In the early days when semiconductor devices were not available, vacuum tubes were the only active devices to implement all necessary functions needed in audio application: AC rectifying, DC power supply regulation, active load, signal conditioning and signal amplification, etc. When semiconductor devices became commercially available in the 1960s, the compact size and good reliability (from later years) made them a very attractive alternative. Semiconductor devices gradually replace vacuum tubes in audio and many industrial applications.

What hybrid amplifier

Compact size and good reliability of a product are important. However, the sound quality of an audio amplifier is equally important to an audio enthusiast. Since vacuum tubes and semiconductor devices create sound signature differently, audio amplifiers produced by both technologies can be found in the market today. It is interesting that most audio amplifiers are either produced in all vacuum tubes or in all semiconductor devices. There are very few audio amplifiers that use both vacuum tubes and semiconductor devices together in a product. We shall call audio amplifier that mixes with both vacuum tubes and semiconductor devices for signal (voltage and current) amplification as hybrid audio amplifier in this white paper. And we shall discuss fully balanced hybrid audio power amplifier in some details.

Vacuum tubes such as triodes and pentodes are good for voltage amplification. Due to its high output impedance and high voltage DC power supply requirement, vacuum tube is not efficient for current amplification. Even though output transformerless (OTL) vacuum tube audio power amplifiers do exist, most vacuum tube audio power amplifiers have output matching transformer for improving output current drive. Therefore, use of a heavy and bulky output transformer is inevitable in a high power amplifier.

On the contrary, BJT and MOSFET semiconductor transistors have the advantages of low output impedance and low voltage DC power supply requirement. They are excellent choices for current amplification. Output transformer can be totally eliminated when semiconductor transistors are used. We shall discuss several hybrid audio power amplifiers that employ vacuum tubes for input voltage amplification and power transistors for output current amplification.

Simple hybrid amplifiers

Let’s start with a typical all semiconductor devices audio power amplifier as shown in Figure 1. This is a single-ended input and single-ended output amplifier. Q1 to Q4 are BJT type small signal transistors. Q5 to Q8 are MOSFET type power transistors. Since the input impedance of MOSFET is high, no driver stage is needed. This further simplifies the design. Q1 and Q2 form a differential amplifier to amplify the difference of input voltage and feedback voltage from the output. Q3 further amplifies the difference. Q4 works as a $V_{BE}$ multiplier setting up a DC voltage for correctly biasing the output power MOSFET Q5 to Q8. If we replace transistors Q1 and Q2 by vacuum tubes T1 and T2, the result is a simple hybrid audio power amplifier as shown in Figure 2. In this hybrid amplifier, an additional high voltage power supply (+HT) is needed. Since the DC level at the plate of the triode T1 is high, the output from T1 is coupling to Q3 via a capacitor. A current source and resistors network are formed at the base of Q3 so as to adjust the output to DC ground level. In this simple design T1 and T2 will bring some “tube sound” to the hybrid amplifier. But it should be noted that transistor Q3 is in the signal path. On the other hand, adjusting to and maintaining at DC ground level for the output isn’t an easy task for this design.

Figure 3 shows a hybrid audio power amplifier that replaces transistor Q3 by vacuum tube T3. In other words, voltage amplification is all done by vacuum tubes T1 to T3. A
Figure 1. A simplified all semiconductors audio power amplifier for single-ended input and single-ended output.

Figure 2. A simple hybrid audio power amplifier with vacuum tubes using in the first stage.
different current source and resistors network are formed between T3 and power MOSFET transistors so as to adjust the output to DC ground level. Since this hybrid amplifier uses all vacuum tubes for voltage amplification, it brings more “tube sound” to the output compared with the hybrid amplifier of Figure 2. The power MOSFET transistors work as buffer amplifier (ie, voltage gain of unity) and their major role is to produce high current drive for the output. In order to adjust the output at DC ground level, a more sophisticated circuit than the one shown in Figure 3 is needed.

Figure 2 and 3 show how a simple hybrid audio power amplifier can be implemented. However there are shortcomings associated with them:

- The output is difficult to maintain at DC ground level.
- The DC level will drift with temperature changes.
- The amplifier is a single-ended input and single-ended output design. Not a fully balanced design.

Figure 3. A simple hybrid audio power amplifier with all vacuum tubes for voltage amplification.

Figure 4. Functional diagram of the Dual Balanced Feedback Topology (DBFT).
Fully balanced hybrid power amplifier

To design a fully balanced hybrid audio power amplifier, we make use of the well-proven design, namely Dual Balanced Feedback Topology (DBFT), as shown in Figure 4. When DBFT is implemented in an all-vacuum-tube power amplifier, the input and second stages use small triodes for voltage amplification. The push-pull output stage contains pair(s) of power tubes (i.e., EL34 or KT88s, etc) and an output transformer. At least one power tube amplifies the positive phase signal and another power tube amplifies the negative phase signal. The two out-of-phase signals combine together at the output transformer to reconstruct the output signal at the secondary side of the transformer.

Since there are two out-of-phase signals in a fully balanced amplifier, we need to use two buffer amplifiers to replace the power tubes and output transformer in a fully balanced hybrid power amplifier. Figure 5 shows a proprietary design of buffer amplifier by JE Audio. It is a high current buffer amplifier (HCBA) with the following properties:
- Unity voltage gain
- High speed and high current gain
- High power capacity
- Input and output are maintained at DC ground level automatically
- Protect output for over current, output DC offset and overheat
- Stable with and without global feedback applying to it

Figure 6 shows a fully balanced hybrid power amplifier that employs two HCBAs in the output stage. One HCBA amplifies signal of one phase and the other HCBA amplifies signal of the opposite phase. Since the input stage and second stage use all vacuum tubes for signal amplification, and the HCBAs have unity voltage gain, the overall sound has retained very much to what we expect from a tube power amplifier. But it has advantage over conventional vacuum tube power amplifier in terms of high current drive provided by the semiconductor buffer amplifier at the output. The fully balanced hybrid power amplifier eliminates a frequency dependent and bulky output transformer altogether. Finally, a fully balanced amplifier has an additional advantage of having a strong immunity against common mode noises.
Figure 6. A fully balanced hybrid power amplifier employs DBFT and dual HCBAs.

Figure 7. Picture of the dual HCBAs.