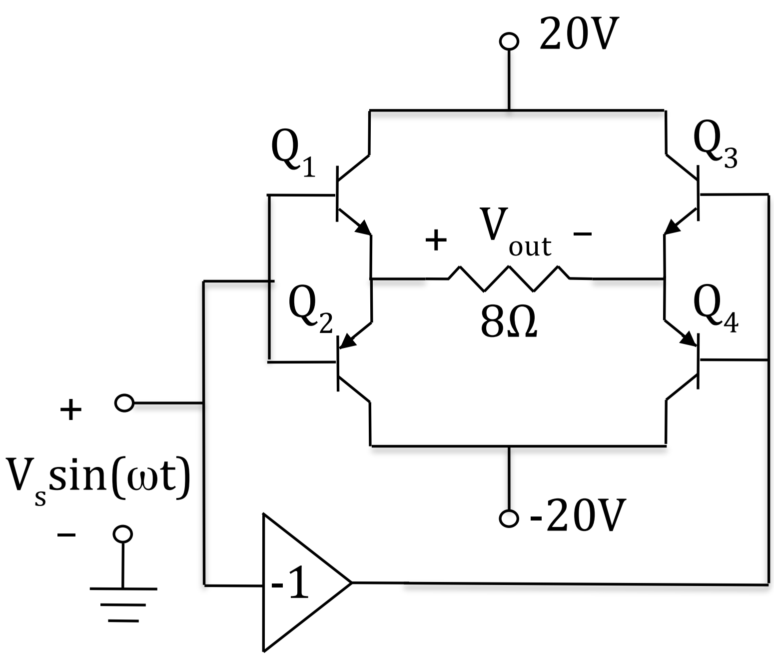
PhD Preliminary Written Exam **Problem #4**
Spring 2014 **Analog/Digital Electronics**

The amplifier shown below is termed a bridge amplifier. The amplifier symbol with the -1 inside is an inverting amplifier with unity gain. The BJT characteristics are shown next to the circuit diagram.



<u>Q1 = Q2 = Q3 = Q4</u>

Beta = 100
V_A = 100 V
$V_{CE,\,sat}$ = 0V
Max. junction temp.
$T_{j,max}$ = 125 °C
Max. ambient temp.
$T_{a,max}$ = 50 °C
Junction-to-case thermal resistance $R_{\theta,jc}$ = 1 °C/W

1. (0.5 points)
   Estimate the maximum average power the circuit can deliver to the 8 ohm load.

2. (1 point)
   What is the efficiency ($\langle P_{load}\rangle / \langle P_{supplies}\rangle$) at maximum output signal swing?

3. (0.5 points)
   What should be the peak voltage rating and current rating of the transistors. Include a 50% factor of safety.

4. (1 point)
   What is the maximum average power dissipated in a transistor?

5. (1 point)
   The transistors are mounted next to each other on a common heat sink. Specify the required heat sink thermal resistance so that $T_{j,max}$ is not exceeded when the ambient is at 50°C.

PhD Prelim, Exam Solutions

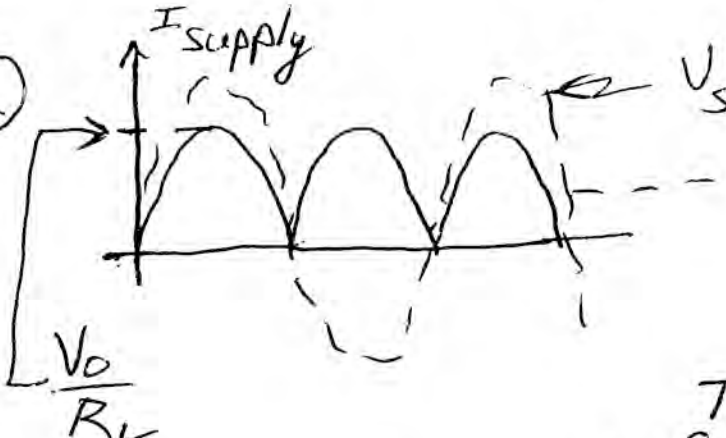
Analog/Digital Electronics

Sp 2014

① $\langle P_{Load} \rangle = \dfrac{V_o^2}{2R_L}$ $\quad V_o\big|_{max} = 40\,v$ b-p

$$\langle P_{Load} \rangle\Big|_{max} = \frac{(40)^2}{(2)(8)} = \frac{1600}{16} = \boxed{100 \text{ watts}}$$

②



current drawn from each supply

$$\langle P_{supplies} \rangle = 2\frac{1}{\pi}\int_0^{\pi} V_{cc}\frac{V_o}{R_L}\sin\theta\, d\theta$$

$$= \frac{2}{\pi} V_{cc}\frac{V_o}{R_L}\Big[-\cos\theta\Big]_0^{\pi}$$

$$= \frac{2}{\pi R_L} V_{cc} V_o \Big[-(-1)-(-1)\Big]$$

$$\langle P_{supplies} \rangle = \frac{4V_{cc}V_o}{\pi R_L}$$

At max. signal swing $V_o = 2V_{CC}$ base-to-peak

$$\text{Efficiency}\Big|_{max} = \frac{(2V_{CC})^2}{2R_L \dfrac{(4V_{CC})(2V_{CC})}{\pi R_L}}$$

$$= \frac{4\pi}{16} = \boxed{\frac{\pi}{4} \sim 79\%}$$

(3) Max. V_{CE} imposed by circuit $= 40V$

Voltage rating $= 40 \times \underbrace{1.5}_{\text{factor of safety}} = \boxed{60V}$

Max. collector current

$$= \frac{40V}{8\Omega} = 5A$$

current rating $= (5)(1.5) = \boxed{7.5A}$

(4) $$\langle P_{trans} \rangle = \frac{\langle P_{supplies} \rangle - \langle P_{Load} \rangle}{4}$$

= pwr dissipated in each transistor

$$\langle P_{trans.} \rangle = \frac{4V_{CC}V_o}{4R_L\pi} - \frac{V_o^2}{(4)(2R_L)}$$

$$\frac{d\langle P_{trans.}\rangle}{dV_o} = 0 = \frac{V_{CC}}{\pi \cancel{R_L}} - \frac{V_o}{4\cancel{R_L}}$$

$$V_o = \frac{4}{\pi} V_{CC}$$ = value of V_o at max. pwr dissipation in BJTs

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$$\langle P_{trans.} \rangle\Big|_{max} = \frac{4V_{CC}}{4\pi R_L} \times \frac{4V_{CC}}{\pi} - \left(\frac{4V_{CC}}{\pi}\right)^2 \Big/ 8R_L$$

$$= \frac{16V_{CC}^2}{4\pi^2 R_L}\left[1 - \frac{1}{2}\right]$$

$$= \frac{2}{\pi^2}\frac{V_{CC}^2}{R_L} = \frac{2}{10}\frac{(400)}{8}$$

$$\boxed{\langle P_{trans.} \rangle\Big|_{max} = 10 \text{ watts}}$$

5 $$T_{j,max} = 4\langle P_{trans}\rangle\Big|_{max}\left[R_{\theta,jc} + R_{\theta,sa}\right] + T_{a,max}$$

$$R_{\theta,sa} = \frac{[125-50]}{(4)(10)} - 1 = \boxed{0,88\ {}^\circ C/W}$$