Some thoughts about Classes and Transistor versus Hexfet/Mosfet versus class-D.

Introduction

There is the idea in audio land that the phrase class-A, class-A/B, class-B is some kind of quality rating. This is not true, it is only referring to how the power stage is trimmed, just technical stuff. Indeed, if the same or a similar amplifier is set in Class-A it performs better than in class-A/B mode. But other, modern components show better performance while set in class-A/B compared to the older, regular transistor based class-A amplifiers, even the ones of high quality. In fact, setting these new types in class-A makes no sense any more…..

"Of course", with class-D this classes thing is of the past. We prove that its NOT !

Modern built class A/B designs like ours beat the best class-D amps in musicality and even high ranked conventional class-A amplifiers. That is, according to more and more listeners and builders.

What is meant by CLASS-A and A/B exactly?

In a linear (today called analogue) functioning power amplifier the output power is provided by a pair (or more) power transistors of some kind. This can be regular ones or Mosfet types.
In order to let this linear power amplifier work as linear as possible, both power transistors in the output stage of the amplifier need to be "conducting" a bit in order to let them work in the more linear working range. Even more important is that this is needed to avoid so called crossover distortion, especially noticeable while small outputs are generated. This setting is known as class-A/B. This A/B thing in principle only refers to the way the power stage is trimmed and has <u>nothing</u> to do with quality aspects. The quality of the components has to be taken in consideration as well, which is mostly totally ignored. With the components and setup we use, it's all different.
Unfortunately, non-technicians believe this classes thing is some kind of quality status indicator, which is not. Below we try to explain in a way we hope most people understand (a bit).

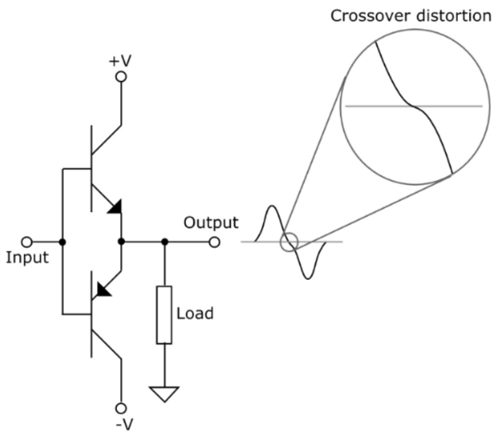
Power stage trimming
This class-A, A/B or even B phrase only has to do with the way the power stage is trimmed in order to obtain the results the designer had in mind. Older transistor (end of '80's) designs sound very acceptable for most people while set in class A/B. About all the stereo sets in those days were trimmed that way. Due to the non-linear transfer characteristics (input > output) of the power transistors used, a class A/B setting was insufficient to obtain the best possible performance. In order to reach the most linear transfer of the power transistors they were trimmed in class-A, meaning that a high amount of conducting was required, even when no music was made.

Most of you are aware that a class-A amp produces a lot of heat. The above explained technical thing explains it all: a lot of current causes a lot of heat.

If the idle current of a power amplifier is set too low, also crossover distortion is shown. Unfortunately, older transistor designs even needed quite some idle current to pass this critical point.

How does this effect present itself?

If you connect an oscilloscope (an instrument showing the shape of an electrical signal) to the output of your amp and feed it with a sine wave signal, this distortion can be seen at the point where the sine crosses the zero point. It is where the upper transistor takes over from the lower one and vv. This setting is known as class-B, where at this point both transistors are hardly conducting.



In order to show you what happens, at the right we show the figures of a class-B setting, where the power stage is trimmed back a bit more, resulting in a small amount of this crossover distortion crossover. This is only used in PA applications or cheap products.

Why does this effect happen?

If the idle current of the power stage is set too low (see graph on next page) neither one of the transistors will "feed" the output, resulting in a short period of 0 Volts at the output. Actually at that point the speaker is even "disconnected" and so out of control since both transistors are not conducting at all. In sound this could be explained as some rough edge around the overall sound and less controlled bass response, so most unwanted in quality equipment.

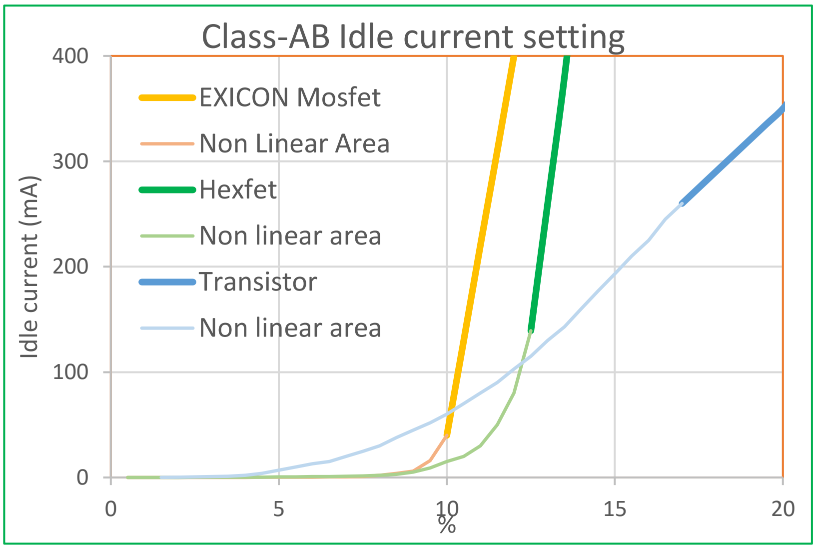
What to do to avoid this typical type of distortion?

If we (and we do) want to avoid this distortion we need to make sure that both power transistors (or Mosfets) are conducting more or less. But how much? This can be done in different ways, and the final results are influenced by the linearity and quality of the components used.

Regular power transistors are mostly used and require a lot of current before they reach some linear working transfer range as we show in the blue line below. Hexfets and older Mosfet types can be set in an acceptable linear range while set with a way lower current flowing.

Unfortunally, Mosfet amps became a bad name, because these types of Mosfets tended to fail quite easy due to the fact that they needed to be "set" with quite some idle current for quality results. Due to this, a pair of Mosfets could only deliver a quite small amount of power. This problem was partly solved by paralleling two or more, looking impressive indeed. Each pair of Mosfets required a significant current flow, resulting in a quite inefficient amplifier. This phase in amplifier design caused some designers to take another direction and developed the now well-known class-D principle, later more.

The EXICON Lateral Mosfets (as we use in our class A/B designs) need way less current than the older ones in order to come in the linear range. Less current means less heat, as you'll notice while using our amplifiers. And even better: only one pair provides more output power than three pairs of the Mosfets others use. Also, they are much more reliable and as a cherry on the cake, they perform linear about straight from conducting point:



This figure shows where the TRUE, technical AB settings in this example are:

- A regular power transistor needs at least 250mA of idle current in order to reach an acceptable linear transfer range. Blue lines. Often multiple pairs used (2x 250mA, etc.)
- A Hexfet (green) needs way less, around 100-150mA and after that point quite linear immediately. Way less current is required to come in the linear working zone of the output devices. Not only that, but also more linear working in that range already.
  Due to their sensitivity to overload, mostly multiple pairs (2x 150mA, etc.) is flowing.
- A EXICON Mosfet (yellow lines) even needs less current to reach it's linear working area, and from that point on, it is extremely linear. Better than any other power transistor or mosfet device we know, even compared to their most linear part of the transfer curve. Actually, these Exicon's set in A/B are more linear than a lot of regular transistors driven in class-A.

For non-technical people: more current means more power consumption and a hotter amplifier.

AGAIN: THE TECHNICAL PHRASE CLASS-A IS JUST DEFINING THE SETTING OF THE OUTPUT TRANSISTORS (=50% conducting in idle mode) ONLY !   It's NOT a quality level by definition.

Other technical issues in linear (analogue) amplifiers
The non-linear function of regular transistors is in practise partly compensated by the Class-A setting, and in more common amplifiers by giving the amplifier a strong feedback, giving it nice 0,000000……% distortion figures we (about) all want to see. Surprise: scientific tests showed that 99% of the people won't hear 1% or even more, sorry. We don't hear anybody about the fact that speakers can distort up to 20% actually. True high-end, costly speakers still distort > 5%. Strange.

Unfortunately, a strong feedback "kills" the musicality of an amplifier. A clean "technical" sound with ice cold mids and pinpointed highs as we hear everywhere today is the result. Cymbals f.e. are made of brass, not of glass and sound for many seconds, not just a simple "tick" or "tssssjjjj" as we hear everywhere! They siiiiiiiiiinnnnnnnnngggggg. Piano notes are fading out similar, not just "pling".

Since Hexfets and Mosfets as we use need less feedback, our amps sound as "being there". More and more people confirm this and mention a strong, correct and powerful bass, clan, nose touching mids and 3D, nice and correct sounding highs. About everybody noticed immediately the overwhelming amount of "tube-like" air around instruments. You can even estimate the size of the room people where it is recorded, played or spoken. Check it out yourself and compare to others.
More and more customers tell us and others their experiences on our special webpage.

Below a table for REGULAR power transistors where all info is given with the amp in idle state:

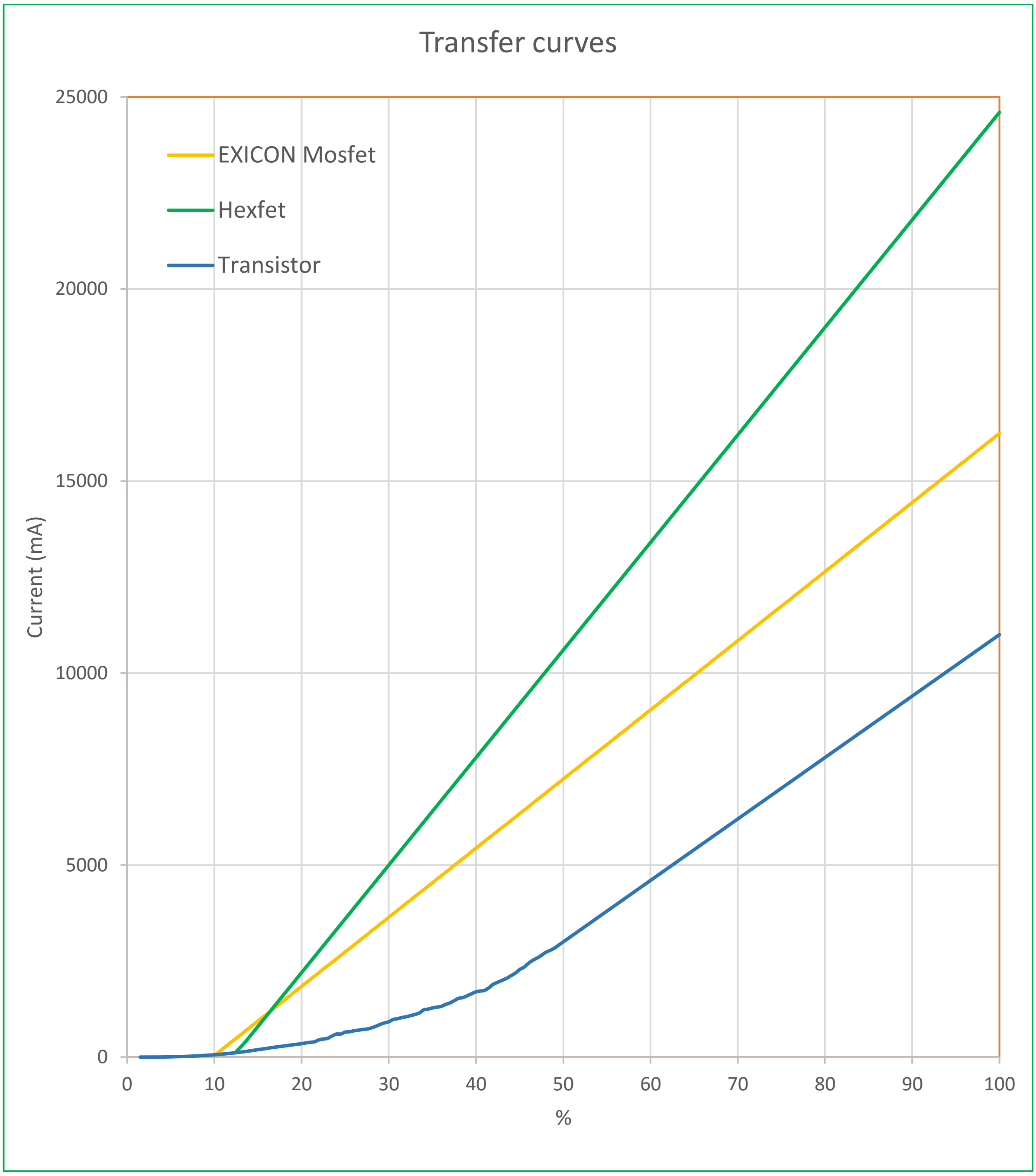
Class-A	Power transistors are conducting around 50%	Extremely high sound quality, but very low efficiency or in other words: the amp will become really hot. Reference amps. Efficiency is around 50%
Class-A/B	Power transistors are conducting 15-20%	Very high sound quality with way better efficiency. HiFi/High-End amplifiers. Efficiency is around 65-70%
Class-B	Power transistors are just conducting	Average sound quality with quite high efficiency (PA-amplifiers). Efficiency is around 75-80%
Class-C	Power transistors are just NOT conducting	Very high efficiency, but bad sound quality. Used in RF-transmitter systems and megaphones only. Efficiency is around 90%
Class-"D"	Power transistors are switching very fast	Average to Hifi sound quality with very high efficiency above 30% of rated output. Below that, bad efficiency, sometimes even worse than with amps in a class-A/B setting ! Published efficiency around 85%

Note that these actually are all analogue systems, since there is no digital data processed. IT is just an analogue modulated (PWM), switching principle! No digital about that.
All efficiency ratings are always given at 100% output power, which in practise never happens.
People will listen in the 0,5 – 5W output range, resulting in way worse figures.
Listening on loud speech level with 90dB efficient speakers only requires 1-2 Watts average!

By marketing people class-D is promoted as digital, which it isn't actually.

But, today "digital" is the magic word to sell.

Summary



Horizontal represents the % of conductance, vertical the current of the output stage.

The blue line marks the transfer characteristic of a typical, traditional power transistor. Up to around 50% of its working range it is not behaving linear as it should do.
Another fact is, that regular power transistors can only handle up to 10A, so in high power (capable) amplifiers two or even more pairs of transistors are required. This results in the heat generating amplifier designs, even class-A/B, we all are aware of, also giving class-A/B a bad name.

A Hexfet as we use them (green lines) is at first about hardly conducting at all, and then rising quite fast AND very linear immediately. With our models an idle current of 30-80mA brings it well inside the linear zone, so a Hexfet has a way lower class-A/B point (definition: just in acceptable linear range = class-A/B) as a common Power transistor shows. With this setting, a Hexfets in its 20-40mA class-A/B setting is already more linear as a regular power transistor which is never linear and so it even beats most class-A transistor amps on distortion and harmonic figures, even the expensive ones. The fact that these Hexfets can take double (24A) current grants as well. You only need one pair instead of two. So, let's say 50mA instead of 2x 250mA a regular amp would take with same drive capability.

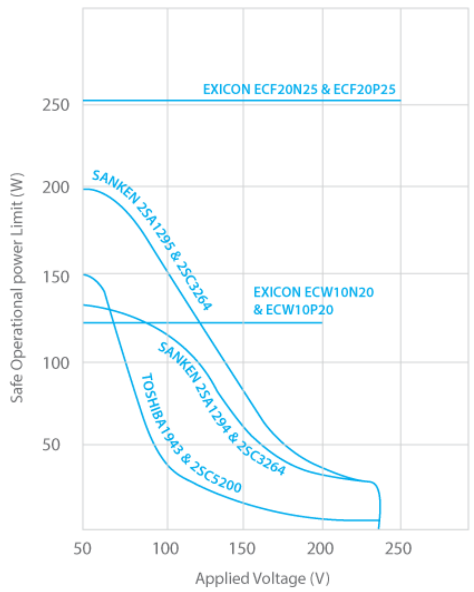
Besides these facts, a Hexfet can be abused way more than a regular power transistor, reason why we use them in our PA-range amplifiers. One pair can take 80A peak current without damaging.

The orange lines show the setting of the lateral Mosfets we use in our top models. With these the class-A/B setting is at an unbeaten low level of only 20-40mA. From that point on they behave even more linear than a regular transistor in a class-A setting and the best available in the market today.

With this low idle current you can hardly feel that our amps are switched on. Besides that, the low temperature causes that the amp "sounds" right, immediately after switching on. There is hardly any temperature drift in the components causing differences in sound like in other equipment which have to become warm/hot first before sounding properly. Firing them up 2-3 hours before you want to listen makes no sense any more, since the trimming is right about immediately.

So, it makes no sense to give these lateral Mosfets a higher idle current, because they will hardly show better figures due to this. More about them at the next page.

MOSFET story
Mosfets? We know they sound great, but break down easily, right? Right so far. Former models of power Mosfets were known for their nice sound, but also for the fact that they break down easy and that the amplifiers were complicated due to the multiple pairs required. This was caused by a limited SOA (Safe Operating Area) range.
With the EXICON's we use, this problem is also solved; there simply is no SOA area as with all other power transistors, see the graph at the right, coming from EXICON:



Compared to our more "common" Hexfets they are way more expensive though, about 1 : 15 ratio….

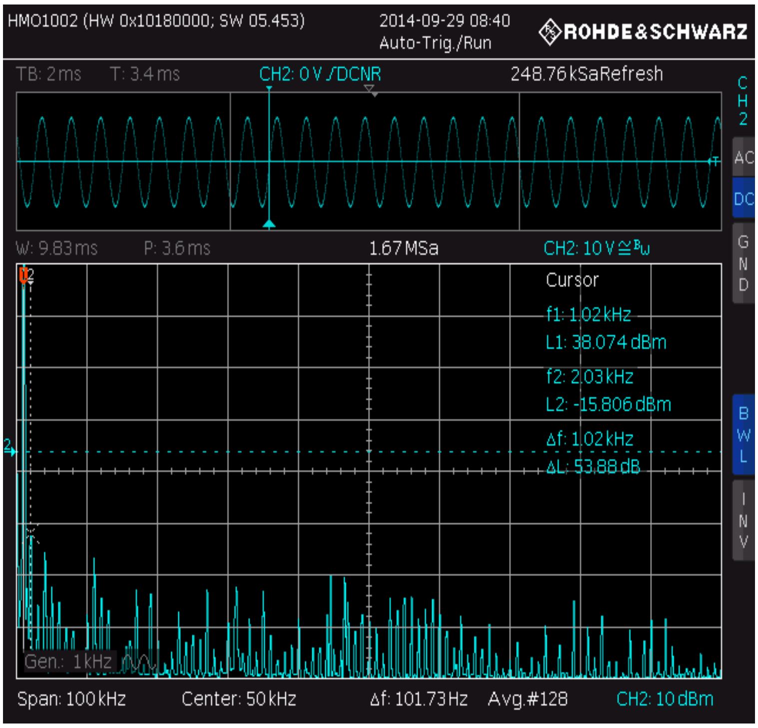
We decided to use them in our new HQ/RQ models.
Check our updated info's @ www.eltim.eu.

Actually, we were driving our prototype Monoblocks for weeks without tightening the mounting screws of the EXICON's. Not the slightest problem, while driving our 4 ohms SOLO speaker. Even loud. Now tightened, the hardly profiled panels only become hand-warm while playing really loud.

Harmonics and other behaviour

Beside “regular” distortion, there is also the phenomenon called harmonics distortion. This means that f.e. while feeding the amp with a 1kHz signal, it also produces multiples of this frequency by itself, say 2kHz, 3kHz, 5kHz, etc. Fortunately, these are quite low in practise and are caused by the non-linear behaviour of the electronic circuitry, but mostly due to power transistor behaviour. Below a frequency domain picture while testing this CS-80 HQ model with EXICON lateral Mosfets:

All “harmonics” are more than 60dB below the base signal of 1kHz, measured at full power.



Vertical is the sound level, horizontal the audio bandwidth (0-100kHz). At left is our 1kHz test signal.

-60dB is noted as just noticeable by human ear. So, try to “hear” these tiny signals in the disco level regular sound your amp is producing. You won’t. But, then again, we don’t have those anyway. A graph like this of a class-D amp would show truly dramatic figures. Not only in harmonics, but also in a lot of other fields, lie impulse response, rise time, etc. Ours reach 60V/uS, 3x faster as an opamp.

All harmonics are below -60dB and even more important, there is none specific as you’ll find in regular transistor designs, simply due to their non-linear transfer characteristics. More important, unlike regular transistor amps there are also NO third harmonics (“transistor sound”) visible. Neither are second one’s (“tube sound)” actually. You even won’t hear any noise. What comes in goes out.

The idle current causes a large part of the heat (read efficiency) produced, so in idle mode our amps just become warm slightly. In regular transistor designs a lot of extra electronics is required in order to avoid a so called “thermal runaway”. Due to higher temperature the transistor draws more current, due to that it gets hotter, due to that draws more current, etc. till the point that it breaks down. So, those need to be close to each other to make sure they all have the same temperature. But then: this causes a “hotspot” on the heatsink and due to that not using the heatsinks cooling capacity in an optimal way. Since Hexfets/Mosfets don’t’ suffer this runaway effect, we can place them apart from each other and use the heatsink in optimal way. In practise this means that our amps become only hand warm, even running at full power for a longer period of time. This als means that you don’t need to fire them up a few hours before you want to listen. Switch them on and start listening.

Furthermore, our Hexfets can handle over twice as much power as a regular transistor, so where a single paired A/B set Hexfet amplifier uses 30mA, a similar transistor amplifier has to be set at 2x250=500mA…… This is about 15 times more. Due to this, class-D came in sight as well unfortunately and (about) everybody left the class-A/B principle, unaware of these nice lateral Mosfets.

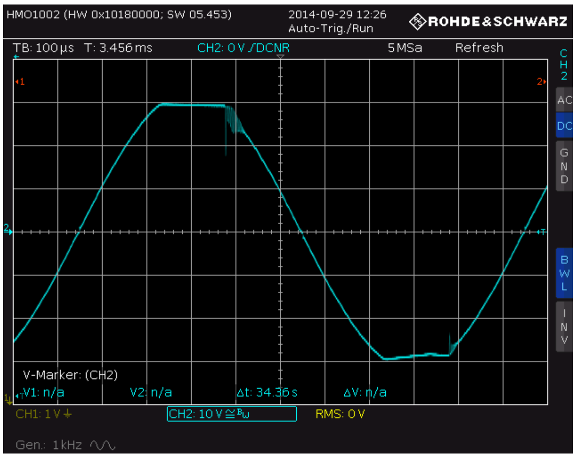
Pro’s and contra’s

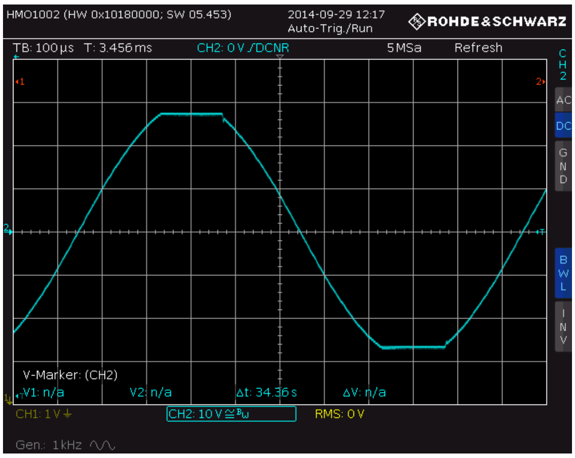
Besides the actual technical data one can find in the datasheets of the products, there are a lot of characteristics one can define in the “true life” behaviour of these devices:

Pro’s & Contras of Transistors, Hexfets and EXICON Mosfets			
	Transistor	**Hexfet**	**EXICON Mosfet**
Knowledge	High	Low	Very low
Way to drive	Commonly known	Easy, but different and how?	
Frequency range	Average	High	Very high
Impulse power	Average/modest	Very high	High
Impulse response	Modest	Accurate	Precise
Slew Rate	Modest	Very high	Extremely high
Peak power	Average	Very high	High
Break down	Easy	Hardly	Not
Efficiency	Modest	High	Average
Linearity	Average	High	Very high
Sound quality	“Technical”, explained as A/B	Tube like open sound	Clean linear
Harmonics	Odd (unnatural) and average	Even (natural) and low	About none
Clipping behaviour	Huge harmonics and high frequency peaks, damaging tweeters.	Small HF-oscillation around signal peaks	Soft clipping without any irregularities
Temp. stability	Low (pos. temp. coeff.) Blowing itself up without precautions> therm. runaway	Very high (neg. temp coeff.), therefore no need to take precautions, read: more simple design.	
Paralleling	Most difficult	Very easy	Easy, but with tricks
Availability	High	Low (esp. P-channel)	About not

We believe that the “clipping behaviour” text needs some more explanation for many.
Clipping is where the amplifier output voltage reaches the power supply voltages. Since there is no “more”, the signal will become a flat top. While doing so, regular transistors show the most spectacular side effects, breaking itself down and/or blowing up your tweeters due to the high amount of high-frequencies produced then. While breaking down, the full supply voltage could reach your speakers, damaging your woofer voicecoils as well.

Hexfets and Mosfets hardly show these effects, but with all: a flat top means DC on your speaker, which is all “eaten up” by the woofer’s voicecoil. A lot can’t handle that, so the woofer voicecoil will have a “melt down”, sometimes resulting in smoke signals and/or locked woofer movement.





At left: Hexfets tend to show only some minor and harmless high frequency oscillation when driven into clipping as visible just after the positive and negative tops.
Our EXICON Mosfet models (right) are totally free from any irregularities when driven this way.
Notice the slight (2-4V) voltage drop over Mosfets compared to the Hexfets, meaning that these Mosfets have a slightly lower output compared to our Hexfet models.

CLASS-D is more efficient and/or better sounding?

In the preceding text you can read the tendency from changing transistor based designs to Mosfet driven types. Unfortunately, due to their bad SOA the Mosfets needed to be paralleled in order to stay working, causing a lot of heat dissipation (bad efficiency) and a complex design. The latter issue was a problem for manufacturers, since people only have a certain amount of money in their head they want to spend on an amplifier. This became more difficult, so something had to be done.
Engineers started to find a way how less components could be used where preferably also time in aligning the amplifier (time) could be reduced. So, less costs while still the same consumer price results in more profit for the manufacturers and dealer chain.
Around the millennium change, electronics became fast enough to fix this "problem" regular transistor based equipment showed in the end. A new type of amplifier was born. However, this new development has nothing to do with an improvement in sound quality! By marketers its sold as "digital" > better sound (but isn't), having a higher efficiency (also isn't sonically). Switching is NOT "digital"! Digital means that a string of data bits ("0" and "1") represents the analogue value at that moment! Is not the case.

Figures are always measured at full power, but in practise a listening level of not even 1 Watt is above normal speech level already. That would be about 90% of the way you use it, right? In that case our amps hardly draw current while a class-D is switching and switching and….dying after a few years already due to stress and about always because of the use of cheap crap and overheated components.

NOBODY mentions it, but Class-D efficiency is always related to full power use. Then it is 90% indeed. This indicates that f.e. a 100Wrms amp would dissipate around 10 Watts (duhhh) all the time. But this 10 watts is taken regardless what the amp is producing. At 1W output, it's still dissipating this 10W, meaning an efficiency of only 10% most of the time.......

It even becomes worse. While working in the switching domain, people more and more use Switched Mode Power Supplies instead of transformers. If there was an advantage in efficiency, its killed by the use of those, since they only have an efficiency of 70-80%, where a transformer based supply easily comes above 90%. We don't understand these kinds of decisions at all. Marketing!

A class-D only consumes less power itself while used above around 30% of the maximum power. Since about all are high power amplifiers and efficiency is measured at full power, this high-power capability is so a disadvantage regarding average power consumption as used in your living room.

A 100Wrms ELTIM class-A/B is also dissipating around 10 watts at low output levels, so in our opinion class-D only makes sense if it must be small and/or performing >30% of rated power all the time, like PA. This cannot be done with regular power transistors, as we explained at one of the former pages.

Now the true facts. Class-–D is only designed to make an amplifier smaller, cheaper and faster to assemble due to the less parts required. Furthermore you don't need to align them, saving even more time ! And of course, we all want it "digital". Sorry, but class-D is an analogue, yet switching amplifier! It is not working with bits and bytes, but the signal is Pulse Width Modulated (PWM), which is an analogue conversion procedure working in f.e. electric motor RPM control for ages already. F.e., the varying whistle tone you hear while an electric train is leaving is caused by this PWM procedure….. Also, electric driven cars use this analogue, yet switching principle more and more now.

There are also no "digital motors" in f.e. vacuum cleaners. They are just driven by this PWM technology, as stated also non digital. Again: marketing. Finally people don't buy this kind of inaccurate "screaming" info anymore and today this D….. company presents it proudly as a powerful motor, which is probably true indeed. All "digital motor" advertisement can't be found anymore.

We hope that class-D manufacturers follow, since class-D is not digital nor bringing better sound, nor is more efficient compared to modern class A/B anymore. Let's make joyful music again, shall we?

Final.

With the amplifiers as we build them at ELTIM there is NO need for a class-A setting to get good results.

Also, the power consumptions is equal or the same as class-D, so you don't need to "chop" your music in pieces, losing the fine details, 3D and "air", which especially makes music enjoyable.

With today's components quality, carefully chosen as we did, one can build a fantastic sounding power amplifier, working in a very acceptable class-A/B setting ! Why?

Because the transistor A/B setting we have in our mind is not the same as Hexfet nor Mosfet A/B.

Please note that while playing just above speech level your amp not even delivers 1 watt, which is at least 90% of the time you are using your amp! Our true analogue amplifiers only dissipate <10W then. And then think of this one: the amp is in your living room, not outside, so the energy isn't lost at all ! It's just helping your heating system a tiny bit. Heating systems are 15-50kW in normal houses, so what 10 Watts???? The light in your bathroom consumes more.

With our designs we proof that it is not necessary to use class-D in order to "save the planet". In fact, in regular daily use our designs spend less energy than modern class-D designs do, especially if they are fed by a switched mode power supply as more and more do. Besides that, their useful lifespan is way longer than the stressed class-D designs we see everywhere. So less electronic waste.

Our products are made by European, skilled grownups. Not by little children who should be at school. About all class-D modules are assembled in Far East under bad conditions for people and planet. European and American companies hide this phenomenon, they just develop in EU or USA.

We produce and sell products lasting for many years, not just "jumping" over the warranty period. Then we talk about 15-20 years or even more. Not only to do you a favour, but our planet as well.

By now, an increasing crowd becomes simply thrilled about the quality level and musicality our ELTIM amplifiers show. They even tell us that our amps beat very high ranked class-A amplifiers, using regular power transistors and even highly regarded tube amplifiers…

Please check our website www.eltim.eu about these fantastic performing amplifier designs.
In that webshop we provide them as hand-built modules and some are also available as DIY kits.

We also hand build bespoke amplifiers, exactly in a way you want them. For those we started a special website www.eltimaudio.com where we list a lot of examples to give you an idea of what we can do for what price. We could list over a hundred though, just due to the way our modular design is constructed.

People say that other competing amplifiers cost 4-10 times more…… While clicking the link, you'll see comments in English. Change the language and you'll read Dutch or German comments.

Check the video of our first test of a 500-700Wrms amp, DC-500kHz (-3dB) and a phase lineairity < 3º in the audioband. Slew rate: >60V/us).

Or, listen to this sample and compare.