The 300B as Regulator

The 300B has justly won the reputation for being a superb output tube in single-ended amplifiers. Of course, it actually has a much wider application, such as a push-pull amplifier's output tube and possibly as a headphone amplifier tube or super-buffed line stage tube. But it will take some rethinking to imagine this great tube in a non-audio role. It is sort of like trying to imagine Arnold Schwarzenegger playing Goethe: sure he has the accent, but are the biceps really necessary or even desirable?

The pluses the 300B brings to a voltage regulator is its ability to pass a fair amount of current at low cathode-to-plate voltages, the result of having a low rp. And its 40 watt plate dissipation limit does not hurt either. An advantage few would highlight, however, is its 5 volt heater specification. Why would this count as an advantage? Most high voltage power transformers retain a 5 vac winding for heating a tube rectifier. Rectifiers with rare exception require a floating 5 volt power supply. Had rectifiers used the same nominal 6.3 volts that most tubes use, many would be tempted to attach the rectifier's heater to the common 6.3 vac winding that is referenced to ground. This would spell catastrophe, as the isolation material the separates the heater from the cathode cannot withstand more than 100 volts in most tubes; in fact, most indirectly heated rectifiers have the one leg of the heater element connected to the cathode and thus have a 0 volt heater-to-cathode voltage limit. And those rectifiers that use directly heated cathodes would obviously also short the high-voltage to ground! Choosing 5 volts for rectifiers was a wise decision. Coincidentally, the 300B uses a 5 volt heater. This heater voltage allows us to use the often free 5 vac winding, free because solid-state rectifiers were used instead. (Solid-state rectifiers result in a higher power supply voltage and a much low power supply impedance. High speed rectifiers do perform much better than the slower variety and are heartedly recommended.)

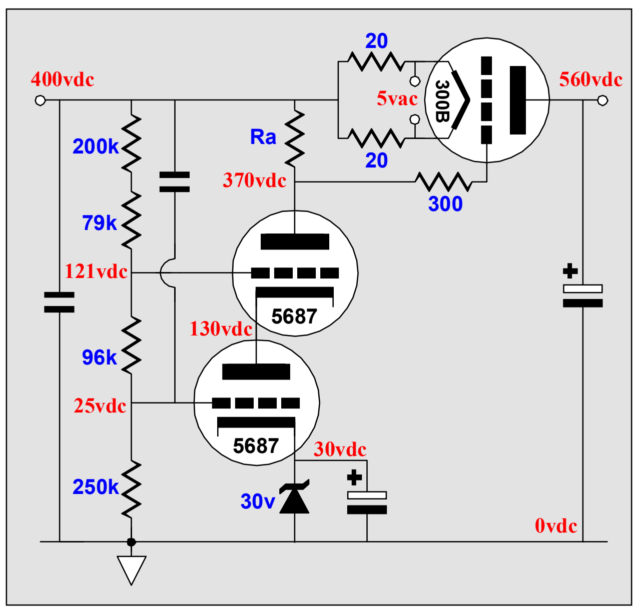
Of course, if a tube rectifier is used, the 300B will require its own separate heater transformer.

The last advantage to the 300B as a regulator tube is its low price. What? Aren't NOS WE 300Bs going for up to $700 each? Yes they are, but Chinese 300Bs can be had for under $60. So from a dissipation watt per dollar basis, these tube can be seen as cost effective.

Series Regulators

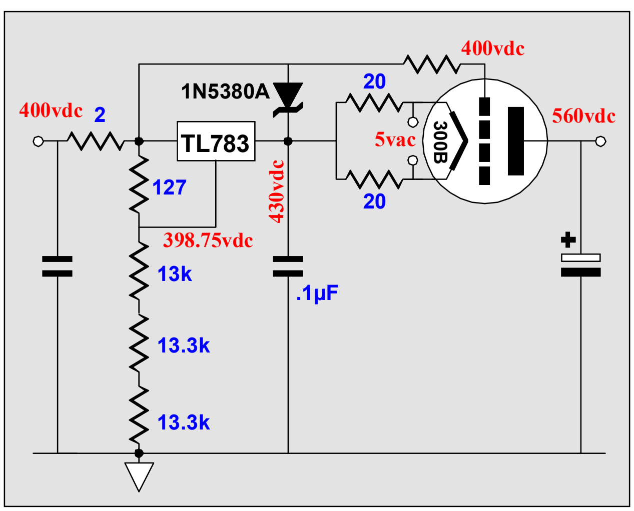
The difference between the series and the shunt regulator has been covered in past issues. So only the briefest recap is given on how each regulator type works. The series regulator is best suited to applications that have a varying current draw, such as a Class-AB, B amplifier. The pass device, the 300B in this case, sees all of the current flowing into the load, which sets a current limit of 100 mA per 300B. A feedback mechanism and a voltage reference are all that is needed to complete the regulator.

The circuit below uses a 5687 as the main feedback mechanism and a zener for the voltage reference.



The cascode circuit provides a relatively high gain and only draws 4.7 mA of current. The value of resistor Ra is determined by the finding of the required negative grid voltage for the 300B at the given cathode-to-plate voltage and desired idle current and then taking this voltage and dividing it by 0.0047. For example, if the cathode-to-plate voltage is 150 volts and the total idle current draw through the 300B is 105 mA (the cascode's current draw must be added), then the 300B needs to see –12.5 volts, thus Ra must equal 12.5/0.0047 = 2660 ohms. The best move would be to replace the plate resistor Ra with a constant current source, as a current source will help realize much more gain. A tube current source is not possible here, but a FET current source such as the 1N5314 or CRO-470 will work well.

Since adding a solid-state current source has cracked the hybrid door ajar, let's swing it wide open. Texas Instruments makes a great little three pin adjustable regulator with a 125 volt input-to-output voltage limit, the TL783, which houses a MOSFET pass device. Using this regulator in series with the 300B gives us the best of both technologies, the TL783 is quiet and accurate and the 300B is high-voltage tough. The principle of operation is simple enough. The 3 pin regulator strives to maintain a constant voltage output by increase and decrease its conduction. As the TL783 responds to voltage fluctuations at its output, the 300B sees a varying cathode-to-grid voltage, which allows the 300B to track the IC regulator.

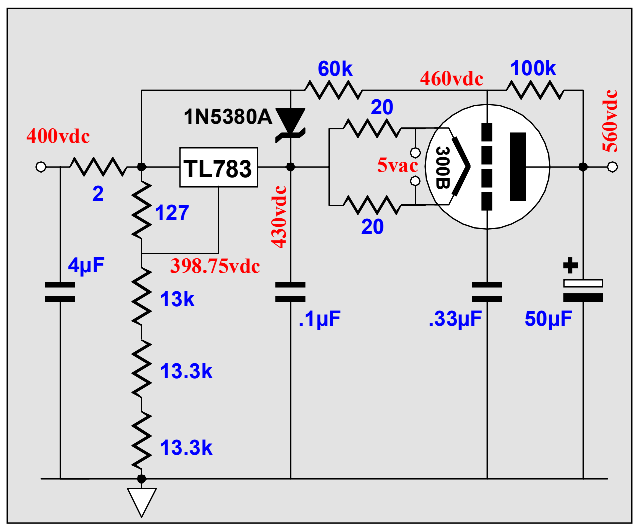


The zener provides a discharge path for the output capacitor and a means of protecting the IC in the event of an over-voltage from short-circuits and a blown fuse.

One problem with this circuit is the input-to-output dropout voltage limit for the IC regulator. In order for TL783 to work, it needs to see at least 10 volts across its leads at 100 mA of current draw. This means that the 300B's grid can only get to within –10 volt of its cathode, which will impose a dropout voltage of 125vdc. Not that much headroom, in other words. Only a 5% drop in the 560 volt power supply can be allowed before the regulator starts to complain. Of course, the lower the total current passed, the smaller the dropout voltage. For example, at 50 mA, the raw power supply can drop 11%, without the regulator falling out of regulation. Still the –10 volt grid voltage sets limit.

The solution is to pre-bias the grid positively so that a o volt or even a positive grid voltage is possible. The circuit below shows one way to achieve this end.

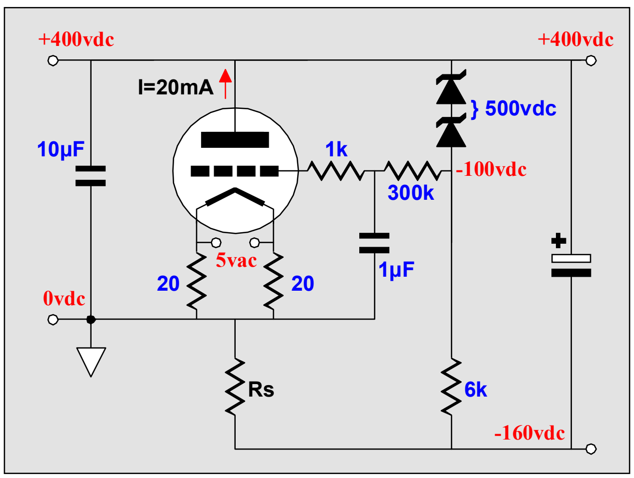
Now the raw power supply voltage can drop 20% from its nominal 560vdc value and the regulator will still maintain regulation.



For greater than 100 mA loads, the 60k resistor that connects to the 300B's grid can be replaced with a 20 volt zener; the .33 capacitor is removed; and the 100k resistor is replaced with a high wattage 1k resistor. This setup delivers the bulk of the output current from the zener and the 1k resistor's path. The 300B handles the difference. Such a only works well when the load current never drops below a threshold value; in this case, it is about 130 mA.

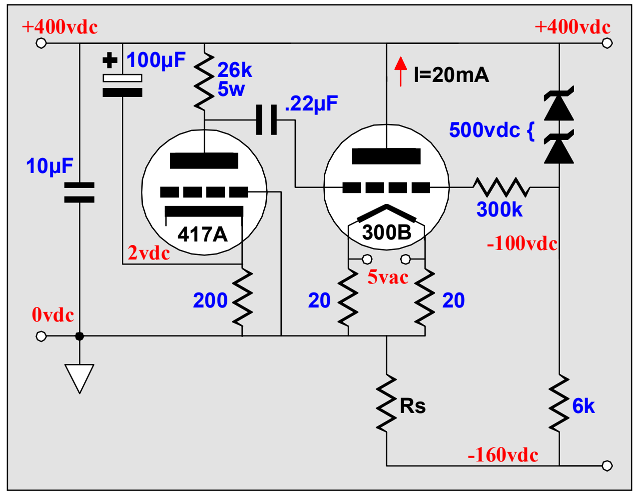
Shunt 300B Regulators

All the advantages that the 300B brought to the series regulator it also brings to the shunt regulator. The shunt regulator works best with load currents that remain mostly fixed, such as single-ended amplifiers and push-pull Class-A amplifiers. The problem the shunt pass device faces is that it must see the whole voltage differential that the load sees. This will greatly decrease the maximum cathode current the 300B can draw. Given the 40 watt dissipation and a 400 volt cathode-to-plate voltage, the maximum current is 100 mA. This 100 mA limit is not maximum idle current. 50 mA is closer to the real maximum idle current, as the shunt pass device must vary its conduction through the series resistor is what makes the shunt regulator to work.



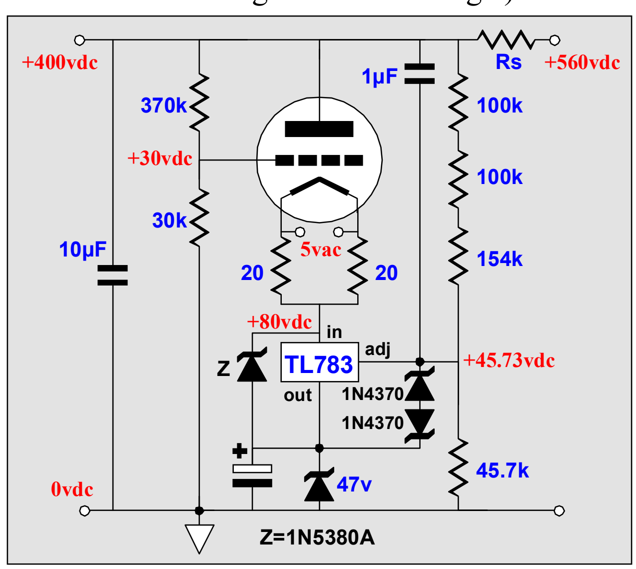
The circuit above is an example of an inverted shunt regulator. The zener works as the voltage reference. The 300B's transconductance provides the feedback mechanism to maintain the output voltage. Unfortunately, the regulator is poor due to the 300B limited transconductance.

Improving the regulation requires more gain, which the 417A provides plentifully, in the following circuit. The 100 µF capacitor relays deviations at the output to the cathode of the 417A, which is then is in phase amplified at its plate. The plate's connection to the 300B's grid via the coupling capacitor is what drives this regulator.



Taking the hybrid route is tougher to accomplish than it was in the series regulator. Because of the high idle current, the TL431, the obvious choice, is not useable.

(One trick might be to use the TL783 in an wildly different configuration. I have not actually built this shunt regulator, so no guarantees are offered. But the premise seems reasonable enough: the TL783 is controlling the current through the 300B. If the output voltage climbs higher than 400 volts, the TL783's adjustment pin sees a voltage closer to its output pin's voltage. As far is the TL783 is concerned, the output voltage is collapsing so it increases its conduction to compensate for the dropping output voltage. This increased conduction will increase the voltage drop across the shunt resistor Rs and bring down the voltage.)



(Should the output voltage drop instead, the TL783's conduction eases up and the regulator's output voltage climbs with the decreased voltage drop across resistor Rs.)

(The output of the TL783 cannot be sent directly ground, as the adjustment pin must see a voltage 1.27 volts lower than its output. Thus the role of the 47 volt zener. It brings the TL783's output up to 47 volts above ground. A further advantage to using the zener is that it allows for higher voltage dropping resistors that relay the regulator's output voltage to the adjustment pin. The two 1N4370 zeners are there to protect the TL783's adjustment pin from high-voltage spikes.

The 1µF capacitor might not be a good idea, as the zeners might prove too slow to save the TL783. Actually, in this circuit and all the other hybrid regulators, avoid over designing. For example, do not eliminate the 2 ohm resistor at the output or decide to shunt the adjustment pin to ground in the series regulators by adding a capacitor. High-voltages kill solid-state devices easily.

Conclusion

The 300B has a potentially wider use than just a single-ended output tube. High-voltage regulator pass device is just one possibility.

Of course other tubes could be used, such as a triode connected 6550. But having a 300B based regulator would be just too delicious to pass up.

If anyone tries any of these circuits, please send the results in to share with all of us.

//JRB

