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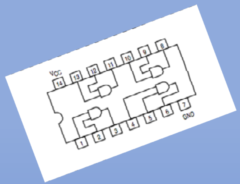
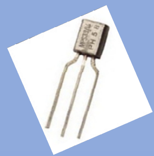
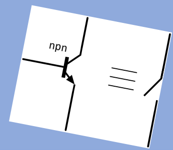
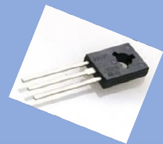
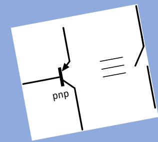
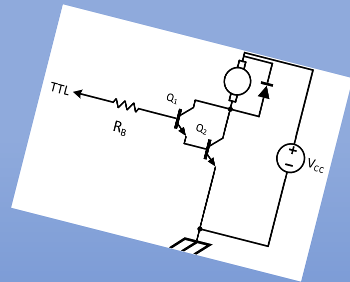




Acionamento de Motores de Corrente Contínua de Baixa Potência


Prof. Antonio José Bento Bottion, Dr.

Alunos BIC-Jr:

Júlia Gandini Blahun

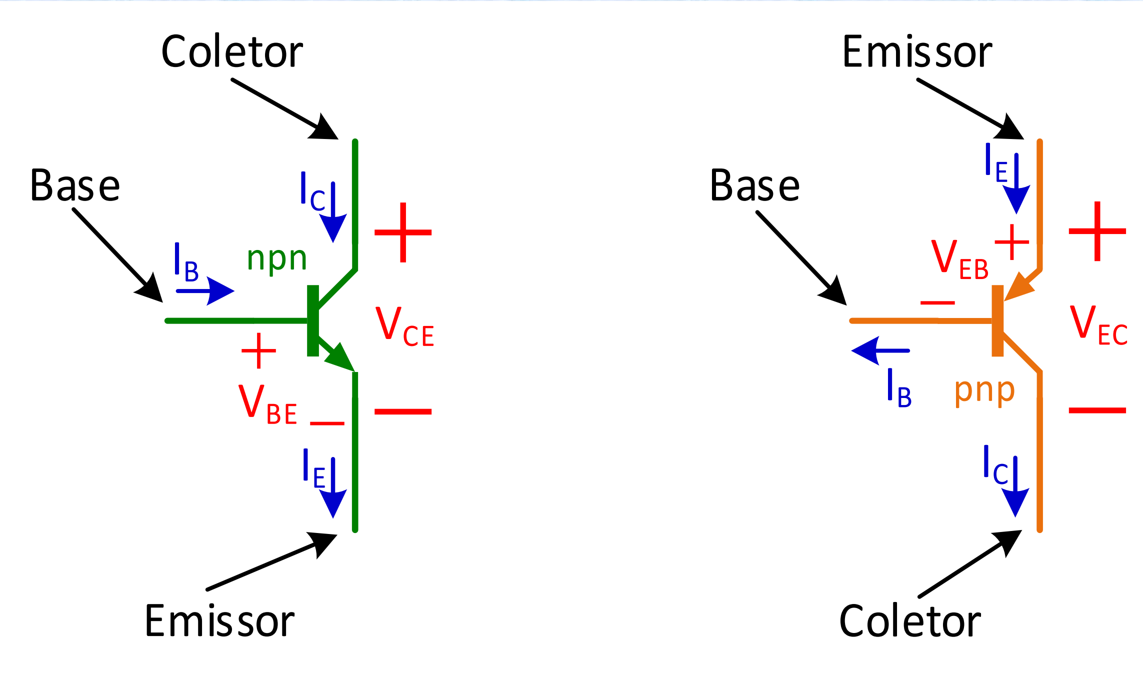
Lucas Emanuel Resck Domingues

Organização

- Transistores de Junção Bipolar (TJB)
- TJB Como Chave
- Motores de Baixa Potência
- Circuitos Driver
- Exemplo de Projeto
- Interface TTL – Driver (Digital-Analógica)
- Ponte H

Transistores de Junção Bipolar

Possibilidades:



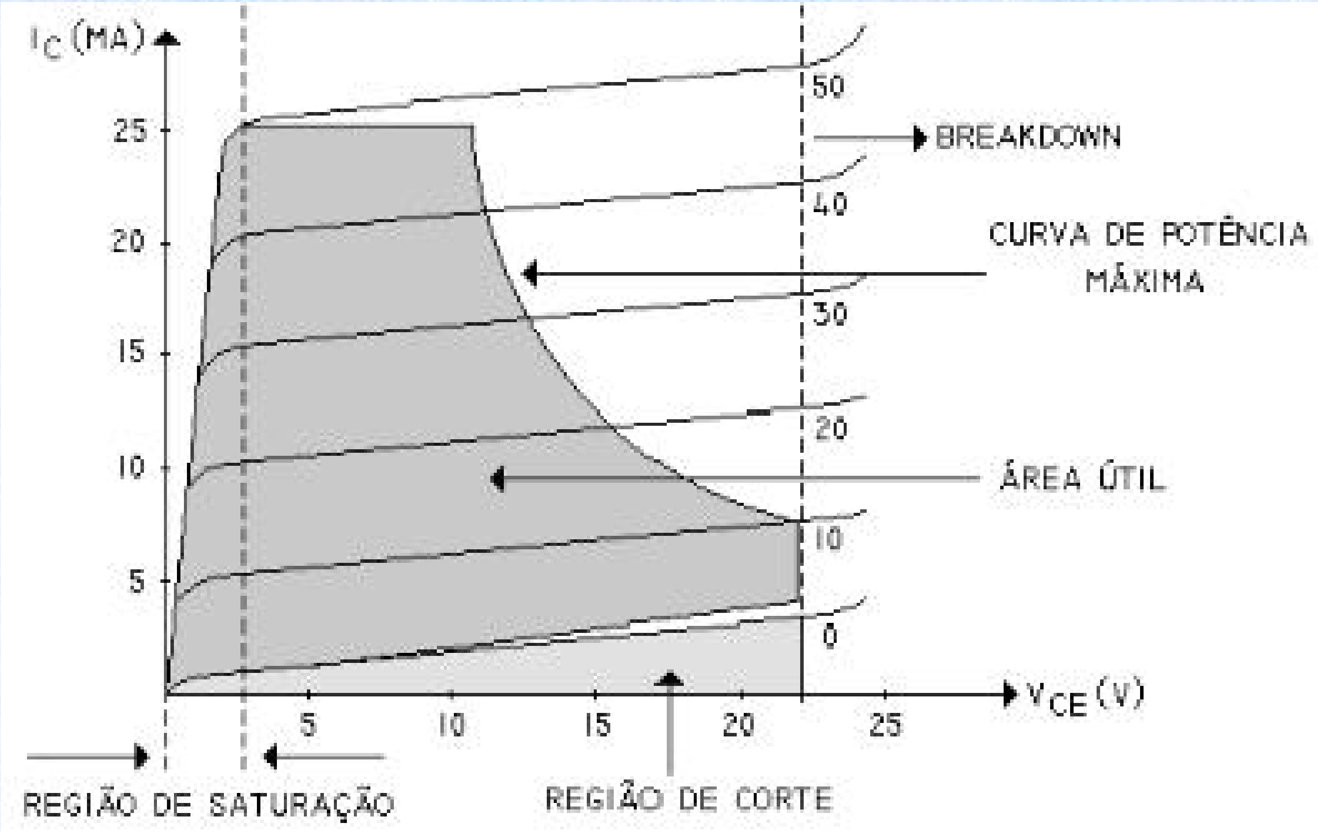
$I_E = I_C + I_B$ $\qquad$ $I_C = \beta I_B$

$\beta > 100 \quad \rightarrow \quad I_E \approx I_C$

Modos de Operação:

- Corte
- Ativo
- Saturação

Transistores de Junção Bipolar



Transistores de Junção Bipolar

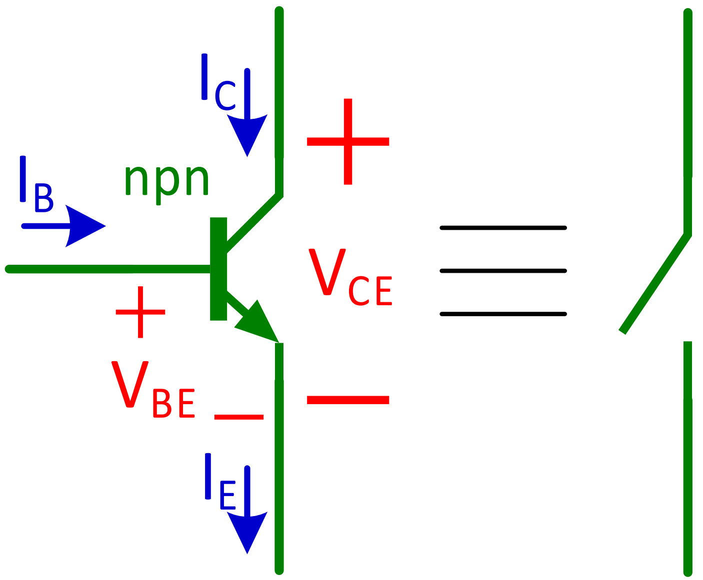
Aspecto físico:

TO-92

TO-220

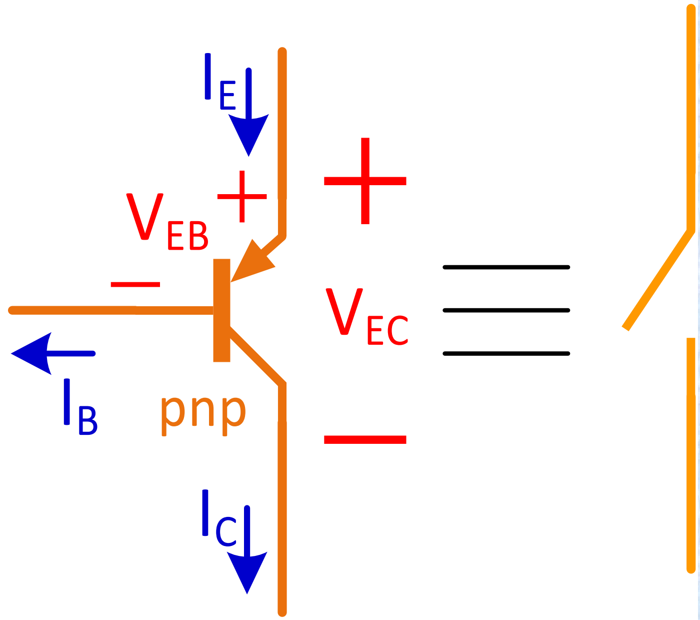
TO-18

TJB Como Chave

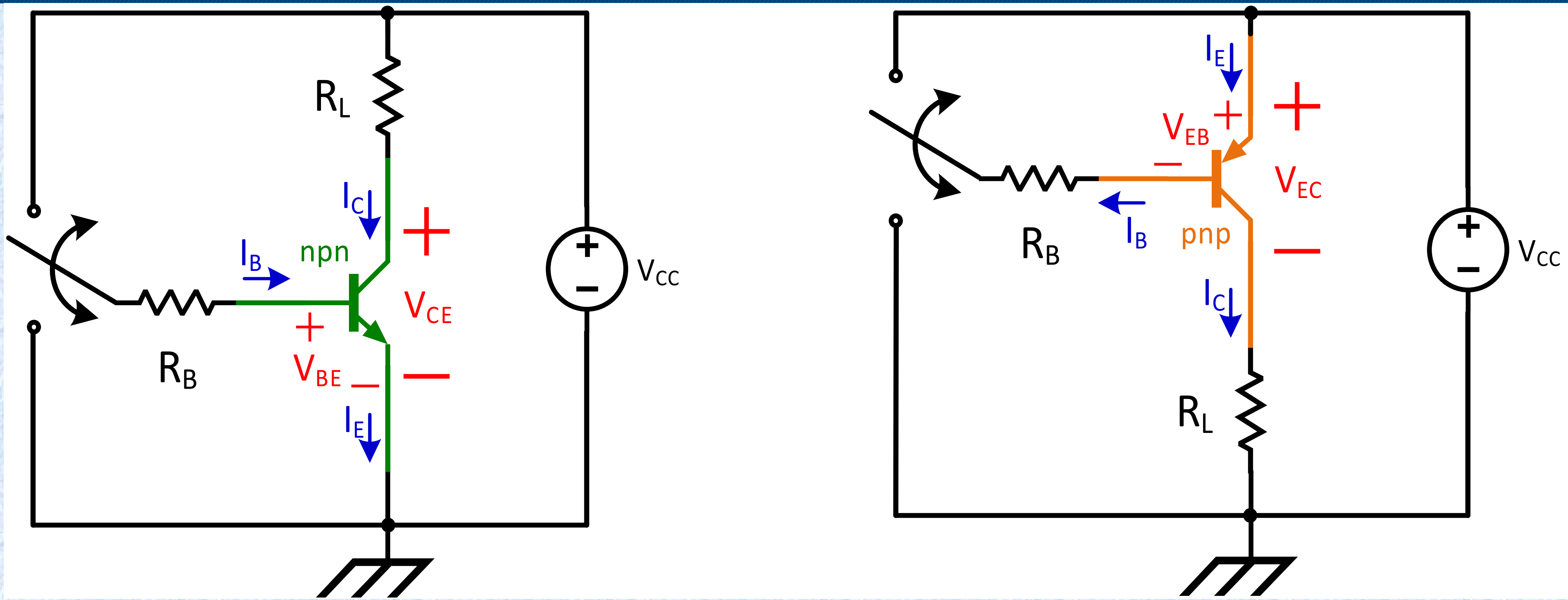


Modos de Operação:

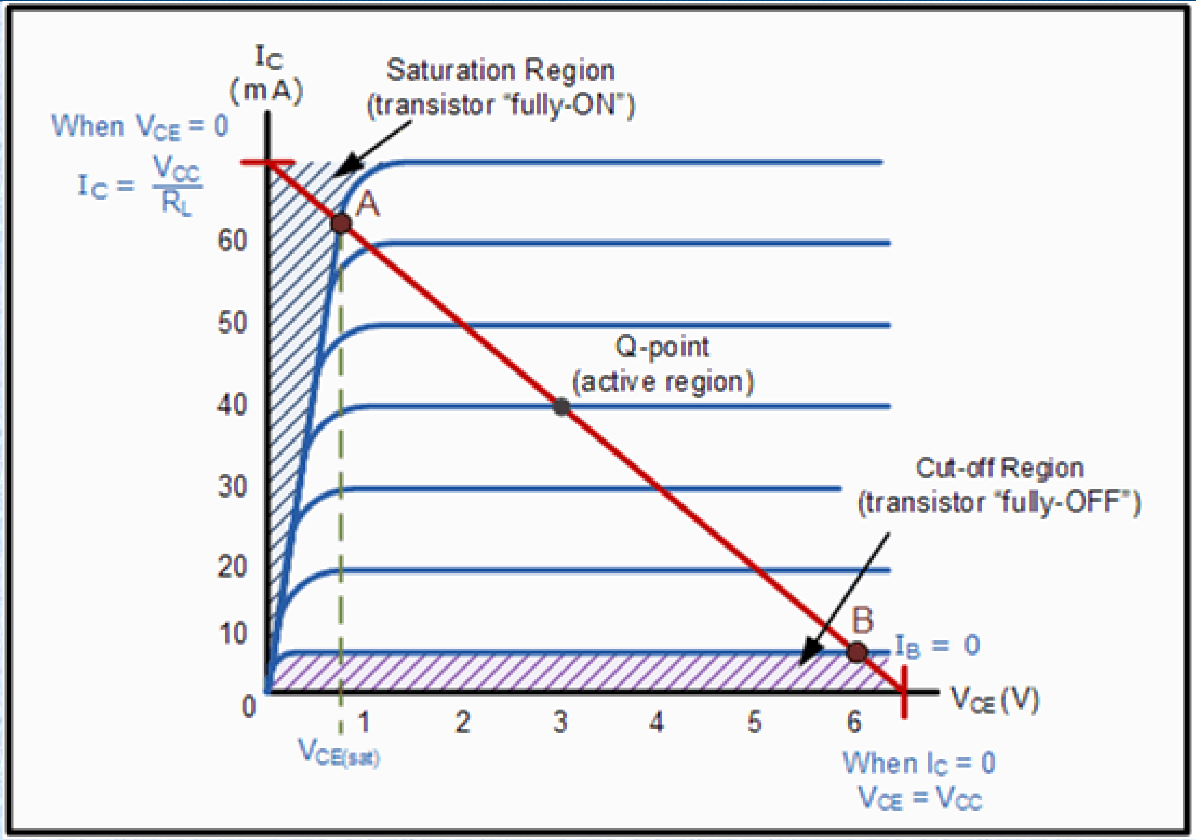
- Corte
- Saturação



TJB Como Chave

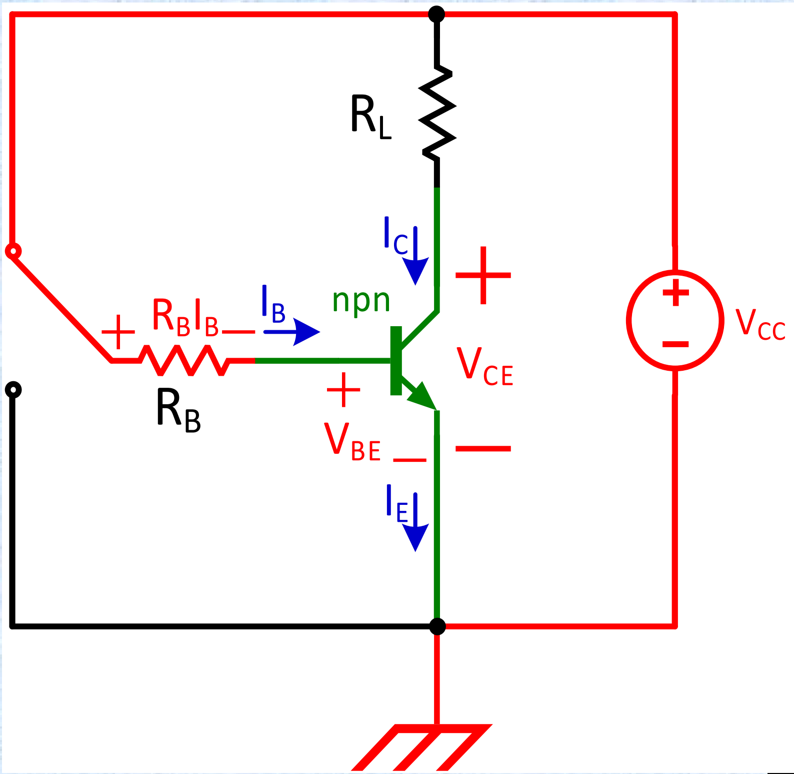


TJB Como Chave



TJB Como Chave

npn "on":



$$I_{B\_sat\_mín} = \frac{I_{C\_máx}}{\beta}$$ Para saturação fraca

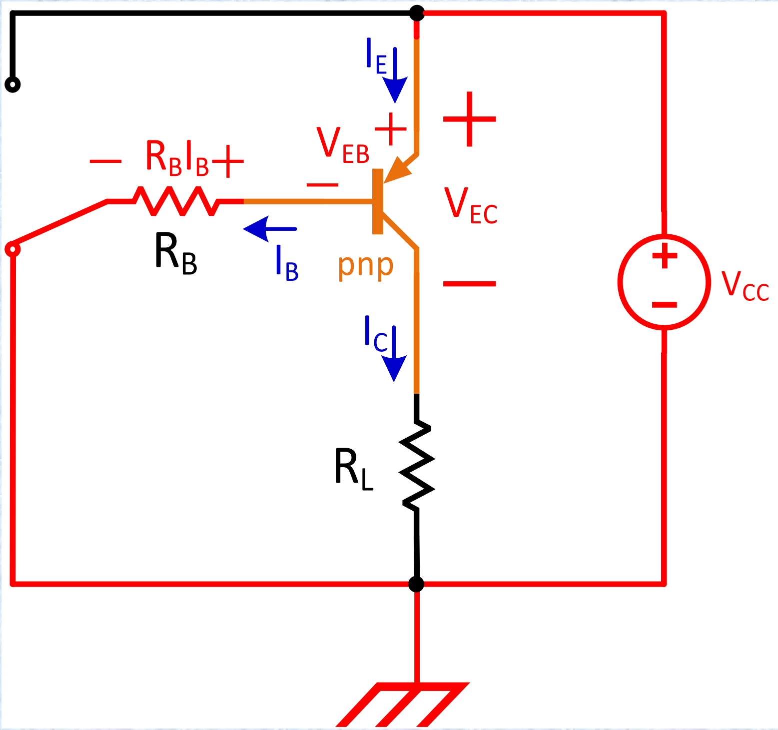
$$\beta_{sat} < \beta$$ Para garantir saturação

$$I_{B\_sat} = \frac{I_{C\_máx}}{\beta_{sat}} \Rightarrow I_{C\_máx} = \frac{V_{CC}}{R_L}$$

$$V_{CC} - R_B I_{B\_sat} - V_{BE} = 0 \Rightarrow R_B = \frac{V_{CC} - V_{BE}}{I_{B\_sat}}$$

TJB Como Chave

pnp “on”:



$$I_{B\_sat\_mín} = \frac{I_{C\_máx}}{\beta}$$ Para saturação fraca

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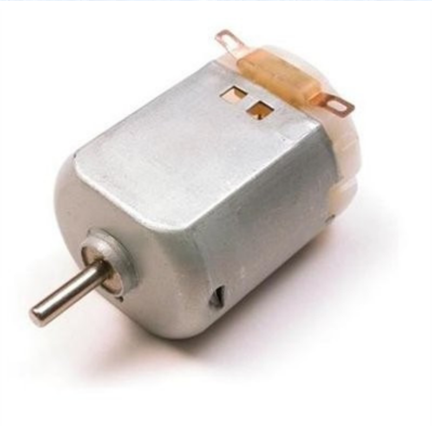
$$V_{CC} - R_B I_{B\_sat} - V_{EB} = 0 \Rightarrow R_B = \frac{V_{CC} - V_{EB}}{I_{B\_sat}}$$

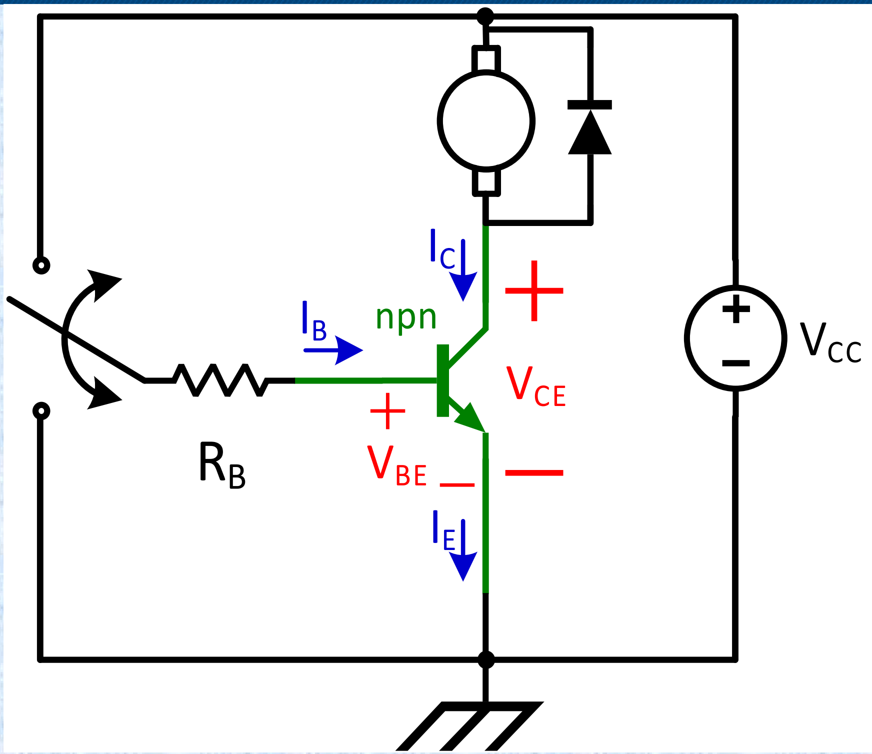
Motores de Baixa Potência



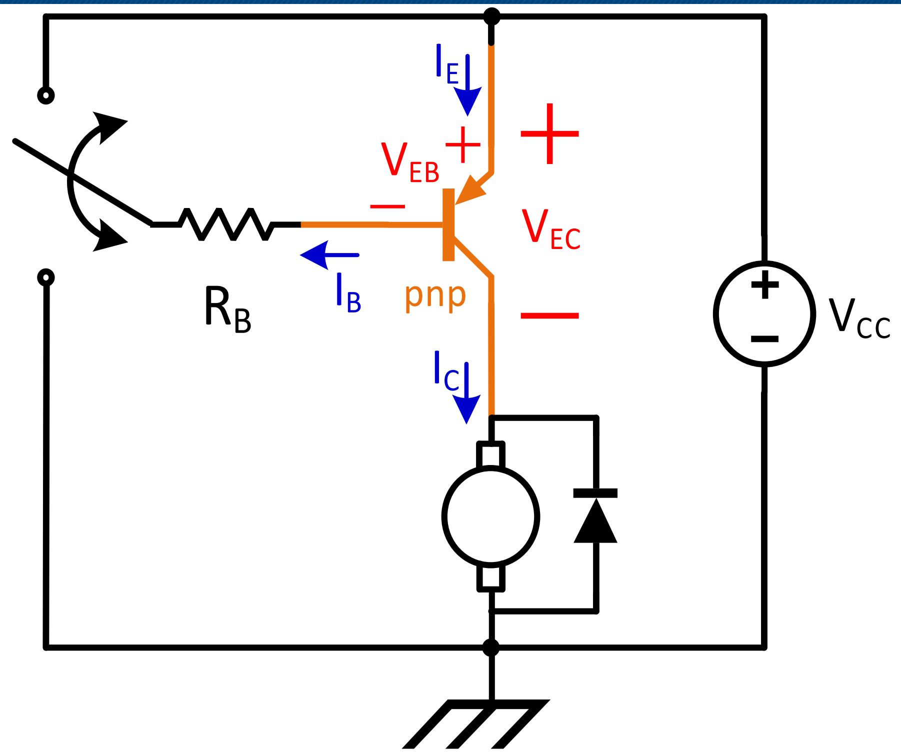
Valores típicos:

Tensão [V]	Corrente [mA]	RPM	Potência [W]
5	100 - 200	9500	0,5 - 1
9	250 - 500	16000	2,25 - 4,5

Circuitos Driver



Lógica Direta



Lógica Inversa

Projeto

- 1º Definir o motor e conhecer sua corrente nominal I_N;
- 2º Definir a lógica de acionamento:
  - Se direta -> npn
  - Se inversa -> pnp
- 3º Determinar o transistor;
- 4º Determinar I_B usando β_{sat} e I_N;
- 5º Calcular R_B.

Exemplo de Projeto

Dados do motor:

Tensão [V]	Corrente [mA]	RPM	Potência [W]
5	200	9500	1

Lógica direta: npn.

Transistor npn: 2N2222

Definindo $\beta_{sat} = 50$

$$I_{B\_sat} = \frac{200.10^{-3}}{50} = 4mA$$

$$R_B = \frac{5 - 1{,}3}{4.10^{-3}} = 925\Omega$$

SYMBOL	PARAMETER	CONDITIONS	MIN.	MAX.	UNIT
V_{CBO}	collector-base voltage	open emitter			
	2N2222		–	60	V
	2N2222A		–	75	V
V_{CEO}	collector-emitter voltage	open base			
	2N2222		–	30	V
	2N2222A		–	40	V
I_C	collector current (DC)		–	800	mA
P_{tot}	total power dissipation	$T_{amb} \leq 25$ °C	–	500	mW
h_{FE}	DC current gain	$I_C = 10$ mA; $V_{CE} = 10$ V	75	–	
f_T	transition frequency	$I_C = 20$ mA; $V_{CE} = 20$ V; f = 100 MHz			
	2N2222		250	–	MHz
	2N2222A		300	–	MHz
t_{off}	turn-off time	$I_{Con} = 150$ mA; $I_{Bon} = 15$ mA; $I_{Boff} = -15$ mA	–	250	ns

PINNING

PIN	DESCRIPTION
1	emitter
2	base
3	collector, connected to case

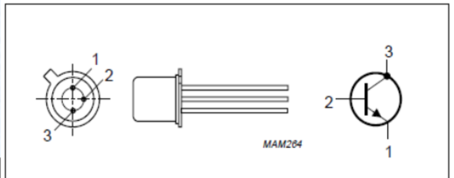
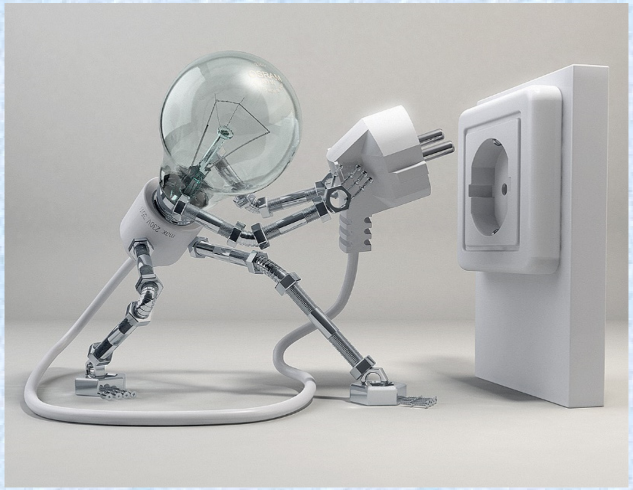


Fig.1 Simplified outline (TO-18) and symbol.

V_{CEsat}	collector-emitter saturation voltage				
	2N2222	$I_C = 150$ mA; $I_B = 15$ mA; note 1	–	400	mV
		$I_C = 500$ mA; $I_B = 50$ mA; note 1	–	1.6	V
V_{CEsat}	collector-emitter saturation voltage				
	2N2222A	$I_C = 150$ mA; $I_B = 15$ mA; note 1	–	300	mV
		$I_C = 500$ mA; $I_B = 50$ mA; note 1	–	1	V
V_{BEsat}	base-emitter saturation voltage				
	2N2222	$I_C = 150$ mA; $I_B = 15$ mA; note 1	–	1.3	V
		$I_C = 500$ mA; $I_B = 50$ mA; note 1	–	2.6	V
V_{BEsat}	base-emitter saturation voltage				
	2N2222A	$I_C = 150$ mA; $I_B = 15$ mA; note 1	0.6	1.2	V
		$I_C = 500$ mA; $I_B = 50$ mA; note 1	–	2	V

Um Problema

?!?!

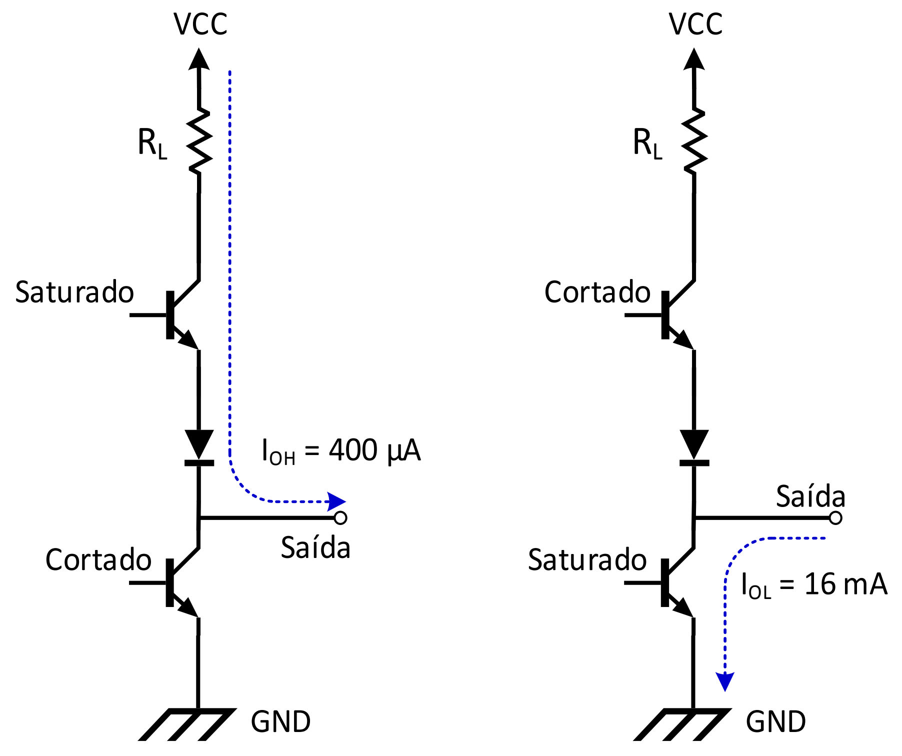


A porta TTL

Características de la familia TTL

parámetro	unidad	74	74L	74H	74S	74LS	74AS	74ALS
t_p	ns	9	33	6	3	9	1.6	5
P_d	mW	10	1	22	20	2	20	1.3
P.V	pJ	90	33	132	60	18	32	6.5
V_{ILmax}	V	0.8	0.7	0.8	0.8	0.8	0.8	0.8
V_{OLmax}	V	0.4	0.4	0.4	0.5	0.5	0.5	0.5
V_{IHmin}	V	2.0	2.0	2.0	2.0	2.0	2.0	2.0
V_{OHmin}	V	2.4	2.4	2.4	2.7	2.7	2.7	2.7
I_{ILmax}	mA	-1.6	-0.18	-2.0	-2.0	-0.4	-2.0	-0.2
I_{OLmax}	mA	16	3.6	20	20	8	20	8
I_{IHmax}	µA	40	10	50	50	20	200	20
I_{OHmax}	µA	-400	-200	-500	-1000	-400	-2000	-400

Pd = Consumo de potencia por compuerta, P.V = producto de potencia-velocidad



Possibilidades

- Uso de lógica inversa direto;
- Uso de lógica direta e par Darlington;
- Uso de lógica direta e seguidor de tensão com AMPOP;
- Uso de lógica direta e buffer TTL.

Lógica Inversa Direto

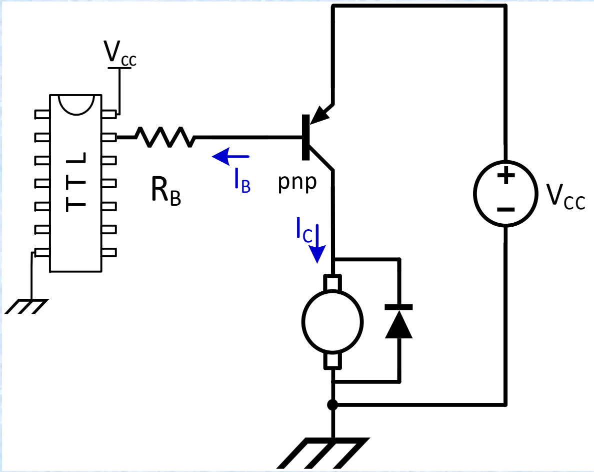
Dados do motor:

Tensão [V]	Corrente [mA]	RPM	Pot. [W]
5	200	9500	1

Definindo $\beta_{sat} = 50$

$$I_{B\_sat} = \frac{200.10^{-3}}{50} = 4mA$$

$$R_B = \frac{5-1,3}{4.10^{-3}} = 925\Omega$$



Transistor pnp: PN2907

			Mín	Máx	Unit
h_{FE}	DC current gain	V_{CE} = –10 V; I_C = –0.1 mA	75	–	
		V_{CE} = –10 V; I_C = –1 mA	100	–	
		V_{CE} = –10 V; I_C = –10 mA	100	–	
		V_{CE} = –10 V; I_C = –150 mA	100	300	
		V_{CE} = –10 V; I_C = –500 mA	50	–	
V_{CEsat}	collector-emitter saturation voltage	I_C = –150 mA; I_B = –15 mA	–	–400	mV
		I_C = –500 mA; I_B = –50 mA	–	–1.6	V
V_{BEsat}	base-emitter saturation voltage	I_C = –150 mA; I_B = –15 mA	–	–1.3	V
		I_C = –150 mA; I_B = –50 mA	–	–2.6	V

Lógica Direta e Par Darlington

Dados do motor:

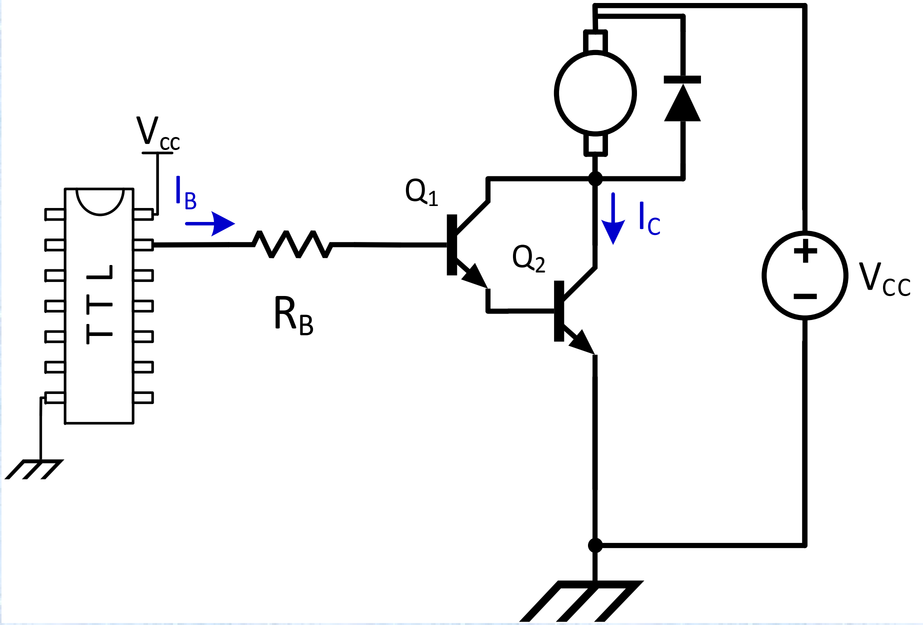
Tensão [V]	Corrente [mA]	RPM	Pot. [W]
5	200	9500	1

Transistores npn: 2N2222

Definindo $\beta_{sat} = 50$

$\beta_{total} = 50*50 = 2500$

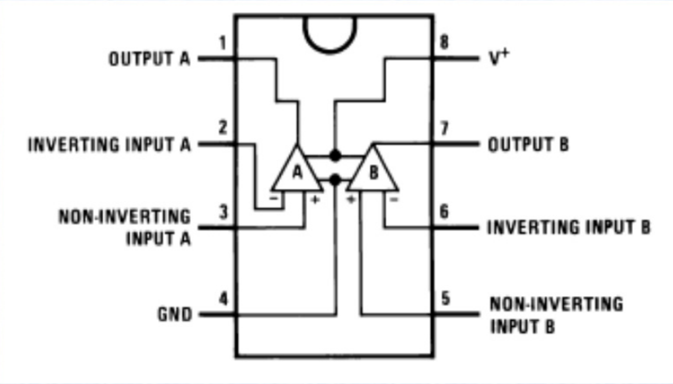
$$I_{B\_sat} = \frac{200.10^{-3}}{2500} = 80\mu A$$

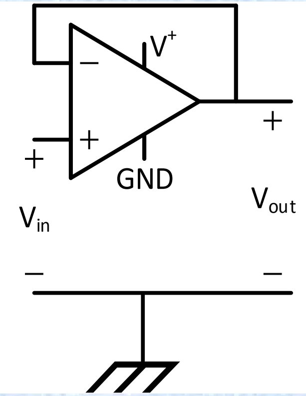


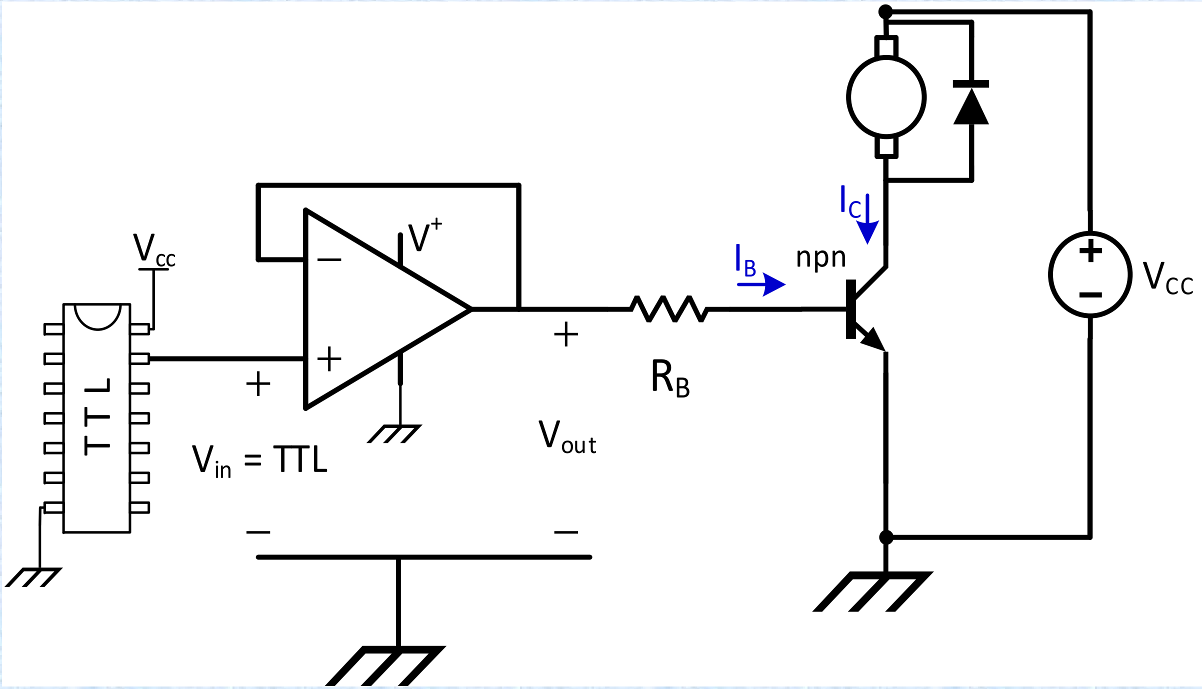
$$R_B = \frac{5 - 2*(1,3)}{80.10^{-6}} = 30k\Omega$$

Lógica Direta e Seguidor de Tensão

Amplificador operacional: LM358

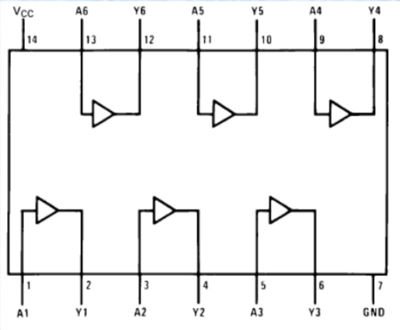




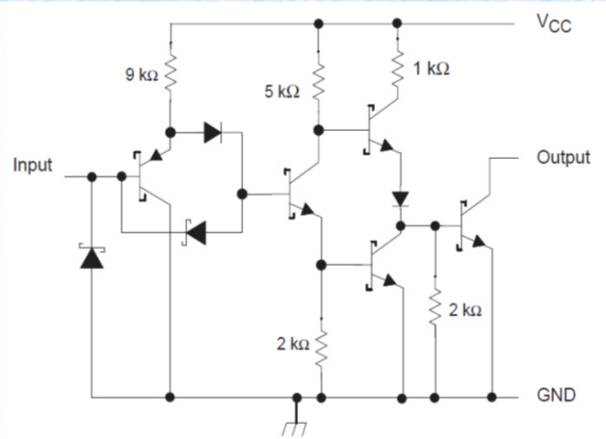


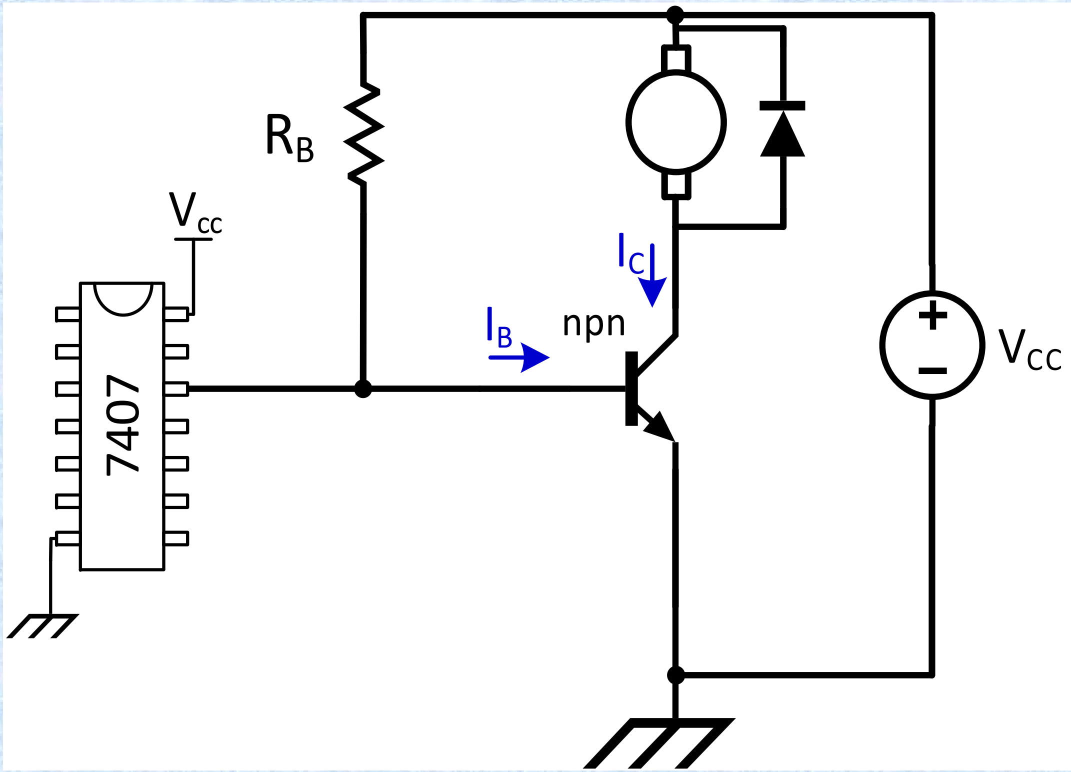
Lógica Direta e Buffer TTL

Buffer TTL: 7407



Saída em coletor aberto:





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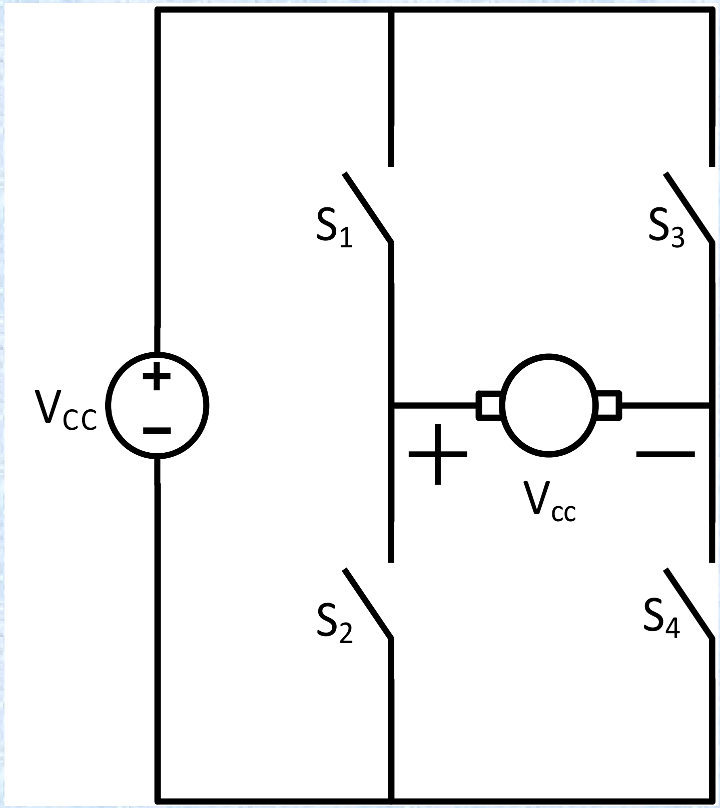
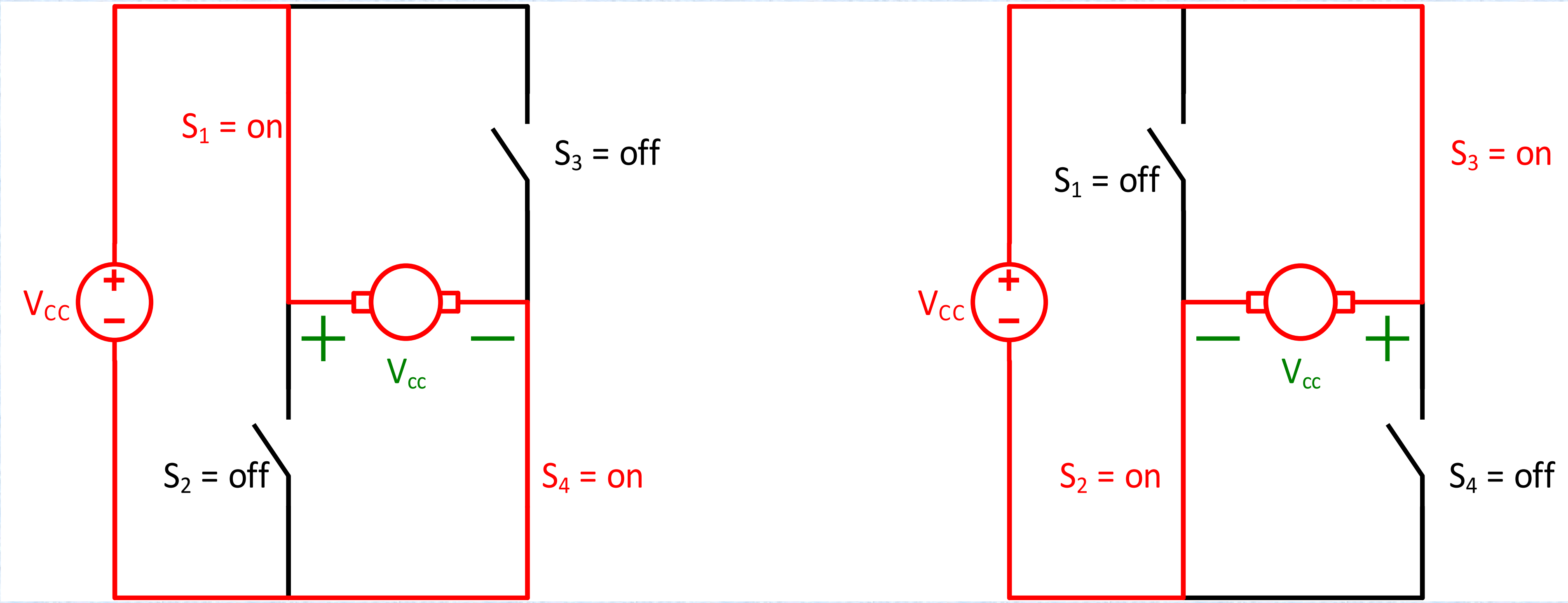
Ponte H

- Usa 4 transistores;
- Possibilita a inversão de rotação do motor.

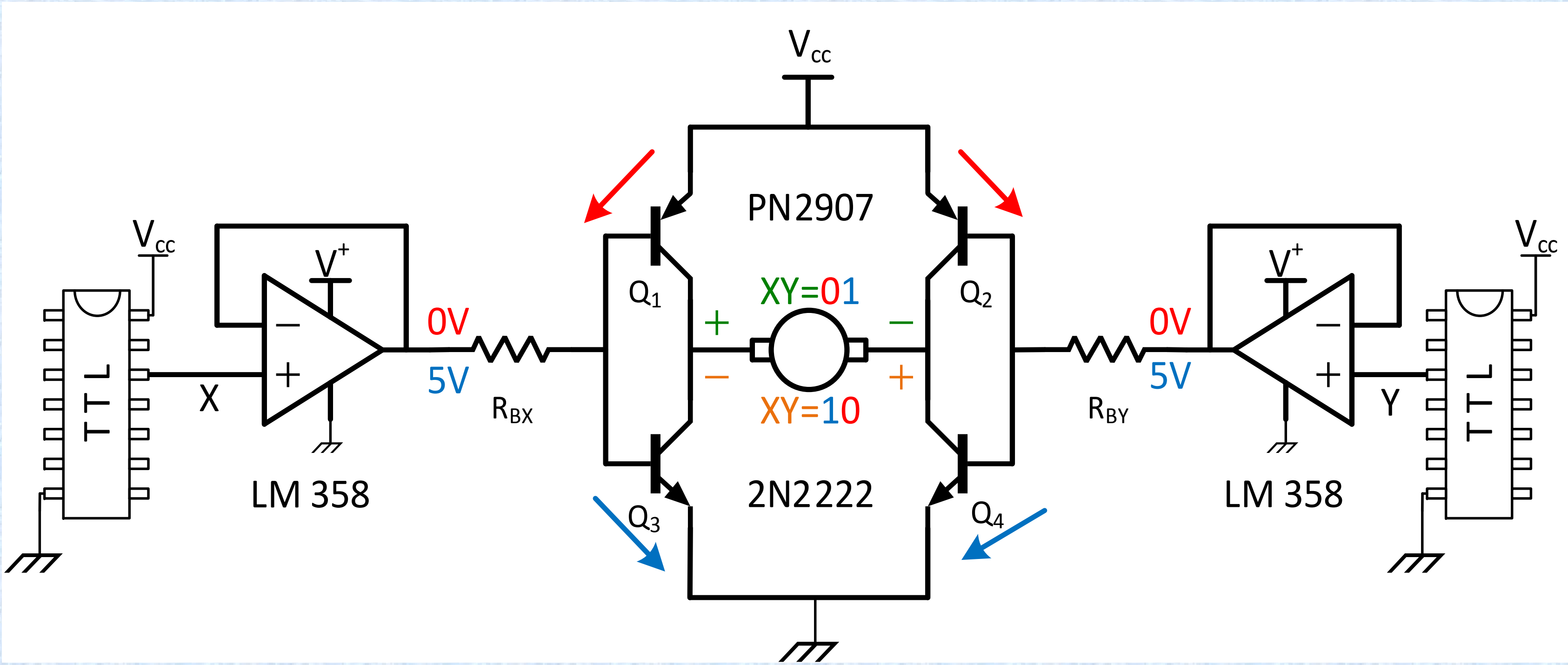


Ponte H: Funcionamento



Ponte H: Circuito Prático

X – Y – Giro
0 – 0 - Não
0 – 1 – Sim
1 – 0 – Sim
1 – 1 - Não



Obrigado pela sua atenção!