Low Noise, Low Distortion Power Amplifier Measurements with the QA401

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How to interconnect equipment to ensure low noise, low hum, accurate power amplifier measurements with the QA401.

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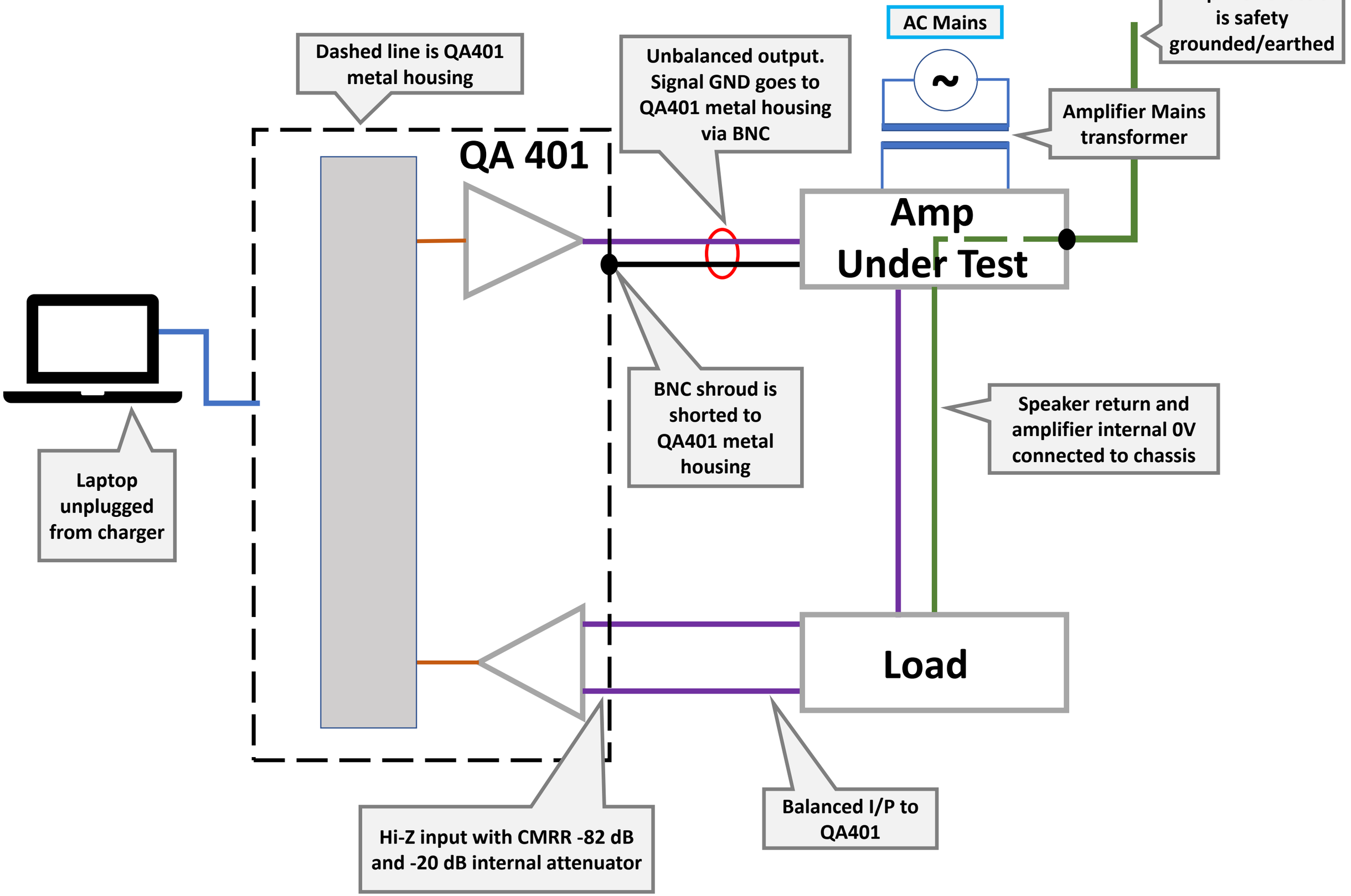
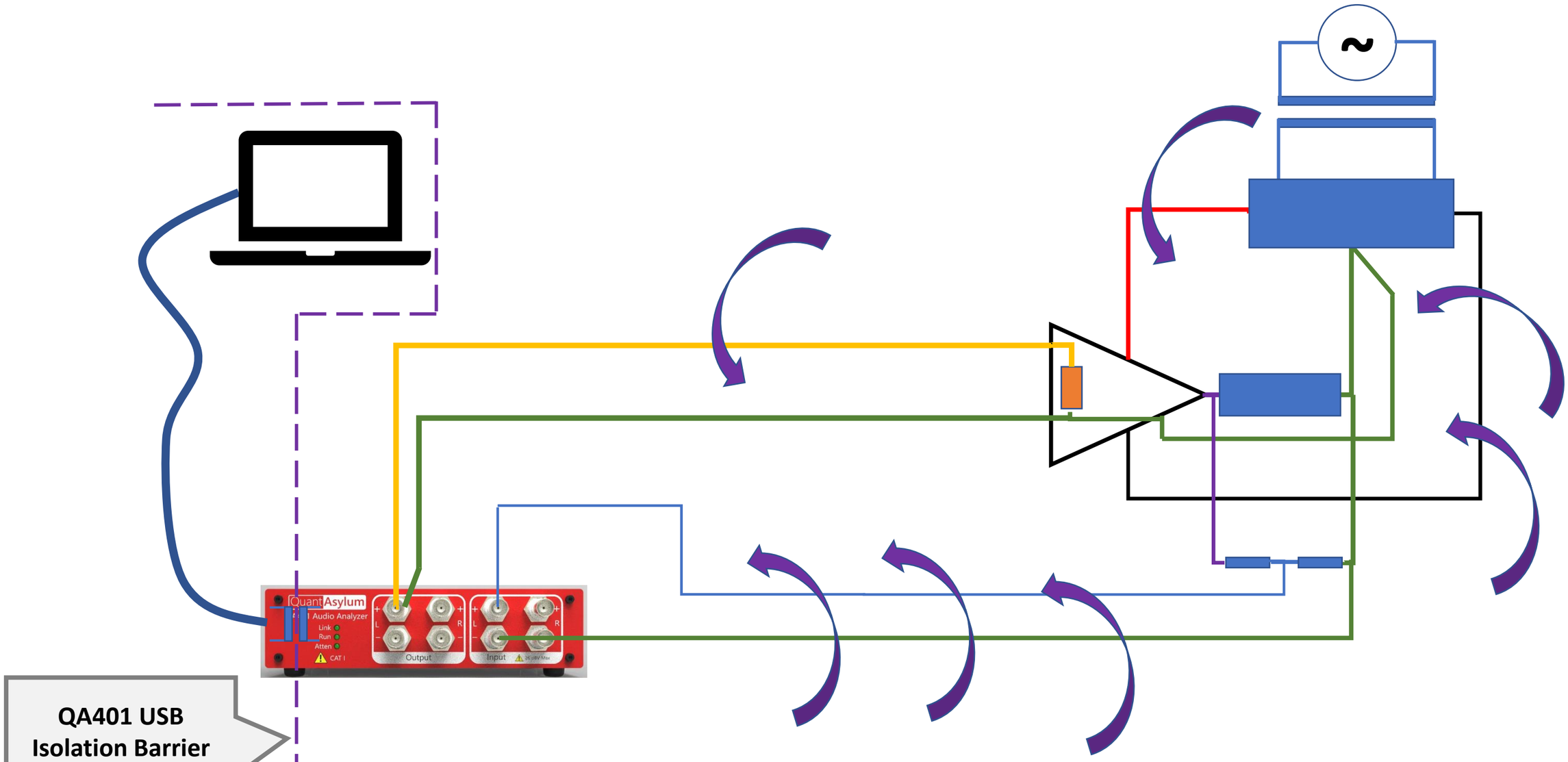
Typical QA401 Measurement setup



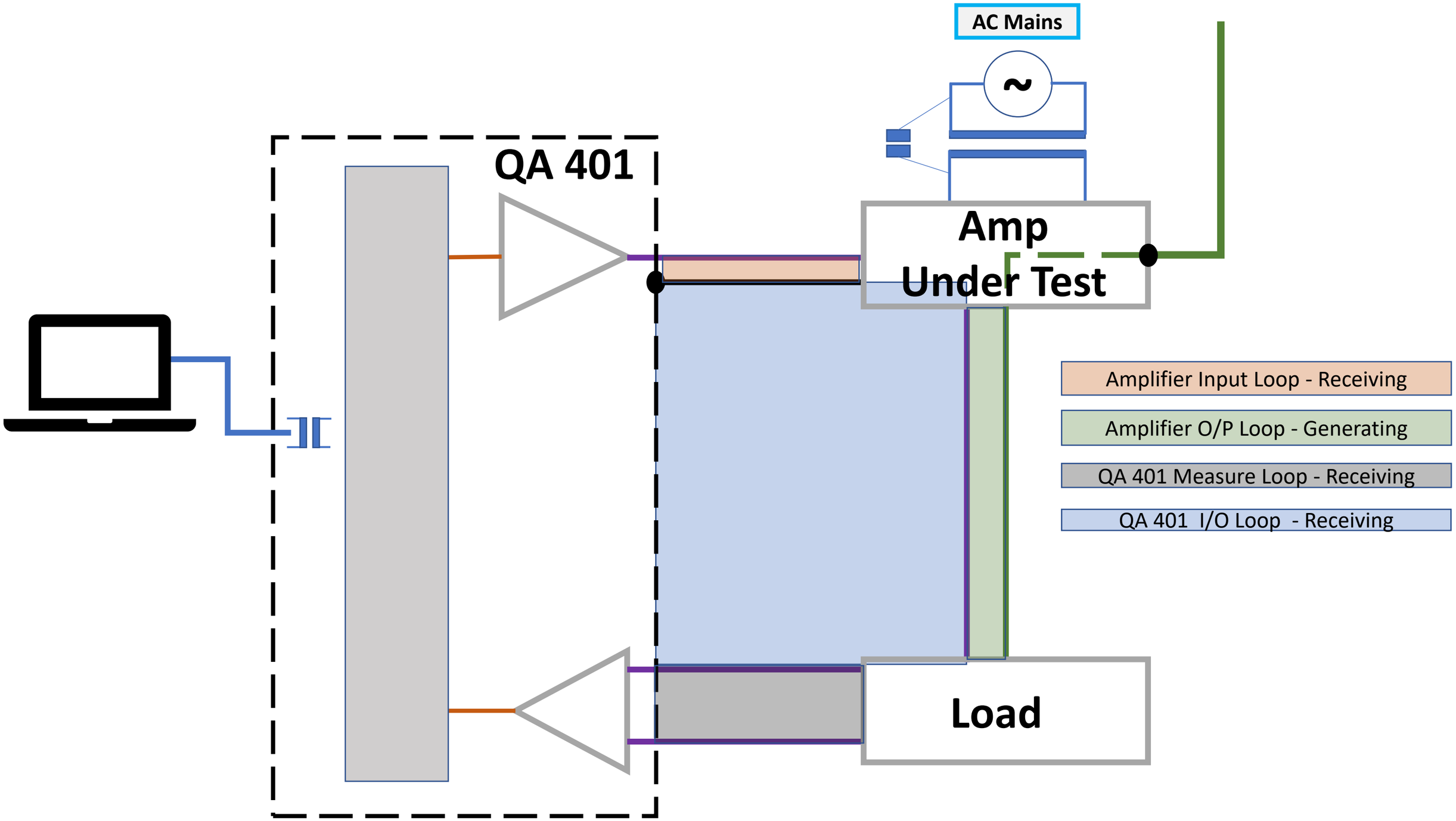
Simplified Overview of Measurement Noise Sources



QA401 USB Isolation Barrier means everything to the RIGHT of the purple line FLOATS wrt the PC

= induced noise – mains and amplifier output signal

Multiple Noise Loops



Noise loops cause high mains harmonics to appear in the measurement and can cause erroneous distortion measurements

Typical QA401 Measurement Setup - HF and LF Noise Coupling

The QA401 USB input is galvanically isolated from the rest of the instrument. However, for lowest noise, always use a laptop without the charger plugged in.

Dashed line is QA401 metal housing

QA 401

Hi-Z input with limited CMRR

Amplifier Primary<>Secondary capacitive coupling is 500pF on a 500VA and 1.3nF on a 1.2 kVA transformer

Amp Under Test

AC Mains

Generalized HF noise source

Parasitic Capacitive coupling 10-50pF

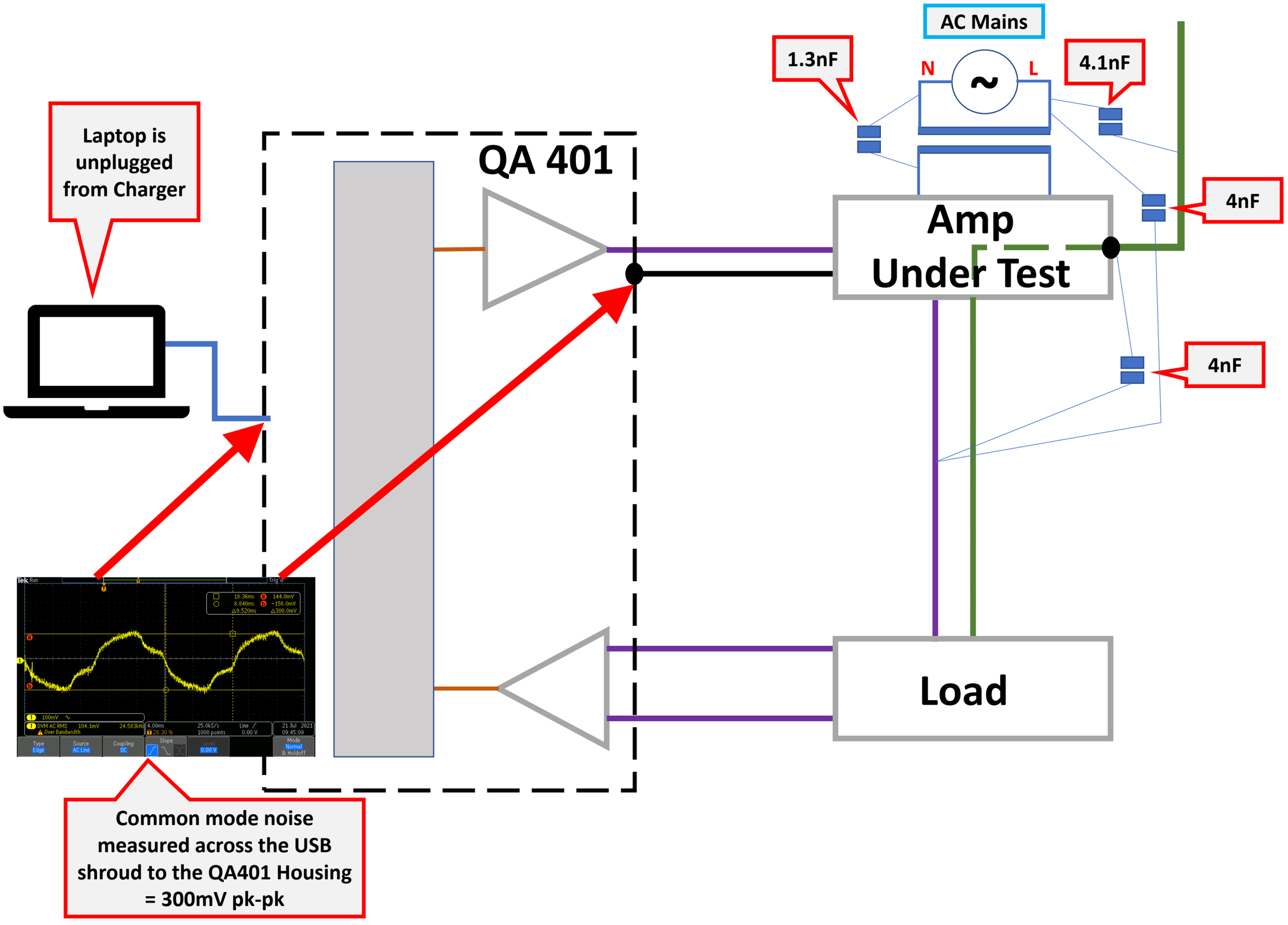
Ground

Load

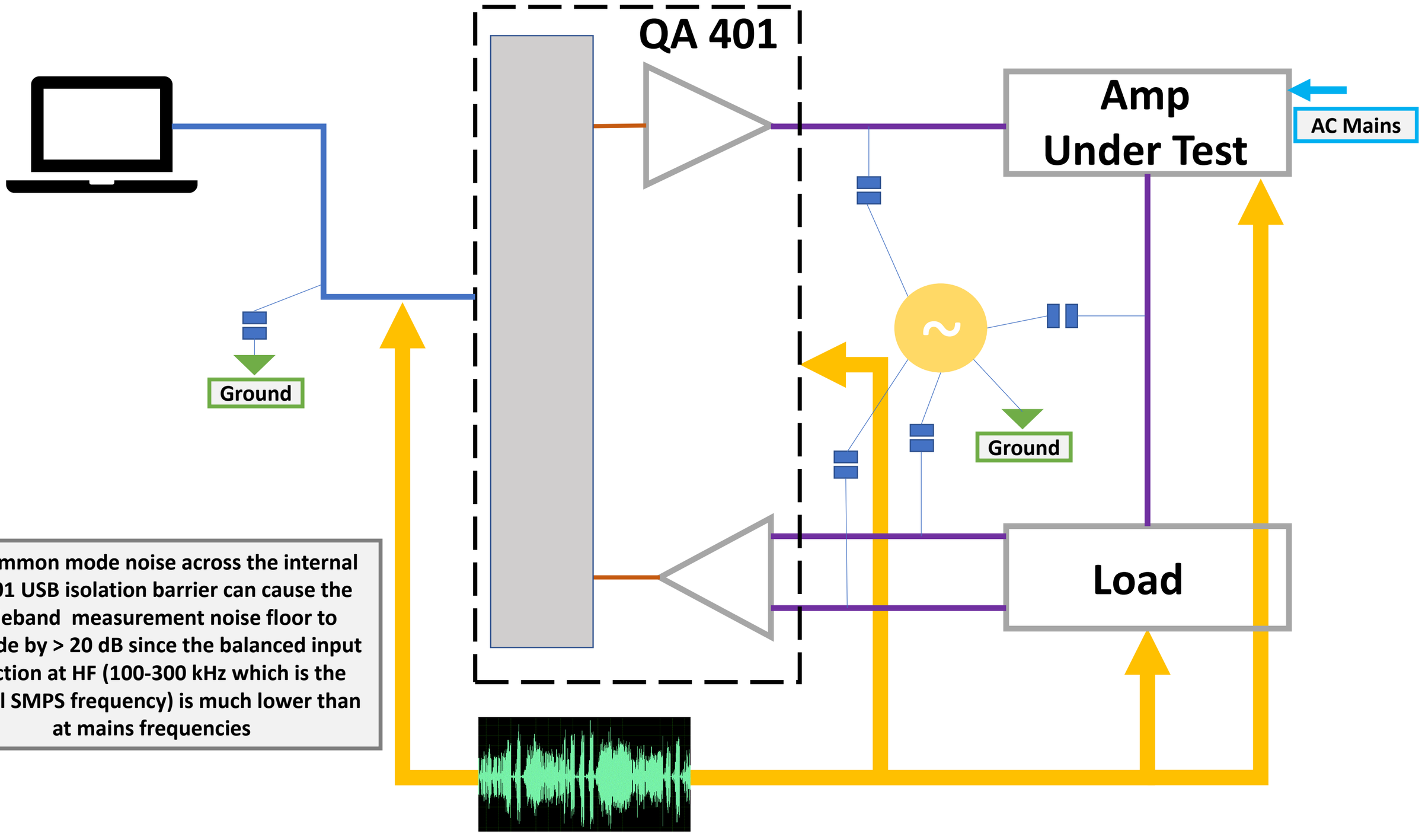
Hi-Z input with 82 dB CMRR

All or parts of the system formed by the QA401 output, QA401 input, amplifier under test, load and PC float wrt EARTH (SAFETY GROUND) and/or partially wrt each other. Since the amplifier test is usually conducted with single ended inputs and the QA401 balanced input common mode rejection ratio is -82 dB, rejection of mains frequency components is limited if trying to suppress mains noise to << -120 dBV. Just 1V of common mode noise between any two parts in the signal chain can result in the QA401 'seeing' 100uV at its input. For low noise readings, the total QA401 input referred hum must be kept ***well below 1uV***

Parasitic Capacitances Measured on a 240W Power Amp

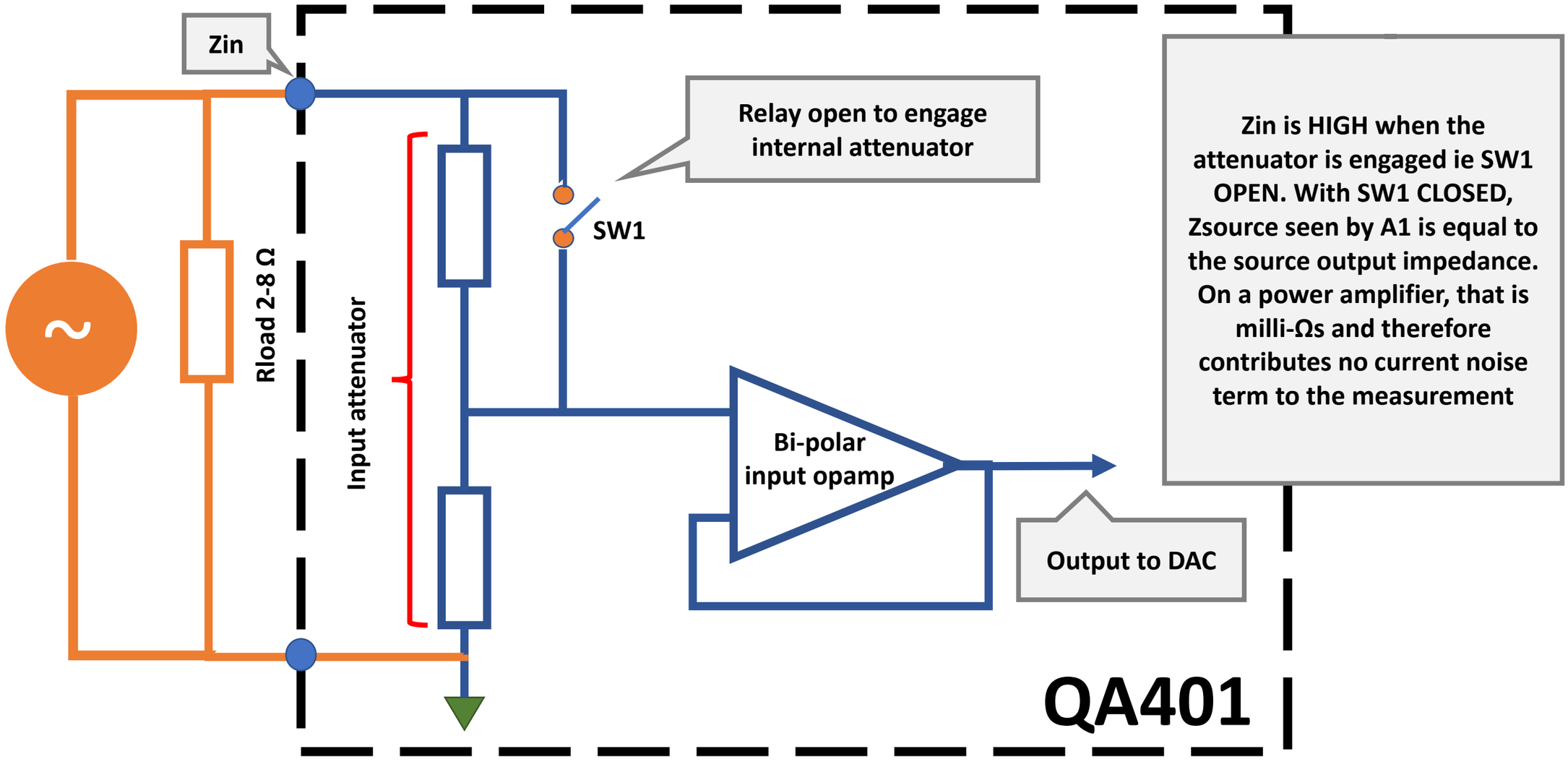


High Frequency Noise From the PC or Other Equipment Can Place Common Mode HF Noise of Many Volts Across the QA401 Isolation Barrier



HF common mode noise across the internal QA401 USB isolation barrier can cause the wideband measurement noise floor to degrade by > 20 dB since the balanced input rejection at HF (100-300 kHz which is the typical SMPS frequency) is much lower than at mains frequencies

Thermal Noise Floor Limitations With the QA401 Internal -20 dB Attenuator



The input attenuator is high impedance and therefore contributes a significant thermal (Johnson) noise term to the measurements. The internal QA401 20 dB attenuator raises the noise floor by about 30 dB. Mains noise components are therefore buried beneath the instruments noise floor which sits at about -100 dBV vs -135 dBV (typical power amp measurements with the power OFF)

5 Rules for accurate low noise measurements

1. Reduce loop areas to minimize magnetic coupling of mains frequency and amplifier output signal

2. Neutralize stray capacitance to reduce HF noise coupling by bonding the grounds all parts in the measurement set-up on the measurement side of the QA401 (i.e. amplifier, load etc)

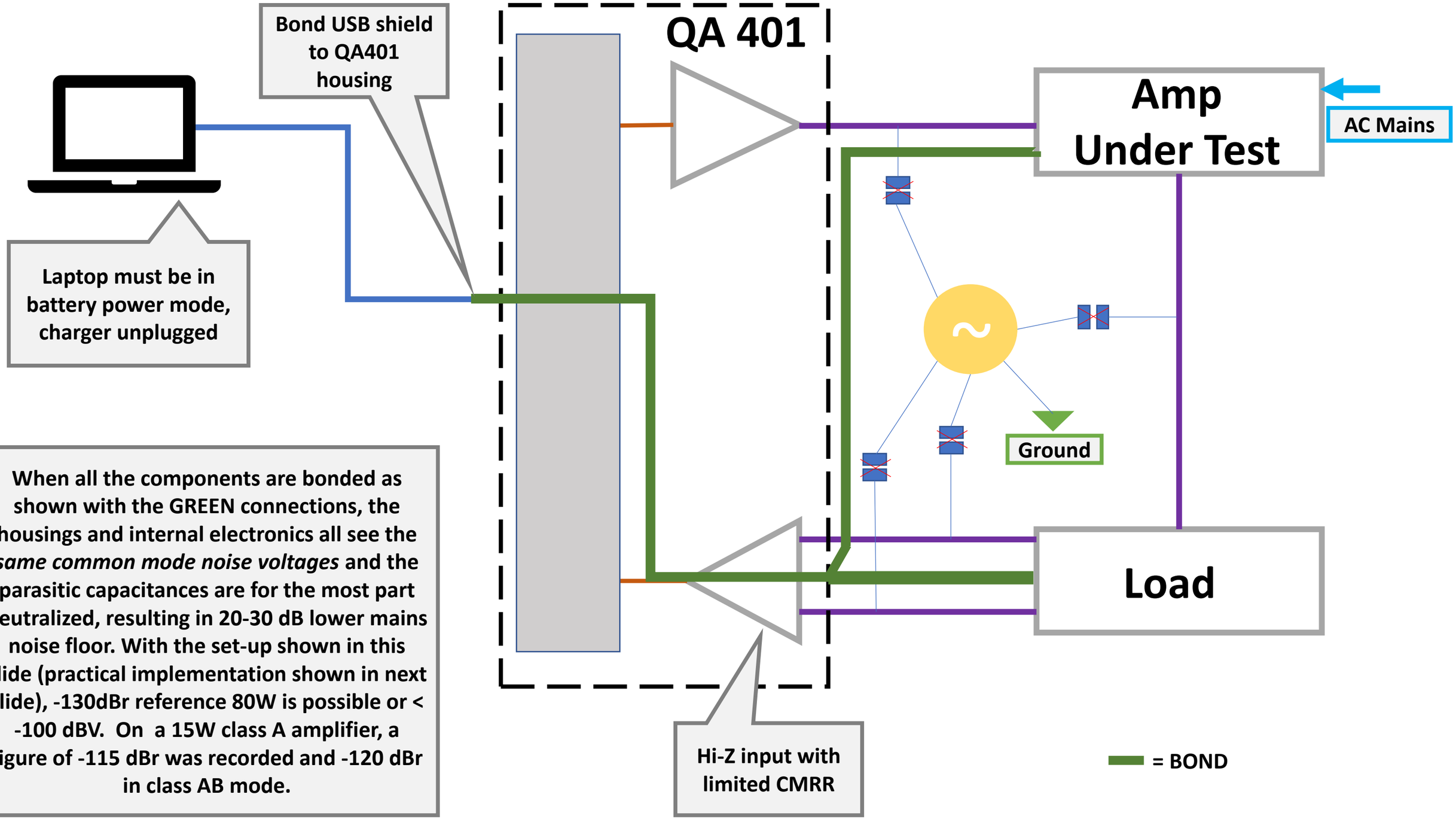
3. On power amplifier measurements, use a lo-z external attenuator - do not use the internal -20dB attenuator on the QA401. This will allow you to see harmonics down to -135 dB

4. Where possible use a laptop without the battery charger plugged in

5. Ensure all unnecessary noise sources are turned off – LED/CFL lamps, battery chargers etc

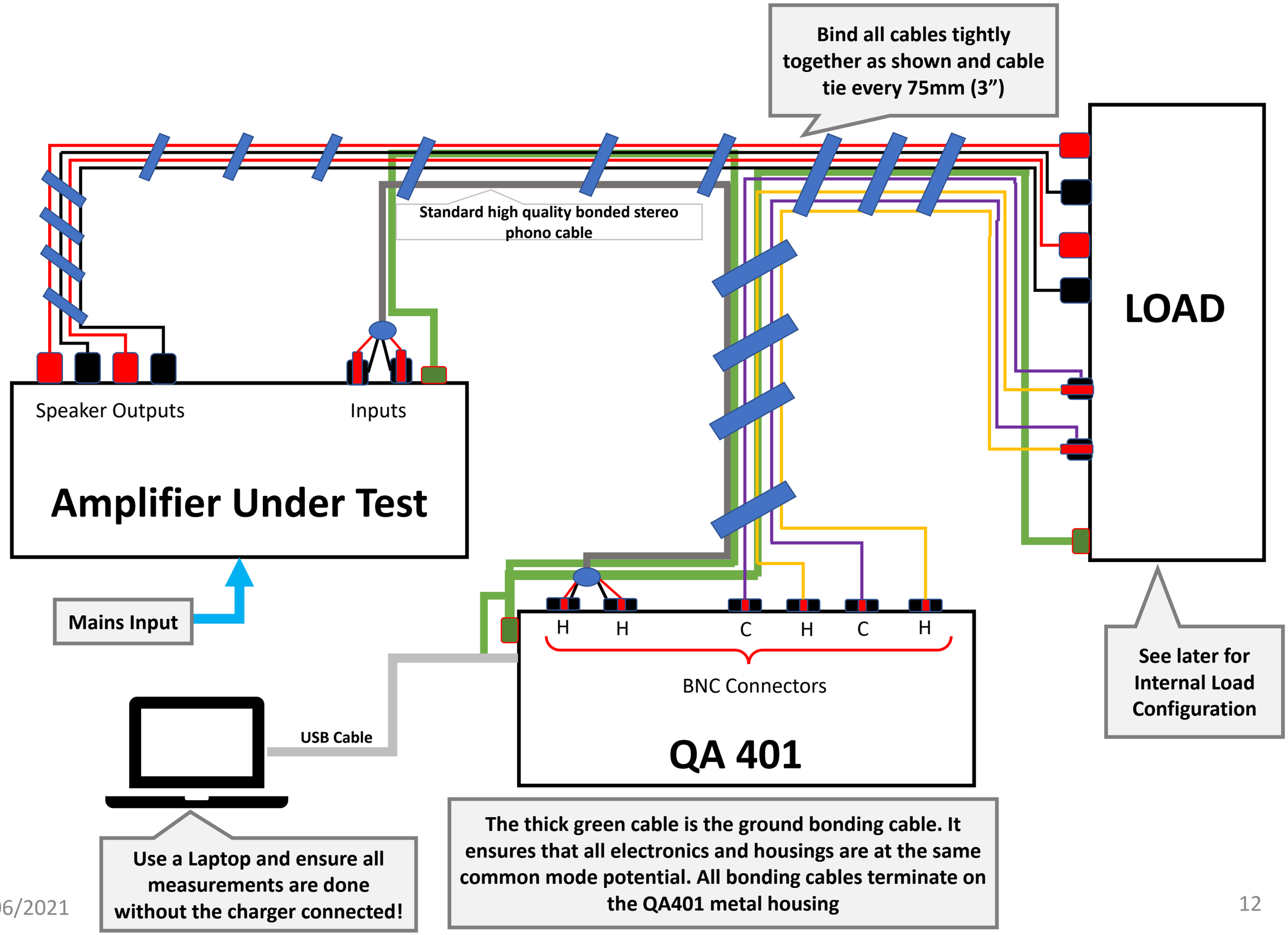
The next slides will show how to accomplish this

1. Bonding the system together reduces noise in measurements by neutralizing stray capacitances

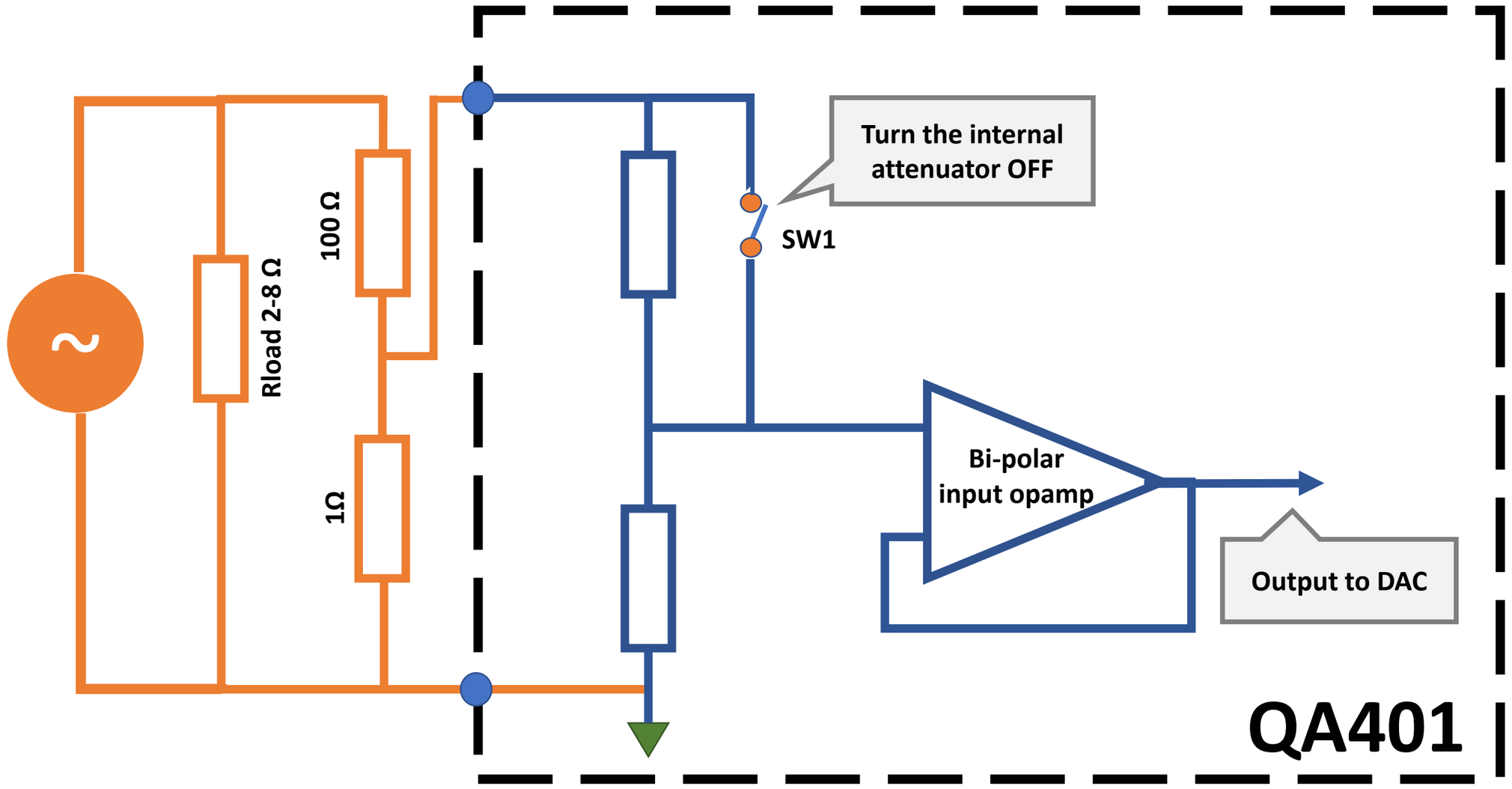


When all the components are bonded as shown with the GREEN connections, the housings and internal electronics all see the *same common mode noise voltages* and the parasitic capacitances are for the most part neutralized, resulting in 20-30 dB lower mains noise floor. With the set-up shown in this slide (practical implementation shown in next slide), -130dBr reference 80W is possible or < -100 dBV. On a 15W class A amplifier, a figure of -115 dBr was recorded and -120 dBr in class AB mode.

2. Prevent Magnetic Coupling by Minimizing Interconnection Loop Areas



3. Reducing the QA401 Thermal Noise Floor Limitation With an External 40 dB Attenuator for High Power Amplifier Testing



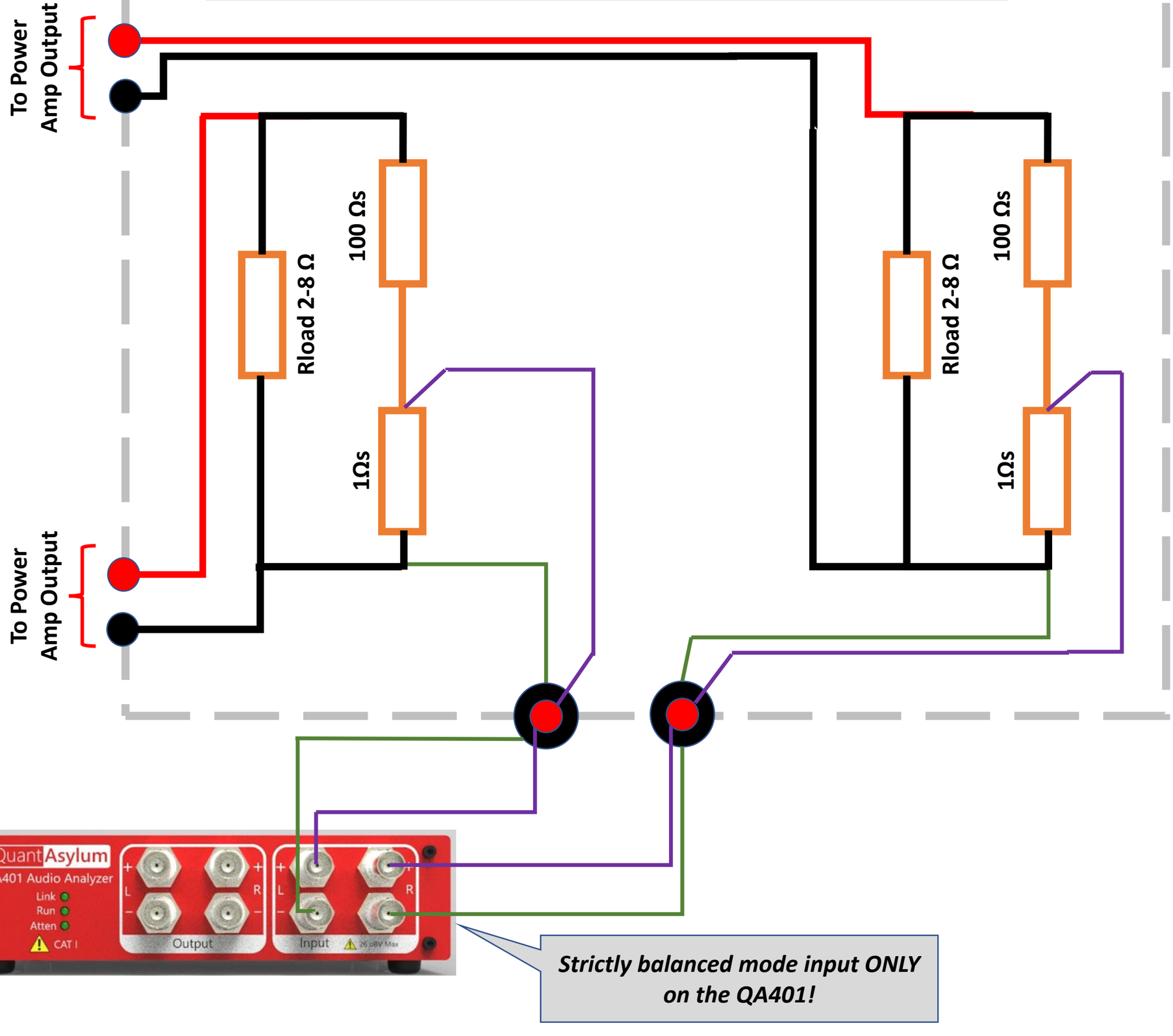
Use a 50W ARCOL resistor for the 100 Ω and a 10W ARCOL resistor for the 1 Ω Resistor. Mount both on the same heatsink as the load resistor. The QA401 now sees a low source resistance (~1 Ω) and there is therefore no noise current contribution from the internal opamp to the measurement. The QA401 ADC noise floor with this setup on a typical power amplifier is between -135 dBV and -140 dBV. The noise floor of the QA401 ADC with the internal attenuator disengaged is -155 dBV. Be sure to set the 'External Gain' dialog box on the QA401 PC interface to '-40 dB' to ensure the display reading is scaled correctly.

Attention! The 'N' suffix Arcol resistors are non-inductive and recommended for the load and attenuators

How to connect the QA401 to a test Load to prevent channel cross-coupling and minimize measurement errors

1. The left and right channels are ***completely isolated*** from each other within the test load.
2. The test signal output grounds are completely isolated from each other
3. Only use fully balanced mode on the QA401 input
4. Never common any signal returns (ie grounds) within the load, or use a common signal return back to the amplifier or to the QA401 – if you do you will get severe noise and/or increased distortion measurements

Power Amplifier Dummy Load



Acknowledgements and References

- Hifisonix How to wire up and Audio Amplifier (PDF)
- Henry Ott – Electromagnetic Compatibility Engineering
- Daniel Joffe - Library of Grounding Problems
- Ilimzn's Excellent Posts on Ground Loops (PDF)
- Jensen Transformers – Application Notes (PDF)
- Bill Whitlock – Grounding and Noise Presentation (PDF)
- Analog Devices – EMI, RFI and Shielding Concepts (PDF)
- Dr. Tom Van Doren – Training Seminar attended by NXP Apps Engineers
- Various discussion threads and private communications on DiyAudio.com
- Excellent overview of EMC by Keith Armstrong Understanding EMC
- Very Good article on balanced audio signals and ground loops (PDF)
- EMC for Product Designers by Tim Williams (see Chapter 10)

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References

- Overview of Ground Loops [Ground Loops (hifisonix.com)]