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

Pos

File Attachments

1) Tube Operating Curve Class A1.pdf, downloaded 89 times
2) Tube Operating Curve Class AB1.pdf, downloaded 92 times
3) Tube Operating Curve Class B1.pdf, downloaded 96 times
4) Tube Operating Curve Class C1.pdf, downloaded 82 times
5) Tube Operating Curves Class D.pdf, downloaded 109 times

Subject: Re: Class A, AB1, B, C Operation/Modes
Posted by Wayne Parham on Mon, 06 Feb 2023 02:54:24 GMT
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Very good stuff! I gotta get a cold soda and some snacks and take time to digest this!

Subject: Re: Class A, AB1, B, C Operation/Modes
Posted by gofar99 on Tue, 07 Feb 2023 02:38:26 GMT
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Hi, yes good stuff. It is why I almost always use push-pull class A for power amps. Inefficient for sure, but really clean with power supply cancelling and low even harmonic distortion.

Subject: Re: Class A, AB1, B, C Operation/Modes
Posted by positron on Tue, 07 Feb 2023 22:13:56 GMT
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I run mine Class AB1, and triode for years. Some day will try UL.

At the volume I listen it is mostly if not all Class A mode as you Go.
At one watt output, the amplifier distortion is ~0,05%, so still quite
low.

I have been running sophisticated listening testing and found my mono

blocks do not alter the sound, when no load. However, my load is a variable cone type speaker so what do I do?

The trick is to match the amp to speaker with the correct total gauge speaker wire. I don't worry too much about self inductance.
This is fun,,, ya right. Each system will be different.
It takes a lot of time, so beware.

As it turns out, I am running all copper, 10 strands of 18 gauge, 6 feet long in parallel for each leg to the speaker, adn the other speaker.
Total gauge is ~9.2 gauge if I remember correctly. Yours will vary.

If I run 9 strands or 11 strands in one leg, the sound is not optimumal in my design. It sounds either too thin or too dull.

Anyone can start testing in their own system for optimum sound.
I would start with hardware store doorbell wire as a starter.
I used double wire in jacket.

Make sure the wire/cable length to one speaker matches the leg length in the other speaker. Otherwise you may have to add or subtract a strand for optimum matching of both speakers. Self inductance will also be different, but maybe low enough to not matter.

Replacing a strand of regular wire with Jenalabs wire will certainly alter the sound. Right now, I am using one strand of Jenalabs 18 gauge wire in each leg with nine regular strands of hardware store wire (99.9% pure).
(Jenalabs wuite is 6N pure, 99.9999% pure, and expensive.)

cheers

pos

Subject: Re: Class A, AB1, B, C Operation/Modes
Posted by gofar99 on Wed, 08 Feb 2023 01:33:03 GMT
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Hi, All my amps are U/L. Nearly no global NFB (just 3 db for stability at way above band possible resonanaces). And yes indeed...everything matters. It took a long time to figure out how to best use my Martin Logan ESLs. They tend to be troublesome loads for some amps (none of mine though) and placement is critical.

Subject: Re: Class A, AB1, B, C Operation/Modes
Posted by positron on Wed, 08 Feb 2023 02:37:50 GMT
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gofar99 wrote on Tue, 07 February 2023 19:33Hi, All my amps are U/L. Nearly no global NFB (just 3 db for stability at way above band possible resonanaces). And yes indeed...everything matters. It took a long time to figure out how to best use my Martin Logan ESLs. They tend to be troublesome loads for some amps (none of mine though) and placement is critical.
Hi Bruce,

Yes, I have heard Martin Logan's are a difficult load. i take it the impedance varies wildly?

I agree Bruce, everything matters.

I am not running any global negative feedback, just a very small amount of cathode/current feedback for the output tubes.

To help match woofer to full range driver, I am currenty using a 15" piece of 18 gauge wire. I have 6" available, or no extra wire, or other custom lengths if necessary.

You are so right concerning speaker placement.

Nice post Bruce. Appreciate your knowledge and input.

I guess back to Class A, AB1, B, and C amps.

Cheers and all the best Gents.

pos

Subject: Re: Class A, AB1, B, C Operation/Modes
Posted by gofar99 on Fri, 10 Feb 2023 03:01:42 GMT
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Hi, MLs act like huge capacitors. They go from just over 4 ohms at low frequencies to 1 ohm at 20K. The slope of impedance can give many amps fits. It was why I added 3 db of frequency limited NFB to my amps. I figured they were about as tough a load as anything anyone would use. (some crossovers might be worse though) I have not had any misbehave without it...but testing shows a strong resonance point in most of the amps at about 70-85KHZ. So I start the slope at about 25-30K and it insures stability no matter what the amp sees on the output side. I have tested all of the various sizes with and without the NFB and have not been able to get any to mess up...still a couple of parts is cheap insurance. In the commercial versions and shown on the diy schematics I show NFB defeat switches and most folks can only say that the use of NFB cuts the

gain by a few db. No surprise there...but in a blind test can't tell which one is which.

Subject: Re: Class A, AB1, B, C Operation/Modes
Posted by positron on Fri, 10 Feb 2023 03:35:14 GMT
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gofar99 wrote on Thu, 09 February 2023 21:01Hi, MLs act like huge capacitors. They go from just over 4 ohms at low frequencies to 1 ohm at 20K. The slope of impedance can give many amps fits. It was why I added 3 db of frequency limited NFB to my amps. I figured they were about as tough a load as anything anyone would use. (some crossovers might be worse though) I have not had any misbehave without it...but testing shows a strong resonance point in most of the amps at about 70-85KHZ. So I start the slope at about 25-30K and it insures stability no matter what the amp sees on the output side. I have tested all of the various sizes with and without the NFB and have not been able to get any to mess up...still a couple of parts is cheap insurance. In the commercial versions and shown on the diy schematics I show NFB defeat switches and most folks can only say that the use of NFB cuts the gain by a few db. No surprise there...but in a blind test can't tell which one is which.
Yes, that is quite a change in load.

After discussing the matter with a Harvard Medical School chair years ago, one item I think we need to be cautious of is blind testing.

There are many confound variables that need to be addressed. Otherwise
the test will always be skewed toward no sonic difference. It then basically becomes a rigged test.

I used to test every day for weeks, months or longer, but addressing confounds. Now I have the ability to hear the change quite easily. I still test every day after a tweak is made, just to be sure though.

cheers and all the best.

pos

Subject: Re: Class A, AB1, B, C Operation/Modes
Posted by positron on Wed, 01 Mar 2023 01:04:53 GMT
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Something else to consider.

First, pin 1 in a power cord is the ground wire, the 3rd prong of a
power plug. See Fig. 1 below.

I don't know if this has been mentioned earlier or in another post,

but when two or more components in a system have pin 1 connected to the same outlet "terminal", there is a connection between the signal ground of the components involved. See Pin1.jpg

In any case, musical information/signal current not only returns via both left and right interconnect shields, but also through the pin 1 power cord ground wires, from component to component signal grounds.

This mixes the channels together to some extent, and is frequency sensitive. There are all sorts of negative ramifications to the musical parameters, such as sound stage, dynamics, frequency response etc. (I know, the resistances and inductances seem small but I am testing 1 part per million in my speaker crossovers, so it does matter to some extent.)

As above, the mixing is non linear since we have two factors to consider, resistance and inductance of the interconnect cable(ic) shields and pin 1 power cord wires.

The ratio of the shield resistance to pin 1 resistance will not be the same as the ratio of the shield inductance to pin 1 wire inductance.

There are solutions, but please be careful if/when implementing them.

1. Only have one component with pin 1 connected to ground. This requires connecting all ics before plugging in any AC power plugs. I do not accept any responsibility. You perform this at your own risk of injury.

2. There is a second method, but I do not accept any responsibility. You perform this at your own risk of injury.

   It is installing multiple resistors, each high power, very low ohmage between pin 1 and the component. The preamplifier is the logical choice since the AC current draw is low, the rated fuse is low.

   (Amplifiers are higher current with higher amperage fuses, so I would not install any resistors in one. Do so at your own risk of injury.)

   For instance, 3 twelve watt resistors in parallel, each resistor 4.5 ohms would result in 1.5 ohm total. The fuse should easily blow, the resistor combo will be 30 watts rated. Even if one or two resistors open, the fuse should easily blow first.

   I cannot state this enough. Please be careful. I do not

accept any responsibility for any accidents or injuries.

cheers

pos

File Attachments
1) AC Plug Pin 1, Wire.pdf, downloaded 77 times
2) PIN1.jpg, downloaded 91 times

Subject: Re: Class A, AB1, B, C Operation/Modes
Posted by Wayne Parham on Wed, 01 Mar 2023 14:28:48 GMT
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Good mention. Ground loops are one of the biggest potential causes of noise, not only for audio but for all kinds of circuits.

Subject: Re: Class A, AB1, B, C Operation/Modes
Posted by gofar99 on Thu, 02 Mar 2023 01:45:50 GMT
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Hi, Indeed. The way I get around this in all my gear, both commercial and diy is to isolate the signal ground from the chassis. I always use the third wire (AC mains ground) and attach it securely to the chassis. The internal circuitry ground is connected to the chassis via a type X2 capacitor and parallel resistor. (some folks prefer a diode bridge) There can be no other connections between the two grounds. This is important. Beware of chassis mounted jacks as they can defeat the protection. What this does is prevent ground loops through the AC mains but allows the chassis to still protect the users. A side benefit is the chassis still can act as an EMI shield for the internal components. This arrangement complies with electrical standards and makes for a quiet piece of gear no matter what it is connected to. Any faults in the circuitry are either handled by the fuse (an absolute necessity) or at least kept from harming the user. The typical component values are between 0.1 and 0.2uf and 100-150 ohms 1-2 watt size is usually fine. The capacitor needs to be AC mains rated thus the X2 designation. Usually the voltage ratings are 275 or 350 VAC. There are a few less common AC mains rated caps but the X2s are easy to source and not costly. Even though many companies used other common types in the past they are not recommended as they are not self healing and can short through. Good discussion.

Subject: Re: Class A, AB1, B, C Operation/Modes
Posted by positron on Sun, 05 Mar 2023 06:33:41 GMT

gofar99 wrote on Wed, 01 March 2023 19:45Hi, Indeed. The way I get around this in all my gear, both commercial and diy is to isolate the signal ground from the chassis. I always use the third wire (AC mains ground) and attach it securely to the chassis. The internal circuitry ground is connected to the chassis via a type X2 capacitor and parallel resistor. (some folks prefer a diode bridge) There can be no other connections between the two grounds. This is important. Beware of chassis mounted jacks as they can defeat the protection. What this does is prevent ground loops through the AC mains but allows the chassis to still protect the users. A side benefit is the chassis still can act as an EMI shield for the internal components. This arrangement complies with electrical standards and makes for a quiet piece of gear no matter what it is connected to. Any faults in the circuitry are either handled by the fuse (an absolute necessity) or at least kept from harming the user. The typical component values are between 0.1 and 0.2uf and 100-150 ohms 1-2 watt size is usually fine. The capacitor needs to be AC mains rated thus the X2 designation. Usually the voltage ratings are 275 or 350 VAC. There are a few less common AC mains rated caps but the X2s are easy to source and not costly. Even though many companies used other common types in the past they are not recommended as they are not self healing and can short through. Good discussion.

The code seems ok, but I am not sure code covers every scenario.
I don't mean to be critical of the code, if I may present an interesting scenario.

The chassis is grounded and as stated above, the fuse size is larger
than the current through the resistor between signal ground and chassis ground.
We also use a capactor across the resistor.

I believe the key is the value of the resistor vs the fuse size.

Now let's suppose the AC wire shorts to signal ground, and 120 vac
occurs between the signal ground and the chassis (worst case scenario).

The resistor will probably overheat and open (depends upon resistor
wattage), so only the capacitor is connected. The impedance of the
cap at 60hz is basically a non factor unless the large ufd value.

The AC voltage between chassis and signal input/output jacks, will be
120 vac. Contacting both the chassis and jack(s) with fingers will
give a nasty shock at minimum.

May I suggest multiple high wattage resistors "X" ohmage in
parallel between chassis and signal ground, creating a high wattage
and very low ohmage resistance. As such, the current through the
resistor is larger than the fuse value, so the fuse blows.
We should be safe.

The musical signal return current through pin 1 will still be very low
due to "X" resistance, yet the risk of shock is virtually zero
as the voltage between signal ground to chassis ground stays very low.

I think the keys are:

1. that the value of the resistor be such that the fuse will blow.

2. The value of the resistor is low enough that one should never be shocked.

I would think this would cover things well.

Other thoughts are much appreciated.

Cheers

pos

Subject: Re: Class A, AB1, B, C Operation/Modes
Posted by Wayne Parham on Sun, 05 Mar 2023 14:05:01 GMT
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I connect signal ground to chassis ground, but at only one location.

Any device that is remote must be isolated in some way, without having grounds connected. The isolator can be a transformer or something like an opto-isolator.

Where this can become tricky is in the definition of "remote." Some might think of this as a physical distance, and in fact, that is often the case. But in fact, what makes a device "remote" is the resistance and reactance of the ground conductor.

If all devices had a hypothetical perfect zero resistance connection between grounds, there would be no possibility of the condition we call a ground loop. What causes the problem is the difference between the local ground potentials at each device. And this is due to the resistance between them.

So I try to limit resistance between ground connections everywhere that's possible. That's the case inside a chassis as well as outside. But if resistance cannot be reduced to very, very low levels - close to perfect zero ohms - then isolation is necessary.

And that includes reactive effects too, which makes things even trickier. A resistance of zero ohms at DC doesn't matter much if the circuit is operated at 10Mhz and there is reactance in the ground conductor, making it higher than zero ohms in the passband of the circuit. Where there is any resistance or relevant reactance in the ground conductor, we must abandon the approach of connecting the circuits and instead completely isolate them by transformer or opto-isolator.

Subject: Re: Class A, AB1, B, C Operation/Modes
Posted by gofar99 on Sun, 05 Mar 2023 14:10:18 GMT
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Hi Pos, That could happen....but to have that occur you have to violate another portion of the codes. The one about all exposed metal parts need to be either double insulated from contact or earth grounded. The failed transformer should be one or the other and then there is no hazard.

The resistor is actually best thought of as a low frequency path for crud between the circuitry and earth. Many designs leave it out. I find that it helps with the S/N a bit. Also the use of a large rectifier (often a bridge) between the two grounds could fail if there is the second grounding violation. I don't care for the rectifiers as they leave the chassis about 0.7 volts different from the earth and 0.7 Volts is a lot of potential noise that is not eliminated.

Just my two cents on how the codes work.

Subject: Re: Class A, AB1, B, C Operation/Modes
Posted by positron on Tue, 07 Mar 2023 01:01:21 GMT
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A I had an experience that moved me to post.

I went to an audiophile friend's house after he mentioned being shocked when he plugged in an ic to his ST70 amplifier. It turned out that the pin 1 (ground wire) was not connected to the chassis and the power transformer internally shorted resulting in some high AC voltage on the chassis. Of course the ics were grounded, so when connecting to the ST70s, he was shocked.

ST 70s are known for power transformer failures, so
I would make sure you do not defeat the ground wire to your ST70, or someone else has not done so. This includes not using a 3 to 2 plug adapter.

If it is disconnected, please reconnect it. If you cannot, please disconnect all AC power plugs before connecting audio component ics. Then plug in your components.

It has made me a little sensitive in this area.
The resistor wattages I use are multiple parallel 10 watters with total resistance around 1.5 - 2 ohms or so. This keeps the chassis ground to jacks/signal grounds at very low voltage differences, so no shocks. The resistors also do not open while the fuse blows as intended.

As a former designer/manufacturer, I plug and unplug ics all the time and I need personal protection, and to keep all component

plugs connected to outlets when performing listening tests. Unplugging and plugging in the power cords could possibly taint the listening tests.

I use my own non shielded 6N copper wire in my ics to the amp for improved sonic quality. (Also for other source components to the preamplifier inputs.) As for any hum, I designed a circuit specific 60hz hum canceling circuit in my amplifiers. Fortunately, ear on the driver and zero hum.

(I edited for fuller and easier understanding of why I do what I do.)

cheers to all.

pos

Subject: Re: Class A, AB1, B, C Operation/Modes
Posted by positron on Sun, 07 May 2023 03:32:45 GMT
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gofar99 wrote on Sun, 05 March 2023 08:10Hi Pos, That could happen....but to have that occur you have to violate another portion of the codes. The one about all exposed metal parts need to be either double insulated from contact or earth grounded. The failed transformer should be one or the other and then there is no hazard.

The resistor is actually best thought of as a low frequency path for crud between the circuitry and earth. Many designs leave it out. I find that it helps with the S/N a bit. Also the use of a large rectifier (often a bridge) between the two grounds could fail if there is the second grounding violation. I don't care for the rectifiers as they leave the chassis about 0.7 volts different from the earth and 0.7 Volts is a lot of potential noise that is not eliminated.

Just my two cents on how the codes work.

Hi Bruce,

I reread your post and it appears to me that the only difference is 100-150 ohm resistor between the chassis and signal ground while I am advocating 1 to 2 ohms at 30 watt resistor rating.

Both our transformers are double grounded for safety so there should not be any problem meeting code for either of us.

I am a worry wart, if lightning strikes and shorts the double insulation, or wiring short I just want to be as safe as possible.
I don't perceive any noise, but we probably use different tubes and designs anyway.

Anyway, all is well, all the best Bruce.

pos

Subject: Re: Class A, AB1, B, C Operation/Modes
Posted by gofar99 on Wed, 10 May 2023 02:30:59 GMT
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Hi, There are several ways to make the chassis to signal ground connections. Everything from the old school way of using the chassis as the signal ground (usually too noisy for me) to huge bridge rectifiers. Any of them can comply with the various electrical codes as long as the user is protected from accidental contact with a live chassis. How we all lived through the 2 wire AC mains days with tube gear is a miracle. What I find is there is a sort of sweet spot when using an X2 capacitor and a resistor in the 120 to 150 ohm range. It is not designed to protect from faults like lightning etc or really any external faults. That is why the chassis is AC mains earth grounded. It will provide a path to the earth ground if there is an internal fault but that is not the main purpose. It is not really all that good at that as the impedance is fairly high. Its purpose is generally accepted as two fold. One it acts as a ground loop prevention measure when other gear is connected that passes signals to the subject device. The signal ground on the one will not find an alternate path through the AC mains and cause hum. Second it allows the chassis to act as an EMI shield without being in direct connection. IMO your one ohm resistor will comply with the codes....but may not provide as much ground loop hum rejection as is possible. And as nearly everyone knows...I hate hum and noise with a passion and the higher value resistor helps. BTW wattage is not really critical (I use 1 watt ones) as fault protection is not the primary function...that is what the chassis and three wire mains connection is supposed to do. Even if the resistor failed, the user is still protected. Now to be difficult...I could make a case for if the resistor and X2 fail open and an internal circuit fault energized the signal ground and it was connected to either an input or output cable that had a circuit ground conductor and the user was touching the ground conductor and something else that really was grounded there could be a hazard. Such a failure would almost always manifest itself as an anomaly in the gear and require attention. But then that sequence can happen with anything attached to the AC mains like lights, appliances etc. Opinions anyone?

Subject: Re: Class A, AB1, B, C Operation/Modes
Posted by positron on Thu, 11 May 2023 05:26:19 GMT
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gofar99 wrote on Tue, 09 May 2023 21:30Hi, There are several ways to make the chassis to signal ground connections. Everything from the old school way of using the chassis as the signal ground (usually too noisy for me) to huge bridge rectifiers. Any of them can comply with the various electrical codes as long as the user is protected from accidental contact with a live

chassis. How we all lived through the 2 wire AC mains days with tube gear is a miracle. What I find is there is a sort of sweet spot when using an X2 capacitor and a resistor in the 120 to 150 ohm range. It is not designed to protect from faults like lightning etc or really any external faults. That is why the chassis is AC mains earth grounded. It will provide a path to the earth ground if there is an internal fault but that is not the main purpose. It is not really all that good at that as the impedance is fairly high. Its purpose is generally accepted as two fold. One it acts as a ground loop prevention measure when other gear is connected that passes signals to the subject device. The signal ground on the one will not find an alternate path through the AC mains and cause hum. Second it allows the chassis to act as an EMI shield without being in direct connection. IMO your one ohm resistor will comply with the codes....but may not provide as much ground loop hum rejection as is possible. And as nearly everyone knows...I hate hum and noise with a passion and the higher value resistor helps. BTW wattage is not really critical (I use 1 watt ones) as fault protection is not the primary function...that is what the chassis and three wire mains connection is supposed to do. Even if the resistor failed, the user is still protected. Now to be difficult...I could make a case for if the resistor and X2 fail open and an internal circuit fault energized the signal ground and it was connected to either an input or output cable that had a circuit ground conductor and the user was touching the ground conductor and something else that really was grounded there could be a hazard. Such a failure would almost always manifest itself as an anomaly in the gear and require attention. But then that sequence can happen with anything attached to the AC mains like lights, appliances etc. Opinions anyone?

I worry about jacks becoming hot, then we would have AC voltage between the jacks and chassis ground. It is a long shot to be sure, I have had plenty of shock therapy when I was a kid. Amazingly, we survived those old AC/DC radios. :lol:

There always seems to be a problem with ground loops; it seems the more components, the more difficult the problem. I did not want the hassle, and wanted my ics using 6N copper wire, so I designed a circuit in each monoblock so that I can completely dial out the hum and garbage, works perfectly.

I did need to shield my ic from TT to phono stage as a slight hum occurred with volume cranked way up. (Even ics with 6N wire need to be properly terminated for accuracy. Not a small feat.)

I think we both have systems to be happy with.

cheers

pos

ps. Sometime I want to dig a little more into "Tube Operating Curves" attached below. Right now, snowed under with responsibilities.

File Attachments

1) 6DJ8 Mu, Gm, Rp, -G1.pdf, downloaded 100 times

Subject: Re: Class A, AB1, B, C Operation/Modes
Posted by positron on Wed, 06 Sep 2023 04:48:23 GMT
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I found that B1 graph in my initial post was obviously wrong.
I have attached the correct graph, B, to this post.
I apologize for the inconvenience.

I would like to add a quote from the RCA Radiotron Designers Handbook, 1960, written by 26 engineers in Collaboration.

This concerns Push Pull operation.

"A Class A amplifier is an amplifier in which the grid bias and alternating grid voltages are such that the plate current of the output valve or valves flows at all times. The suffix 1 indicates that grid current does not flow during any part of the input cycle."

"A very useful operating condition is the borderline case between Class A and Class AB1, that is when the plate current just reaches the point of cut-off"

Notice, each tube in the Push Pull output stage operates Class A until each output tube just reaches the point of cutoff. That means each output tube conducts the entire musical waveform.

Class A output wattages can range from small to many watts output, and with extremely low distortion, especially in the first watt out.

cheers

steve

File Attachments

1) Tube Operating Curve Class B.gif, downloaded 48 times

Subject: Re: Class A, AB1, B, C Operation/Modes
Posted by gofar99 on Sat, 09 Sep 2023 02:12:53 GMT
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Hi, BTW using an RC or pair of rectifiers between the grounds is not new. I have seen it used as far back as the early 50s. As soon as 3 wire mains showed up it was not far behind apparently. In

addition to discovering that old school 2 wire powered radios could bite you I wanted to add to thoughts on separating the grounds and the possibility of getting zinged by an internal fault energizing the input or output jacks if the RC combo I suggest fails. You need two faults one internal and the RC. I considered that. It is a difficult scenario to achieve. Everything I tried resulted in either an amp that would not work or would work so badly that it was clear there was a fault. Anything that resulted in the two grounds being directly connected caused a serious ground based hum. No hazard, but bad operation. I could not energize any input jack or output terminal without it causing an obvious fault in the device. No sound, loud hum or noise. I will grant that in theory if the RC fails open (both parts) and you could cause the signal ground to become highly energized with nothing connected to it that might bleed off the voltage it might be possible to get shocked. It could only happen if nothing else was connected to it that would have its own ground. Anything carrying a signal into the device that had its own ground would act as a path to bleed off the voltage. If the device was already powered up and then the external connection was made there could be a shock hazard between the jack and interconnect. Before that could occur I would expect that the failed device would either blow its fuse or behave so badly that the user would notice and investigate what is wrong. I could wander off into low probability scenarios like lightning strikes that welded parts together and such, but I expect that any user of an electrical device would have at least a minimum of intelligence and accept some responsibility for their own safety.

Subject: Re: Class A, AB1, B, C Operation/Modes
Posted by BreakneckRedneck on Sun, 24 Sep 2023 05:42:10 GMT
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Hi guys, I haven't posted on here in years, though I lurk and read often. I apologize if I sound uncouth to post out of nowhere with something like this; I just wanted to throw in a clarification concerning operating class, as there are many misconceptions concerning it (especially on guitar amp-specific forums), which then are sometimes repeated by good, well-meaning people.

"Notice, each tube in the Push Pull output stage operates
Class A until each output tube just reaches the point of
cutoff. That means each output tube conducts the entire
musical waveform."

Class AB amplifiers are never Class A at any point or time, instead, they operate in a region with conditions similar to Class A up until a certain output level. Operating class is always determined at an amplifier's full, unclipped output, rather than the quiescent operating point or anywhere in between.

Also, Class AB never reaches cutoff at any time, else it would instead be Class B. Class AB always conducts for more than 180 degrees of the AC cycle at its full output, but significantly less than 360 degrees. This keeps the output devices' conduction high enough at the peak of the input signal's negative half-cycle to avoid the highly non-linear region of the characteristic curves near cutoff, while also avoiding exceeding their thermal dissipation limit.

Operating class is also independent of output stage topology, whether single ended or push pull, and is also independent of the biasing method used. A common misconception is that cathode

biased tube amps are always automatically Class A, and grid biased tube amps are always Class AB. The reality is that a Class A amplifier can be grid biased, and a Class AB amp can be cathode biased. However, a cathode biased Class AB amp is indeed limited to 'high' AB operation, close to Class A. The reason is simple: Ohm's Law.

As the average AB plate current increases correspondingly with output level, the same current increase across the cathode resistor in turn produces a higher bias voltage, thereby counteracting and limiting the maximum plate current excursion. This effectively prevents using cathode bias to achieve the higher efficiency 'low AB' operation (moving closer to Class B condition).

Hope this makes sense. For those interested, some especially great reading on the topic (and many others!) can be found in Audio Cyclopaedia by Howard Tremaine, and The Radiotron Designer's Handbook, 4th Edition.

Subject: Re: Class A, AB1, B, C Operation/Modes
Posted by positron on Thu, 12 Oct 2023 16:21:55 GMT
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Hello All,

I just came back from out of state and saw the above post.

>> Recently, I have been seeing standard definitions being altered.

>> I am posting in response to the previous post and simplifying as much as possible to help the newbies who may be reading. Notice I will be using the >> symbol to identify my response.

>> I mean no harm, but still must correct misconceptions. I hate to use my education, academia etc as an argument, but there are major misunderstandings with the above post that I must address.

Hi guys, I haven't posted on here in years, though I lurk and read often. I apologize if I sound uncouth to post out of nowhere with something like this; I just wanted to throw in a clarification concerning operating class, as there are many misconceptions concerning it (especially on guitar amp-specific forums), which then are sometimes repeated by good, well-meaning people.

"Notice, each tube in the Push Pull output stage operates
Class A until each output tube just reaches the point of
cutoff. That means each output tube conducts the entire
musical waveform."

Class AB amplifiers are never Class A at any point or time, instead, they operate in a region with conditions similar to Class A up until a certain output level. Operating class is always determined at an amplifier's full, unclipped output, rather than the quiescent operating point or anywhere in between.

>> If that is the case, then no preamplifier, phono stage, amplifier is operating Class A since none are operating in the optimum center of an optimum load line that you require. Fortunately, such is not the case, whether preamplifier or amplifier, including the output stage.

>> Class A operation only pertains to the entire signal waveform, 360 degrees, being reproduced through a tube(s)/device(s), period. This condition occurs in output stages, driver, input stages, and preamplifier/phono stages. Class A operation occurs anywhere along the load line, as long as the entire waveform, 360 degrees is amplified.

>> I also have a copy of the 4th edition and on page 545 such is stated:

"Limiting Class A push-pull operation is operation such that one valve just reaches plate current cut-off when the other reaches zero bias."

>> Maximum power is not produced, but Class A operation is still in effect.

The next quote from page 572, RCA Radiotron Designers Handbook, 4th edition, written by 26 engineers.

"A very useful operating condition is the borderline case between Class A and Class AB1, that is when the plate current just reaches the point of cut-off--this is called Limiting Class A1 operation."

>> Interestingly, minimum distortion occurs as one sets the idle towards the zero bias operating point (near maximum plate current), not the center point of the load line. So this condition is not Class A? Of course it is. Once again, power output nor center of the loadline has nothing to do with the different Class definitions. This has been taught in the class room for 70+ years.

>> I have also seen confusion, including misrepresenting of Classes on other forums, and YouTube videos.

Also, Class AB never reaches cutoff at any time, else it would instead be Class B. Class AB always conducts for more than 180 degrees of the AC cycle at its full output, but significantly less than 360 degrees. This keeps the output devices' conduction high enough at the peak of the input signal's negative half-cycle to avoid the highly non-linear region of the characteristic curves near cutoff, while also avoiding exceeding their thermal dissipation limit.

>> Another gross misunderstanding. Each tube in push pull (pp) Class AB1 operation does reach cut-off, again by definition. Class AB1 operation allows for the signal waveform to be amplified more than 180 but less than 360 degrees, in each output tube (when past the Class A point of operation). This means each output tube is cut-off, no plate current, for some portion of their respective half of the waveform. That "portion" is determined by the idle bias that is set.

>>Class B means that 180 degrees, or half the waveform is not amplified. It is quite different than AB1 in that Class B usually has a kink and notch in the waveform unless GNF is used. Efficiency is also greater.

Operating class is also independent of output stage topology, whether single ended or push pull,

and is also independent of the biasing method used. A common misconception is that cathode biased tube amps are always automatically Class A, and grid biased tube amps are always Class AB. The reality is that a Class A amplifier can be grid biased, and a Class AB amp can be cathode biased. However, a cathode biased Class AB amp is indeed limited to 'high' AB operation, close to Class A. The reason is simple: Ohm's Law.

>> Basically correct except the last sentence. Class AB1 operation can be operated at a variety of idle currents when the cathode resistor is bypassed by a capacitor of suitable size. This keeps the cathode voltage constant with respect to signal ground. As such, only the signal voltage at the grid alters the grid to cathode voltage, similar to typical grid bias operation where the cathode is signal grounded as well.

As the average AB plate current increases correspondingly with output level, the same current increase across the cathode resistor in turn produces a higher bias voltage, thereby counteracting and limiting the maximum plate current excursion. This effectively prevents using cathode bias to achieve the higher efficiency 'low AB' operation (moving closer to Class B condition).

>> Again, that is why a cathode resistor is bypassed with a suitable size capacitor in Class AB1 operation. The bypass capacitor keeps the cathode voltage constant to reference signal ground. The only change in cathode to grid voltage is due to the musical signal, similar to grid bias with the cathode essentially grounded.

>> I hope this has helped you and viewers in understanding the different classes of operation. As I stated at the beginning, I am addressing the newbies out there, so simplified the post as much as possible for clarity.

>> I also mean no harm to anyone, but gross errors I must address. Otherwise confusion reigns.

>> One may also quote my posts to counteract such misrepresentations of classes of operation in other forums and YT videos etc.

All the best.

pos

Subject: Re: Class A, AB1, B, C Operation/Modes
Posted by positron on Fri, 03 Nov 2023 17:22:38 GMT
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Just to reinforce my previous post, Chapter 13,
of the RCA Radiotron Designers Handbook, section 5:
"Push Pull Triodes Class A, AB1".

"A Class A amplifier is an amplifier in which the grid bias and
alternating grid voltages are such that the plate current of the
output valve or valves flows at all times. The suffix 1 indicates

that grid current does not flow during any part of the input cycle."

Notice, no mention of center of load line, nor any mention of power output
nor maximum power output.

From the Radio Amateur's Handbook, 1969:

" A Class AB audio amplifier is a push-pull amplifier .....
At low signal levels the tubes operate as Class A amplifiers,
and the plate current is the same with or without signal."

Wiki, Push Pull AB:

"Class AB is..... since much of the time the musical signal
is quiet enough that the signal stays in the "class-A" region."

What is quiet enough?

As mentioned in my first post, Push Pull 6L6GC in triode, can
output some 7.5 watts rms in Class A before cut off of each
tube, and into AB1 operation (cut off is substantially less
than 180 degree of each tube).

Academia classroom, the same definition. Any device(s) can be
operated Class A as long as the device(s) operate over 360 degrees,
all of the musical signal waveform.

cheers

pos

Subject: Re: Class A, AB1, B, C Operation/Modes
Posted by gofar99 on Sat, 04 Nov 2023 01:58:13 GMT
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Hi, I agree. It is amazing how things can get screwed up over time.

Subject: Re: Class A, AB1, B, C Operation/Modes
Posted by positron on Sun, 05 Nov 2023 06:38:33 GMT
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gofar99 wrote on Fri, 03 November 2023 20:58Hi, I agree. It is amazing how things can get screwed up over time.
True words Gofar. I have a link to a video YouTube where a

salesman is using Push Pull Class B operation to claim,
and misrepresent how Push Pull Class AB1 works.

When presented with the correct information, he simply
ignored it, still using the same misleading video
information 8 months later.

Amazing how some can misrepresent audio to push their
agenda.

cheers

pos

Subject: Re: Class A, AB1, B, C Operation/Modes
Posted by positron on Fri, 08 Dec 2023 05:12:11 GMT
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Some of the misinformation appears intentional to me Go.
I am just not sure how many are intentional.

I know of a YT video where some "obsessive" gent
uses PA quality Class B operation effects, with
outlandish nonsense, to attack high fidelity
Push Pull quality. (Push pull can sound perfectly
accurate in Class A or AB operation.)

I explained his errors filled explanation broke the
laws of science, but 8 months later he is still pushing
the error filled video. Interesting indeed.

pos

Subject: Re: Class A, AB1, B, C Operation/Modes
Posted by gofar99 on Tue, 19 Dec 2023 02:20:52 GMT
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Hi, Somehow I missed that you had responded recently. Anyhow two things come to mind...one class B PP is only useful IMO in modulating AM ham radio transmitters. Class A and AB are quite suitable for high fidelity reproduction. My preference is class A triodes and class A with U/L if pentodes are used. My experience has been that AB operation seems to change the sound somehow that I can't measure but can hear. On another note the fact that the guy mentioned ignored the truth and insisted in the incorrect information seems to be a thing that many others have been doing in the media and dare I say politics.

Subject: Re: Class A, AB1, B, C Operation/Modes
Posted by positron on Wed, 17 Jan 2024 03:32:11 GMT
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gofar99 wrote on Mon, 18 December 2023 20:20Hi, Somehow I missed that you had responded recently. Anyhow two things come to mind...one class B PP is only useful IMO in modulating AM ham radio transmitters. Class A and AB are quite suitable for high fidelity reproduction. My preference is class A triodes and class A with U/L if pentodes are used. My experience has been that AB operation seems to change the sound somehow that I can't measure but can hear. On another note the fact that the guy mentioned ignored the truth and insisted in the incorrect information seems to be a thing that many others have been doing in the media and dare I say politics.
Hi Bruce,

I have been testing some tubes and found the new Tung Sol 6550 and
Penta KT88 are my reference in PP AB1 operation. I am running ~29 watt
plate dissipation on each tube (~70ma idle), which may be high enough to account for the natural.
(Both type tubes were given to me as a gift years ago.)

Anyway, the transparency of my system is at least 1 part in 4.1 million,
so extremely transparent (polypropylene power supplies) and ear extremely sensitive. Using
20log, that is -132 db.

It allows me to hear real, natural instruments and all the back round at the venue on the recording.
But it took some 43 years, off and on to accomplish. If I mentioned this before, please accept my
apology.

The extreme sensitivity of the ear is probably why you were able to hear
and not measure. I have tested other brand tubes, and sonic changes did
occur if I remember correctly.

Anyway, if one is in central Illinois, please feel free to pm me, love
to show the work I am doing. :)

cheers

pos

Subject: Re: Class A, AB1, B, C Operation/Modes
Posted by gofar99 on Thu, 25 Jan 2024 02:31:12 GMT
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Hi Pos, It's a bit of a long ride from here...plus you guys get snow. I do grant that we get a little

here from time to time (Southern Arizona) mostly because we are at 4600 feet up. It brings to mind another thing that can effect sound....altitude. I recall from a long time ago the folks at Stereophile in the 70s or so said the elevation at their HQ in :? Santa Fe (about 8000 feet) caused them issues. :?

Subject: Re: Class A, AB1, B, C Operation/Modes
Posted by positron on Tue, 09 Jul 2024 01:22:54 GMT
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>> I missed another point that breakneck made that needs correcting. My apology to everyone for being late.

"Operating class is also independent of output stage topology, whether single ended or push pull",

>> A single ended amplifier (SETriode/tetrode or SEPentode) cannot be operated class B in Audio with any fidelity. Think super super high distortion.

>> If one attempted Class AB in audio applications, one is simply increasing Harmonic Distortion (HD), Intermodulation Distortion (IMD) along with lower output power. But who would want such unless for higher or unique distortions from instruments and/or voices etc.

>> On the other hand, Push Pull (PP) can be operated as Class A, AB1, AB2, Class B.

>> In Class A, each output tube operates over the entire 360 degrees of the signal waveform. Less power output, least efficient, low distortion.

>>Class AB1, AB2, each tube, X and Y are cutoff over a portion of the musical signal waveform. However, Y tube conducts over the portion of the musical signal that X tube is cutoff, and X tube is conducting when Y tube is cutoff over a portion of the musical signal. Low distortion.

>>The overlap of conduction in PP makes for a seemless transition and much more constant damping factor (DF) etc vs an SET/SEP amp.

>> (AB2 designation means a musical signal large enough for control grid current flow. AB1 designation, No grid current flow over any portion of the musical signal.)

>> In Class B operation, crossover, notch distortion is usually prevalent,

and both H and IM Distortions are higher; but is the most efficient. This is good for megaphones, RF use etc where efficiency is important.

In conclusion, knowledge is power to make wise choices.

Again my apology for not addressing the comment in a timely manner.

pos