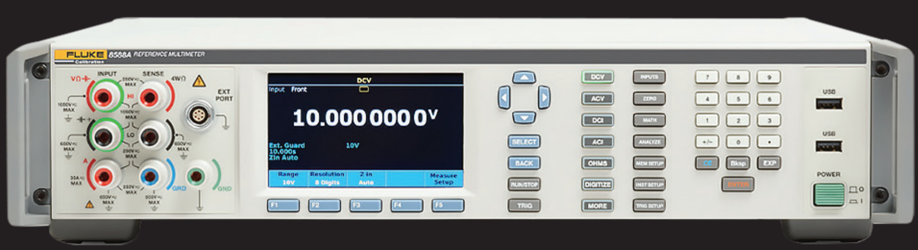
Fluke 8588A Reference Multimeter Evaluation



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Newsflash: "Everett, Wash., March 26, 2019 – Fluke Calibration introduced today two best-in-class digital multimeters, the 8588A and the 8558A 8.5-Digit Multimeters."
I can't recall in recent memory when a new product release has caused such a buzz in the metrology / calibration community. The 8588A and 8558A are the first new product launches in the long-scale multimeter arena in well over a decade promising superior performance, increased productivity and faster access to results. Like many of my metrology comrades we were biting at the bit to get our hands on the 8588A Reference Multimeter especially after reading the following from the Fluke Calibration website;

> **"The 8588A Reference Multimeter is the world's most stable digitizing multimeter. Designed for calibration standards laboratories, this reliable digital multimeter holds the industry's best one-year dc voltage accuracy and pushes the speed envelope by producing a stable 8.5 digits reading in a mere one second, enabling it to outperform any other long-scale reference multimeter on the market. With more than 12 functions, the 8588A helps consolidate your lab's cost of test into a single measurement instrument."**

Leveraging decades long friendships and the promise of an unbiased evaluation fit for publication, we were able to obtain an 8588A for evaluation at Transcat's Houston Texas primary DC-Low Frequency calibration laboratory.

The intention of this evaluation was two-fold;

1. Understand 8588A performance and repeatability
2. Determine if 8588A can be deployed to calibrate multifunction calibrators i.e. Fluke 5522A

One can perceive our first intention was to determine if the 8588A would be a viable candidate for existing long-scale digital multimeter substitution / replacement. Our second, more lofty intention was to see if the 8588A could be the first-ever long-scale meter in history to be able to be shipped to lower echelon calibration laboratories in order to calibrate their own multifunction calibrators, eliminating the need to ship them out for calibration. With these intentions in mind we eagerly awaited receiving a 'minty fresh' 8588A.

OUT OF THE BOX

We received the 8588A with a very nice set of test leads, 4-way PCB short, operator's manual and calibration certificate. The calibration certificate carried the UKAS accreditation logo and listed the procedure as '*8588A Factory Cal (A System). ft Rev:1.02*'.

Factory Automated Calibration System.

Unboxing the the Fluke 8588A Reference Multimeter.

The 8588A's calibration certificate listed the following standards used to perform the calibration:

Standards Used:

Description	Model	Serial No.	Asset No.	Cal Due Date
Calibrator	5730A	3388502	C1/03455	27 May 2019
Amplifier	5725A	3400001	C1/03447	27 May 2019
Calibrator	5522A	3344901	C1/03441	25 Jul 2019
Amplifier	52120A	4148701	C1/03601	09 Jun 2019
1 Ω Standard	742A-1	4095001	C1/03591	28 May 2019
1 GΩ Standard	7000K	407572965	C1/03583	24 Jun 2019
10 GΩ Standard	10grStdRes	3565	C1/03565	01 Aug 2019

Figure 1.

It was noted that a 10MHz frequency standard was not listed on the calibration certificate as called out in Fluke's application note, ***'Overview of 8588A and 8558A calibration support processes and equipment requirements'*** for 8588A performance verification. Per this application note, the 8588A service manual which, at time of this writing had yet to be published, appears to be a must have for calibrating it (see following snippets);

> *If all the recommended points are tested, full verification of the 8588A requires approximately 600 points (fewer for the 8558A), around 2.5 times as many compared to 8508A.*
>
> *Full details of the equipment requirements (sufficient to allow substitution of appropriate alternatives), adjustment and verification points appear in the 8588A and 8558A Service Manual.*
>
> *Performance verification points used in the Fluke factory and service center calibration systems, and data appearing in the calibration certificates delivered from the factory, include additional points beyond the minimum needed to traceably confirm complete and correct adjustment of all functions and ranges following the calibration adjustment process outlined above. These additional points provide extra information some users may find helpful and informative. They are not essential and may be optionally omitted, reducing the calibration time, support complexity and costs. The Service Manual calibration procedure includes and identifies these additional 'optional' points.*

Our 8588A calibration certificate contained the aforementioned optional points and all captured calibration data were within stated specifications (specifications apply for default configuration for aperture and resolution at 99% confidence level). The unit powered on and completed self diagnostics flawlessly.

FUNCTIONALITY EVALUATION

The 8588A front panel menus and controls are ergonomically laid out for efficiency with terminal connectors backlit depending on measurement function selected. The display is easily read at arms length and provides essential measurement control functions on the lower portion of the screen accessible via functions keys (F1 thru F5). The dedicated Zeroing button is a most welcome feature.

The 8588A Math menu provides selections for a variety of linear, averaging, and logarithmic calculations such as Display = (mx– c) / z, Display = ((Reading - R)/R * 100 and Display = 10 * log10(R2 /50)/1mW), etc., available in all functions except Digitize and RF Power.

The abundance of USB connectors (2 Type A on front panel, 1 Type A and 1 Type B on rear panel) makes for easy data collection to a memory stick (.csv format) with time stamping. It was noted that the 8588A has no ready means for storing and recalling measurement setups either to internal memory or a memory stick.

The 8588A has a new functional feature, recognizing Rhode & Swartz compatible RF power sensors, and displaying measurements in either absolute or relative modes in units of dBm, Watts, Vrms, Vp-p and dBµV. The readout displays the probe's measurement values in linear units of watts or volts use W, mW, µW or V, mV, or µV depending on measured value. The probe's measurement signal frequency must be entered into the DMM via its keyboard as the DMM cannot measure the frequency as it is higher than the DMM's frequency counting bandwidth. The DMM measures frequency / period from front panel terminal connectors (up to 10MHz) as well as rear panel BNC connector (up to 100MHz) with ability to connect to an external 10 MHz reference clock.

As a DMM, the 8588A capabilities do not extend into the advanced functions of RF instrumentation, offering the basic functions of the power sensor. It was observed the 8588A has no provisions for RF power sensor mismatch (Gamma) corrections (if mismatch characteristics of relevant devices are known in terms of both magnitude and phase, a correction factor may be calculated and applied to compensate results for mismatch errors, thus reducing total measurement uncertainty).

The 8588A's PRT (2, 3 and 4 wire configurations) and Thermocouple (which requires external cold reference junction) measurement menus are logically laid out with provisions for a variety of probe types.

The 8588A has excellent capability for current measurement beyond those usually found in the current functions of DMMs. It has the ability to measure the voltage across an external shunt and compute the calculated current, taking into account specific characteristics of the shunt i.e. shunt corrections, is extremely useful with Power reference level and Power coefficient entries used to calculate the additional uncertainty of the displayed current due to self-heating of the shunt i.e. Power uncertainty = Power coefficient x { 1 - (Measured current/Power ref level)^2 }.

The 8588A digitizing functionality is a significant advancement over digitization done in previous long-scale digitizing meters. It has an 18-bit, 5 Mega sample per second converter, very flexible triggering & timing capabilities, and enough memory to store as many as 10 million measurements! The graphic display provides very fast and informative displays for analyzing applied signals in guises of frequency plots, trending plots and histograms along with displaying applicable statistics.

Of particular excitement is the 8588A's ability to perform ratioing between front and rear terminals manually or with automation for dc voltage, resistance and current functions. Ratio measurements have the best uncertainty of any function in a DMM and can be a valuable capability in the area of metrology. Ratio measurements primarily are affected by the characteristics of linearity, repeatability, and short-term stability. Additional error components such as traceability uncertainties, long term stability and temperature related uncertainties are usually not a concern with ratio measurements. The ratio capability taking advantage of multiple inputs is standard in the 8588A. It offers advances beyond the ratio measurements found in other meters.

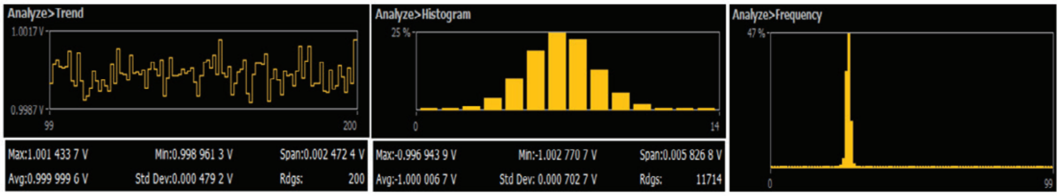
Evaluation of 8588A calibration adjustment functionality was not performed.

EVALUATION SCHEME

With the 8588A's ability to emulate a Fluke 8508A and a Keysight 3458A programming, existing and new automation code was modified / written to perform evaluation measurement routines. This approach had two hiccups;

1. Checking out 8588A's ratioing functions we experienced problems executing SCPI commands (Standard Commands for Programmable Instruments)
2. Ratio and division modes did not always change displayed units into engineering notation format.

These problems were forwarded to the Fluke technical support where it was resolved with a firmware update, 1.19 (2019 July 4) … The Fluke technical team was very quick to respond.



REPEATABILITY EVALUATION

Numerous repeatability studies were performed for each measurement function. The DC voltage function is usually the most accurate measurement function in a multimeter, so evaluating this performance is an excellent indicator of the core measurement capabilities of the instrument. One of the studies involved taking direct measurements of a Fluke 732B DC reference standard with a proven history of stability and predictable drift per Fluke's 10V Measurement Assurance Program performed bi-annually. The relative specifications for the 8588A measuring 10 volts are repeatability of ±1.2µV (or 0.12 ppm) over 20 minutes. The relative accuracy is ±7.1µV (or 0.71 ppm) over 24 hours, and over 90 days it is ±19µV (or 1.9 ppm). This is an improvement of 20% to 30% over other 8.5 digit DMM's.

The 8588A was programmed to make multiple 8½ digit resolution measurements at 60 power line cycles (PLC) for each run, in order to obtain an average measurement value which was compared to the Fluke 732B's predicted 10V value for that day. The 8588A was configured for 8-digit resolution, 8 measurements were taken, 3 were tossed and 5 were averaged to produce the final measurement.

Between the 3rd and 4th runs the 8588A was powered down for 24 hours and moved from the primary laboratory's controlled environment to an office environment then returned to the primary laboratory's control environment, powered up and allowed sufficient time to stabilize. The intentional interruption between the 3rd and 4th runs was to get a feel for the 8588A's ability to return to a known state after powering off and movement to another environment. The results are shown below in Figure 2.

An analysis was performed to evaluate the 8588A's ability to measure a certified 10V standard having a predicted drift. This is shown graphically below. The difference in the measured value from the standard's value was analyzed against the performance specification of the 8588A. The following graph (Figure 3) illustrates the certified values of the standard (blue dots), a linearization of the drift rate over the 2-week period (dotted blue line). Each of the 8588A's two days of measurements (orange dots), both at the start and end of the 2-week period, are also shown. These measurements include a vertical band (orange lines) illustrating the 24-hour spec of the 8588A around each measurement. Also shown adjacent to each set of 2-day measurements is the average of the measurements in the two-day time (green dots). Included is a vertical band (green lines) showing the S. Standard Deviation of the measurements averaged to form the specific measured values.

10 V Measurement Evaluation w/732B					
Sequence	Date	732B Predicted Value (V)	Average Measured Value (V) w/ 24 hr. spec limits	8588A Delta from 732B Predicted Value (ppm)	8588A Best Measurement Spec (24 Hours Since Cal)
A - Run 1	27-Jun	9.999999898	10.000000568	0.67	±1.9 ppm
A - Run 2	27-Jun	9.999999898	10.000000548	0.65	±1.9 ppm
A - Run 3	28-Jun	9.999999904	10.000000654	0.75	±1.9 ppm
B - Run 1	10-Jul	10.000000028	10.000000318	0.29	±1.9 ppm
B - Run 2	11-Jul	9.999999950	10.000000350	0.4	±1.9 ppm
Average of A - Runs			10.000000590	S. Std Dev: A - Runs	5.63E-07
Average of B - Runs			10.000000334	S. Std Dev: B - Runs	2.26E-07
Diff. Between A & B Runs Averages			2.56E-07		

Figure 2.

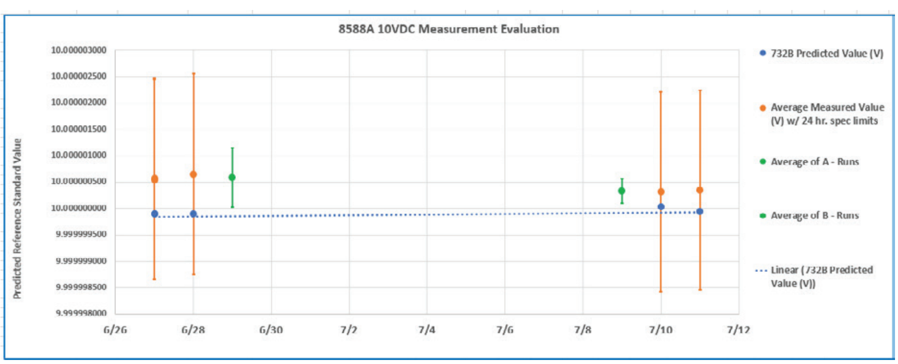


Figure 3.

Summary of 8588A 10 Volt DC Measurement Test:

The 8588A measurements were seen to be extremely good. It performed well within its best specifications throughout the nearly two weeks that we evaluated it. The DMM's measurement difference from the 10 volt standard value was consistently well within its specification for one day following a calibration (this was for a time period longer than 30 days following calibration!) and very much better than its 90-day specifications which would apply in this situation. In our tests the difference between the predicted value of the standard and the 8588A's average measured value were in a range of only 0.29 to 0.75 ppm. The standard deviation around the average of the two days of measurements show this to be well within just one third of the allowable specification range of measurement values. Also consider that the meter was taken out of its controlled environment for a significant period of time and then returned to resume the testing, and still demonstrated these excellent results. This 8588A is significantly better than its specifications in measuring 10 volts DC.

RATIOING EVALUATION

Another series of evaluations focused on 8588A ratioing two independent measurements. Ratio is a measurement technique where the DMM makes two related measurements over a short time. It is intended for use to test or calibrate similar parameters such as when a known standard is compared to an unknown (such as two resistors, or two voltages). As such, the measurements made are strictly relative, one measurement compared to another, and the resulting ratio comparison has very small uncertainty versus a traditional individual measurement of the unknown parameter needing to be measured. In ratio measurements the uncertainty of the ratio measurement is simply based on the ability of the meter to make two high quality measurements over a short time of two similar parameters. This ratio measurement relies on the quality of the basic measurement system in a DMM, primarily looking at the linearity, repeatability, and short-term stability of the measurement system. On the other hand, traditional direct measurements have significantly more uncertainty due to the traceability components of that measurement parameter, the time since that calibration, and any temperature differences between the calibration and the present operating environment. The resulting ratio uncertainty is usually much better than a single direct measurement of the unknown. In this evaluation we evaluated both DC voltage and resistance ratios.

For the DC voltage evaluation, we measured two Fluke 732B DC reference standards. Both have proven histories of stability and predictable drift per Fluke's 10V Measurement Assurance Program performed bi-annually, compared using the voltage ratio capability. As described below, this evaluation of the DMM's measurements confirmed with the predicted values with excellent results.

First as we study this evaluation, let's just consider the individual measurements of the DMM on each of the two standards. Independent measurements of each reference were taken. As seen below, the individual measurements show a difference on the order of 0.549 and 0.666 ppm between the 8588A's measurements and the certified/predicted values of each reference standard. This shows the strong agreement between the DMM's measurements and the standard's control chart values. Considering the 8588A's guaranteed specification is ±3.7 ppm of 10 volts (10VDC, 1 year, ±1°C, 99% confidence), the demonstrated performance used a fraction of the specification!

732B Predicted Value (8588A Front Connection)	9.99999063 V
8588A Measured Value (Front)	9.99999612 V
Measured to Predicted Difference	0.549 ppm

732B Predicted Value (8588A Rear Connection)	9.99999902 V
8588A Measured Value (Rear)	10.00000568 V
Measured to Predicted Difference	0.666 ppm

Calculated Ratio: Front - Rear	-8.3900000E-06 V
8588A Ratio: Front - Rear	-9.10E-06 V
Measured to Calculated Difference	-7.1E-07 V
Calculated Ratio: Front / Rear	0.999999161 V
8588A Ratio: Front / Rear	0.9999991 V
Measured to Calculated Difference	-6.1E-08 V
Calculated Ratio: (Front - Rear) / Rear	-8.39000082E-07 V
8588A Ratio: (Front - Rear) / Rear	-9.00E-07 V
Measured to Calculated Difference	-6.1E-08 V

Figure 4.

Now considering the DMM's calculated ratio of these independent measurements, calculations were evaluated using all three of the 8588A's ratio calculation methods. They are shown in the table above, although the first ratio difference calculation of front voltage measurement minus the rear measurement best illustrates the measurement performance. Examining the DMM's calculated ratio result, the difference measurement calculation shows a -0.71µV difference between the certified predicted values and the DMM's calculated difference of its measured values. This again illustrates the excellent performance of the 8588A's ratio capabilities.

The other ratio calculations shown are convenient for use in other ratio applications.

The second 8588A ratioing evaluation compared two standard resistors, each with calibrated values and proven histories of stability and predictability connected to the 8588A front and rear terminals in a 4-Wire configuration.

This evaluation test measured the two resistors and calculated ratios in three ways. Initially the difference between each resistor's measured values was calculated and compared to the difference of the certified values of the resistors. Secondly a ratio of the measurements of one resistor to the other was calculated by the DMM, and in turn was compared to a similar calculation from the resistors certified values. Thirdly a normalized difference ratio was done, ratioing the difference of the measured resistors to the value of one of the resistors. A table of the results is shown below in Figure 5.

The first part showed the DMM's calculated difference from the separate measurements done on each resistor compared to the calculated difference of the certified values. They agree within 1 ppm. This illustrates the individual 8588A measurements closely match respective resistors certified/projected values.

Secondly the mathematical ratio of the measured larger resistance value against the smaller resistance's measured values show they ratios agree within 3.6 ppm to the calibrated values. Considering the DMM's relative ratio measurement specification is 4.3 ppm – the performance is consistent with the calculated difference of 3.6 ppm.

Considering the alternative technique of making the similar measurement with non-ratio techniques (a DMM in its normal measurement mode), the DMM's specification is approximately 14.5 ppm. (Based on measuring the 190-ohm resistor at 9.5 ppm, and 11 pm for the 33-ohm resistor. An RSS combination of these two specifications yields an overall uncertainty of about 14.5 ppm.) This confirms using the 8588A's ratio capability improves the specified uncertainty for a ratio measurement by more than 3.3 times better than normal independent measurements.

Thirdly, the normalized ratio of the front to rear difference against the rear measurement value has a slightly larger difference for this ratio measurement at 4.8 ppm. This conforms to a similarly larger 8588A ratio spec for this calculation at about 5.7 ppm. Again, the 8588A measurement performance is consistent with the calculated expectations.

In summary of the ratio evaluation, the 8588A was seen to perform well within specification. When evaluated measurements on certified and controlled standards, the demonstrated uncertainties show that both the individual measurements and those taken in ratio configurations provide valuable measurement capabilities to the user.

Resistor Value (8588A Front Connection)	190.0008544 Ω
Resistor Value (8588A Rear Connection)	33.33022 Ω

Calculated Ratio: Front - Rear	156.6706344 Ω
8588A Ratio: Front - Rear	156.6707894 Ω
Measured to Calculated Difference	1.0 ppm
Calculated Ratio: Front / Rear	5.700558064 Ω
8588A Ratio: Front / Rear	5.7005784 Ω
Measured to Calculated Difference	3.6 ppm
Calculated Ratio: (Front - Rear) / Rear	4.700558064 Ω
8588A Ratio: (Front - Rear) / Rear	4.7005808 Ω
Measured to Calculated Difference	4.8 ppm

Figure 5.

EVALUATION FOR VERIFYING MULTI FUNCTION CALIBRATORS

It is natural to consider a 12-function reference multimeter as a tool to measure and verify multifunction calibrators. Earlier precision multimeters are used to verify multiple functions in such calibrators already. But the increased functionality and improved uncertainties of in the 8588A make it a measurement tool for these applications which offer better functional coverage than before. The obvious questions are whether such a DMM can measure all the functions of such calibrators? And secondly which of the various calibrators in this class can be best verified by the 8588A? (Given that such calibrators performance ranges through several orders of magnitude to address the different performance classes of instruments they calibrate.) In this evaluation we will examine the 8588A's performance against the best in class calibrator, the Fluke 5522A.

Evaluation of 8588A published specifications compared to Fluke 5522A multifunction calibrator published specifications was performed to determine Test Uncertainty Ratios (TUR) for Absolute specifications and Test Accuracy Ratios (TARs) used for Relative specifications. As one of our intentions for evaluating the 8588A was to see if it could be deployed to lower echelon calibration laboratories in order to calibrate their multifunction calibrators, only 1-year absolute and 90-day relative specifications are used in this evaluation. The TUR evaluations of DCV are shown in Figure 6.

The TUR and TAR evaluations for DCI (red shaded cells denotes ratios less than or equal to two) are shown in Figure 7.

DC Voltage					5522 1year Abs 99%			8588A 1year Abs 95%			
	5522 Range	Nominal	8588A Range	freq	Output	Floor	Total	Reading	Range	Total	
Test Point	(V)	(V)	(V)	(Hz)	(ppm)	(V)	(V)	(ppm)	(ppm)	(V)	TUR
0 mV	0.330	0.0000	0.1	N/A	20	1.00E-06	1.00E-06	5.1	2.00	2.00E-07	5.0
30 mV	0.330	0.0300	0.1	N/A	20	1.00E-06	1.60E-06	5.1	2.00	3.53E-07	4.5
300 mV	0.330	0.3000	1	N/A	20	1.00E-06	7.00E-06	2.8	0.30	1.14E-06	6.1
0 V	3.3	0.000000	1	N/A	11	2.00E-06	2.00E-06	2.8	0.30	3.00E-07	6.7
0.3 V	3.3	0.300000	1	N/A	11	2.00E-06	5.30E-06	2.8	0.30	1.14E-06	4.6
3 V	3.3	3.000000	10	N/A	11	2.00E-06	3.50E-05	2.8	0.05	8.90E-06	3.9
0 V	33	0.00000	10	N/A	12	2.00E-05	2.00E-05	2.8	0.05	5.00E-07	40
3 V	33	3.00000	10	N/A	12	2.00E-05	5.60E-05	2.8	0.05	8.90E-06	6.3
30 V	33	30.00000	100	N/A	12	2.00E-05	3.80E-04	4.1	0.30	1.53E-04	2.5
30 V	330	30.0000	100	N/A	18	1.50E-04	6.90E-04	4.1	0.30	1.53E-04	4.5
300 V	330	300.0000	1000	N/A	18	1.50E-04	5.55E-03	4.3	0.50	1.79E-03	3.1
100 V	1000	100.000	100	N/A	18	1.50E-03	3.30E-03	4.1	0.30	4.40E-04	7.5
500 V	1000	500.000	1000	N/A	18	1.50E-03	1.05E-02	4.3	0.50	2.65E-03	4.0
1000 V	1000	1000.000	1000	N/A	18	1.50E-03	1.95E-02	4.3	0.50	4.80E-03	4.1

Figure 6.

DC Current					5522 1year Abs 99%			8588A 1year Abs 95%				8588A 90day Rel 95%			
	Range	Nominal	8588A Range	freq	Output	Floor	Total	Reading	Range	Total		Reading	Range	Total	
Test Point	(Units)	(Units)	(Units)	(Hz)	(ppm)	(A)	(A)	(ppm)	(ppm)	(A)	TUR	(ppm)	(ppm)	(A)	TAR
0 μA	330	0.000	0.001	N/A	150	2.00E-08	2.00E-08	7.6	4	4.00E-09	5.00	6	4	4.00E-09	5.00
300 uA	330	300.000	0.001	N/A	150	2.00E-08	4.50E-02	7.6	4	2.28E-03	19.74	6	4	1.80E-03	25.00
0 mA	3.3	0.00000	0.01	N/A	100	5.00E-08	5.00E-08	8.9	4	4.00E-08	1.25	7	4	4.00E-08	1.25
3 mA	3.3	3.00000	0.01	N/A	100	5.00E-08	3.00E-04	8.9	4	2.67E-05	11.22	7	4	2.10E-05	14.26
0 mA	33	0.0000	0.1	N/A	100	2.50E-07	2.50E-07	33	10	1.00E-06	0.25	30	10	1.00E-06	0.25
30 mA	33	30.0000	0.1	N/A	100	2.50E-07	3.00E-03	33	10	9.91E-04	3.03	30	10	9.01E-04	3.33
0 mA	330	0.000	1	N/A	100	2.50E-06	2.50E-06	100	100	1.00E-04	0.03	80	100	1.00E-04	0.03
300 mA	330	300.000	1	N/A	100	2.50E-06	3.00E-02	100	100	3.01E-02	1.00	80	100	2.41E-02	1.24
0 A	3	0.00000	1	N/A	200	4.00E-05	4.00E-05	100	100	1.00E-04	0.40	80	100	1.00E-04	0.40
1 A	3	1.00000	1	N/A	200	4.00E-05	2.40E-04	100	100	2.00E-04	1.20	80	100	1.80E-04	1.33
2.9 A	3	2.90000	10	N/A	380	4.00E-05	1.14E-03	174	40	9.05E-04	1.26	125	40	7.63E-04	1.50
0 A	20	0.0000	10	N/A	500	5.00E-04	5.00E-04	174	40	4.00E-04	1.25	125	40	4.00E-04	1.25
10 A	20	10.0000	10	N/A	500	5.00E-04	5.50E-03	174	40	2.14E-03	2.57	125	40	1.65E-03	3.33
19 A	20	19.0000	10	N/A	1000	7.50E-04	1.98E-02	174	40	3.71E-03	5.33	125	40	2.78E-03	7.12

Figure 7.

The following are TUR and TAR evaluations for ACV at higher voltage ranges (red shaded cells denotes ratios less than or equal to two):

AC Voltage					5522 1year Abs 99%			8588A 1year Abs 95%				8588A 90day Rel 95%			
	5522 Range	Nominal	8588A Range	freq	Output	Floor	Total	Reading	Range	Total		Reading	Range	Total	
Test Point	(V)	(V)	(V)	(Hz)	(ppm)	(V)	(V)	(ppm)	(ppm)	(V)	TUR	(ppm)	(ppm)	(V)	TAR
3 V	3.3	3.0	10	9.5	50000	1.65E-02	1.67E-01	64	5	2.42E-04	688				
3 V	3.3	3.0	10	10	300	5.00E-05	9.50E-04	64	5	2.42E-04	3.9				
3 V	3.3	3.0	10	45	150	6.00E-05	5.10E-04	64	5	2.42E-04	2.1				
3 V	3.3	3.0	10	1K	150	6.00E-05	5.10E-04	64	5	2.42E-04	2.1				
3 V	3.3	3.0	10	10K	150	6.00E-05	5.10E-04	110	5	3.80E-04	1.3	66	5	2.48E-04	2.1
3 V	3.3	3.0	10	20K	190	6.00E-05	6.30E-04	210	10	7.30E-04	0.9	132	10	4.96E-04	1.3
3 V	3.3	3.0	10	50K	300	5.00E-05	9.50E-04	510	50	2.03E-03	0.5	331	50	1.49E-03	0.6
3 V	3.3	3.0	10	100K	700	1.25E-04	2.23E-03	510	50	2.03E-03	1.1	331	50	1.49E-03	1.5
3 V	3.3	3.0	10	450K	2400	6.00E-04	7.80E-03	10000	1000	4.00E-02	0.2	9300	1000	3.79E-02	0.2
3.3 V	33	3.3	10	45	150	6.00E-04	1.10E-03	64	5	2.61E-04	4.2				
3.3 V	33	3.3	10	10K	150	6.00E-04	1.10E-03	110	5	4.13E-04	2.7				
30 V	33	30	100	9.5	50000	1.65E-01	1.67E+00	70	5	2.60E-03	640				
30 V	33	30	100	10	300	0.00E+00	9.00E-03	70	5	2.60E-03	3.5				
30 V	33	30	100	45	150	6.00E-04	5.10E-03	70	5	2.60E-03	2.0	40	5	1.70E-03	3.0
30 V	33	30	100	1K	150	6.00E-04	5.10E-03	70	5	2.60E-03	2.0	40	5	1.70E-03	3.0
30 V	33	30	100	10K	150	6.00E-04	5.10E-03	90	5	3.20E-03	1.6	59	5	2.27E-03	2.2
30 V	33	30	100	20K	240	6.00E-04	7.80E-03	210	10	7.30E-03	1.1	132	10	4.96E-03	1.6
30 V	33	30	100	50K	350	6.00E-04	1.11E-02	510	50	2.03E-02	0.5	331	50	1.49E-02	0.7
30 V	33	30	100	90K	900	1.60E-03	2.86E-02	510	50	2.03E-02	1.4	331	50	1.49E-02	1.9
33 V	330	33	100	45	190	2.00E-03	8.27E-03	70	5	2.81E-03	2.9				
33 V	330	33	100	10K	200	6.00E-03	1.26E-02	90	5	3.47E-03	3.6				
300 V	330	300	1000	45	190	2.00E-03	5.90E-02	90	25	5.20E-02	1.1	59	25	4.27E-02	1.4
300 V	330	300	1000	1K	190	2.00E-03	5.90E-02	90	25	5.20E-02	1.1	59	25	4.27E-02	1.4
300 V	330	300	1000	10K	200	6.00E-03	6.60E-02	90	25	5.20E-02	1.3	59	25	4.27E-02	1.5
300 V	330	300	1000	18K	250	6.00E-03	8.10E-02	210	25	8.80E-02	0.9	132	25	6.46E-02	1.3
300 V	330	300	1000	50K	300	6.00E-03	9.60E-02	510	100	2.53E-01	0.4	331	100	1.99E-01	0.5
300 V	330	300	1000	100K	2000	5.00E-02	6.50E-01	510	100	2.53E-01	2.6				
330 V	1000	330	1000	45	190	2.00E-03	6.47E-02	90	25	5.47E-02	1.2	59	25	4.45E-02	1.5
330 V	1000	330	1000	10K	300	1.00E-02	1.09E-01	90	25	5.47E-02	2.0	59	25	4.45E-02	2.5
1000 V	1000	1000	1000	45	300	1.00E-02	3.10E-01	90	25	1.15E-01	2.7				
1000 V	1000	1000	1000	1K	250	1.00E-02	2.60E-01	90	25	1.15E-01	2.3				
1000 V	1000	1000	1000	5K	250	1.00E-02	2.60E-01	90	25	1.15E-01	2.3				
1000 V	1000	1000	1000	8K	300	1.00E-02	3.10E-01	90	25	1.15E-01	2.7				
1020 V	1000	1020	1000	1K	250	1.00E-02	2.65E-01	90	25	1.17E-01	2.3				
1020 V	1000	1020	1000	8K	300	1.00E-02	3.16E-01	90	25	1.17E-01	2.7				

Figure 8.

The following are TUR and TAR evaluations for ACI at higher current ranges (red shaded cells denotes ratios less than or equal to two):

AC Current					5522 1yr Abs 99%			8588A 1yr Abs 95%				8588A 90d Rel 95%			
	5522 Range	Nominal	8588A Range	freq	Output	Floor	Total	Reading	Range	Total		Reading	Range	Total	
Test Point	(A)	(A)	(A)	(Hz)	(%)	(A)	(A)	(ppm)	(ppm)	(A)	TUR	(ppm)	(ppm)	(A)	TAR
1.09 A	3	1.09000	1	10	0.18	1.00E-04	2.06E-03	260	100	3.83E-04	5.4				
1.09 A	3	1.09000	1	45	0.05	1.00E-04	6.45E-04	260	100	3.83E-04	1.7	214	100	1.71E-04	3.8
1.09 A	3	1.09000	1	1K	0.05	1.00E-04	6.45E-04	260	100	3.83E-04	1.7	214	100	3.33E-04	1.9
1.09 A	3	1.09000	1	5K	0.60	1.00E-03	7.54E-03	510	100	6.56E-04	11				
1.09 A	3	1.09000	1	10K	2.50	5.00E-03	3.23E-02	510	100	6.56E-04	49				
2.99 A	3	2.99000	10	10	0.18	1.00E-04	5.48E-03	800	50	2.89E-03	1.9	477	50	5.70E-04	9.6
2.99 A	3	2.99000	10	45	0.06	1.00E-04	1.89E-03	800	50	2.89E-03	0.7	477	50	5.70E-04	3.3
2.99 A	3	2.99000	10	1K	0.06	1.00E-04	1.89E-03	800	50	2.89E-03	0.7	477	50	1.93E-03	1.0
2.99 A	3	2.99000	10	5K	0.60	1.00E-03	1.89E-02	800	50	2.89E-03	6.5				
2.99 A	3	2.99000	10	10K	2.50	5.00E-03	7.98E-02	800	50	2.89E-03	28				
3.3 A	20	3.3000	10	500	0.10	0.002	0.0053	800	50	3.14E-03	1.7	477	50	1.93E-03	2.8
3.3 A	20	3.3000	10	1K	0.10	0.002	0.0053	800	50	3.14E-03	1.7	477	50	1.93E-03	2.8
3.3 A	20	3.3000	10	5K	3.00	0.002	0.1010	800	50	3.14E-03	32				
10.9 A	20	10.9000	10	45	0.06	0.002	0.0085	800	50	9.22E-03	0.9	477	50	2.07E-03	4.1
10.9 A	20	10.9000	10	65	0.06	0.002	0.0085	800	50	9.22E-03	0.9	477	50	2.07E-03	4.1
10.9 A	20	10.9000	10	500	0.10	0.002	0.0129	800	50	9.22E-03	1.4	477	50	5.70E-03	2.3
10.9 A	20	10.9000	10	1K	0.10	0.002	0.0129	800	50	9.22E-03	1.4	477	50	5.70E-03	2.3
10.9 A	20	10.9000	10	5K	3.00	0.002	0.3290	800	50	9.22E-03	36				
20 A	20	20.0000	10	45	0.12	0.005	0.0290	800	50	1.65E-02	1.8	477	50	5.70E-03	5.1
20 A	20	20.0000	10	65	0.12	0.005	0.0290	800	50	1.65E-02	1.8	477	50	5.70E-03	5.1
20 A	20	20.0000	10	500	0.15	0.005	0.0350	800	50	1.65E-02	2.1				
20 A	20	20.0000	10	1K	0.15	0.005	0.0350	800	50	1.65E-02	2.1				
20 A	20	20.0000	10	5K	3.00	0.005	0.6050	800	50	1.65E-02	37				

Figure 9.

Our evaluation shows that the 8588A does cover many functions and ranges of the 5522A. (In fact, one new capability of measuring capacitance does cover the needs of the 5522A; however we do not include information for this function in this article.)

Not available to us at the time of this evaluation was the Fluke A40B Shunts for which the 8588A memory accepts, as mentioned above, A40B shunt correction factors that would greatly improve the uncertainties in this evaluation. A cursory review of the A40B shunt specifications suggests that many points listed above less than a TUR of two (<2) would easily be increased many points to greater than three (>3).

In summary in this evaluation task, we observe that the uncertainties required by the 5522A are not fully supported by the 8588A. Other evaluations performed outside of this article do show the 8588A will satisfactorily cover calibrators of the 5502A and similar performance levels. In order to successfully use the 8588A to verify a 5522A it would need to continue to use a precision divider for voltages greater than 20 volts, precision AC measurement techniques for AC functions, and precision shunts for current. Yet the 8588A is very viable to use in calibrating the lower and mid-range performance classes of calibrators.

SUMMARY

It was unanimously agreed that the 8588A's ease of use (menus and controls), displayed (screen) information, smart shunt corrections and programmable ratioing are outstanding attributes of this unit compared to other industry long-scale digital multimeters. The 8588A's accuracy and functionality make it the most suitable multimeter for a multitude of demanding metrological tasks currently being performed by other long-scale digital multimeters. Our evaluation results do not support this unit being deployed from a pivot laboratory to other laboratories for calibrating their best 'metrology grade' multifunction calibrators.

STRENGTHS AND BEST CAPABILITIES

- Measurements we made performed well within their specifications
- Ergonomic designed menu and display
- Programmable ratioing
- RF Power measurements
- Capacitance measurements
- Fast data acquisitions (dependent on aperture settings)
- Several USB connectors for storing measurement results
- Smart shunt corrections

NOTED FOR IMPROVEMENT

- No means to store measurement setups
- Strengthen RF oriented functionality
    - No means to correct for mismatch uncertainties (RF Power Gamma correction)
    - No automatic acquisition of applied signal frequencies for automatic RF power measurements corrections
    - No means to measure applied signals greater than 100MHz (compatible RF Power sensors go up to 40GHz)
- No built-in Cold Junction Reference Junction for thermocouple measurements
- Increased number of 'recommended' calibration setpoints compared to Fluke 8508A

CLOSING:

Thanks go out to Fluke's Richard Roddis for making an 8588A available for this evaluation (especially considering the high demand for this unit). A special shout out goes out to Fluke's Bill Spath and Fluke's Technical team for their timely explanations and responses to our observations as well as Transcat's Houston calibration group for their help and support throughout this evaluation ... you guys rock!