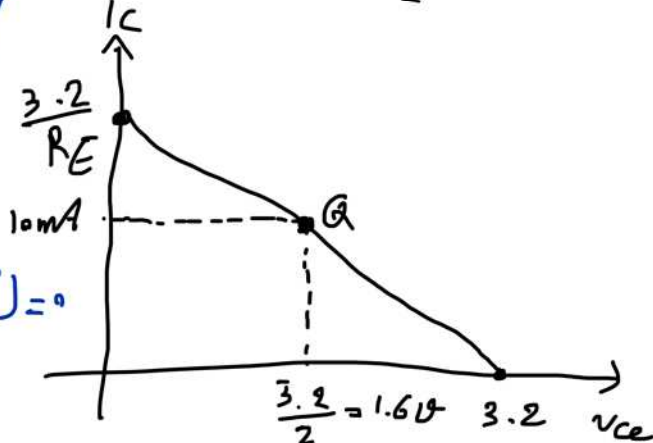
$$\begin{aligned}
 \text{Solve} \Rightarrow R_e &\approx 158 \Omega \\
 \text{STD} \Rightarrow R_e &= 150 \Omega
 \end{aligned}$$

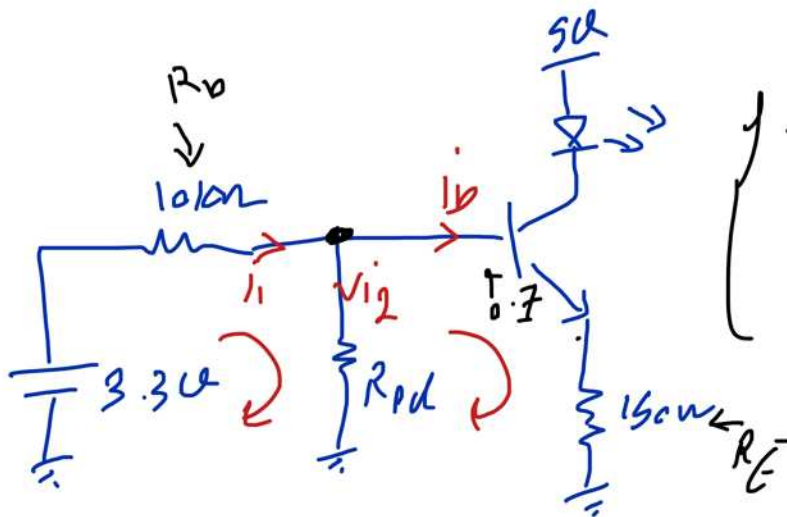
$$-3.3 + 100 \times 10^{-6} R_b + 0.7 + 158 (100 + 1) (100 \times 10^{-6}) = 0$$

$$\text{Solve} \Rightarrow R_b \approx 10 \text{ k}\Omega$$



$$v_{ce} + R_e i_e = 3.2$$





$$i_1 = i_{cc}$$

$$\begin{cases} -3.3 + R_b \times i_1 + i_2 R_{pd} = 0 \\ 0.7 + R_E (1 + \beta) i_b - R_{pd} i_2 = 0 \\ i_1 = i_2 + i_b \end{cases} \quad \text{with } R_{pd} = 100k\Omega$$

R_{pd}

i_{cc}

i_{pd}

i_b

i_c

100kΩ

116μA

21.4μA

94.9μA

≈ 9.5mA

10kΩ

189μA

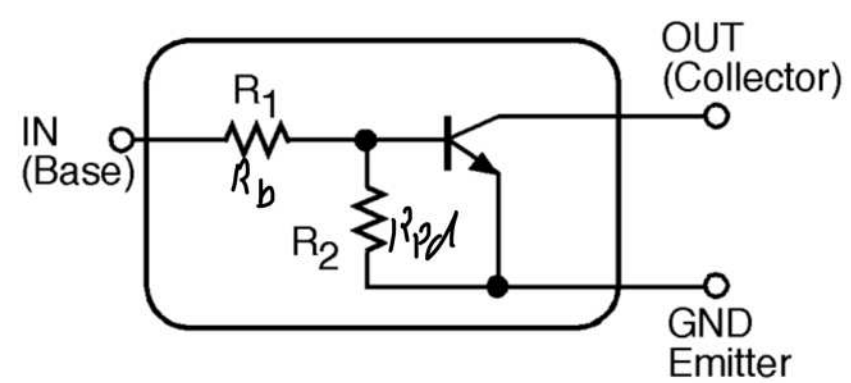
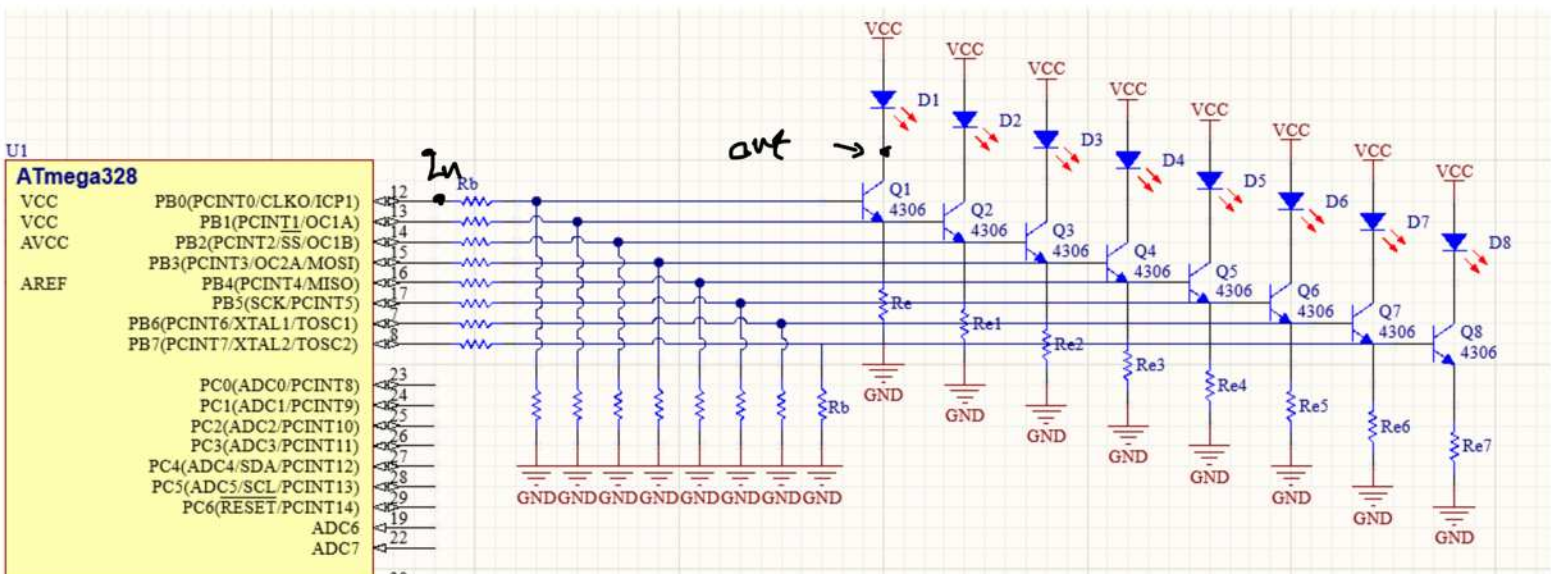
141μA

47.1μA

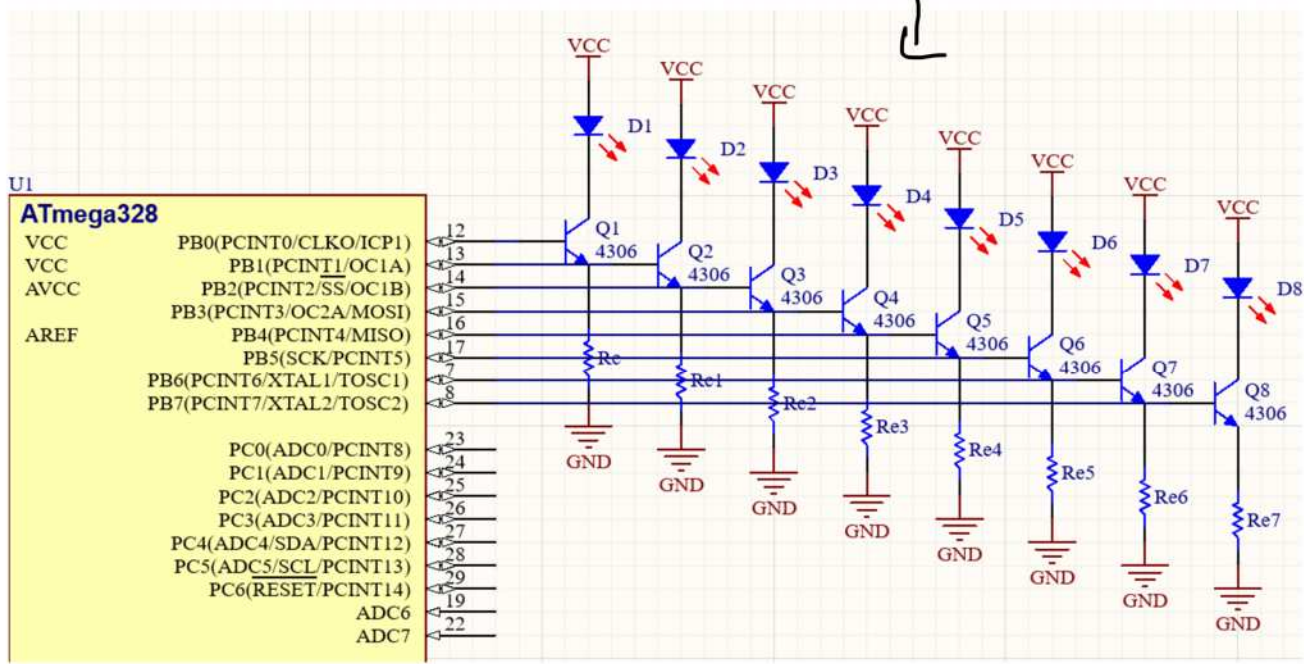
≈ 4.7mA

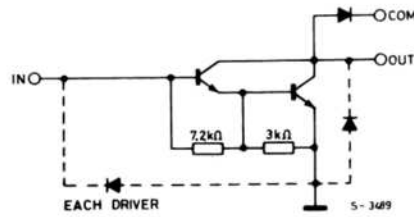
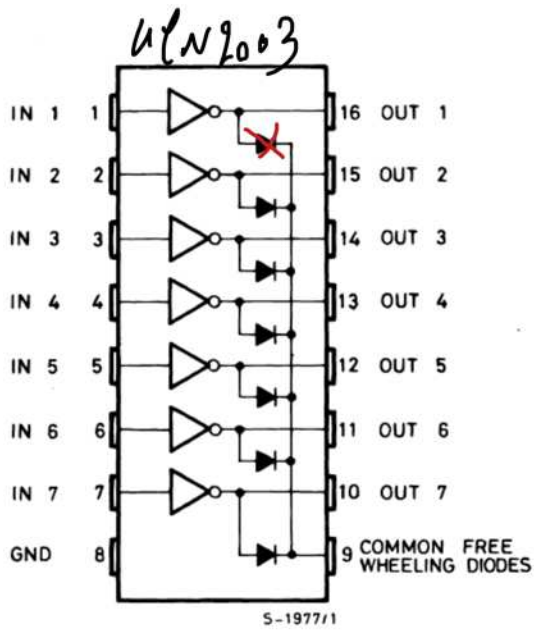
$$R_{pd} \approx 10 R_b$$

1m

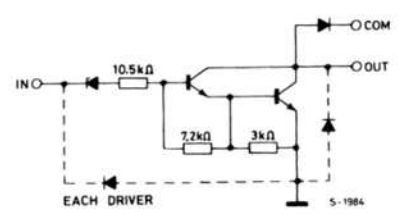


ترانسیستور
digital
13Pd1
NPN

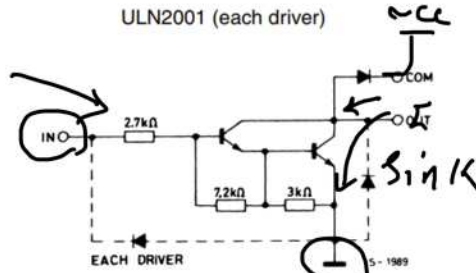




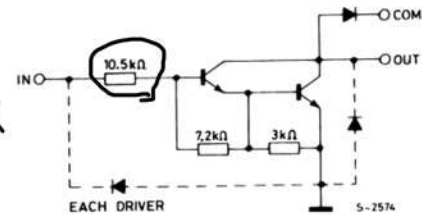
ULN2001 (each driver)



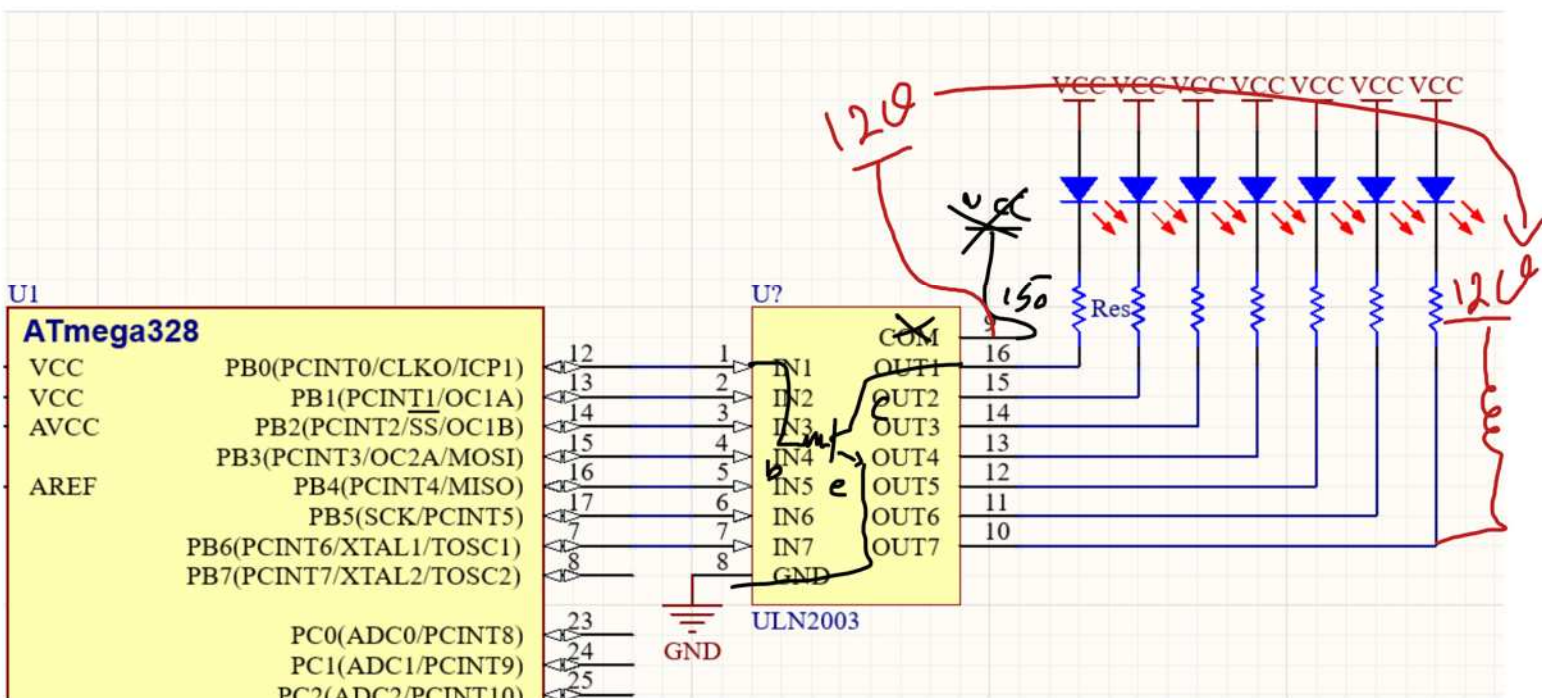
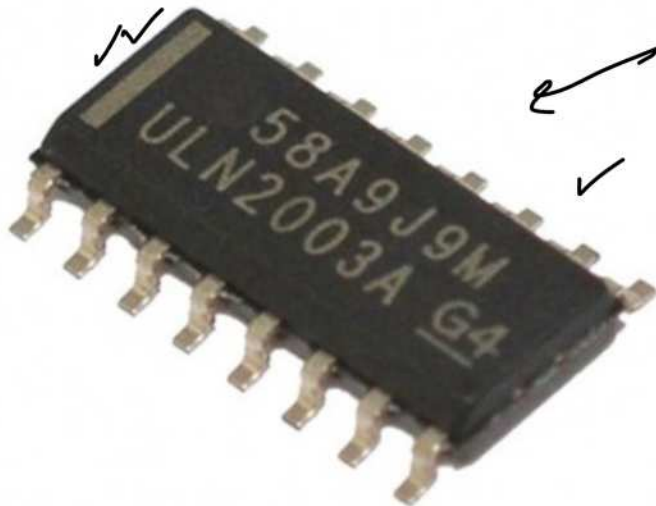
ULN2002 (each driver)



ULN2003 (each driver)

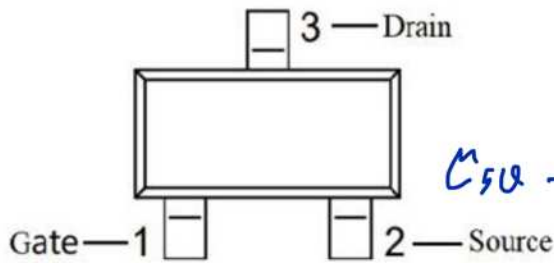


ULN2004 (each driver)

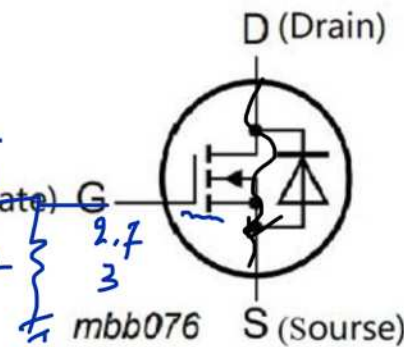


2N7002 N-channel Logic Level MOSFET

$V_{GS} \approx 2.7$



2N7002 Pinout



Graphic Symbol

$V_{GS} \approx 3$

$V_{GS} \approx 2.7$

Handwritten notes and formulas:
 $V_{out} \approx 2.7$
 $\frac{R_2}{R_1 + R_2} V_{in}$
 $R_1 \rightarrow$
 $100k\Omega$
 2.7

