Fundusze Europejskie
Wiedza Edukacja Rozwój

Unia Europejska
Europejski Fundusz Społeczny

Politechnika Śląska jako Centrum Nowoczesnego Kształcenia
opartego o badania i innowacje

POWR-03.05.00-00-Z098/17-00

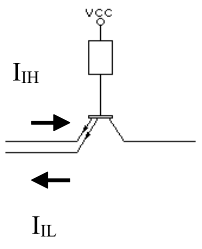
Digital Circuits Design

Faculty of Automatic Control, Electronics and Computer Science / Informatics, Engineer Degree, sem. 3

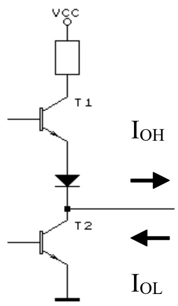
Materiały dydaktyczne współfinansowane przez Unię Europejską ze środków Europejskiego Funduszu Społecznego

Classes 1 – Inputs and outputs of digital circuits

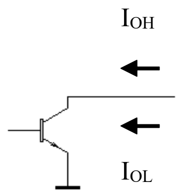
Inputs and outputs



input

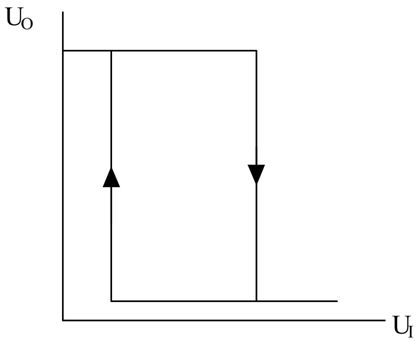


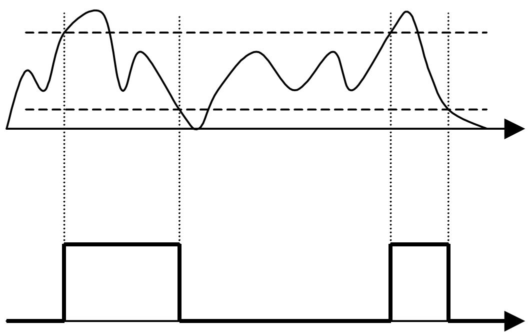
totem-pole output



open-collector output

Schmitt input





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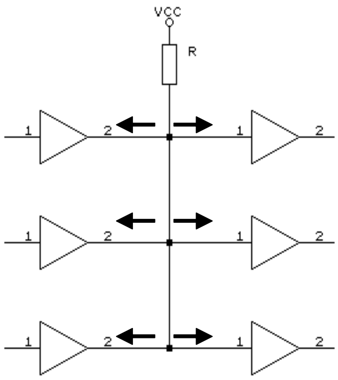
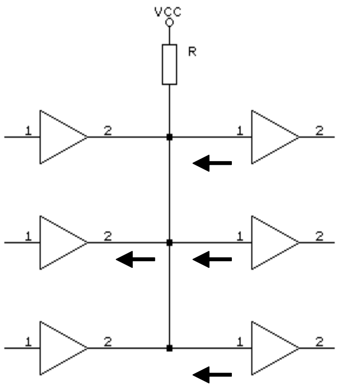
Resistor value calculation for open-collector outputs



High state

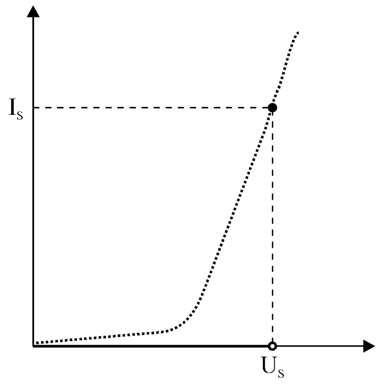


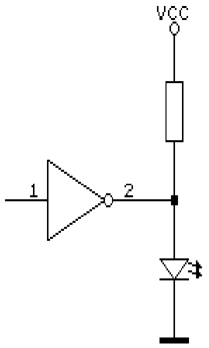
Low state

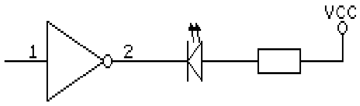
$$R_{max} = \frac{V_{CC} - \max(U_{OHmin}, U_{IHmin})}{\sum I_{OHmax} + \sum I_{IHmax}}.$$

$$R_{min} = \frac{V_{CC} - \min(U_{OLmax})}{\min(I_{OLmax}) - \sum I_{ILmax}}.$$

LED connection







$$R_{min} = \frac{V_{CC} - U_{OLmax}}{I_{OLmax}}, \quad R_{max} = \frac{V_{CC} - U_S}{I_S}. \qquad\qquad R = \frac{V_{CC} - U_S - U_{OLmax}}{I_S}.$$

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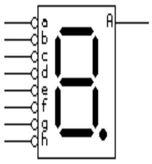
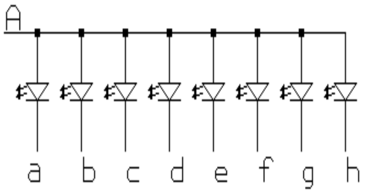
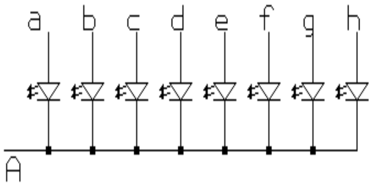
7-segment display





Common anode



Common cathode

Typical parameters of digital IC's

- V_{ILmax} - highest input voltage in the low state
- V_{IHmax} - lowest input voltage in the high state
- V_{OLmax} - highest output voltage in the low state
- V_{OHmax} - lowest output voltage in the high state
- I_{ILmax} - highest input current in the low state
- I_{IHmax} - highest input current in the hight state
- I_{OLmax} - highest output current in the low state
- I_{OHmax} - highest output current in the high state
- I'_{OLmax} - highest output current in the low state for the high-load circuits
- I'_{OHmax} - highest output current in the hight state for the OC outputs

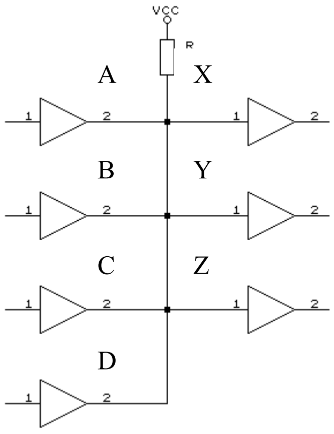
Series		V_{ILmax} [V]	V_{IHmin} [V]	I_{Ilmax} [mA]	I_{IHmax} [µA]	V_{OLmax} [V]	V_{OHmin} [V]	I_{OLmax} [mA]	I_{OHmax} [mA]	I'_{OLmax} [mA]	I'_{OHmax} [mA]
TTL	Std	0.8	2.0	1.6	40	0.4	2.4	16	0.8	48	0.25
	ALS			0.2	20	0.35	3.2	8	0.4	24	0,1
	AS			1.0	20	0.35	3.2	20	2.0	48	0,25
	F			1.2	40	0.35	3.4	20	2.0	48	
	H			2.0	50	0.2	3.4	20	1.0		
	L			0.18	10	0.2	3.4	4	0.2		
	LS			0.36	20	0.5	2.7	8	0.4	24	0.1
	S			2.0	50	0.5	2.7	20	1.0	48	0.25
CMOS	AC	1.5	3.5	1	1	0.1	4.9	24.0	24.0		
	ACT	0.8	2.0	1	1	0.1	4.9	24.0	24.0		
	C	1.5	3.5	5 nA	5 nA	0.5	4.5	1.75	1.75		
	HC	1.0	3.5	1	1	0.1	4.4	0.02	0.02		
	HCT	0.8	2.0	1	1	0.26	3.98	4.0	4.0		
	HCU	1.0	4.0	1	1	0.1	4.4	0.02	0.02		

Materiały dydaktyczne współfinansowane przez Unię Europejską ze środków Europejskiego Funduszu Społecznego

Examples

ex. 1

For the circuit shown below calculate R so that the circuit works properly. All gates belong to the TTL series.



$$R_{max} = \frac{V_{CC} - U_{OHmin}}{N_O \cdot I_{OHmax} + N_I \cdot I_{IHmax}} = \frac{5 - 2{,}4[V]}{4 \cdot 250 + 3 \cdot 40[\mu A]} = \frac{2{,}6[V]}{1120[\mu A]} = 2321\Omega$$

$$R_{min} = \frac{V_{CC} - U_{OLmax}}{I_{OLmax} - N_I \cdot I_{ILmax}} = \frac{5 - 0{,}4[V]}{16 - 3 \cdot 1{,}6[mA]} = \frac{4{,}6[V]}{11{,}2[mA]} = 410\Omega .$$

ex. 2

For the circuit given in the previous example calculate R. A and D gates are TTL, B – TTL LS, C – TTL S. X, Y and Z are TTL.

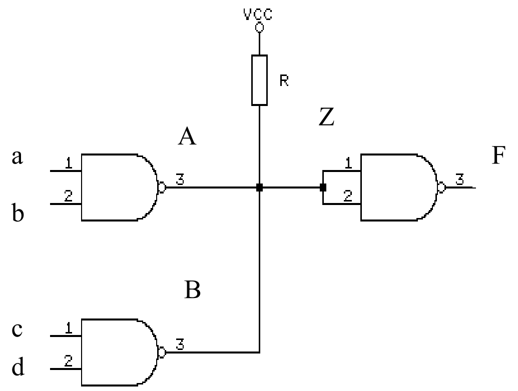
$$R_{min} = \frac{V_{CC} - U_{OLmaxTTL}}{I_{OLmaxLS} - N_I \cdot I_{ILmaxTTL}} = \frac{5 - 0{,}4[V]}{8 - 3 \cdot 1{,}6[mA]} = \frac{4{,}6[V]}{3{,}2[mA]} = 1438\Omega.$$

$$R_{max} = \frac{V_{CC} - U_{OHminLS}}{2 \cdot I_{OHmaxTTL} + I_{OHmaxS} + I_{OHmaxLS} + N_I \cdot I_{IHmaxTTL}} = \frac{5 - 2{,}7[V]}{2 \cdot 250 + 250 + 100 + 3 \cdot 40[\mu A]}$$

$$R_{max} = \frac{2{,}3[V]}{970[\mu A]} = 2371\Omega.$$

ex. 3

For the circuit shown below calculate R so that the circuit works properly and give the logic expression describing the function implemented in the circuit. A gate is TTL, B – high power TTL (increased output load), Z – TTL S.



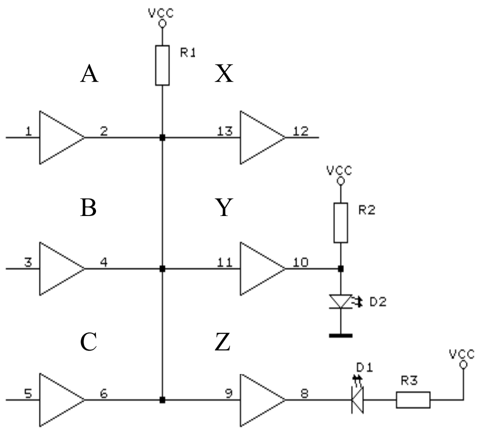
$$R_{max} = \frac{V_{CC} - U_{OHmin}}{N_O \cdot I_{OHmax} + I_{IHmaxS}} = \frac{5 - 2{,}4[\mathrm{V}]}{2 \cdot 250 + 50[\mu\mathrm{A}]} = \frac{2{,}6[\mathrm{V}]}{550[\mu\mathrm{A}]} = 4727\Omega,$$

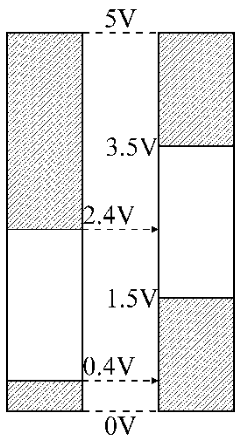
$$R_{min} = \frac{V_{CC} - U_{OLmax}}{I_{OLmaxTTL} - I_{ILmaxS}} = \frac{5 - 0{,}5[\mathrm{V}]}{16 - 2{,}0[\mathrm{mA}]} = \frac{4{,}5[\mathrm{V}]}{14[\mathrm{mA}]} = 321\Omega.$$

$$F = \overline{\overline{(a \cdot b)} \cdot \overline{(c \cdot d)}} = \overline{\overline{(a \cdot b)}} + \overline{\overline{(c \cdot d)}} = ab + cd.$$

ex.4

For the circuit shown below calculate R1, R2 and R3 so that the circuit works properly. A, B and C gates belong to the TTL series. X is CMOS, Y and Z – TTL LS. Assume LED parameters: I_S=10 mA, U_S=1,5 V.





$$R_{1max} = \frac{V_{CC} - U_{IHminCMOS}}{N_O \cdot I_{OHmaxTTL} + N_I \cdot I_{IHmaxLS}} = \frac{5 - 3{,}5[\mathrm{V}]}{3 \cdot 250 + 2 \cdot 20[\mu\mathrm{A}]} = \frac{1{,}5[\mathrm{V}]}{790[\mu\mathrm{A}]} = 1898\Omega$$

$$R_{1min} = \frac{V_{CC} - U_{OLmaxTTL}}{I_{OLmaxTTL} - N_I \cdot I_{ILmaxLS}} = \frac{5 - 0{,}4[\mathrm{V}]}{16 - 2 \cdot 0{,}36[\mathrm{mA}]} = \frac{4{,}6[\mathrm{V}]}{15{,}28[\mathrm{mA}]} = 301\Omega.$$

$$R_{2max} = \frac{V_{CC} - U_S}{I_S} = \frac{5 - 1{,}5[\mathrm{V}]}{10[\mathrm{mA}]} = \frac{3{,}5[\mathrm{V}]}{10[\mathrm{mA}]} = 350\Omega.$$

$$R_{2min} = \frac{V_{CC} - U_{OLmaxLS}}{I_{OLmaxLS}} = \frac{5 - 0{,}5[\mathrm{V}]}{8[\mathrm{mA}]} = \frac{4{,}5[\mathrm{V}]}{8[\mathrm{mA}]} = 562\Omega.$$

$$R_3 = \frac{V_{CC} - U_S - U_{OLmaxLS}}{I_S} = \frac{5 - 1{,}5 - 0{,}5[\mathrm{V}]}{10[\mathrm{mA}]} = \frac{3[\mathrm{V}]}{10[\mathrm{mA}]} = 300\Omega.$$

R_1 = 301 to 1898 Ω. R_2 can't be calculated, because R_{2max}<R_{2min}. R_3 is not correct either, because I_{OL}<I_S.

for Y and Z gates of higher load (e.g., TTL) we get:

$$R_{2min} = \frac{V_{CC} - U_{OLmaxTTL}}{I_{OLmaxTTL}} = \frac{5 - 0{,}4[\mathrm{V}]}{16[\mathrm{mA}]} = \frac{4{,}6[\mathrm{V}]}{16[\mathrm{mA}]} = 287\Omega,$$

while R_3 remains the same, but in this case it's correct.

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ex.5

CMOS powered from $V_{DD}>V_{CC}$