Application Note

Frequency Response of 1433 Decade Resistors

The IET Labs 1433 Decade Resistor is designed for DC application but as well can be used for AC applications. The frequency response of the 1433 will be shown for each decade below from 1 ohm to 100 kohms. The frequency response was measuring using a 7600 Plus from 1 kHz to 1 MHz.

AC Resistance Measurements

The IET Labs 7600 Plus is extremely easy to use and provides excellent accuracy for AC resistance measurements over its frequency range (10Hz to 2 MHz). Unfortunately many precision resistance measurements call for DC instead of AC, even though AC measurements avoid thermal voltage errors, have lower noise and can use precise transformer-ratio scaling techniques.

For most resistors, the AC-DC difference is negligible at 100Hz or even 1 kHz. For flat-card wire-wound resistors, the difference can be less than 1ppm up to 1MΩ if equivalent parallel resistance is used at high values to avoid errors due to lumped parallel capacitance and series resistance is used at low values to avoid errors due to series inductance. Lower measurement frequencies should also be used for very low values to avoid skin effect errors. There are significant differences for high-value, coil-wound resistors, because of capacitance not inductance, and for high-value, multi-resistor networks such as decade boxes and build-up standards. The AC-DC difference of resistance standards are generally very small and often can be easily determined by measuring it, and a small metal film resistor of similar value at both AC and DC. Here the assumption is made that the film unit has negligible AC-DC difference (which it probably does) and that it was stable for the time required (which it usually will be if one doesn't heat it up by applying too much power or touching it). Once such differences are determined, AC could be used for precision calibrations.

1 ohm/step Decade

Hz	Rs	Diff. from Nom.	Rs	Diff. from Nom.	Rs	Diff. from Nom.
	1 ohm		5 ohm		X ohm	
1000	0.999692	0.03%	5.000275	-0.01%	10.00024	0.00%
50000	0.999173	0.08%	5.000798	-0.02%	10.00169	-0.02%
100000	0.998698	0.13%	5.002379	-0.05%	10.00565	-0.06%
250000	0.998155	0.18%	5.008386	-0.17%	10.01919	-0.19%
500000	0.997856	0.21%	5.018815	-0.38%	10.04229	-0.42%
1000000	1.001108	-0.11%	5.045862	-0.92%	10.09739	-0.97%

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10 ohm/step Decade

Hz	Rs	Diff. from Nom.	Rs	Diff. from Nom.	Rs	Diff. from Nom.
	10 ohm		50 ohm		X ohm	
1000	9.999968	0.00%	49.98794	0.02%	99.96775	0.03%
50000	9.999769	0.00%	49.99242	0.02%	99.9775	0.02%
100000	10.00048	0.00%	50.00094	0.00%	99.99901	0.00%
250000	10.00249	-0.02%	50.02367	-0.05%	100.0546	-0.05%
500000	10.00546	-0.05%	50.05782	-0.12%	100.1475	-0.15%
1000000	10.01365	-0.14%	50.13895	-0.28%	100.3806	-0.38%

100 ohm/step Decade

Hz	Rs	Diff. from Nom.	Rs	Diff. from Nom.	Rs	Diff. from Nom.
	100 ohm		500 ohm		X kohm	
1000	100.0206	-0.02%	499.9822	0.00%	999.8637	0.01%
50000	100.1254	-0.13%	500.8352	-0.17%	1001.916	-0.19%
100000	100.1548	-0.15%	501.1248	-0.22%	1002.708	-0.27%
250000	100.2386	-0.24%	502.3011	-0.46%	1006.446	-0.64%
500000	100.4869	-0.49%	506.0896	-1.22%	1018.878	-1.89%
1000000	101.422	-1.42%	521.0346	-4.21%	1069.597	-6.96%

1 kohm/step Decade

Hz	Rs	Diff. from Nom.	Rs	Diff. from Nom.	Rs	Diff. from Nom.
	1 kohm		5 kohm		X kohm	
1000	999.8637	0.01%	4998.60	0.03%	9996.78	0.03%
50000	1001.9160	-0.19%	5010.55	-0.21%	10028.35	-0.28%
100000	1002.7080	-0.27%	5026.20	-0.52%	10074.17	-0.74%
250000	1006.4460	-0.64%	5128.83	-2.58%	10389.01	-3.89%
500000	1018.8780	-1.89%	5514.84	-10.30%	11607.79	-16.08%
1000000	1069.5970	-6.96%	7553.53	-51.07%	18528.23	-85.28%

10 kohm/step Decade

Hz	Rs	Diff. from Nom.	Rs	Diff. from Nom.	Rs	Diff. from Nom.
	10 kohm		50 kohm		X kohm	
1000	9996.381	0.04%	49984.53	0.03%	100072.7	-0.07%
50000	10034.57	-0.35%	50235.97	-0.47%	99405.32	0.59%
100000	10096.83	-0.97%	50798.34	-1.60%	98143.26	1.86%
250000	10547.25	-5.47%	54977.38	-9.95%	94911.48	5.09%
500000	12378.78	-23.79%	70857.9	-41.72%	90835.74	9.16%
1000000	13332.55	-33.33%	60701.53	-21.40%	85651.28	14.35%

100 kohm/step Decade

Hz	Rs	Diff. from Nom.	Rs	Diff. from Nom.	Rs	Diff. from Nom.

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	100 kohm		500 kohm		X Mohm	
1000	100072.7	-0.07%	498363.8	0.33%	997662.5	0.23%
50000	99405.32	0.59%	498314.4	0.34%	1047632	-4.76%
100000	98143.26	1.86%	498198.2	0.36%	1204881	-20.49%
250000	94911.48	5.09%	504917.9	-0.98%	1499764	-49.98%
500000	90835.74	9.16%	485788.9	2.84%	1233720	-23.37%
1000000	85651.28	14.35%	385399.1	22.92%	716425.7	28.36%

100 kohm/step Decade

Hz	Rs 100 kohm	Diff. from Nom.	Rs 500 kohm	Diff. from Nom.	Rs X Mohm	Diff. from Nom.
1000	100072.7	-0.07%	498363.8	0.33%	997662.5	0.23%
50000	99405.32	0.59%	498314.4	0.34%	1047632	-4.76%
100000	98143.26	1.86%	498198.2	0.36%	1204881	-20.49%
250000	94911.48	5.09%	504917.9	-0.98%	1499764	-49.98%
500000	90835.74	9.16%	485788.9	2.84%	1233720	-23.37%
1000000	85651.28	14.35%	385399.1	22.92%	716425.7	28.36%

Summary

The IET Labs Model 7600 Plus is ideal for characterizing resistors across a wide frequency range. The 1693 model can be used for even more measurements in lower-level labs and for almost all RLC measurements when AC resistance measurements are acceptable and frequencies measured are below 200 kHz. The 1433 Decade standard can be used as a standard for AC resistance. For most resistance values up to 1 kHz there is minimal change in resistance from nominal. Low resistance values perform the best at high frequencies due to relatively small values of series inductance. At higher resistance values the inductance increase causing increased errors for values up to 100 kohms. Above 100 kohms parallel capacitance is the main cause of error.

For complete product specifications on the entire 1433 Decade Resistor family or any of IET Labs's products, visit us at http://www.IET_Labs.com/products. Call us at 1-800-253-1230 or email your questions to info@IET Labs.com.

References:

Hill, J.J.: "Calibration of DC Resistance Standards and Voltage Ratio Boxes by an AC Method", Proc. IEEE Vol. 112 No.1, January 1965

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