

A Really Different Custom 300B Pushpull Amplifier....

Introduction:

These amplifiers represent the culmination of 10 years of design and listening experience, so how do they sound? Lush, vibrant, revealing, dynamic, warm, open, authoritative, and just about any other adjective that has ever been applied to a tube amplifier. These amplifiers are the most neutral, detailed and open amplifiers I have ever designed or heard in my own system. Imaging and sound stage depth are amazing, microdynamics, not to mention dynamics seem just right, and not a shred of euphony to be heard.. Although output power is only 30Wrms, these amplifiers sound much more powerful through my Magneplanar MG1.6's than I have any right to expect. I must attribute a lot of this to the really excellent performance of the SV300B's, and the excellent quality of the Citation II output transformers.. I merely provided an electrical environment that allowed them to shine.. A lot of hyperbole perhaps, but nonetheless truthful.. I might have died and gone to heaven...

They arose primarily out of my desire to design and own a practical, high quality DHT triode amplifier with reasonable output power, efficiency, and excellent reliability. My design goals were to design an amplifier of high resolution, accuracy, and tonal correctness without the harshness of some designs or the euphony of others, most of all I wanted an amplifier that was highly listenable by virtue of its correctness..

I chose the 300B output tube because I feel it is hard to better both its sonic virtues and exemplary electrical performance, and because I wished to avoid extreme drive voltage, and supply voltage requirements for this design. I chose the Svetlana 300B as my output of choice as it performs electrically and sonically about as well as the few vintage WE300B I have come across at a fraction of the overall cost. The Svetlana 300B is in fact the best output tube of any type with which I have worked, and exhibits exceptional consistency, bias stability, and quality of construction...

Comments about the relative sonic merits of DHT triodes versus conventional type beam power tubes lead me about 8 months ago to design and build a stereo SE amplifier around the 45 triode in order to determine the merits of these output tubes.. This design incorporated a simple audio path with an extremely well regulated tube based power supply, and the results convinced me that indeed a DHT amplifier could be designed that would more than satisfy my needs for excellent performance and non fussy operation.. That SE amplifier has been in continuous operation for 6 months without problems, and without any disappointment concerning its sonic merits.. The main points of the design were; a lack of global feedback, a very linear drive stage, well regulated and decoupled supplies, careful auditioning with varying plate supply and operating currents, and fixed bias to eliminate the need for a large, coloration inducing electrolytic or film caps for output stage bias resistor bypassing..

I think many if not most of the sonic benefits of SE operation can be realized in a DHT based pushpull amplifier, as long as very high quality iron is employed and global feedback is not.. . I followed most of the same design rules indicated above, but in addition went to pushpull operation in order to produce enough power to drive my Magnepan MG-1.6 planar loudspeakers. The amplifier design is fully differential in nature, and may preferably be driven by a balanced source or if need be by an unbalanced source. Equally important to the sonic virtues of this design both the bias and main power supplies are fully tube regulated.

TECHNICAL DESCRIPTION:

The topology employed is not particularly unconventional in most senses, the goal was to keep the design as simple as possible without compromising on bandwidth or output tube drive capabilities. Available gain is such that ~1.0Vrms of unbalanced drive, and ~500mVrms balanced drive should be more than sufficient to drive this amplifier to full output, making this design suitable for use with active as well as passive pre-amplifiers, and buffered designs having no actual voltage gain.

These units were built as monoblocks, and are completely self-contained.. All the power supplies and other required circuitry are on the same chassis with the amplifier circuitry. Layout is of crucial importance, and for this reason the power supplies are located on the rear area of the chassis, the output stage towards the middle, and the input and driver stages are located at the front. All AC wiring near sensitive circuitry is fully shielded to keep hum and noise away...

The first amplifier stage is a differential amplifier (long-tailed pair) employing a 6SL7, and quiescent current of 1mA per section for a total of 2mA. No current source is employed as this runs counter to my philosophy of keeping the circuit path as simple as reasonably possible, in previous experiments it became clear that using a simple resistor in the long tailed pair only reduced common mode rejection by a just few dB, and has no measurable impact on stage balance, provided that the tail resistance is large relative to the internal cathode resistance. A combination of fixed bias (represented by the tail tied to the -200V rail) and self bias provided by the individual cathode resistors tied to the tail resistor provides a reasonable measure of dc balance even with some unmatched tubes, although some minimal matching is recommended. Stage gain is typically in the range of 22dB with unbalanced drive, and 6dB greater with balanced drive..

The differential driver stage is direct coupled to the preceding stage, and like the input stage relies on a combination of fixed and self bias for the same reasons as outlined previously. Overall gain in this stage will be in the range of 14dB.. Quiescent current is 3.4mA per section for a total of 6.8mA, and the total output current from the driver stage at clipping is approximately 0.35mA_{pk}, excluding the loading due to miller capacitance in the 300B's.. (Miller + grid to filament capacitance is estimated to be 70pF.) Full signal bandwidth at this point is 80kHz @ -3dB, and 170Vpp per plate, without the 300B's installed.

Cathode followers are not employed as it felt that the standing current in the 6SN7 differential driver stage should allow for sufficient output current to drive both the miller capacitance of the 300B as well as the current requirements of the 221K Ω grid bias resistors..

The output stage employs a pair of Svetlana 300B in pushpull, operating in class AB1 at a quiescent current of 80mA per tube. Fixed bias is employed, and each tube has its own filament winding to allow for easy bias measurements. AC heating is employed simply because I prefer the sound of DHT's that way, and pushpull operation will cancel most of the hum so induced as the filament hum is a common mode signal. (My 45SE amplifiers also employ AC on the DHT filaments and absolutely NO hum is audible at the speakers, and hum on the output was well below 1mVrms..)

The Citation II output transformers employed are excellent quality devices with a primary impedance of 3200 Ω , however the Bartolucci 123 at 3K Ω would be highly suited. Several excellent Magnequest as well as the Brooklyn B23 output transformers can also be employed in this design. The key issue is that the primary inductance should be quite high relative to the plate

to plate impedance, and values of 150H and above are not unreasonable to prevent distortion at low frequencies..

No provisions are made for global feedback as I find increasingly that it is unnecessary and in many instances quite detrimental to the sound quality. The overall linearity of this amplifier is excellent without the use of any global feedback..

There are two tube regulated high voltage supplies in this design; the plate supply, and the bias supply, as well as a low voltage IC regulated filament supply for the front end driver circuitry. Power supply design is crucially important to the performance of an amplifier, and a lot of attention was devoted to this issue. These supplies offer excellent performance in all areas important to audio amplifier design, tight regulation, low output impedance, (just a few ohms at dc..) good to excellent ripple rejection, and low noise..

The regulated plate supply offers a continuous capacity in excess of 250mA (the limit of the 5AR4 rectifier chosen) at +400vdc, with loadline regulation better than 1%, and ripple levels of 2.5mVpp or less under load.. The pass element is a parallel strapped 6336/A/B, the error amplifier is a 12AX7A connected in a cascode configuration for high open loop gain, and the raw supply is pi filtered with 47uF film capacitors and a 5H choke.. Output impedance calculates to ~ 1.5Ω or less from dc on up, and is capacitor dominated at high frequencies. No electrolytic capacitors have been employed in this regulator.. Interaction between the power amplifier and its supply has been virtually eliminated..

The bias supply is based on a single 6U8A with the pentode serving as the pass element, and the medium mu triode serving as the error amplifier.. The regulator can source up to 20mA at -200V for the output tube bias, input stage, and driver stage negative supplies.. Ripple and noise are < 2mVpp, and warm up is under 45 seconds, handily beating the main plate supply..

Note protection against bias supply failure and delayed B+ during bias supply warm up should be provided as shown in the schematics. If this feature is omitted a 300mA fuse must be installed in the center tap lead of the plate supply transformer..

Most of the tubes have dedicated filament windings on their respective supply transformers, and all tube filaments including the 300B's operate on AC, except for the driver stages which have a tightly regulated filament supply with 6.3Vdc output.

Amplifier Specifications:

Voltage Gain: ~20dB unbalanced, 26dB balanced

Frequency Response: ± 0.5 dB 20 - 20kHz small signal

Power Bandwidth:

1W : -3dB @ 33kHz

25W: -3dB @ 33kHz

Harmonic Distortion:

1W: < 0.16% thd @ 100Hz, 1kHz, 10kHz.

10W: < 0.35% thd @ 100Hz, 1kHz, 10kHz.

25W: <1.0% thd @ 100Hz, 1kHz, 10kHz.

Noise: < 1mVpp, typical into 4 Ω

Maximum Power into 4 Ω : 31Wrms at 2% thd and 1kHz...

Notes: All measurements performed with unbalanced RCA input mode selected, and Citation II output transformers..

Construction & Testing:

In terms of constructing this amplifier it may be useful to think in terms of individual circuit blocks, there are actually five blocks to consider; the first block the 300B based output stage, the second block the input stage (perhaps the most critical of all), the third block the +400Vdc regulated supply, the fourth block the -200Vdc bias supply, and the fifth block the dc filament regulator, filament supplies and fault protection.. Individual circuit blocks may be tested before proceeding to the next stage if desired. Testing of the actual amplifier circuitry requires that the power supplies be built and debugged first..

Input Stage, Driver Stage, Neon Clamps, 300B Coupling & Bias Circuitry:

The first and second blocks are present in the first schematic (P.1 of 4) and consists of the 6SL7 based balanced input stage, a +200V supply decoupling capacitor C1, the 6SN7 based driver stage, two neon lamps which serve as protective clamps for cathode insulation protection in V1 and V2 during warm-up, and the 300B pushpull output stage.

Those neon lamp LP1, and LP2 with D1, must not be omitted! Immediate destruction of the cathode to filament insulation may result. During warm up these devices serve to clamp the cathodes to safe voltage values. LP1 ceases conduction once V1 warms up to the point where normal plate current is flowing, and D1 prevents the neon LP2 from conducting during normal operation of V2 by becoming reverse biased. These neon lamps should extinguish once the tubes warm up..

The first stage functions both as a phase splitter and provides most of the voltage gain in this amplifier. The plate voltage on this stage should be approximately 105V $\pm 5\%$, and should be matched to within $\pm 2.5\%$. R103 and R104 provide both a limited amount of cathode degeneration and help to correctly bias V1.. This stage may be testing by removing V2 at which point the plates should be capable of swinging at least 40Vpp per plate, and should swing ~ 20Vpp per plate with ~1.4Vpp at the rca input, with switch S1 in the closed position.

The second stage consists of a 6SN7 running as a differential amplifier, and primarily serves to develop the large voltage swings required to drive the 300B output tubes to full output. R113 and R114 are tied to the negative bias supply and act as a 4W power resistor. (This resistor dissipates ~ 2W in normal operation.) The purpose of the connection to the bias supply is to allow the use of a large common resistance to assure good AC balance in this stage despite the presence of the largish 5.6K Ω cathode resistors which provide some self bias in addition to the fixed bias created due to direct coupling the first stage to the driver stage. This allows adequate voltage swing at the grids of the 6SN7 to assure linear operation at the maximum plate swing required.. This stage should swing at least 170Vpp linearly per plate before any observable clipping occurs, and 180Vpp is typical.. Bandwidth at this stage should be greater than 80kHz @ -3dB without the 300B's installed

The output stage consists of a pair of Svetlana SV300B in pushpull driving an output transformer of at least 3K primary impedance. (See parts list for recommendations here..) The output stage is capacitively coupled to the 6SN7 driver stage, and employs fixed bias. Each 300B has its own independent bias adjustment pot, the component values chosen allow an adjustment range of -80V to -100V, with -82V resulting in about 80mA (+400V plate) of plate current per tube. If necessary R117 may be decreased slightly in order to change the bias range if you cannot adjust the plate current to 80mA per tube. These component value were chosen to prevent destruction of the output tubes should the pots be mis-adjusted... Small, high quality film caps of 0.1uF - 0.22uF/250Vmin may be added between the pot wipers and ground if desired. 10 Ω 5% 1W carbon composition resistors selected to 1% are used to sample the cathode current and are inserted in series with the individual 300B filament winding center taps, and the bias pots are adjusted until 800mVdc is measured across them..

+400V Plate Supply Regulator and Raw DC Supply:

Arguably this is the first block that should be constructed and tested, as all other blocks except the -200Vbias regulator require it for operation, and troubleshooting purposes.. This regulator may be operated safely with as little as 2mA loading from V1..

This regulator consists of a number of sections including 5AR4 rectifier feeding a pi-filter consisting of two 47uF/630Vdc film capacitors, and a 5H, 250mA choke.. This filtered +560V supply then feeds the pass element which consists of both sections of a 6336A low mu power triode connected in parallel. R1 and R2 are optional resistors to force current sharing, and in this application are not required due to the relative modest power dissipation in the two sections of the 6336A. I recommend their omission for this reason, however the compulsive amongst you may install as recommended in the tube specifications..

The next section consists of the error amplifier and reference complete with its feedback network and pseudo constant current operation for the zener diode. The error amplifier operates in a cascode connection for greater bandwidth, gain, and in some instances where higher output voltages are required to keep the 12AX7A operating comfortably within its design margins.. Closed loop gain is 12dB (4X) and with the 100V reference results in a +400V output, the equation describing the voltage setting function is: $(R6/R7) + 1$.. The 6336A needs a minimum of ~125V across it to avoid drop out problems, and this is typically 160V in this design. Output regulation should typically result in 0V - 2V change when the output tubes are installed and biased for a total quiescent current of 160mA.. Ripple should not exceed 5mVpp under load, and warm up time is typically 2 minutes.. Do not use any rectifier other than the 5AR4 if the protection circuitry described in the last block is not used - cathode stripping of the 6336 and the 300B's may result.. (See schematic page 3 for details.)

-200Vdc Bias Supply:

The -200V bias supply is crucial to the safety and functionality of this amplifier. Solid state bridge rectification, and a 6U8A are used to assure a quick warm up, particularly important if the optional protection circuits are not used.. The raw dc is pi filtered for the screen and error amplifier, and directly connected to the plate of the pentode section of the 6U8A.. The filament is powered off of its own dedicated winding and is intentionally left floating to equalize voltage stress on the cathode/filament insulation in the triode and pentode elements. It is important to note that this is a floating supply and that the ground connection occurs at the cathode node of the regulator, and that the output is taken from the negative output leg of the circuit. (See schematic page 3 for details..) The regulator is otherwise fairly conventional in design with a triode error amplifier driving a pentode connected pass element. The loop gain margin provides for about a 20dB reduction in ripple amplitude and output impedance, while the pentode connection of the pass element provides an additional 30dB of ripple rejection typically.. Gain setting for desired output voltage is as described in the previous section. This supply should reach full output in ~30 seconds or less. Output voltage should be $-200V \pm 1\%$ (select zener or trim R10 as required - zener selection preferred..) Ripple should be 2.5mVpp or less at full load..

Filaments and Protection Circuitry:

All filaments except V5 and V6 operate off of secondaries on T2. A provision is made for operating V1 & V2 off of regulated dc, using a simple regulator circuit based on the Linear Technologies LTC -1083/4/5K low drop out regulator. A LM317K may be substituted if required. Ripple should be less than 5mVpp under load.. The dc filament supply is floated at ~ +40Vdc to assure cathode/filament insulation longevity in V1 & V2 and to reduce noise coupling through the filament/cathode insulation capacitance.. In addition this block also includes a circuit to sense bias supply presence before closing a relay in the center tap lead of T1. This prevents destruction of the output tubes in the event of bias supply failure, both at turn-on, and during operation.. If this protection circuit is omitted a 300mA fuse should be installed in the center tap lead to protect against bias supply failure. (See schematic page 4.)

PART LIST:

(Double for Stereo)

AMPLIFIER PARTS LIST

Resistors:

R101, R102, R115	- 100K Ω , 1%, 1W, MF, Holco H2
R103, R104	- 1.21K Ω , 1% , 1/2W, MF, Holco H4
R105, R106	- 15.0K Ω x 2 in series, 1%, 1W, MF, Holco H2 (Total 4 per amplifier.)*
R107, R108	- 5.62K Ω , 1%, 1/2W, MF, Holco H4
R109, R110	- 221K Ω , 1%, 1W, MF, Holco H2
R111, R112	- 1.0K Ω , 1%, 1/2W, MF, Holco H2
R115, R116	- 221 Ω , 1%, 1/2W, MF, Holco H2
R117, R118	- 68.1K Ω , 1%, 1/2W, MF, Holco H2
R100	- 100K Ω , 1%, 1W, MF, Roederstein Resista
R113	- 23.2K Ω , 1%, 2W, MF, Roederstein Resista**
R114	- 22.1K Ω , 1%, 2W, MF, Roederstein Resista**
R116	- 24.9K Ω , 1%, 1W, MF, Dale, Holco, Resista
R117	- 19.2K Ω , 1%, 1W, MF, Dale, Holco, Resista

RV1, RV2 - RV4LYSA103, 10K, 20%, 2W, locking pot, slotted shaft, or equivalent..

Film Capacitors:

C1 - 12uF, 5%, 630V, Angela Capacitor by SCR
C2, C3 - 0.1uF, 5% (matched to 1%), 600V, Reliable RTX..

Tubes:

V1 - 6SL7WGT
V2 - 6SN7GTA/B
V3, V4 - SV300B, matched pair, Svetlana

Sockets, Connectors:

J1 - RCA Jack, Vampire, Tiffany or Cardas as preferred..
J2 - ITT Cannon XLR, female, bulkhead mount..
Outputs - 5 Way binding posts, or Edison Price Music Posts or as preferred..
2 - Octal, as preferred..
2 - 4 pin UX type for 300B, ceramic.. Amphenol recommended if available..

Switches:

S1 - Alcoswitch SPDT, silver contacts, miniature, or equivalent...
S2 - Alcoswitch, SPDT, 5A @ 120Vrms, miniature, or equivalent..

Chassis:

2 - Large enough to accommodate each channel. ~ 12" W x 20" L x 5" D.
Builders choice....

Misc.:

LP1, LP2 - Neon lamp, type NE2H.. Available from Radio Shack.™
D1 - UF4007, Fast recovery rectifier, 1Kpiv, 1A.. (Active Electronics)

Wire - Kimber TCSS 5 Nines pure copper..
- Belden Silver plated copper w/Teflon insulation for AC power wiring..

Fuse - 3A slo-blo, Littlefuse

Fuse Holder - Littlefuse chassis bulkhead mount

Output Transformers

Vintage NOS/Used Harman Kardon Citation II Output transformers, potted, 3.2K Ω primary impedance, 150mA per side, 60W power handling, 4 Ω , 8 Ω , 16 Ω secondary taps.

Bartolucci Model 123, potted, C-Core, 3K Ω primary impedance, 170HY primary inductance, 150mA per side, 60W power handling, 4 Ω , 8 Ω , 16 Ω secondary taps.

Brooklyn B23, 4K Ω primary impedance, 50W power handling, 100mA per side, 10mA imbalance allowable.

Hammond 1650KP, potted, 3.4K Ω primary impedance, 50W power handling, 100mA per side, 4 Ω , 8 Ω , 16 Ω secondary taps.

Notes:

* R105 and R106 consist of two Holco H4 15K resistors in series.

** R113 and R114 may consist of any combination that produces 45.3K Ω 1% at 4W.

Output transformers are ranked in order of preference, the only types I can vouch for are the HK Citation II, and the Bartolucci 123...

POWER SUPPLY PARTS LIST (Double for stereo)

Resistors:

R1, R2	- 47 Ω , 5%, 10W, Non Inductive Wirewound, Mill or equiv... <u>Optional Item</u>
R3, R6	- 301K Ω , 1%, 1/2W, MF, Roederstein Resista.
R4, R7, R10, R11	- 100K Ω , 1%, 1/2W, MF, Roederstein Resista.
R5, R9, R12	- 49.9K Ω , 1%, 1/2W, MF, Roederstein Resista.
R8, R19	- 2.21K Ω , 1%, 1/2W, MF, Roederstein Resista.
R13	- 4.75K Ω , 1%, 1/2W, MF, Roederstein Resista
R14	- 1.21K Ω , 1%, 1/2W, MF, Roederstein Resista
R15	- 150K Ω , 1%, 1W, MF
R16	- 15K Ω , 1%, 1/2W, MF
R17	- 1K Ω , 1%, 1/2W, MF, Roederstein Resista
R18	- 10K Ω , 1%, 1/2W, MF
RV3	- 1K Ω , Cermet Pot

Capacitors:

C4, C5	- 47.0uF, 630V, Film, Angela Cap.
C6	- 0.47uF, 630V, Film, Angela Cap., or SCR.
C7, C11	- 2.2uF, 630V, Film, AEON.
C8	- 22.0uF, 630V, Film, AEON.
C9	- 50uF x 2, 500V, LCR, Electrolytic.
C10	- 0.01uF, 10%, 500V, ceramic or mica.
C12	- 12uF, 630V, Film, Angela Cap..
C13	- 4700uF, 16V, Electrolytic
C14	- 22uF, 16V, Electrolytic
C15, C17	- 1000uF, 16V, Electrolytic
C16	- 100uF, 50Vmin, Electrolytic

Tubes:

V5	- 5AR4/GZ34
V6	- 6336/A/B
V7	- 12AX7A/WA
V8	- 6U8A/WA

Semiconductors:

D2, D3 - 100V Zener, 1W, 5% tolerance - selected to $\pm 1\%$ @ 2mA if possible, 1N4764A.

D4, D5 - 1N4002

BR1 - Bridge Rectifier, 600PIV, 2 - 6A GI GBU06

BR2, BR3 - Bridge Rectifier, 200PIV, 6A, GI GBU02

Q1 - 2N3906

Q2 - 2N3904

VR1 - LTC-1083/4/5CK

Sockets:

2 - Octal, chassis mount, ceramic or mfpe...

2 - B9A, miniature, 9 pin, mfpe...

Main Power Transformer (T1):

KTA #834171: 400VCT @ 250mA, 5.0V @ 3A, 6.3V @ 5.0A, 6.3V @ 450mA

Chicago PC8413; 400VCT @ 250mA, 5.0VCT @ 3A, 6.3VCT @ 5.0A

Hammond 278X; 400VCT @ 200mA, 5.0VCT @ 3A, 6.3V @ 6.0A

Bias/Filament Transformer (T2):

KTA #834172: 220VAC @ 40mA, 5.0VCT @ 2A, 5.0VCT @ 2A, 6.3V @ 300mA, 6.3V @ 600mA, 10.0V @ 2.0A

Choke (L1):

KTA #833939: 5H, 250mA, 50 Ω

5H, 200mA, 65 Ω Hammond 193H



