Power Dissipation in a Class B Output Stage

Version 2.0

J E Green

ICE Amplifiers

26 November 2007

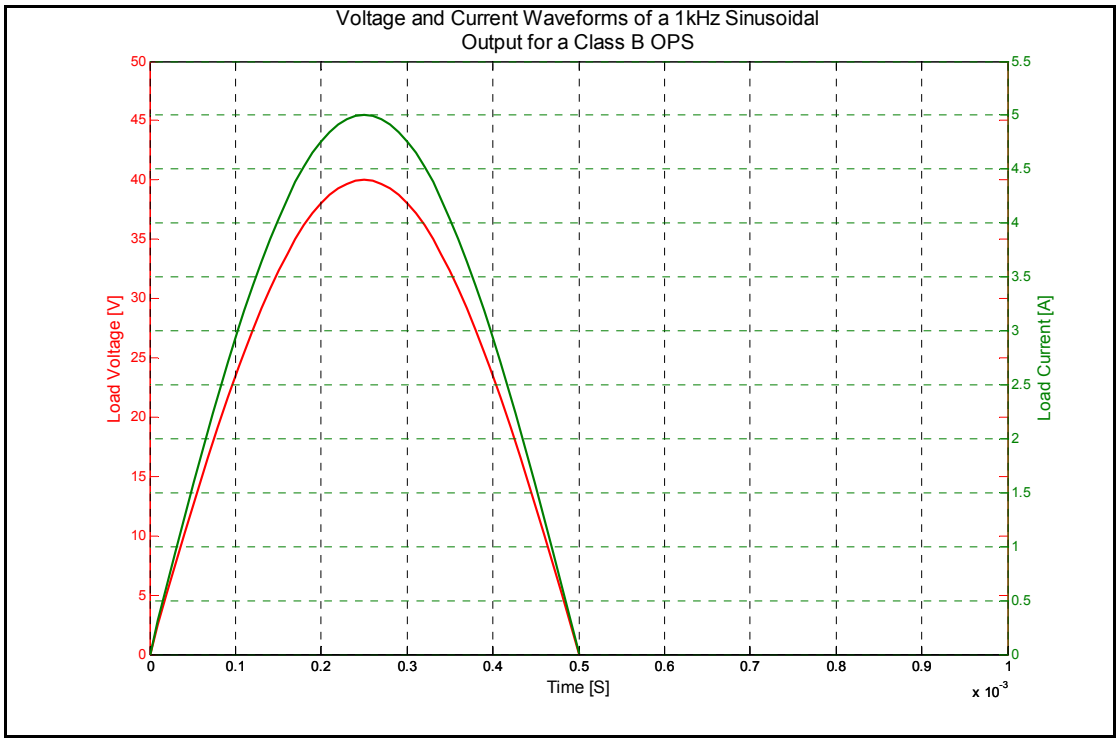


Figure 1: Voltage and Current Waveforms of a 1 kHz Sinusoidal Output for a Class B OPS

$$P(t) = \frac{1}{T}\int_0^{T/2} V_D \sin(\omega t)\cdot I_P \sin(\omega t)\cdot dt$$

$$P(t) = \frac{1}{T}\int_0^{T/2} (V_S - V_P)\sin(\omega t)\cdot I_P \sin(\omega t)\cdot dt$$

$$P(t) = \frac{1}{T}\int_0^{T/2} \frac{V_S V_P}{R_L}\sin(\omega t) - \frac{V_P^2}{R_L}\sin^2(\omega t)\cdot dt$$

$$P(t) = \frac{1}{T}\int_0^{T/2} \frac{V_S V_P}{R_L}\sin(\omega t)\cdot dt - \frac{V_P^2}{T\cdot R_L}\int_0^{T/2}\left(\frac{1-\cos(2\omega t)}{2\omega}\right)\cdot dt$$

The second integral becomes:

$$\frac{1}{T}\cdot\frac{V_p^2}{2R_L}\int_0^{T/2}1-\cos(2\omega t)\cdot dt$$

$$\frac{1}{T}\cdot\frac{V_p^2}{2R_L}\left(\int_0^{T/2}1\cdot dt-\int_0^{T/2}\cos(2\omega t)\cdot dt\right)$$

$$\frac{V_P^2}{2T\cdot R_L}\left(\left[t\right]_0^{T/2}-\left[\frac{\sin(2\omega t)}{2\omega}\right]_0^{T/2}\right)$$

Therefore:

$$P(t)=\frac{1}{T}\int_0^{T/2}\frac{V_S V_P}{R_L}\sin(\omega t)\cdot dt-\frac{V_P^2}{2T\cdot R_L}\left[t\right]_0^{T/2}+\frac{V_P^2}{T\cdot R_L\cdot 2}\left[\frac{\sin(2\omega t)}{2\omega}\right]_0^{T/2}$$

$$P(t)=\frac{1}{T}\left[\frac{-V_s V_p}{R_L}\cdot\frac{\cos(\omega t)}{\omega}\right]_0^{T/2}\frac{V_P^2}{2T\cdot R_L}\left[t\right]_0^{T/2}+\frac{V_P^2}{2T\cdot R_L}\left[\frac{\sin(2\omega t)}{2\omega}\right]_0^{T/2}$$

Inserting:

$$\omega=\frac{2\pi}{T}$$

$$P(t)=\frac{1}{T}\left[-\frac{V_S V_P}{R_L}\frac{\cos\left(\frac{2\pi}{T}\cdot t\right)}{\frac{2\pi}{T}}\right]_0^{T/2}-\frac{V_P^2}{2T\cdot R_L}\left[t\right]_0^{T/2}+\frac{V_P^2}{2T\cdot R_L}\left[\frac{\sin\left(2\frac{2\pi}{T}t\right)}{\frac{2\pi}{T}}\right]_0^{T/2}$$

Applying the limits of integration:

$$P(t)=\left[\left(-\frac{V_S V_P}{T\cdot R_L}\frac{\cos\left(\frac{2\pi}{T}\cdot\frac{T}{2}\right)}{\frac{2\pi}{T}}\right)-\left(-\frac{V_S V_P}{T\cdot R_L}\frac{\cos\left(\frac{2\pi}{T}\cdot 0\right)}{\frac{2\pi}{T}}\right)\right]-\left[\left(\frac{V_P^2}{2T\cdot R_L}\cdot\frac{T}{2}\right)-\left(\frac{V_p^2}{2T\cdot R_L}\cdot 0\right)\right]$$

$$+\left[\left(\frac{V_P}{2T\cdot R_L}\cdot\frac{\sin\left(2\cdot\frac{2\pi}{T}\cdot\frac{T}{2}\right)}{2\cdot\frac{2\pi}{T}}\right)-\left(\frac{V_P}{2T\cdot R_L}\cdot\frac{\sin\left(2\cdot\frac{2\pi}{T}\cdot 0\right)}{2\cdot\frac{2\pi}{T}}\right)\right]$$

Simplifying:

$$P(t) = \left(-\frac{V_S V_P}{R_L} \cdot \frac{\cos(\pi)}{2\pi} \right) - \left(-\frac{V_S V_P}{R_L} \cdot \frac{\cos(0)}{2\pi} \right) - \frac{V_P^2}{4R_L}$$

$$P(t) = \frac{V_S V_P}{\pi \cdot R_L} - \frac{V_P^2}{4R_L}$$

For R_L = 8Ω, V_S = 50 the following graph can be plotted

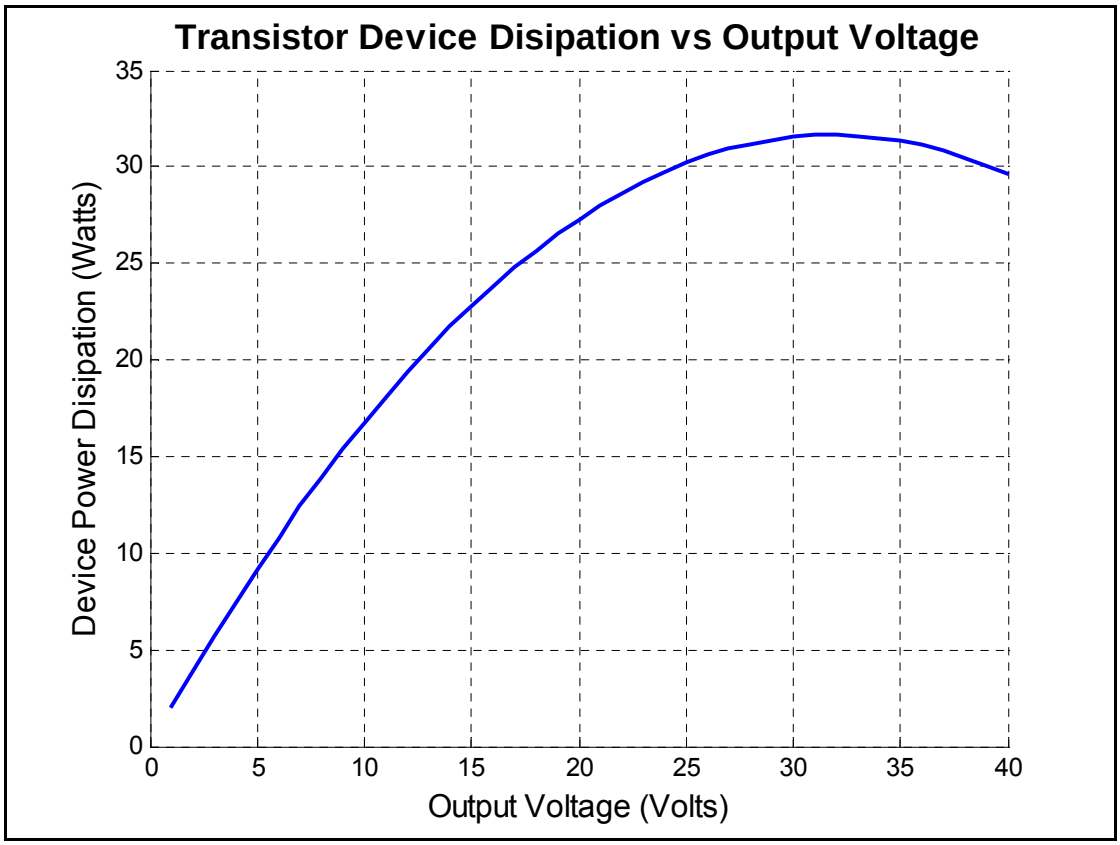


Figure 2: Device Dissipation vs Output Voltage Example

To find the peak load voltage that develops maximum power in the device, this function must be differentiated, or the graph could be used to show the turning point.

$$\frac{dP(t)}{dV_P} = \frac{V_S}{\pi \cdot R_L} - \frac{2V_P}{4 \cdot R_L} = C$$

$$V_P = \frac{2V_S}{\pi}$$

The maximum power is given by substituting the above into the equation for P(t)

$$P_{MAX} = \frac{V_S \cdot \frac{2V_S}{\pi}}{\pi \cdot R_L} - \frac{\frac{2V_S^2}{\pi}}{4 \cdot R_L}$$

$$P_{MAX} = \frac{V_S^2}{\pi^2 \cdot R_L}$$

This is the average power in one output device (or parallel set of output devices) in one cycle. If both NPN and PNP (or N channel and P channel) devices are mounted on one heat sink then the value must be doubled.

For the case given in the example of Figure 1 and Figure 2 the result is 31.66 Watts. Assuming all output devices are mounted on the same heatsink the total maximum dissipation is 63.33 Watts.

The maximum efficiency assuming no quiescent current or power supply losses etc. is 61.22%

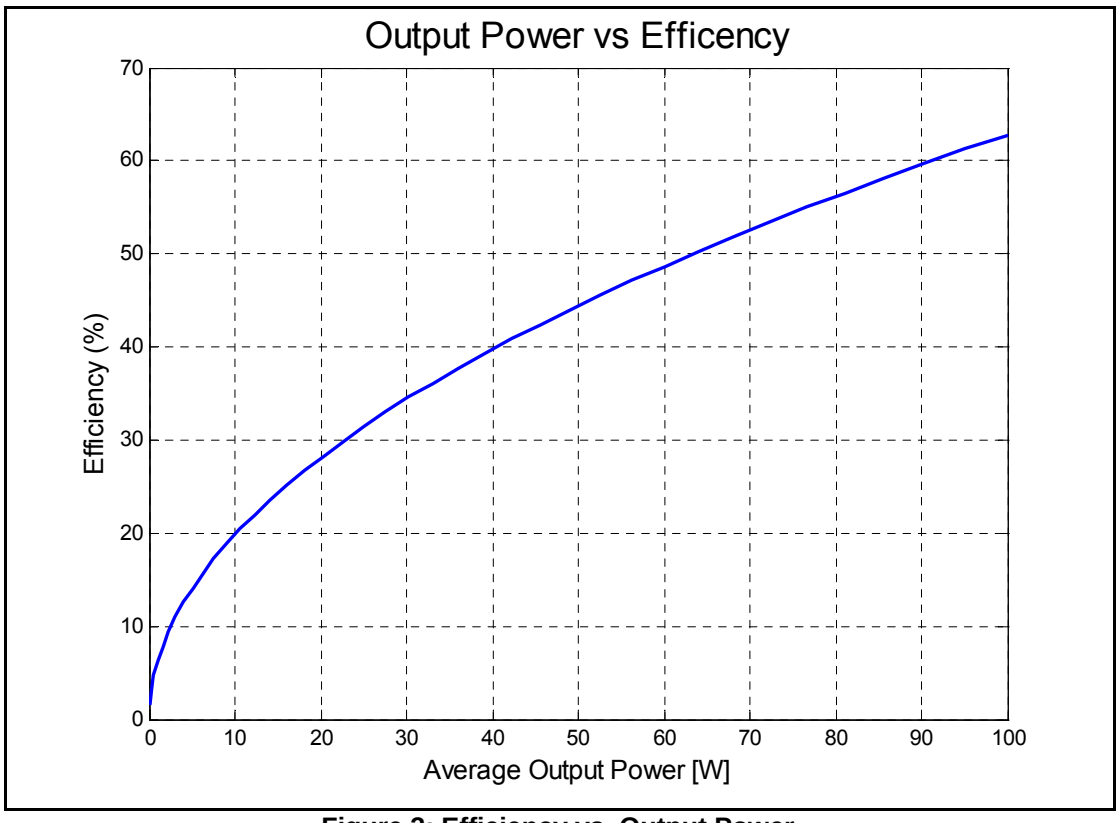


Figure 3: Efficiency vs. Output Power

Given the high peak to average nature of popular program material, such as rock music, it is easily seen that the average efficiency is unlikely to exceed a few percent.