

Application note

Verifying the capacitance function of the 8588A Reference Multimeter



This application note provides guidance to those wishing to verify the performance of the capacitance function of their 8588A Reference Multimeter. It describes the methodology, examines the measurement process, and describes some of the pitfalls that can occur.

As capacitance is derived from resistance, do we need to routinely verify the capacitance function at all? To answer this, let us first look at how the 8588A measures capacitance.

The 8588A measures capacitance using a dc discharge method that is fundamentally the same as the method used by handheld multimeters, but of a higher precision. In the case of the 8588A, the unknown capacitor is discharged until it is close to zero and then charged with a known constant current; this results in a negative going linear ramp that returns to zero at the end of each measurement cycle. The voltages close to the start and end of the ramp are measured and the capacitance calculated from $C = I \cdot \delta t / \delta v$ where C is the capacitance in Farads, I is the current in amps and v is the change in voltage over the time interval t .

The resistance function provides the constant current and voltage measurement capability and uses the same calibration constants for voltage and current that were determined during resistance adjustment, except for the 1 nF range, which is adjusted using an external reference capacitor due to the difficulty in characterising the internal bias currents.

The capacitance function is also affected by timing errors. Internally the 8588A has one master clock, so these timing errors can be evaluated by measuring the frequency counter. The clock specification is 1 µHz/Hz, which is many orders better than the specification of the best capacitance range, so any timing errors can be effectively ignored.

From this description we can see that the performance of the 10 nF range and above could be monitored by evaluation of the appropriate resistance range. For many laboratories this may be the preferred option due to lack of suitably traceable standards. It is possible that the capacitance measurement could be affected by internal physical changes that would not show as a change in resistance; however, any change would have a greater impact on the lower capacitance ranges, which can be evaluated by comparison with readily available reference capacitors. Any change seen on these lower ranges would very quickly become insignificant as we go up range.

In conclusion, the answer to the question of whether we need to separately verify the capacitance function is: Yes, for the 1 nF range because its calibration is independent of the resistance range it uses, but optional for the 10 nF range and above. This is because the performance of these ranges can be monitored by observing the change in the appropriate resistance range given in Table 1.

Capacitance range	Resistance range used
1 nF	100 MΩ, Lo I
10 nF	10 MΩ, Lo I
100 nF	1 MΩ, Lo I
1 µF	100 kΩ, Lo I
10 µF	10 kΩ
100 µF	1 kΩ
1 mF to 100 mF	100 Ω
1 mF to 100 mF Lo I	1 kΩ

Table 1. Resistance to capacitance range mapping

Using reference capacitors to verify the 8588A

The value of a typical reference capacitor commonly found in calibration laboratories changes with frequency and its configuration as a 2-terminal or 3-terminal device. The 8588A measures 2 terminal capacitance using the dc discharge method described above. We therefore need to know what the effective test frequency of the 8588A is, and the 2-terminal value of the reference capacitor at this frequency.

There is no direct equivalence between the ramped waveform of the 8588A and the frequency of a sine wave. However, a good approximation can be made by equating the slew rate of the ramp generated by the 8588A with the maximum slew rate of a sine wave using the relationship: $v/s = 2 \cdot \pi \cdot f \cdot V_{pk}$ where v/s is the slew rate in volts per second, f is the frequency in Hz and V_{pk} is the peak voltage. Table 2 lists the equivalent test frequencies determined using this relationship. Note that the frequency not only changes with range but also where the value lies within the range.

8588A range	Applied value % of range	Equivalent test frequency
1 nF to 1 mF	20 %	5.63 Hz
	100 %	1.13 Hz
	200 %	0.56 Hz
10 mF	20 %	0.68 Hz
	100 %	0.14 Hz
	200 %	0.079 Hz
100 mF	20 %	0.056 Hz
	50 %	0.023 Hz
	100 %	0.011 Hz
1 mF Lo I	20 %	0.56 Hz
	100 %	0.11 Hz
	200 %	0.056 Hz
10 mF Lo I	20 %	0.056 Hz
	100 %	0.011 Hz
	200 %	0.005 6 Hz
100 mF Lo I	20 %	0.005 6 Hz
	50 %	0.002 3 Hz
	100 %	0.001 1 Hz

Table 2. 8588A effective test frequency

It is unlikely that traceability will be available at the frequencies listed in the table, so the reference capacitor will need to be measured at multiple frequencies going as low as possible and the value extrapolated.

Fortunately, the 1 nF range is much simpler to verify. Air dielectric capacitors are available at this value which have negligible frequency dependence; this allows them to be characterised at 1 kHz and used at these low frequencies. The main consideration with these capacitors is that they are generally 3-terminal devices. Therefore, they will need to be modified by fitting a shorting connector to their low terminal that connects it to the case and then measured as a 2-terminal device.

An alternative approach

A slightly different approach is used at Fluke due to the volume of instruments going through the laboratory. We use a characterised 5522A Multi-Product Calibrator that has been characterised using an 8588A transfer standard and the previously described 1 nF capacitor.



The capacitance traceability for the transfer standard is derived from voltage, current and time which has been validated against reference capacitors and a standalone measurement system which is also based on voltage, current and time. This standalone measurement system has been used since the early 90's by Fluke and is listed in the UKAS schedule of accreditation.

Fluke Calibration.

- Electrical
- RF
- Temperature
- Humidity
- 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
 Web access: <http://www.flukecal.eu>

For more information call
 In the U.S.A. (877) 355-3225 or
 Fax (425) 446-5716
 In Europe/M-East/Africa +31 (0) 40 2675 220
 or Fax +31 (0) 40 2675 222
 In Canada (800)-36-FLUKE or
 Fax (905) 890-6866
 From other countries +1 (425) 446-6110 or
 Fax +1 (425) 446-5716
 Web access: <http://www.flukecal.com>

Modification of this document is not permitted without written permission from Fluke Calibration.

©2021 Fluke Calibration.
 Specifications subject to change without notice.
 Printed in U.S.A. 1/2021 210088-en