QuantAsylum QA451(B) User's Manual

Programmable 4/8 Ohm Load

SW Release 1.4
October 2023

Product Notice

The QA451 and QA451B are the same product, using the same software. There is a difference in current sensing accuracy between the two products used on the DC Switch + Sense port. This port is for use in measuring the current consumption of an amplifier board. On the QA451B product, the resolution is 10-20 mA, while on the QA451 product the resolution is 5-10 mA.

Throughout this document, the QA451 reference should be taken to mean the QA451 and QA451B products. Differences between the products, if any, will be noted.

Safety Notice

- This device is not designed for working on potentially dangerous voltages.
- This device is not designed for working on high energy circuits.
- Know and understand the voltage and current limits for each input
- See additional safety notices throughout this document.

Limited Warranty

This product has a limited warranty for 6 months from the time of purchase. During this time, a device failure that occurs under normal operating conditions will be replaced or repaired for free, not including shipping. Generally, you will be responsible for shipping to us, and we will be responsible for shipping it back to you.

Devices that have suffered a failure due to operation in excess of specified parameters can usually be repaired for a nominal fee.

The contents of this document are provided "as-is" and may be changed or updated without notice. The specifications on a particular product may also be changed at any time and without notice as we seek to improve a product or improve availability of a product.

The limit of our warranty will not exceed the value of the product purchased under any conditions.

Contents

Legal

In the Box

Your QA451 box contains the following:

- QA451 Programmable Load
- Power supply and Speaker connectors that mate with the QA451. These are installed on the QA451 and can be removed by gently pulling.

Installation software, this manual, and application notes for the analyzer are available on the web at http://www.QuantAsylum.com.

Important Things to Understand

Ground Reference

The QA451 USB interface shares a ground with the PC. The load portion and current sensing portion of the analyzer does not. You should measure, and from time to time confirm, that the BNC grounds are electrically isolated from the USB grounds.

This isolation is limited to 50V. Do not connect the QA451 to a product that has its ground reference more than +/-50V from the PC ground.

Current Sense Inputs

The QA451 has a 2-wire DC load switch and current sense connector (S+ from power supply, S- to DUT) for monitoring the high-side DC supply of an amplifier. This can be thought of as a solid-state relay. The voltages on the S+ pin of this connector must not exceed 50V DC. All of these pins are isolated from the PC/USB ground. Isolation is measured to be >10 GOhm at 1 KV.

WARNING: Do not plug/unplug an amplifier power supply when using the current sensing AND the green DUT LED is active. On very large amplifiers, this can cause hundreds of amps to flow for hundreds of microseconds which may destroy the high-side switch. Always ensure the green "DUT Power" LED is off before connecting amplifiers.

Load Inputs

The load inputs are isolated from the PC/USB subsystem and also from the current sense subsystem. You will connect the amplifier outputs to the L- and L+ inputs for the left channel, and the R- and R+ inputs for the right channel.

Depending on your specified settings, the QA451 will present either a 4, 8 or open load to the amplifier.

When open, 4 or 8 ohm loads are selected, attenuated (by 12 dB) versions of the speaker signals will appear at the BNC outputs of the QA451. For example, the L- speaker input will appear at the L- BNC output, attenuated by 6 dB.

If you are using a single-ended amplifier, then the negative load inputs the QA451 should be connected to the DUT ground.

QA451 Programmable Load Features

The QA451 features:

- Programmable load values of 4, 8 or open (~10K) ohms.
- Current sensing of amplifier DC supply.
- On/off control of the DC supply via high-side PMOS switch
- Power handling up to 300W (duration limited)
- Current limiting of supply for accidental shorts (trips when >15A for more than 2mS)
- Soft-start, allowing gentle turn-on of the amplifier DUT
- 6th-order filter between the load and the measurement output, with a corner frequency at 65 kHz.

We hope you enjoy your purchase! Check back from time to time for new software updates.

QA451 Front Panel

This section covers the various connectors on the analyzer and reviews the input and/or output characteristics of these connectors.

Front Panel Summary

The front panel is shown in the picture below. From left to right, the following items are explained.

LEDs

Link LED This LED indicates the QA451 is connected to the PC and talking to the QA451 application.

8 Ohm LED	This LED indicates the QA451 is presenting an 8 ohm load at the load inputs
4 Ohm LED	This LED indicates the QA451 is presenting a 4 ohm load at the load inputs
DUT Power LED	This LED indicates if the high-side switch is enabled or not. If the LED is flashing rapidly, then soft-start is in process.

If both the 8 and 4 ohm LEDs are flashing, then it means the QA451 has reached a thermal limit. This is not harmful to the QA451. When this happens, the QA451 will open the relays automatically and ensure the load inputs are removed from the internal load resistors.

Current Sense Inputs

The QA451 uses dual-range isolated Hall sensing device to measure the power supply DC. The positive terminal of the amplifier's DC power supply flows into the S+ pin on the front panel, is sensed by the Hall sensing devices, and then flows out of the S- terminal to the amplifier (see Appendix I Connection Diagram). The Hall sensors used on the QA451 is an Allegro Micro ACS711, with +/- 25A of measurement range, and an ACS70331 with +/-2.5A of measurement range. On the QA451B, a single Ti TMSCS1108A1U) is used. On the QA451, only positive current (from DC supply to the amp) are reported. If a negative current is measured, it is clamped at 0 amps.

The DC switch on the QA451 is designed to operate continuously at 50V with 10A of load and can withstand normal transients excursions above 50V.

The current sensing is not required to be used. For example, if you are testing Class D amplifier boards, it might make sense to use the current sense and power the boards from a fixed external supply. But if you are testing finished amplifiers that runs from AC, then the DC measurement provided by the QA451 isn't useful and can be skipped.

ATTENTION! DO NOT CONNECT THE CURRENT SENSE CONNECTOR WHEN THE DUT POWER LED IS ON!

Do not swap amplifier boards when the DUT POWER LED is on!

If your power supply and amplifier both have massive capacitors, and you connect the amplifier while the DUT power is enabled, then potentially hundreds or even thousands of amps can flow through the high-side switch and cause it to fail as the charge is re-distributed

The Current Sense connector on the QA451 is a Molex 39536-0002. The mating connector is a Molex 39534-0002. This connector has a rating of 300V and 15A per pin.

Do not exceed the 10A RMS rating or 15A max rating of the Current Sense subsystem.

DUT Power Soft Start

When the DUT Power is activated, the DUT Power LED will flash rapidly for 1 second. This indicates that soft-start is underway. During soft-start the DUT amplifier is connected to the high-side rail (S+) through a 10 ohm resistor. This allows amplifiers with very large filter caps to charge at current levels that won't stress components in the power supply, the QA451 and the DUT amplifier. A large amplifier might have 10 mF of bulk capacitance. The RC time constant of the 10 mF and 10 ohm is 100 mS. Thus, the one-second soft-start allows 10 time constants of soft-start to elapse before bypassing the soft-start resistor. See the discussion below on Faults for more analysis.

Load Inputs

The load inputs are where the amplifier/DUT will connect. The loads are switched internally by relays rated for 12A at 250VAC and 12A at 24VDC. The loads are DC coupled, but it's expected that ONLY AC signals will be presented to the QA451. Given the QA451 maximum ratings, the voltage on the load inputs must not exceed 50VAC RMS

The maximum currents at the QA451 maximum ratings occur when the load is set to 4 ohms at 300W. This corresponds to an 8.66A RMS current.

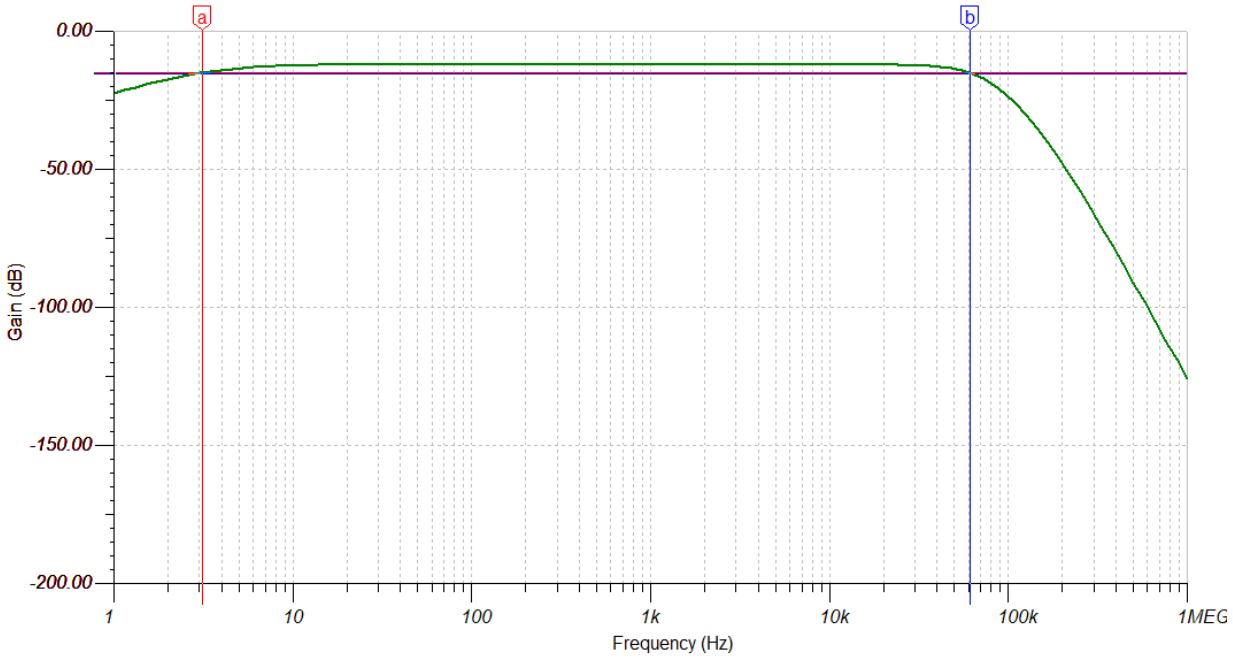
The Load Input connector on the QA451 is a Molex 39536-0004. The mating connector is a Molex 39534-0004.

Do not exceed the 200W for 220 mS rating of the Amplifier Load subsystem.

BNC Outputs

The BNC outputs are single-ended attenuated version of the load inputs. The attenuation is 12 dB. This means if your amplifier is 10 dBV = 3.16Vrms (as measured with DVM in AC mode across L+ and L-) and the QA451 load is set for 8 ohms, then the QA451 will be dissipating (3.16^2)/8 = 1.24W. The BNC outputs will measure 6 dB lower, which would be 4 dBV = 1.58Vrms

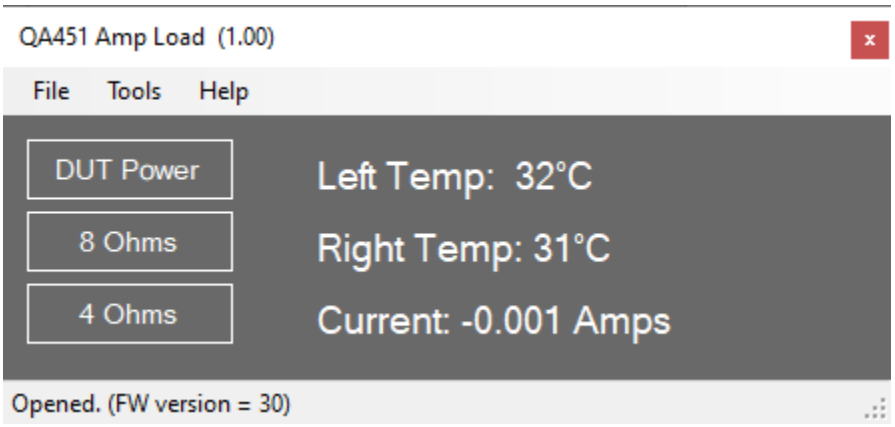
The 6th order low-pass filter in the QA451 has its corner at approximately 65 KHz. A SPICE simulation of the output is shown below, with the 3 dB points marked. For Class D amplifiers with switching frequencies between 200 and 500 kHz, the filter will provide significant attenuation of switching products while still permitting a 3rd harmonic measurement to be made with a 20 kHz fundamental.



QA451 Software

The QA451 and QA451B will appear on your PC as a "HID" device with a USB VID:PID of 0x16C0:0x4E35. It doesn't need drivers. It will show up in the Device Manager as a "HID-compliant vendor-defined device."

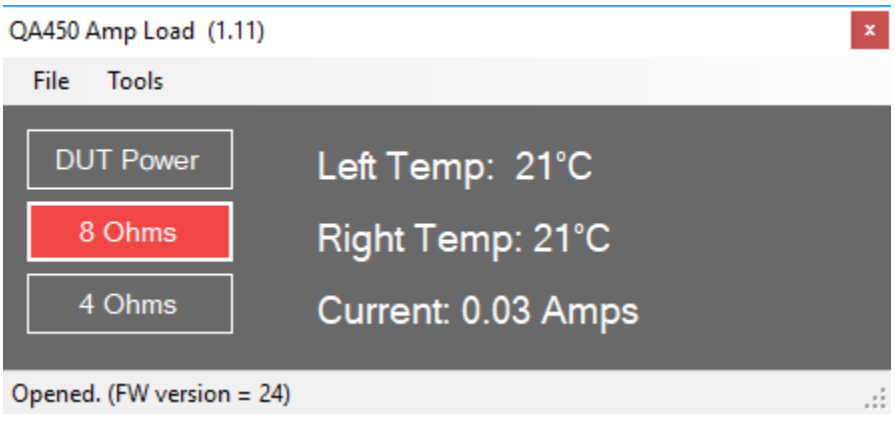
When you first plug in the QA451 device, Windows should spend a bit of time configuring the device. Download and install the QA451 application from Github. After launching the application, you should see the following UI:



In the title bar, you can see the version of the software, shown here as 1.0. In the status bar, we can see the hardware device is "opened" and that this is firmware version 30. You will be alerted if the firmware version is incorrect and given a chance to re-flash the QA451 hardware. It is important to NOT use the application if the firmware version is reported as incorrect as malfunctions could occur.

When the QA451 and application are "talking", should see the "LINK" LED on the QA451 hardware illuminated.

If you press the "8 Ohms" button, you will hear a "click" from the QA451 relays and the application will report the 8 ohm load is active as shown below. At this point, you can use a DVM to measure across the L+ and L- Load Input pins and confirm that 8 ohms is being presented. You can repeat the experiment for 4 ohms, too, and also for the right channel.



Pressing an illuminated load button again will turn the loads off. When both the 4 and 8 ohm buttons are off, then the QA451 presents an "infinite" or open load to the amplifier. Note that when the QA451 is open, the QA451 +/- outputs are meaningless. That is, the input signals cannot be measured when the loads are disconnected.

Application Temperature Sensing

On the right side of the QA451 application, you can see the temperature for both the left and right channels. Generally, under normal operation, these temperatures must remain under 60C. Above 60C or below 5C, the QA451 will disconnect the loads and require time to cool down or warm up. The sensors are very accurate and respond very quickly. Generally, as long as you do not impart more than 300W of power per channel, you do not need to worry about harming the QA451. It will self-protect. The temperature readings are provided for information only.

Application Current Sensing

The QA451 reports the current measured by the Current Sensing subsystem. The resolution is around 5 to 10 mA. That is, you will see readings jump by perhaps +/- 5 mA. On the QA451B, the resolution is around 10 to 20 mA. For high-power amplifiers that might draw 10A or so, this generally isn't a problem. Of course, if you want to measure an amp with a max current of 100 mA, then this resolution can contribute significant errors.

DUT Power

The DUT POWER button is used to the turn on the high-side PMOS in the QA451. When enabled, the S+ and S- will be connected by a low impedance of 25 mOhms or so. This is Rds(on) of the high-side PMOS pass device.

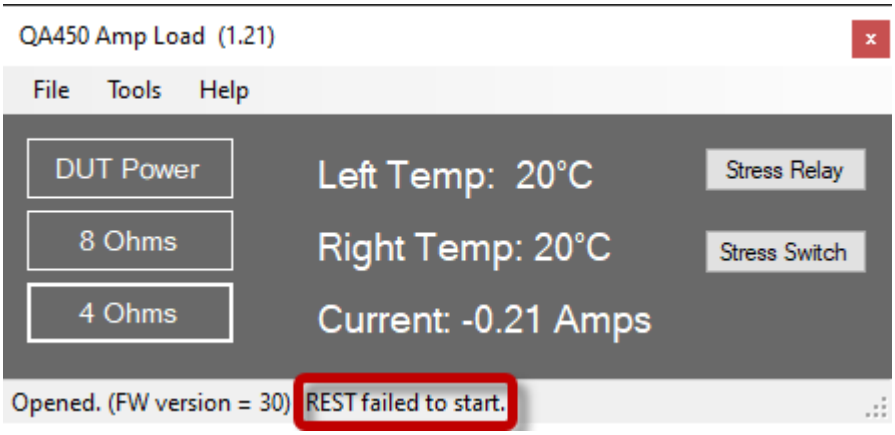
If the QA451 application is closed or stops responding, or if the QA451 is disconnected from the USB, then the QA451 will automatically open the load relays and disable the load power.

Fault Conditions

If absolute current exceeds 15A for more than 2 milliseconds, the high-side switch will be disabled. A fault will be reported on the QA451 application and the USB power must be removed and re-applied to clear the fault and restore normal operation.

Remote Connections

The QA451 provides a simple web service that allows remote control of the settings via a REST API. If the REST web server fails to start, you will see a message as shown below on the status bar:



If this message appears, the application can still be used for manual control of the hardware, but remote access won't be possible.

If the message does not appear, then it means the server successfully started. The server responds to a very limited set of commands and does not serve files or data. You can see the REST API published by the QA451 by going to your browser and opening the url (the same URL is used for the QA450 and QA451):

http://localhost:9450

The browser should display a page outlining the QA451 REST API. If it does not and you aren't seeing the failure message above in the application status bar, then it might mean that you have a security application or firewall blocking port 9450.

If you are sure that the firewall on your machine has port 9450 opened, then run the QA451 application with admin rights and see if that allows a browser to open the link above. If that solves the problem, then you can either run the app with admin rights when you want to enable the REST API, or you can enable the port generally using a command line solution. To do this, open a command prompt with admin privileges and type the following:

```
netsh http add urlacl url=http://*:9450/ user=DOMAIN\\user
```

Replace the 'DOMAIN' and 'user' text with the appropriate domain and user name for your account. To find your domain name, open the control panel, selection "System and Security" then "System" and your will see an entry showing the Full Computer Name.

If you want to see what existing reservations are present on your machine (which should also give a clue about the domain and user settings on your machine for other ports), then you can type:

```
netsh http show urlacl
```

To later remove the permission added above, you would enter:

```
netsh http delete urlacl url=http://*:9450/
```

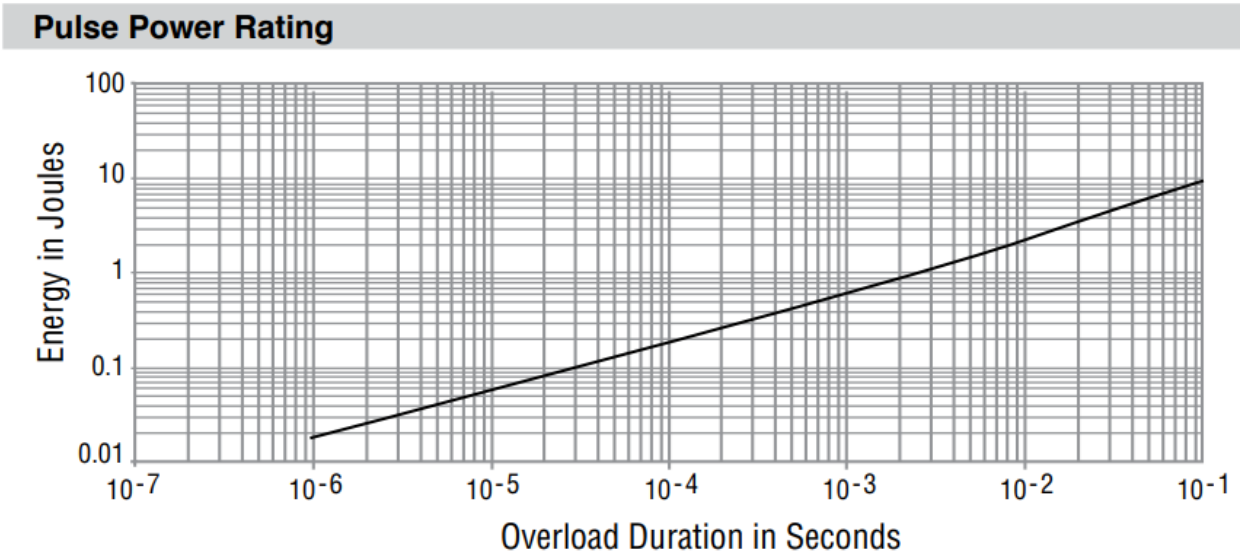
QA451 Load Resistors

The QA451 uses a special type of load resistor called a "Pulse Withstanding" load resistor. These are specially formulated resistors built on metal substrates designed to handle extremely large pulses of power for very short periods of time. They are non-inductive.

An example resistor used for the QA451 is the Bourns PWR163 series or similar. The QA451 has 16 of these resistors—8 per channel. When presenting an 8 ohm load, four 2 ohm resistors per channel are used (4S1P). When presenting a 4 ohm load, eight 2 ohm resistors per channel are used (4S2P). There are half as many resistors used when presenting an 8 ohm load versus a 4 ohm load. This has implications for maximum power handling.

The PWR163 resistors are each rated to handle 25W when the case temperature is 25C. That 25W figure is de-rated by about 15% as the backplate temperature reaches 50C. If the resistors are near room temperature and the QA451 is configured for 4 ohms (8 resistors), then you can hit the load with 8 * 25 = 200W for several seconds until the thermal protection kicks in. The temperature will quickly rise over several seconds and further de-rating will be necessary as it increases. When the resistor temperature exceeds 60C, the QA451 will self-protect and disconnect the loads.

The PWR163 spec also shows the pulse power rating, reproduced here:



For 1 second, the spec has prescribed 25J (25W * 1sec @ 25C). For 100 mS, we see a single load resistor can handle 10J of energy. Note that 1J = 1W for 1 second, and thus 10J = 100W for 100 mS. So, the array of 8 resistors (when configured as a 4 ohm load) can handle 800W for 100 mS. If using as an 8 ohm load, this this figure is 400W for 100 mS.

Tabularizing the observations above, we see the following:

Sample Rate	FFT Size	Pulse Duration (sec)	Max Joules per R	Max Power per R	Max P into 4 Ohms	Max P into 8 ohms	Irms Current 4 ohms	Irms Current 8 ohms	Vrms 4 Ohms	Vrms 8 Ohms
48K	2K	0.085	9.7	114.6	916.7	458.4	15.1	7.6	60.6	60.6
48K	2K	0.085	9.7	114.6	300.0	300.0	8.7	6.1	34.6	49.0
48K	4K	0.13	10.5	80.8	646.2	323.1	12.7	6.4	50.8	50.8
48K	4K	0.13	10.5	80.8	300.0	300.0	8.7	6.1	34.6	49.0
48K	8K	0.22	12.0	54.5	436.4	218.2	10.4	5.2	41.8	41.8
48K	8K	0.22	12.0	54.5	300.0	218.2	8.7	5.2	34.6	41.8
48K	16K	0.38	14.7	38.6	308.6	154.3	8.8	4.4	35.1	35.1
48K	16K	0.38	14.7	38.6	300.0	154.3	8.7	4.4	34.6	35.1
48K	32K	0.72	20.3	28.2	225.9	112.9	7.5	3.8	30.1	30.1

The table above shows regions that may overstress the QA451 and should be avoided. For example, the resistors would survive an 85 mS burst of audio—which is a 2K FFT @ 48Ksps—at 114W per R. This would deliver 916W into the load. But this would result in 15.1A of connector current and 60Vrms. These overstresses are marked in red. Limiting the max load power to 200W for 220 mS into 8 ohms and 4 ohms provides a reasonable reliability margin. This is an 8K FFT.

The temp sensing on the QA451 has a lag. If the load resistors are hit with 800W for 100 mS, then the temperature of the resistor active area will climb very quickly while the temp sensor located 2-3 mm away from the resistor body will remain unchanged. Because of this lag, the 200W figure must not be exceeded as the QA451 won't be able to protect itself quickly enough. But at power levels below 200W, the QA451 can fully protect itself and you don't need to worry about harming the QA451.

Audio Bursts

The QA401 Audio Analyzer operates on bursts of audio. It is these bursted modes where the utility of the QA401 and QA451 combine to allow thorough testing at high power levels.

The QA451 is obviously not the platform you'd chose for burning-in amplifiers. But a test suite that has an average power level of 4-5W can run continuously without stressing the QA451.

Low Temperature Operation

The temperature sensors used on the QA451 are absolute sensors with a tolerance around +/-1%. The QA451 firmware expects to see a temperature of at least 5 degrees. This ensures the sensors are properly communicating with the CPU. If the ambient temperature is near 5 degrees, the QA451 will not allow load control.

Soft-Start

The QA451 is designed to enable very low-cost audio testing bays. The idea is that expensive lab-grade programmable power supplies can be replaced with commodity open-frame power supplies. For example, a 1KW fixed 48V power supply with fixed current limiting is under $100, while a 1 KW adjustable lab supply with programmable current limiting costs several thousand dollars.

To make use of these low-cost fixed supplies in a test environment where a new board is being fixtured for test every minute, the ability to control the power supply is needed. If the supply is left on continuously, when the operator "plugs in" the board to be tested extremely high currents will flow as

the massive amplifier capacitors charge. These currents can easily reach hundreds of amps, overstressing components.

The QA451 provides an "on/off" switch for supplies up to 50V. This allows a commodity fixed power supply to be used in the test bay. While the operator is connecting the amp to be tested, there won't be any arcing or high currents flowing because the power to the amp is off due to the QA451 switch.

When instructed to turn on, the QA451 will always apply a 1 second "soft start" where the amp is connected to the power supply through a 10 ohm resistor. During this time, the massive amp capacitors can charge though the 10 ohm resistor. After 1 second, the 10 ohm resistor is bypassed and the amp is directly connected to the supply. This happens automatically when the QA451 power switch is enabled.

If the amp has bulk capacitance greater than 10 mF or so, then the 1 second soft start time may not be enough. Assume for a moment you are running an amp with 50 mF of bulk capacitance. When the power switch is turned on, an RC circuit comprised of the 10 ohm soft-start resistor and the 50 mF bulk capacitance begins to charge. One time constant will be 10 * 50 m = 500 mS, and thus after one time constant the voltage will have risen to 31.6V. At that point, the 10 ohm is bypassed and the current increases rapidly leading to an overcurrent condition.

If you have more than 10 mF of bulk capacitance, and you are getting overcurrent warnings when turning on the switch, contact us at the support alias and we can work to help solve the problem.

Thermal Considerations

The QA451 is NOT designed for sinking 10's of watts for long periods of time. The QA451 cannot dissipate the heat that comes from those power levels. The QA451 is designed for high-speed testing of amplifiers. That is, you will subject the amplifier to many short bursts of audio, typically around 1-2 seconds each. The power levels of these tests may be anywhere from milliwatts to hundreds of watts.

The average power you subject the QA451 to must be around 5-10W or so. That is, if you compute the watt*second product of your tests, and then divide that by your total test time (including operator change over to the next amplifier), then the average should be around 5-10W to ensure continuous operation. This depends somewhat on your factory. If you keep the factory near 25C with good airflow you can be closer to the 10W figure, otherwise, the 5W figure might be more appropriate.

The table below shows what a test plan might look like. Test #1 would subject the board to 300W for a short test of THD at max power (300W). Test 2 might look at THD at 100W, and test 3 perhaps 50W. Subsequent tests would focus more on noise measurements, IMD, and other parameters at a typical listening level.

Finally, "switchover" in the table below refers to the time it takes an operator to remove the amplifier that was just tested and replace it with another amplifier. The 20 second figure used in the table below suggests a very fast switchover operation, most likely automated and extremely high volume. The test flow below suggests a 15 hour (2-shift) production of 1200 amplifiers tested per day per test bay.

Test Number	Watts	Duration	Processing	Total Bay Time	Watt Seconds
1	300	0.4	1	1.4	120
2	100	0.4	1	1.4	40
3	50	0.8	1	1.8	40
4	1	2	1	3	2
5	1	2	1	3	2
6	1	2	1	3	2
7	1	2	1	3	2
8	1	2	1	3	2
9	1	2	1	3	2
10	1	1	1	2	1
Switchover	0	20	0	20	0
				44.6	213

Test Time wo switchover:	24.6	Average Power	4.78	Watts

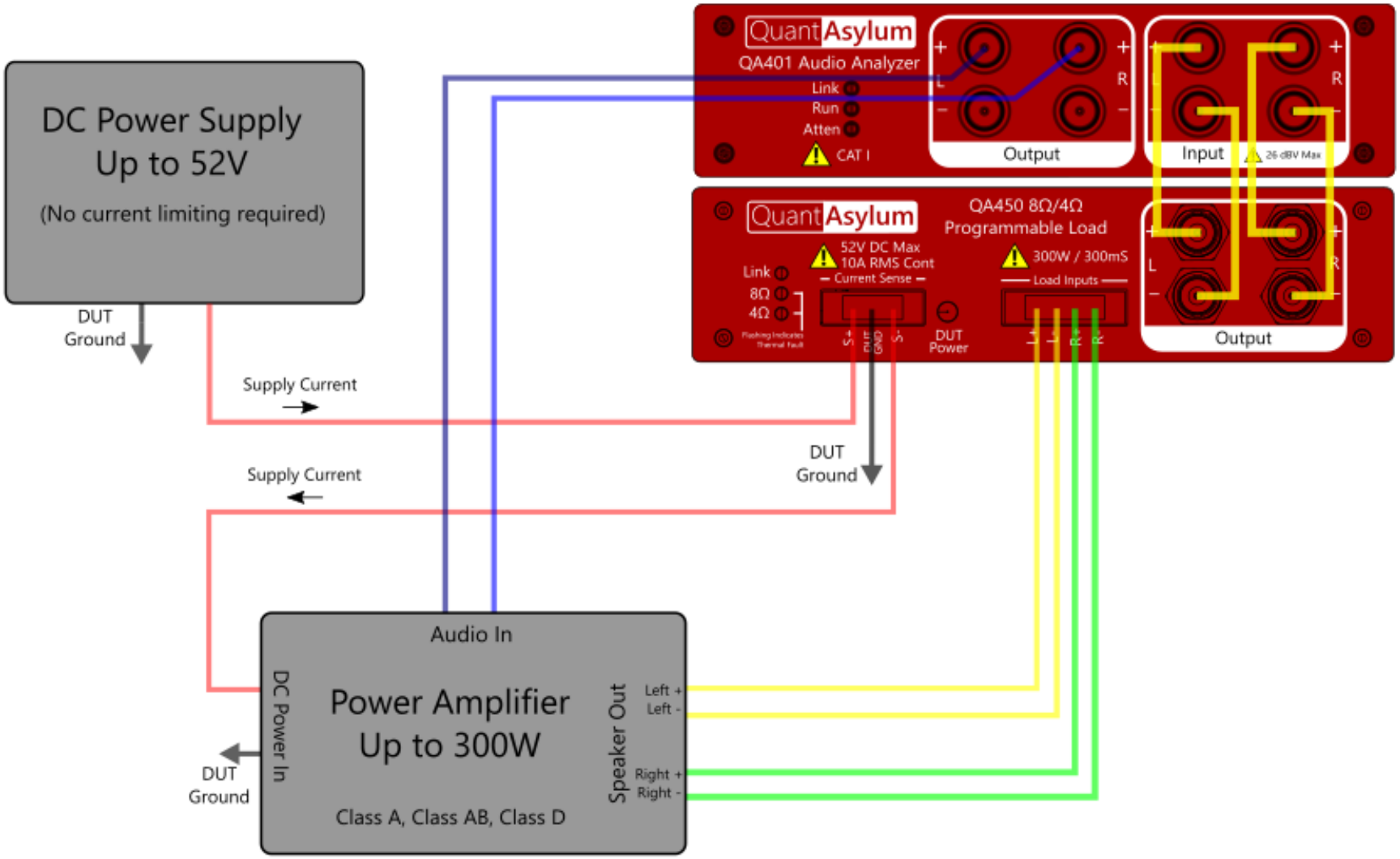
Impact of Switchover

The impact of switchover time is significant in the average power calculation. If the switchover time is 2 minutes, due in part to an operator managing several bays and a fully manual switchover, then the average power drops to 1.5W.

In summary, you need to plan your thermal budget ahead of time to ensure the QA451 can meet your needs. Hitting the thermal targets above will ensure continuous operation without having to wait for cooldowns.

Because the QA451 can also report the temperature to other applications via the REST web interface, it's also possible to program your test flow to wait for the temperature to fall below a threshold before you begin testing a new amplifier.

Appendix I: Typical Connection Diagram



Appendix II: QA451(B) Specifications

Current Sense Inputs (S+/S-)	
Maximum Voltage (normal operation)[1]	50V, relative to DUT GND
Maximum Current	10A RMS continuous, 15A peak
Resolution	QA451: 5-10 mA QA451B: 10-20 mA
Trip Current	>15A for 2 mS
Soft Start[2]	10 ohms for 1 second
Load Inputs (L+/L-/R+/R-) Relative to DUT GND	
Load Options[3]	Open, 4 and 8 ohms
Maximum DC[4]	-5V to 35V
Absolute Maximum Input[5]	60Vrms AC
Maximum Input[6]	32 dBV = 40Vrms
Max Current on any pin	10Arms
Max Power into Load Inputs[7]	200W per channel for 220mS
Load Tolerance	+/- 5%
Output	
Attenuation	12 dB
Frequency Response	F3db = 70 kHz
Output Impedance	~50 ohms
General	
Measurement CAT Rating[8]	CAT I, 40VAC, 250V transient
Maximum Isolation Voltage	+/-100V (USB GND to DUT GND)
USB Isolation[9]	>10 GΩ @ 1KV
Interface	USB, 12Mbps
Power	USB, < 500 mA
Ambient Operating Temperature	15 to 35C
Case Size (mm, WxHxD)	177 x 44 x 97, 116mm deep with BNC
Case Material	Powder-coated Aluminum

[1] The MOSFET used for high-side switching is an 80V V_{DSS} MOSFET with a 17.6mJ avalanche rating. It is expected that S+ will always be higher than S-. That is, when switch is off, S- will be near ground. And when switch is on, S- will be equal to S+. The switch is not bidirectional. If S- exceeds S+, then current will begin to flow through the MOSFET body diode.

[2] Soft-start is provided to allow power supplies with large output capacitors to charge DUTs with large input capacitors. Without the soft-start, turning on the supply could result in hundreds of amps flowing as the output capacitors charge the input capacitors.

[3] When "open" the QA451 will present a ~10K load to the DUT on the Load Inputs.

[4] Some Class D amplifiers that are powered from a single rail will "idle" at a DC voltage that is half of the supply rail. For example, a Class D amp running at 50V will have outputs that idle at 25V DC.

[5] Do not subject the QA451 to extended periods with input levels exceeding the Maximum Input.

[6] Operation beyond these levels will result in increasing distortion due to input overload.

[7] See the QA451 User's Manual for de-rating curves

[8] The CAT I rating is the weakest designation for measurement equipment. This requires that your DUT is NOT directly connected to the mains or other high-energy circuit without protection, and that the DUT can protect against momentary overload conditions (such as lightening strike) on the mains.

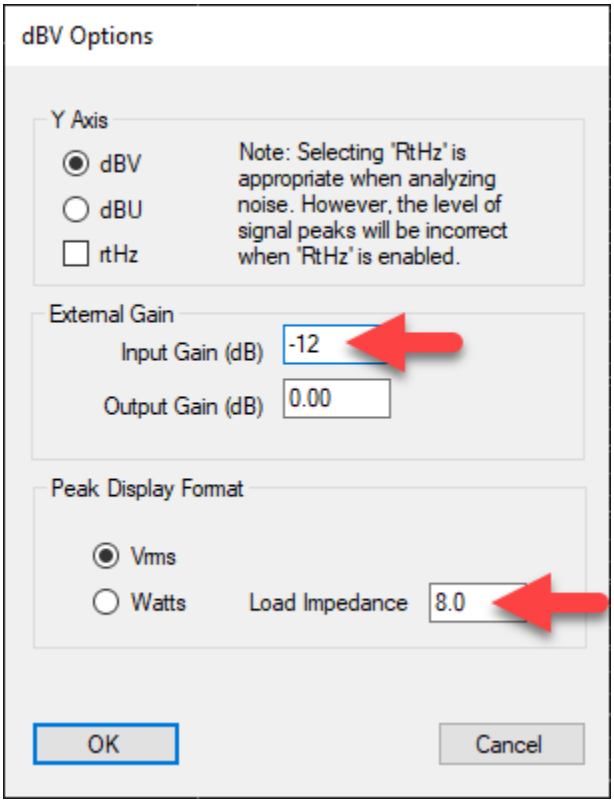
[9] This is not measured on all units. A DVM impedance reading between BNC shell (DUT GND) and USB ground should indicate an "open" or infinite impedance.

Appendix III: Interfacing with Other Applications

QA 401 Application: QAAnalyzer.exe

The QA401 application isn't generally aware if the QA451 hardware is being used or not. There are a few places you will want to adjust the settings to ensure accurate values are being shown in the QA401 application.

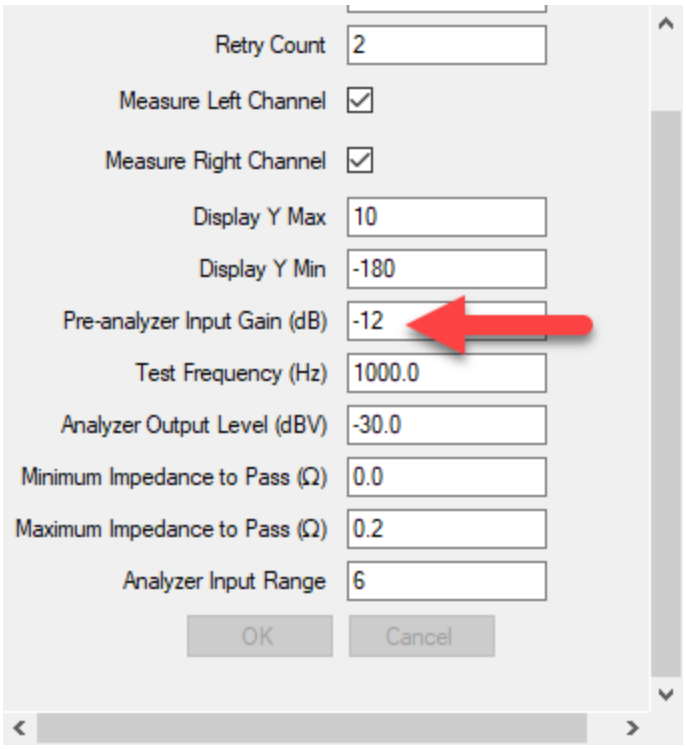
Because the QA451 has 12 dB of attenuation built-in, you will want to specify that in the Input Gain option on the QA401. This is how you tell the QA401 application that the value it is measuring is less than the actual value and thus the reported peaks and noise, for example, must be increased by 12 dB when being displayed.



Next, notice above there is an option to specify load impedance. If you want to display in watts, then you need to set this figure to the value you have set on the QA451.

Tractor

Tractor treats the QA450 and the QA451 as the same hardware. When you specify "Pre-analyzer Input Gain" in Tractor (example below), you will want to specify -12 dB if you are using the QA451, and -6 dB if you are using the QA450.


Retry Count
2
Measure Left Channel
Measure Right Channel
Display Y Max
10
Display Y Min
-180
Pre-analyzer Input Gain (dB)
-12
Test Frequency (Hz)
1000.0
Analyzer Output Level (dBV)
-30.0
Minimum Impedance to Pass (Ω)
0.0
Maximum Impedance to Pass (Ω)
0.2
Analyzer Input Range
6
OK
Cancel