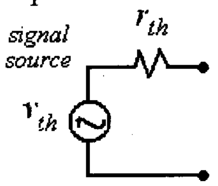
Electronics I * Exam I * July 22,2010 * 55 minutes * closed books and notes

I have neither given nor received unauthorized help with this exam, nor do I believe anyone else has.

ID number: ERKAYA Name: SOLUTIONS Signature:__________

50 pts 1) A signal source has 0.1 V open-circuit signal amplitude and 100 μA short-circuit current amplitude at 1000 Hz. Find the Thevenin equivalent of the signal source.

9:12

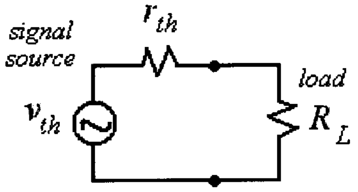


$V_{th} = \frac{0.1}{\sqrt{2}} = 0.0707\ V_{rms}$

$r_{th} = \frac{V_{oc}}{I_{sc}} = \frac{0.1\,V}{0.1\,mA} = 1k\Omega$

$v_{th} =$ 0.0707 *V rms* $r_{th} =$ 1kΩ

If a load resistance $R_L = 220$ ohm is connected to the signal source, find the power delivered to the load.

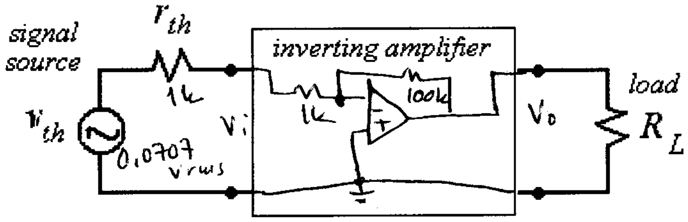


$V_L = V_{th}\frac{R_L}{R_L + r_{th}} = 0.0707 \times \frac{0.22}{1+0.22} = 0.0128\ V_{rms}$

$P_L = \frac{V_{L\,rms}^2}{R_L} = \frac{(0.0128)^2}{0.22} = 7.39\times10^{-4}\ mW$

$P_L =$ _______

Now, design an inverting amplifier (made of an opamp) with a gain of -100 and insert it between the signal source and the load. Then, find the power delivered to the load.



$V_o = -100\,V_i$

$V_i = V_{th}\frac{1k}{1k+1k} = \frac{0.0707}{2} = 3.5\times10^{-2}\ V$

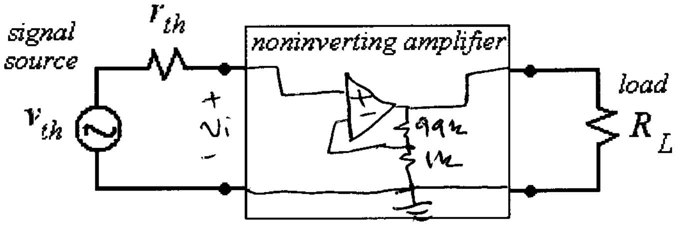
$V_o = -3.5\ V$ rms

$P_L = \frac{(-3.5)^2}{0.22} = 55.65\ mW$ $P_L =$ _______

Now, design a noninverting amplifier (made of an opamp) with a gain of +100 and replace the amplifier above with it. Then, find the power delivered to the load.

$V_i = V_{th}$ since $r_{in} = \infty$

$V_o = 100 \times V_{th} = 7.07\,V$



$P_L = \frac{(7.07)^2}{0.22} = 227\ mW$

$P_L =$ _______

9:20

50 pts 2) Opamps have finite bandwidth (f_t), finite slew rate (SR), and limited output voltage (V_{omax}). Consider a noninverting amplifier with a nominal gain of 15. The opamp used in the design has f_t = 2 MHz, SR= 1V/µs, and V_{omax} = 12 V. The amplifier input is a sine-wave with peak amplitude V_i.

a) If V_i = 0.6 V, what is the maximum signal frequency before the output distorts?
b) If the signal frequency is 20 kHz, what is the maximum value of V_i before the output distorts?
c) If V_i = 0.03 V, what is the useful frequency range of operation?
d) If the signal frequency is 5 kHz, what is the useful input voltage range?

a) $max\,f$ = 17.7 kHz

b) $max\,V_i$ = 0.53 V

c) $f\,range$: 0 - 133 kHz

d) $V_i\,range$: 0 - 0.8 V

a) $V_i = 0.6V \rightarrow V_o = 0.6 \times 15 = 9V$ amplitude

$V_o \sin\omega t$ has max slope $\omega V_o \leq SR$

$$f \leq \frac{SR}{2\pi V_o} = \frac{1\ V/\mu s}{2\pi \times 9} = 17.7\ kHz$$

b) $20 \times 10^3 \times 2\pi \times V_o \leq SR$

$$V_o \leq \frac{10^6\ V/s}{40000\pi} = 7.95\ V$$

$$V_i \leq \frac{7.95}{15} = 0.53\ V$$

c) $V_i = 0.03V \rightarrow V_o = 0.45V$

$$f \leq \frac{10^6}{2\pi \times 0.45} = 0.353\ MHz$$

since f_t = 2 MHz, the bandwidth of amplifier $\frac{2}{15} = 0.133\ MHz$

Before the SR limitation, the bandwidth limitation makes

$f \leq 0.133\ MHz$

d)

$f = 5\ kHz$ what is $V_{i\,max}$?

from SR limitation

$$V_{omax} \leq \frac{SR}{2\pi f} = \frac{10^6}{2\pi \times 5000} = 31.83\ V$$

However, opamp has $V_{omax} \leq 12\ V$

Hence max $V_i = \frac{12}{15} = 0.8\ V$

9:32