American University of Beirut

Department of Electrical and Computer Engineering

EECE 310 – Electronics Fall 2007 – 2008

Homework 1

Due Tuesday October 9, 2007

1.

An amplifier has the transfer characteristic: $v_O = 12 - 8(v_I - 1)^3$

where v_O and v_I are in volts. This transfer characteristic applies for $1 < v_I < v_O + 1$, and v_O positive. At the limits of this region, the amplifier saturates.

a) Sketch and clearly label the transfer characteristic. What are the saturation levels $L+$ and $L–$ and the corresponding values of v_I?

b) Bias the amplifier to obtain a DC output voltage of 7 V. What value of input DC voltage V_I is required?

c) Calculate the value of the voltage gain (in V/V and in dB) at the bias point.

d) If a sinusoidal input signal is superimposed on the DC bias voltage V_I, that is: $v_I = V_I + V_i \cos(\omega t)$ find the resulting v_O. Express v_O as the sum of a DC component, a signal component at ω with amplitude A_1, and other components at 2ω (with amplitude A_2) and at 3ω (with amplitude A_3). The components at 2ω and 3ω are undesirable and are the result of the nonlinear transfer characteristic of the amplifier. If it is required to limit the ratio $\frac{\sqrt{A_2^2 + A_3^2}}{A_1}$ to 1%, what is the corresponding upper limit on V_i?

2.

An amplifier operating from +/– 12 V power supplies has a linear transfer characteristic except for output saturation at +/– 10 V.

a) The RMS value of the largest sine wave that can be applied at the amplifier input without output distortion is 0.4 V. Find the amplifier voltage gain in V/V and in dB.

b) What is the corresponding output power for a 50 Ω load?

c) What is the power gain, in W/W and in dB, if the input power is 10 mW? What is the current gain of the amplifier, in A/A and in dB?

d) What is the amplifier efficiency if the DC current drawn from each supply is 78 mA?

Problem 1:

a)

- For $v_I = 1$ V (lower limit for v_I),

We get: $v_O = 12 - 8(1-1)^3 = 12$ V

So $L_+ = 12$ V

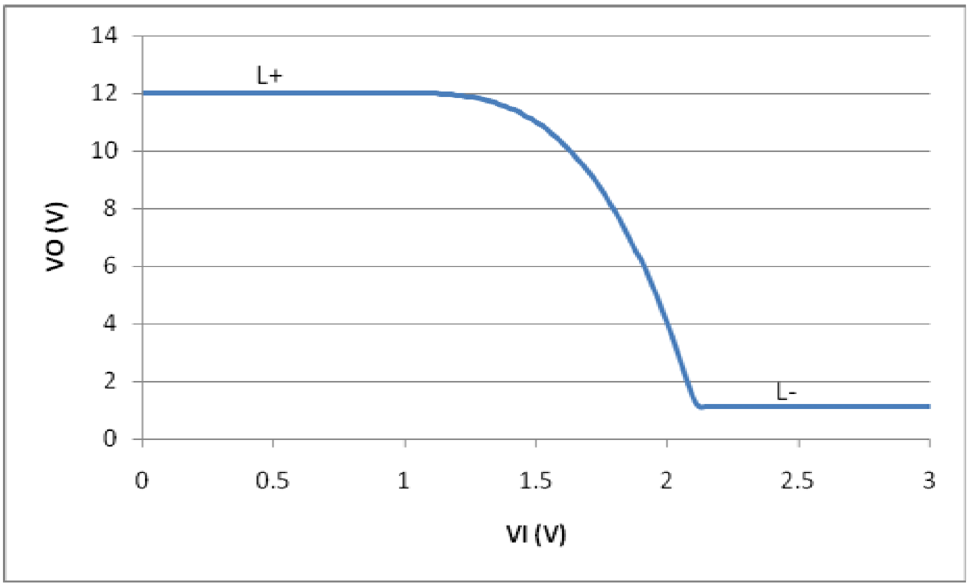
- For $v_I = v_O + 1$ (upper limit for v_I),

We get: $v_O = 12 - 8(v_O + 1 - 1)^3 = 12 - 8\, v_O^3$

$8\, v_O^3 + v_O - 12 = 0$

Since we only want the real root, $v_O = 1.1$ V

So $L_- = 1.1$ V



b)

To obtain $v_O = 7$ V,

$7 = 12 - 8(v_I - 1)^3$

$5 = 8(v_I - 1)^3$

So we need $v_I = 1.854$ V

c)

$A_v = (dv_O/dv_I)|_{VI = 1.854}$

$A_v = -24(V_I - 1)^2 = -24(1.854 - 1)^2 = -17.5$ V/V

A_v (in dB) = 20 log (17.5) = 24.86 dB d)

$v_O = 12 - 8(V_I + V_i \cos(\omega t) - 1)^3$

$= 12 – 8 [(V_I - 1)^3 + 3(V_I - 1)^2 V_i \cos(\omega t) + 3(V_I - 1) V_i^2 \cos^2(\omega t) + V_i^3 \cos^3(\omega t)]$

$= 12 – 8(V_I - 1)^3 - 24(V_I - 1)^2 V_i \cos(\omega t) - 24(V_I - 1) V_i^2 (1+\cos(2\omega t))/2 - 8V_i^3(0.75 \cos(\omega t) + 0.25 \cos(3\omega t))$

$= -12(V_I - 1) V_i^2 + 12 - 8(V_I - 1)^3 + [-24(V_I - 1)^2 V_i - 6 V_i^3] \cos(\omega t) - 12(V_I - 1)V_i^2 \cos(2\omega t) - 2V_i^3\cos(3\omega t)$

$= -12(0.854) V_i^2 + 12 - 8(0.854)^3 + [-24(0.854)^2 V_i - 6 V_i^3] \cos(\omega t) - 12(0.854)V_i^2 \cos(2\omega t) - 2V_i^3\cos(3\omega t)$

$= -10.248 V_i^2 + 7.017 + (-17.5 V_i - 6 V_i^3) \cos(\omega t) – 10.248 V_i^2 \cos(2\omega t) - 2V_i^3\cos(3\omega t)$

$A_1 = -(17.5 V_i + 6 V_i^3)$

$A_2 = - 10.248 V_i^2$

$A_3 = - 2V_i^3$

$DC = -10.248 V_i^2 + 7.017$

$[(A_2^2 + A_3^2)^{1/2}]/A_1 = [(105.02 V_i^4 + 4V_i^6)^{1/2}]/ -(17.5 V_i + 6 V_i^3) \leq 0.01$

$105.02 V_i^4 + 4V_i^6 \leq 10^{-4} (306.25 V_i^2 + 36V_i^6 + 210 V_i^4)$

Let $X=V_i^2$

$105.02 X^2 + 4X^3 \leq 10^{-4} (306.25 X + 36X^3 + 210 X^2)$

$3.9964 X^3 + 105 X^2 -0.0306 X =0$

$X=V_i^2=2.9\times10^{-4}$

$V_i \leq 1.7\times10^{-2}$

$V_i \leq 0.017$ V

$V_i \leq 17$ mV

Problem 2:

a)

Given $V_{Irms} = 0.4$ V

$V_{Orms} = 10/\sqrt{2}$ V

$Av = V_{Orms} / V_{Irms}$

$= 10/(\sqrt{2} \times 0.4)$

$= 17.67$ V/V

A_v (in dB) = 20 log 17.67 = 24.94 dB

b)

$P_L = V^2_{Orms}/R$

= 50/50

= 1 W

c)

given $P_I = 10$ mW

$A_P = P_L / P_I$

$= 1/10 \times 10^{-3}$

= 100 W/W

A_P (in dB) = 10 log 100 = 20 dB

$A_P = A_v . A_i \Rightarrow A_i = A_P/A_v = 100/17.67 = 5.65$ A/A

A_i (in dB) = 20 log 5.65 = 15.05 dB

d)

$\eta = (P_L / P_{dc}) \times 100$

$P_{dc} = 78 \times 12 + 78 \times 12 = 1872$ mW

So $\eta = (1000/ 1872) \times 100 = 53.41\%$