Various BJT Amplifiers (H.18)

20170613-2

References

Based

[1] Floyd, Electronic Devices 7th ed
[2] Cook,

[2] en.wikipedia.org

Robert Boylestad & Louis Nashelsky

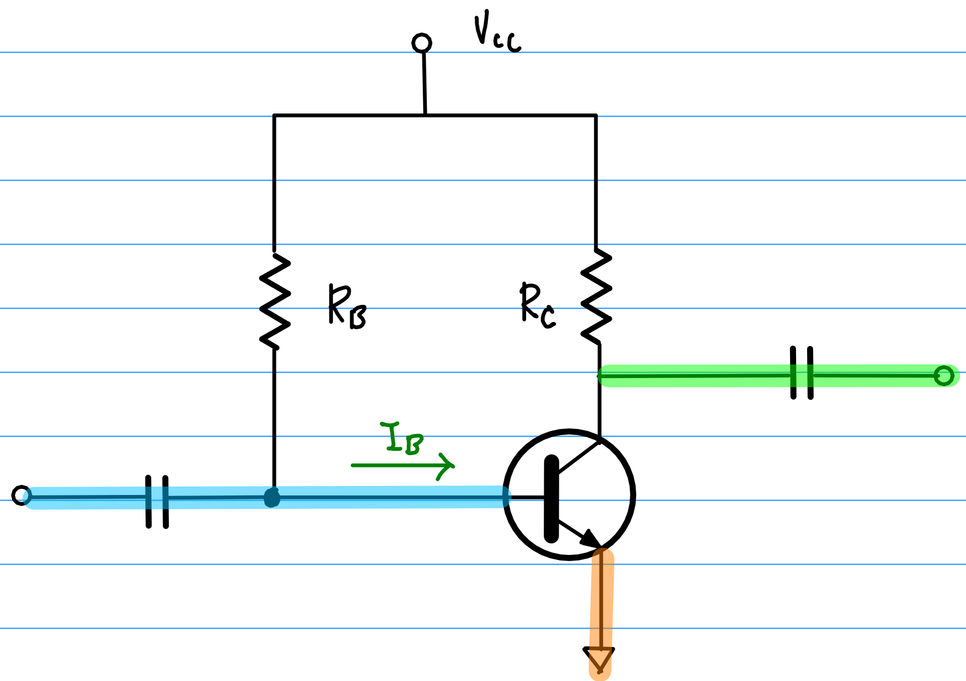
Electronic Devices and Circuit Theory (10th ed)

	Z_i	Z_o	A_v	A_i
1. Fixed Bias	βr_e	R_C	$-\frac{R_C}{r_e}$	β
2. Voltage Divider Bias	$R_1 \parallel R_2 \parallel \beta r_e$	R_C	$-\frac{R_C}{r_e}$	$\frac{\beta (R_1 \parallel R_2)}{R_1 \parallel R_2 + \beta r_e}$
3. Unbypass Emitter Bias	$R_B \parallel \beta R_E$	R_C	$-\frac{R_C}{R_E}$	$-\frac{\beta R_B}{R_B + \beta(r_e + R_E)}$
4. Emitter Follower	$R_B \parallel \beta R_E$	r_e	1	$-\frac{\beta R_B}{R_B + \beta(r_e + R_E)}$
5. Common Base	r_e	R_C	$\frac{R_C}{r_e}$	-1
6. Collector Feedback	$\frac{r_e}{1/\beta + R_C/R_F}$	$R_C \parallel R_F$	$-\frac{R_C}{r_e}$	$\frac{R_F}{R_C}$

	Z_i	Z_o	A_v	A_i
1. Fixed Bias	Med (1kΩ)	Med (2kΩ)	High (-200)	High (100)
2. Voltage Divider Bias	Med (1kΩ)	Med (2kΩ)	High (-200)	High (50)
3. Unbypass Emitter Bias	High (100kΩ)	Med (2kΩ)	Low (-5)	High (50)
4. Emitter Follower	High (100kΩ)	Low (20Ω)	Low (1)	High (-50)
5. Common Base	Low (20Ω)	Med (2kΩ)	High (200)	Low (-1)
6. Collector Feedback	Med (1kΩ)	Med (2kΩ)	High (-200)	High (50)

① a

Fixed Bias



$$Z_i = R_B \parallel \beta r_e' \cong \beta r_e' \qquad \text{Medium } (1\,k\Omega)$$

$$R_B \geq 10\beta r_e'$$

$$Z_o = R_C \parallel r_o \cong R_C \qquad \text{Medium } (2\,k\Omega)$$

$$r_o \geq 10 R_C$$

$$A_v = -\frac{(R_C \parallel r_o)}{r_e} \cong -\frac{R_C}{r_e} \qquad \text{High } (-200)$$

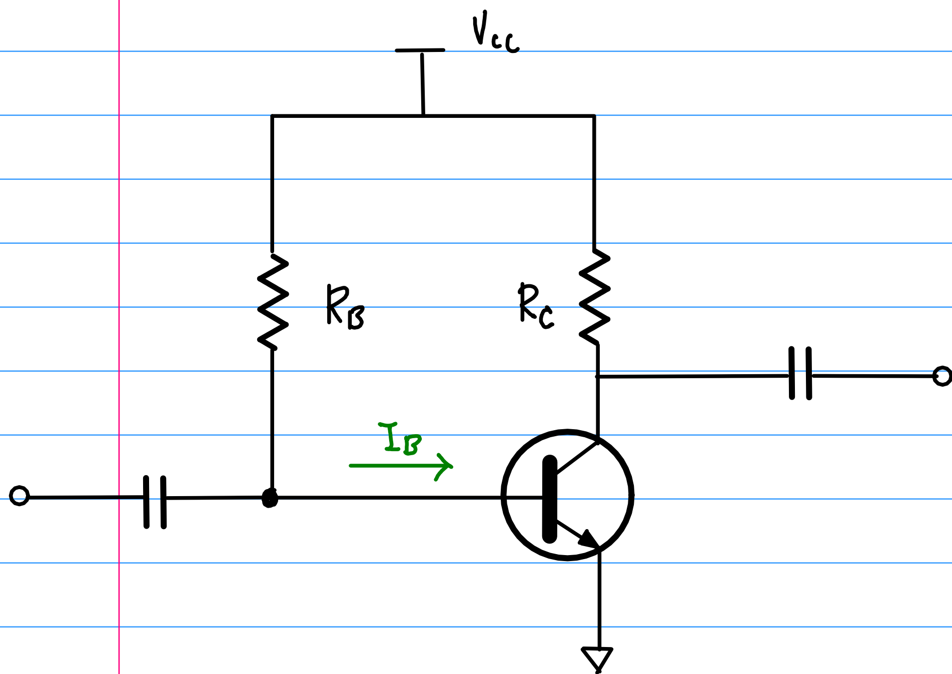
$$r_o \geq 10 R_C$$

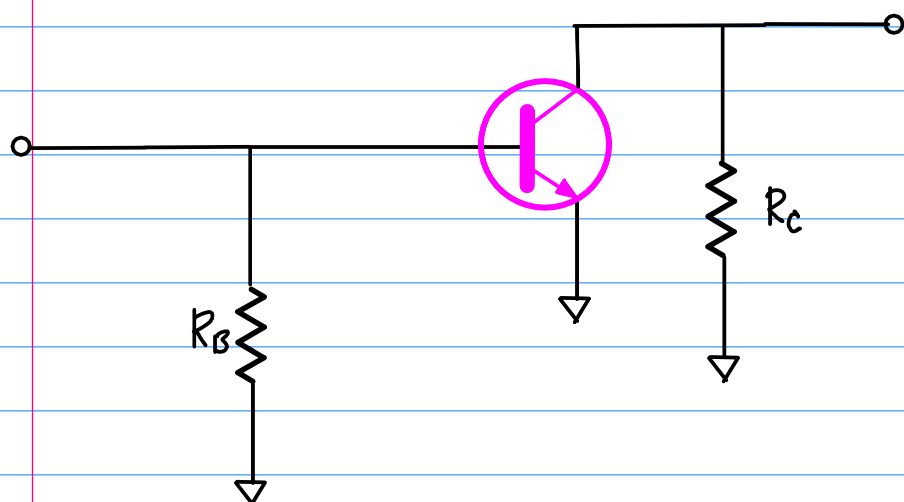
$$A_i = \frac{\beta R_B r_o}{(r_o + R_C)(R_B + \beta r_e)} \cong \beta \qquad \text{High } (100)$$

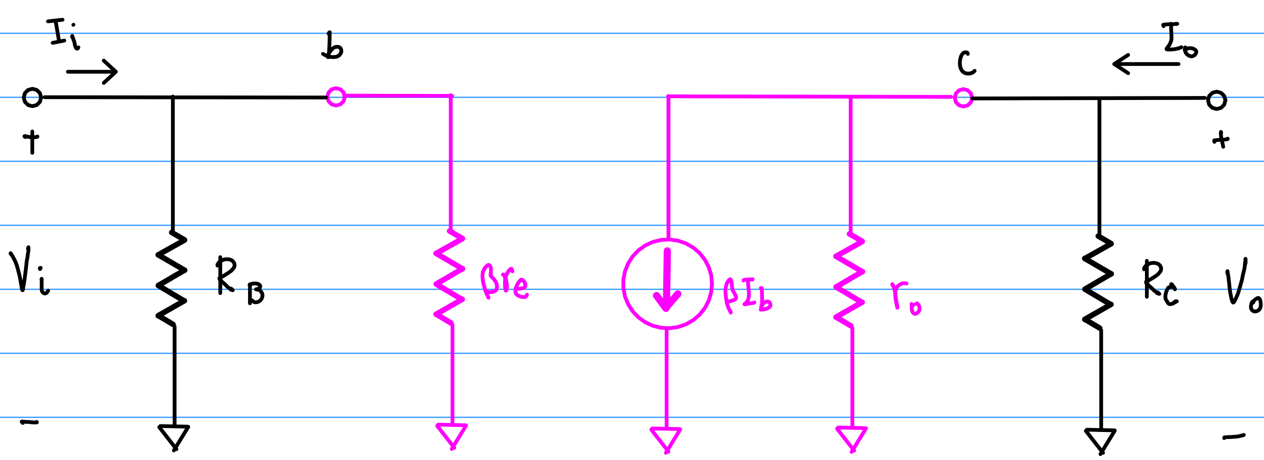
$$R_B \geq 10\beta r_e' \qquad r_o \geq 10 R_C$$

1

b

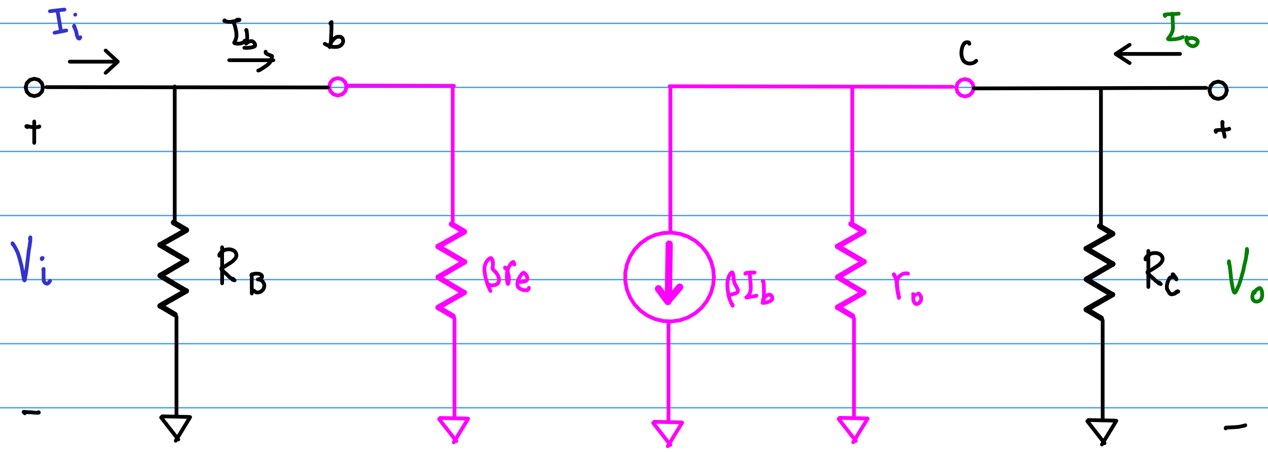






①

c



$Z_i = R_B \parallel \beta r_e \cong \beta r_e \qquad (R_B > 10\beta r_e)$

$Z_o = R_C \parallel r_o \cong R_C \qquad (R_C > 10 r_o)$

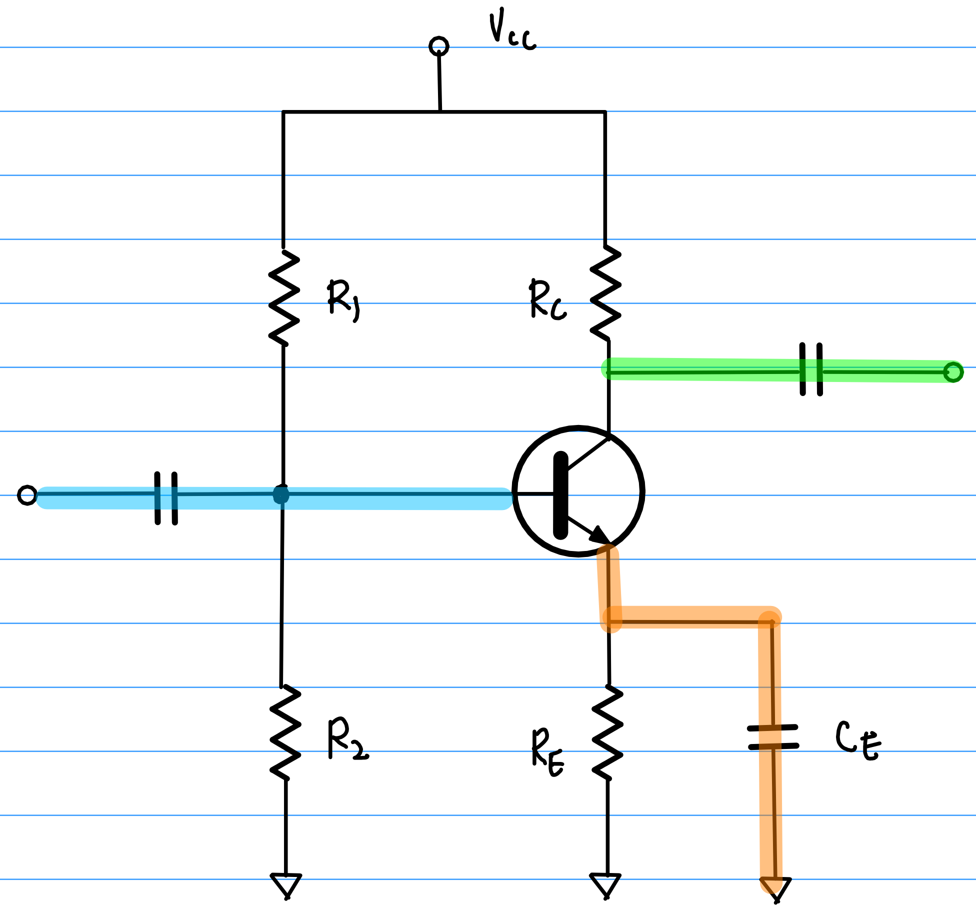
$V_o = -\beta I_b \, (R_C \parallel r_o)$

$V_i = I_b \cdot \beta r_e$

$$A_v = \frac{V_o}{V_i} = -\frac{R_C \parallel r_o}{r_e} \cong -\frac{R_C}{r_e} \qquad (R_C > 10 r_o)$$

(2) a

Voltage Divider Bias



$$Z_i = R_1 \| R_2 \| \beta r_e'$$ Medium (1 kΩ)

$$Z_o = R_C \| r_o \cong R_C$$ Medium (2 kΩ)

$r_o \geq 10 R_C$

$$A_v = -\frac{R_C \| r_o}{r_e'} \cong -\frac{R_C}{r_e'}$$ High (−200)

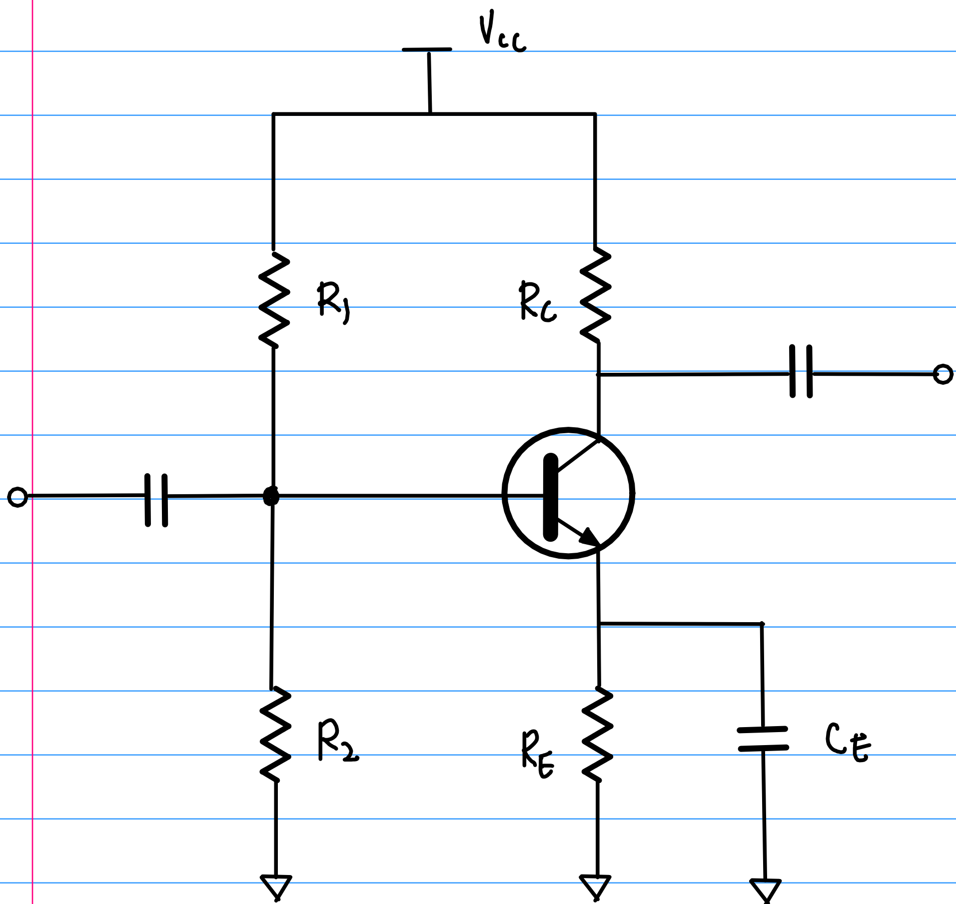
$r_o \geq 10 R_C$

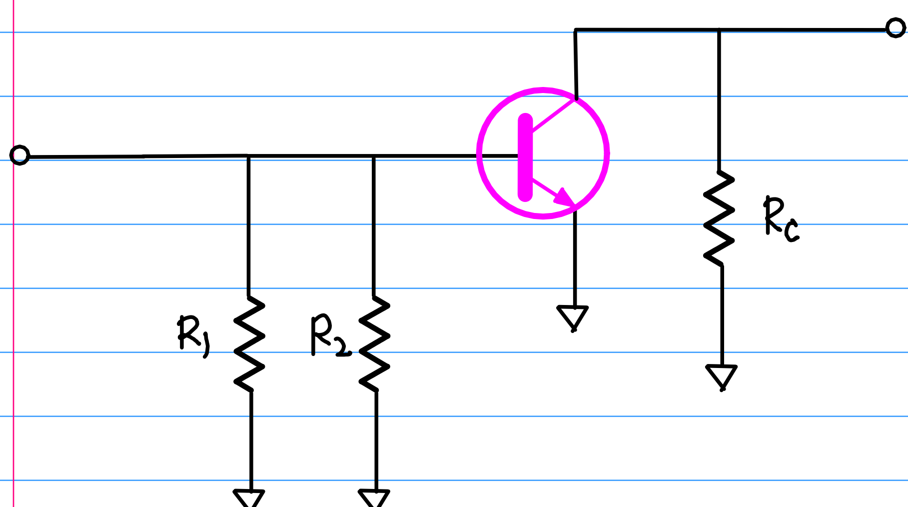
$$A_i = \frac{\beta (R_1 \| R_2) r_o}{(r_o + R_C)(R_1 \| R_2 + \beta r_e')} \cong \frac{\beta (R_1 \| R_2)}{R_1 \| R_2 + \beta r_e}$$ High (−50)

$r_o \geq 10 R_C$

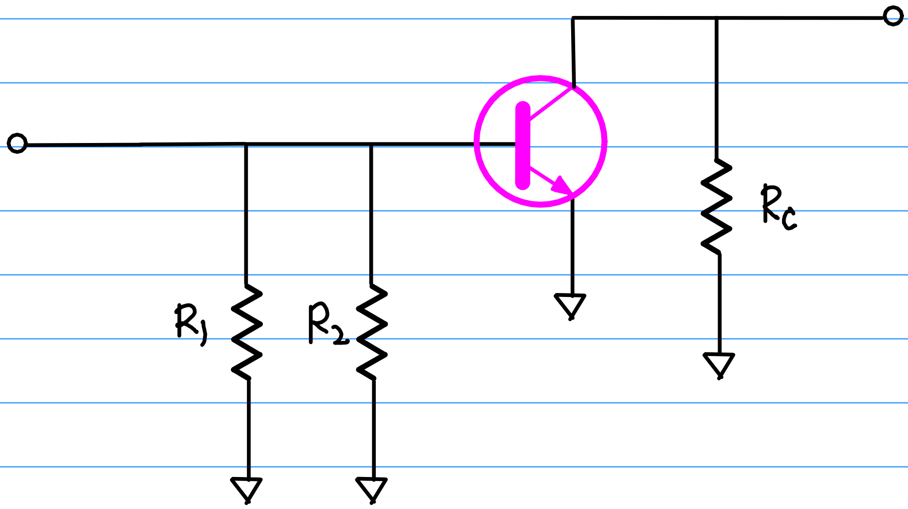
(2)

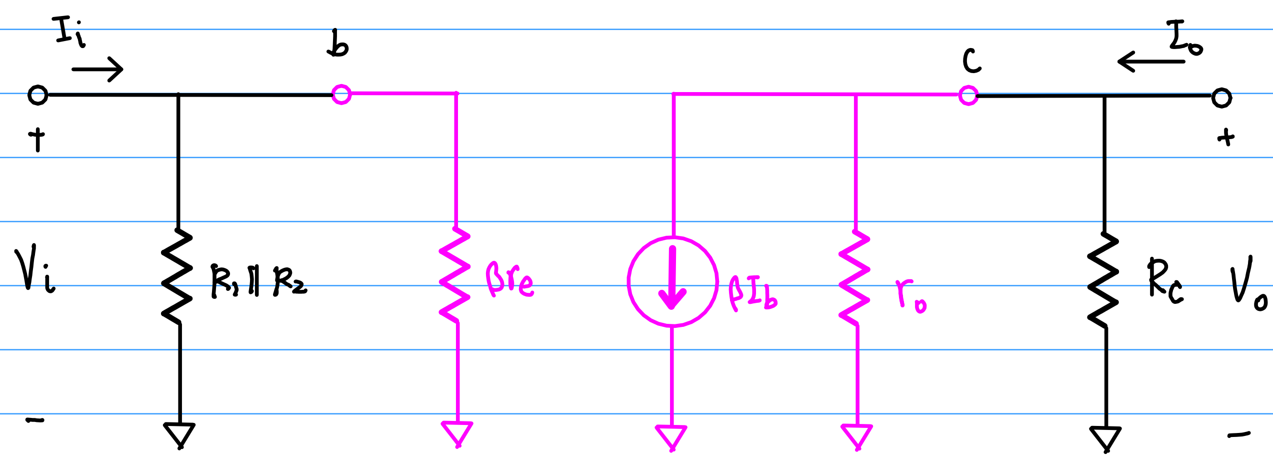
b





② c





$Z_i = R_1 \| R_2 \| \beta r_e$

$Z_o = R_c \| r_o \cong R_c \qquad (r_o > 10 R_c)$

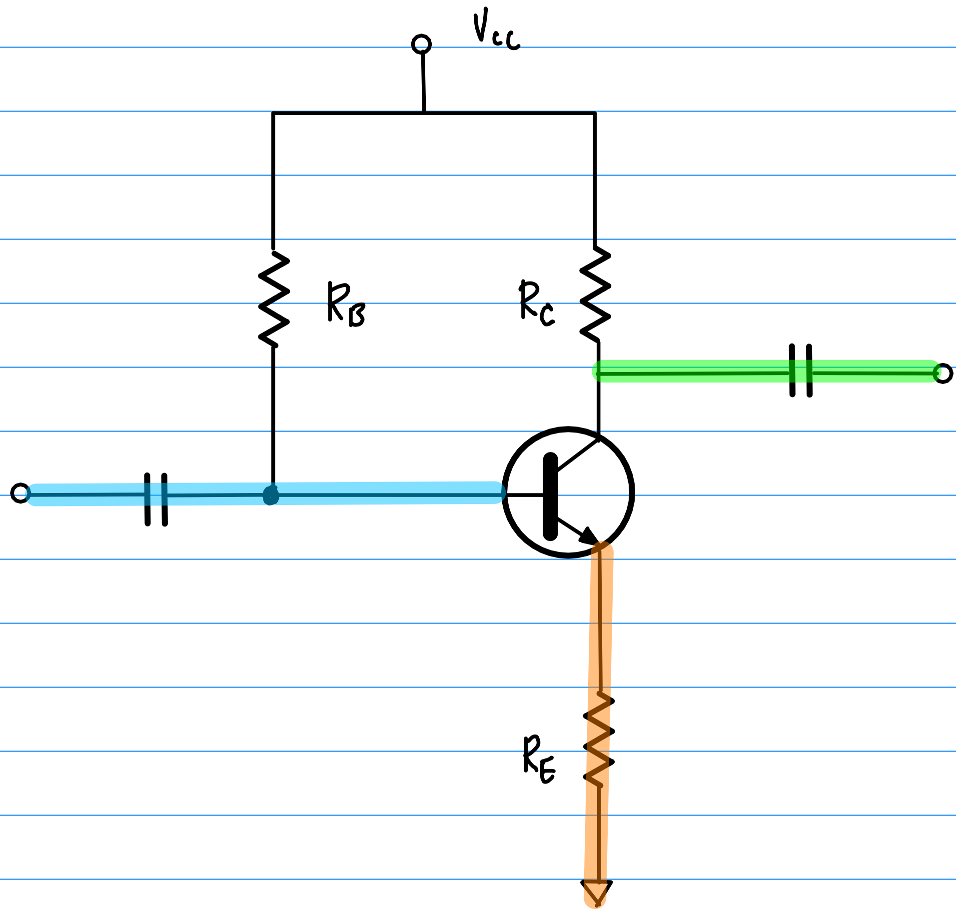
$V_o = -(\beta I_b)(R_c \| r_o)$

$V_i = (I_b)(\beta r_e)$

$A_v = \frac{V_o}{V_i} = -\frac{R_c \| r_o}{r_e} \cong -\frac{R_c}{r_e} \qquad (r_o > 10 R_c)$

③ a

Unbypassed Emitter Bias



$$Z_i = R_B \parallel \beta(r_e' + R_E) \cong R_B \parallel \beta R_E$$ High (100 kΩ)

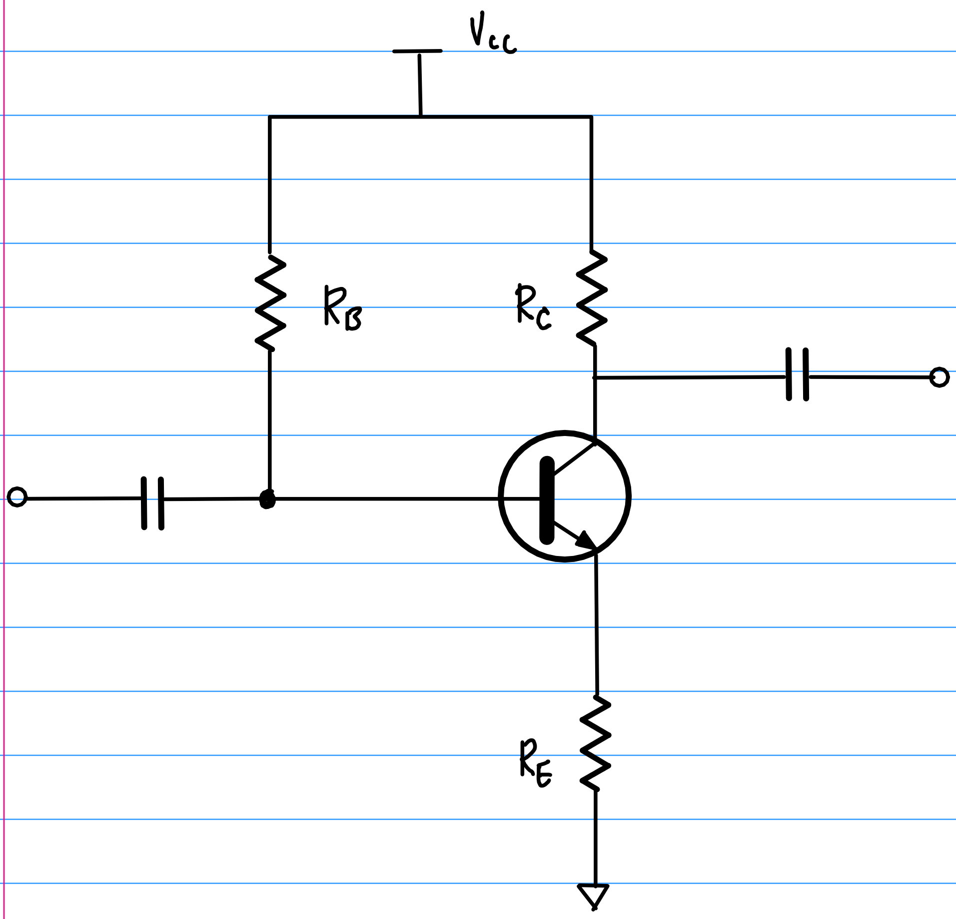
$R_E \gg r_e'$

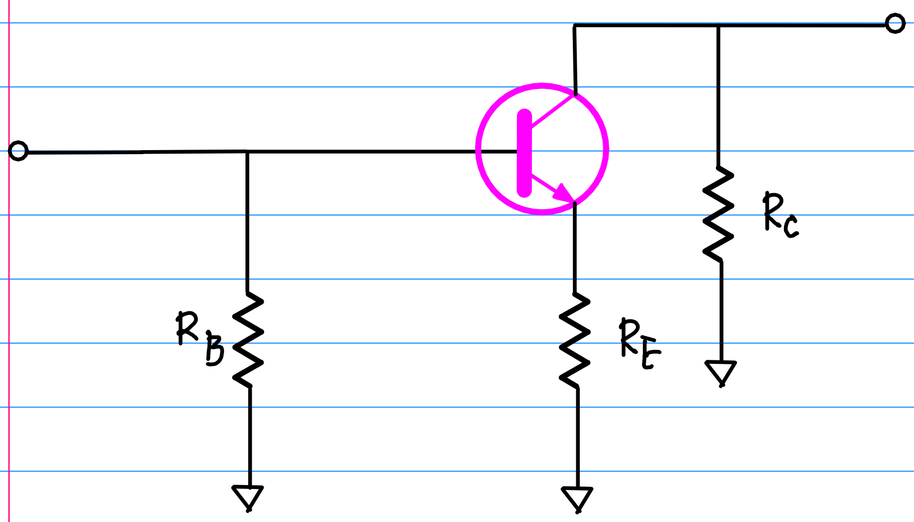
$$Z_o = R_C$$ Medium (2 kΩ)

$$A_v = -\frac{R_C}{r_e + R_E} \cong -\frac{R_C}{R_E}$$ Low (-5)

$$A_i = \frac{\beta R_B}{R_B + \beta(r_e' + R_E)}$$ High (50)

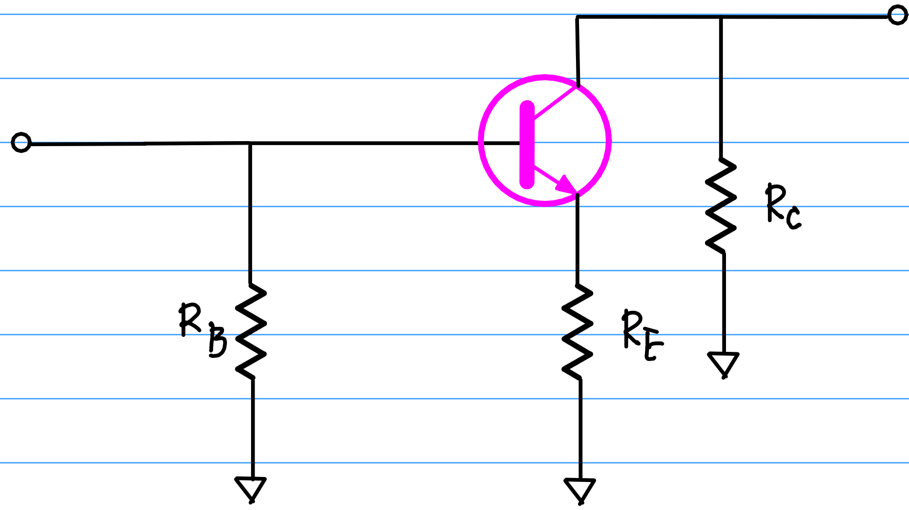
③
b

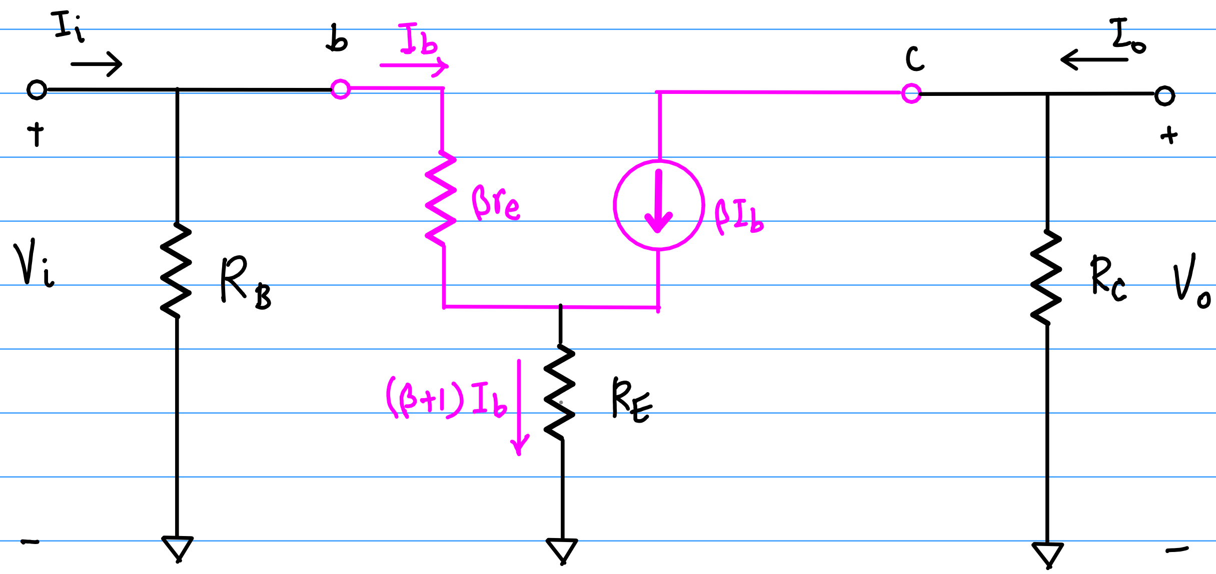




③

c





$$V_i = I_b(\beta r_e) + (\beta+1) I_b R_E$$

$$Z_b = \frac{V_i}{I_b} = \beta r_e + (\beta+1) R_E \cong \beta(r_e + R_E) \cong \beta R_E$$

$$Z_i = R_B \| Z_b \cong R_B \| \beta(r_e + R_E) \cong R_B \| \beta R_E$$

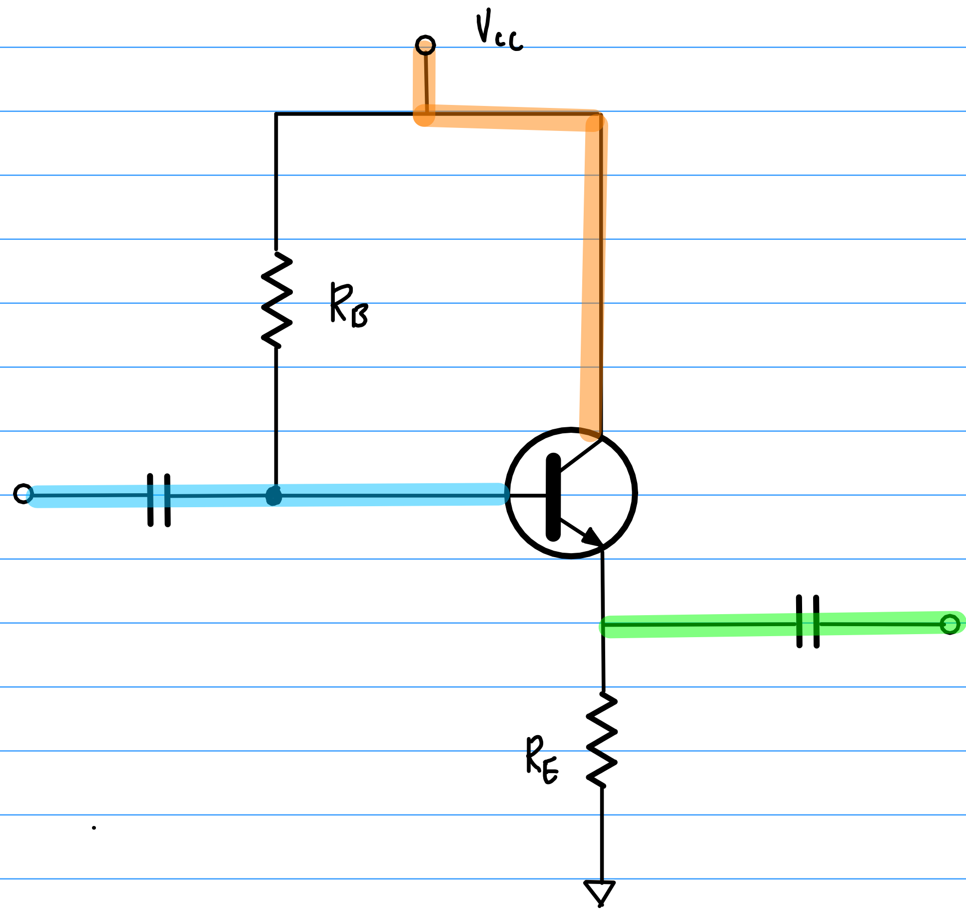
$$Z_o = R_C$$

$$V_o = -\beta I_b R_C = -\beta\left(\frac{V_i}{Z_b}\right) R_C$$

$$A_v = \frac{V_o}{V_i} = -\frac{\beta R_C}{Z_b} = -\frac{\beta R_C}{\beta(r_e + R_E)} = -\frac{R_C}{r_e + R_E} \cong -\frac{R_C}{R_E}$$

4 a

Emitter Follower



$$Z_i = R_B \parallel \beta(r'_e + R_E) \underset{R_E \gg r'_e}{\cong} R_B \parallel \beta R_E$$ High (100 kΩ)

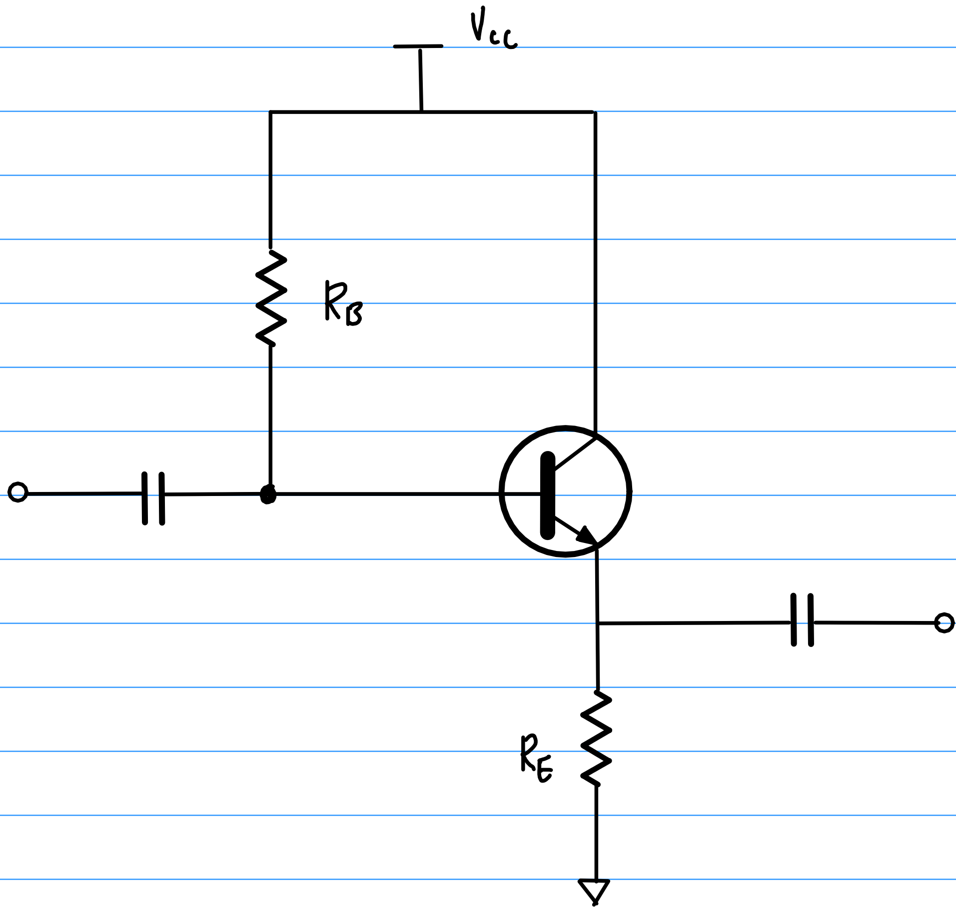
$$Z_o = R_E \parallel r'_e \underset{R_E \gg r'_e}{\cong} r'_e$$ Low (20 Ω)

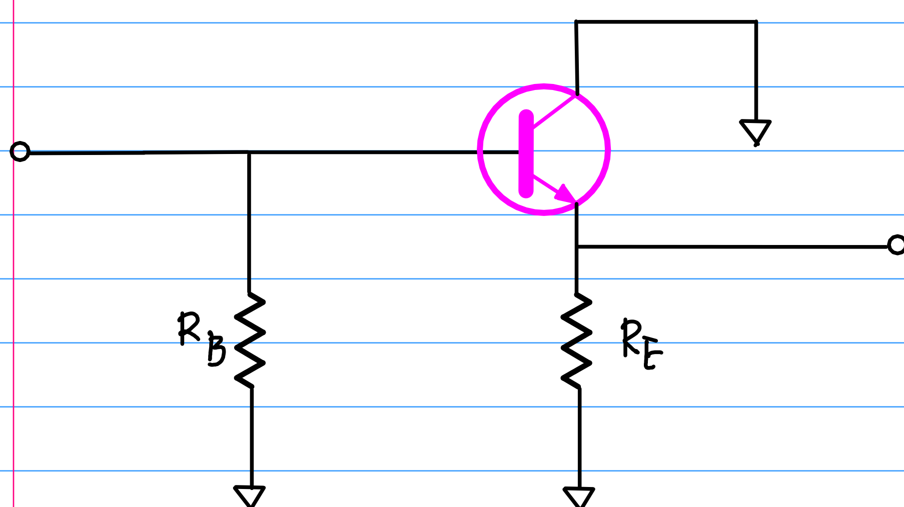
$$A_v = \frac{R_E}{r'_e + R_E} \cong 1$$ Low (1)

$$A_i = \frac{\beta R_B}{R_B + \beta(r'_e + R_E)}$$ High (50)

④

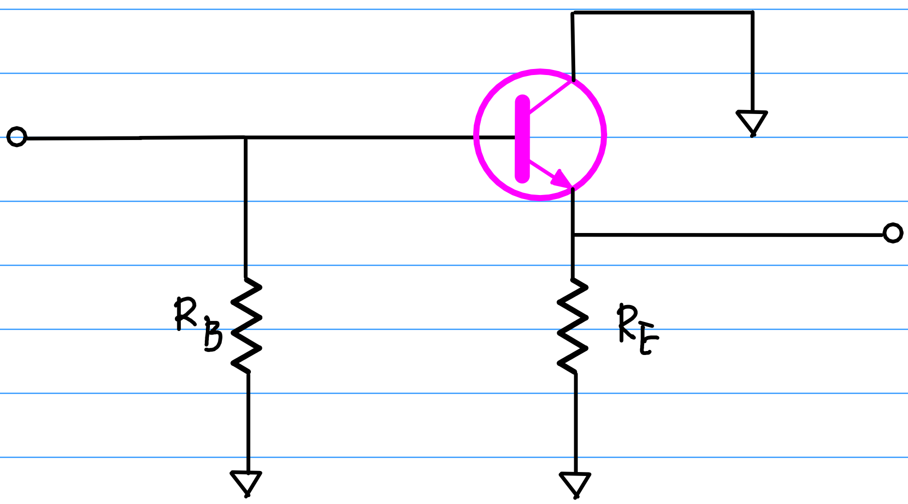
b

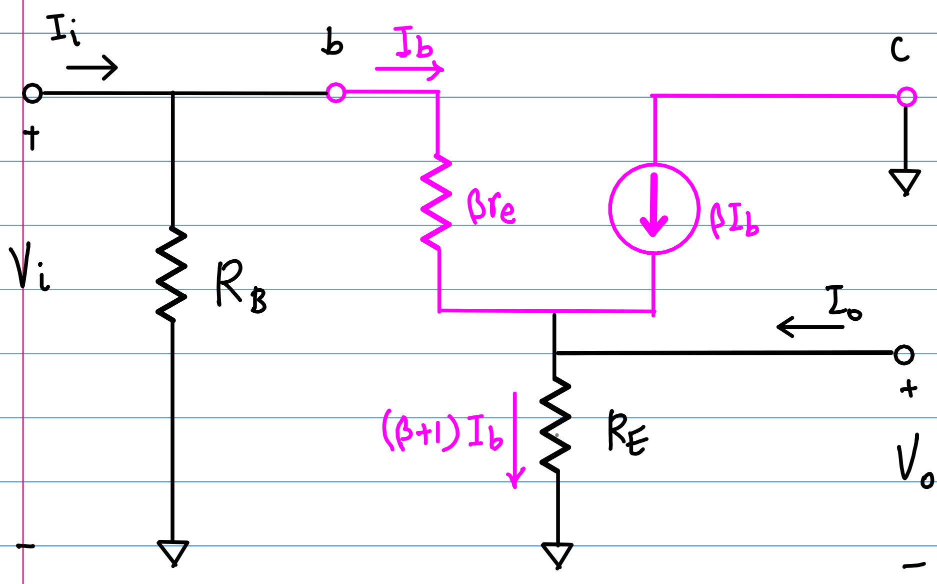




④

c





$$V_i = I_b(\beta r_e) + (\beta+1) I_b R_E$$

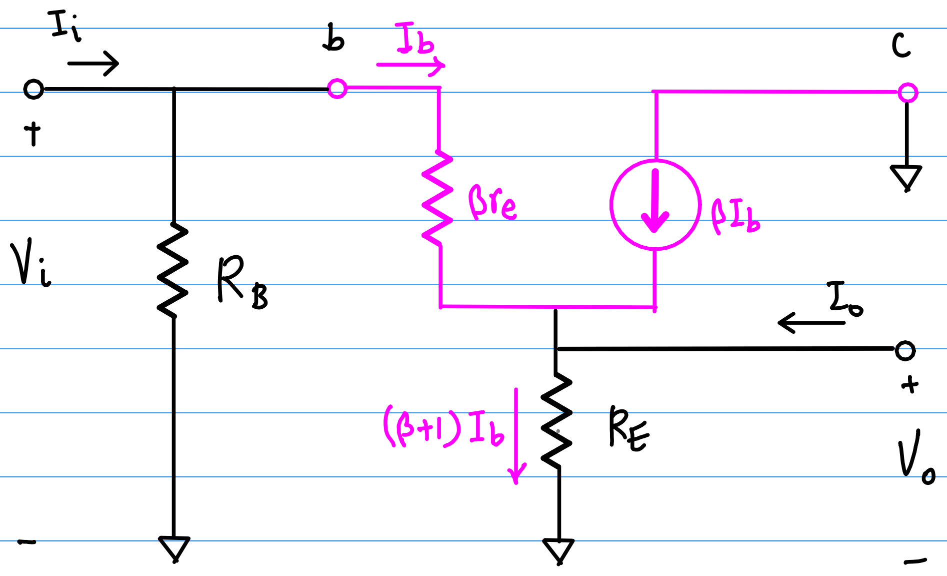
$$Z_b = \frac{V_i}{I_b} = \beta r_e + (\beta+1) R_E \cong \beta(r_e + R_E) \cong \beta R_E$$

$$Z_i = R_B \| Z_b \cong R_B \| \beta(r_e + R_E) \cong R_B \| \beta R_E$$

$$Z_o \not\cong R_c$$

④

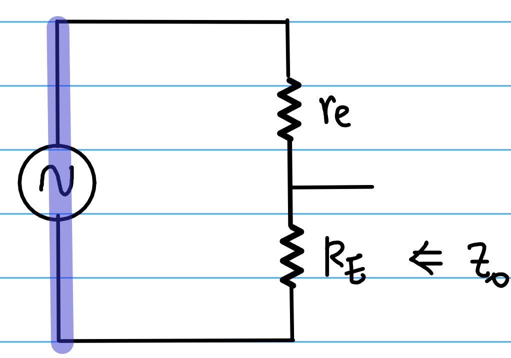
d



$$I_b = \frac{V_i}{Z_b} \qquad (\beta+1) I_b = (\beta+1) \frac{V_i}{Z_b}$$

$$I_e = \frac{(\beta+1) V_i}{\beta r_e + (\beta+1) R_E} = \frac{V_i}{(\beta/(\beta+1)) r_e + R_E} \cong \frac{V_i}{r_e + R_E}$$

$$I_e = \frac{V_i}{r_e + R_E}$$



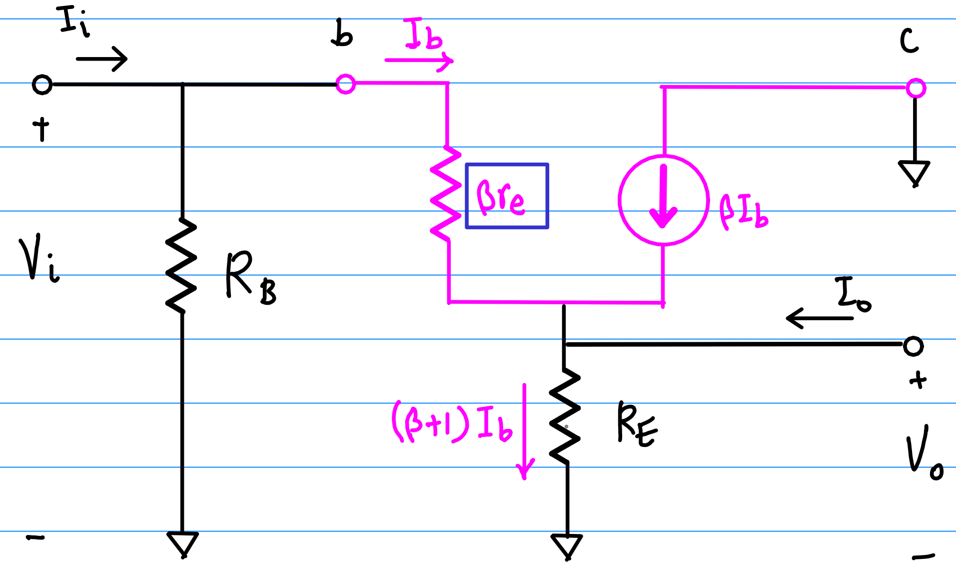
$$Z_o = R_E \| r_e \cong r_e$$

$$V_o = \frac{R_E}{r_e + R_E} V_i$$

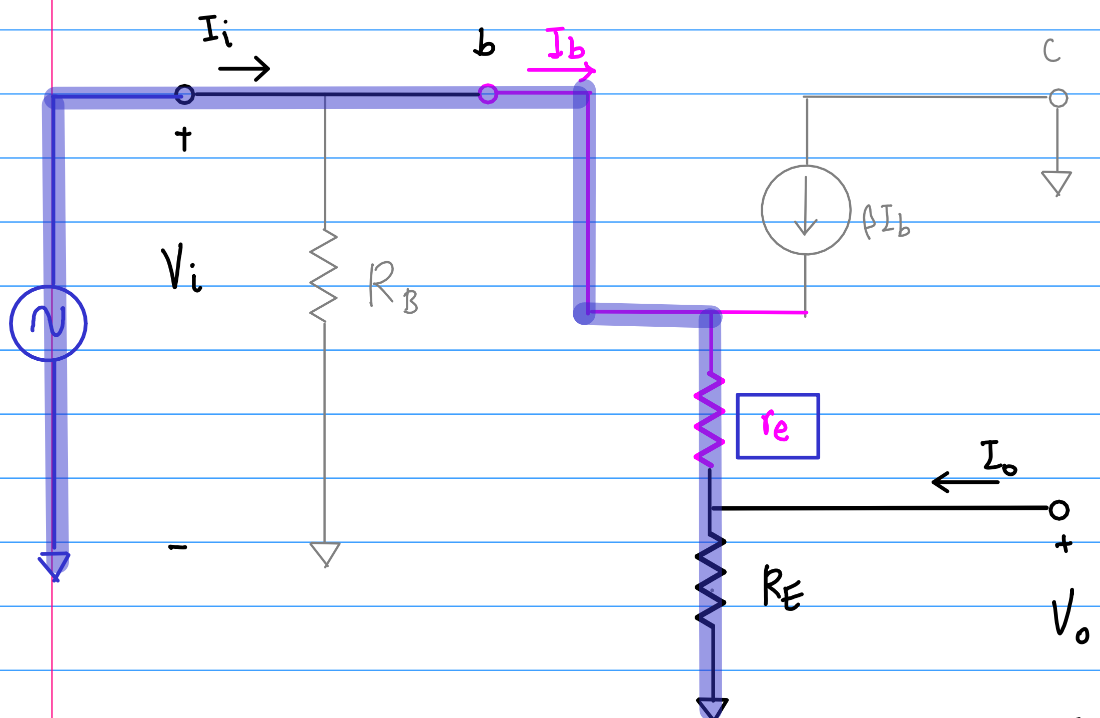
$$A_v = \frac{V_o}{V_i} = \frac{R_E}{r_e + R_E} \cong 1$$

④

e



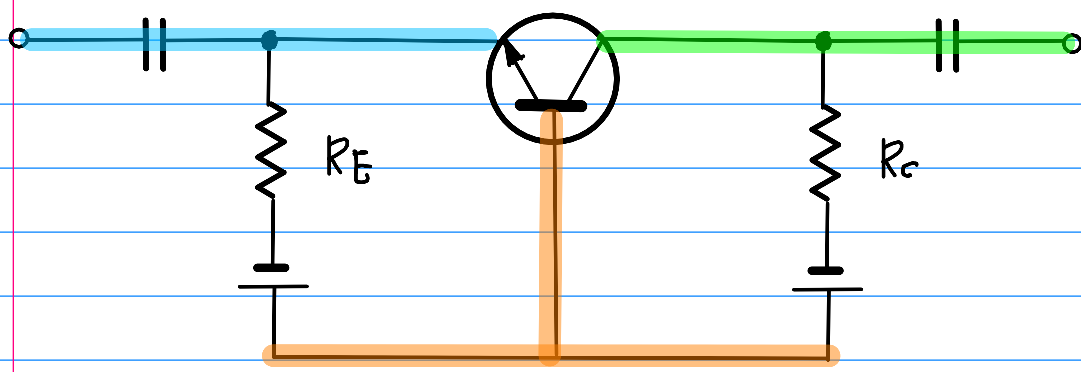
I_i
b
I_b
c
+
V_i
R_B
βr_e
βI_b
I_o
+
$(\beta+1) I_b$
R_E
V_o
−
−



I_i
b
I_b
c
+
V_i
R_B
βI_b
r_e
I_o
+
R_E
V_o
−
−

5a

Common Base



$Z_i = R_E \parallel r_e' \cong r_e'$ Low (20 Ω)

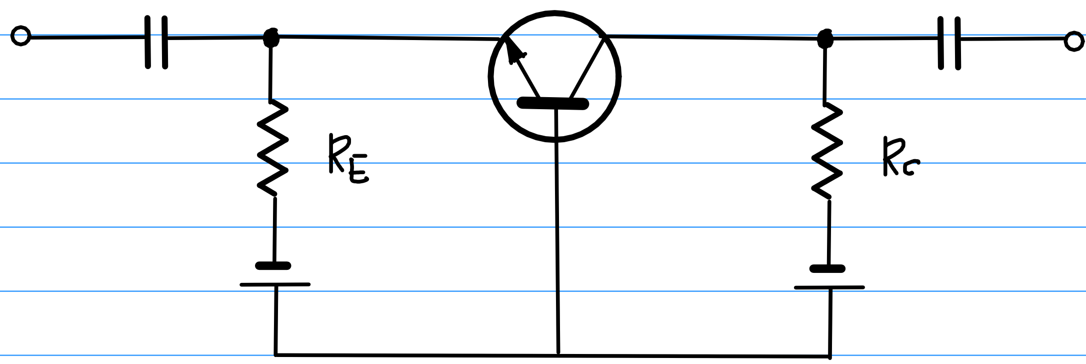
$Z_o = R_C$ Medium (2 kΩ)

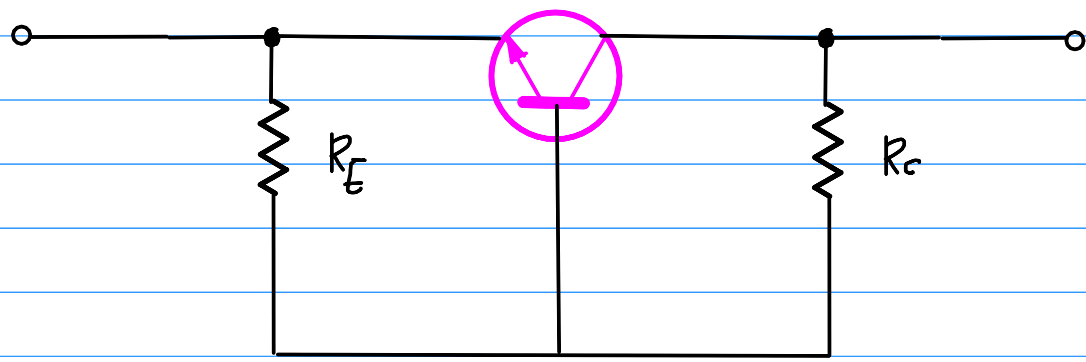
$A_v = \frac{R_C}{r_e'}$ High (200)

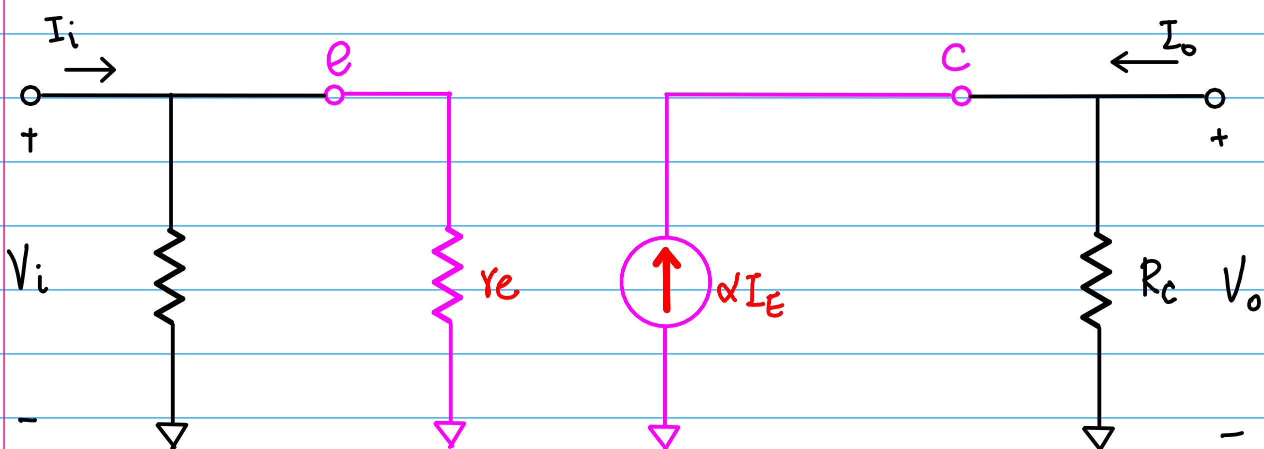
$A_i = 1$ Low (1)

⑤

b

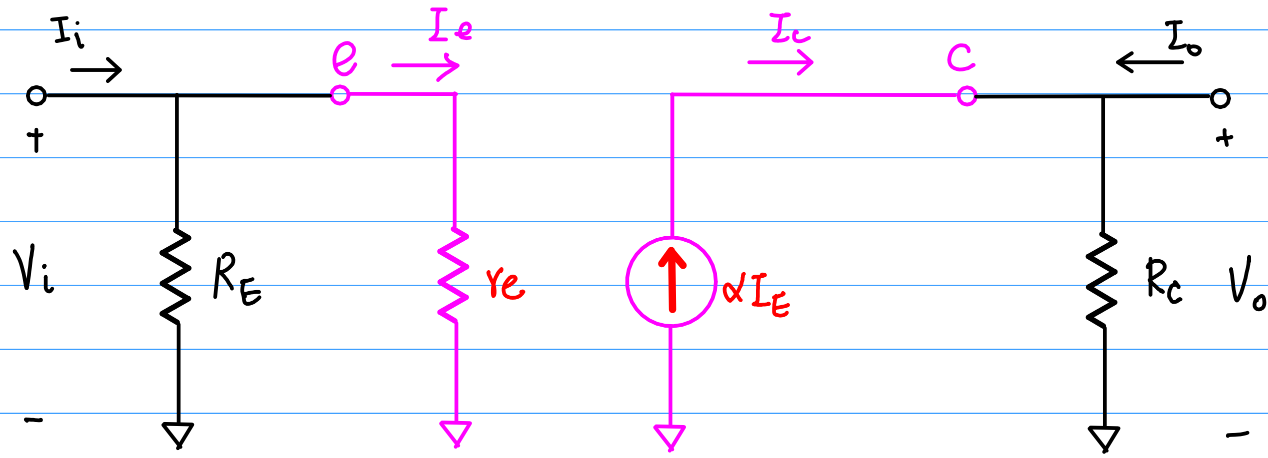






(5)

c



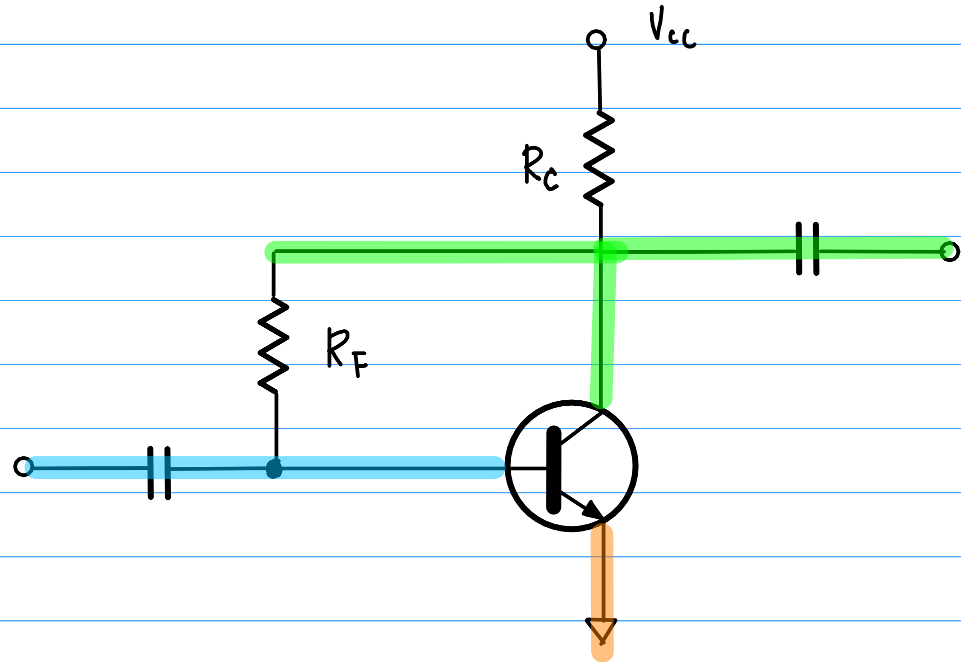
$$Z_i = R_E \parallel r_e$$
$$Z_o = R_C$$

$$V_o = -(-I_c)\,R_C = \alpha I_e R_C$$
$$V_i = I_e r_e$$

$$A_v = \frac{V_o}{V_i} = \frac{\alpha R_C}{r_e} \cong \frac{R_C}{r_e}$$

⑥ a

Collector Feedback



$Z_i = \dfrac{r_e'}{\frac{1}{\beta} + \frac{R_C}{R_F}}$ Medium (1kΩ)

$(r_o \geq 10R_c)$

$Z_o = R_C \parallel R_F$ Medium (2kΩ)

$(r_o \geq 10R_c)$

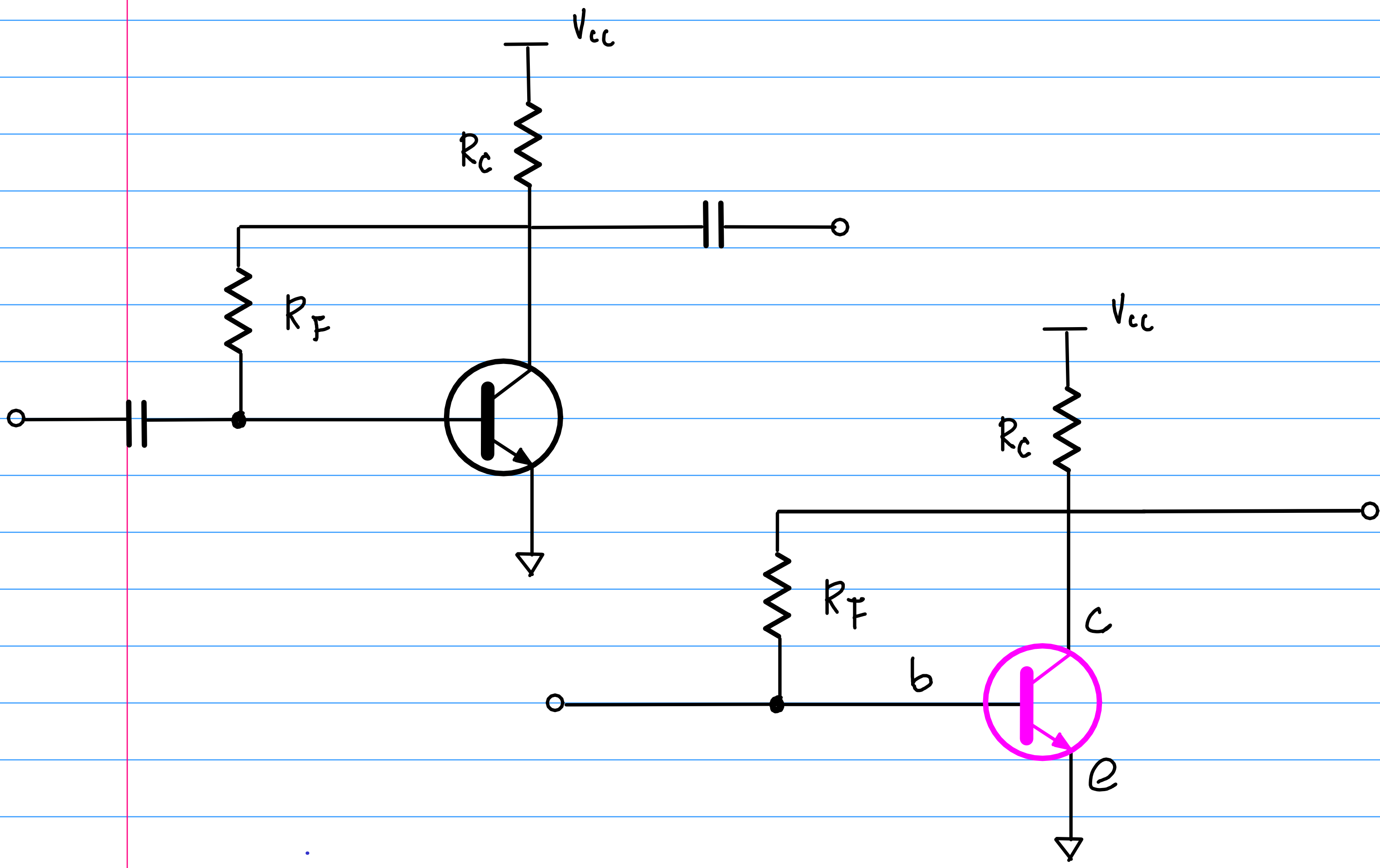
$A_v = -\dfrac{R_C}{r_e'}$ High (-200)

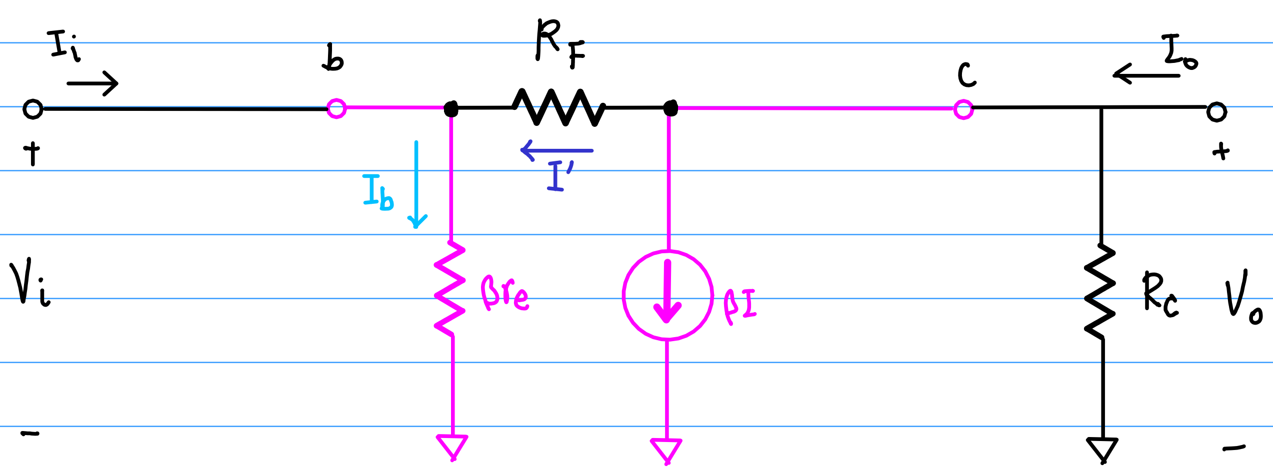
$r_o \geq 10R_C, \ R_F \gg R_C$

$A_i = \dfrac{\beta R_F}{R_F + \beta R_C} \cong \dfrac{R_F}{R_C}$ High (50)

(6)

b

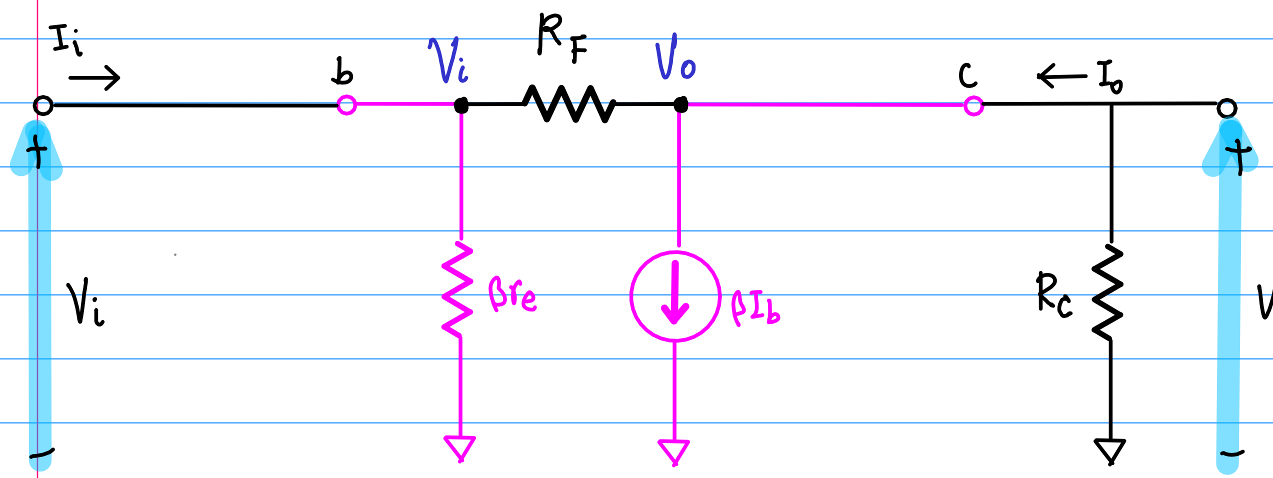




(6)

c

$$Z_i = \frac{V_i}{I_i}$$



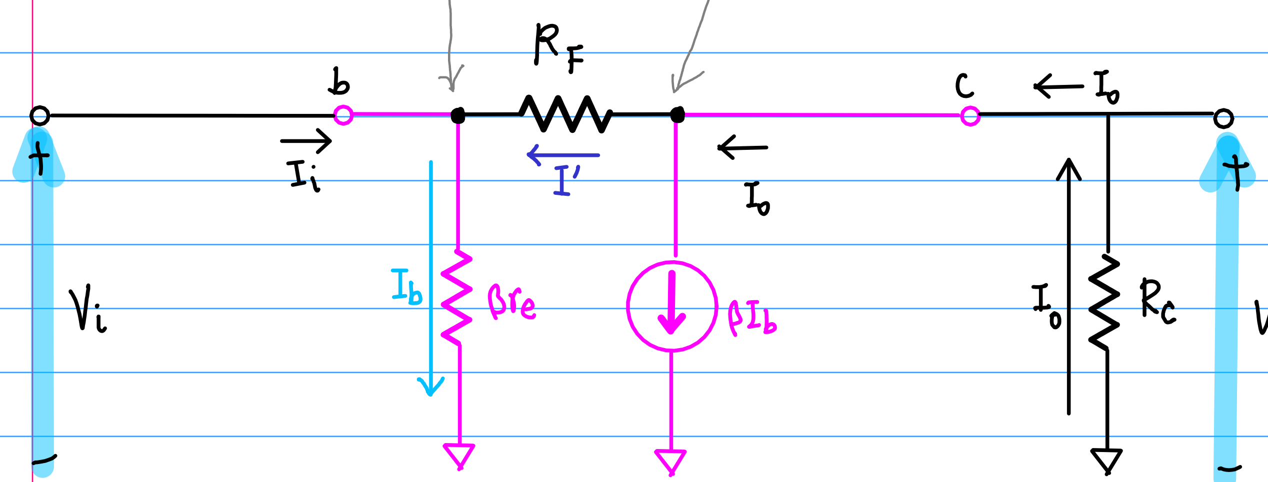
$I_b = I_i + I'$

small   small

$I' + \beta I_b = I_o$

$\beta I_b \simeq I_o$

small   large   large

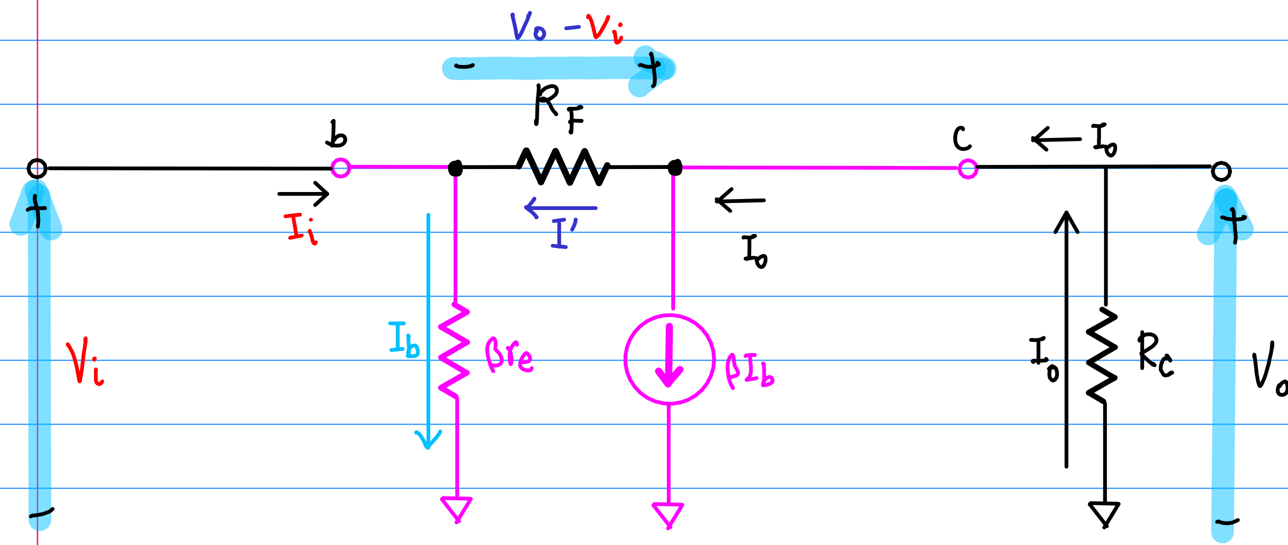


$V_i = \beta I_b r_e$

$V_o = -I_o R_c = -\beta I_b R_c$

⑥

d



$$V_i = \beta I_b r_e \qquad V_o = -I_o R_c = -\beta I_b R_c$$

$$I_b = I_i + I'$$

$$\boxed{I' = \frac{V_o - V_i}{R_F}}$$

$$\Bigg\} \quad I_b = I_i + \frac{V_o - V_i}{R_F}$$

$$V_i = \beta I_b r_e = \beta (I_i + I') r_e = \beta \left(I_i + \frac{V_o - V_i}{R_F} \right) r_e$$

$$V_o - V_i = -V_i + V_o = -V_i \left(1 - \frac{V_o}{V_i}\right)$$

$$= -V_i \left(1 + \frac{\beta I_b R_c}{\beta I_b r_e}\right)$$

$$= -V_i \left(1 + \frac{R_c}{r_e}\right)$$

$$V_i = \beta \left(I_i + \frac{V_o - V_i}{R_F} \right) r_e = \beta \left(I_i - \frac{V_i}{R_F}\left(1 + \frac{R_c}{r_e}\right)\right) r_e$$

⑥

e

$$V_i = \beta\left(I_i + \frac{V_o - V_i}{R_F}\right) r_e = \beta\left(I_i - \frac{V_i}{R_F}\left(1 + \frac{R_c}{r_e}\right)\right) r_e$$

$$V_i \approx I_i \beta r_e - \beta r_e \cdot \frac{V_i}{R_F}\left(1 + \frac{R_c}{r_e}\right)$$

$$V_i\left[1 + \frac{\beta r_e}{R_F}\left(1 + \frac{R_c}{r_e}\right)\right] = I_i \beta r_e$$

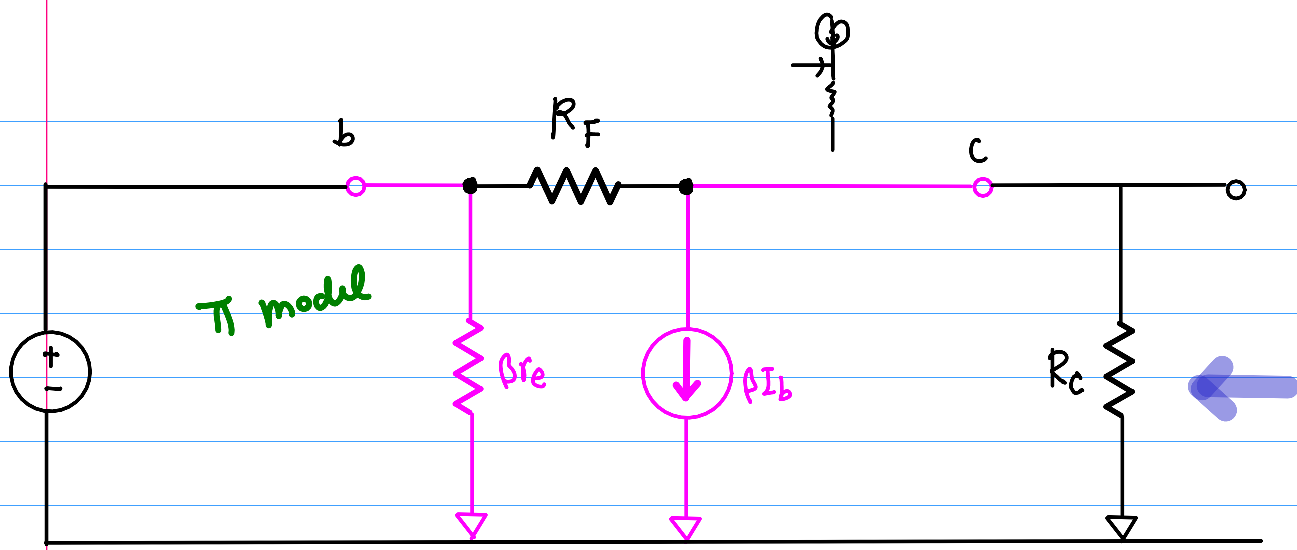
$$Z_i = \frac{V_i}{I_i} = \frac{\beta r_e}{\left[1 + \frac{\beta r_e}{R_F}\left(1 + \frac{R_c}{r_e}\right)\right]} \qquad \left(1 + \frac{R_c}{r_e}\right) \cong \frac{R_c}{r_e} \quad \left(\frac{R_c}{r_e} \gg 1\right)$$

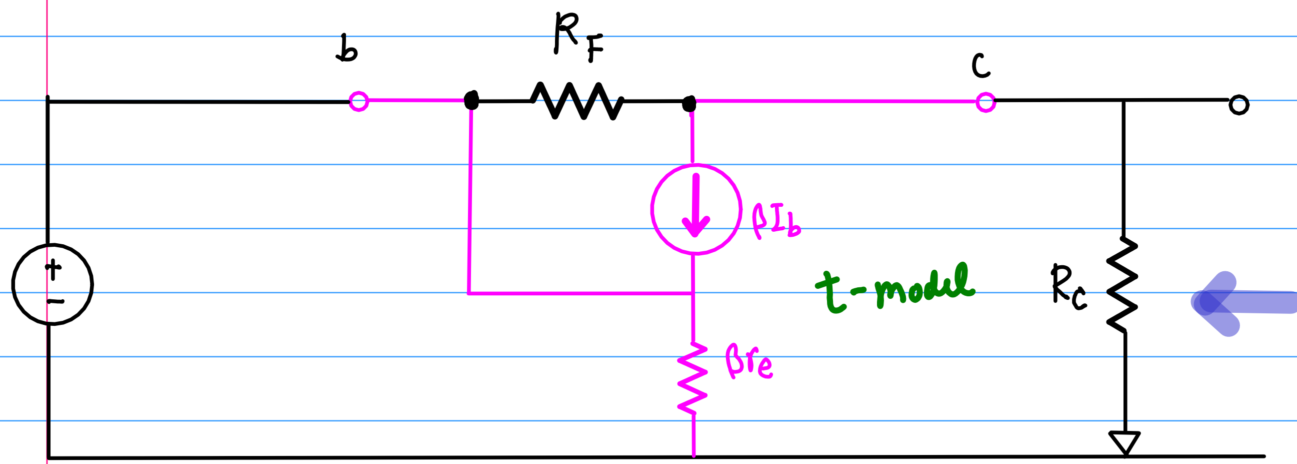
$$\cong \frac{\beta r_e}{\left[1 + \frac{\beta r_e}{R_F}\left(\frac{R_c}{r_e}\right)\right]} = \frac{\beta r_e}{1 + \frac{\beta R_c}{r_e}}$$

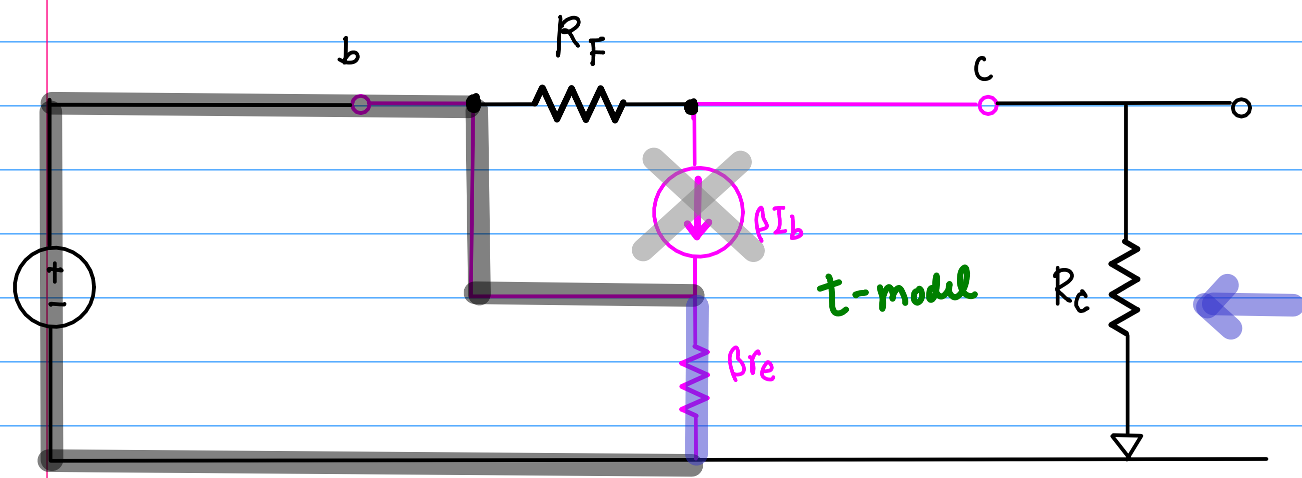
$$Z_i \cong \frac{r_e}{\frac{1}{\beta} + \frac{R_c}{r_e}}$$

(6)

f

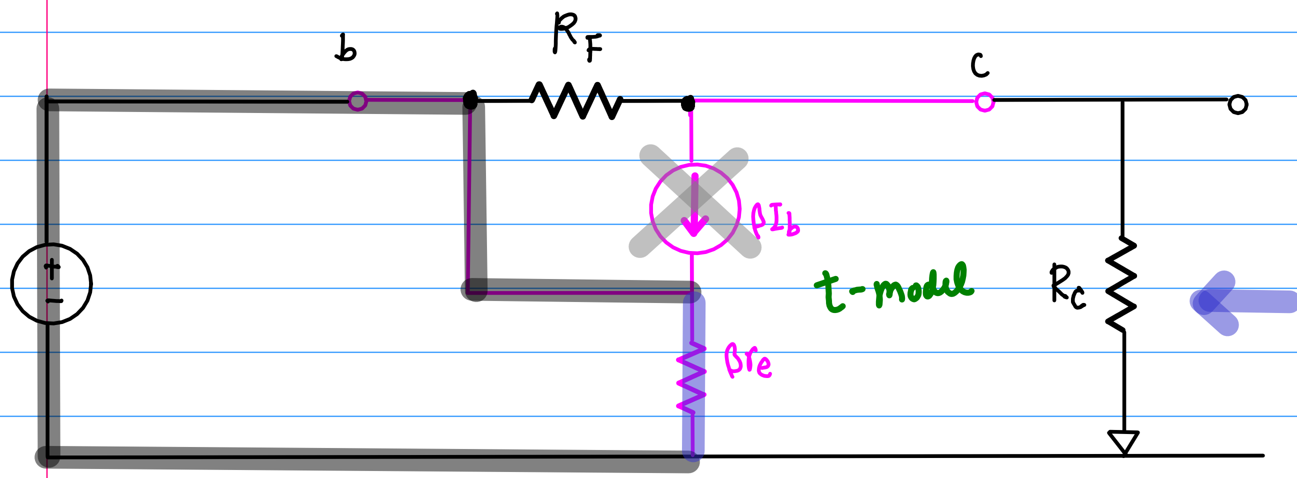

b
R_F
c
π model
βre
βIb
Rc

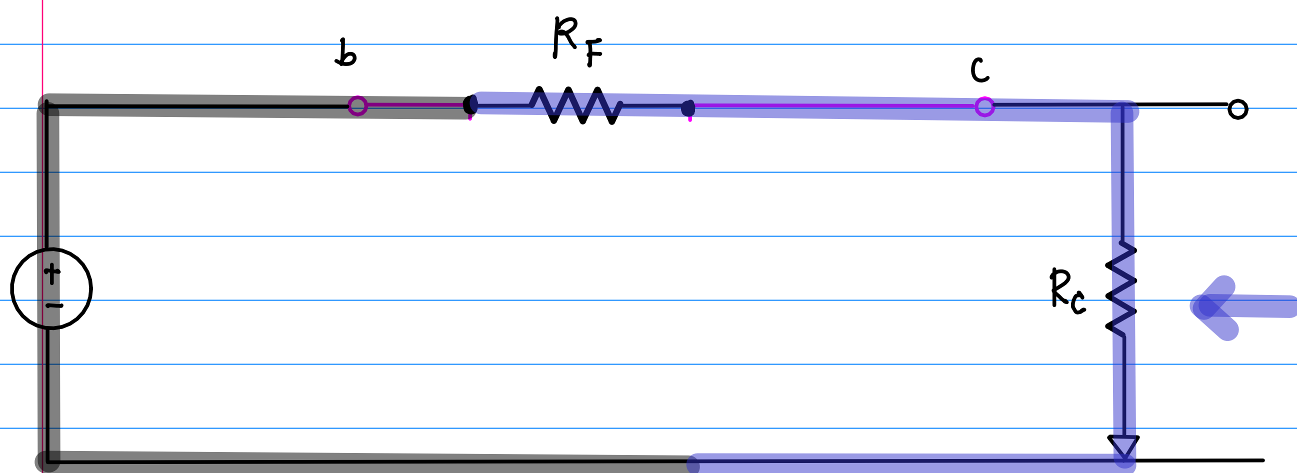

b
R_F
c
βIb
t-model
Rc
βre


b
R_F
c
βIb
t-model
Rc
βre

⑥

g

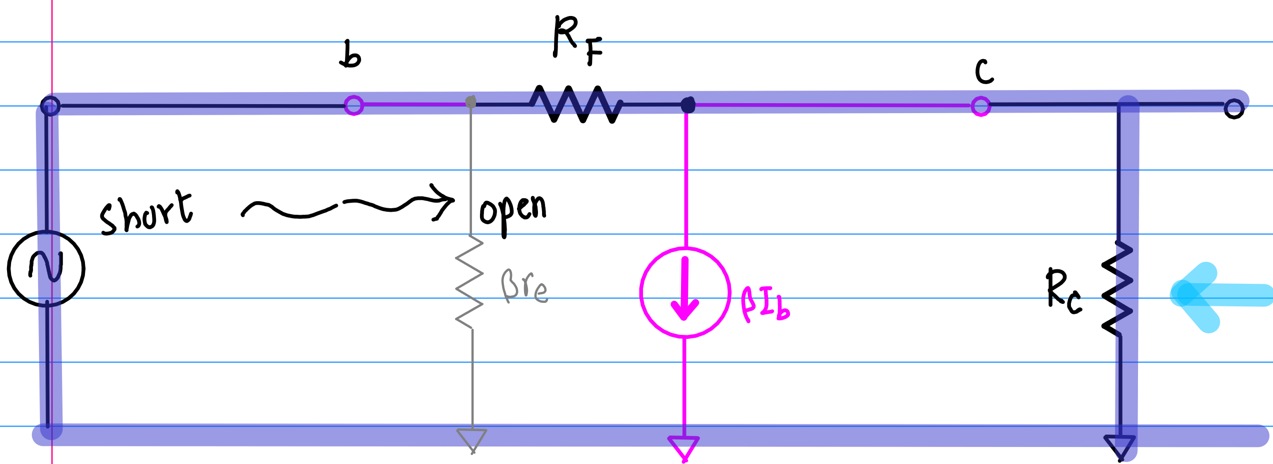




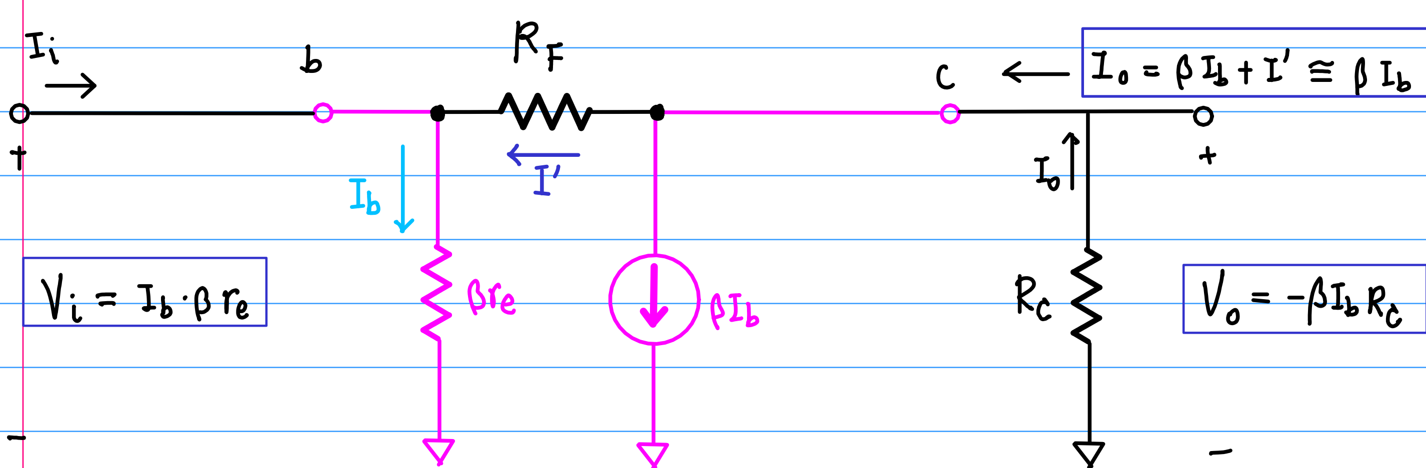
$$Z_o = R_C \parallel R_F$$

(6)

h



$$Z_o = R_C \parallel R_F$$

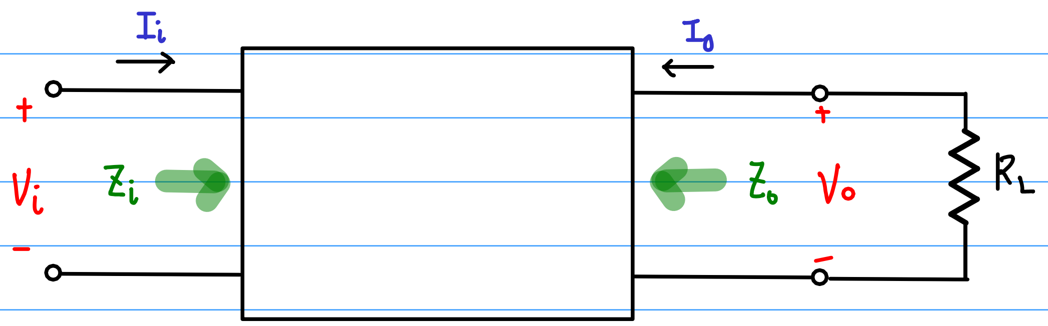


$$I_o = \beta I_b + I' \cong \beta I_b$$

$$V_o = -\beta I_b R_C \qquad V_i = I_b \cdot \beta r_e$$

$$A_v = \frac{V_o}{V_i} = \frac{-\beta I_b R_C}{I_b \cdot \beta r_e} = -\frac{R_C}{r_e}$$

Current Gain



$$I_i = \frac{V_i}{Z_i} \qquad I_o = -\frac{V_o}{R_L}$$

$$A_{iL} = \frac{I_o}{I_i} = \frac{-\frac{V_o}{R_L}}{\frac{V_i}{Z_i}} = -\frac{V_o}{V_i}\cdot\frac{Z_i}{R_L}$$

$$A_{iL} = -\frac{V_o}{V_i}\cdot\frac{Z_i}{R_L} = -A_{vL}\cdot\frac{Z_i}{R_L}$$

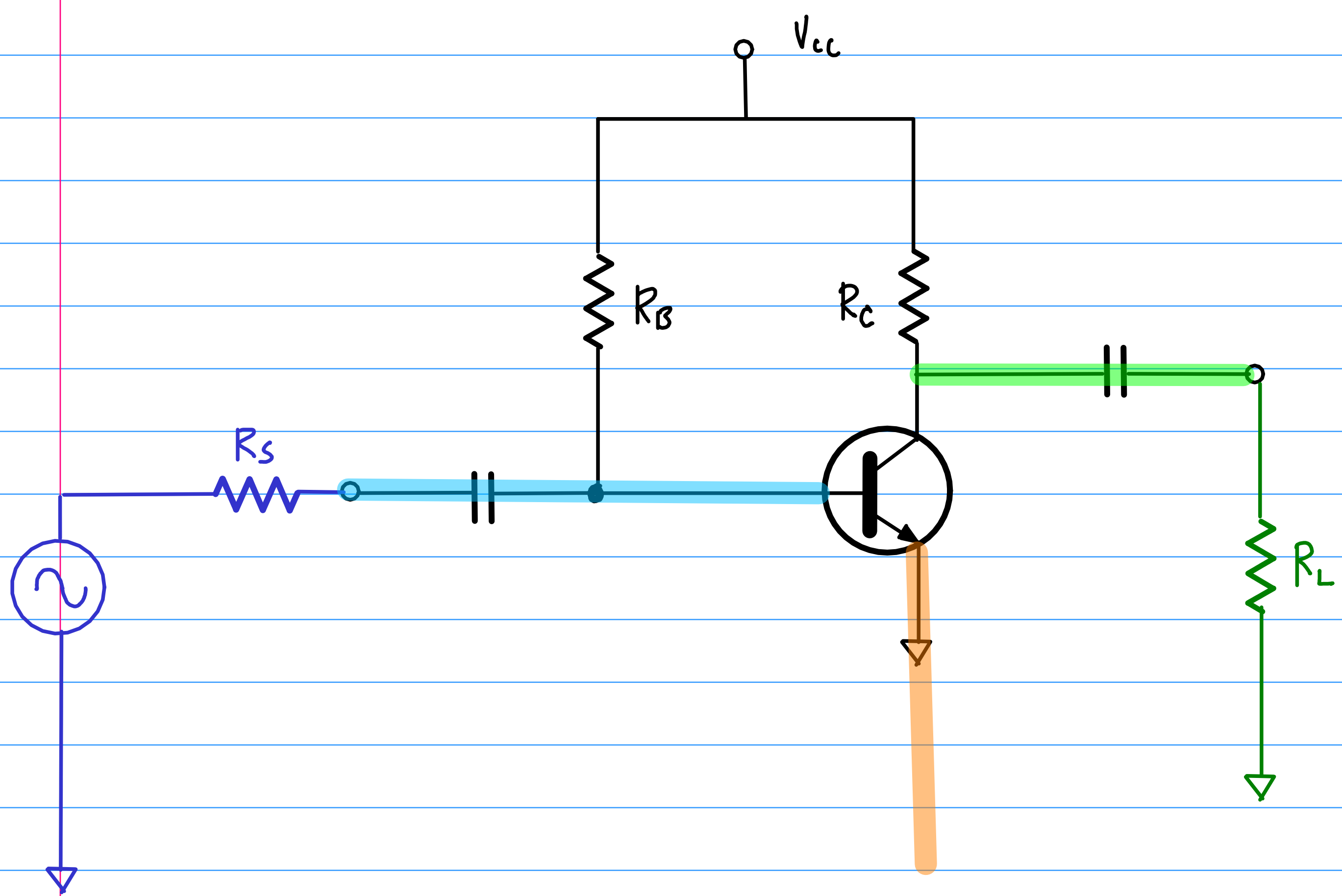
* i_L, v_L ..... with R_L load

R_s R_L included

	Z_i	Z_o	A_v	A_i
1. Fixed Bias	$R_B \parallel \beta r_e$	R_c	$-\frac{(R_L \parallel R_c)}{r_e}$	
2. Voltage Divider Bias	$R_1 \parallel R_2 \parallel \beta r_e$	R_c	$-\frac{(R_L \parallel R_c)}{r_e}$	
3. Unbypass Emitter Bias	$R_1 \parallel R_2 \parallel \beta(r_e+R_E)$	R_c	$-\frac{(R_L \parallel R_c)}{R_E}$	
4. Emitter Follower	$R_1 \parallel R_2 \parallel \beta(r_e+R_E)$	$R_E \parallel \left(\frac{R_s'}{\beta}+r_e\right)$	1	
5. Common Base	$R_E \parallel r_e$	R_c	$-\frac{(R_L \parallel R_c)}{r_e}$	
6. Collector Feedback	$\beta r_e \parallel \frac{R_F}{\lvert A_v \rvert}$	R_c	$-\frac{(R_L \parallel R_c)}{R_E}$	

	Z_i	Z_o	A_v	A_i
1. Fixed Bias	βr_e	R_c	$-\frac{R_c}{r_e}$	β
2. Voltage Divider Bias	$R_1 \parallel R_2 \parallel \beta r_e$	R_c	$-\frac{R_c}{r_e}$	$\frac{\beta(R_1 \parallel R_2)}{R_1 \parallel R_2 + \beta r_e}$
3. Unbypass Emitter Bias	$R_B \parallel \beta R_E$	R_c	$-\frac{R_c}{R_E}$	$-\frac{\beta R_B}{R_B+\beta(r_e+R_E)}$
4. Emitter Follower	$R_B \parallel \beta R_E$	r_e	1	$-\frac{\beta R_B}{R_B+\beta(r_e+R_E)}$
5. Common Base	r_e	R_c	$\frac{R_L}{r_e}$	-1
6. Collector Feedback	$\frac{r_e}{1/\beta + R_c/R_F}$	$R_c \parallel R_F$	$-\frac{R_c}{r_e}$	$\frac{R_F}{R_c}$

① Fixed Bias (R_s, R_L)

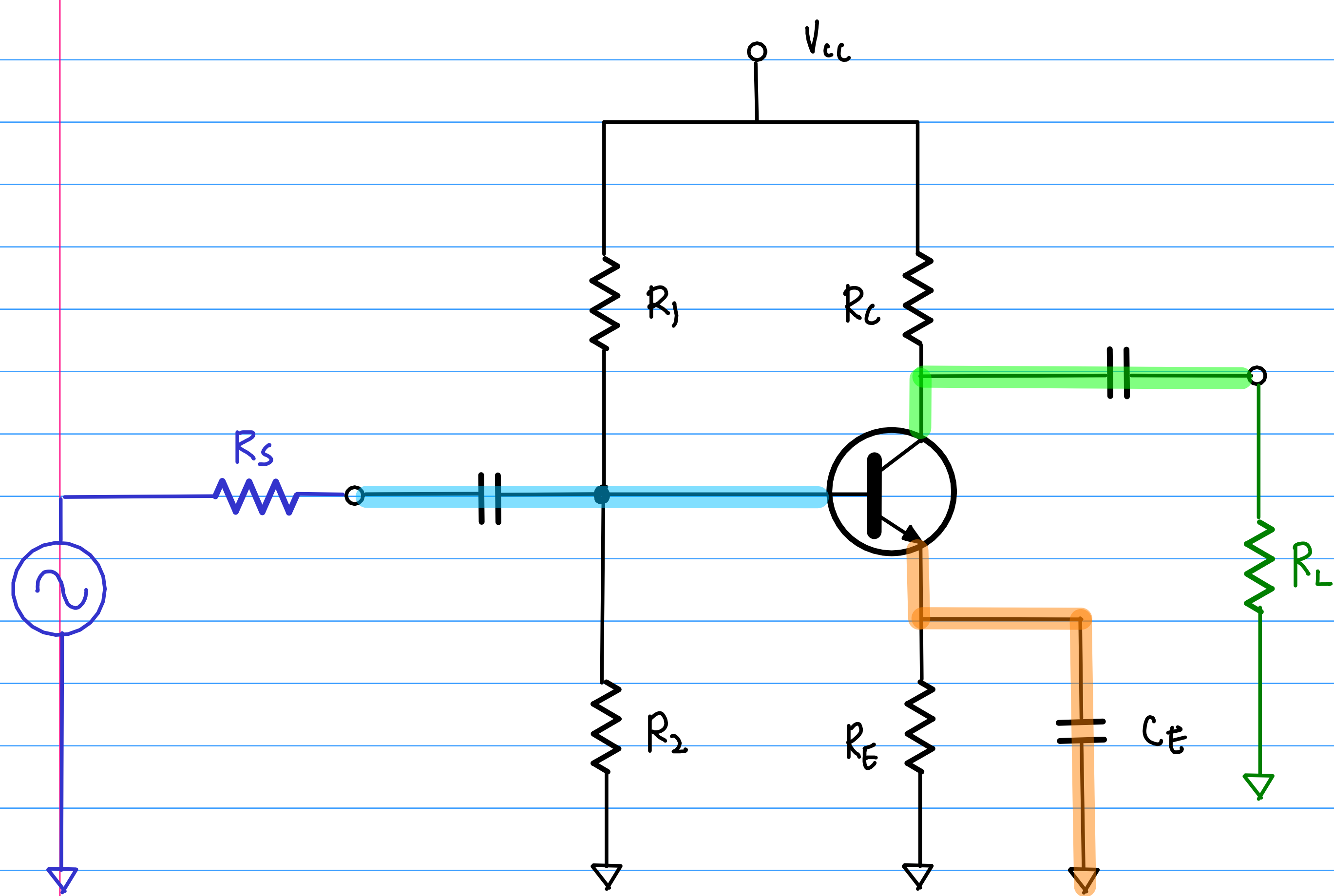


$$A_v = -\frac{(R_L \parallel R_c)}{r_e'} \qquad -\frac{(R_L \parallel R_c \parallel r_o)}{r_e'}$$

$$Z_i = R_B \parallel \beta r_e' \qquad R_B \parallel \beta r_e'$$

$$Z_o = R_c \qquad R_c \parallel r_o$$

② Voltage Divider Bias (R_s, R_L)

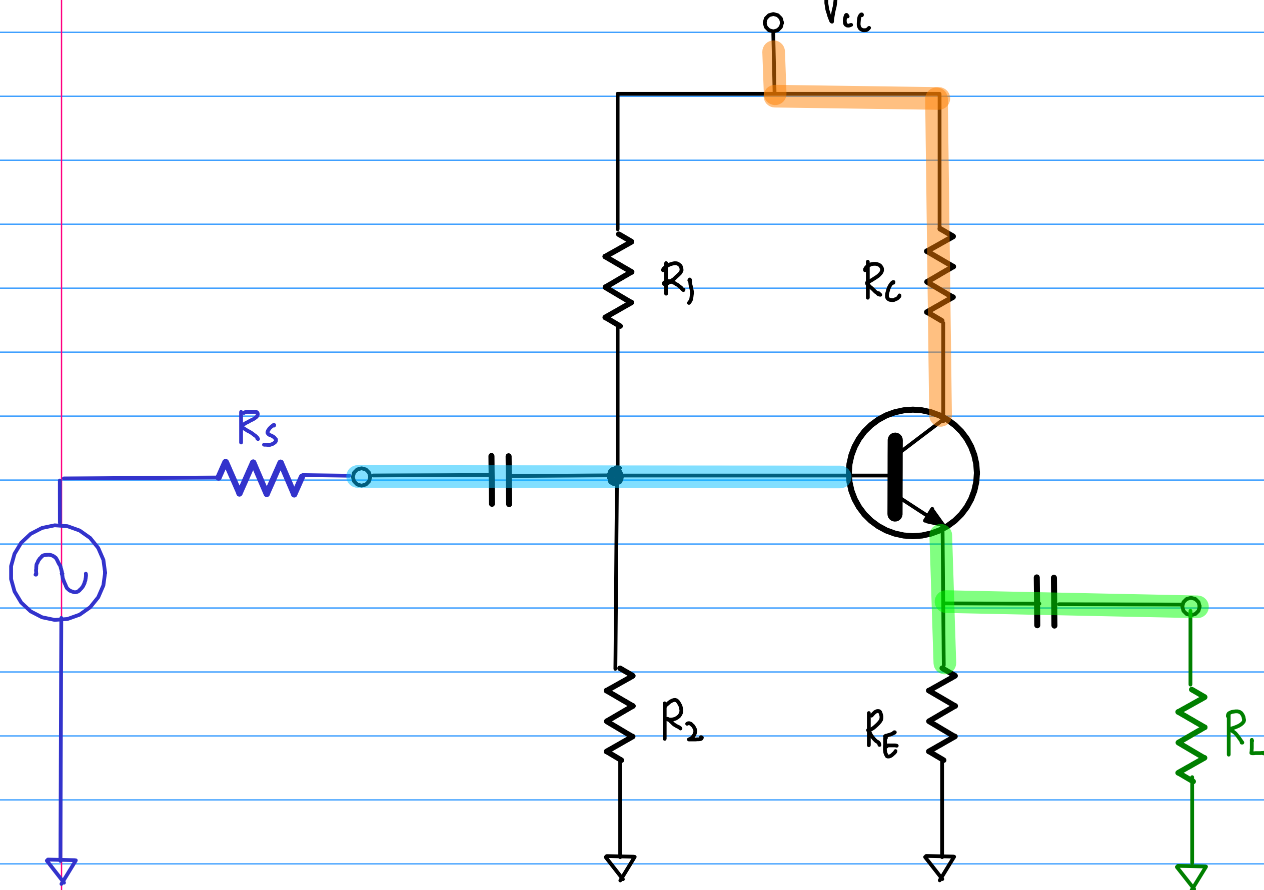


$$A_v = -\frac{(R_L \parallel R_C)}{r_e'} \qquad -\frac{(R_L \parallel R_C \parallel r_o)}{r_e'}$$

$$Z_i = R_1 \parallel R_2 \parallel \beta r_e' \qquad R_1 \parallel R_2 \parallel \beta r_e'$$

$$Z_o = R_C \qquad R_C \parallel r_o$$

④ Emitter Follower (R_s, R_L)

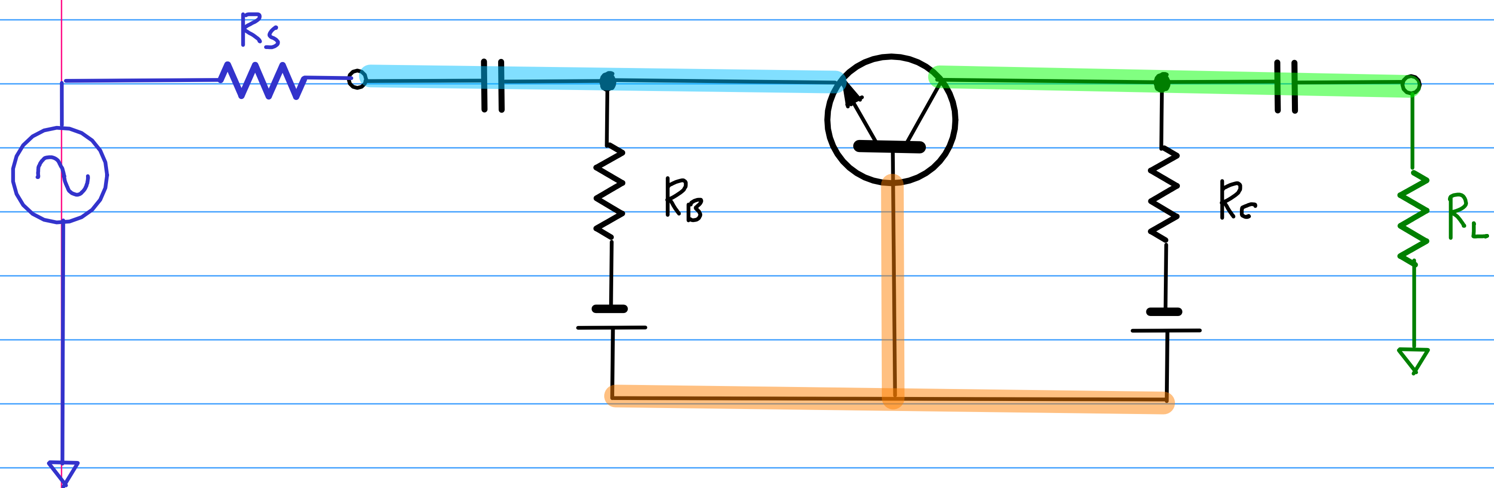


A_v = 1 1

$Z_i = R_1 \| R_2 \| \beta (r_e' + R_L \| R_E)$ $R_1 \| R_2 \| \beta (r_e' + R_L \| R_E)$

$Z_0 = R_E \| \left(\frac{1}{\beta} (R_s + R_1 + R_2) + r_e' \right)$ $R_E \| \left(\frac{1}{\beta} (R_s + R_1 + R_2) + r_e' \right)$

⑤ Common Base (R_S, R_L)

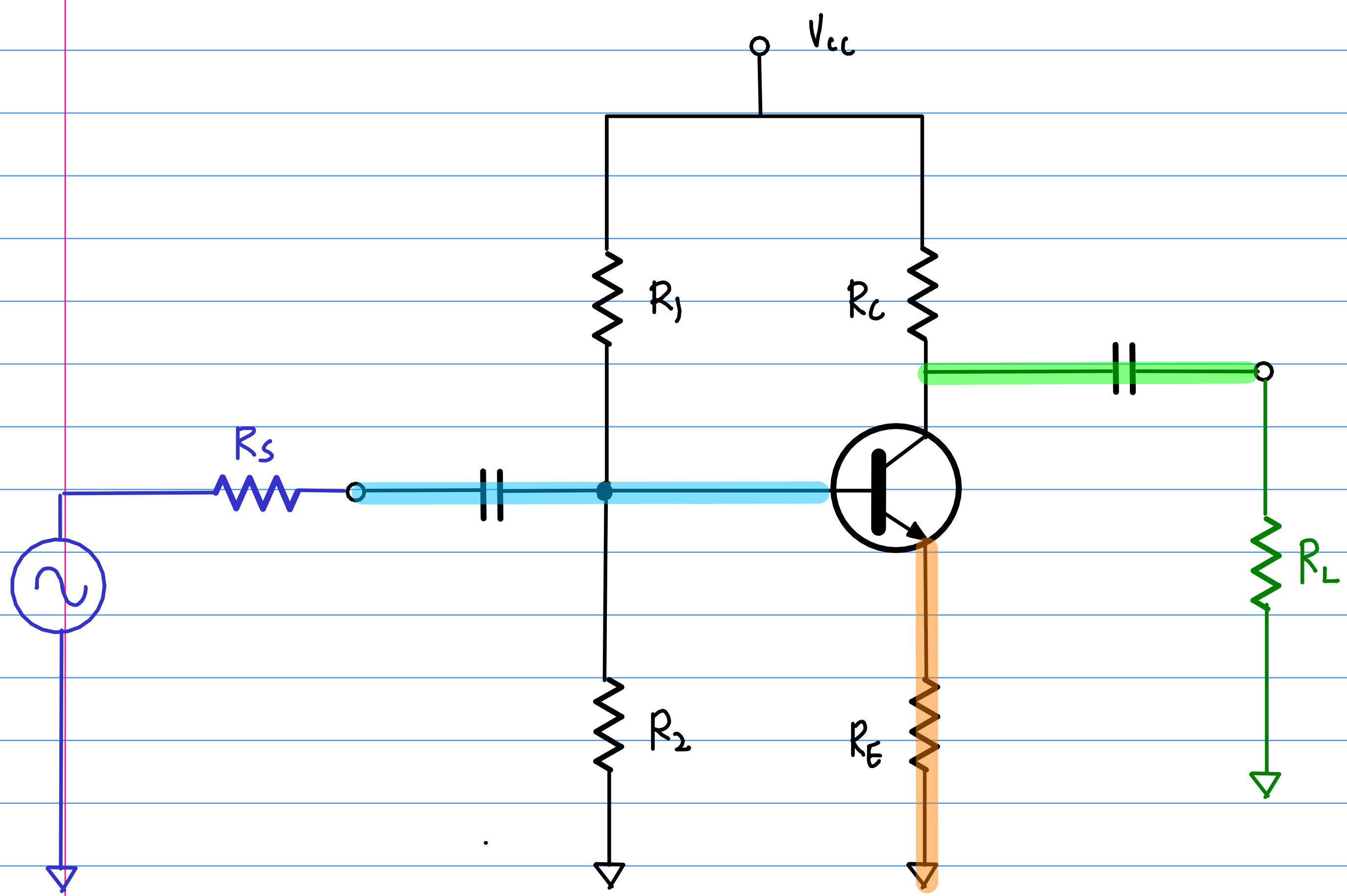


$$A_v = -\frac{(R_L \parallel R_c)}{r_e'} \qquad -\frac{(R_L \parallel R_c \parallel r_o)}{r_e'}$$

$$Z_i = R_E \parallel r_e' \qquad R_E \parallel r_e'$$

$$Z_o = R_c \qquad R_c \parallel r_o$$

③ Unbypassed Emitter Bias (R_S, R_L)

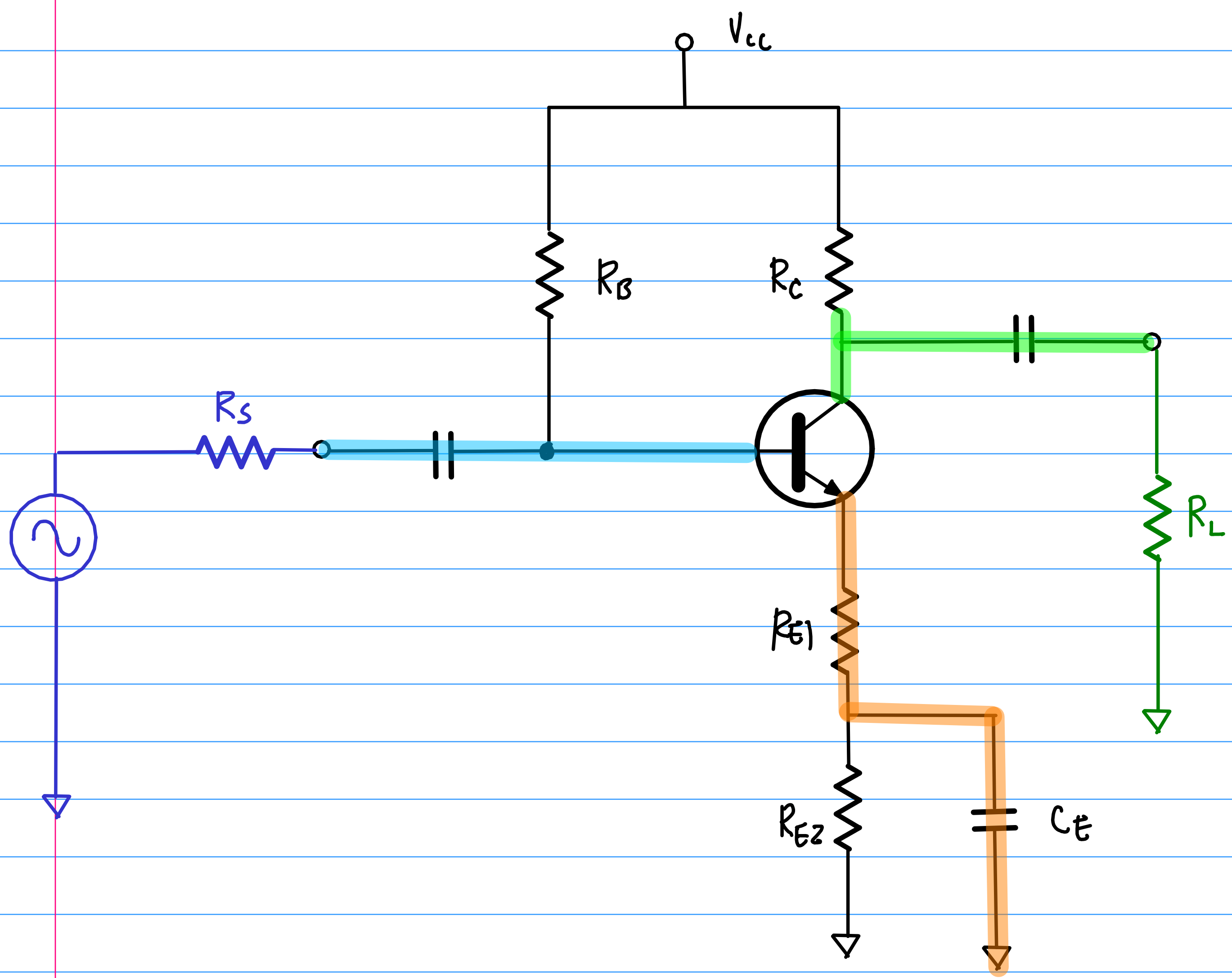


$$A_v = -\frac{(R_L \parallel R_C)}{R_E} \qquad -\frac{(R_L \parallel R_C \parallel r_o)}{R_E}$$

$$Z_i = R_1 \parallel R_2 \parallel \beta(r'_e + R_E) \qquad R_1 \parallel R_2 \parallel \beta(r'_e + R_E)$$

$$Z_o = R_C \qquad R_C \parallel r_o$$

(R_s, R_L)

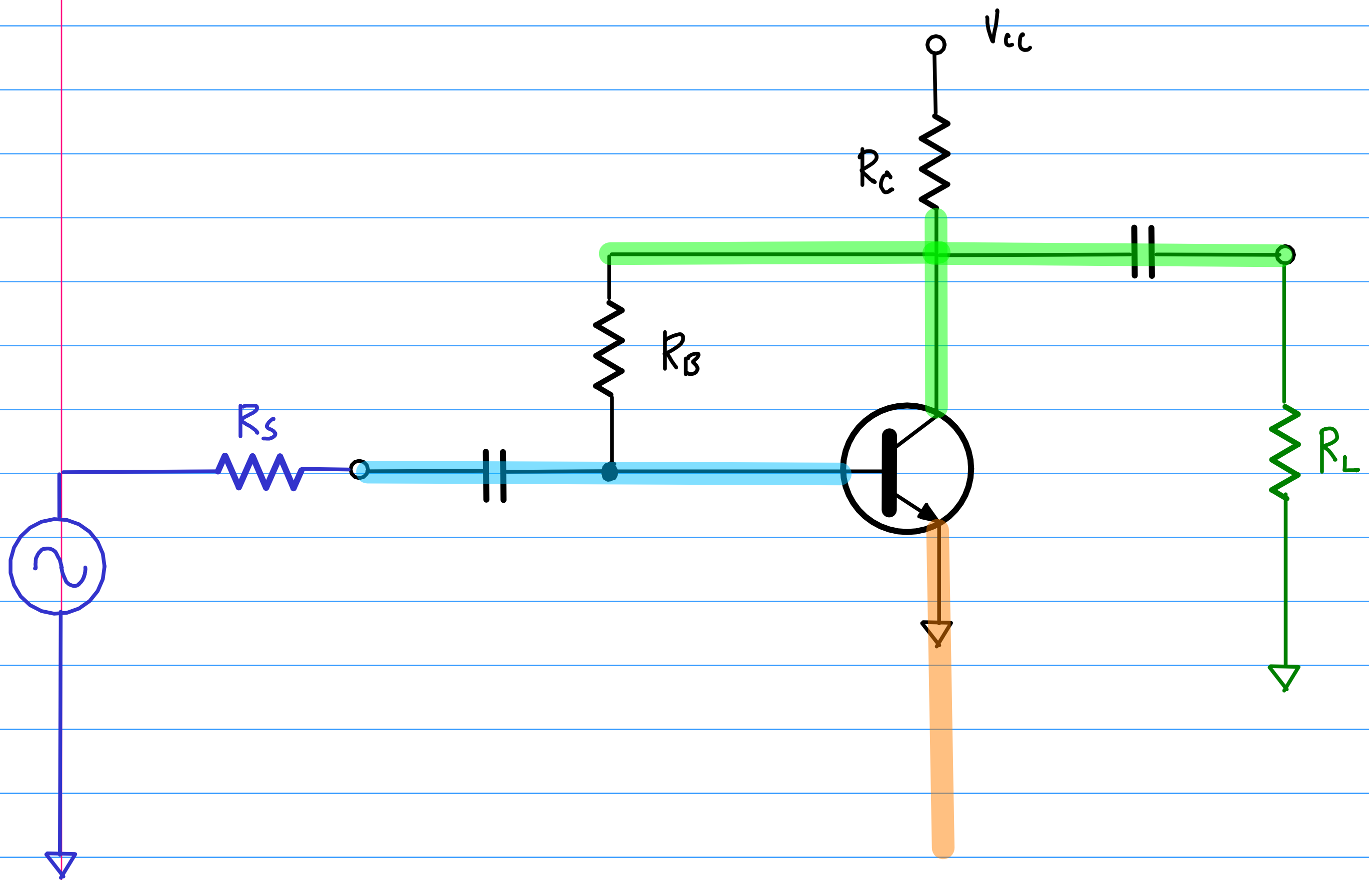


$$A_v = -\frac{(R_L \parallel R_c)}{R_{E1}} \qquad -\frac{(R_L \parallel R_c \parallel r_o)}{R_{E1}}$$

$$Z_i = R_s \parallel \beta(r'_e + R_{E1}) \qquad R_s \parallel \beta(r'_e + R_{E1})$$

$$Z_o = R_c \qquad R_c \parallel r_o$$

⑥ Collector Feedback (R_s, R_L)

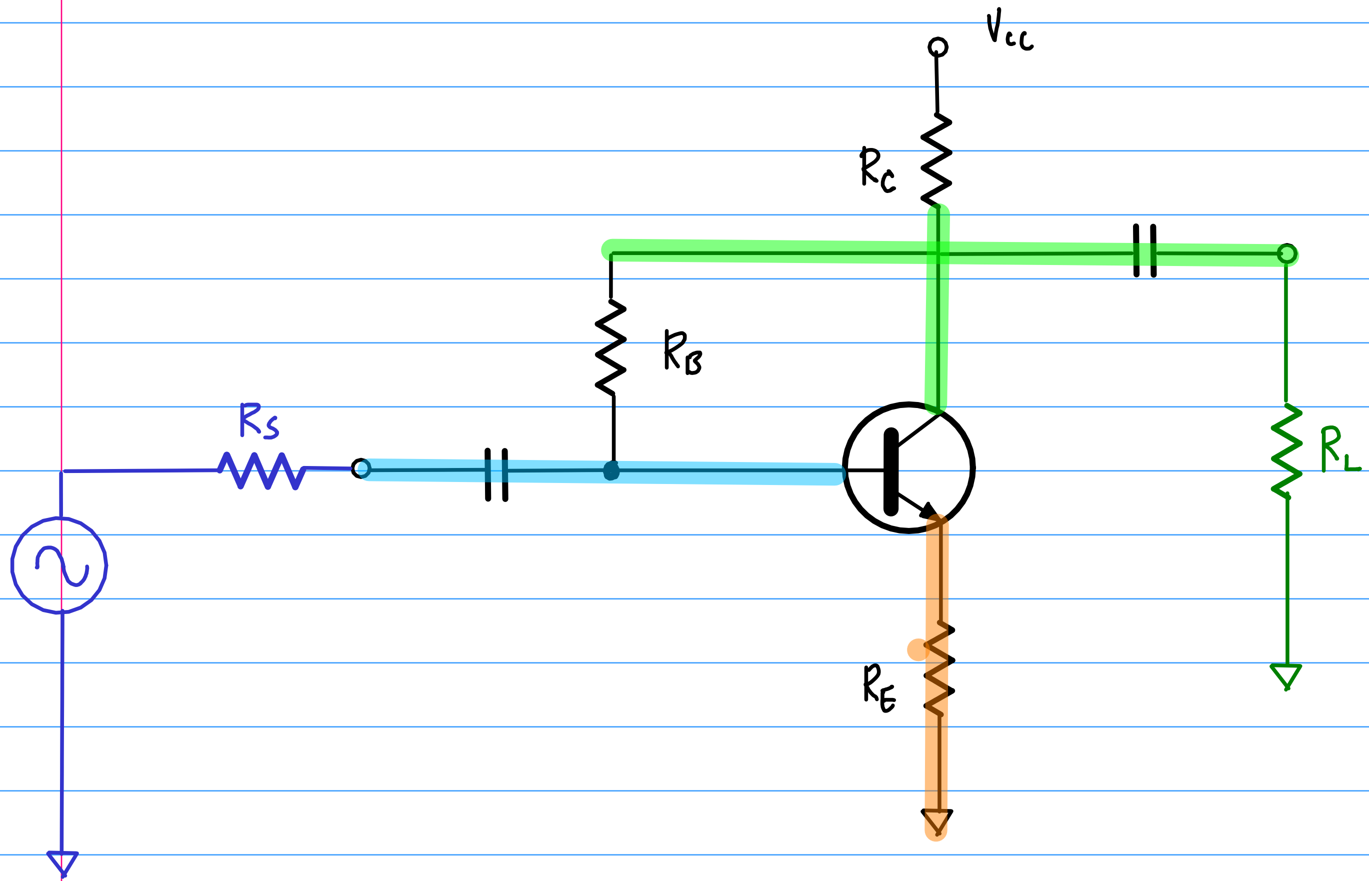


$$A_v = -\frac{(R_L \parallel R_c)}{r_e'} \qquad -\frac{(R_L \parallel R_c \parallel r_o)}{r_e'}$$

$$Z_i = \beta r_e' \; R_F / |A_v| \qquad \beta r_e' \; R_F / |A_v|$$

$$Z_o = R_c \qquad R_c \parallel R_F \parallel r_o$$

(R_s, R_L)



$$A_v = -\frac{(R_L \parallel R_C)}{R_E} \qquad -\frac{(R_L \parallel R_C \parallel r_o)}{R_E}$$

$$Z_i = \beta R_E R_F / |A_v| \qquad \beta R_E R_F / |A_v|$$

$$Z_o = R_C \parallel R_F \qquad R_C \parallel R_F \parallel r_o$$