Experiments with Standard Power Amplifier Circuits

Three classes of power amplifier were designed and tested. Transistors used were TIP31C (n-p-n) and TIP32C (p-n-p) type. Total power dissipation for both was 2W, for a transistor with no heat sink and ambient temperature of 25°C. Classes of power amplifiers were class-A, class-B and class-AB.

Class-A

This class of amplifier was easy to design, with biasing current and voltage, but low efficiency. As mentioned earlier, $P_T = 2W$ however 1.8W was chosen as a starting point for additional safety, thus:

Figure 1, below showed the design of the class-A amplifier. $V_{cc}$ was chosen to be 12V, and $R_L = 20\Omega$ was assigned.

![Figure 1. Design of a Class A Amplifier](image-url)
Figure 2. Safe Operating Area (SOA) Diagram

Diagram of a safe operating area was drawn based on the values from 2, where:

Small circuit analysis was also performed in order to acquire the value of $C_{eq}$, and was based on Figure 3, below.
\[ R_{ob} = \frac{V}{I} = \frac{V}{\frac{V}{R_s (1 + \beta)}} = \frac{R_s}{1 + \beta} \]

\[ R_s = \frac{V_{T.\beta}}{I_{ca}} = \frac{0.026 \cdot 10^{-2}}{0.3 \cdot 10^{-3}} = 2.16 \Omega \]

\[ R_0 = (R_e || R_{ob}) \]

\[ R_0 = \left( \frac{2.5}{1 + 0.25} \right) \]

\[ \bar{R}_s = C_{c2} (R_e + R_0) \]

\[ \bar{R}_s \leq \frac{1}{2 \pi \cdot 20 \text{ Hz}} \]

\[ \text{Thus, } C_{c2} \geq \frac{1}{2 \pi \cdot 20 \text{ Hz} \cdot 2.083 \Omega} \]

\[ C_{c2} \geq 396 \mu \text{F}, \quad C_{c2} = 400 \mu \text{F} \text{ was chosen} \]

Noting \( R_{ob} = 0.1 \Omega \), \( R_e \) gave an \( R_{ob} \) value of 52.5\( \Omega \). This value seemed low, since \( R_e \) and \( R_{c2} \) would have been 74.5\( \Omega \) and 175.5\( \Omega \) respectively.

These seemed as too low values, since current through them would have been very low.

\[ \text{For close to 03/6, output circuit,} \]

\[ \text{Figure 4. Input Circuit} \]
Efficiency of the class-A amplifier was calculated using the measured data. As mentioned previously, this class of amplifier has low efficiency.

**Class-B**

This class of amplifiers had much higher efficiency, however it produced crossover distortion due to a dead band portion of the output curve. Design of the class-B circuit was shown in Figure 5.

![Class-B Amplifier Diagram](image)

*Figure 5. Class-B Amplifier*
Based on the measured values, efficiency of the class-B amplifier was calculated:

\[ 47\% \]

This value was much higher than the efficiency of the class-A, however, the clipping of the output signal was present (as expected).

**Class-B**

Sacrificing some efficiency, class AB eliminates crossover distortion. Design of this circuit was shown in figure 6.

**Figure 6. Class-AB Amplifier Design**
Maximum current Transistor 2N5210 was rated for was 100 mA. Therefore, 50 mA for $I_{c}$ was assumed. This value was enough to create limiting out flow. This load

\[ V_{ac} = 5V \]

Figure 7. Transistor 2N5210 Load Line

\[ R_3 = \frac{10.5V}{100mA} = 105 \Omega \]

Two resistors of 120 Ω were used in parallel for $R_3$, to give $R_3 = 110 Ω$.

Biasing resistors, $R_1$ and $R_2$ were calculated based on information from

2N5210 sheet, $V = 10V$, $f = 1500Hz$

7V

23 kΩ

10 kΩ
When the circuit was built and tested, $R_2 = 6.49 \text{k} \Omega$ was used to achieve an output of $5\text{V}$. The discrepancy was due to low Votm conditions and $R_2$. The current was held to be near zero for low signal distortion. It was noticed and showed in Figure 10, some small distortion was still present. This distortion was increasing and becoming significant as the signal input was raised into the clip-off region. Figures 8 to 10 show the signals of all three classes of amplifier build.
Figure 8. Class-A, Input (CH1) and Output (CH2) Signals

Figure 9. Class-B, Input (CH1) and Output (CH2) Signals

Figure 10. Class-AB, Input (CH1) and Output (CH2) Signals