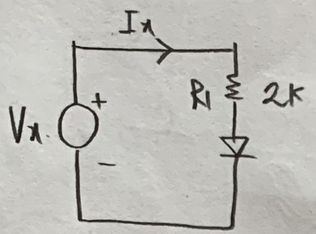
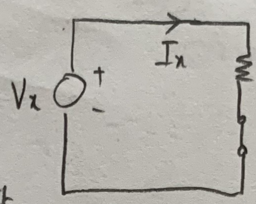
2.18 consider circuit where $I_s = 2\times10^{-15}$ A. calculate V_{D1} and I_x for $V_x = 0.5$ V, 0.8V, 1V and 1.2 V. Note that V_{D1} changes little for $V_x \ge 0.8V$.



기본적으로 $V_x > 0.8V$ 일 때 V_x가 $V_{D,ON}$을 넘어서 전류가 흐르므로 forward bias이다.

그로,



형태의 short circuit.

이 두 식을 통해 값을 얻을수있다.

- $I_x = I_s \cdot \exp\left(\frac{V_D}{V_t} - 1\right)$
- $V_D = V_T \cdot \ln \frac{I_D}{I_S}$

이때 $T = 300K$라 가정하고, $V_T = 26\cdot10^{-3}$ V.
문제에서 $I_s = 2\times10^{-15}$A 라고 주었음.

i) $V_x = 0.5V$, $0.8V$ 일 때, $V_{D,ON} \doteq 0.8V$을 넘지못하므로 $I_x = 0$, $V_{D1} = 0$

ii) $V_x = 1V$ 일 때.

- $-V_x + I_x R_1 + V_{D1} = 0$ $\quad V_{D1} = V_x - I_x R_1 = 1 - 2\times10^{-15}\cdot\exp\left(\frac{V_{D1}}{26\cdot10^{-3}} - 1\right)$

$$I_x = \frac{1 - V_{D1}}{2000}$$

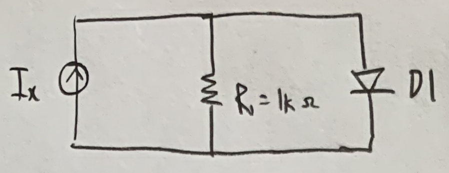
iii) $V_x = 1.2V$ 일 때 역시.

- $V_{D1} = 1.2 - 2\times10^{-15}\exp\left(\frac{V_{D1}}{26\cdot10^{-3}} - 1\right)$
- $I_x = \frac{1.2 - V_{D1}}{2000}$

이 두 식을 풀면 된다.

B615065 남재우.

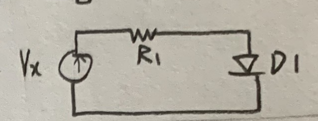
2.21



If $I_s = 3 \cdot 10^{-16}$ A, calculate V_{D1} for I_x = 1mA, 2mA, 3mA

두 가지 방법이 떠올랐다. 1. I_x = 1mA, 2mA, 3mA 3가지 경우로 나누어서 $V_D = V_T \cdot \ln \frac{I_x}{I_s}$ 로 V_{D1}을 구하는 것

2. 전기회로 이론 2에서 배운 Source transformation 을 이용해 R_1에 걸리는 전압을 통해 V_{D1}을 구하는 것.



첫번째 방법으로 풀 것이다.

i) $I_x = 1mA$

$$V_D = V_T \cdot \ln \frac{I_x}{I_s} = \underbrace{26 \times 10^{-3}}_{300K일\ 때} \cdot \underbrace{\ln \frac{10^{-3}}{3 \times 10^{-16}}}_{28.8} = 26 \times 10^{-3} \times (28.8) = 0.748V$$

ii) $I_x = 2mA$

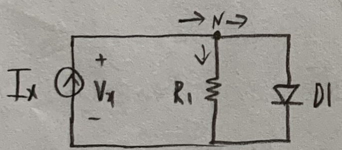
$$V_D = V_T \cdot \ln \frac{I_x}{I_s} = 26 \cdot 10^{-3} \cdot \ln\left(\frac{2}{3} \cdot 10^{13}\right) = 26 \times 10^{-3} \times (29.5) = 0.767V$$

iii) $I_x = 4mA$.

$$V_D = V_T \cdot \ln \frac{I_x}{I_s} = 26 \cdot 10^{-3} \cdot \ln\left(\frac{4}{3} \cdot 10^{13}\right) = 26 \cdot 10^{-3} \cdot (30.22) = 0.785V$$

2.23

$I_x = 1mA \rightarrow V_x = 1.2V$, $I_x = 2mA \rightarrow V_x = 1.8V$ 일 때, R_1, I_s = ?



Node KCL을 돌려보자.

- $I_x = \frac{V_x}{R_1} + I_{D1}$ --- $I_{D1} = I_x - \frac{V_x}{R_1}$
- $V_x = V_T \cdot \ln \frac{I_{D1}}{I_s}$

$\rightarrow$ • $V_x = V_T \cdot \ln\left(\frac{I_x - \frac{V_x}{R_1}}{I_s}\right)$

$I_x = 1mA$ 일 때, $1.2_V = 26 \cdot 10^{-3} \cdot \ln\left(\frac{1 - \frac{1.2}{R_1}}{I_s}\right) \rightarrow I_s(125.45) = 1 - \frac{1.2}{R_1}$

$I_x = 2mA$ 일 때, $1.8V = 26 \cdot 10^{-3} \cdot \ln\left(\frac{2 - \frac{1.8}{R_1}}{I_s}\right) \rightarrow I_s(188.18) = 2 - \frac{1.8}{R_1}$

$I_s = \frac{1 - \frac{1.2}{R_1}}{125.45} = \frac{2 - \frac{1.8}{R_1}}{188.18}$, $\underset{간편성을\ 위해\ 소수점\ 생략}{188}\left(1 - \frac{1.2}{R_1}\right) = 125\left(2 - \frac{1.8}{R_1}\right)$, $188(R_1 - 1.2) = 125(2R_1 - 1.8)$

$R1 = 9.67 \times 10^{-5}$).

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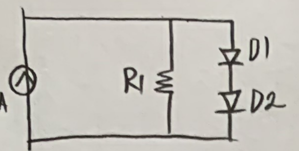
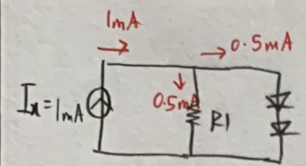
2.24.



determine R1 such that this resistor carries 0.5 mA. $I_s = 5 \times 10^{-16}$



한 다이오드의 전압.

$V_x = V_T \cdot \ln\left(\frac{I_D}{I_S}\right)$

$= \frac{26}{1000} \cdot \ln\left(\frac{0.5mA}{5 \times 10^{-16}}\right)$

$= \frac{26(27.6310)}{1000} = 0.718$

R1 과 다이오드는 parallel 이므로 걸리는 전압 같다.

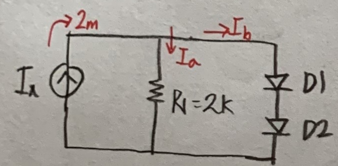
$2V_x = 0.5mA \times R1$

$R_1 = 2872\ \Omega$

2.25

$I_s = 5 \times 10^{-16}$

calculate voltage across R_1 for $I_x = 2mA$



• $I_x = 2mA = I_a + I_b$

• $V_D = V_T \cdot \ln \frac{I_b}{5 \times 10^{-16}}$

R1과 다이오드 들은 parallel 이므로 걸리는 전압이 같다.

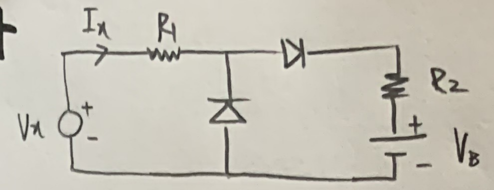
$2k \cdot I_a = 2 \times \frac{2.6}{1000} \times \ln \frac{I_b}{5 \times 10^{-16}}$

$\cancel{2}000(I_a) = \cancel{2} \times \frac{2.6}{1000} \times \ln \frac{(2 \cdot 10^{-3} - I_a)}{5 \times 10^{-16}}$

식을 통해 I_a를 구하면,

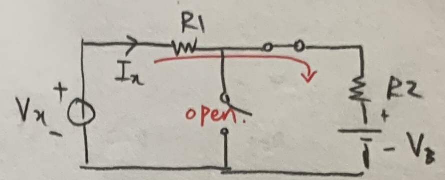
$V_{R1} = 2000 \cdot I_a$

3.4



Plot I_x as function of V_x, if $V_B = 1V$, $V_B = -1V$.

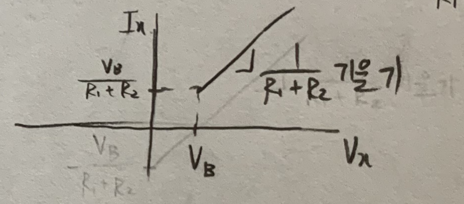
i). $V_x > 0$.



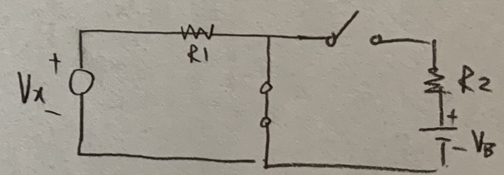
KVL 돌리면,

$-V_x + I_x R_1 + I_x R_2 = 0$. V_B는 추가 배터리로 따로 plot에 추가한다.

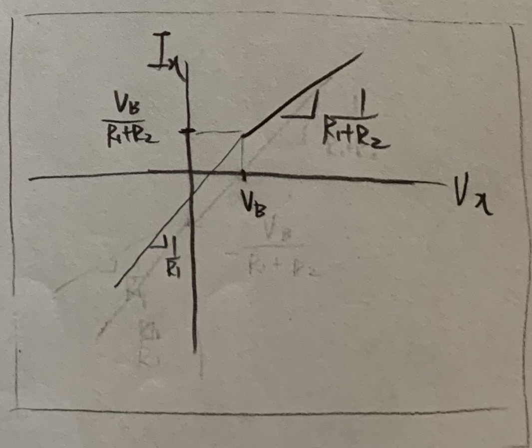
$I_x(R_1 + R_2) = V_x \rightarrow I_x = \frac{1}{R_1 + R_2}(V_x)$



ii) $V_x < 0$ 일 때.



Short 되므로 기울기 $\frac{1}{R1}$ 인 직선이 된다.



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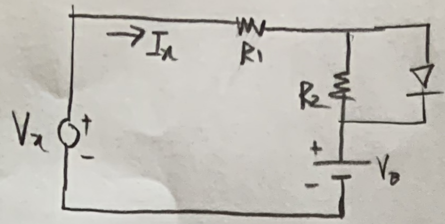
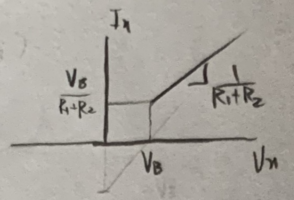
3.6 Plot I_x as function of V_x, $V_B>0$



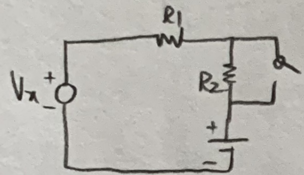
i) $V_x>0$.

$-V_x + I_xR_1 + I_xR_2 = 0$ V_B는 plot에 따로

$I_x = \frac{1}{R_1+R_2}(V_x)$

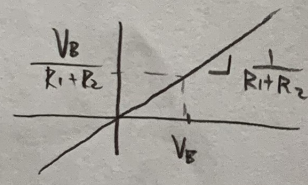


ii) $V_x<0$.



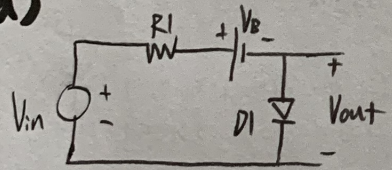
$-V_x+I_xR_1+I_xR_2=0$

$I_x=\frac{1}{R_1+R_2}(V_x)$

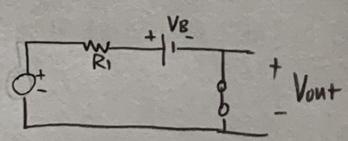


3.11 plot input-output character / ideal model

(a)

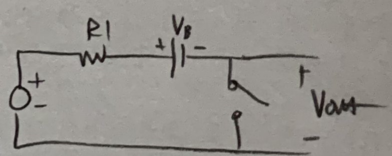


i) $V_{in}>0$

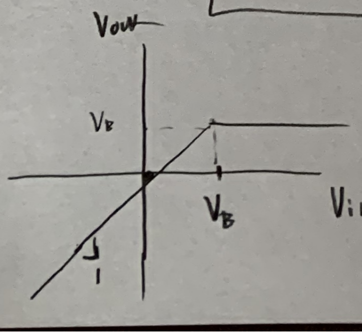


다이오드에 전압이 안 걸리므로, V_{out}에 걸리는 전압이 없다 (V_B는 배터리므로 plot에 포함)

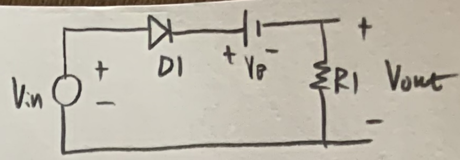
ii) $V_{in}<0$.



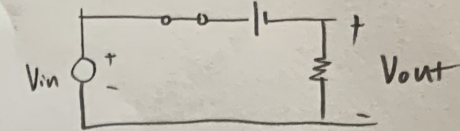
$V_{in}=V_{out}+V_B$



3.11(c)

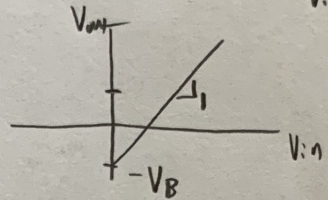


i) $V_{in}>0$

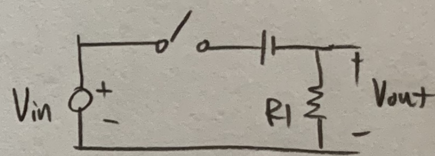


다이오드가 on이므로, R1에 걸리는 전압은 V_{in}과 같게 된다 (+V_B)

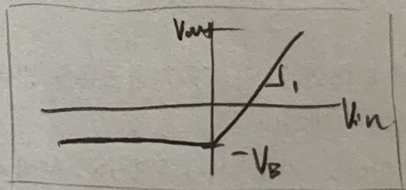
KVL: $-V_{in}+V_B+V_{out}=0$. $V_{in}=V_B+V_{out}$



ii) $V_{in}<0$.



Diode off 이므로, 전류가 흐르지 않는다.



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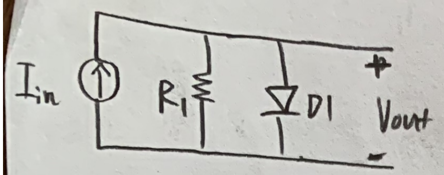
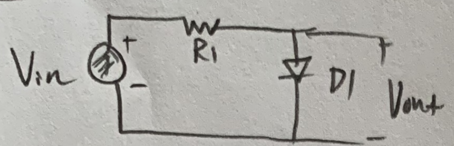
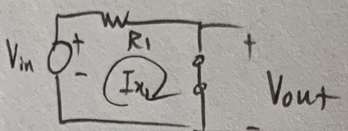
3.14 (a) Plot current flowing R_1 as function of V_{in} / constant voltage diode model



전기회로이론 2에서 배운 Source transformation을 쓰면

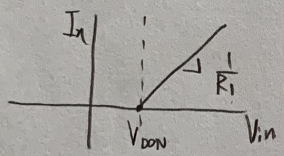


i) $V_{in} > V_{D,ON}$.

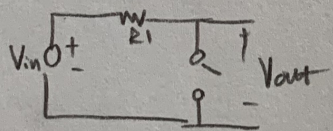


Diode on → 전류흐름 → R1에 전류흘러 전압걸림.
KVL로 정확한 수치를 계산하면,

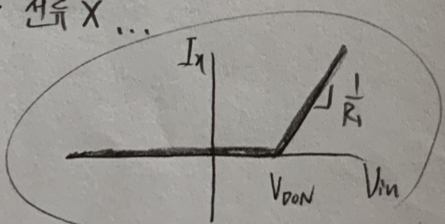
$-V_{in} + I_x \cdot R_1 + V_{DON} = 0$ $\quad I_x = \frac{1}{R_1}(V_{in} - V_{DON}) = 0$



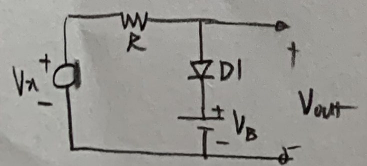
ii) $V_{in} < V_{DON}$



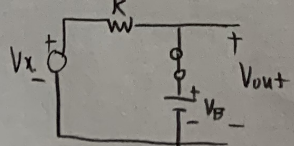
Diode off → 전류 X ...



3.19 (a) Plot input-output 특성 / constant-voltage diode

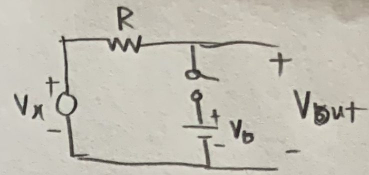


i) $V_x > V_{DON}$.

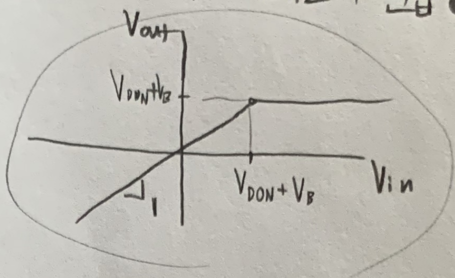


다이오드 on
↳ 전류 0 → 다이오드에 걸리는 전압 = X → $V_{out} = V_B$

ii) $V_x < V_{DON}$

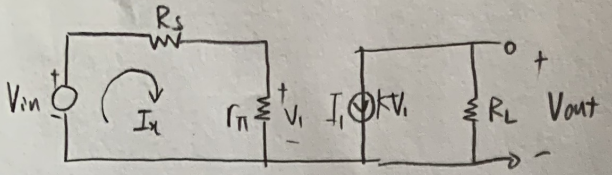


다이오드 off → R에 전류흘러서 전압 0 → $V_{out} = V_x + V_B$



B[redacted]505
남재우

4.2 Determine V_{out}/V_{in}.



• $I_x = \frac{V_{in}}{R_s + r_\pi}$

• $+V_{in} + I_x \cdot R_s + V_1 = 0 \rightarrow$ • $V_1 = V_{in} - I_x R_s$

• $V_{out} = -I_1 R_L = -kV_1 R_L = -kR_L \cdot V_1$

$= -kR_L(V_{in} - I_x R_s)$

$= -kR_L\left(V_{in} - \frac{R_s}{R_s+r_\pi}\cdot V_{in}\right)$

$V_{out} = V_{in}(-kR_L)\left(\frac{r_\pi}{R_s+r_\pi}\right)$

$A_v = \frac{V_{out}}{V_{in}} = -kR_L \cdot \frac{r_\pi}{R_s+r_\pi}$

4.5 I_C of Q_2 is twice of Q_1.

$V_{BE1} - V_{BE2} = 0$

determine ratio of base width.

$I_{C2} = 2I_{C1} \leftarrow V_{BE1} = V_{BE2} = V_{BE}$ 라 가정.

W_B의 ratio는?

$I_{C2} = I_S \cdot \exp\frac{V_{BE}}{V_T}$ other parameters = identical

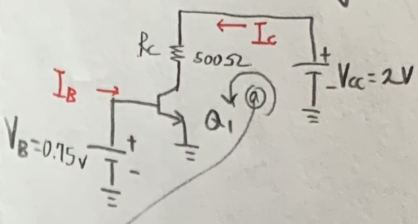
→ $\exp\frac{V_{BE}}{V_T}$는 same.

$I_{S2} = 2I_{S1}$

$I_S = \frac{A_E \cdot q \cdot D_n \cdot n_i^2}{N_B \cdot W_B}$

$2W_{B2} = W_{B1}$

4.9 Calculate V_{CC} that places Q_1 at edge of active region. $I_S = 5\times10^{-16}$.



Active region

V_{BE} : forward bias

V_{CE} : reverse bias

$I_C = I_S \cdot \exp\frac{V_{BE}}{V_T} = 5\cdot10^{-16}\exp\left(\frac{0.75}{26\cdot10^{-3}}\right)$

$= 16.75\times10^{-4}$

$-V_{CC} + I_C R_C + V_{Q1} = 0$

$V_{Q1} = V_{CC} - I_C R_C = V_{CC} - 500(16.75)\frac{1}{10^4}$

$= V_{CC} - 0.8375$

그리고 active region 이 되려면,

$V_{Q1} \geq V_B(=0.75)$ 이다.

$V_{CC} - 0.8375 \geq 0.75$. V_{CC}는 1.5875 이상

즉 문제에서 처럼 2V일 때, $V_{Q1} = 1.1625$ V 되므로

당연히 active region 이 된다.

4.10 $I_1 = 1mA$, $I_2 = 1.5mA$, $I_S = 3\cdot10^{-16}$ A

construct required circuit wt min number of transistor.

• I_{C1}에 영향받는 모든 transistor의 I_C 합을 ΣI_{C1}이라고 가정한다.

• a = I_1이 흐르는 transistor 수

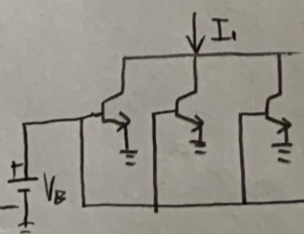
• b = I_2 ″ 수 라 가정 한다.

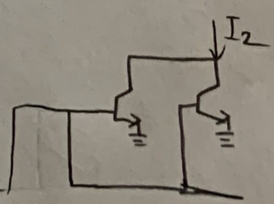
$\Sigma I_{C1} = a\times1\cdot10^{-3} = I_S\exp\frac{V_{BE}}{V_T}$

$\Sigma I_{C2} = b\times1.5\cdot10^{-3} = I_S\exp\frac{V_{BE}}{V_T}$

a=3, b=2 일 때 $\Sigma I_{C1} = \Sigma I_{C2}$ 이다.

즉,





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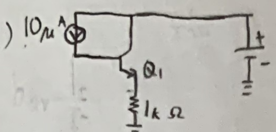
4.19 determine operating point and small signal model of Q1

$I_s = 8\times10^{-16}$ A, $\beta = 100$. $V_A = \infty$.

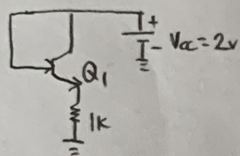
(a) 

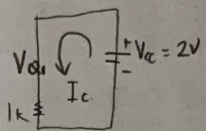
$I_B = 10\cdot10^{-6}$ A $= 10^{-5}$ A

$I_C = \beta\cdot I_B = 10^{-3}$ A

$g_m = \frac{I_C}{V_T} = \frac{10^{-3}}{26\cdot10^{-3}} = \frac{1}{26} = 0.038.$

$r_\pi = \frac{\beta}{g_m} = 2631\,\Omega$

(b) 

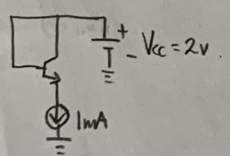


KVL: $-V_{cc} + V_{Q1} + I_C\cdot \underset{\substack{\| \\ 1k}}{R_1} = 0$

$\rightarrow -2 + V_{Q1} + I_C\cdot1000 = 0.$

$I_C = \frac{1}{1000}(2 - V_{Q1})$

$I_C R_1 = I_E = I_C\cdot1000$

(c). 

$I_E = 10^{-3}$ A

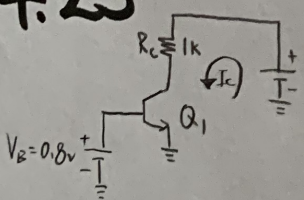
$I_E = \frac{\beta+1}{\beta} I_C = \frac{101}{100} I_C$

$I_C = 9.9\times10^{-4}$

$g_m = \frac{I_C}{V_T} = \frac{9.9\times10^{-4}}{26\cdot10^{-3}} = 0.038$

$r_\pi = \frac{\beta}{g_m} = 2631\,\Omega$

4.23



$I_s = 6\times10^{-15}$ A

(a) $V_A = \infty$ (b) $V_A = 4V$ 일 때 I_C와 $V_x = ?$

1) $V_A = \infty$. Large signal.

• $I_C = I_s\cdot \exp\left(\frac{V_{BE}}{V_T}\right) = 6\cdot10^{-15}\cdot 2.28\cdot10^{13} = 0.1368$

KVL

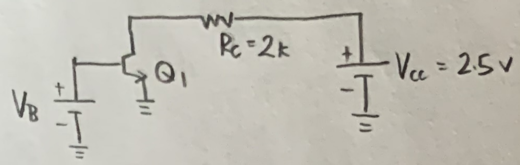
• $-V_{cc} + I_C R_C + V_X = 0$

$-2.5 + 0.1368 + V_X = 0$

$I_C = 0.1368$ A

$V_X = 2.3632$ V

4.28 $V_A = \infty$, $I_s = 6\cdot10^{-16}$



(a). V_B that Q1 operates at edge of active region.

먼저 I_C를 구하자. V_B도 미지수이므로 I_C로 이루어진 equation 두 개를 찾아보자.

• KVL → $-V_{cc} + I_C\cdot(2k) + V_{Q1} = 0$

• $I_C = 6\cdot10^{-6}\cdot \exp\left(\frac{V_B}{26\cdot10^{-3}}\right)\left(1+\cancel{\frac{V}{V_A}}^{\,0}\right)$

• $V_A=\infty$일 때, $V_B = V_T\cdot \ln\frac{I_C}{I_S} = 26\cdot10^{-3}\cdot \ln\frac{I_C}{6\cdot10^{-16}}$

$V_{Q1} = 2.5 - 2000 I_C$ $V_B = \frac{26}{1000}\ln\frac{I_C\cdot10^{16}}{6}$

$V_{Q1} \geq V_B$ ∵ active region

$2.5 - 2000 I_C \geq \frac{26}{1000}\ln\frac{10^{16} I_C}{6}$

를 만족하는 $I_C = I$, $V_B = \frac{26}{1000}\ln\frac{I\cdot10^{16}}{6}$

(b).

$V_B = V_T\cdot \ln\frac{200mV}{6\cdot10^{-16}} = V_T\cdot \ln\frac{200\cdot10^{-3}}{6\cdot10^{-16}}$

$V_B = V_T\cdot \ln\left(\frac{1}{3}\cdot10^{15}\right) = (33.44)(V_T)$

33.44

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남재우