Electronics I * Midterm 1 * October 25, 2005 * 60 minutes

ID number: ERKAYA Name: SOLUTIONS Signature: ____________

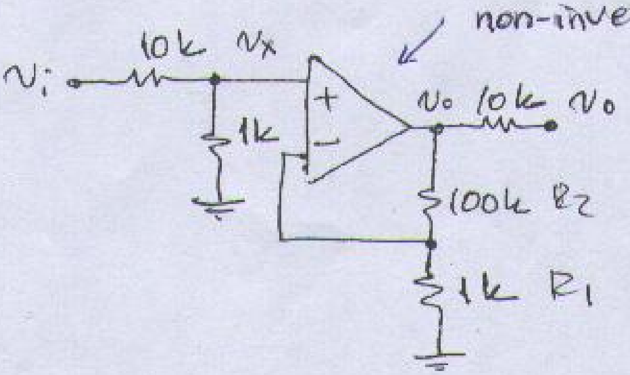
1) Find the input resistance, output resistance and open circuit voltage gain of the amplifier given below.

9:44

Rin = 11k

Rout = 10k

Avo = Vo/Vi = 9.18



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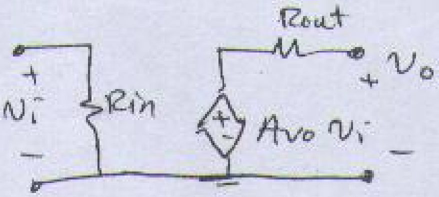


gain $\frac{v_o}{v_x} = 1 + \frac{R_2}{R_1} = 101$

$\frac{v_x}{v_i} = \frac{1}{10+1} = \frac{1}{11}$ $\frac{v_o}{v_i} = 101 \times \frac{1}{11} = \frac{101}{11} = 9.18$

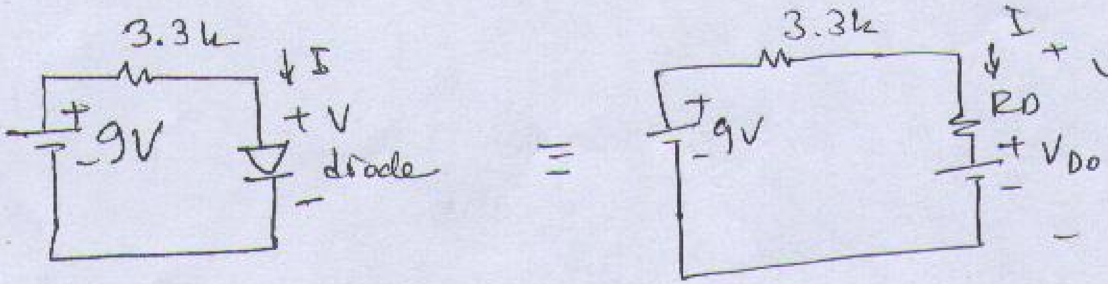
$R_{in} = 10k + 1k = 11k$

$R_o = 10k$ by inspection

9:46

2) A diode has 1 mA at 0.60 V and 11 mA at 0.72 V. Find a DC model for the diode if it is used in the circuit below:

9:46



$$V = V_{DO} + I R_D$$

$$V_1 = V_{DO} + I_1 R_D$$

$$V_2 = V_{DO} + I_2 R_D$$

$$V_2 - V_1 = (I_2 - I_1) R_D$$

$$R_D = \frac{V_2 - V_1}{I_2 - I_1} = \frac{0.72 - 0.60}{11 - 1 \text{ mA}} = \frac{0.12 \text{ V}}{10 \text{ mA}} = 0.012 \text{ k}\Omega = 12\,\Omega$$

$$V_{DO} = V_1 - I_1 R_D = 0.60 - 0.012 \times 1 = 0.588 \text{ V}.$$

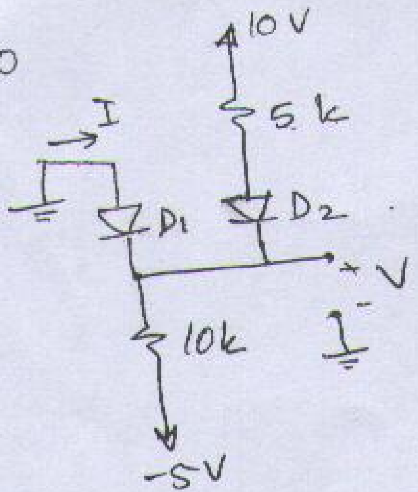
$$V_{DO} = 0.588 \text{ V}$$

$$R_D = 12\,\Omega$$

9:50

3) Find I and V in the circuit below (diodes are ideal). I = 0 , V = 5 V

9:50



Assume D1 = OFF
D2 = ON

$$I_{D2} = \frac{10-(-5)}{5+10} = 1\ mA$$

$$V = 10 - 5 \times 1 = 5V.$$

The voltage on D1 is $0 - 5 = -5V < 0$

→ D1 is OFF. Assumption is valid.

Hence $I = 0$
$V = 5\ V$

9:52

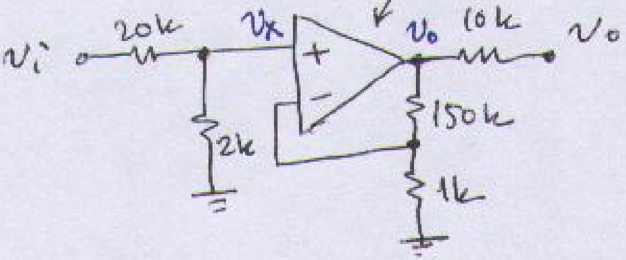
10. 11. 2005

Electronics I – Midterm 1 – 60 minutes

ID number: ERKAYA Name: SOLUTIONS Signature: ______

1) Find the input resistance, output resistance and opencircuit voltage gain for the amplifier given below:

20pt



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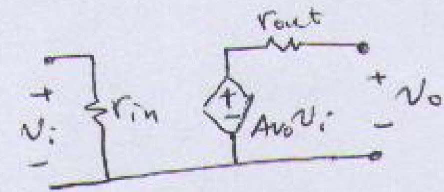


r_{in} = 22k

r_{out} = 10k

A_{vo} = 13.72

no load → output of opamp = v_o

$r_{in} = 20k + 2k = 22k$

$r_{out} = 10k + 0k = 10k$

↑ ideal opamp

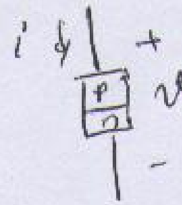
$$\frac{v_o}{v_x} = \frac{1+150}{1} = 151$$

$$\frac{v_x}{v_i} = \frac{2}{20+2} = \frac{1}{11}$$

$$A_{vo} = \frac{v_o}{v_i} = \frac{v_o}{v_x} \cdot \frac{v_x}{v_i} = 151 \times \frac{1}{11} = 13.72$$

2) A pn-junction diode has the following voltage and current values. a) Find a non-linear model for the diode b) Find a piece-wise linear model for the diode.

30pt



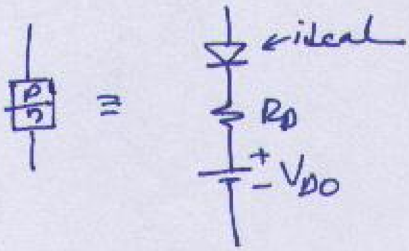
v	i
0.60 V	0.1 mA
0.74 V	11.1 mA

$V_T = 0{,}025\,V$

a) ideality factor $\eta = \underline{1.189}$

reverse sat. current $I_s = \underline{1.71 \times 10^{-10}\,A}$

b)



$R_D = \underline{12.7\,\Omega}$

$V_{DO} = \underline{0.5987\,V}$

a)

$$i = I_s(e^{v/\eta V_T} - 1) \cong I_s e^{v/\eta V_T}$$

$$0.1 = I_s e^{0.6/\eta 0.025}$$

$$11.1 = I_s e^{0.74/\eta 0.025}$$

dividing side by side

$$111 = e^{(0.74-0.60)/\eta 0.025}$$

$$\ln(111) = \frac{0.14}{\eta 0.025} \rightarrow \eta = \frac{0.14}{0.025 \ln 111} = 1.189$$

$$11.1 = I_s e^{0.74/1.189 \times 0.025} = 6.47 \times 10^{10} I_s$$

$$I_s = \frac{11.1}{6.47 \times 10^{10}} = 1.71 \times 10^{-10}\,A$$

b)

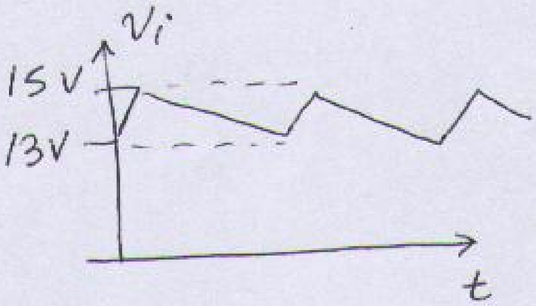
$$R_D = \frac{\Delta V}{\Delta I} = \frac{0.74 - 0.60}{11.1 - 0.1} = 0.0127\,k\Omega = 12.7\,\Omega$$

$$0.6 = V_{DO} + 0.1 \times 0.0127$$

$$V_{DO} = 0.6 - 0{,}00127 = 0.5987\,V$$

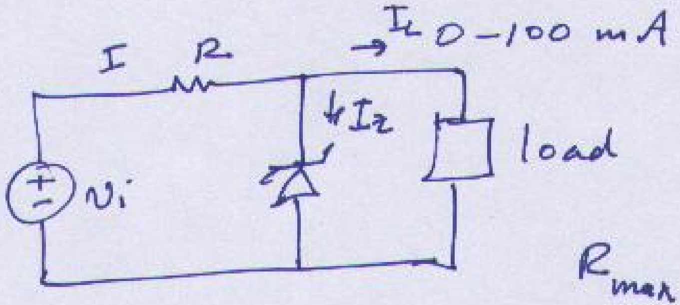
3) Design a shunt regulator to obtain 9 V output voltage. The load requires 0 – 100 mA current. The input voltage is as shown below:

20 pt



Specify the power rating of the components you use in your design.

Zener diode $V_{ze} = 9V$ the same as the output voltage



$$R_{max} = \frac{V_{imin} - V_o}{I_{Lmax} + I_{zmin}}$$

assume $I_{zmin} = 1mA$

$$R_{max} = \frac{13-9}{101} = 0.0396\ k = 39.6\ \Omega$$

Power rating for zener diode:

Max current in zener is when $V_i \to V_{imax} = 15V$

$I_L \to I_{Lmin} = 0$

$$I_z = I_{max} - I_{Lmin} = \frac{15-9}{39.6} - 0 = 0.1515\ A$$

$$P_{zmax} = 9 \times 0.1515 = \underline{1.36\ W}$$

Power rating for R: $I_{max}^2 R = (0.1515)^2 \times 39.6 = \underline{0.91\ W}$

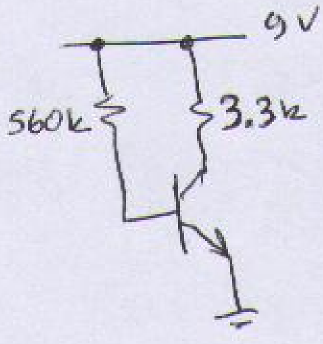
R: 39.6 W, 0.91 W

Zener: 9 V, 1.36 W

4) Find the operating points for the BJTs in the ckts given below: $V_{BE} = 0.7V$, $\beta = 100$

30pt

a)



$I_c = \underline{1.48mA}$

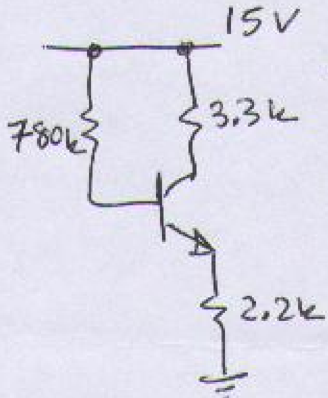
$V_{CE} = \underline{4.10V}$

$$I_B = \frac{9-0.7}{560k} = 0.0148\,mA$$

$$I_c = 100 I_B = 1.48\,mA$$

$$V_{CE} = 9 - 3.3 \times 1.48 = 4.10V$$

b)



$I_c = \underline{1.427mA}$

$V_{CE} = \underline{7.12V}$

$$(I_B + I_c) \times 2.2 + 0.7 + I_B 780 = 15$$

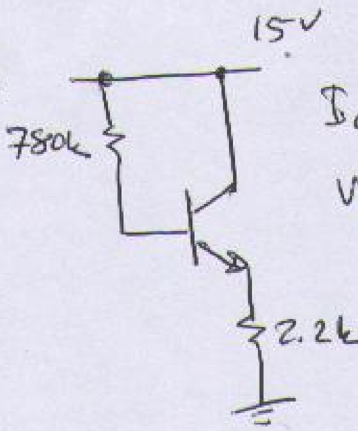
$$I_c = \beta I_B = 100 I_B$$

$$I_B = \frac{15-0.7}{2.2 \times 101 + 780} = 0.01427mA$$

$$I_c = \beta I_B = 1.427\,mA$$

$$V_{CE} = 15 - 2.2 \times \frac{101}{100} \times 1.427 - 3.3 \times 1.427 = 7.12V$$

c)



$I_c = \underline{1.427}$

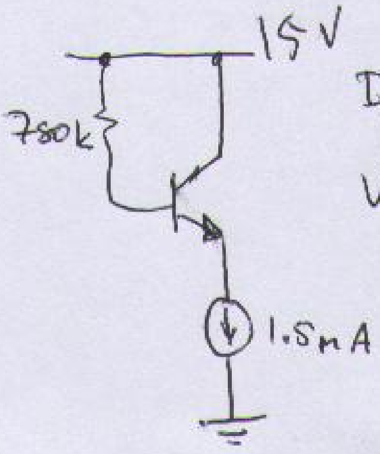
$V_{CE} = \underline{11.87V}$

I_B is the same as in (b)

$I_c = 1.427\,mA$

$$V_{CE} = 15 - 2.2 \times \frac{101}{100} \times 1.427 = 11.87V$$

d)



$I_c = \underline{1.485\,mA}$

$V_{CE} = \underline{12.28V}$

$$I_c = \frac{100}{101} I_E = \frac{1.5}{1.01} = 1.485\,mA$$

$$V_{CE} = 15 - V_E, \quad I_B = 0.01485\,mA$$

$$V_E = V_B - V_{BE} = 15 - 780 I_B - 0.7 = 2.717V$$

$$V_{CE} = 15 - 2.717 = \underline{12.28V}$$

Electronics I * Midterm 1 * October 31, 2006 * 60 minutes

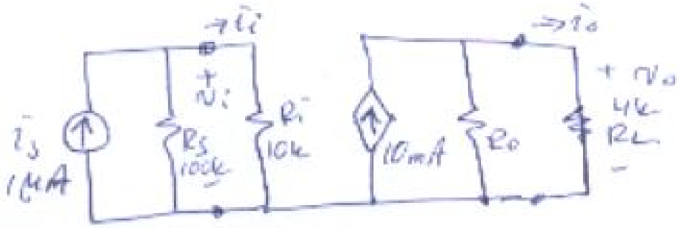
I have neither given nor received any unauthorized help with this exam, nor do I have any reason to believe that anybody else has.

ID number: ____________ Name: SOLUTIONS ____________ Signature: ____________

1. An amplifier with an input resistance of 10 kΩ, when driven by a current source of 1 μA and a source resistance of 100 kΩ, has a short-circuit output current of 10 mA and an open-circuit output voltage of 10 V. When driving a 4-kΩ load, what are the values of the voltage gain, current gain, and power gain expressed as ratios and in dB?

$A_v =$ 880 (58.89 dB)
$A_i =$ 2198 (66.84 dB)
$A_p =$ 1.934×10^6 (62.86 dB)

pts



$10mA \times R_o = 10V$

$R_o = \frac{10V}{10mA} = 1k\Omega$

$V_o = 10mA \times 1k \| 4k = 10 \times 0.8 = 8V$

$V_i = 0{,}001mA \times (100k \| 10k) = 0.001 \times 9.09 = 0{,}0091V$

$A_V = \frac{V_o}{V_i} = \frac{8}{0{,}0091} = 880 \rightarrow 20\log(880) = 58{,}89dB$

$i_i = \frac{0{,}0091}{10k} = 0.00091\ mA = 0.91\ \mu A$

$i_o = \frac{V_o}{R_L} = \frac{8}{4k} = 2mA$

$A_i = \frac{2mA}{0{,}91\ \mu A} = 2198 \rightarrow 20\log(2197.8) = 66.84\ dB$

$A_p = \frac{V_o \times i_o}{V_i \times i_i} = A_V \cdot A_i = 880 \times 2198 = 1.934 \times 10^6 \rightarrow$

$10\log(1.934 \times 10^6) = 62.86\ dB$

2. In designing with op amps one has to check the limitations on the voltage and frequency ranges of operation of the closed-loop amplifier, imposed by the op amp finite bandwidth (f_t), slew rate (SR), and output saturation (V_{omax}). This problem illustrates the point by considering the use of an op amp with f_t=2.5 MHz, SR=1.2 V/μs, and V_{omax} = 10 V in the design of a noninverting amplifier with a nominal gain of 10. Assume a sine-wave input with peak amplitude V_i.

(a) If V_i = 0.5 V, what is the maximum frequency before the output distorts?
(b) If f = 20 kHz, what is the maximum value of V_i before the output distorts?
(c) If V_i = 50 mV, what is the useful frequency range of operation?
(d) If f = 5 kHz, what is the useful input voltage range?

a) f_{max} = 38.197 kHz
b) $V_{i\,max}$ = 0.955 V
c) f range = 0–250 kHz
d) V_i range: 0 – 1 V

a) $V_i = 0.5\,V$, $V_o = 0.5 \times 10 = 5\,V$

$$f_{max} = \frac{SR}{2\pi V_o} = \frac{1.2\times10^6}{2\pi\times5} = 38{,}197\ kHz$$

b) $f = 20\ kHz$, $V_o \le \frac{SR}{2\pi f} = \frac{1.2\times10^6}{2\pi\times20\times10^3} = 9.55\,V$

$$V_i = \frac{V_o}{10} = 0.955\,V$$

c) $V_i = 50\,mV$, $V_o = 10\times50\,mV = 500\,mV = 0.5\,V$

$$f_{max} = \frac{SR}{2\pi V_o} = \frac{1.2\times10^6}{2\pi\times0.5} = 381.9\ kHz$$

There maybe another restriction/limitation → gain-bandwidth product

$$f_{max} \times gain = f_T \rightarrow f_{max} = \frac{f_T}{gain} = \frac{2.5\times10^6}{10} = 250\,kHz.$$

Since 250 kHz is smaller than 381.9 kHz, the freq. range (bandwidth) is limited by 250 kHz

d) $f = 5\,kHz$, slew rate limitation: $V_o \le \frac{SR}{2\pi f} = \frac{1.2\times10^6}{2\pi\times5\times10^3} = 38.19\,V$

However, the supply voltages limit the output voltage to 10 V. (given) Hence, the input voltage is limited by $\frac{10\,V}{10} = 1\,V$. Useful range 0–1 V.

3. Assuming that the diodes in the circuits of Fig. P3 are ideal, utilize Thévenin's theorem to simplify the circuits and thus find the values of the labeled currents and voltages.

I_a = 0.225 mA

V_a : 4.5 V

I_b : 0

V_b : −2 V

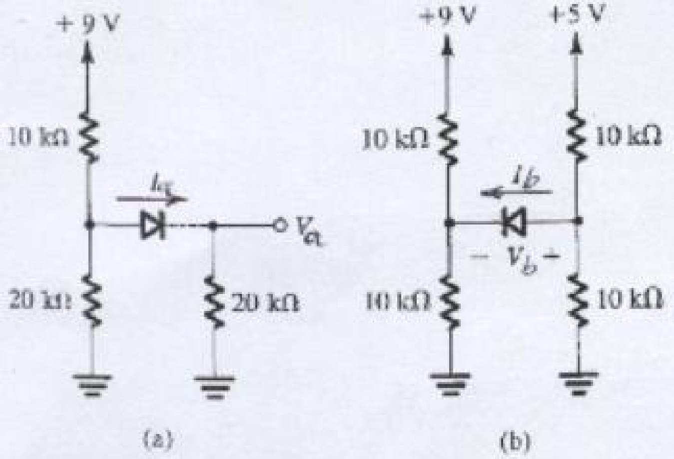
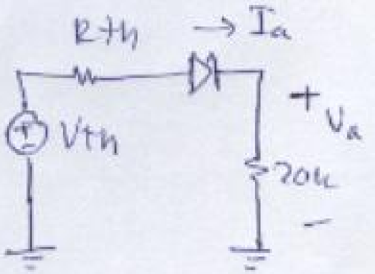


FIGURE P3

a)



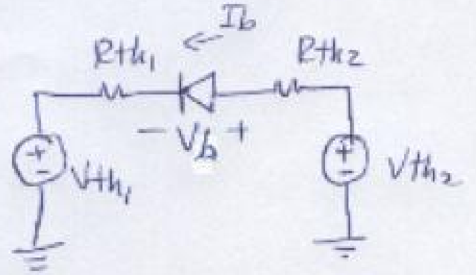
$R_{th} = 10k \parallel 20k = 6.66k$

$V_{th} = 9 \times \frac{20}{10+20} = 6\ V$

$I_a = \frac{V_{th}}{(20+6.66)k} = \frac{6}{26.66} = 0.225\ mA$

$V_a = I_a \times 20k = 4.5\ V$

b)



$R_{th_1} = 10k \parallel 10k = 5k\Omega$

$V_{th_1} = 9 \times \frac{10}{10+10} = 4.5V$

$R_{th_2} = 10k \parallel 10k = 5k\Omega$

$V_{th_2} = 5 \frac{10}{10+10} = 2.5\ V$

Since $V_{th_1} > V_{th_2}$, the diode will be reverse biased.

$V_{th_1} + V_b = V_{th_2}$

$V_b = V_{th_2} - V_{th_1} = 2.5 - 4.5 = -2\ V.$

$I_b = 0$ for reverse bias

ELECTRONICS - I MIDTERM 1 60 minutes

ID number: ERKAYA Name: SOLUTIONS Signature: ______

→ open ckt voltage gain 0.95

1) A common collector BJT amplifier draws 2.5 mA from a 9V power supply. The amplifier has 300 kΩ input resistance and 10 Ω output resistance. If it is connected to a signal source whose open circuit voltage is 1 V rms and whose short circuit current is 0.1 mA rms, and if it has a load of 75 Ω, what would be its voltage gain, current gain, power gain, and efficiency?

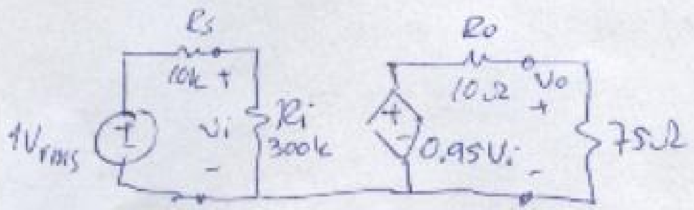
$\frac{v_o}{v_i}$ = 0,84

$\frac{i_o}{i_i}$ = 3360

$\frac{p_o}{p_i}$ = 2820

η = 0,391

DC power: $2.5 \times 9 = 22.5$ mW



$R_s = \frac{1\,V}{0,1\,mA} = 10k\Omega$

open ckt - voltage gain = 0,95

$$\frac{V_o}{V_i} = 0{,}95 \, \frac{75}{10+75} = 0.84$$

$$\frac{i_o}{i_i} = \frac{V_o/75}{V_i/300k} = \frac{V_o}{V_i} \times \frac{300k}{75} = 0.84 \times 4000 = 3.36k = 3360$$

$$\frac{P_o}{P_i} = \frac{V_o \cdot i_o}{V_i \cdot i_i} = 4\left(\frac{V_o}{V_i}\right)^2 = 2820$$

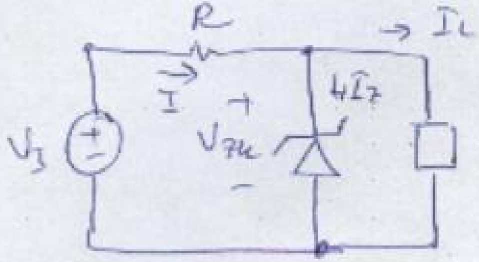
$$V_i = \frac{300}{310}\,V_{rms}, \quad V_o = 0{,}95 \times \frac{75}{85} \times \frac{300}{310} = 0{,}811\,V_{rms}$$

$$P_o = \frac{V_{o\,rms}^2}{75\,\Omega}$$

$$P_o = \frac{(0.811)^2}{75\,\Omega} = 0.0088\,W = 8.8\,mW$$

$$\eta = \frac{P_o}{P_{DC}} = \frac{8.8}{22.5} = 0{,}391$$

2) Desing a shunt regulator with a zener diode to provide 0–60 mA to a load at constant voltage of 9.1 V. The input source has the peak voltage 13.5 V and a peak-to-peak ripple of 1.5 V. Specify the component values and power ratings that you use in your design.



$V_{I_{min}} = 13.5 - 1.5 = 12\,V$

$V_{I_{max}} = 13.5\,V$

Let $I_{Z_{min}} = 1\,mA$

$$R = \frac{V_{I_{min}} - V_o}{I_{L_{max}} + I_{Z_{min}}} = \frac{12 - 9.1}{61\,mA}$$

$V_{ZK} = 9.1\,V$

$$R = \frac{2.9}{61\,mA} = 47.5\,\Omega$$

$P_{R\,max} = R\,I_{max}^2$

$$I_{max} = \frac{V_{I_{max}} - V_o}{R} = \frac{13.5 - 9.1}{47.5} = 0,0926\,A = 92.6\,mA.$$

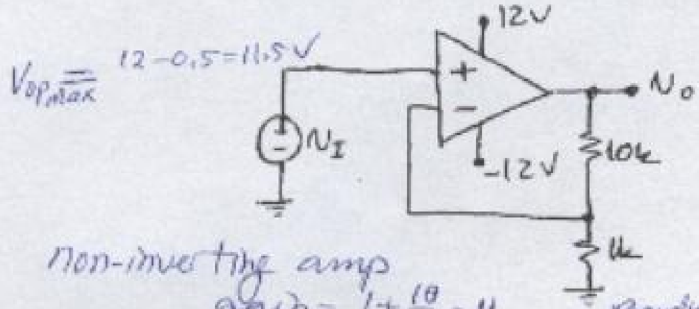
$P_{R\,max} = 47,5 \times (0,0926)^2 = 0.407\,W.$

$P_{Z\,max} = 9.1 \times I_{max} = 0,0926 \times 9.1 = 0.84\,W.$

R power rating $\geq 0.4\,W$ → 0.5 W

Zener " " $\geq 0,84\,W$ → 1 W.

3) In the amplifier below, the opamp has a gain-bandwidth product of 1800 kHz, slew rate of 0.8 V/μs.



The output voltage can approach the supply voltages no closer than 0.5V.

$v_I = V_{IP} \sin\omega t$, no distortion is desired.

a) If $V_{IP} = 0.6V$, what would be the max signal frequency?

non-inverting amp gain $= 1+\frac{10}{1} = 11$, Bandwidth $= \frac{1800 \text{ kHz}}{11} = 163.6$ kHz

max f: ________

b) If f = 30 kHz, what would be the max V_{IP}?

max V_{IP}: ________

→ c) If $V_{IP} = 30$ mV, what is the max signal frequency?

max f: ________

d) If f = 3 kHz, what would be the max V_{IP}?

Max V_{IP} = ________

a) $2\pi f V_{op} \le SR$

$$f \le \frac{SR}{2\pi V_{op}} = \frac{0.8\times10^6}{2\pi\times0.6\times11} = 19\,291 \text{ HZ}$$

b) $$V_{op} \le \frac{SR}{2\pi f} = \frac{0.8\times10^6}{2\pi\times30\times10^3} = 4.244V, \quad V_{IP_{max}} = \frac{4.244}{11} = 0.386 \text{ V.}$$

c) $V_{IP} = 30$mV, $V_{op} = 330$ mV $\quad f \le \frac{SR}{2\pi\, 0.33} = \frac{0.8\times10^6}{0.66\pi} = 385.8$ kHz

since the bandwidth is 163.6 kHz, max freq. of the signal is 163.6 kHz.

d) $$V_{op} = \frac{SR}{2\pi f} = \frac{0.8\times10^6}{2\times\pi\times3000} = 424 \text{ V not possible}$$

$V_{op} \le 12-0.5 = 11.5$V. $\quad V_{IP} \le 1.045$ V.