FLUKE®
Calibration

Calibrating current sources using A40B Series Current Shunts and the 5790B AC Measurement Standard

Application Note

The Fluke Calibration 5790B AC Measurement Standard is a multi-purpose ac measurement and transfer standard designed for the most demanding calibration applications. It combines the accuracy you would expect from a thermal transfer standard with the ease of use of a digital multimeter. Absolute ac voltage measurement uncertainties are as low as 24 ppm for one year in a 23 °C ± 5 °C environment. The 5790B in combination with the Fluke Calibration A40B Current Shunts allow you to make absolute or relative current measurements that are shown directly on the display as a current readout. This feature provides a very simple method to expand the 5790B's functionality to make precision current measurements.

The 5790B's user interface provides you with a current shunt menu, allowing you to input and store up to 150 shunts' information, including serial numbers, calibration dates, and primary and secondary calibration parameters (nominal dc resistance, dc resistance error, 24 ac/dc difference points, and five loading error points). After the shunt information is loaded, the 5790B can be set up to take an absolute or relative current measurement within seconds by connecting the shunt and simply selecting the appropriate shunt from the main menu. When using a current shunt, 5790B displays both the voltage and current measurements along with the shunt information. Legacy Fluke A40 and A40A current shunts' information as well as custom shunts can be loaded and used to make current measurements.

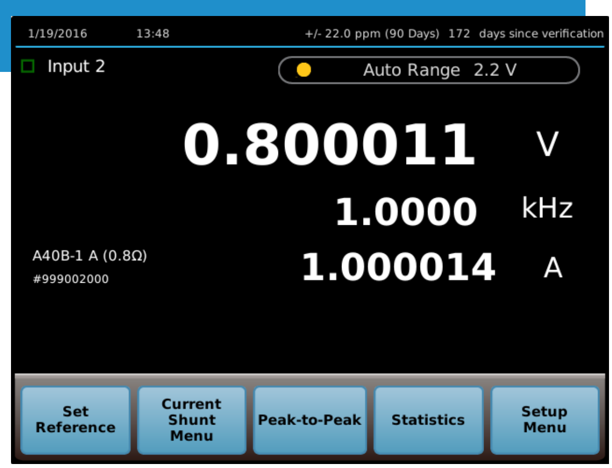

Figure 1. 5790B current readout

Benefits of using A40B Current Shunts

The A40B shunts exhibit outstanding resistance stability, with an excellent self-heating power coefficient, a low temperature coefficient, and a very flat frequency response up to 100 kHz. With all of these characteristics combined, the shunts offer direct measurement of current from dc to 100 kHz. The 5790B takes the various A40B flatness characteristics and automatically calculates and displays actual current based on these factors, at a given frequency. This allows you to be more confident with the on-screen measurement and significantly reduces time spent manually calculating the effects of primary and secondary shunt characteristics, and the possibility for errors.

Figure 2. Shunt menu

Loading A40B shunts into the 5790B user interface

The 5790B shunt menu allows you to add, edit, and manage a library of current shunts.

The current shunt menu is located in the Instrument Setup menu, which is accessed via the **Setup Menu** on the touch screen display. All additions, edits, and management of current shunts are done through this menu only. There is a direct link to select a saved shunt on the main menu, but this is only to select the shunts. This workflow protects the shunts from accidental alterations to the shunt properties. When the menu loads, you will be presented with a standard list of all of the A40B current shunts as shown in the Overview section, organized by their current value. From here, to load a shunt, select the range of the A40B and a submenu will appear. To add a shunt, simply select "**Add New**."

Each shunt has properties that provide the 5790B with the information necessary to calculate the current measurement from the voltage measurement:

1. **Serial number** – Unique identifier of the current shunt.
2. **Calibration date** – Last calibration date of the current shunt.
3. **DC resistance error (A40B) or true resistance (A40/A40A/custom shunt)** – For an A40B, this is the deviation in ppm from the nominal resistance value of the current shunt (*see Figure 3*). For A40, A40A, or custom shunts, this is the true (commonly referred to as "nominal") resistance of the shunt (*see Figure 4*). If the true resistance is known for the current shunt, it should be entered into the field, otherwise it should be left as "unknown". *Note: Without the true resistance, the current readout will not be displayed. Refer to the previous section for more information.*
4. **AC/DC difference errors** - the amount the ac resistance value would have to be changed to make it the same as the dc resistance value. To change this into a frequency flatness error, reverse the sign.
5. **Loading errors** – Measurement error caused by the input impedance of the 5790B. For A40B shunts, these values are preloaded but can still be altered if required.

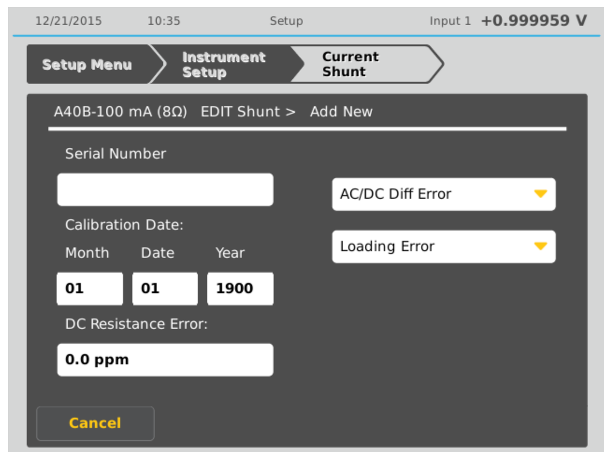

Figure 3. A40B properties

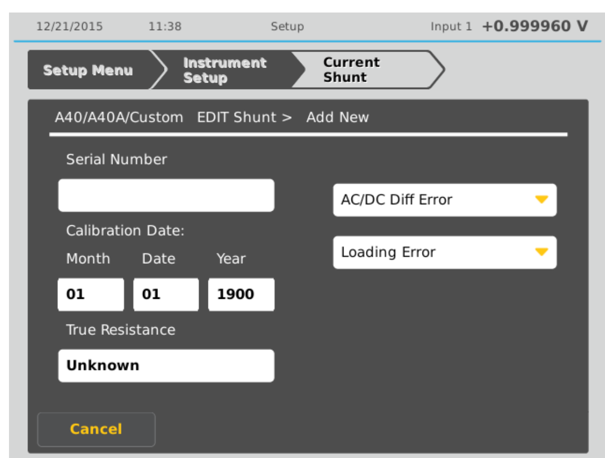

Figure 4. A40/A40A/Custom properties

The shunt menu and functionality is optimized for A40B current shunts, but does allow you to enter and use Fluke A40, A40A, and custom shunts as well. This said, a key component of the real-time current readout is knowing the true resistance, and the deviation from nominal, typically referred to as the "dc resistance error." Without a resistance value, the current readout will not be displayed. When using the A40 and A40A shunts, to display the current readout, enter in the nominal resistance for these shunts, with a dc resistance error of "0." The displayed current is for indication only since the true resistance is not specified for the A40 and A40A shunts.

How current is calculated

Using the errors for A40B shunts, the 5790B calculates the current as follows:

$$I = \frac{V}{R_{dc}} \times \left(1 + \left(\frac{ACDC_{Err}}{1{,}000{,}000}\right) + \left(\frac{Load_{Err}}{1{,}000{,}000}\right)\right)$$

V = 5790B voltage measurement (*V*)

I = 5790B current readout (*A*)

ACDC_Err = AC/DC difference values from the A40B calibration certificate (µΩ/Ω or ppm)

R_DC = Actual dc resistance of the A40B shunt that that equals the nominal dc resistance minus the dc resistance error which is provided on the calibration certificate (Ω)

Load_Err = 5790B loading error (preloaded into 5790B) (µΩ/Ω or ppm) when using A40B shunts

Note: When the frequency being measured is between the stored errors' points, $ACDC_{Err}$ and $Load_{Err}$ in this formula are linearly interpolated.

Connecting the A40B Current Shunt to the 5790B

An additional benefit that the A40B Current Shunts offer over the legacy A40 and A40A Current Shunts is the ability to make direct, adapter-free connections to the 5790B. If you worked with the legacy A40/A40A adapters, you understand the complexity of the connection as illustrated in Figure 5 and how much more measurement risk is present due to the need to take the cable uncertainties into consideration. Now, with the 5790B you can have more confidence in your current measurement by significantly reducing complexity. Figure 6 illustrates the connection simplicity of the A40B, which can either be connected directly to Input 1 (N-type coaxial) or Input 2 (standard terminal jacks). Connecting the A40B shunt directly to Input 1 eliminates cable and associated errors. Please note that if this is the preferred connection, consider the following to prevent damage to the equipment:

1. Support the A40B so that a downward force will not break the shunt or the 5790B. Fluke Calibration recommends a scissor-style jack stand that can be adjusted up and down to support multiple sizes of shunts.
2. Support the A40B so that a side load will not break the shunt or the 5790B. Consider positioning the 5790B and A40B so that the shunt will not be bumped, which could destroy the A40B and/or the 5790B.
3. For the larger A40B shunts, there is not much clearance when the shunts are directly connected. In this case, Fluke Calibration recommends the use of one of the A40B-leads, shown in Figure 6; and not making a direct connection into Input 1.

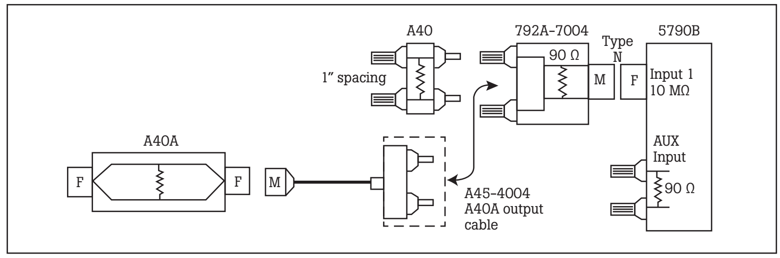

Figure 5. A40A connection example with adapters

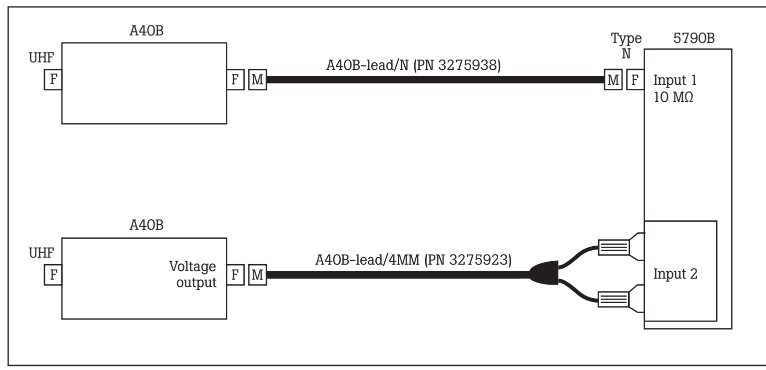

Figure 6. A40B connection examples

Cabling must also be carefully evaluated to ensure best measurement results. Consider the following when connecting the shunt:

1. Keep current input and voltage output cables/paths separated or at least perpendicular to each other to avoid magnetic coupling at higher currents.
2. Use coaxial or twisted pair cables to minimize radiation and susceptibility.

Fluke Calibration offers many leads, connectors, adapters, and accessories for the A40B current shunts. You can learn more about these items in the Fluke Calibration brochure titled: "A40B Precision Current Shunts adapters, cables and connectors" available on **www.flukecal.com**.

Making a current measurement with the A40B shunts

Now that the shunt information has been loaded and it is connected to the 5790B, making precise current measurements can be enabled in seconds by selecting the A40B Current Shunt from the main menu. When selected, the real-time current readout will appear on the display.

When measuring current with the A40B shunts, the current readout is always shown on the lower portion of the main display under the voltage measurement. Note that the uncertainty shown at the top of the display only relates to the voltage measurement and not the current readout.

Note: It is good practice to let the shunts stabilize after current is applied.

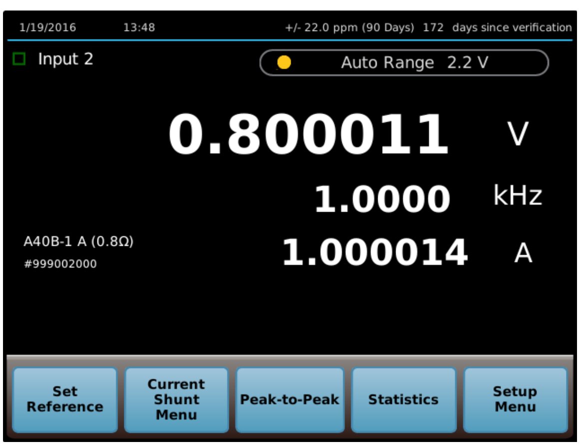

Figure 7. Current measurement

The 5790B significantly helps reduce measurement errors

The 5790B calculates the current based on the voltage measurement using Ohms Law, and also the secondary parameters associated with non-ideal resistors. Simply the voltage measured across the resistor will be as follows where V_s is voltage, Io is the current, and R_s is the known resistance value:

$$V_s = I_o \cdot R_s$$

Unfortunately, all current shunts are non-ideal resistors, meaning that the behavior of the resistor is dictated by more than just the relationship specified by Ohms Law. The error sources associated with non-ideal resistors include ac/dc differences at specific frequencies and loading errors and must be accounted for when making precise current measurements. Figure 8 presents a detailed look at the connection diagram of the A40B, along with many of the potential error sources.

The illustration shows that there are many potential errors that could be present in the current measurement. The 5790B significantly reduces measurement errors by accounting for the A40B and 5790B device specific errors.

As illustrated in Figure 8, more connection and UUT related errors could be present such as:

- Non-ideal output resistance of the source
- Transmission line behavior of cables
- Common-mode effects

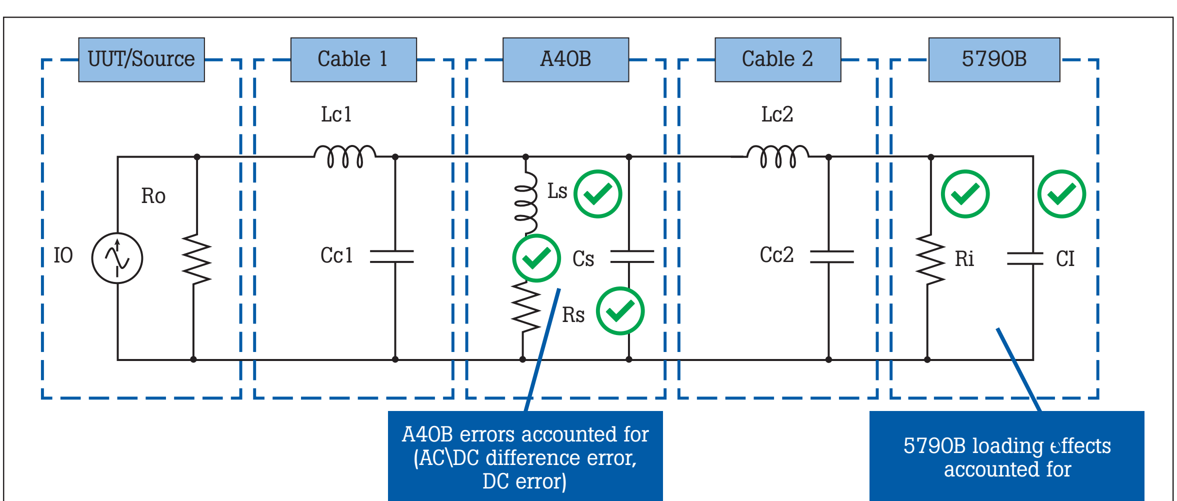

Figure 8. Error sources and what is considered

These types of errors are variable and are based on the external connections and the UUT being tested, thus making it difficult to account for. For cable error mitigation, Fluke Calibration recommends the use of the A40B cables specifically designed for the A40B, or making the direct connection previously described. Both methods make the errors associated with "Cable 1" and "Cable 2" insignificant. You can learn more about these items in the Fluke Calibration brochure titled: *"A40B Precision Current Shunts adapters, cables and connectors"* available on **www.flukecal.com**.

For more information on connection and UUT related errors, refer to Fluke Calibration's book on metrology titled: *"Calibration: Philosophy in Practice, Second Edition."* This book contains information on how these errors can be identified and mitigated.

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Electrical | RF | Temperature | Pressure | Flow | Software

Fluke Calibration
PO Box 9090,
Everett, WA 98206 U.S.A.

Fluke Europe B.V.
PO Box 1186, 5602 BD
Eindhoven, The Netherlands

For more information call:
In the U.S.A. (877) 355-3225 or Fax (425) 446-5116
In Europe/M-East/Africa +31 (0) 40 2675 200 or Fax +31 (0) 40 2675 222
In Canada (800)-36-Fluke or Fax (905) 890-6866
From other countries +1 (425) 446-5500 or Fax +1 (425) 446-5116
Web access: http://www.flukecal.com

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