18 January 2005

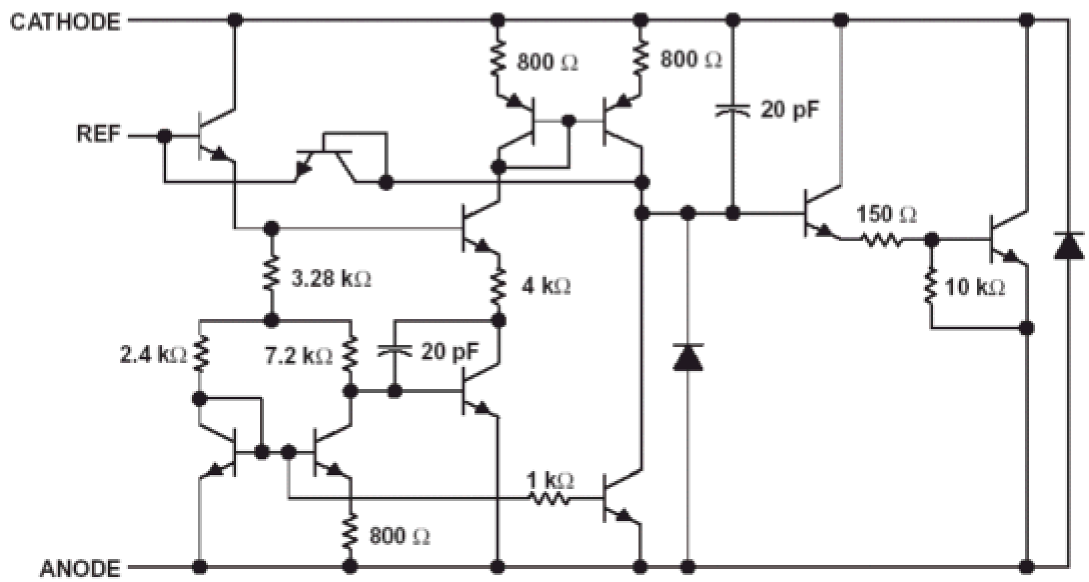
T-Rex

Dick Olsher has created a mighty 300B amplifier: the T-Rex (Transformer King, in other words, as the amplifier uses Plitron toroidal output transformers, power transformers, and chokes). Steve Bench and myself have lent a helping hand and the DIY article is available at Enjoy the Music.com. The T-Rex is big, complex, and expensive. It certainly isn't your father's 300B amplifier. And few will have the resources to build the T-Rex, but then the T-Rex is not a Volks-amplifier. I see it as being much like a concept car at an auto show, something that inspires, rather than something to buy in a corner auto lot. I highly recommend that you give the article a read, as it is explanation filled, explaining how shunt regulators and partial feedback are used in the amplifier's design.

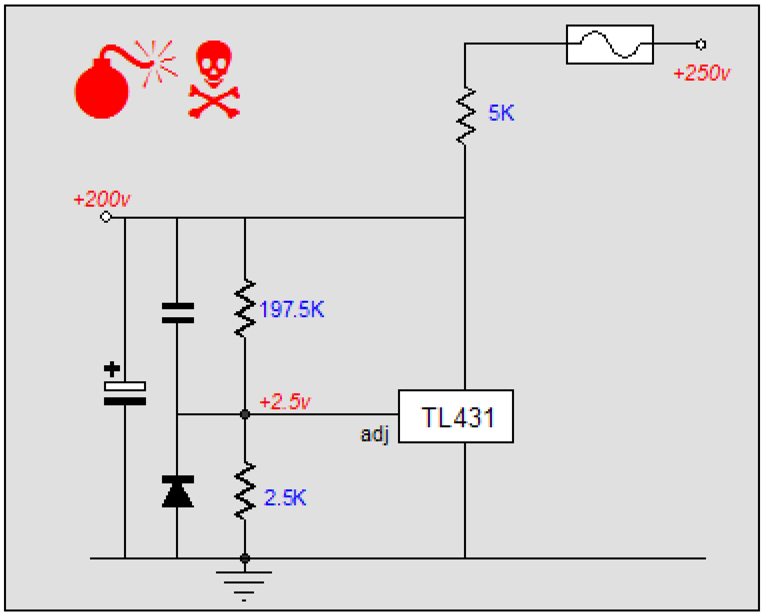
(Enjoy the Music took a big gamble in publishing this article, as the site is not a DIY site and this is not a trivial 300B, so be sure to check the article out to let them know that high-standard DIY tube projects are worth the effort.)

Shunt Regulators

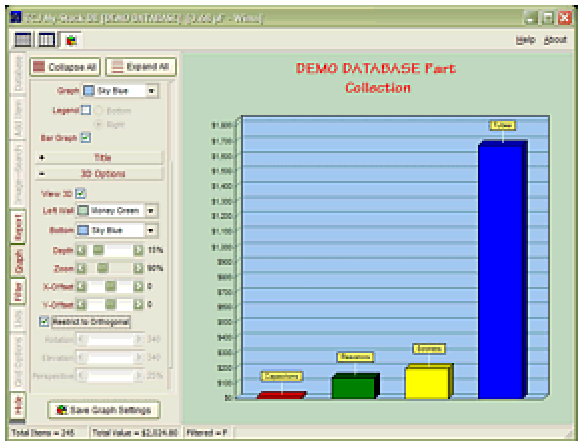
I must get at least five e-mails a week regarding the shunt regulator. It is popular, but little understood (hence its popularity?). One reason behind its new-found acceptance is the TL431 shunt regulator IC. This small three-pin IC is almost perfect in the eyes of many tube fanciers. Now, if it held only two leads it would be perfect, as I have found that tube folk like their solid-state simple, not internally simple (the TL431 holds scores of solid-state parts), but simple on the outside; and two leads are simpler than three leads; eight leaded ICs are undesirably and unthinkably complex, even if they only hold one diode. For example, if I recommend using the circuit below, many would just shake their heads in disbelief at my clumsy attempts to smuggle in solid-state devices into the pure-tube sanctuary. "As if I would ever let so many transistors get in the signal path of my RCA NOS 2A3!"

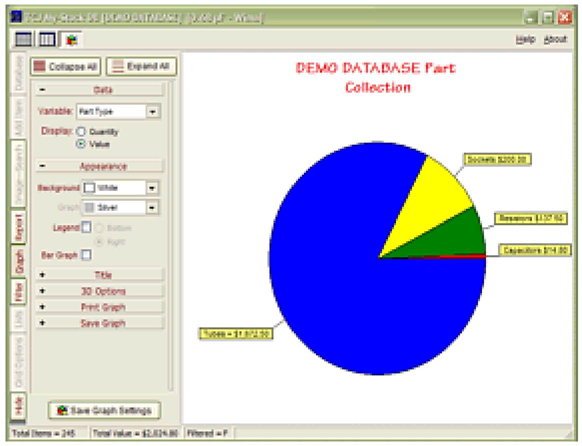


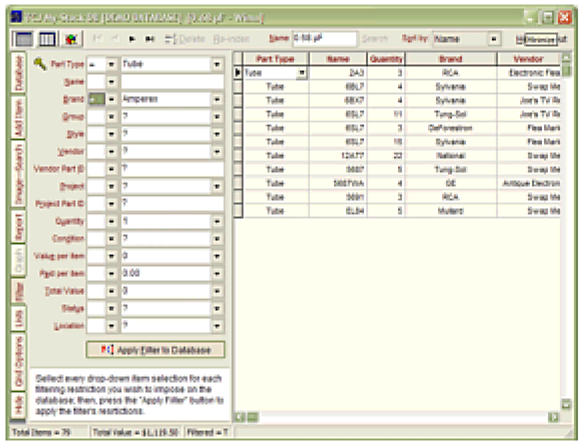
The only problem is—albeit a small problem, but a problem nonetheless—the schematic above is the TL431's internal schematic. As great as the TL431 might be, many ask too much of it, either demanding it withstand too much voltage or draw too much current. The TL431 can only withstand 36 volts, so the circuit below is definitely a bad idea.



The TL431 can only source up to 100mA, so the circuit below is equally a bad idea.







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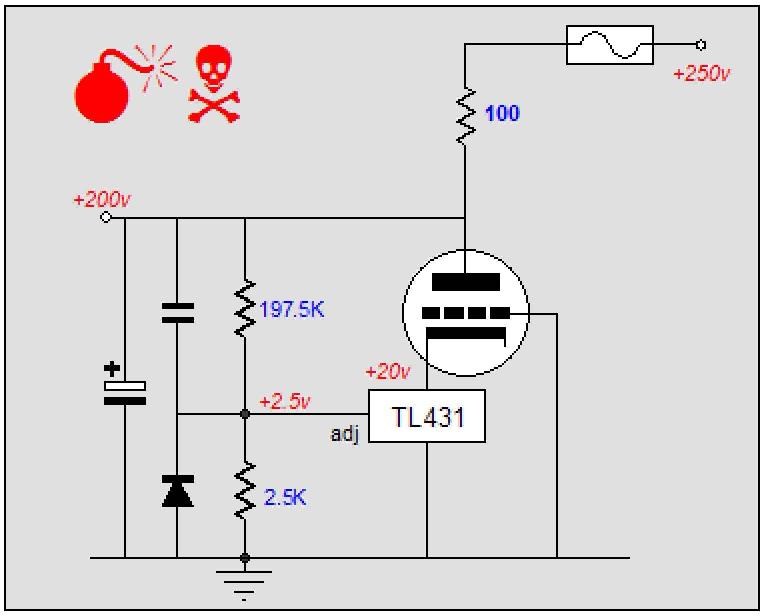


Absolute Maximum Ratings

(Operating temperature range applies unless otherwise specified.)

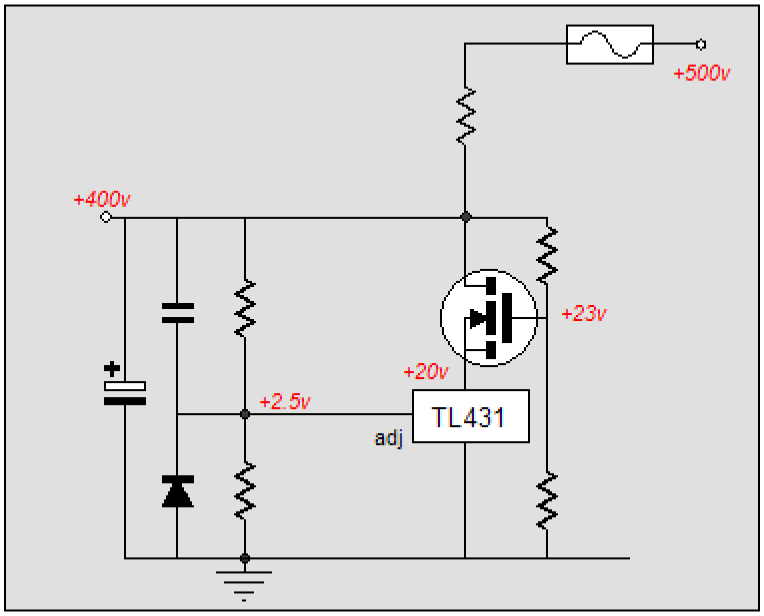
Parameter	Symbol	Value	Unit
Cathode Voltage	V_{KA}	37	V
Cathode Current Range (Continuous)	I_{KA}	-100 ~ +150	mA
Reference Input Current Range	I_{REF}	-0.05 ~ +10	mA
Power Dissipation D, LP Suffix Package P Suffix Package	P_D	770 1000	mW mW
Operating Temperature Range	T_{OPR}	-25 ~ +85	°C
Junction Temperature	T_J	150	°C
Storage Temperature Range	T_{STG}	-65 ~ +150	°C

Recommended Operating Conditions

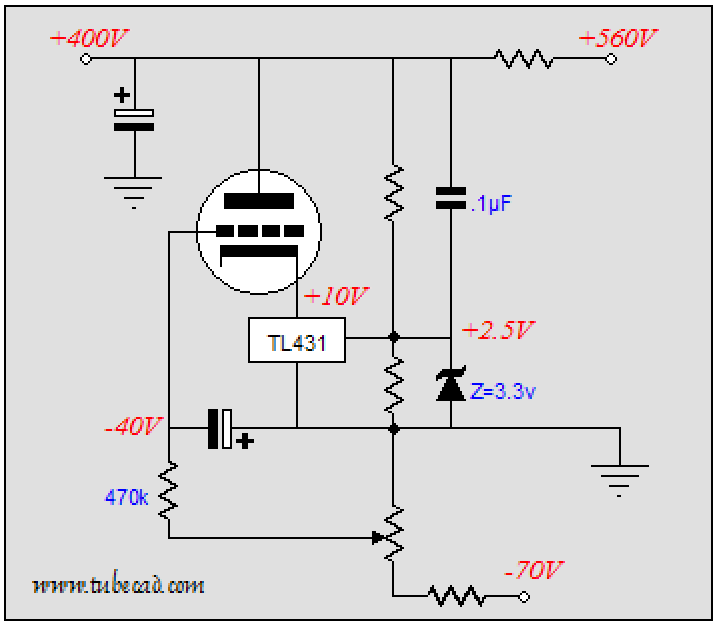
Parameter	Symbol	Min	Typ	Max	Unit
Cathode Voltage	V_{KA}	V_{REF}	-	36	V
Cathode Current	I_{KA}	1.0	-	100	mA

The above table was lifted from the Fairchild TL431A PDF and it lists the limits within which the device will operate. Note, the TL431 cannot see 36 volts across its leads and draw 100mA at the same time, as that would result in 3.6 watts of dissipation, far more than the 770mW that it can withstand. (Also note that 770mW limit is at a cool 30 c and must be derated for higher temperatures.)

Extending the TL431's voltage limit is easy enough, as we can cascode the TL431 with either a tube or a transistor or a MOSFET (placing a zener in series with it is neither safe nor desirable). Above we saw a tube sitting atop the Tl431; below, a high-voltage MOSFET.

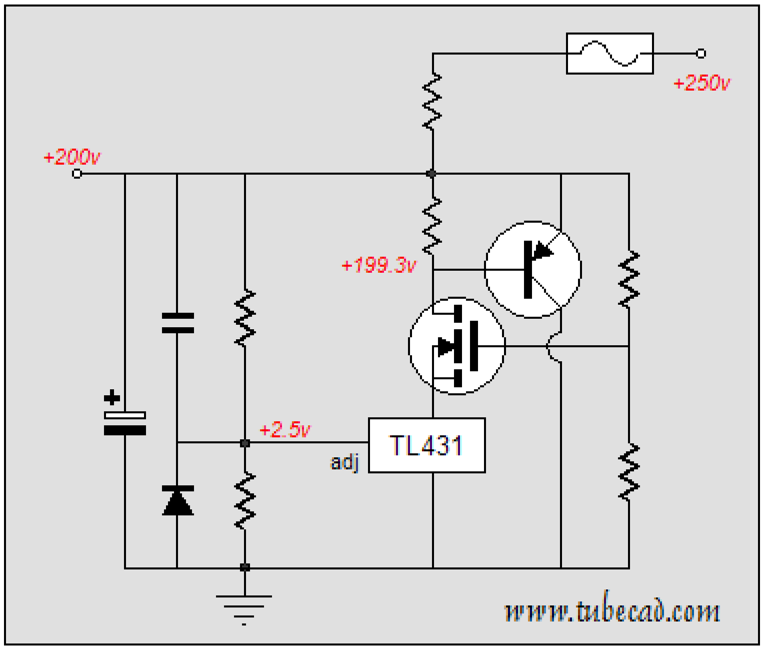


The potential problem with the tube-based hybrid shunt regulator is that at turn-on the tube's cathode is cold and not conducting, which means no voltage regulator until it is hot. Second, the triode might require a much larger negative bias voltage than the TL431's 36 volt limit. The workaround is to use a negative power supply connection to help bias the triode.

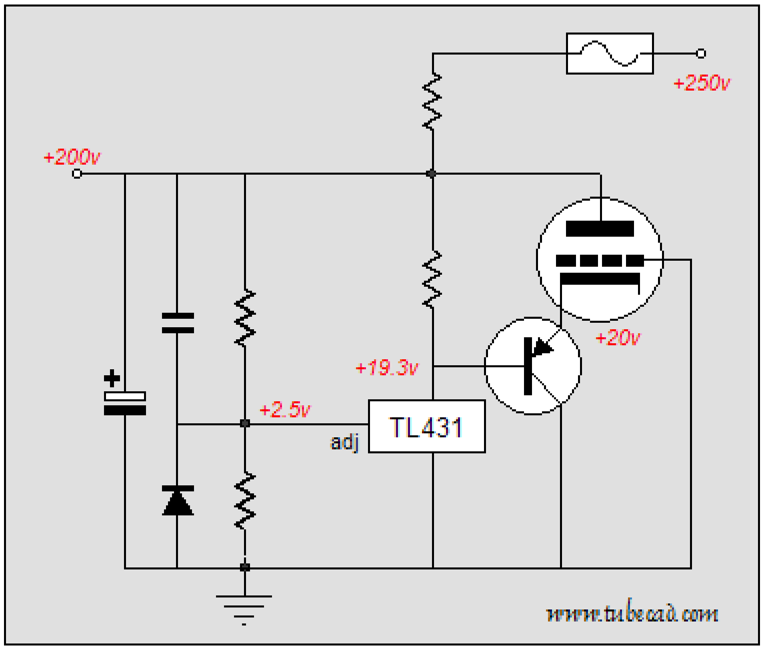


Here the triode sees a –50 volts grid-to-cathode bias voltage, while the TL431 only sees a 10 volt differential. (The optimal anode-to-cathode voltage for the TL431 would equal (36V – 2.5V) / 2 + 2.5V, as it would allow the greatest cathode swing on the TL431.)

Increasing the current capability of the TL431 is also easily accomplished with more parts.)



Or

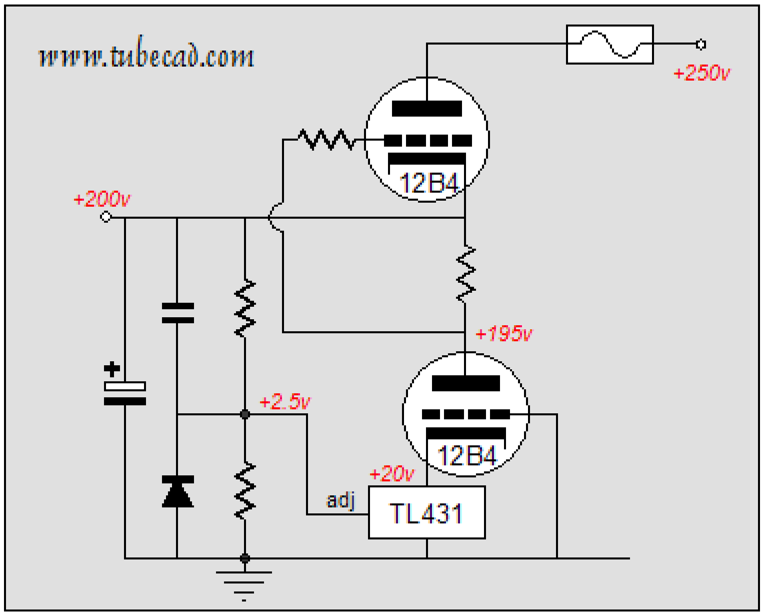


One common mistake is to ask the control element of a shunt regulator (the TL431 in this case) to draw too much current. For example, let's say you have a phono preamp that draws a total of 40mA, How much current should the TL431 draw? 90% of readers will answer 40mA, but in fact, much less is needed. Consider this: the preamp only puts 1V of output signal, which into a 100K potentiometer only equals 0.01mA of current variation.

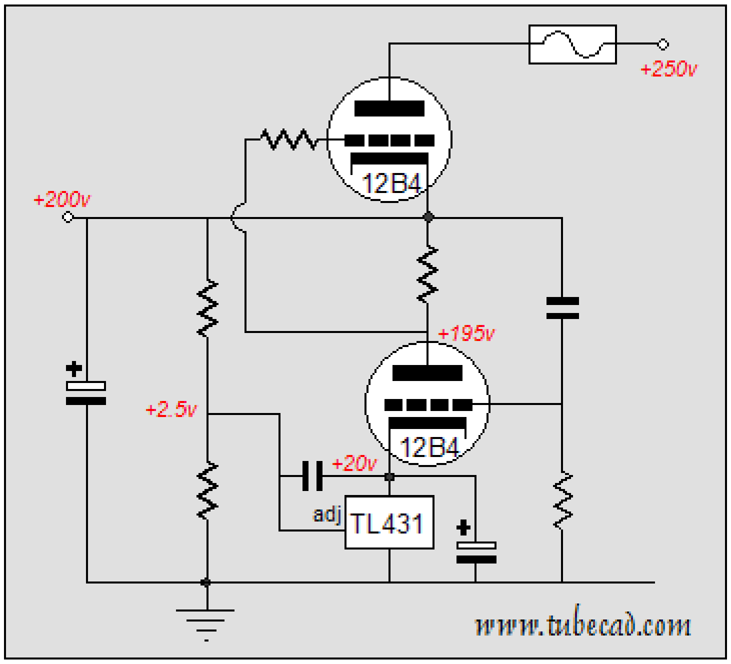
If the load draws a fairly steady current, as single ended circuits and class-A output stages tend to do, then the shunt regulator need only make up the delta in current draw between minimum and maximum, plus whatever wall voltage fluctuations that must be compensated. In other words, 40mA is way too much current, as a total (shunt regulator and load) current draw of 60mA would probably be more than sufficient.

SRPP shunt regulators

Here's a circuit to ponder: an SRPP shunt regulator. The TL431 is cascoded with a 12B4 triode, which in turn drives another 12B4. This regulator can source and sink current, as it comprises a shunt and series regulator.

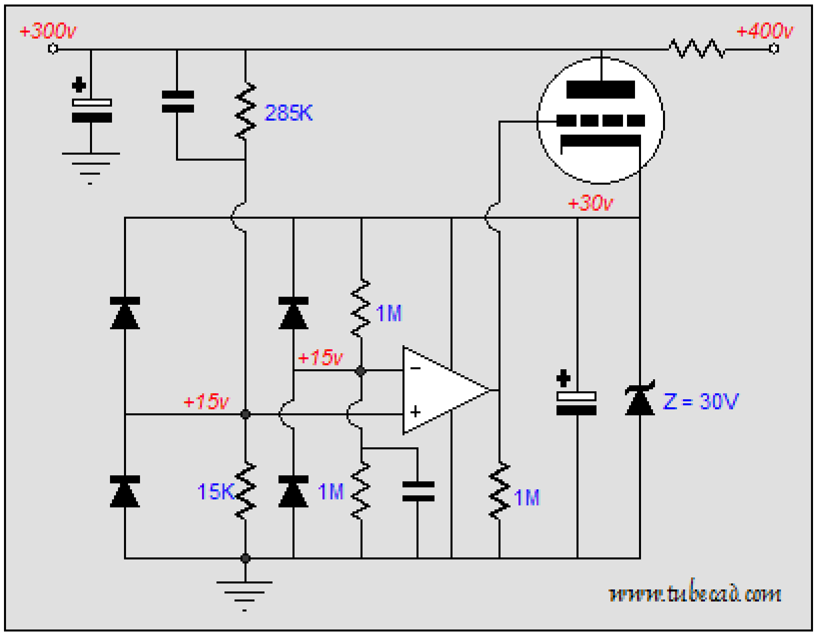


For some, the thought of letting a IC control the output of the shunt regulator is as scary as letting a IC control the sound coming out of a tube amplifier. The circuit below uses the TL431 to adjust the DC output voltage of the regulator, while the 12B4s control the AC output of the regulator.



TL431-less shunt regulator

What if all the TL431's internal functions were handled by discrete devices, devices that exhibited much higher performance? Such a circuit would look much like the one below.



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