Solution Manual for Analog Circuit Design Discrete and Integrated 1st Edition Franco 0078028191 9780078028199

Full link download

Solution Manual: https://testbankpack.com/p/solution-manual-for-analog-circuit-design-discrete-and-integrated-1st-edition-franco-0078028191-9780078028199/

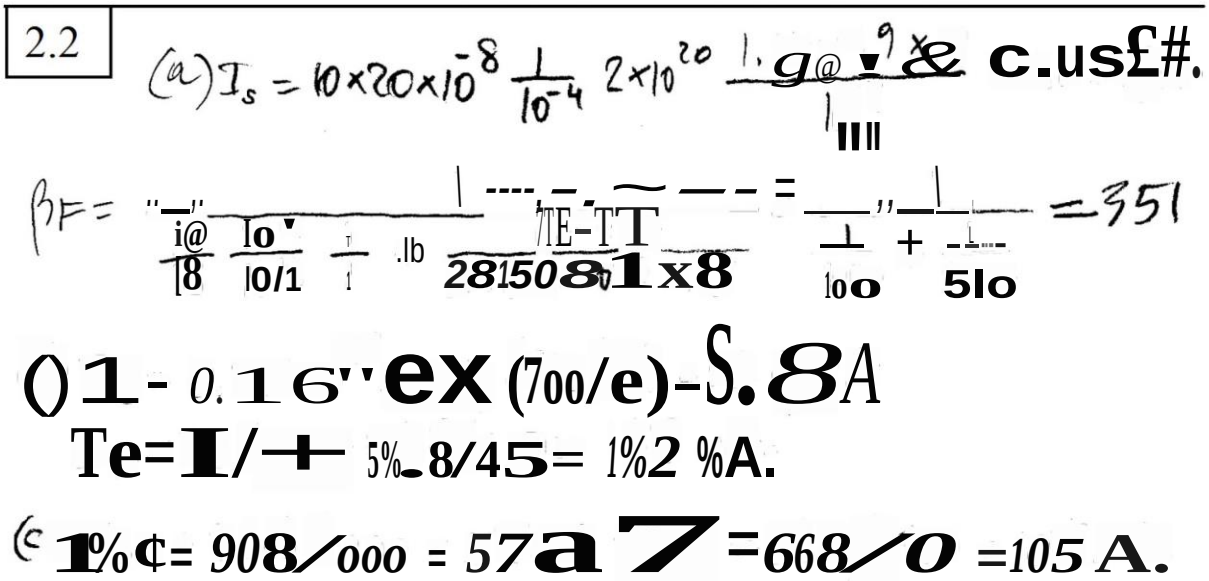
CH. 2-- PROBLEM SOLUTIONS (UPDATED DECEMBER 16, 2013)

2.1 Two conditions are necessary for successful BJT operation: (a) the emitter must be doped much more heavily than the base; (b) the emitter and collector must be separated by a thin contiguous base.

In the case of two discrete diodes, it is not known a priori whether (a) is met; (b) is certainly not met, as the two anodes are not contiguous; the holes injected from the emitter-acting anode would rather recombine with the electrons supplied by the "base" wire, than progress towards the collector-acting anode.

In the case of two half-BJTs, condition (a) is met, but condition (b) still isn't, as the two base regions, though thin, are not contiguous, but separated by interconnecting wires. The electrons supplied by those wires will recombine with the holes injected by the emitter, resulting in virtually zero collector current. Thus, $\beta_F \cong 0 / I_B = 0$.

2.2



(a) $I_s = 10 \times 20 \times 10^{-8} \frac{1}{10^{-4}} 2 \times 10^{20}$

$\beta_F =$

$= 351$

$Q_1 - 0.16 \cdot ex(700/e) - 5.8A$

$T_e = I/+ 5\% - 8/45 = 1\%2\ \%A.$

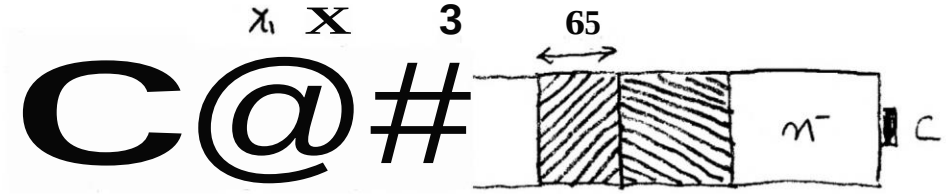
$1\%¢ = 908/000 = 57a7 = 668/0 = 105\ A.$

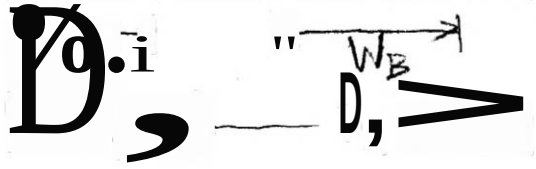
[23] @) pe- sO(h+)y- 0 ; B Vee

I-, /I/+/)- 250 == 50

500 2GD2» 201506/ =>Wg- lO9»

500 DNe W - 18XI0" We (





h.6 0 10'ol F4 >>/ } =700»v

k2 0.

,,=-/sde wg' f@@@@@ io!" 108»m

@e Nasr+N 1GT,jot? 1j7no"?

x —#it?e.- "A =a«

$x_{30} = \sqrt{\frac{2\times10^{-12}\times0.7}{1.6\times10^{-19}\times10^{17}}\frac{10^{15}}{10^{17}+10^{15}}} = 9.4\,mm$

$D_1 = W_E + x_1 = 520\,mm + (1.1\,mm)\sqrt{1-\frac{0.7}{0.94}} \cong 520\,mm.$

$D_2 = W_B + x_2 + x_3 = 1{,}039\,mm + (108\,mm)\sqrt{1-\frac{0.7}{0.94}} +$

$+ (9.4\,mm)\sqrt{1-\frac{-2}{0.7}} \cong 1{,}039 + 55 + 18 = 1{,}112\,mm.$

2.4

(a) $I_S = (25\times10^{-4})(50\times10^{-4})\frac{1}{10^{-4}}\times2\times10^{20}\frac{1.6\times10^{-19}}{10^{17}}8 = 0.32\,fA.$

$$\beta_F = \frac{1}{\frac{3}{8}\frac{1017}{1019}\frac{1}{1} + \frac{(10^{-4})^2}{2\times100\times10^{-9}\times8}} = \frac{1}{\frac{1}{267}+\frac{1}{160}} = 100$$

(b) $I_S = \frac{K_1}{W_B} \Rightarrow I_S$ doubles to $0.64\,fA$.

$$\beta_F = \frac{1}{K_2W_B + K_3W_B^2} \Rightarrow \beta_F = \frac{1}{\frac{0.5}{267}+\frac{0.5^2}{160}} = \frac{1}{\frac{1}{533}+\frac{1}{640}} = 291.$$

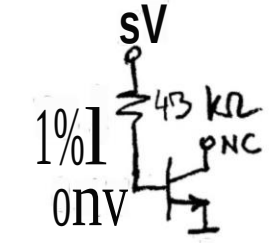
(c) $I_S = 0.32\,fA$ (unchanged).

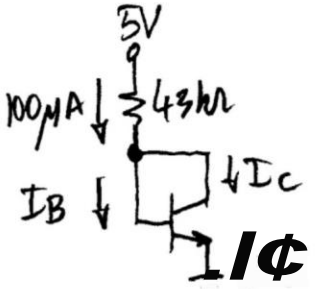
$$\beta_F = \frac{1}{K_3/W_E + 1/160} = \frac{1}{\frac{1}{267\times2}+\frac{1}{160}} = 123.$$

W_B affects both I_S and β_F, and halving it will double I_S and increase β_F by more than a factor of 2. W_E affects only β_F, and doubling it will halve the B-E diffusion component of I_B, thus increasing β_F.

5 @1e HO−A ,'Ve=004—40—-0..x2¢;
4O!5
e- 4= 1.00 S A
+ 1 1%' .095 ¢/4
7no V u 7 I 7 7g 7
Tc le-le- \Oo5–0.00¢ =], 99 A.
9 (
() 1es =000 1 o. £ 2; TseA.
) Zc= 0, 1%–IE elK.

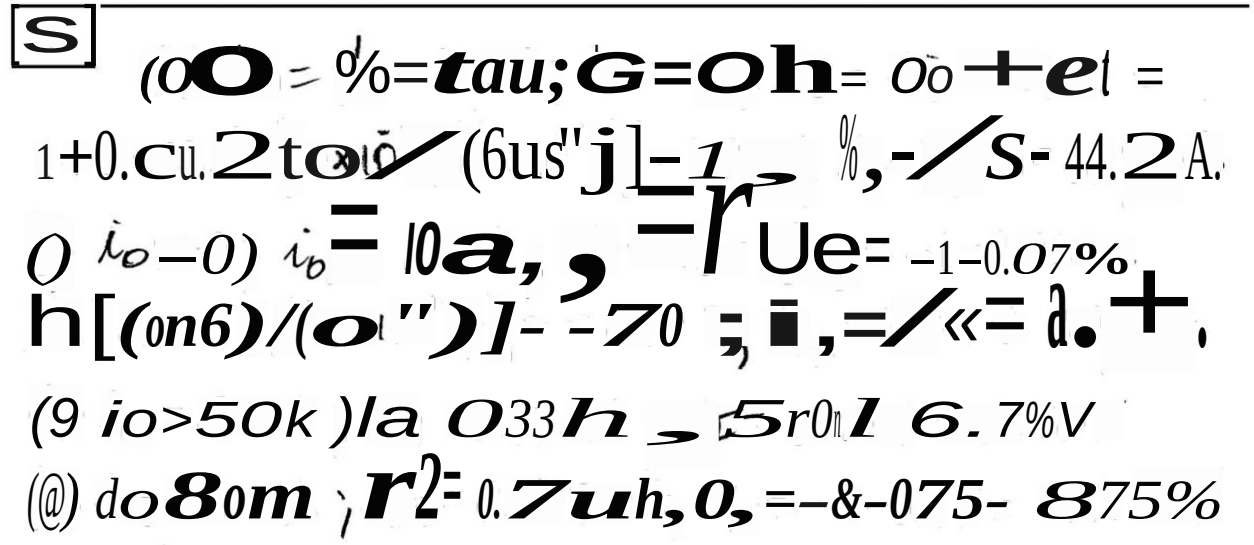
2.6

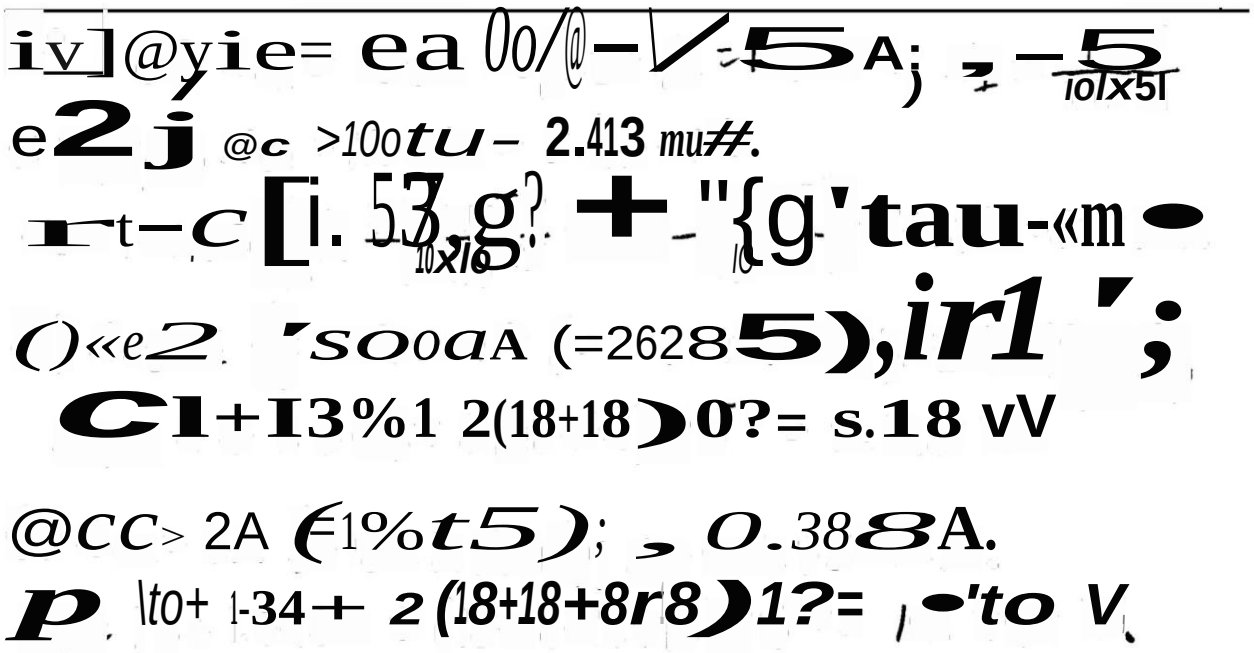




[27] a--5-o%=-5.8V, 1z=Tl= 50A}
2=1e/(0,+) =500/81=67mk}, Zc=I¢T±40A.

S





]210]a» (lat ea = /4= 750; 'rio 260 q 7J;

e, - l00x0.46.04Mk. 3

Dr=-1-0.00¢ [gm,i'rg 6.04? pr@qxe 7

=-1-(070+0.84) = -2.567 V.

06 è n- 5/4=1·26 A(=50x0/aw);

±- Ooh 702 B}

Or =-1V-[(123+00-8)rV+(@4+1.60-198)}av

--4-(0765+007)--2,672 /.

|-!'| @ue-r5 %Yee/6' (+z,) =he WT>>V.

(5) =(0us)[(e?/hrs)/(t+5t9)}1.0875 auh

1C.oar){(+/6)/(r5576)]- 0.95a.

) AT--5·c/le--2(29)=+S0%V

Ve=7/7-+50-767N.

FrO,7wk=((a4A)(2/le)7ONee=+1—60- -H2/l;

2-50-25 +25V =ONop—2(5)e -50N

4V%by --2-60--2ml; Ve=7l— =6%V.

Neeb)= V& +8-2(40—9)=- %%V; Ve='72V.

=1100 »A; Vc- l;–lc–5-21770=1.5%V.

@ 9%at-g, et 6 8orWve,fps15bV ta sV.

mi Tc–k(Vee/V),ne 'ho

1.720 = k(+ «.5%/100), I = (+ 5loo)

I/.70–(+5/0)/(1+15%/0) => Ic= 1.78 A.

@)1%= 73-.5a, =pe=2-05·

0.28%W, V=5-10x0282.13 V.

[TI@%. 5=2,e= ·9,= 3

–Z · 2/0-043 [o. 0

7,-1-/— 2a5?/e, (/w)- 2.n% A.

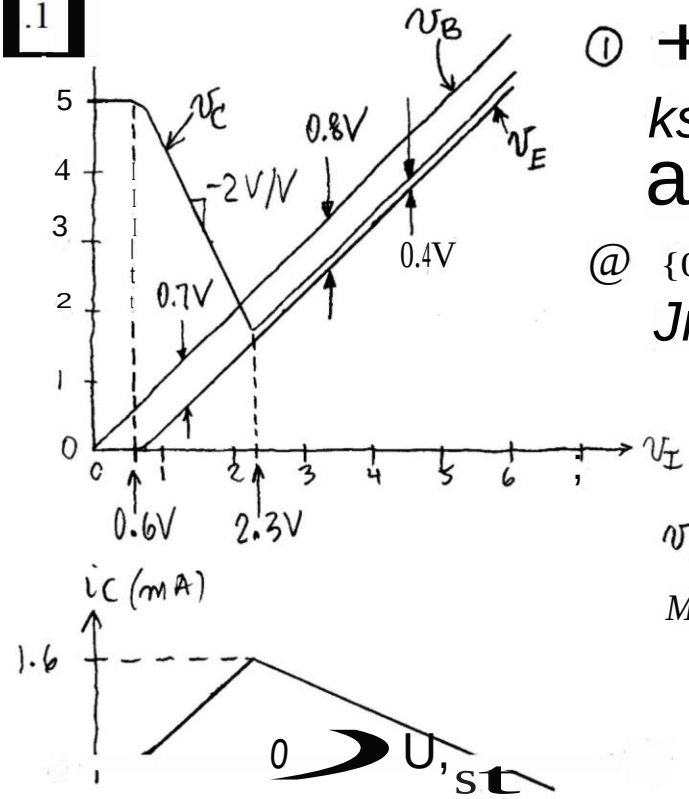
()Va- IV,Te–2»P, V2.\90 V, T=(5–2-50)/1–@.05aA

2.05/2=+2950/09)/(+1.0/%) => V= 77/.

@) ▾ -G 2)/o–o.A, Ig=/5-07/0-0.3»A

= -3/0.13z2.

.1



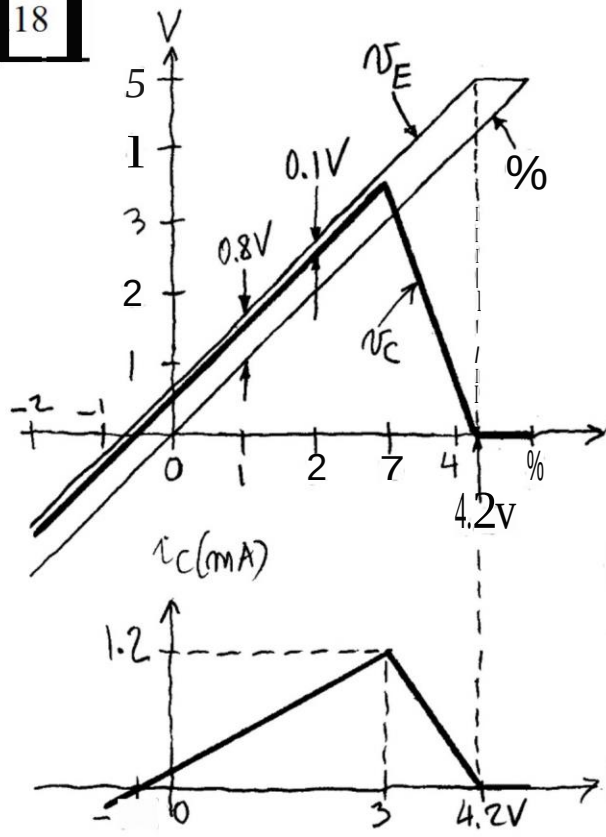
① +@,<Vco s¢y
ks 8122i ct{~,
a =I,>V, dc=0.
@ {0i5054 aloe 0.eV
Jr»» tAT a.
7ala0Ms , tho
vi rA, done
= s--Ve -)= O- 07V.
Megown , C- V-cdc
zV,-C -%,-e'
Ela or
Te

¢ =7% {tees - "$;e. (ate, tkw te .
Aoasl·[-Rahe >–2V//
@ k 5T rah»» ke cos Ra £. 5=(g19,n

e= %v. t 1do Wt, (re e+0. =18V) de=
t.+o.72.3V — kes = (–1&/2- 1.% +A
@ A «e on«wig , tk Jala&»,Ok
a- r –0.&V, - e+0. · –0V, and i=

(6-e)/2 =[5-(-,-02)]/2 =(57–»)/. Conk
newd9waneo wt. AF,,
@) A rAko 5V ic detlo eus. Fd ±>5.7
«C 8com m3sky %e5-Cuna.a io {oa.A
lass. ,on»k ic OVO owt 4 uModsh !

18



#e Oh,> V-Vs(cc2=

5-0,8- 1.2V, BT=Co

C>0, ic=O,

Loron, Oz 1ear

4.2V S BJT

m,»»otale, A,

-& hue

, ='+el) =(r+0.8V.

Meet8n, Ur=@cuckcic

V=Se

="'' 2(-0,-o8

@- 3 (42-G,). (eanl,, «o r 2» lonewed below (al,

We oicce»op adtl.els.A+WV, ad. cmo8

ct tlnsh 4(v/(1y- '(aAN. C ooo» jUlin.

0.-}e,tt 6Ado»ta o5. WWK

—-f. n 3(— (c+08)-0.',e}kd1st

%o BJ1%tale» tts 605 —2.'75 3J. 'Attwo

my~C' 4,$32(@2-3)=-1.2»A. lo+

cel.r

V dinwotli mo?e al mole ts <lnaos,

9 re=0e-0.1= +0.8-0.1= r+0.7V, ic> O/¢=

(@+077)/(31). 0»e 1; 2o» lsonolt» -0.7V, ~cleav»

0,ol Trmes-(t. Ui.kl,ks rs -c

I g<0 V>BSTCo=czvsO,c—6V,

• S>0.7/ =>BTO, vwilcl0, FA :

ie-'s8,%- ff = >-D7 ic-pie= fo—07.

e=±po--s+2[-g2).

(@) a We noa.dawn, es-Ve~(es)—0.—0.1 €0,6l, BJT nuadwo eos. th» post,

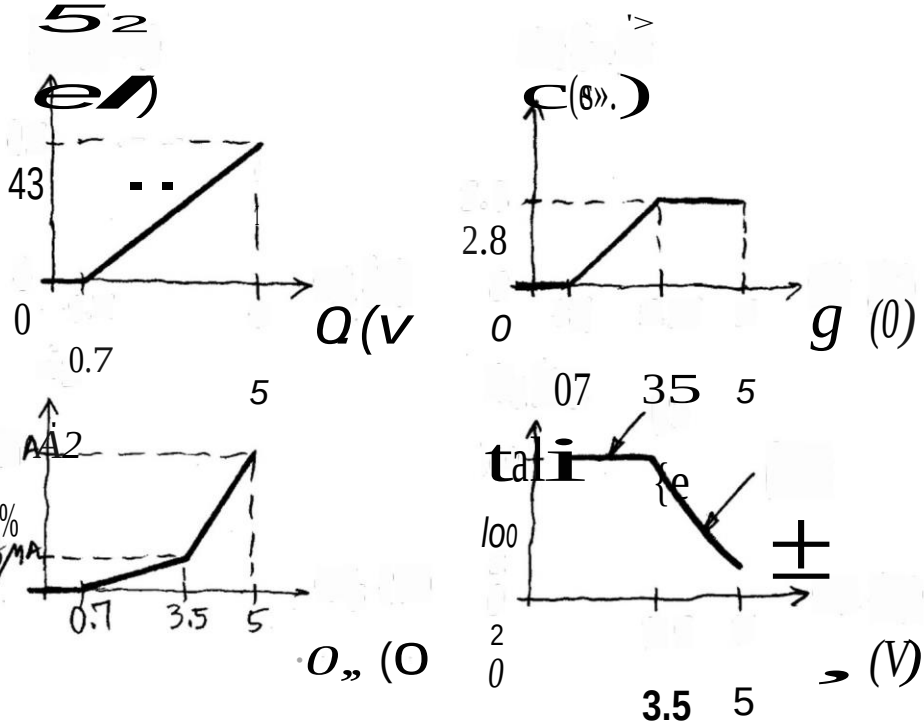
eoe-4448%«k, Ve9-07+11etee)

07+Pas) = 0.7+2.8–3.5V; =x;}= 2A.

+) re ,>35, bJT=Sat : ic=cos)- 2.8sh,

a,-"s-07,i,=e -ic= -O 7 2.8–(T>-35%#.

tc 2.@ U– ,r.a , tus,) &c–2b zel1b8 .



[.2] @

WVl: Vcz>(c1+1ce@Eeslor2 +2+2((rs)8;

kt V— fP+Ve4(&es=3007+01+2(+;

==3+)1%,1—o2+2p2)B =

2.02 > (=1o

47—302+2r l'

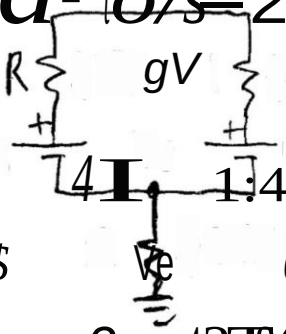
k

(b) L:. s=1tc+02+2Te VE ad1c+02+2IE402+1¢

=le:5-02)/3= 1.%uk 216- -2V:,V=32+0=

3.V; P=l.6/3- 1.2, Ke($—3.9)/.0—0.

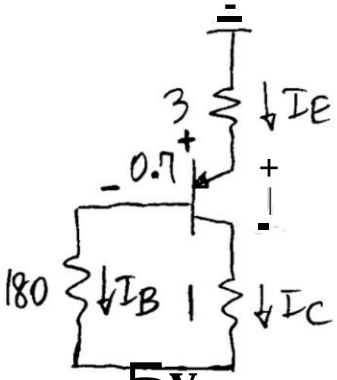
(9)/d= 1o/s—2% =Tc+2%P.1e=371e.

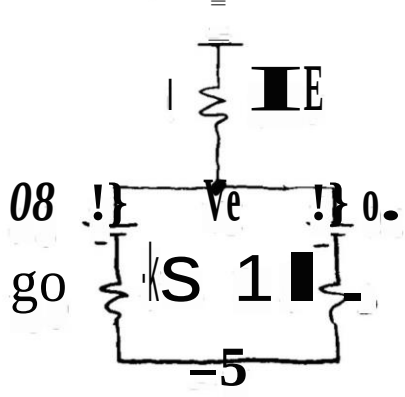


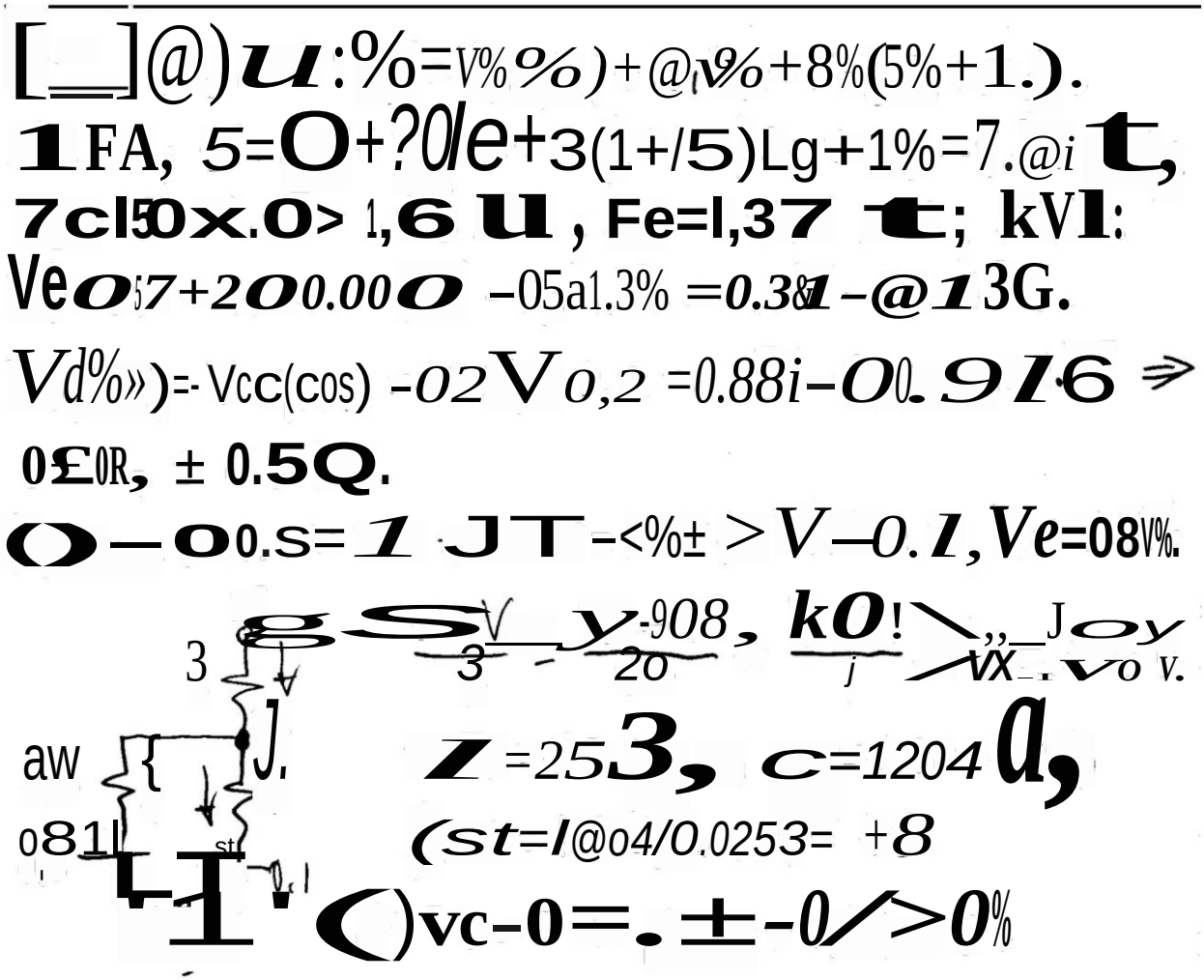
4L 1.426% 5-1x261+0.+5\le1a-6l.25A,

0$ Ve 0.1 Vg- 540.062125+0.&= 3.4075V.

2 ·42T% R=(-3.#019)/04175→ 14.%.


3
IE
0.7
180
IB
IC
5V


IE
Ve
0.
kS 1
5



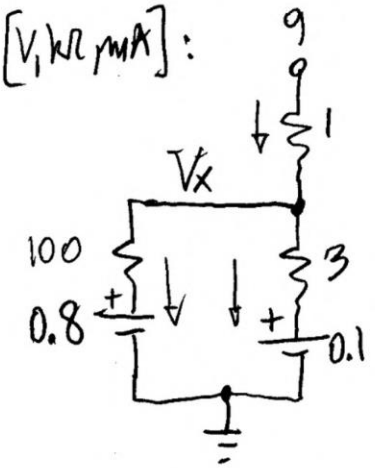
2.23 (a) Assume FA, and check. By inspection, $I_{R_2} = I_B + I_C$
$= (\beta_F + 1) I_B = 151 I_B$. KVL:

$9 = 20(151 I_B) + 100 I_B + 0.7 \Rightarrow I_B = 2.66\,\mu A$, $I_C = 150 I_B =$
$0.399\,mA$, $I_E = 151 I_B = 0.402\,mA$. By KVL again,

$V_{CE} = V_C = V_S - R_2 I_E - R_3 I_C = 9 - 20 \times 0.402 - 1 \times 0.399 = 0.567V$
$> 0.2V \Rightarrow$ FA!

(b) Assume saturation, and check. KCL:

[V, kΩ, mA]:



$\frac{9 - V_x}{1} = \frac{V_x - 0.1}{3} + \frac{V_x - 0.8}{100} \Rightarrow V_x = 6.73V.$

$I_B = \frac{6.73 - 0.8}{100} = 59.3\,\mu A$

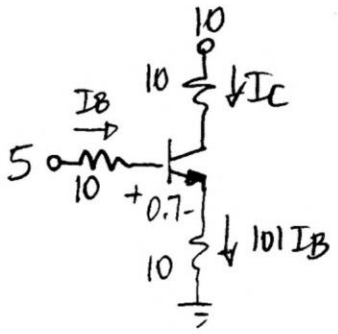
$I_C = \frac{6.73 - 0.1}{3} = 2.221\,mA$

$I_E = I_C + I_B = 2.28\,mA$

$\beta_{sat} = I_C / I_B = 2.221 / 0.0593 = 37 < 150 \Rightarrow$ Sat!

2.24

(a) [V, mA, kΩ]. Assume FA. KVL:



$5 = 10 I_B + 0.7 + 10(101 I_B) \Rightarrow I_B = 4.2\,\mu A$

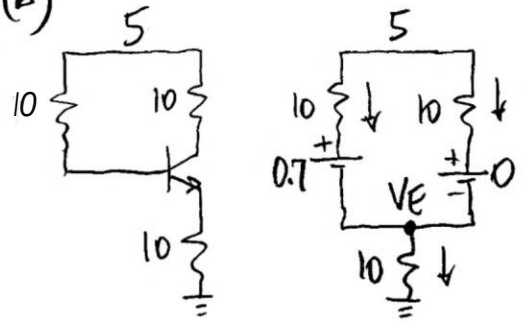
$I_C = 0.422\,mA$; $I_E = 0.426\,mA$

$V_B = 5 - 10 I_B = 4.958\,V$; $V_E = 4.26\,V$

$V_C = 10 - 10 \times 0.422 = 5.78\,V$

$V_{CE} = 5.78 - 4.26 = 1.52\,V > 0.2\,V \Rightarrow FA!$

(b)



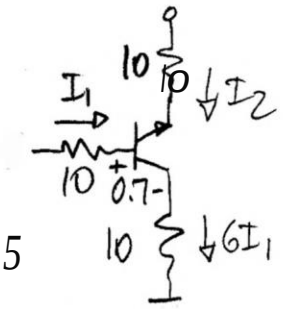
Now BT~ slaleA, CL

$\frac{5(e72)}{lo}, \frac{5\text{-}E\bullet\ VE}{IO\quad IO}$

2>Ve=31V.

T=0.I%A; 1Ip–0.12mu, I=04A. X+(-LL

O &voe qCoe mole. kvL:



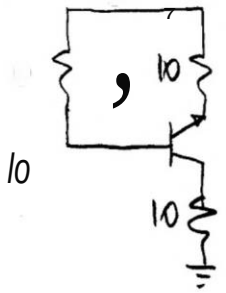
5=101, + 07+61, =I= (I. HA

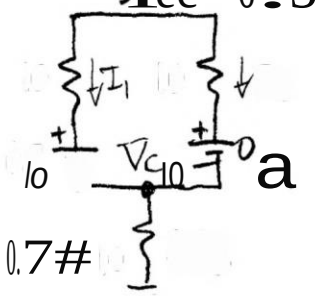
7,=51=307, 6= %A.

Ve=s-01,- V; Vc1-0.7

=3.@V, Ve=o-lo1,=6.3V

(d)





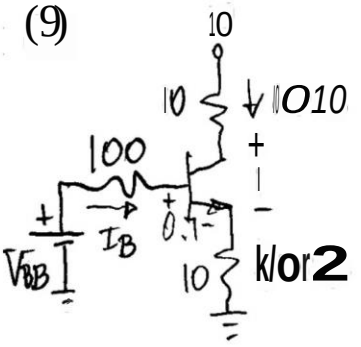
5lec- 6.3—%% >0.2V =Z 0A!

BJ7 kO » p2&e-ode lo«las. so!a oi.cad bo» ox»kcllant (), e=.V, I,-0.12R

to W 72- 0./%ah, [st = 0.1/0.4z = I.G•

[s] [,A,~].

(9)



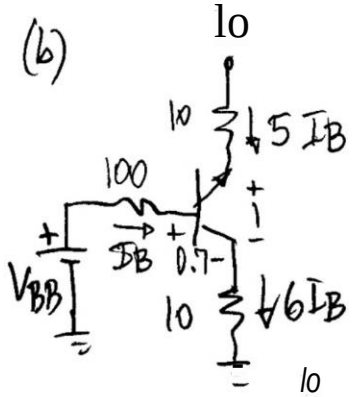
Vu:. 10 – 10(0/e) ++ 0(10re)

=1%= 44&uH,

V¢1oxI@It, = 1.522 V, Ve Ve+oV

- 5.22¥ Ve/e+02s= 5.%7 V•

(b)



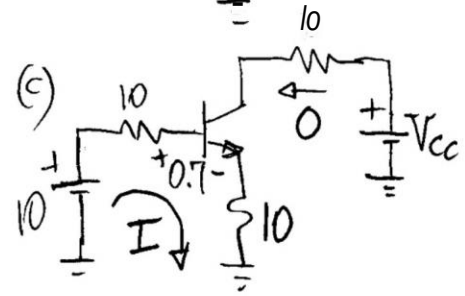
Vt: 0 – 10(51e) 4+10(6»)

1 e= 81.8i0#

V = 0 – 4. V, 'W=5.61V

Ve= 5.61+1000.08\– 13.8 V.

(c)



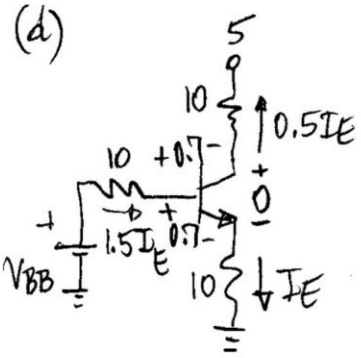
col 1 = I. NL:

10101 +07+10 1 I=0.%5%

V¢ -4.%sV, V>533.

o tc=0, VCVa-0.65±,1V.

(d)



I=151¢ = Tc-0.51(odl] clots)

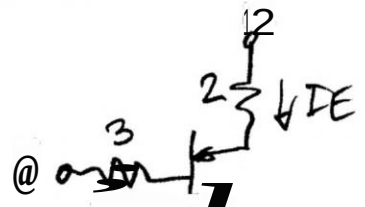
=7 t-(05P~)/(151)>-1<pr %et.

- – Vee=07V = O=5+10(0.51¢)

> IE- l»A => Va=lo(1.5)+0.7+

10()= 5V.

22«[@ [,a,].



Yoe th: VL;

12– 2x/51lg+07+3lE +%

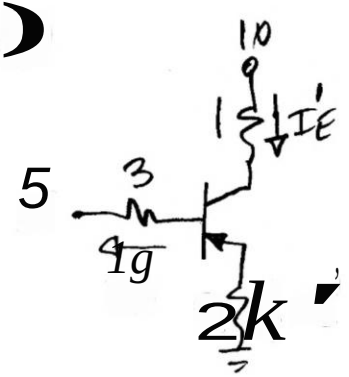
I■ =/7MP,7=2.6la,

— 2.42aA, V=6O2 V,

ve67529i=.¢v

VecauV o.1 v cA!

)



Assume RA ; kVL

lOlx5T +0.7+lb+"

= z->0,5375a%

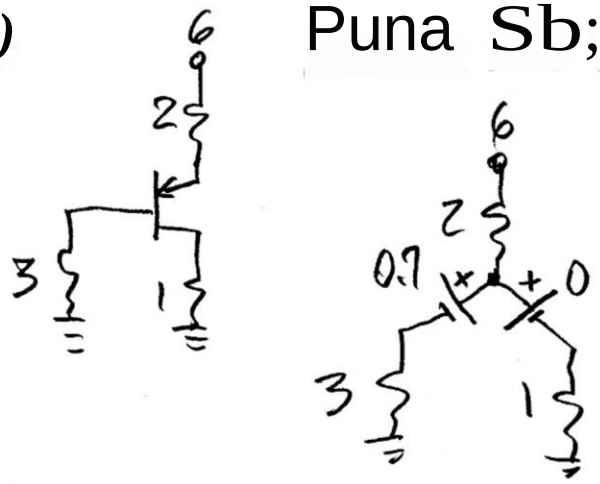
7,'=lx0.575–2.15A

p>5<0575>2.4875a

%–5+80.5375–6.6/25V; Vc= 6.c25m7= 7./5V

Vg22u5k/ 1.35-4>0.le> A]

@) Puna Sb; ucL;



@–__Vo], -O

Ve-lr7% v

Vc=1.736 V

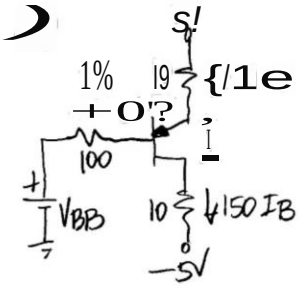
Ic=1.736 mA

VB=1.036 V

IB=1.036/3=0.345 mA; βsat=1.736/0.345≅5<β=

⇒Sat!

oat, a



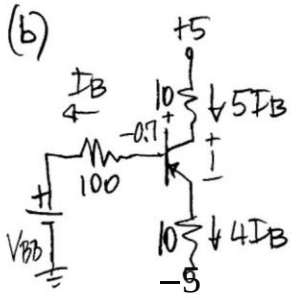
lvl: s-(s)- lo(1s1Pe) +lo(52le)

7Ib= 2.19 μA

\au= S-lo(19»)-07-OB

=-0.51 V.

(b)



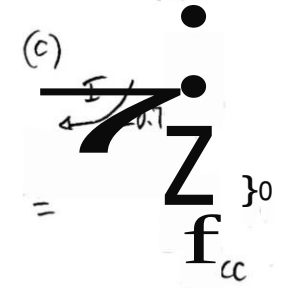
0-(51s)+ 1+10 (412)

= 1=0.4 »

1s- 5-1(50.)-01- 10oxOL

=-10,7V

(c)

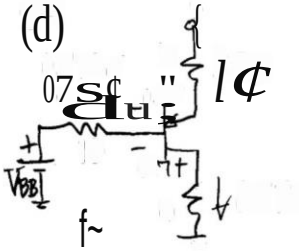


I . kVL:

: 0,415 mA.

Vee~ V'o-r-D.bS~ Lt--15""+-0., S-=- 4,W.

(d)



1,-0.51¢ 1c-0.5 , u.

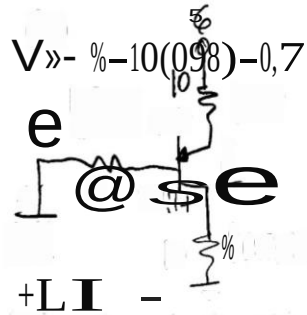
(- Tc/%-(.512)[.1512- L

5<150= al.reo

"''use u:%-ore+lo(se=>

Ir-08&u. VL'

V»- %-10(098)-0,7-10 (0519+0.48)- -3.1V.



T,-L5¢I=0751e(%l: tle

alta9). Pl-(-47512)[las12

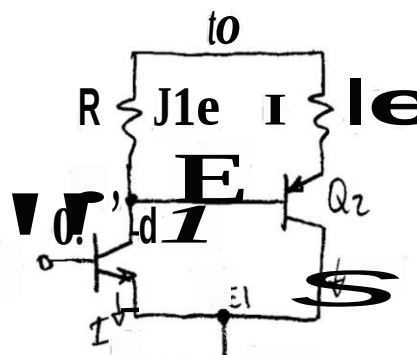
=O2<ls0=<kale>

Vc=0. vl:

hew a··10a51% ,, +o(0.5Le)- 19/e =J±08A

%» =G-O(0.8)-0.7-lo(1.50.8)= -27 V.

[228] [v,aka]. os»L90–A.1ez,,0s=0.s1»A.



to

vte Ve–l0–10x0.51–, , Vl:

V=4.—07A.2V=Ve. cl:

Te=Ta-1%= =0105- 0.%A.

W?»e?3+ . CL:

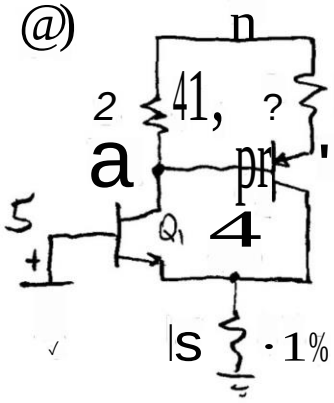
"·;5 11%-m%;-95-#} A.

0hm? R= \0 gOO - 10 10 u, ~! -Vcoi:; 4,1- (4–o,<i'I > 0.2 V

=0–A. Vcz–%–(–0.7)>0.V >G=FA.

- =1= IC/p=(/52)/55= 10'1 A.

]229] [4k]. As»«eQ,O-=FA,0»d cu-k Ve, Va, =



5-07-43V. 170wig,,bane croon»ho,

7,-Te a·Ila, «

lz _2-Va ,r-(Nao.D
1.5 23 2

Va= 2.uV=lee1,- Rll=

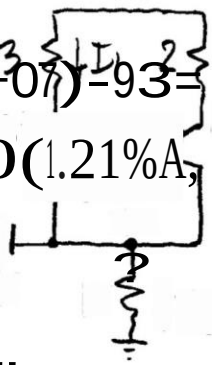
n a m "--' -~ ~I _ 12-,S. /4. =0,7=

l

l.5nA, e-2u-43-.8 •

·4-cz-an-2 2

(3. 4+07)=93= 454/(O<V1>(o)=>Goidl



0,-O(1.21%A, 3.84); 0a>0.(1.58 570)· V;

(%) karc@st, Q7A, al ck»ck.

Ie Vet-ca= 8-07- 7.3/,7,o.3⅘5=

1d'"±,, " 1» > -V»-1.+al=n

9-] i We=Va+7= 8.1V1(7-70)/3=

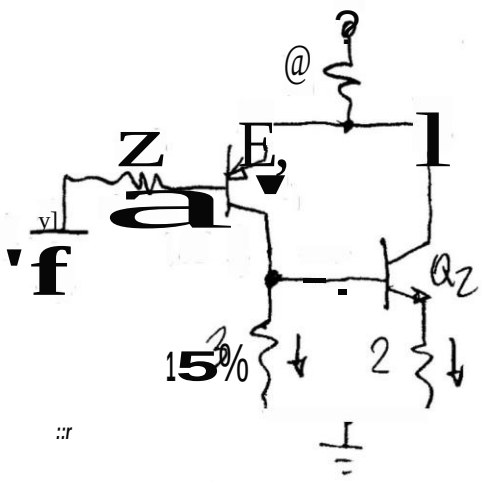
0' sl, 1.53mu, Te-(2-8.)/2= l.5%h.

O-O(1.5A,08V), FA. kcl

Jr-1,-(1,)- 481-(53+115)- 1.38%A. F/en,£

2/1w= 15/18=.I = 0=t,al 0-(1-53%4, 0.1V).

[2.3]



e.lg, Sn Na:01 z -4.7¥

e.4,0–1.85%A

50

Iv 2–I8/ A

5le %

er5r=5is-ta

ge Tcp .3lank

1 –70/9 16/,0= 0.O, Vey- 6+320,0— 4-/;

Ve- V+07='1.6 , Rr(12–7.6)/3.3€ 1. %.

(wh: We -(2-13833)–4.34£ 33V>0/=FA.

WZ(12-1.3433)–((3-07)< 4/O.W A.

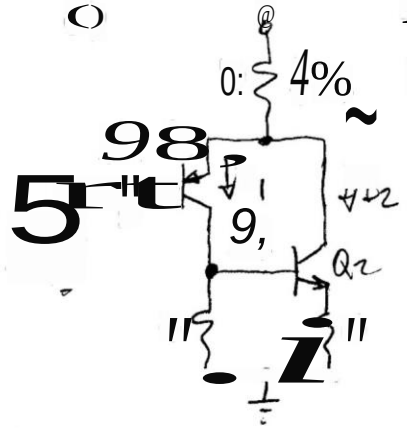
() kw)& zoo.doaoa le mud,vek vs

olds.tog tko »bag, .ow - Vows,

Ve 1ssV, Te, is'07)/= 1%h', T,=

l.s+ - = 3.%k; R,–(\2–1.6)/3.4= 127 in1.3k0.

231] {V,%4)]. koms 0O- FA,nu Reh.



Tei} Pa Pl. Lsz,we hae ,b8kl,

0: 4% Ve–Ve -%+07e 5+0.7- 57/. n:

98 ~ »=(–5/0=0.6mA. ct:

5 7+,=04= j," Ve Va–0.'7 / 10

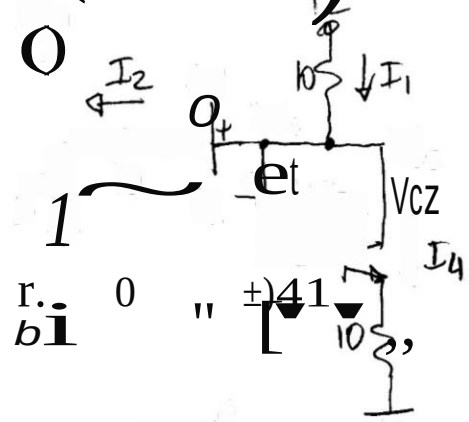
%we-S1-7;-0-

Jc–063--035 0287MA.

lea-551-35–2.2V>oV F+, Ve,=57-(5-0.)•

2 />>oWA. 18, Qye O(095A,2.20); 02°

O(0&A, .)



wti R, evkedfo aua,, Te

72e2 = w Snell,5 nu

Pvt k1/ -, L~ Ar:1 ::r-u..

r. 0 " ±)41 bi [10 ,

"D, \ =al.Z

ii7dis, Ve2=o7+0)>

08V>0.IVOA.

IK=VVc. oL

1 x 0 = .£.

11 ""J-z-r, .+-r::4- "- rz.vTif, t,1..

lo –(–o)-5 lo ,-09-0 lo 1V-6.(V 10

1-. .40£-g05-00i,, 1v90

=052A. Ia=7=1[r. Wg,pez)

hs. it Te < 0.575/c05 3%A pl+<5.3/.

O.1 O>«k. TuOw», Q–0,(<5.36A,01V),ad

OO(0.53%ah,0.8v).

[3h,,,a1. Use ll, oh' horpsh.dy.

Vcc = Rca+V az(eos) +ks[g ≅ (@u+@g)cz +v~c(o) ⇒

5=22I¢2 +02 Dz2=¢.77 m#.

le= 1%.in - (V; Vea=%.7-07=%.07V=Ve·

e-47/0- 7.z7¢_

7a=5-%.0z)/3o +62.710?=0,3%52A. /same Q,A.

Jr= 0.3%%3/o= 3.66A

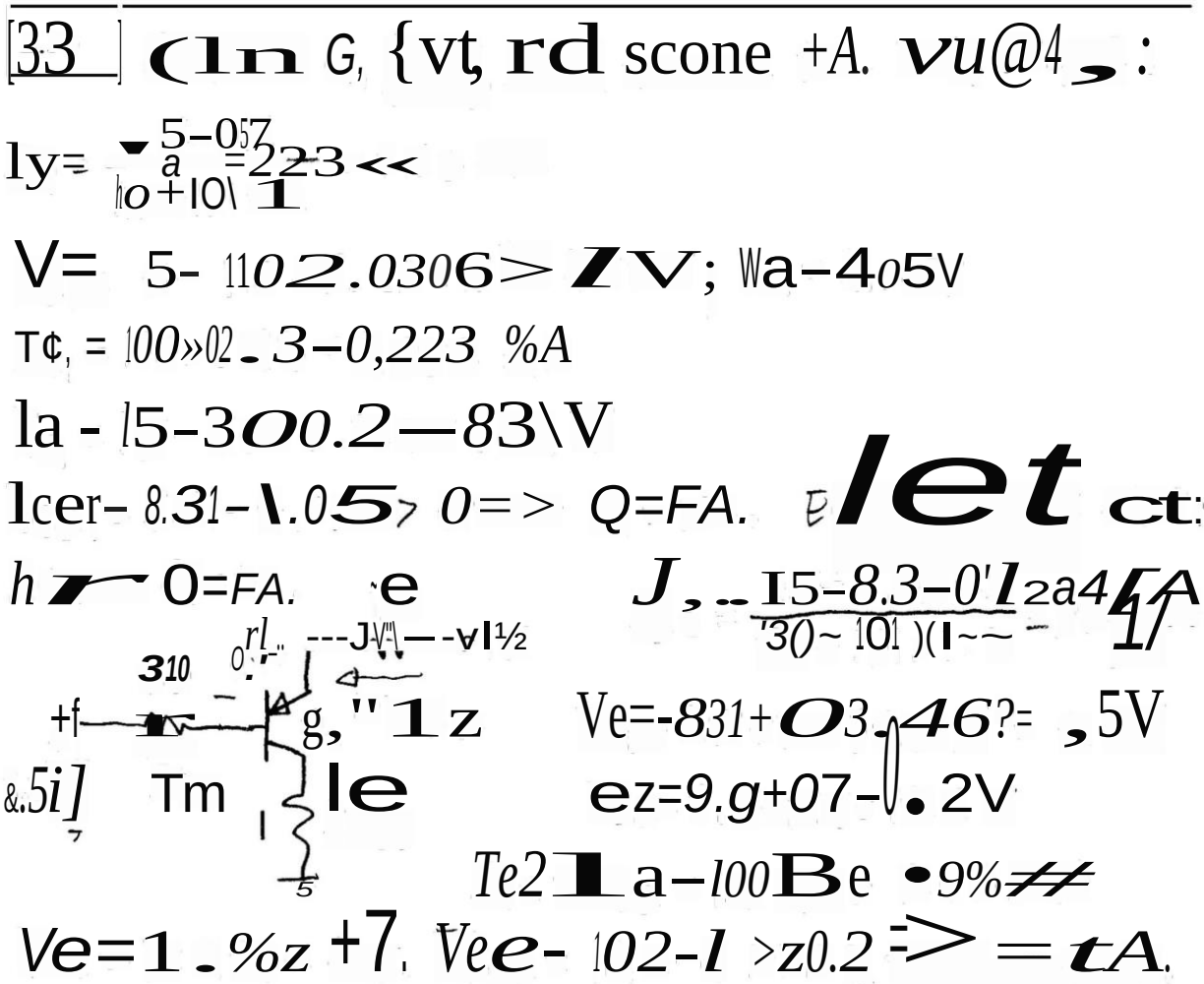
Ve;- V«—,le, =5-10X3%%16?:4.%V

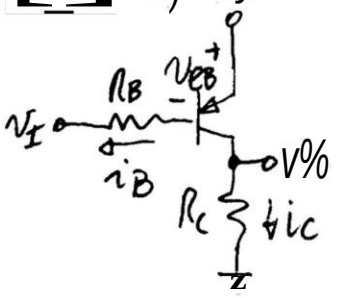
Va- +6-07-3.9 v

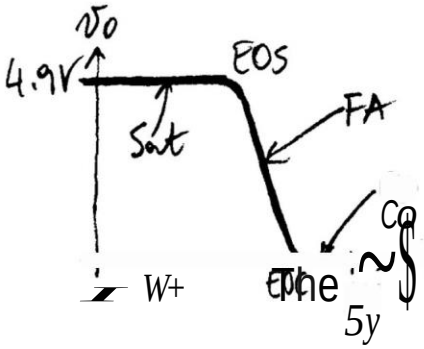
el :I = 0.7au±

6%=-9/0.37=105e

Ve Io21 -3,9 >0.2 »Q=A.






4.9V
EOS
FA

2.35 (a) KVL: $v_I = R_B i_{R_B} + v_{BE} = R_B\left(i_B + \frac{v_{BE}}{R_{BE}}\right) + v_{BE} =$
$R_B i_B + (1 + R_B/R_{BE})\, v_{BE}$.

(b) $v_I = 10^4\left(\frac{5 - v_O}{10^3}\right) /\!/ 100 + \left(1 + \frac{10}{5}\right) 0.026 \ln \frac{5 - v_O}{10^3 \times 2\times 10^{-15}}$

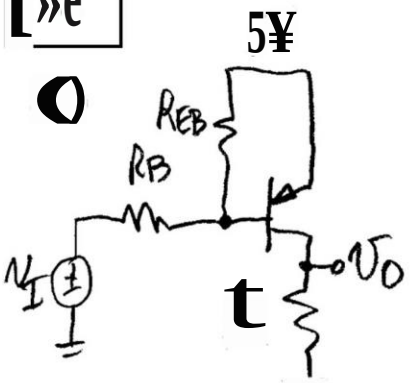
$v_I = \frac{5 - v_O}{10} + 0.078 \ln \frac{5 - v_O}{2\times 10^{-12}}$.

(c) $V_I = \frac{5 - 2.5}{10} + 0.078 \ln \frac{5 - 2.5}{2\times 10^{-12}} = 0.25 + 2.173 = 2.423\ \text{V}$
(shifted to the right by about $2V_{BE}$'s).

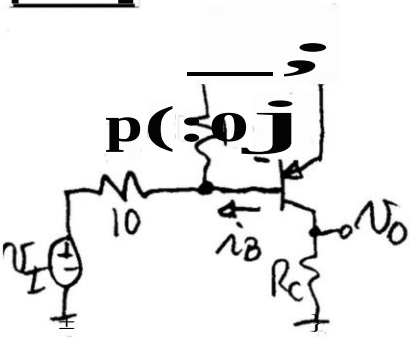
(d) $\frac{dv_I}{dv_I} = \frac{1}{10}\frac{dv_O}{dv_I} + 0.078 \frac{2\times 10^{-12}}{5 - v_O}\left(-\frac{1}{2\times 10^{-12}}\frac{dv_O}{dv_I}\right) \Rightarrow$

$1 = -\frac{a}{10} - 0.078 \frac{a}{5 - v_O} \Rightarrow a = -10\frac{5 - v_O}{5.78 - v_O}$.

@ $v_O = 2.5\ \text{V}$, $a = -7.62\ \text{V/V}$. In the example, $a = -9.06\ \text{V/V}$.
Reduced gain stems from the presence of R_{BE}, which forms an input voltage divider with R_B.



$V_I = 5 - V_{EB} - R_B\left(i_B + \frac{V_{EB}}{R_{EB}}\right)$

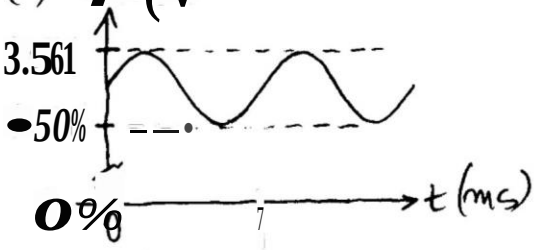


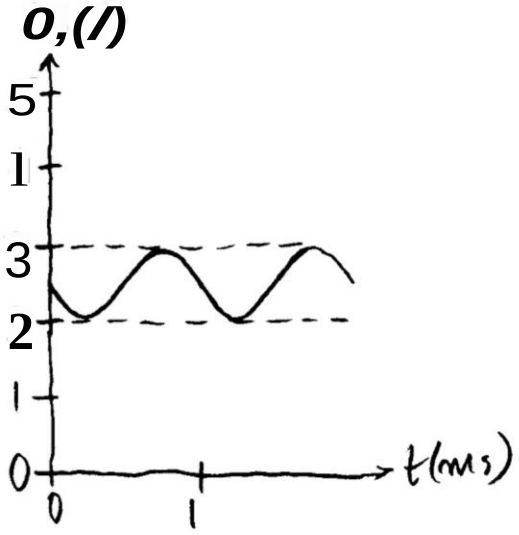
$$v_O = 5 - 5\cos(\omega t)\ \text{V}$$

$$v_O = 5 - 5\cos(2\pi \times 500 t)\ \text{V}$$

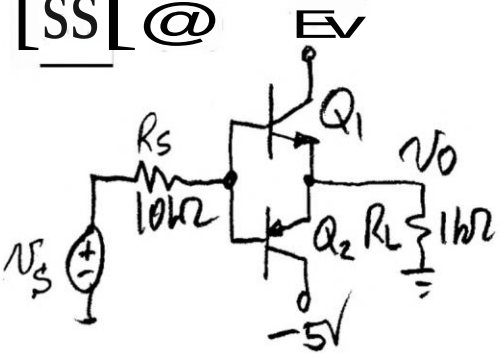
$$a = (6-2)/(-5\cos(-3.567)) = (6-2)/(-0.94) = -4.26\ \text{V/V}$$

(c)





[SS[@



VC?ibis,so owl-{
tu con ro. [,Aj.

0<o,0.% =O=-Co.

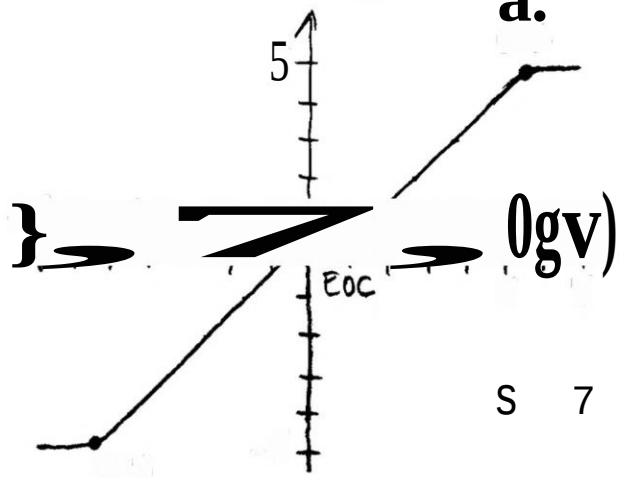
r-0.V =>Q,= E0¢,

0<O< 5-0.2=4.8V0=r_

Olo 0

a. O=_Vs 0=€0%,».1

Z= 48+07+ R< Lg
- 55+m0-# f



} 0gv) =5.»V: + 4+++

S 7 =>r>5.55/0.ch

e05 -S

(e) %-2.sV=Ur -+'2.5+07+10'1%)7±345/

.3

[] 6

A	8	@	G	'-(
L	L	Co	Co	kH
L	H	Co	Sk	L
H	L	St	Go	L
H	H	St	5Sot	L

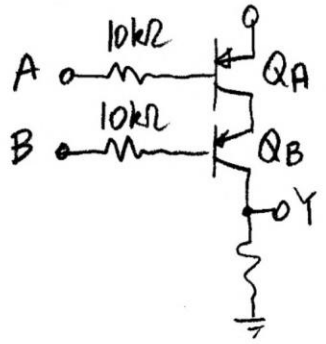
(b) $\beta_{F(min)} > \left(\frac{5-0.1}{1}\right)/\left(\frac{5-0.8}{10}\right) \simeq 12$

[.40 @6

A	8	@	%	Y
L	U	Co	CO	HL
	H	C	Co	H
H	L-	Co	Go	H
H	11	%.t	sad	L-

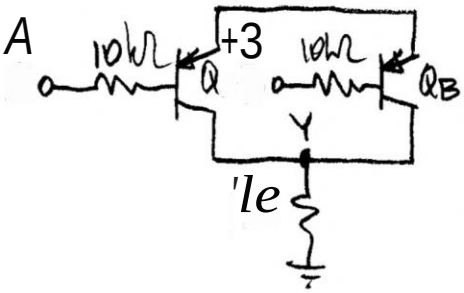
o- [74p1/[=0.8+0 7 .%+
10
z,[4, 0.1 ±44/#\•
1

2.41 50



A	3	QR	~~	Y
L	L	5I	$k	H
L	J	O	Go	L-
A	L	Co	Co	L
H	H	Co	Co	L

2.42 gV



A	3	Q	S	Y
L	L	b	1	1
	~	Sal	O	H
k	L	Co	5	H
H	H	Co	Co	L

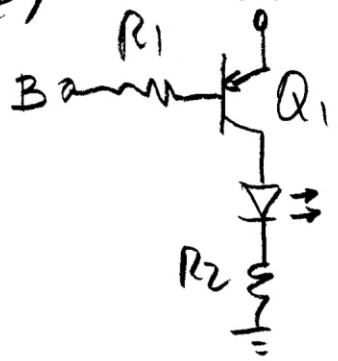
(@) 0a–(5-15-0.⁄ - O3+»02 (ee 3309).

1)> (5–1.5–0.)/0.33- 103a

1(o»)- 10.⁄50– O20%auA.

&,< G–08)/0.2o¢ -2on

(b)



3=1–0V>O–stIEb 9m.

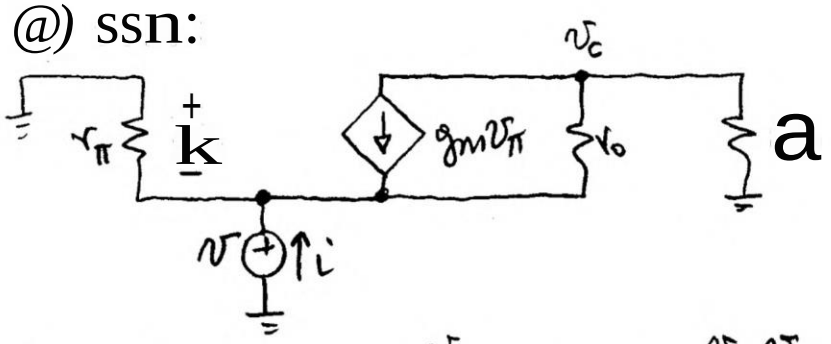
BH6/0–co ⇒ LE~dank

prwrg 7.e Sam.o parameters

no t6s4 prob O

@–10I ,ll,3309.

u @ ssn:



KVL: $v_\pi = -v$. KCL: $i + \frac{v_\pi}{r_\pi} + g_m v_\pi + \frac{v_c - v}{r_o} = 0$, or

$i - \frac{v}{r_\pi} - g_m v + \frac{v_c - v}{r_o} = 0$. Supernode: $i = \frac{v}{r_\pi} + \frac{v_c}{R_C}$, or

$v_c = R_C\left(i - \frac{v}{r_\pi}\right)$. Eliminating v_c gives

$$i\left(1 + \frac{R_C}{r_o}\right) = v\left(\frac{1}{r_\pi} + g_m + \frac{1}{r_o} + \frac{R_C}{r_\pi}\frac{1}{r_o}\right) = v\left(\frac{1}{r_e} + \frac{1}{r_o} + \frac{R_C}{r_\pi}\frac{1}{r_o}\right)$$

$$R_e = \frac{v}{i} = r_e \frac{r_o + R_C}{r_o + r_e + (r_e/r_\pi)R_C}$$. Considering that $r_e \ll r_o$

and $\frac{r_e}{r_\pi} = \left(\frac{\beta_o}{\beta_o+1}\frac{1}{g_m}\right)/\left(\frac{\beta_o}{g_m}\right) = \frac{1}{\beta_o+1}$, we get

$$R_e \cong r_e \frac{r_o + R_C}{r_o + R_C/(\beta_o+1)} = r_e \frac{1 + R_C/r_o}{1 + R_C/[(\beta_o+1)r_o]}$$

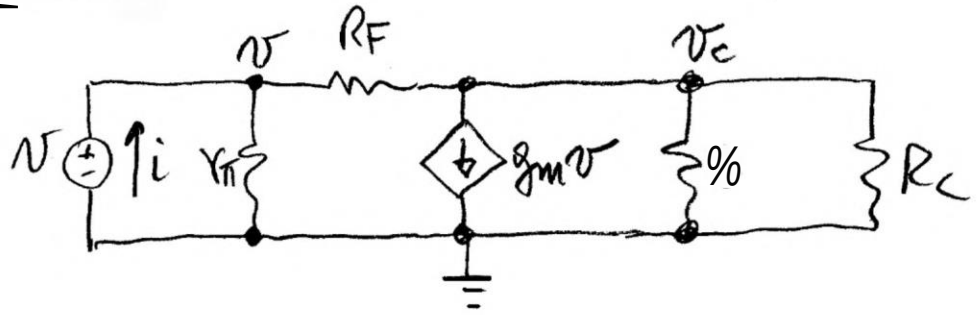
(b) $r_e = \frac{100}{101} \times \frac{26}{1} \cong 26\,\Omega$, $r_o = \frac{100}{1} = 100\,k\Omega$

$$R_e \cong 26\,\frac{1 + 10/100}{1 + 10/[101 \times 100]} \cong 28\,\Omega.$$

(c) $R_e \to r_e = 26\,\Omega$.

(d) $R_e \to r_e \frac{R_C/r_o}{R_C/[(\beta_o+1)r_o]} = r_e(\beta_o+1) = r_\pi = 2.6\,k\Omega$.

4.1 S



$$i = \frac{v}{r_\pi} + \frac{v - v_c}{R_F};$$

$$\frac{v - v_c}{R_F} = g_m v + \frac{v_c}{r_o \| R_C} \Rightarrow v\left(\frac{1}{R_F} - g_m\right) = \frac{v_c}{R_F \| R_C \| r_o} \Rightarrow$$

$$v_c = \frac{R_F \times (R_C \| r_o)}{R_F + (R_C \| r_o)} \frac{1 - g_m R_F}{R_F} v = \frac{R_C \| r_o}{R_F + (R_C \| r_o)} (1 - g_m R_F) v;$$

$$i = \frac{v}{r_\pi} + \frac{1}{R_F}\left[1 - \frac{R_C \| r_o}{R_F + (R_C \| r_o)}(1 - g_m R_F)\right] v$$

$$= v\left[\frac{1}{r_\pi} + \frac{1}{R_F} \frac{R_F + (R_C \| r_o) - (R_C \| r_o) + g_m R_F (R_C \| r_o)}{R_F + (R_C \| r_o)}\right]$$

$$= v\left[\frac{1}{r_\pi} + \frac{1 + g_m (R_C \| r_o)}{R_F + (R_C \| r_o)}\right]$$

$$R_i = \frac{v}{i} = \left(\frac{1}{r_\pi} + \frac{1 + g_m (R_C \| r_o)}{R_F + (R_C \| r_o)}\right)^{-1} = r_\pi \,\|\, \frac{R_F + (R_C \| r_o)}{1 + g_m (R_C \| r_o)}$$

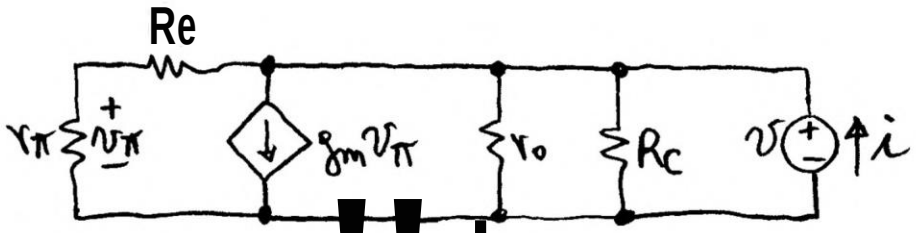
(b) $r_\pi = 100(26/1) = 2.6\ \text{k}\Omega$, $r_o = 100/1 = 100\ \text{k}\Omega$, $g_m = 1/(26\ \Omega)$

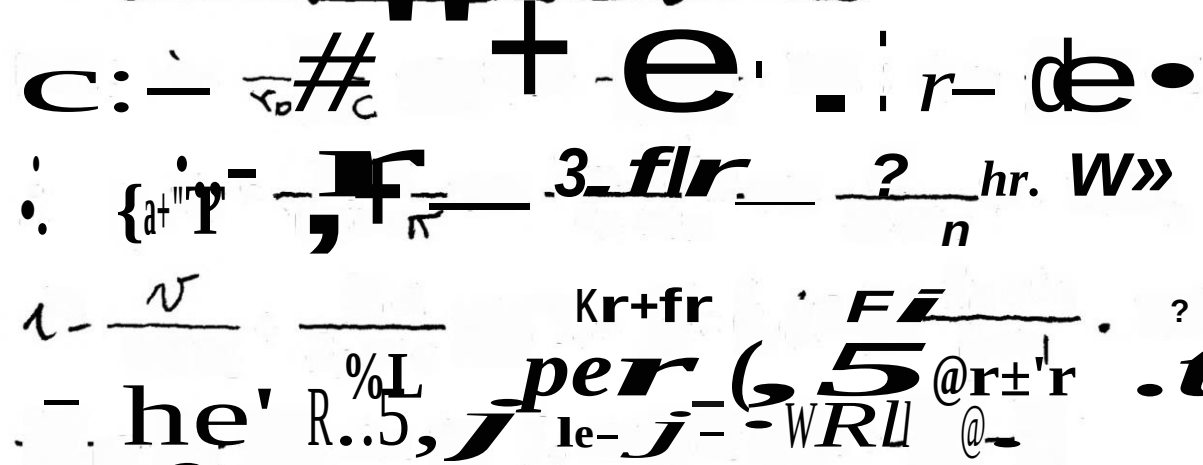
$$R_i = 2.6 \,\|\, \frac{10 + (1 \| 100)}{1 + (1 \| 100) 10^3/26} = 2.6 \| 0.281 = 254\ \Omega.$$

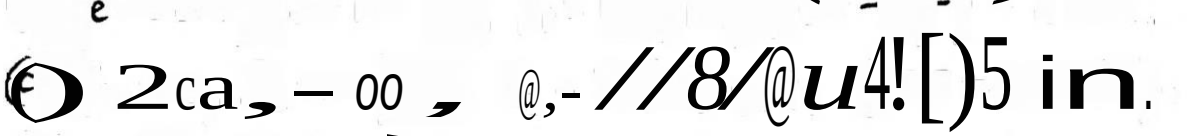
(c) $R_F \to 0$ and $R_C \to \infty \Rightarrow$ BJT is diode-connected, and $R_i = r_\pi \| \left[\frac{r_o}{1 + g_m r_o}\right] \to r_\pi \| \frac{1}{g_m} = r_e \cong 26\ \Omega$.

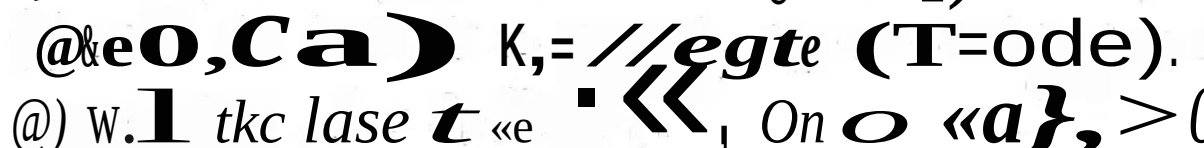
(d) $R_F \to \infty \Rightarrow R_i \to r_\pi \| \infty = r_\pi$.

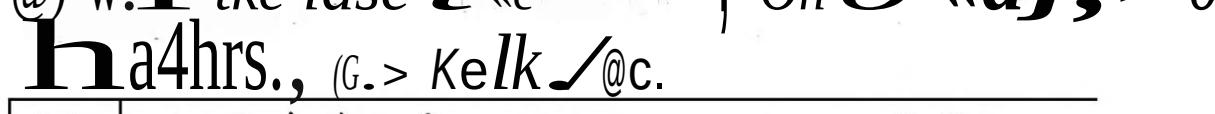
[246] @955:

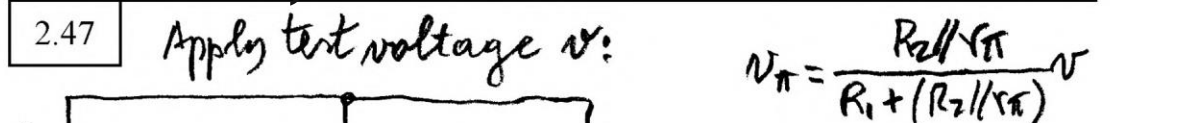












2.47

Apply test voltage v:

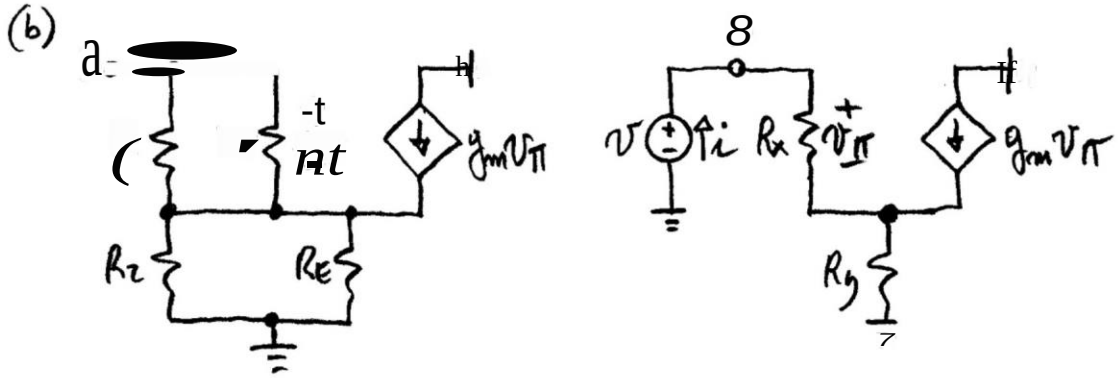
$$v_\pi = \frac{R_2 \| r_\pi}{R_1 + (R_2 \| r_\pi)} v$$

$$i = g_m v_\pi + \frac{v}{R_1 + (R_2 \| r_\pi)} = \frac{g_m (R_2 \| r_\pi) + 1}{R_1 + (R_2 \| r_\pi)} v$$

$$R = \frac{v}{i} = \frac{R_1 + (R_2 \| r_\pi)}{1 + g_m (R_2 \| r_\pi)} = \frac{[12 + (15 \| 10)]10^3}{1 + (15 \| 10)10^3/50} = \frac{18000}{121} = 149\,\Omega.$$

2.43] @ 6 dim, R-(+a·/Re-g 5·()

K-@@lll[++ (39)]



wtd.td sold cbel , 9tA cK tks BAL.

Tio ,Ts» ,o ask to v%.t ttkens@t,

WWila «e Jet 1 Rdo»ad R> @ Z-ply

a tot ta,0» so.,— gw , cl &Vu,

-":+ea«r-.'tl'.d,or-&¢.eta»ch,

ct&d ,el tlgythenado — 0eo

Kv= &+(+, 09)83.

(@) W- l/(26O), +r- 2.61. Fo ca(aw) «w. gt

&-(o+)l(7.% + tot0) =10.Gk (+2·). F

Oox(b) augt (- lol/. = 20% , , - lo/lo5;

R— 2.00+(+ -'') s- 6% (86). Th» i

ma.A.- hew.ta.(6)! kewimp>>

noise tkew vjpd pa« da»»sale~ht,'!

|-" |@ye-(/)1–6, Ve(/)1-V, «e-@-h= 1.601, wt 9,-0 Ta,2=(@o/c0= 20A.

Thea« R,–l0la- o.2m4, ASsuwig Ve5(a»)= o51 , me la. Ve- (-0.7)53/ 0-(–5.3)/0.2- (8.5@ (we @u) al ,' 53/(0.2+0.02)–24kn.

(2) &– /lf–l0.3 , Veg - 9»24/18+24) 5.NV 7, leeS-Vtow ,

(8/g + ¢

Tc(onv»0)y- –5.&–01 _ 1,7A
(103/100+1,5

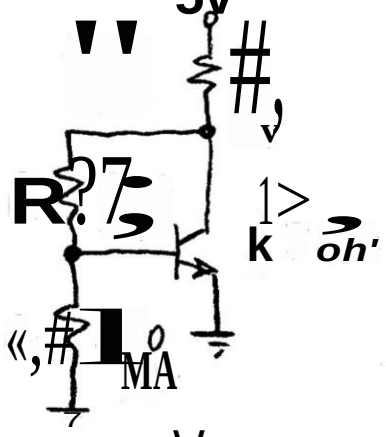
c%a)_ —5(on5)–01 ≈ 2.3%A
(05~@5[s +15(005)

co)- @–5.(l.gs)–o'] 2,7h
(9810s)/5 +15[cs) -

(t0.3/-±5% eiadds a. Tc).

S

@) Tg= 2»/lo2oMA =lR,·



R,-07/0.02- 35kw(re 3%)

g- 20/0.02 4-.375I (e33k

«a–5-2,11la (e Is#),

2+0.o

Ve= 07+33(%+ 0.7/3%)= 1.34 V+(30)2p .

= 22–231%=242-273 7/. 54,p . Fe,

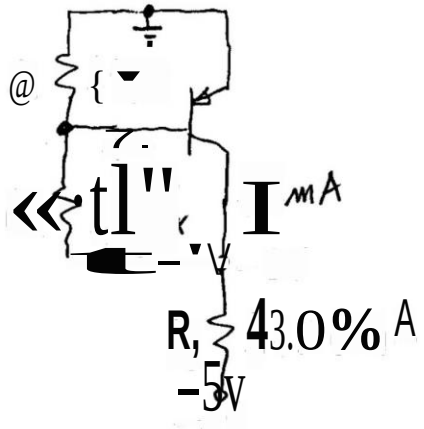
IC; 1jj, 3 = 0, 00020 AL Ic 1.6%

A

1.«A, 2.(7au4. NetJal! Mo2cue=v:

1+1c/» =2.41, 1V, l10V, al reefs

iNolak rel 4 N.


R, 43.0% A
-5V

2.54

(a) $V_{BE1} = (26\,mV)\ln\frac{(6-0.7)/10^4}{2\times10^{-15}} \cong 684\,mV$

$V_{BE2} = 0.026\ln\frac{0.184 - V_{BE2}}{10^3\times 2\times10^{-15}}$; start out with $V_{BE2} = 0.6\,V$.

$V_{BE2} = 0.026\ln\frac{0.684-0.6}{2\times10^{-12}} = 0.636\,V$

$V_{BE2} = 0.026\ln\frac{0.684-0.636}{2\times10^{-12}} = 0.620\,V$

Iterate further, and end with $V_{BE2} = 626\,mV$.

$I_{C2} = (0.684-0.626)/10^3 \cong 58\,\mu A$.

(c) With $V_{CC} = 6V$, $I_{C1} = (6-0.684)/10 = 0.5316$;

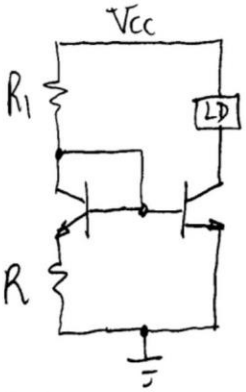
$(1/2)I_{C1} = 0.5316/2 = 0.2658$; Rule of Thumb:

$V_{BE1} = 684-18 = 0.666\,V$; $V_{CC} = 0.666 + 10\times0.2658 =$ 3.324 V. Reiterate as before, and find

$V_{BE2} = 0.026\ln\frac{0.666 - V_{BE2}}{2\times10^{-12}} \Rightarrow V_{BE2} = 620\,mV \Rightarrow$

$I_{C2} = (0.666-0.620)/10^3 = 46\,\mu A$. While I_{C1} has dropped to $\frac{1}{2}$ its initial value, I_{C2} has dropped from 58 μA to 46 μA. Not 1/2, as I_{C2} is not linearly proportional to I_{C1}.

[S] (1,- ?~= Ve=(00aV@ = l»A.



cy-05al > Vee =7o-1&- %%82V

1ca=0% = Ve2 =70o+IR=7/&nl

:.&=@8-682bs- '72 ,

4-(@-O8)/a.s- 8.564 MR.

(8t— luA =>e: lo»l, Va721-72 %iV.

he2= Too2- 772%V-(7oor 4·18) Vt1''>

l(auk. Ta, Slu ve, hon da«led once, Thao

le«l-al Jato»!

] @) «-(2-=9/= z. (2co).

&z- (56-07)/2 -2 _5 (e 2.4).

%- 2/6- /(13), , =0ox1=13k0; r%> ▾37%2.

K= - [+».(@a//o)] =31/+(@cl06/1 2.5 Mn.

(b) A owes 2n V doeneao Vc as %woo, dee&ens

7%, The 2dox ie sue tat 41%/4—-—-—=~=

- 0.+0A/V. At cue vs]AVe] » cveow» } t

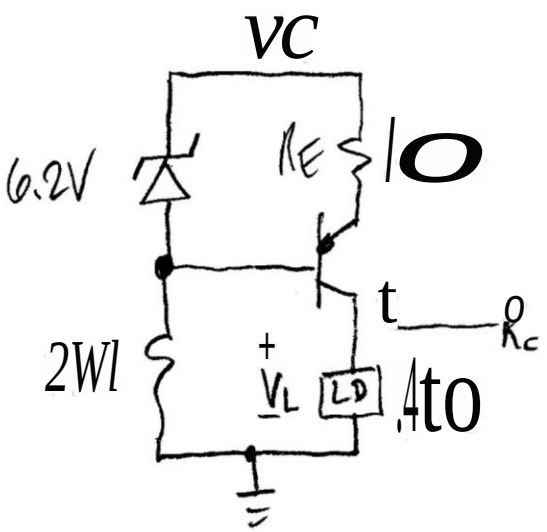
Va awl Ve ,«cc#kip To

s ''= ,te, l''el- ñ.'-.le.l= ▮'', s-luveal.

BL%- AN, A |Ael , \Alee! -(ye09)r'']Ad

:#et-3l+.

[S]



kuoiiceee 2« l dovwoleotoolovuos0To.

ass

@)1%7 74is. = 73,I+ 1.07%A,

IVg–3713210?= 0.41V

Ve -V+ Vee[»)= 0.241+0.7 =0. 41 V

=--10+71.07- -.82 V.

(''1 - 1.0l = 27n) (pr 7 4410 o- 44,3 1K.

K- 33/3.55- 2 = «. =47//415.5= 4.20W

g, 3+3.2 (235i Zn2 --I' vW

e)-V+ =0 - +m,5,()ob

= 0 - V +(k.57 ml) coot;

–W+o. = -•uzv–121(5av) qt;

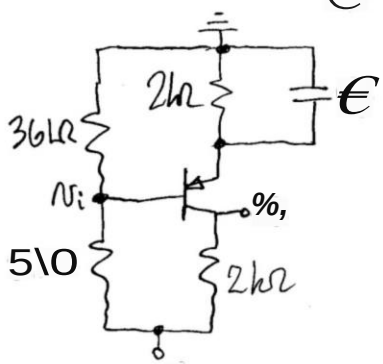
v = -4.82v +(0.%05 V) o» (e –180);

e= 0+(.60sv) c (t–180°);

= o,Iv + 0,

S»

@ V%%- 2e[-4)--3.12V
3%+51!



s-%//51= 2n

Ta- Ip 12-0 ▾ 1, u, ,A
C ZIk15 I 2 +a

Q,~ > 208k, - 3l0

-aw @v- %//s//28-25\3, R.= 2/13-26l0,

eh--%lo= - 2.9%/0,01855 –133 L.

€), -e Re/(e.+)- 18·5+ 21g0/1915 1600.

, 1/(<6ox10?) 2 J. le Cc= lO,F.

[z@] ;V,+,a]. - t0-. 1c+681z/21+07 >

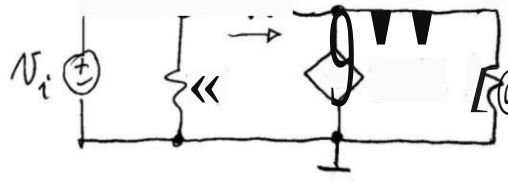
e=2.08%n Ic=2.07%A }=l/(2.% n), Yr=

15n,1·z 48 M, R//.=3./48 3.%2

«-] Rr+(@a) _,e8+3.1 z 2n

"I jg(@d.) "+3.@/.6

=oh[:{]e«ft.#4]· «sr



Vi ne e - ±.

@%. U o''' @el.

e(#e-·(#%> i.n.

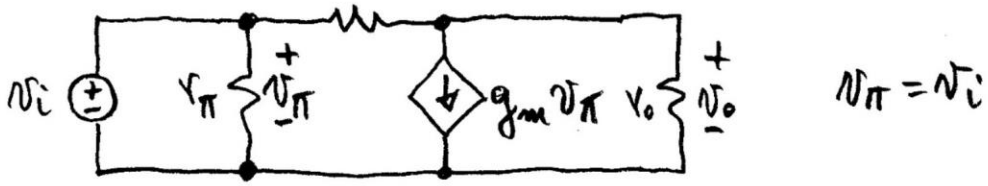
#.:-%- #k)(eel&dee)=-(kn.ka)(@mL/)}-zn

]26] @) I¢=1auk= /a; I >dTo, »A,

7= Te/((@+9) -(/to) «F; Ve- Ve+RrTs -07+loo⁄0l

≅ 1 — V,«.- V091 = lot Ml, 3%- 0.9⁄2%=1l(26.35).

5M: [F



CL: @-ve / @E o/oJr 4 = 0(4.-1)-$, 9e, T T,?

%.--S« (t)(t-,'t,)--2eo0a)w(-r 1/26)

=-1/3 /V.

(b) , dodMe, e os/! Z t.else»to 50.sER,

no« 6,kin Wtht I: —$ (Re//-),s

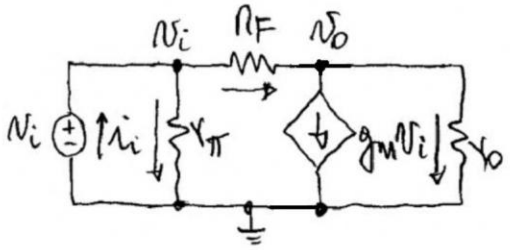
%=- -[$,-- (o I s)yw?- -2s55 W. bee 4•

huace , Re, w!cd was uncap, Te Aabv,

}»« pa&-% on tt heli-} 4s,» e W

ogle icnwaeo.

2.62 (a) $I_C = 1\text{mA} \Rightarrow g_m = 1/(26\Omega)$, $r_\pi = 2.6\text{k}\Omega$, $r_o = 100\text{ k}\Omega$.



KCL: $i_i = \frac{v_i}{r_\pi} + \frac{v_i - v_o}{R_F} = \frac{v_i}{r_\pi // R_F} - \frac{v_o}{R_F}$.

KCL: $\frac{v_i - v_o}{R_F} = g_m v_i + \frac{v_o}{r_o} \Rightarrow$

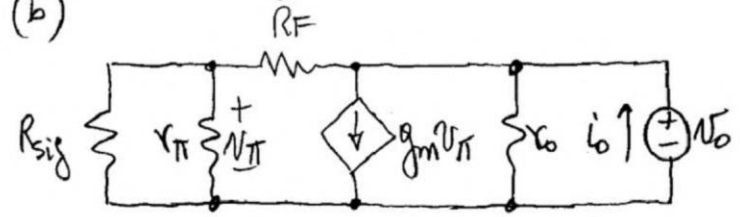
$$\frac{1 - g_m R_F}{R_F} v_i = \frac{v_o}{R_F // r_o} \Rightarrow$$

$$v_o = \frac{1 - g_m R_F}{R_F} \frac{R_F r_o}{R_F + r_o} v_i = \frac{1 - g_m R_F}{1 + R_F/r_o} v_i \Rightarrow i_i = \frac{v_i}{r_\pi // R_F} - \frac{1 - g_m R_F}{R_F(1 + R_F/r_o)} v_i$$

$$R_i = \frac{v_i}{i_i} = r_\pi // R_F // \frac{R_F(1 + R_F/r_o)}{g_m R_F - 1} = 2.6 // 100 // \frac{100(1 + 100/100)}{100/0.026 - 1} \cong 52\,\Omega.$$

If $R_L = 100\text{k}\Omega$, replace r_o with $r_o // R_L = 100 // 100 = 50\text{k}\Omega$. Then, $R_i = 2.6 // 100 // \frac{100(1 + 100/50)}{100/0.026 - 1} \cong 76\,\Omega$. R_i is dominated by the third term, roughly representing R_F divided by the gain $|v_o/v_i|$ (Miller effect). Loading the amplifier reduces the gain and thus increases R_i.

(b)



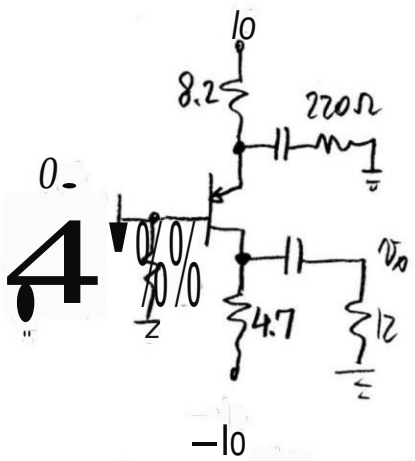
$$i_o = \frac{v_o}{r_o} + \frac{v_o}{R_F + (R_{sig} // r_\pi)} + g_m \frac{R_{sig} // r_\pi}{R_F + (R_{sig} // r_\pi)} v_o = v_o \left[\frac{1}{r_o} + \frac{1 + g_m(R_{sig} // r_\pi)}{R_F + (R_{sig} // r_\pi)} \right]$$

$$R_o = \frac{v_o}{i_o} = r_o // \frac{R_F + (R_{sig} // r_\pi)}{1 + g_m(R_{sig} // r_\pi)}. \quad R_o(R_{sig} = 0) = r_o // R_F = 50\text{ k}\Omega.$$

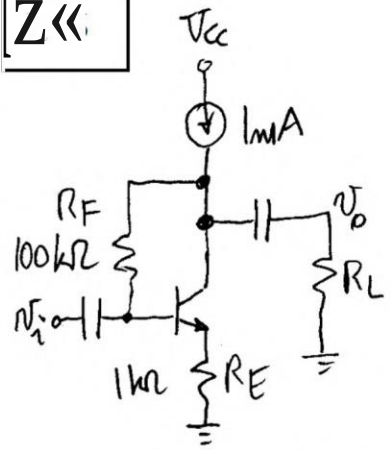
$$R_o(R_{sig} = 1\text{k}\Omega) = 100 // \frac{100 + 1 // 2.6}{1 + (1 // 2.6)/0.026} \cong 3.4\text{ k}\Omega$$

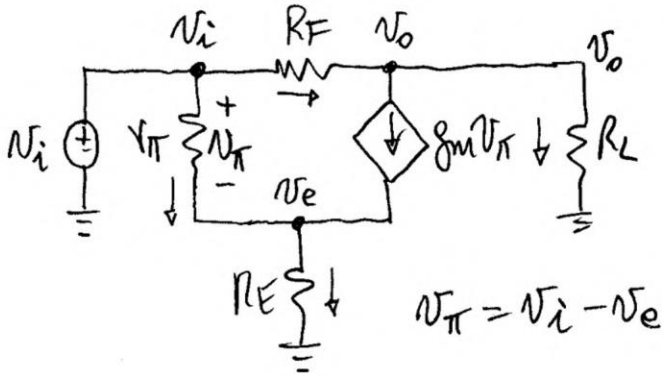
With $R_{sig} \neq 0$, $v_\pi \neq 0$ and $g_m v_\pi \neq 0$, so i_o increases, reducing R_o. In the limit $R_{sig} \to \infty$, we get $R_o \to 1\text{ k}\Omega$.

2.63



Z«





$I_C = \alpha I_E = \frac{150}{151} 1 \cong 1\text{mA}$, $g_m = \frac{1}{26.25\Omega}$, $r_\pi = 3.9.3\ k\Omega$.

kCL @ v_e: $\frac{v_i - v_e}{r_\pi} + g_m(v_i - v_e) = \frac{v_e}{R_E} \Rightarrow v_e = \frac{1}{1 + r_e/R_E} v_i$

kCL @ v_o: $\frac{v_i - v_o}{R_F} = g_m(v_i - v_e) + \frac{v_o}{R_L} \Rightarrow$

$$v_i\left(\frac{1}{R_F} - g_m + \frac{g_m}{1 + r_e/R_E}\right) = v_o\left(\frac{1}{R_F} + \frac{1}{R_L}\right) = \frac{v_o}{R_F \| R_L}$$

$$\frac{v_o}{v_i} = \frac{R_F R_L}{R_F + R_L} \frac{1}{R_F}\left[1 - g_m R_F\left(1 - \frac{1}{1 + r_e/R_E}\right)\right] = \frac{R_L}{R_F + R_L}\left[1 - g_m R_F \frac{r_e}{R_E + r_e}\right]$$

But, $g_m r_e \cong 1$, so

$$\frac{v_o}{v_i} = \frac{1}{1 + R_F/R_L}\left(1 - \frac{R_F}{R_E + r_e}\right) = \frac{1}{1 + 100/100}\left(1 - \frac{100}{1 + 0.026}\right) \cong -48\ \text{V/V}.$$

For $R_E \gg r_e$, we can approximate

$$\frac{v_o}{v_i} \to \left(1 - \frac{R_F}{R_E}\right)\frac{1}{1 + \pi_F/R_L} = -\frac{99}{2}\ \text{V/V}.$$

2.67

(a) $R_i = r_{\pi 1} + (\beta_{o1}+1)(R_E // r_{e2}) \cong r_\pi + (\beta_o+1) r_e = 2r_\pi$;

$R_c = r_{o1}[1 + g_{m1}(r_{\pi 1} // R_E // r_{e2})] \cong r_o[1 + g_m r_e] \cong 2r_o$;

$R_o = R_{c1} // R_c \cong R_c$; $\frac{v_o}{v_{sig}} = -\frac{g_{m1} R_o}{1 + g_{m1}(R_E // r_{e2})} \cong -\frac{g_m R_o}{2}$.

(b) $I_{C1} \cong I_{E1} = \frac{1}{2}\frac{12 - 0.7}{7.5} \cong 0.75\,mA$

$g_m = \frac{0.75}{26} = \frac{1}{34.7\,\Omega}$, $r_o = \frac{100}{0.75} = 133\,k\Omega$; $r_\pi = 200 \times 34.7 = 6.9\,k\Omega$

$R_i \cong 2r_\pi = 13.8\,k\Omega$; $R_c \cong 2 \times 133 = 267\,k\Omega$; $R_o = R_c // R_C = 267 // 10 = 9.64\,k\Omega$; $\frac{v_o}{v_{sig}} = -\frac{1}{2}\frac{9640}{34.7} \cong -140\ V/V$.

268] $\frac{v_o}{v_{is}} = \frac{}{1 + \frac{R + \pi}{(\beta+1)(1 \| R_o)}} \simeq \frac{1}{1 + \frac{R_{sig} + r_\pi}{(\beta_o+1)R_L}}$

where $v_{gs} \gg V_T$.

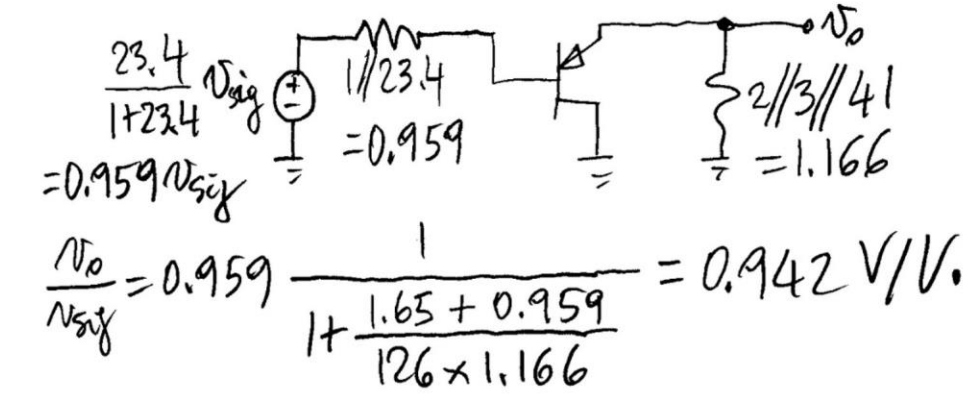
$$0.853 = \frac{}{1 + \frac{D_k}{(\beta+1)700}} = \frac{}{1 + e^{-700}} \quad \phi = 51.752$$

$$> I_{CQ} = 26.57 \text{ mA}$$

$$0.1\% - \frac{}{(\beta)_L} - \frac{}{(\beta+1)\%0} \quad \text{OO} \quad +1 \quad 30$$

$$7(-150, \quad Y = 1551.7 = 775$$

$$\#ij, \frac{\text{ass'ha}}{T = 75ix \cdot z00^{5}} \quad \text{OSW} \quad VW.$$



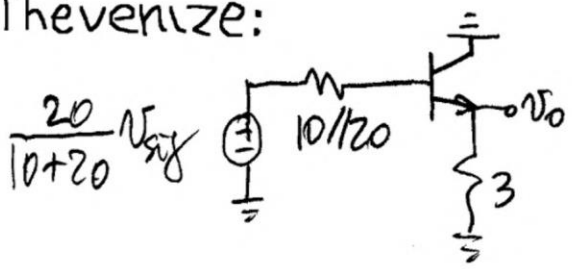
2.70

(a) $I_C = 100\,\frac{6-0.7}{20+101\times3} = 1.64\,mA$, $r_e = 15.7\,\Omega$,

$r_\pi \cong 1.6\,k\Omega$. $R_i = 20 // (1.6 + 101\times3) \cong 19\,k\Omega$

$R_o = 3{,}000 // [15.7 + (10{,}000 // 20{,}000)/101] \cong 80\,\Omega$.

Thévenize:



$$\frac{v_o}{\frac{2}{3}v_{sig}} = \frac{1}{1+\frac{1.6+(10//20)}{101\times3}}$$

$$\frac{v_o}{v_{sig}} = 0.649\ V/V$$

(b) With C_2 in place, the upper 10-kΩ resistance is placed in parallel with r_π, giving $r_{\pi(eq)} = 10//1.6 \cong 1.4\,k\Omega$; the lower 10-kΩ resistance is placed in parallel with R_E, giving $R_{E(eq)} = 10//3 = 2.3\,k\Omega$. We now have

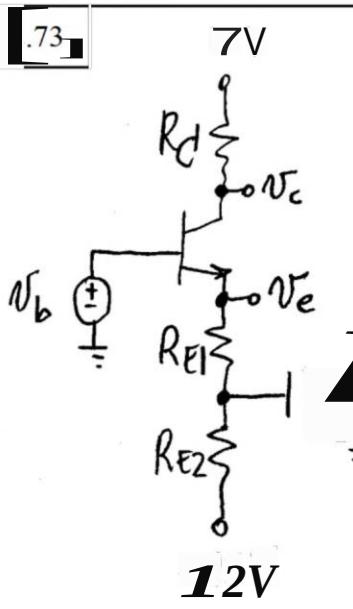
$R_i = r_{\pi(eq)} + (\beta_o+1)R_{E(eq)} = 1.4 + 101\times2.3 = 234\,k\Omega$

$R_o = R_{E(eq)} // \left(r_e + \frac{R_{sig}}{\beta_o+1}\right) = 2{,}300 // \left(15.7 + \frac{10{,}000}{101}\right) = 110\,\Omega$

$$\frac{v_o}{v_{sig}} = \frac{1}{1+\frac{r_{\pi(eq)}+R_{sig}}{(\beta_o+1)R_{e(eq)}}} = \frac{1}{1+\frac{1.4+10}{101\times2.3}} = 0.953\ V.$$

Bootstrapping increases R_i significantly, thus reducing input loading and making gain closer to unity.

.73



1WW. I=1A, V-% V.

=R= GM (ee 4.2M.,5%.)

We kootit cefo ≃ 4 VV,

to t a U el,z-1 4/V

fer-f= 6.2 -

wu Lc lmA,

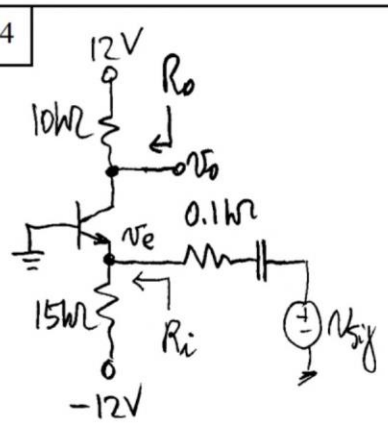
nod. efe—(r—0)/l,

Ke= 11.3-%.2=5.1O,5%.

8- e2//(et,)- s.//[6a+0o0)- 2.& -

C> $\frac{}{2r28¥10^{3}}$ t-5aF. Uk —tuF.

2.74



$I_C \simeq I_E = \frac{12-0.7}{15} = 0.753\ mA$

$r_e = \frac{26}{0.753} \simeq 35\Omega$. $R_o \simeq 10k\Omega$.

$R_i = 35 // (15k\Omega) \simeq 35\Omega$.

$v_e = \frac{0.035}{0.035+0.1} v_{sig} = 0.26\, v_{sig}$.

$v_o = g_m v_e R_o = \frac{1}{35}(0.26 v_{sig})\,10{,}000 = 74\, v_{sig}$. $v_o/v_{sig} = 74\ V/V$.

[illegible]

[illegible]

[illegible]

cha,' [illegible]

2.76 (a) $R_i = R_1 // R_{e1}$, $R_{e1} = r_{e1} + \frac{r_{e2} // R_2}{\beta_{o1}+1} \cong r_{e1}$;

$r_{e1} = \frac{V_T}{I_{C1}} \cong \frac{26}{10/10} = 26\Omega$; $R_i = 10{,}000 // 26 \cong 26\ \Omega$.

$R_o \cong r_{o1}\left[1 + g_{m1}\left(R_{sig} // R_1 // r_{\pi 1}\right)\right] = \frac{80}{1}\left[1 + \frac{1 // 10 // (150 \times 0.026)}{0.026}\right]$

$\cong 2.35\ M\Omega$. $v_i = \frac{R_i}{R_{sig}+R_i} v_{sig} = \frac{26}{1000+26} v_{sig} = \frac{v_{sig}}{39.5}$.

$i_o = g_m v_i = \frac{1}{26}\frac{v_{sig}}{39.5} = \frac{v_{sig}}{1026\ \Omega}$.

(b) $v_o = (R_L // R_o) i_o \cong R_L i_o = \frac{5000}{1026} v_{sig} \Rightarrow \frac{v_o}{v_{sig}} = 4.87\ V/V$.

(c) As long as $R_{sig} \gg R_i$ and $R_L \ll R_o$, we have

$v_o = R_L i_o = R_L \alpha_o i_i \cong R_L (v_{sig}/R_{sig}) \Rightarrow v_o / v_{sig} \cong R_L / R_{sig} = 5\ V/V$.

