Thread about an electronic plate load for testing power tubes and more
1/9/22 Posted by Steve Lafferty, Tronola.com
Supplement for the Reader Comments section of the article, "How to Test Power Tubes with Common Lab Gear"

January 2nd, 2022: Dmitriy G. ("grindfix") posted, asking for more info after I mentioned, "What I really had in mind was building an electronic load, which would let me set RL accurately with low-level resistors and leave the power dissipation in a beefy MOSFET. I can elaborate on that if you wish..." That started this email thread. Since it may be useful for other readers. Dmitriy kindly agreed to let us publish it. Some parts may be edited or deleted for clarity or brevity. This is in presented in bottom-posting order (forward in time) in contrast to the top-posting order used by the Reader Comments software. Dmitriy's text is in dark blue color.

"I can elaborate on that if you wish..."
Please, if you don't mind. I don't have any 6550 to work with but would like to make the tester versatile and include the most common tube types. I have a bunch of 6BQ5 types to go through and for the moment rheostat should work but if you have a Mosfet circuit to share, I'd like to consider it.
Thanks for your help!

Hi Grindfix, Happy to help. I will gather-up what I have on the electronic RL and post that here either later today or tomorrow. Yes, the rheostat should be fine for the 6BQ5.
Steve

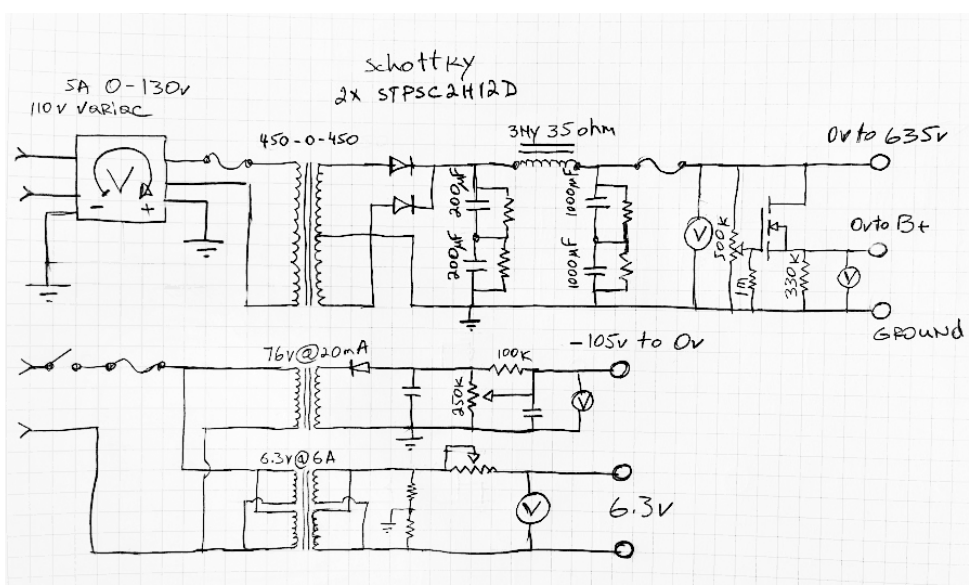
Hi Steve,
Happy New Year!

I'm an auto repair tech with an understanding of most electrical and basic electronic circuits.
I can and I have built several tube amplifiers with help of the AK community. I can follow the circuit diagram, build it on the perf board, or point to point, but I cannot (yet) design my own circuit. Most of the time, I have enough skills to understand and modify existing circuits to tailor the response, stability, or gain I'm looking for.

I recently acquired around 300 NOS Soviet tubes and wanted to be able to see what I got, besides testing my stash of old used tubes. I own a Hickok 533 but I'm sure you know the limitations.
I wandered onto your tube test publication while mulling ideas to build a tester that would allow me to test tubes at real-world voltages and be able to see what current flows through the tube at idle for matching purposes. This project evolved to include a full power test. I'm very grateful to all who helped me with ideas but since you know and probably used Dave's custom tester, I decided to ask you a few questions.

During the troubleshooting of one of my previous builds, I knocked together a remote power supply in the aluminum drawer that came out of HP tape library. I never finished it to be a real bench supply but now it will be combined, bench supply and tube tester in one chassis. I doubt that I'd need to use them both at the same time.

Here is my idea of the power supply for this tester (**at right**):



Questions that I have at the moment, besides the design of the RL:

1. I plan to include 100ohm stability resistors at each tube socket screen pin. Good or bad?
2. Question on using filament transformer at the output of SS amp. I have 6.3v / 2A filament transformer. Its secondary measures around 0.5ohm. Can it be safely connected across the output of an amp with 8ohm minimum impedance? I suspect that since the transformer is an inductive device and impedance will match the amp output requirements once current is flowing, but just wanted to be sure and ask.
3. In the top picture of your article, "rats nest" of DUT connections... Any suggestions on how to wire several parallel tube sockets for different tube types and to avoid interference? I know that the screen stopper should be as close to the screen pin as possible. How close should scope test points be to the tube socket? Can those points be shared between parallel tube sockets? One tube tested at the time, of course.

I may have additional questions if you don't mind.
Thank you for your help!
Dmitriy G.
Owner/ASE Certified Master Technician
Fogle's Automotive Service

Hi Dmitriy,
And Happy New Year to you!

- Well, it seems you have a good background to build the electronic load, if you wish. Thank you for letting me know.
- The power supply schematic you included seems workable. There is a lot to be said for keeping things simple. About the mosfet circuit: You probably already know this but note that due to the 635V range, the 330K, 1M and 500K pot will need to be rated at higher power than what the article discussed. I get actual dissipations of 1.2W, 0.4W and 0.8W respectively, so of course, their ratings should be twice that or better. I don't think the 1M resistor is needed but maybe you have a special reason for it. Personally, I would miss having a regulated heater voltage...
- **I plan to include 100ohm stability resistors at each tube socket screen pin. Good or bad?** This of course presumes the screen pin is fixed for a particular socket. If that's okay, it should work. But tubes can also oscillate due to parasitics with the plate and grid pins. For that reason, I would encourage using ferrite beads at each socket pin. They're pretty cheap, only affect RF and are excellent at suppressing oscillation. There is no significant resistance at low frequencies. You can find the ones I used at the end of the BOM for the Vacuum Tube Analyzer (**VTA**). http://www.tronola.com/Vacuum_Tube_Analyzer_BOM.pdf
- **Question on using filament transformer at the output of SS amp...I have 6.3v / 2A filament transformer...Can it be safely connected across the output of an amp with 8ohm minimum impedance?** Yes, that should work. Naturally, you would want to avoid accidentally high levels from the amp. Should only take a few volts or less of drive.
- **Any suggestions on how to wire several parallel tube sockets for different tube types and to avoid interference? How close should scope test points be to the tube socket? Can those points be shared between parallel tube sockets?** With beads at each tube pin, there shouldn't be much to worry from multiple sockets and test points. After all, the test signal is just 1kHz or so. The main suggestion I would make is to use the thinner-insulation (600V) wire that I discovered for rewiring the VTA. The thinner wire allowed me to wire the sockets in parallel MUCH more directly. That drastically reduced wire length and parasitic capacitance. If you look at slide-44 of the VTA gallery, you can see the original 600V wire and the new wire. http://www.tronola.com/vtagallery/vtagallery.htm [After opening the gallery, press End and hit the left-arrow key 4 times.] Incidentally, this wire insulation is also immune to shrink-back and resists a brief touch from a soldering iron. You can find it in the VTA BOM linked above--search for "hook". Unfortunately, I see that Mouser is out of it at the moment but you may find enough info on the product page to locate it elsewhere. The secret is polyolefin insulation with a very thin coating of PTFE.

I'll try to get the info out on the electronic load tomorrow.
Best Regards,
Steve

Hi Steve,

Very nice looking build! Very impressive! I don't think I have enough time to grow up to learn electronics at that level. :-)

1M resistor was just in case the pot wiper loses contact. But I think if that happens screen will get 0v from the Mosfet and no current will flow through the DUT, correct?
A regulated heater supply would be nice. Do you happen to have a schematic in mind that would work with my existing Hammond 266M12 filament transformer?

Ferrite beads are something totally new to me. I understand the reason. All socket pins except heater leads, right? Why are you suggesting using different ones by the socket type?

I found TE Connectivity wire 400R0111-22-9 at Arrow under TE internal number from their site. Here is the link to the page: https://www.te.com/usa-en/product-EG8799-000.html

Thanks for your help!

Dmitriy G.

Thanks, Dmitriy.

I see what you're after with the 1M resistor. And those of us who have dealt with vintage equipment may well have seen cases of flaky wiper contact. If the wiper truly goes "open," that leaves the gate floating of course. While the gate-source capacitance will hold it for a while, surface leakage on the PCB could drag the gate up to the drain voltage. On the other hand, at these voltages, the 1M would need to be rated at 1W. The pot will have a load, without which it would need to be rated at 2W. With the load, I will guess that it might need to a 3W rating. That's possible but all this is making things rather (shall we say) heavyset. My vision is to contrast this with the fact that I've never seen an open wiper in modern equipment and leaving out the 1M simplifies things. But I totally understand if you would feel better with the 1M.

> A regulated heater supply would be nice. Do you happen to have a schematic in mind that would work with my existing Hammond 266M12 filament transformer?

--- IF you are open to using a switcher module, that is the best solution which comes to mind for this heater supply. However, some tube enthusiasts would hold up a Cross and scream, "back," "back" at the mention of such. But I found the switcher solution by far the best approach for a heater supply for both the VTA and the uTracer/HR projects which I did. A problem for trying to get regulated 6.3VDC at 6A from a 6.3VAC at 6A transformer is the fact that a capacitor-input supply draws spikes of current at each half-cycle. That taxes the transformer more so than a continuous load. In fact, the classic factor used is that you need a transformer whose AC current rating is 1.8X the DC current you expect to get. That factor is in addition to the losses in the regulator and other things. A conventional regulated supply might waste 50% of the power passing through.

A switcher efficiently uses the 7.5VDC or so that you would get from rectifying and filtering the 6.3VAC to produce the regulated 6.3VDC. It wastes typically 10-15% of the power delivered. If you are concerned about switcher noise (which I don't think is much of an issue for tube testing) you can add extra LC filtering at the DC input and output of the switcher but I doubt that's needed in this case. The key to keeping it simple and easy is to buy a prepackaged switcher. These are available from places like Mouser, Jameco and eBay. Here are three examples you might find interesting:

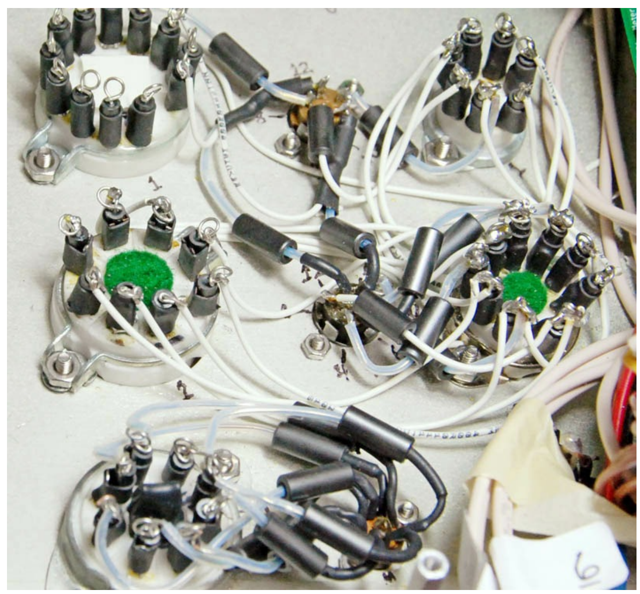
- Art Grannell's article on Tronola where he uses a 12V switcher to power pairs of tube heaters in series. He also discusses using a 7.5V unit to provide 6.3V and covers the startup issues. http://www.tronola.com/html/unique_tube_heater_supply.html
- My Tronola article featuring a custom-designed switcher for the uTracer/HR. It's built around a cheap, eBay-sourced module which claims 5A output. This demonstrates using external filtering on input and output. http://www.tronola.com/html/tube_analyzer_you_can_build_page1.html#HRB-intro
- The cheaper solution which Big Josh published in answer to my "Cadillac" article. https://groups.google.com/g/utracer/c/3G-K6epmvRY I mention this to highlight the nice $36 switcher module you can get on Amazon, complete with current and voltage readouts.

The ones mentioned might be limited to 5A at best but if you really need 6A, you may be able to find beefier modules. The one I did for the uTracer can do 5A for a limited time but I rated it at 3A for continuous use. Note that a switcher truly transforms the power, meaning that if 12VDC is going in and the load is at 6VDC 2A, input current is about 1A (plus 10-15% for losses). Magic :)

> Ferrite beads are something totally new to me. I understand the reason. All socket pins except heater leads, right? Why are you suggesting using different ones by the socket type?

--- Mostly for physical reasons. I didn't have space in the article to go into the manufacturing design for adding the beads to the existing physical layout. There were up to 5 connections going to socket pins. Having the beads spread out around the sockets was out of the question due to space. I was also limited on what I could do vertically because the main PCB is mounted under the sockets. Other than physical size, I went for the higher resistances. (The resistance only appears at high frequencies. Otherwise, it's just a short piece of wire.)

So it was a struggle to fit the space requirements, make it sturdy and accommodate up to 5 connections. As I recall, the sleeve beads were larger for a given resistance but they could work with some of the existing (intricate) wiring on the tiny sockets. Some sleeve beads needs a larger hole to accommodate the original 600V wire but that reduced their resistance. The leaded beads worked well with the physical design I developed for the larger sockets. You can see it best at the 8-pin octal socket in the attached photo [**at right**]. It's at left, in the middle, vertically. Socket pins were cut to about 1/4" (6mm). The bottom lead of the bead is soldered to the pin, at the bottom, next to the socket. Shrink wrap is added around the bead and pin. The top lead is formed into a loop.



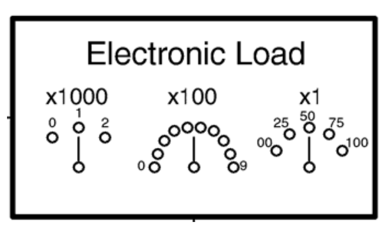
Thank you for the link to the TE wire! I was afraid it would be hard to find. I really need to update the article I did about better quality hookup wire to feature this product. Unlike pure PTFE insulation, it's easy to strip, yet it has the excellent thermal properties. That works with the small diameter to allow, for the first time, leads to be safely routed between socket pins. That greatly reduced parasitics, as you saw in slide-44 of the VTA gallery. The highest capacitance on a pin line went from 166pF to 74pF.

Dmitriy, I apologize that I've taken too much time on this letter and that means the info on the electronic load will have to be tomorrow.

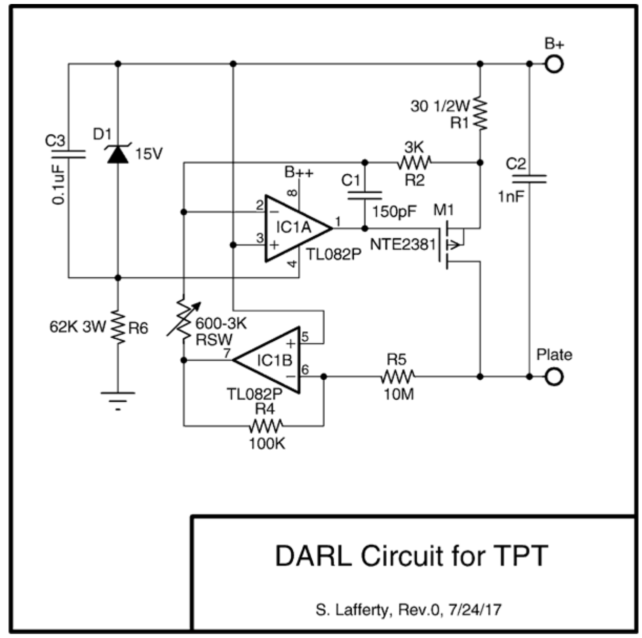
All the best,
Steve

Hi Dmitriy,
I have attached the concept schematic for the electronic load. [**on next page**] Some points about that:

- It's called the DARL circuit, which stands for Digital Active RL. (The only thing which is digital about it is that the value of RL is set with digits.)
- This hasn't been thoroughly tested in the lab, so should be considered experimental.
- The purpose is to accurately simulate a plate load resistor (RL) from B+ to the Plate terminal, which goes to the device (tube) under test (DUT).
- MOSFET M1 dissipates the power which a real RL would.
- The resistance of the simulated resistor will be the same as the resistance of RSW. If precision resistors are used, the effective RL will be very accurate and will not be subject to temperature drift from power dissipated in M1.
- RSW (which stands for "R switch") dissipates very little power. The idea is to implement RSW as three rotary switches which set the value as shown [**at right]**:

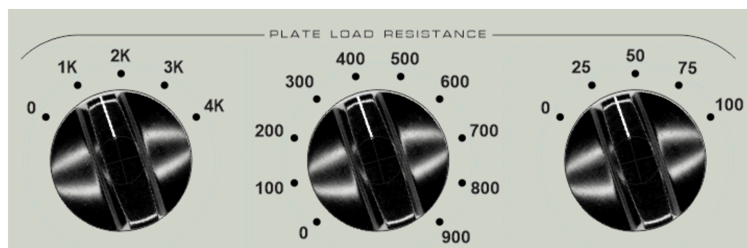


The first switch selects zero, 1K or 2K. The second selects 0, 100, 200...900 ohms. The third selects 0, 25, 50, 75 or 100ohms. The three are wired in series and become RSW. Of course you could choose other values. The planned front panel of a somewhat related project is also attached [**below right**], showing more range.



Note that the circuit requires a B++ voltage. That's a low-current +15V supply which is referenced to B+. I had in mind AC-coupling from the main power transformer with a small cap, rectifying and filtering. It just runs the opamp. The coupling cap drops most of the voltage without dissipating power.

Dmitriy, in looking at this, it strikes me that I don't know whether you are sufficiently comfortable with solid state circuits to pursue this. I would hate to lead you down a path fraught with frustration. And that's absolutely no reflection on your abilities! I'm in awe of your automotive service business and related technical capabilities. (I had my own small software business for many years and have great respect for anyone who has made a business work.) Anyway, the DARL circuit would require building a small breadboard and testing it with an oscilloscope, DMM, etc. Of course, I would be happy to help with any problems but remote trouble-shooting isn't easy and would depend on your skills.



Please let me know what you think. If you would like to pursue it, I will be happy to help all I can. If you would rather not, I totally understand will still have great respect for your accomplishments!

Best Regards,
Steve

PS: Adding one more thing: The DARL circuit was sketched for B+ = 400V. If it's going to be a lot higher, R6 and especially M1 need to be changed!

Hi Steve,

Thank you for your informative replies!
I love this hobby and people like yourself, Dave G, and several others I have interacted with since I got into this hobby about 5 years ago make it a more enjoyable and learning experience!

This doesn't look like a very complicated circuit to build but... This project started with repurposing the PT and 2 parallel chokes that used to be a part of the old Hammond organ tone cabinet. These components were quickly assembled into a narrow tape library storage drawer in order to troubleshoot my amp build. The problem I had was not PS-related and I discovered it later, after multiple different troubleshooting attempts, recommended by the circuit designer. The problem I had was a wild HF boost due to the huge inductive dummy loads I used. Though I haven't had this issue with previous builds using the same dummy resistors, I never used them since. Lesson learned. After I finished that amp, the remote PS box went on the shelf below my bench in the basement. I knew that one day I will need to either finish it into bench supply or convert it into something else. The recent tube lot acquisition prompted the tester project and I decided to combine the existing "Hammond" box with a test rig. I have another, matching narrow drawer that will be parallel bolted to the existing one to add additional components: built-in Variac, sockets, test and tap points, meters, pots...

I try to build amplifiers to be attractive looking but did not plan it for this piece of the test equipment from the start. It will be fairly rough and industrial-looking. I don't know yet how much room I have left for all the features I want to add. Realistically, I think I should set limits to this build and use it as a test-bed for the future, full-function featured tester in the appropriately configured chassis with proper PT that doesn't go into 700 plus volts DC when used with 110v Chinese Variac. Seriously, I plan to add a mechanical limit to the Variac knob so I don't accidentally bump it and blow PS caps. In an equalized series configuration, they are good for 630v max. I have selected 800v Mosfet for the screen supply divider instead of 600v one shown in your article.

For filaments, I ordered an assembled switcher supply with the display from Amazon. I think it will work great for tube testing. 5A peak sounds plenty. If I ever decide to use this "Hammond" apparatus for bench supply, I probably will need a traditional approach for filaments.

Back to RL. At this point, I'm not sure I have room for this additional stuff. Maybe.
I need to see what room I have left after fitting all panel meters and their PS. I have a circuit to consider. This adds another transformer and a small board with Fet and DC converters. Or, I can use a small wallwart adapter and small relays to switch the 9v battery supply to meters. I haven't decided yet.

I think I will install the 50w rheostat that I already have for now and will try to leave room for 3 switches if I decide to add your suggested circuit later. This 2.5k rheostat should be fine to use with 6P14P tubes. I have 170 of them!
A thought... Can 3 switches be replaced with a potentiometer with test points? To set resistance with a multimeter before powering the circuit? More work to set up and to prevent accidental knob bumping but the result can be more precise, no? I don't know if pot setting measurements will be skewed by circuit resistance through other devices though.

Magnavox amp 185

Hammond 7591 amp

Voice of Music 6BQ5 SE

Kevin Ward 6L6 Amp

Thank you again for participating in my project! I will report on my progress as I come along.

Below are a few pictures of my builds. All of them were learning curves for me and presented different challenges but the results are pleasing and rewarding. Proud moments for sure.

Be well!

Dmitriy G.

Hi Dmitriy,
I think that's a wise and practical idea, to use the rheostat for RL. It's so easy to get lured down a rabbit hole in this hobby! There's always another branch of the hole to explore and it's easy to forget that you're there to catch a rabbit :) It's heartwarming to hear that you've enjoyed your experience in the hobby.

> A thought... Can 3 switches be replaced with a potentiometer with test points? To set resistance with a multimeter before powering the circuit? More work to set up and to prevent accidental knob bumping but the result can be more precise, no? I don't know if pot setting measurements will be skewed by circuit resistance through other devices though.

--- Yes, you could do that but as you imply, it would be best to have a switch to open one side of the pot for resistance measurement. But that somewhat defeats the simplicity of using a pot. As far as precision is concerned, with the 3 switches, I had in mind making the 14 or so values precise. However, note that only the 2-3 values of the K-ohm switch are really critical. Generally, the rest will be diluted in the sum. The most critical ones could be provided with adjustment pots or one could use fixed, precision resistors. The 0.1% resistors I used in the VTA cost only $2 or so. Since the selection of high precision ones is limited, one might need to add a lesser-precision value in parallel or series to get close to the target, as was done for the feedback resistors in the uTracer Heater Regulator. (After writing this, it occurs to me that you might have meant using power resistors instead of low-level ones and the electronics. If so, doing all those precision, power Rs wouldn't be so easy, of course.)

> I have selected 800v Mosfet for the screen supply divider instead of 600v one shown in your article.

--- This prompted me to remind you about the part of the article (search "NTE2385") which points out the problem with most heatsink insulators--that they don't work for high voltages! Found that out the hard way. Even if the material is rated for the voltage, there is breakdown around the screw hole. The insulator must be physically thick to provide surface distance. The 0.07" (1.8mm) aluminum oxide ones worked for me at 400V. I'm fearful of 600V. If at all possible, I'd recommend using a device packaged similarly to the FDPF12N60 which has an insulated mounting tab. Fortunately, the screen pulls rather low current, so there is less concern that the insulated tabs result in somewhat higher thermal resistance.

This 2.5k rheostat should be fine to use with 6P14P tubes. I have 170 of them!

--- Wow, a lifetime supply! The Voice of Music amp you restored will always have fresh tubes :) With that many tubes to test, buying a precision, low-tempco, fixed RL would be justified. But the 50W rheostat should run fairly cool and will be using most of its range, and it's nice to have "a bird in the hand." *Speaking of the VoM amp, thank you for including the beautiful restoration pics!* Those amps look marvelous. Love the way you preserved the logos. I'll bet they sound as good as they look!

I've enjoyed corresponding with you about your project and look forward to hearing more in the future.
Best Wishes, Steve

Hi Steve,

In reply to your previous email... Thank you for your kind words!
...

As for your other recommendations and comments, I plan to use an insulated version of the Mosfet. I think they all have "F" suffixes in the part number.

I will see if I can put together a reasonable combination of chassis-mounted aluminum resistors to accommodate the testing of common output tubes. If that can be done in appropriate wattage and be accurate in resistance, this will require a single switch that I can install in place of the rheostat that I'm thinking to use for a moment.

One question on the power supply for the Amazon switcher unit
https://www.uctronics.com/download/Amazon/U5168.pdf
There's no word on the current requirements for input supply. I doubt its 1:1 ratio to the output, is it?

Thanks for your help, Steve!

[Hi Dmitriy,]
On the Amazon Switcher unit, you should be able to estimate input current by assuming the input power is the same as the output power plus 10-15%. But at very low output power, the overhead power of the module also comes into play. Typically, a switcher might burn 1-2W, just idling. Now, in this case, the module has to run the display, so that could burn some power. I don't know the display technology. If it's LCD, then I guess the backlight is most of it, if it has that. If it's LCD and there's no backlight, then the display may not burn significant power. Note: below, the "in" and "out" are from the module's point of view.

Bottom line: My guess would be the module's Pin = Pout x 1.15 + 3W. For example, if it's running just one 6P14P, Pout = 4.8W, so Pin = 4.8 x 1.15 + 3 = 8.52W. If you full wave rectify with a bridge and filter 6.3V, you might get Vin = 6.3 x 1.414 - 2 x 0.7V = 7.5VDC. So input current to the module Iin = 8.52/7.5 = 1.34A.

The switcher will be more efficient for high current output, since the overhead might not increase much. So for 5A out at 6.3V:
Pin = 31.5 x 1.15 + 3 = 39.2W
Let's say the Vin drops to 7.0VDC, so Iin = 39.2/7 = 5.6A.

Hopefully, my fixed-overhead and 85% efficiency estimates are pessimistic. If so, the input currents may be considerably less. I'll be happy to help if you have any questions about that.

Steve