Subject: Class A, AB1, B, C Operation/Modes
Posted by positron on Mon, 06 Feb 2023 02:40:15 GMT
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How Class A, AB1, B, and C Operation Work and Differences

I thought it would be informative to discuss the differences between Class A, AB1, B, and C operation. By doing such, one will more fully understand how each component in your system operates. Knowledge is power and the more you understand, the less chance of being misinformed. I am going to keep this discussion as simple as possible for our newbie friends. I will not cover every detail nor every proof.

Caveat: Lets leave out transformers from our discussion.)

Note: It might be good idea to print out all the figures at the bottom of this post to examine while reading.

So let's get started.

What is a sine wave? A sine wave is:

"a curve representing periodic oscillations of constant amplitude as given by a sine function. Also called sinusoid."

The sine wave is a constantly varying voltage. Figure 1 has a pictorial of a sine wave, the wavy line. 120 vac at the wall outlet is a sine wave, and voltage.

So is music made up of sine waves? The answer is yes. Although looking at a musical signal with an oscilloscope might look haphazard, with sharp peaks, those sharp peaks are simply very high frequencies. Even a solo instrument's signal might look haphazard due to natural harmonics from the instrument.

It will be easier to understand the different classes of operation if we use a single frequency sine wave as pictured in Figure 1. The entire input signal wavy line is a complete sine wave, 360 degrees. Half of a sine wave is 180 degrees. One fourth of a sine wave is 90 degrees, one eighth of a sine wave is 45 degrees etc.

Class A operation.

Suppose we have a single vacuum tube and we have it just drawing current (idle current, Point Q of fig. 1) with no signal present. Now we apply the input signal to the tube's grid and the output appears as X and Y output in fig. 1. Notice X and Y look the same as the input sine wave signal.

So what happened? The input voltage applied to the tube grid controls the current flowing through the tube. In Class A, the current flows through the tube all the time, the entire sine wave input signal, 360 degrees. That is very good. Again, that is also the classic definition of Class A operation, or mode.

Virtually all phono stages, pre-amplifiers, input and phase splitters in amplifiers are operated Class A. The following tube stage presents a fairly constant load. That is good news.

Let us continue for tubes operated in Class AB1, B, and C. Will all operations work in linear audio applications?

Class AB1, B, and C are defined as operating a single tube when the current through the tube can be stopped, cut off, meaning 0 ma. (ma is milliamps, or thousandths of an ampere.) So what is the difference between AB1, B, and C operations?

First, we need to see something significant in fig 1, Class A operation. It has to do with the tube's idling current in fig 1, the Q point, which is set to 65 ma, half way between 0 ma and maximum 130 ma. in our example. Notice we can go 65 ma. to 0 ma. and 65 ma to 130 ma.

Above and below are equal. So X and Y are equal output and mimic the input signal. This current variation allows the tube to remain conducting current the entire input sine wave voltage cycle, 360 degrees. Again, this is Class A operation. Understanding Class A operation allows us to understand Class AB1, B, and C operation more fully.

Let's bypass fig 2, AB1, for now.

Let's jump to fig 3, Class B operation/mode. Notice Q point is different. It is not 65 ma but now 0 ma idling. We still have the same exact value input signal, but only X appears at the output, Y being absent. Only half the input signal is at the output. What happened?

Q point is set at 0 ma. As the signal goes positive, more current flows through the tube, so X output appears. However, how can we go less than 0 ma. current as the input signal voltage goes negative? We cannot. Thus no Y output signal voltage. Only ½ of the input signal appears at the output (180 degrees). This is a classic example, definition of Class B operation.

Class B presents severe distortion to the input signal, and is generally used in RF and industry. It can be used in audio if we go Push Pull, but it will produce crossover distortion, higher distortion in general, so is mostly used in PA systems where fidelity is not important.

Fig. 2, AB1 operation is between A and B, fig. 1 and fig. 3 respectively.

Let us check out fig. 2, AB1 operation. Once again we have our input signal sine wave, and X and Y output voltage. However, we have only some Y output sine wave signal present. Notice, however, the tube's idle current, Q is between our Class A and Class B Q points, 65 ma and 0 ma respectively.

In our AB1 example, the idle current is set to 55 ma. Ok, as the input signal is increased from no signal, X and Y output rise equally, Class A operation, until the negative input signal causes the tube current to reach 0 ma. At that point the tube cannot go less than 0 ma current, so Y signal cannot continue to follow the negative input signal.

So what good is it if X becomes larger while Y? What about adding a second output tube which mirrors the first tube, except it handles the negative portion of the input signal, increasing in current as the signal goes more negative. Then X and Y output sine wave mirrors the input sine wave signal. They naturally blend together. That is called Push Pull.

So is there any advantage in designing Push Pull?
IF designed properly, efficiency is much higher than class A, much more power output with the same or less distortion. One can also eliminate the inherent negatives of a class A output stage. See below *.

However, a push pull stage is much more difficult to design. But the nice thing in AB1 mode is that both output tubes operate in Class A mode at the same time until each output tube reaches its 0 ma point respectively.

For example, a 6L6GC, beam power tube in AB1 mode can produce 55 watts rms output in Class AB1 operation. However, both output tubes are operating at least 15 watts in Class A mode before sliding into AB1 mode. That is conservative ratings.

In triode mode, we can figure half the power output of beam power mode, so at least 7.5 watts Class A operation of both tubes before sliding into AB1 operation.

Even at 1 watt Class A output, a typical speaker can at least peak into the mid 80s spl, depending upon the efficiency of one's speakers. And the harmonic distortion is extremely low. My whole KT88 amp produces only 0,05% at 1 watt output, with no global negative feedback.

Ok, we have discussed Class A, AB1, and B operation. Let us check out fig. 4, Class C operation.

The first thing one notices is that Q idle is below 0 ma. How can that be? Notice the perforated line to Q. What is actually pictured is the grid bias is so negative that less than half, in fact, a very small portion of the input signal is even large enough to cause current flow through the tube. Thus X appears to be small and Y does not exist at all. A larger, huge input signal must be present to obtain lots of power output in Class C mode.

The plus is that the efficiency can reach 80%, but the minus is that the distortion is gigantic. Class C operation is usually used in radio frequencies (RF) and Industrial applications.

So what have we learned?
A. Class A is used in virtually all small signal applications since the load is relatively constant.
B. Class AB1 Push Pull and A are used in most output applications.
C. Class B is used as Push Pull, almost exclusively for PA systems.
D. Class C is never used in linear analog audio designs.
E. There is a smooth blending in properly designed Push Pull stages.
F. In Class AB1, both output tubes X and Y run Class A until each tube reaches 0 ma. on positive and negative peaks of the sine wave cycle.
G. The output impedance/damping factor remains virtually constant over the entire sine wave with Push Pull. Class A single ended amplifiers are a different story. See below *.
H. There is no signal gap between output tubes, nor crossover distortion until approaching Class B mode/operation.
I. 120 hz power supply hum is mostly cancelled.

* For a single output tube amplifier, different considerations apply. For instance, we want the amplifier's output impedance (Z) to be constant with varying power output and over the entire signal cycle, 360 degrees. To accomplish this, the tube's plate resistance (Ra) must remain constant.

However, Fig. 5 shows the Ra line of a typical single ended triode tube varies/curves substantially as the current changes. Of course as the current changes, the output power also changes. At peak power output, the damping factor varies from maximum damping of that SET amplifier design to virtually no damping. Pull remains virtually constant under the same conditions.

There are other pros and cons that we might discuss later. I hope this has helped in understanding how Class A, AB1, B, and C work.

One can check out:

RCA Tube Manual
RCA Radiotron Designers Handbook
Semiconductor and Tube Electronics by James G Brazee

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File Attachments

1) Tube Operating Curve Class A1.pdf, downloaded 298 times
2) Tube Operating Curve Class AB1.pdf, downloaded 295 times
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