DHT Pre-amplifiers

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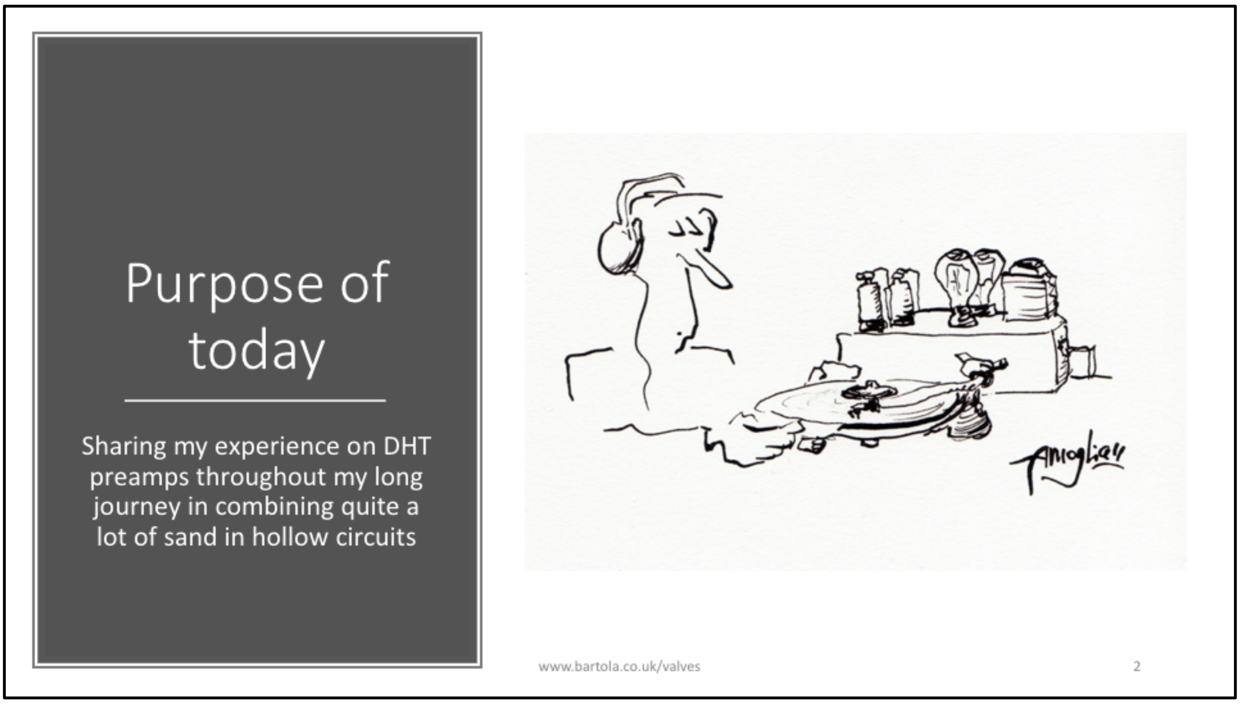
An unorthodox approach…



I've been down a path of experimentation around DHTs pre-amplifiers. In particular, focused on a specific topology: the "hybrid" mu-follower which didn't capture me only because of its sterling performance, but instead for its sound.

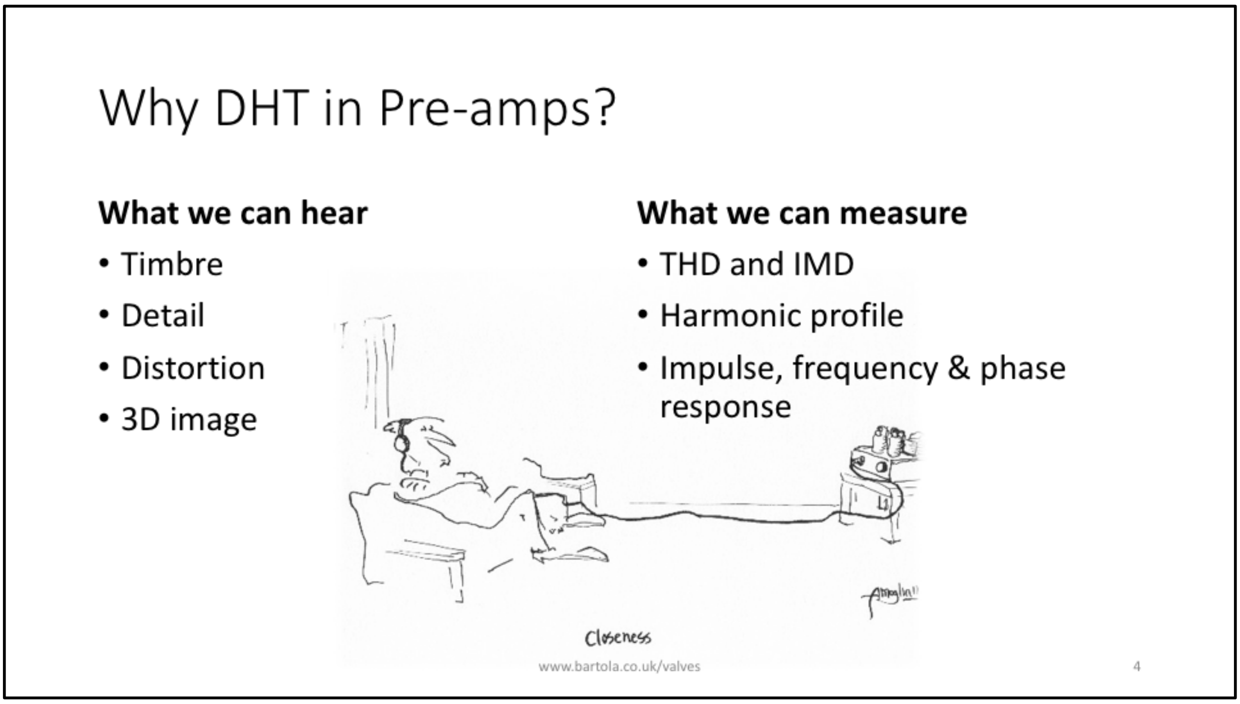
I'm not suggesting you should take this path at all. I wanted to share my long road of successes (and failures) of trying different DHTs, adapting and refining the mu-follower stage and most importantly by listening to it.

There are no sacred cows in DHT audio so I hope you enjoy this presentation.

About Myself

- Background
- Hobbies
- Audio

To be completed



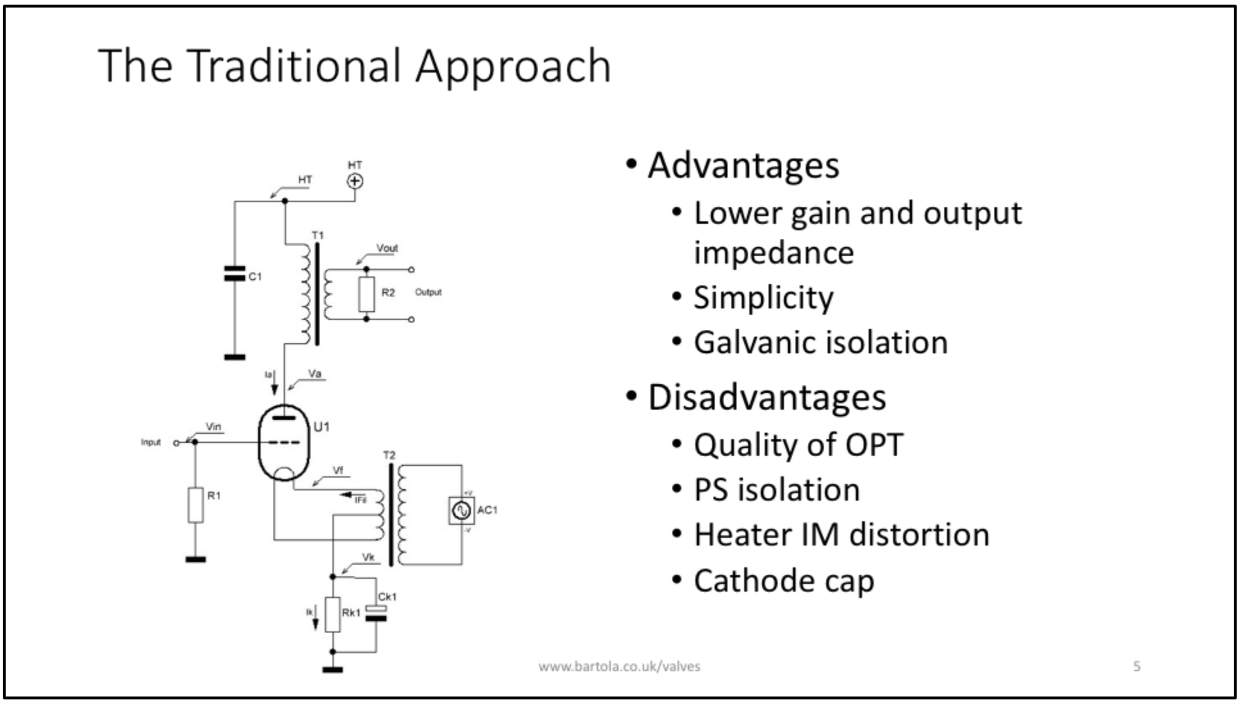
For many of you, this may be a trivial question. However, I'd like to share my own perspective of why DHT in pre-amps. A valve in a pre-amp has a significant impact in the sound mainly due to its amplification role early in the system chain.

The audience here is very technical and make component choices and circuit designs following rigorous science. Despite this, many of you make same decisions based on what your ears can hear and not just what we measure.

We can measure distortion profile, THD and IMD. We can look at impulse (time domain), frequency and phase responses.

I've been trained as musician and played music for many years. I forced and trained my ear as a result of this. Therefore, I look for timbre, detail, distortion and image separation when I listen to any equipment. I found DHTs (like many of you) to "sound" better – and mostly measure better as well – than most of the IHTs out there.

Having said this, I also found that DHTs (or IHTs) that measure really well, not necessarily correlate with same level of sound. This is not new of course. I will present at the end of this lecture, a summary table of my top (preferred) DHTs for pre-amps which I ranked after 10 years of experiments on this subject.

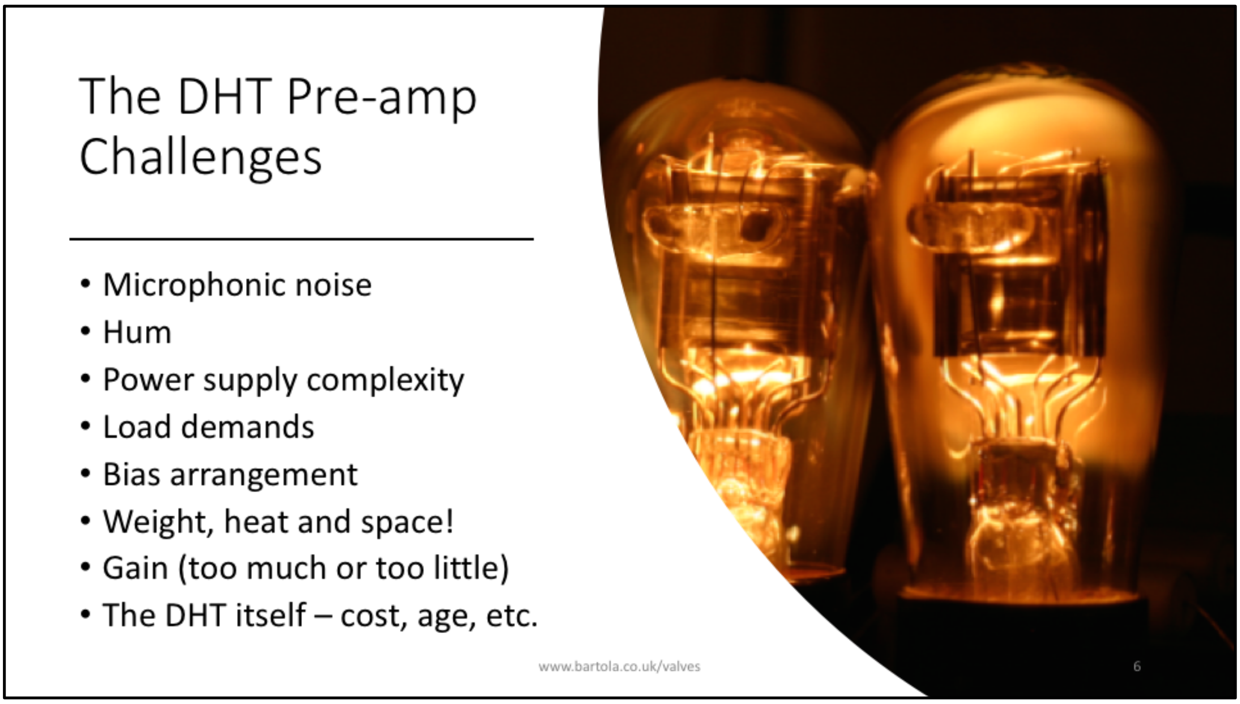


Let’s start with the well-known line stage design using a DHT. The load in this case is a transformer, but it can be also a choke as well as a simple resistor. If we use either of the last two, you will need a coupling capacitor at the output and also the gain will be higher.
The use of a “step-down” OPT provides lower impedance, increased current drive and reduced gain. This is what we need in most of the cases. However, the OPT has to be of very good quality and this is expensive.

You will get the DHT sound, but you will also have some “hum” and IM distortion due to the use of AC heating. Also the bypassing of the cathode resistor means that a capacitor is on the cathode path, which for many of us who can hear it, we prefer not having one. Filament bias is an option here, which we will discuss later.

The stage sound will be dominated by the quality of the OPT. And with that the price of the stage. There are great options available from Lundahl, Monolith Magnetics to Tribute or any custom made OPT.

I started with an transformer-based design 10 years ago and as many out there looked for improving this stage over the years.
Let me know deep-dive into the path I personally took.



Before we start, let me put out there the main challenges we all face when dealing with DHT in pre-amps.
Probably the most irritating one is the “microphonic” noise. This depends on the valve type and construction as well as the “state” of the valve. Remember, these are very old devices made up by hand back in the 1920s!
Hum can be a big issue. Some valves picks more interference than others, however most of the hum issues are around the heating circuitry. Also keeping chokes and power transformers close are also challenging.

DHT bring power supply complexity. They are intrinsically simple to operate, however to get the best out of them, we end up with additional complexity in the power supply. This translates into more iron, weight and cost.

The load demands can make some DHT struggle. Solid state amps with very low input impedance as well as high-capacitive loads (e.g. step up transformer) may push the DHTs too hard and distortion will increase significantly.

Bias arrangement may introduce un-wanted components due to increase distortion or impact in the overall sound. Personally, I’d avoid a bypass cap in any cathode if I can.

DHTs means weight, heat and space. This may not be welcomed in some cases though

DHTs have low to mid-mu so gain is restricted. If you need gain, you will need to resource to step up transformers and specific circuit topologies to get most of the gain out of the triode. Some people complain about too much gain, some about too little. You need to pick up your design topology based on your gain requirements.

DHTs are rare and old specimens. This means they tend to et pricey and also they are inconsistent in terms of parameters and performance from sample to sample. You will need to cherry-pick them to get the best out of them.

What I've Learnt Over The Years

- What goes in the cathode is as important (or more than) as the anode load
  - Filament bias
  - SiC Diodes
- Filament supply
  - DC regulators
  - Choke input raw PSU
  - Filament starvation
- Keeping the noise down
  - Ground scheme and layout
  - Multi-chassis
  - Microphonic noise
- My preferred topologies and anode loads
  - Hybrid µ-follower (aka Gyrator)
  - Choke
  - CCS (with µ-output)
  - Transformer

Usually I have between 4 to 6 preamps in operation which I rotate whilst I mod or tweak them. I can't recall the exact number, but I must have built around 20 to 30 different preamps along this journey. Let me share they main key points I've learned as a result

What goes in the cathode is as important (or even more important) than what you have as anode load. It's somehow obvious as technically the signal variation between grid and cathode are "mu" times more significant than the anode ones. It's not new that the different bias arrangements have a big influence in sound. Me personally, I prefer not having a bypass electrolytic capacitor in the cathode and simply this is because (as many of you) can hear the influence of it. However, a smaller good quality input or output capacitor has much less influence in the overall sound. Without opening a can of worms around the component, I have to say that I don't have an obsession for the component selection (e.g. use of expensive boutique capacitors, etc.). However, I found by listening sessions with my friend and musician Andy Evans that cathode resistors (or bias diodes) have a significant impact in the overall sound. We can't measure this, but many of you out there can hear the difference.

Although I liked battery and LED bias arrangements, I found firstly that filament bias sounded better. In particular good quality wire-wound resistors (e.g. I use some NOS Russian Military ones). Recently I also found that some SiC diodes sound as good or even better here.

My bottom line on this point is that you should pay careful attention on your cathode resistor and obviously for the same reasons why you need to do the same with the filament supplies.

Filament supplies

There has been plenty of discussion on this subject as the filament is the cathode in a DHT. Guido Tent as well as Rod Coleman have covered this in detail and is not my intention to cover the science behind this. I've achieved better results by using implementing choke input PSUs, DC filament using filament regulators like what Rod Coleman offers and starving filaments where needed. Hold on this point as I will cover this in more detail on the next slide.

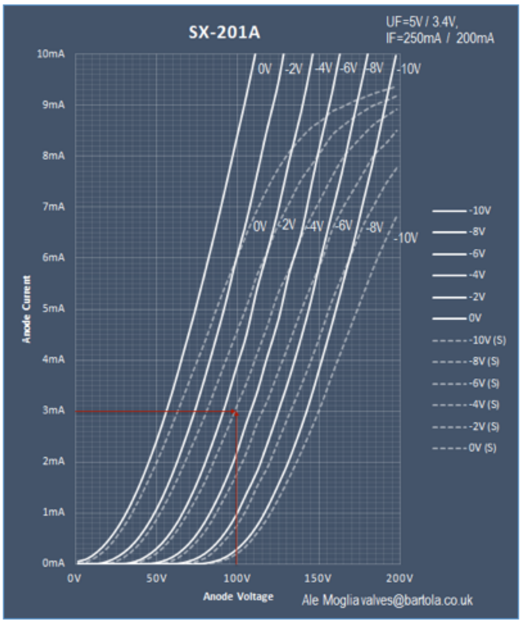
One of the biggest (if not the biggest) challenges in implementing a DHT pre-amp is keeping the noise floor to minimum. This isn't easy at all. As with any preamp/line-stage you have to pay careful attention to the grounding scheme. More importantly, with DHTs the challenge is the hum pickup by the DHT itself and microphony. Some valves are more prone to pick up hum than others. Some aren't even suitable at all. I'm not a big fan of creating a faraday cage around the DHT. Who doesn't like their valves being displayed at all?
What works really well is a multi-chassis approach. Keeping the power supply transformers, rectifiers and chokes further away from the valve and input circuitry is a great approach for very low noise results.
Also a thick aluminum or even wood top plate does work very well to suppress microphonic noise. Also using rubber mounting devices (e.g. silent blocks) but increasing the top plate mass works like a charm.

My preferred topologies/ anode loads

I found one of the best sounding topologies to be the hybrid mu-follower (aka as "gyrator" which is incorrectly referred to when the output is taken from the mu-connection). This is the main topic which I will cover as part of this presentation.

Filament Starvation

- Reduced microphonic noise
- Reduced emission
- Increased ra, reduced gm and (nearly) constant μ
- Reduced distortion
  - Increased region where gm, ra and μ are constant [5]
- Reduced valve life
  - Surface-level barium depletion (Oxide Fil)
  - “Cathode stripping” (TT filaments)



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This is caused by thermal expansion - high temperature means filament goes 'slacker’.

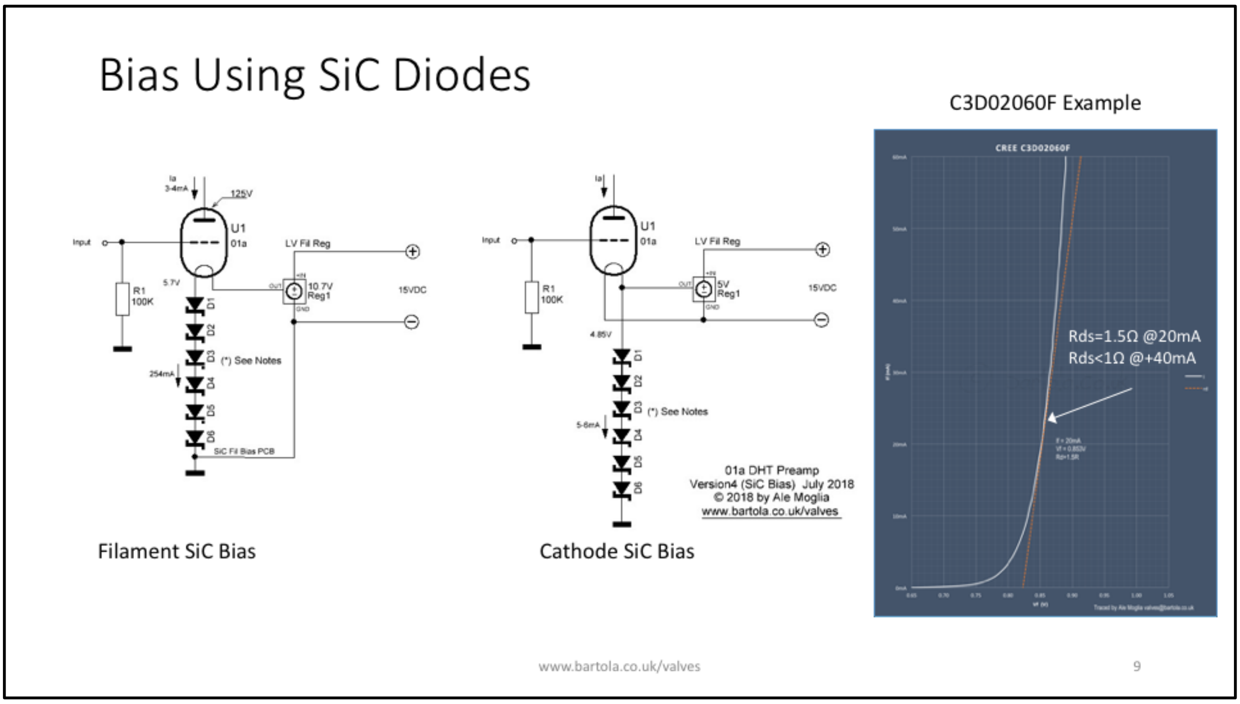
Steve’s Bench results: by starving the filament in DHT devices, the tube characteristics show a substantial region of not only constant mu, but constant gm and constant rp, thereby essentially removing all distortion causing mechanisms.

Under-heating Thorium impregnated Tungsten while working at high currents is a problem. But oxide cathodes generally have WAY ample emission, so they never "strip" and there is no problem running them +/-10%, even +/-20% away from nominal voltage.

Cathode life is certainly reduced, but cathode stripping is unlikely from starved filaments combined with preamp levels of anode current.
But life is reduced because the supply of subsurface barium in oxide-cathode systems slows down at temperatures below the rated heating power.
The barium evolves from the depths of the cathode up to the surface, driven by the temperature. The rated power of the filament sets the temperature, and in turn this sets the rate of evolution of barium. This is the reason that overheating is so bad - the barium is simply burned up. With low temperatures, not enough supplies of barium reach the emissive surface; eventually, the surface-level barium is too depleted, and emission falls. to some extent, this can be corrected by heating at normal voltage again for a while.

I ran the 01a at 200mA (-20%) for some years without a detrimental impact on the life of the valve. However, by carefully selecting the devices and applying the techniques mentioned earlier to reduce microphonic noise, I reverted back to run them at nearly rated voltage.

This technique I use it instead in oxide filament DHTs like 4P1L which are more troublesome from a microphonic noise perspective.

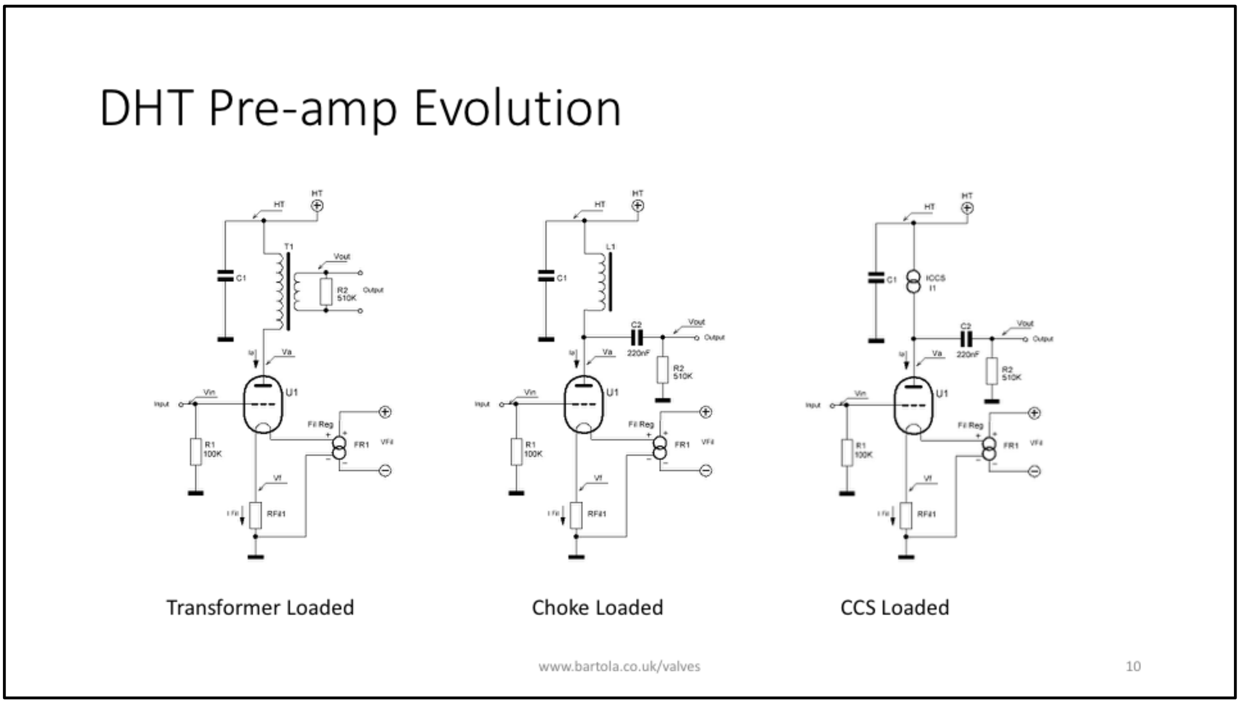


The use of Silicone-Carbide (SiC) diodes for biasing the DHT has been mainly made as a result of some listening experiments. Despite the popular use of LED-bias in many cases, the SiC do sound much better in my experience. The do operate well from low currents and impact on the increase of Rds is minimal. Running them at low currents (e.g 3-4mA for a 01a stage) provides no measurable additional distortion due to the lower operating point in the knee.

I found the Cree type C3D02060F to sound particularly nice, and is my preferred one in my designs.

Filament bias

The C3D02060F SiC has a thermal resistance from junction to case of about 13.8C/W. It doesn't specify the thermal resistance from junction to ambient am afraid. Either way, typically for a TO220 it's about 62C/W. If you want to keep the junction at not more than 150C and with an ambient of 25C, that is about (150-25)/62 = 2W. The voltage drop is about 0.9V on the SiC and increases with junction temperature increase. In theory you can run about 2A without a heatsink. Otherwise a small clip-on TO-220 heatsink will suffice.

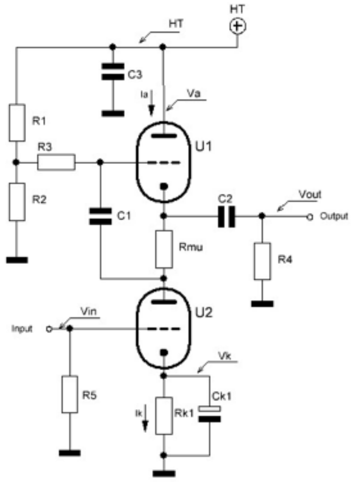


Over the years, audio enthusiasts all over the world have exploited DHTs extensively for pre-amplifiers and line stages. As I covered a few slides before, one of the most used topologies is the transformer-loaded with filament bias. Valves like 26, 01a and even 10Y/VT-25 are the most popular. High-quality step-down transformers provide lower output impedance and enable the stage to drive volume controls and amplifiers. The quality of the stage transformer is key and dominates significantly the sound of the stage. Should you need higher gain, the choke-loaded stage is very popular. In both cases, DHTs with high anode resistance creates a challenge for the OPT or the Choke in terms of desired frequency response. High anode resistance means higher primary inductance required and therefore increased leakage impedances due to size and geometry of the winding needed. The HF is compromised, so there is no free lunch here.

CCS were introduced as anode load to improve the PS rejection and provide a flatter load line for the triode so improving the linearity of the stage. Average CCSs don't sound as good as a high-quality choke or OPT. Hence you have a school of audio enthusiasts that have ruled them out unnecessarily.

I didn't, and instead experimented with different CCSs which led me to the topology I will cover next.

The µ-follower



Advantages

- Push-pull
- Low output impedance
- Lowest distortion when optimized for specific load
- Higher bandwidth
- U1 Pentode: constant gm, lower distortion and better PSR

Disadvantages

- HT to accommodate full output swing
- Optimisation only for a specific load
- Heater supply (and elevation)
- The higher Rµ, the lower the current drive

The series push-pull, totem-pole topology is very well known to all. Although the "shunt regulated push pull" name actually got stuck around the 90s, this topology is know by various names from totem-pole, to single-ended push pull (SEPP). It found its origins in 1940s (US patent "balanced direct and alternating current amplifier" and got popular in TV circuits but somehow lost visibility at later stage.

One of its variation is the mu-follower and here is a generic version. This circuit can provide excellent drive and voltage amplification which is close to mu, hence it's name. The output impedance is low and independent of the bottom triode. It's close to 1/gm (gm of the top triode). The distortion can be minimised when the stage is balanced and optimised for a specific load, in which case the value of Rµ has to be chosen for one specific load.

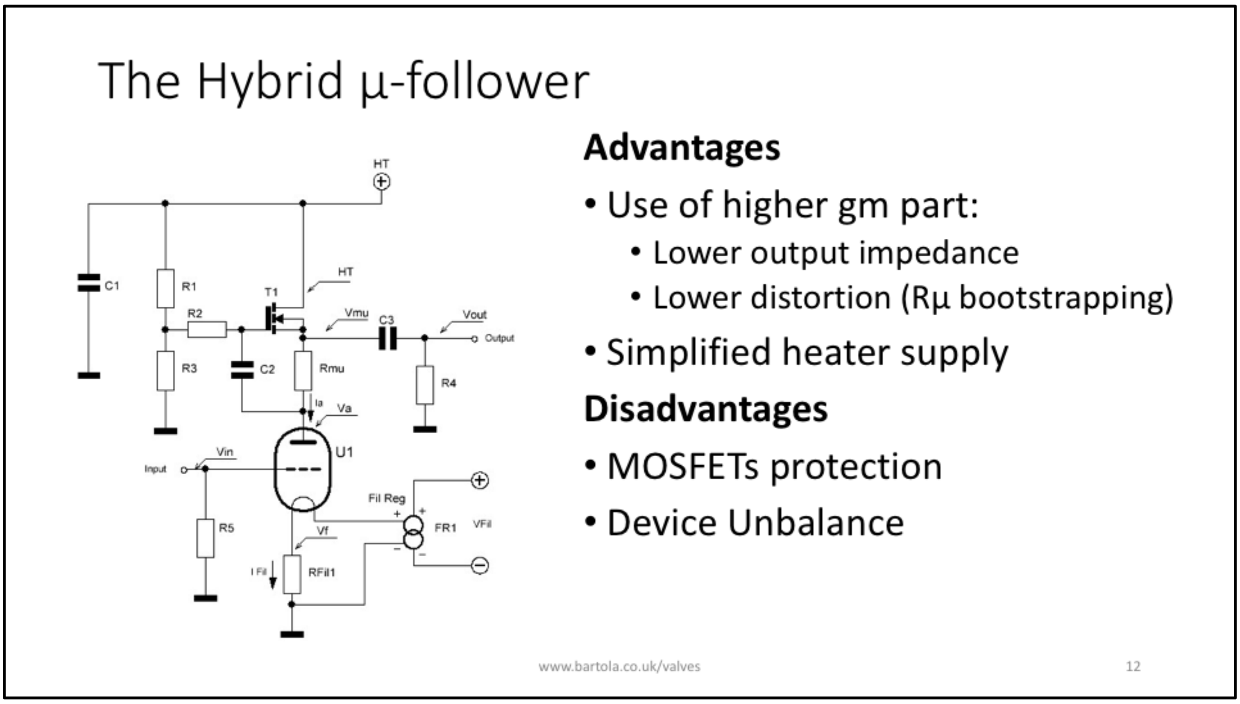
Harder loads to drive require instead the SRPP (or SRPP+) topologies which can provide sufficient current at very low distortion. In that case, cathode resistor is un-bypassed (increased linearity and improved sound) and Rµ has to be optimised considering the load impedance.

The SRPP can swing up to 2 times the quiescent current, whereas the limitation of the µ-follower is that the current swing into the load comes closer to the idle current due to the larger value of Rµ.

The Rµ is bootstrapped by U1 via C1, therefore provides a high impedance load to the bottom triode. The top part of the circuit is actually an impedance multiplier. The load is reflected as a higher impedance based on the value of Rµ and the 1/gm of the top device. When optimised (SRPP) the load is reflected as 2*RL as if both devices are sharing the same load. The higher the value of Rµ, the lower distortion and the bigger the imbalance is between devices as the top triode ends up doing most of the work.

Although this circuit is meant to driver lower-value loads and it would seem a waste of the push-pull topology when driving the input of an amplifier (50K-100k), the performance and the sound of this stage is what really attracted me to explore further.

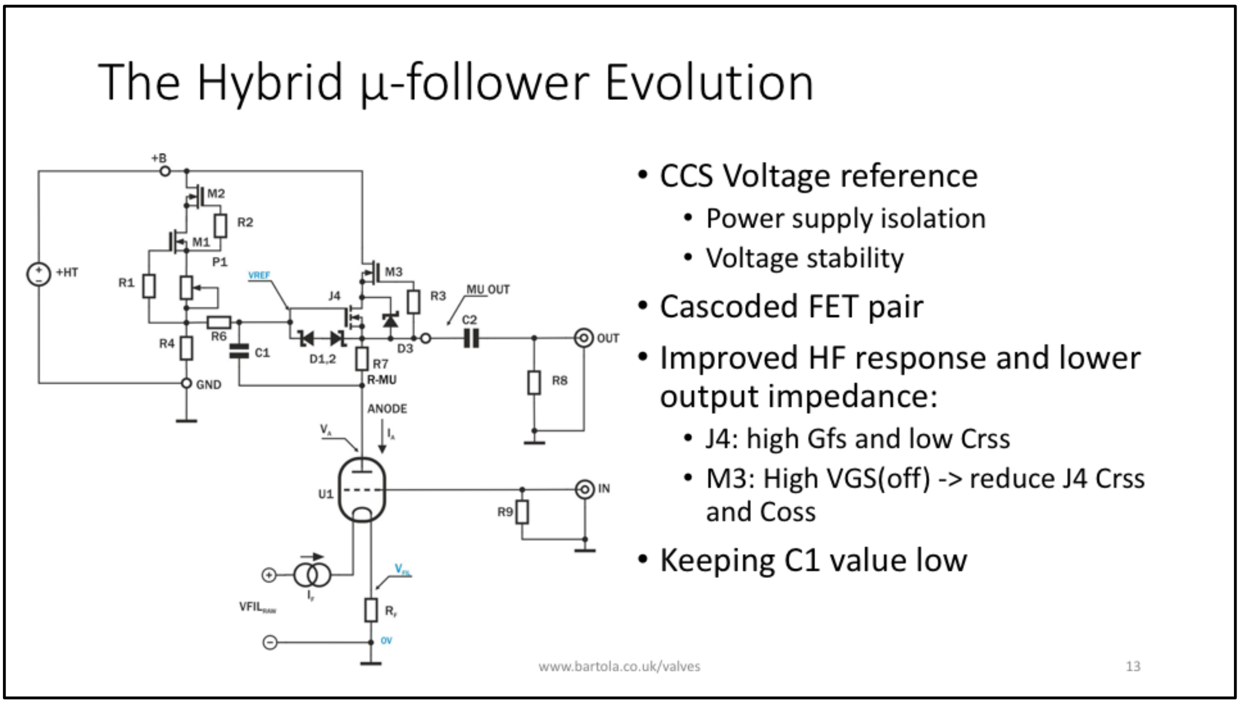
If we replace the top triode by a pentode, which has more constant gm, the distortion is lower due to the increased boostrapping effect and improves the rejection of the PS noise. However, introducing a pentode here adds complexity to the circuit.



Early 2000s, audio enthusiasts were building hybrid version of the mu-follower shown in previous slide. A great improvement was made by replacing the top device by a high-voltage depletion MOSFET (an enhancement works too). The availability of HV parts made several people to investigate the different FETs.

If the output is taken from the anode instead, the circuit changes back to a single-ended one with a fixed-voltage CCS load which has been wrongly named “gyrator” due to the frequency behaviour similar to the choke. This created confusion somehow. Clearly, when the output is taken up from the source of T1, the circuit is a totem-pole mu-follower.

My first version was around the 4P1L valve. I discovered a clearer sound timbre and detail with this topology. I’ve been using for many years, choke-input supplies raw DC supplies, filament regulators (Rod Coleman) as well as filament bias arrangements as found to be one of the best sounding elements of the preamps.



So after many years of experimenting with this topology, building and listening to them, I made the following changes to the circuit.

Voltage reference replacement with a CCS-driven reference:

A more stable reference can be achieved with the ubiquitous LND150 in a cascoded pair. A stable current which is carefully chosen to optimize the tempco of the FET CCS generates a reference voltage across R4. This improved the power supply noise rejection due to the high impedance of the cascoded CCS.

Cascoded pair for top device

Cascoding the top FET enables us to use the right component for the right role. An HV part as top device takes all the heavy load. We can then carefully chose a lower device (J4) which has better characteristics than the top HV part. This means higher gfs as well as very low Crss and Coss. We can improve significantly the high-frequency response as well as reduce further the output impedance (1/gfs).

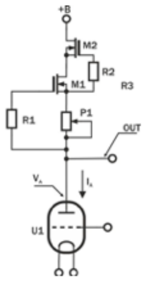
Cascoding improves the high-frequency operation, increases high-voltage operation or compliance. Variations in the HT supply are accommodated by M3's drain. M3 accommodates the voltage drop which means that you usually have to add a heatsink (TO-220) depending on the quiescent anode current. You will have to take into account a 20-25V headroom in M3 depending on the voltage swing for good performance to avoid HF roll-off due to creeping leakage capacitances due to low VDS.

Also there are some specific HV depletion FETs like the IXT08N100D which have a higher VGS(off) than a typically used DN2540. This allow the lower FET to operate at a higher VDS voltage level which means that the parasitic capacitances are minimized (Crss and Coss).

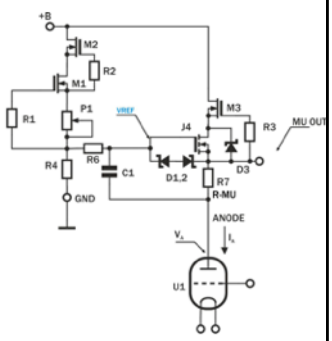
There are a few protection diodes which are mandatory. In some devices (e.g. BSH111BK) the gate to source protection Zener diodes (D1 and D2) are included in the device. Although in normal operation M3 will guarantee a low VDS level for J4, I found the inclusion of D3 to be mandatory to protect J4 during start-up.

Sonically speaking, I always try to keep C1 as low as possible. About 100nF works well which requires R6 to be 10M. A good Teflon or film cap works well, not requiring any fancy and expensive part. Similarly, I found using Kiwame or TAKMAN metal-film parts for Rmu (R7) to be one of the best choices.

CCS vs Hybrid µ-follower



	CCS	Hybrid µ-Follower
Valve parameter fixed	Anode current	Anode Voltage
Output impedance	Mid-High (anode resistance)	Very Low (1/gfs)
Mode	Single-ended	Push-Pull
Complexity	Low	High
Low impedance loads	No	Yes



Some of you may ask the question: ”why bother with the extra complexity of the gyrator load when can use a simple CCS?”
In this table I summarise the main areas of comparison. In fact, the comparison is the CCS with the hybrid µ-follower, not gyrator as the output is taken from the µ output, not the anode.

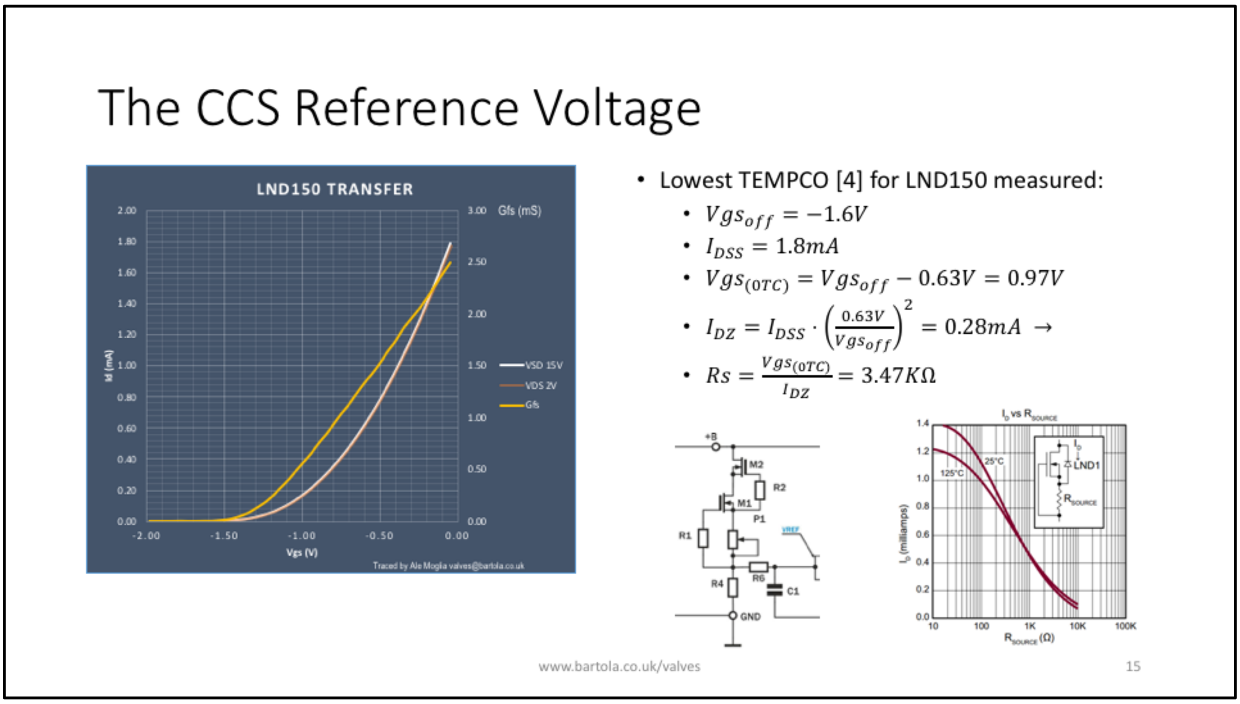
The CCS provides a fixed anode current which will stay fixed regardless the change in valve parameters due to aging, for example. The µ-follower on the other hand will fix the voltage at the anode, not the current. This may be better in cases where we are DC-coupling the output. Otherwise, the reduced emission due to valve aging won’t have a material impact in the operation of the stage, other than reducing the anode quiescent current.

The major difference between the two is the output impedance. In the CCS is mainly the anode resistance which if it’s high, can be a problem depending on the value of the load. Also the coupling capacitor size will be bigger

The CCS as anode load creates a single-ended circuit whereas the hybrid µ-follower is a push-pull one. This is better for driving a reactive load (e.g. cable or transformer) as can push and pull current into and out from the load as required.

In terms of complexity the CCS is clearly a winner if we are using a cascoded pair of depletion FETs which made it ultra-simpler with only 2 poles. The hybrid µ-follower on the other hand has a CCS for fixing the reference voltage and a capacitor at least.

The other main key difference is the type of loads we can manage effectively. The µ-follower can be optimised and turn into a SRPP stage if we tune “Rµ” resistor (R7) for a particular load. More importantly, as discussed before, the reflected load to the anode is multiplied by “the bootstrapping of Rµ”. On the other hand, the CCS sees the load in parallel with the anode resistance increasing the distortion



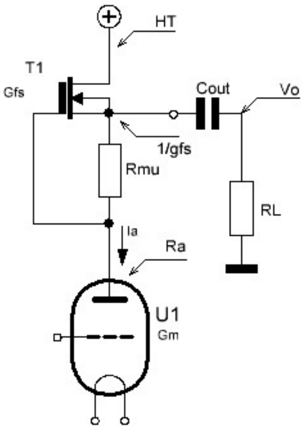
Cascoding the pair of LND150 significantly reduces the output conductance (Gos) which provides excellent current regulation against variation of the HT voltage.

One important remark to make is that the CCS needs to be designed taking into account the TEMPCO of the LND150. Linden T. Harrison published on "Current Sources & Voltage References" how to best estimate the zero temp point for any jFET in a CCS. I've taken the time to trace and measure a few samples of the LND150. I found that the IDZ should fall somewhere between 300 to 500uA. You can see the published datasheet graph on the right which may suggest closer to 500uA. However if you take into account the FET parameter variance, you should expect a variation around this point which is shown in my testing example above.

Both VGS(off) and IDSS shift with temperature, in fact VGS(off) has a negative tempco of -2mV/C

Unless you need to keep the quiescent anode voltage really tight, the variation of Rs isn't that critical. If you deviate far from the IDZ point, you may get a few volts of drift maximum which isn't too critical in most of these circuits. I have included a 5K trimpot for Rs (P1) to provide a good voltage range for a given fixed R4 (which is normally on the 220K to 390K range.

Some Math…



- For totem-pole current balance $g_{fs} = g_m$ so $R_\mu \cong \frac{1}{g_m}$ for current balance in the load
- Output impedance: $Z_O = \frac{R_a + R_\mu}{1 + R_\mu \cdot g_{fs}}$
- For a low R_a then $Z_O \cong \frac{1}{g_{fs}}$

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Although there is plenty of math behind the SRPP/Mu-follower circuits which have been well covered by John Broskie and Merlin Blencowe [Reference 6], I will only highlight a few points which are mostly relevant to the hybrid mu-follower.

Firstly due to the asymmetric nature of the hybrid mu-follower, we've got in this circuit 2 devices with different transconductance. In fact, even with the lowest gfs jFET (e.g. LSK170/BF862), you still get 5 to 10 times more transconductance than any of the typical DHTs we use as U1.

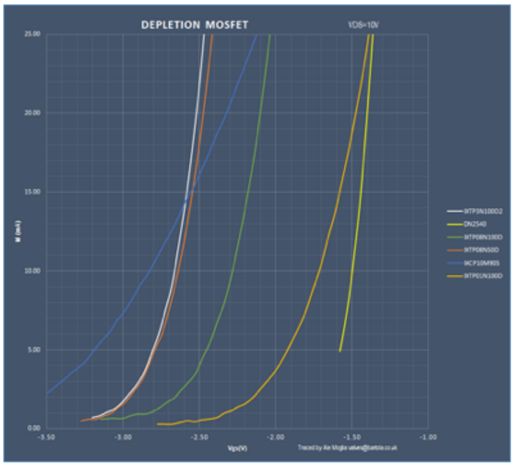
To balance the hybrid mu-follower, you need to set Rµ to the inverse of U1's gm. Typically you get U1's gm to be somewhere around 1 to 2mS. So Rµ's value should be somewhere 500 to 1K. I've used ranges of 470R to 1K5 depending on the valve used. Of course the higher Rµ, the higher the impedance multiplication effect of the load will be for U1, hence distortion will be reduced. However, the current imbalance will be higher between the triode and the MOSFET. Also current drive will be reduced which may cause some trouble depending on the load being used. If we want to use this circuit to drive a high impedance load, then is fine.

The Output impedance is simply the sum of both anode resistance and mu resistance and then applying the impedance "reduction" effect by the term (1+Rmu*gfs) from the top device. What this formula tells us is that the higher the gfs of the MOSFET (at the idle current) the lower the output impedance. When the anode resistance is small and if Rµ*gfs >> 1, then the output impedance approximates to 1/gfs which is generally in the order of 50ohms or smaller depending on the FET used.

FETs and MOSFETs: an Endless Tale

	LSK170	BF862 (*)	BSH111BK	DN2540	BSN20BK	BSP149	RU1C001UN
Ptot (W)	0.4	0.3	0.3	1	0.31	1.8	0.15
VDS	40	20	55	400	60	200	20
VGS off	2	-1.2		-1.5	1	-1.4	
IDSS (mA)	12	25	210	120	265	660	
Gfs (mS) (*)	22	45	640	300	710	800	180
Id Gfs (mA)	18	18	200	125	200	480	100
Id (mA)	10	10	10	10	10	10	10
Gfs @ Id (ms)	16	34	143	85	159	115	57
Ciss (pF)	20	10	19.1	200	20.2	326	7.1
Crss (pF)	5	1.9	1.5	1	2	17	1.7
Coss (pF)			2.7	12	3.1	41	3.3
1/gfs (ohms)	61	30	7	12	6	9	18

HV Depletion MOSFETs (Id vs Vgs)



(*) EOL now, 2SK3557 and CPH3910 instead

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Over the last years, I experimented extensively with different FETs in the hybrid-mu follower circuit. As there are very few through-hole (TO-92) jFETs still available, I also explored other options including newer enhancement MOSFETs with high GFS and low CRSS which proved to work really well as lower devices of the Cascode pair.

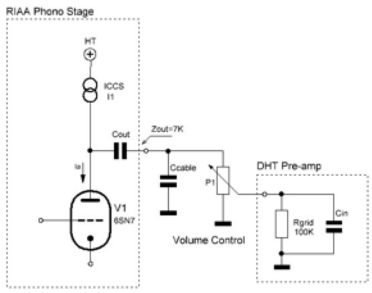
I’ve used extensively the BF862 for preamps for currents under 20mA due to the IDSS limitation. The BF862 is now EOL, so there are other similar options like the 2SK3557 and CPH3910 which work and sound very well.

For currents above 20mA (e.g. 4P1L) I use the BSH111BK or BSN20BK which will have at least 200-250mS of transconductance above 20mA.

For the top device, I found that the ubiquitous DN2540 isn't the best choice for this position. There are other depletion MOSFETs in the IXYS IXTP family that have a higher VGS (off) level which is normally above -2V. On the right curve tracing example you can see the difference between these MOSFETs. Either way, we need to be careful here as MOSFET parameter variance is significant – VGS(off) being one of those parameters. For example the DN2540 datasheet quotes a 2V range between -1.5 to 3V for VGS(off). On the other hand, the IXTP3N100D2 has the same 2V variance but from -2.5V to -4.5V!.

Ideally, you would like to manually select them by testing their VGS(off) level.

Where To Place The Volume Control?

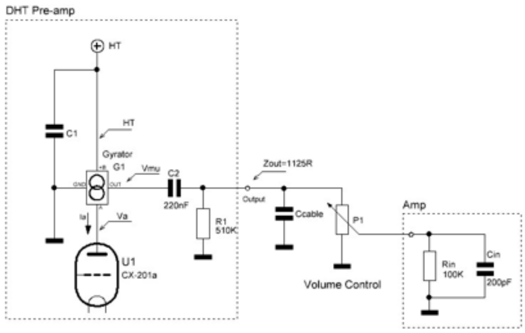


Can we use a 20K vol. control at the input of the DHT pre-amp?

Example 1

- Short interconnect cable ($C_{cable} \approx 200pF$)
- DHT preamp valve is 10/VT-25:
  - $C_{in} = C_{gk} + (\mu + 1) \cdot C_{ag} \approx 70pF$
- If volume control is 20KΩ (90% position):
  - $f_{-3dB} = 123kHz$
- If volume control is 100KΩ (90% position):
  - $f_{-3dB} = 98kHz$

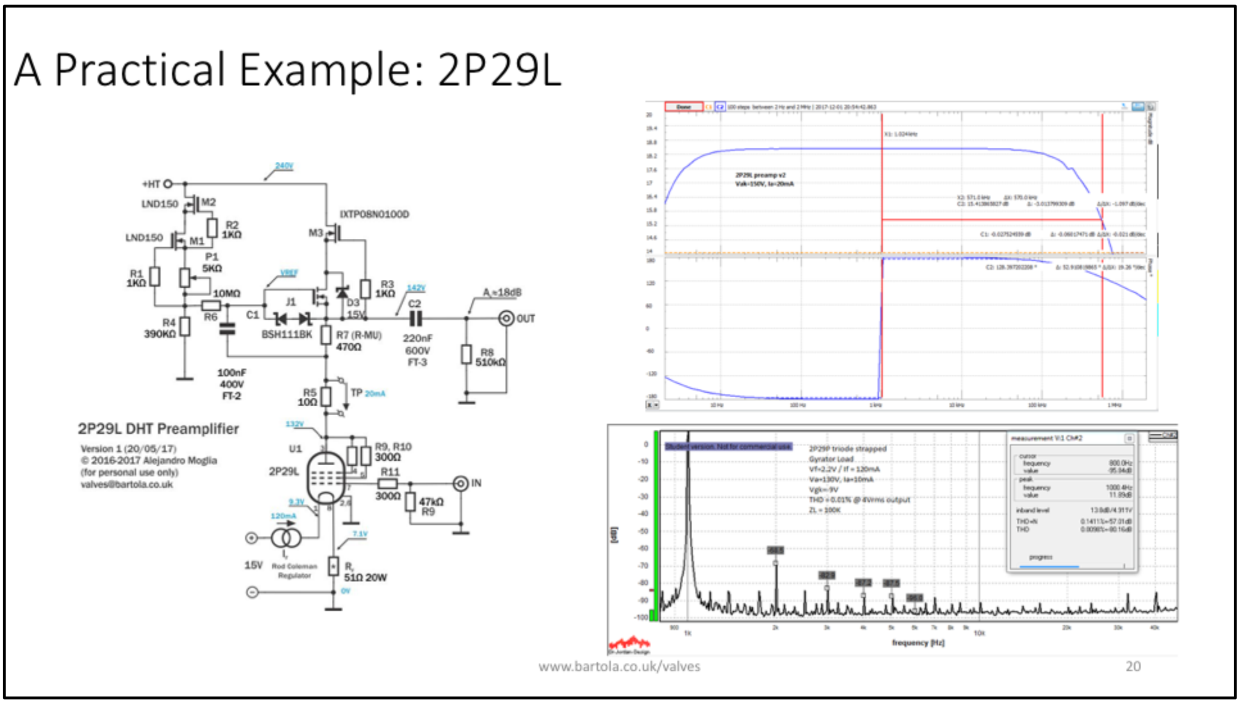
Can You Drive Me?



Can the DHT Pre-amp drive 5m cable?

- 5m interconnect: ($C_{cable} \approx 1.1nF$)
- CX-201a follower $R_{OUT} \cong 1125\Omega$ for $R_\mu = 470\Omega$ and $G_{fs} \cong 20mS$ @ $I_a = 3mA$
- If volume control is 20KΩ (90% position):
  - $f_{-3dB} = 118kHz$
  - However, $C_2 \geq 1\mu F$ for $f_{-3dB} = 9Hz$
- Slew rate limitation:
  - $I_C = C \cdot 2\pi \cdot f \cdot V_{peak}$
  - If $I_A = 3mA$ and $V_{peak} = 10V$ then $f_{max} = \frac{I_A}{C \cdot 2\pi \cdot V_{peak}}$ =36kHz
  - For $f_{max} = 100$kHz then $I_A = 8mA$.
  - Source or cathode follower solution

Maximum capacitance the 01a can drive for 10Vpeak and 3mA is about 470pf for 100kHz operation.



The 2P29L is a real sleeper valve. I used for many years the 4P1L which is a great valve, but microphonic noise can be troublesome. The 2P29L on the other hand, has some key attributes which make it ideal for a preamp valve. The filaments are far less demanding with 120mA/2.2V and the valve isn't microphonic at all! Although it has a higher anode resistance of 2.8-3KΩ and transconductance of 3mA/V when triode-strapped. The gain is similar to the 4P1L with μ of around 9-10.

The more important aspect of this valve is that it sounds really nice. It's very transparent and detailed. To me, it's very close to my favourite DHTs with thoriated-tungsten filaments: 01a and 801a/10Y.

I have made a PCB which makes holds most of the components of the hybrid μ-follower excluding the filament regulator, output coupling capacitor and the filament bias resistor.

I'm running a bit too hot this valve, but I found it to sound better between 15 and 20mA of quiescent anode current. The filament bias resistor can be also replaced by a SiC diode array as have found lately to sound better.
The stage also can be used as a headphone amp, which I do with a step-down Sowter amorphous core transformer to drive the low impedance headphones. If you tune the "μ" resistor you can make this stage to drive a 300Ω headphones directly. You will need to change C2 obviously and output power will be limited by the 2P29L valve.

From a measurement perspective, the harmonic profile is very nice with H2 and H3 decaying. Frequency response is very good as well with up to 500kHz bandwidth when loaded with 100KΩ .

This is a lovely stage which I recommend you to build, you can find many other examples and pictures in my blog (www.bartola.co.uk/valves)

Valve	Timbre & Detail	Microphony	Current Drive	Gain	Notes
801a 10-Y VT-25	●●●	Amber	Green	M	• Challenging for filament bias (heat) but doable • Thoriated-tungsten filaments • ER801a a great option!
01a	●●●	Amber	Red	M	• Be careful with old valves and microphonic devices • Great for filament bias • Thoriated-tungsten filaments
2P29L	●●	Green	Green	M	• Still cheap and plentiful • Remove the aluminum can and use it naked! • Great for filament bias
Aa / Ba	●●●	Red	Red	H	• Rare and expensive • Ba picks too much hum – needs shielding • Good for gain but needs SF/CF stage
4P1L	●●	Red	Green	M	• Still available • Easy to match pairs • Can be very microphonic
26	●●	Amber	Amber	M	• Be careful with old valves and microphonic valves
199	●●●	Red	Red	M	• Very microphonic • Old and scarce, Variance between samples • Short pin UV99/199
45 / 46	●●	Green	Green	L	• Bias levels prevents filament bias use • Low gain
112a	●	Amber	Green	M	• Better current drive than 01a, but lack of thoriated tungsten filaments
RE-804	●●	Green	Amber	H	• Hard to find in NOS. Valvo brand is best.
71a	●	Green	Green	L	• Low µ and anode resistance. Ideal for line stage when gain isn't needed

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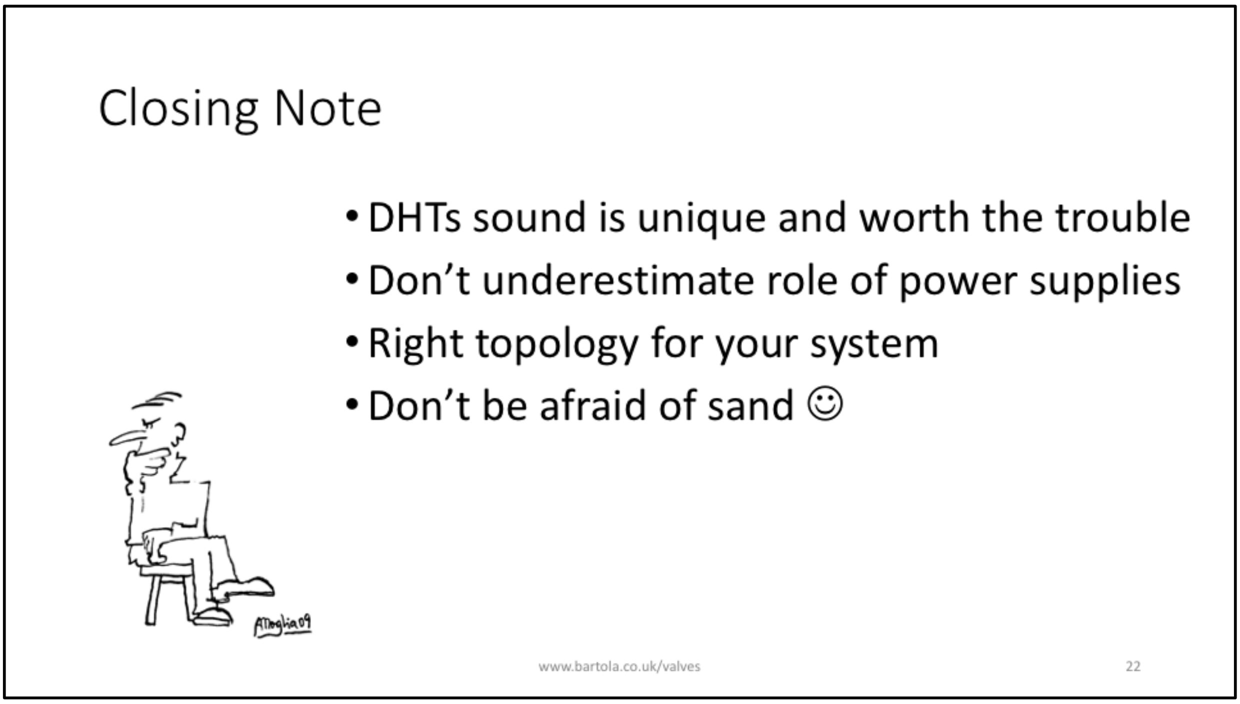
My intention with this summary table is to provide you with a high-level guide to which DHTs, based on my experience, are probably the best to work with. It includes a combination of technical facts with also listening impressions. In the end, taste is a personal matter, so don't take this for final and make your own experimentation.

The RAG is probably self-explanatory for the level of microphonic noise: RED: very bad, AMBER: you can manage with extra "help" and GREEN: very low
For current drive, the RAG is as follows:

1. GREEN: Above 10mA
2. Amber: between 3 and 5mA
3. Red: Below 3mA

Timbre and detail impressions are subjective. It's the result of my own work by building and listening to these stage over the years.

The ones I didn't find as good include: 30/30sp, 3B7, 2Ж27Л / 2Z27L



The DHT sound is unique as level of detail and timbre which brings to life in our systems is definitely worth the trouble. Should I really need to say this at ETF? Clearly no!

Although a pre-amplifier with DHTs is a very simple circuit and many beginners are temped easily with it, the complexity comes with the power supplies and in particular the filament ones. Paying close attention to the design and component selection of them significantly improves the preamp performance and sound

Chose the right topology for your system. Whether you have a solid stage amp with low input impedance or you have long cables or volume control to drive, you need to take into account the end-to-end system requirements when you chose an DHT and the associated preamp topology. There isn't one size fit all approach here.

Finally, don't be afraid of sand. Silicon can perform very well at the right places. As a CCS or when is not performing voltage amplification (e.g follower). I've found, like many others, that there is a real benefit in using them to improve the circuit (e.g. filament regulators, anode loads and output source followers)

Experiment as much as you can, it's amazing how much you can learn each time!

Acknowledgements

- Morgan Jones
- Rod Coleman
- Andy Evans & Tony Rees
- Tom Browne

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