Heathkit IN-3147 Capacitance Substitution Box

Model Derivation & Capacitance Measurement Comparison

Chris Grossman

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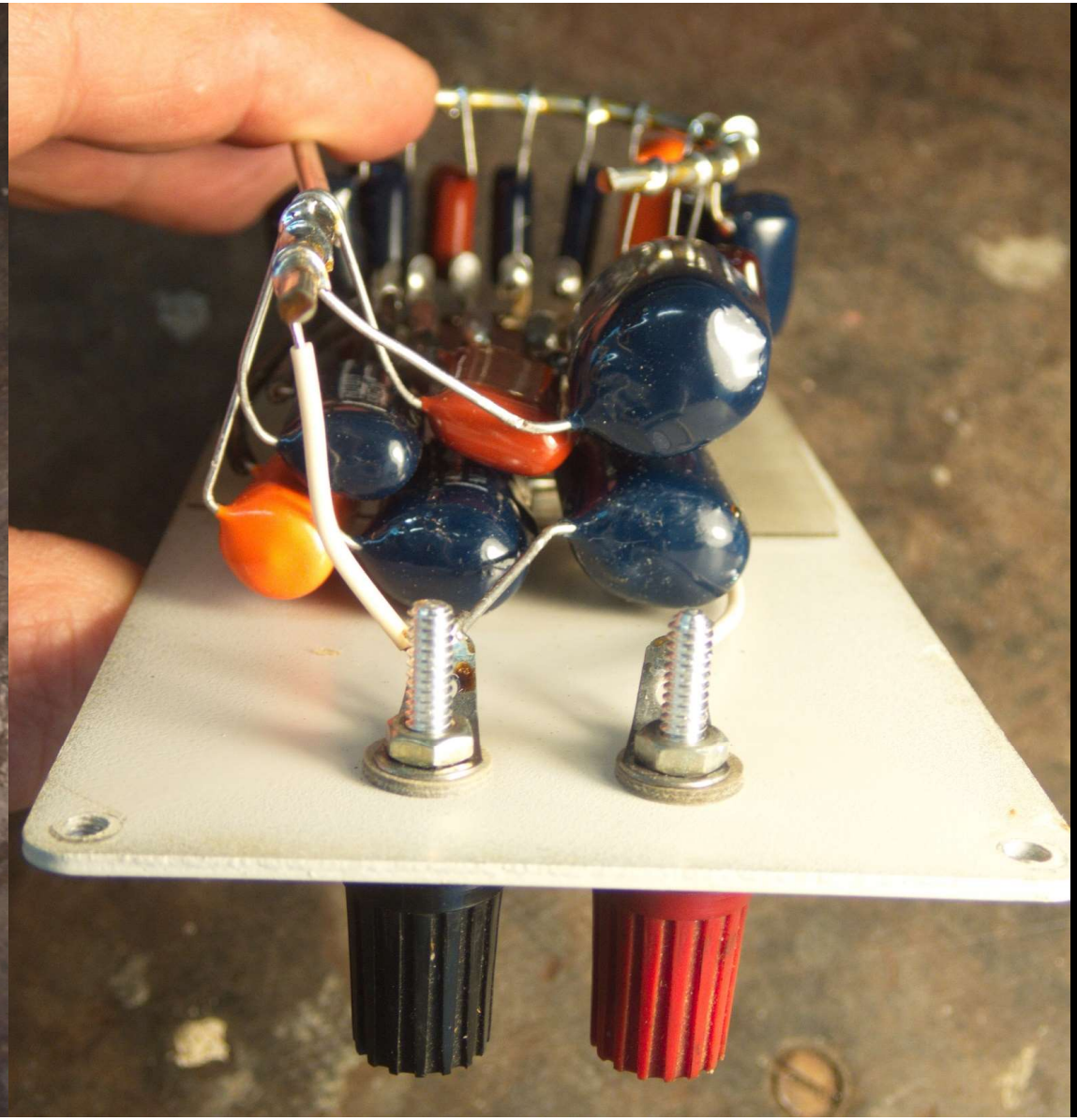

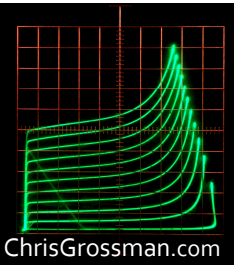

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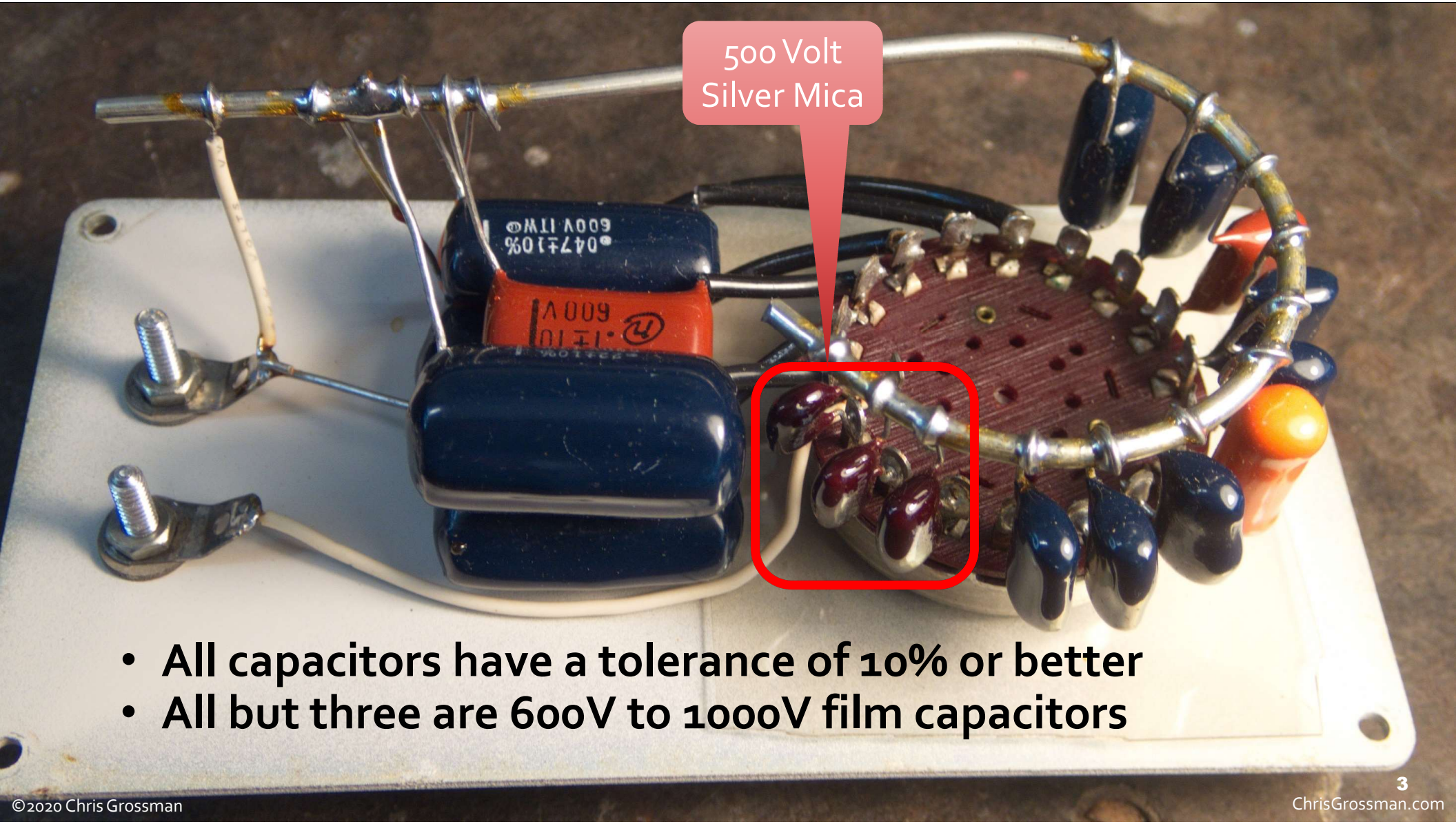
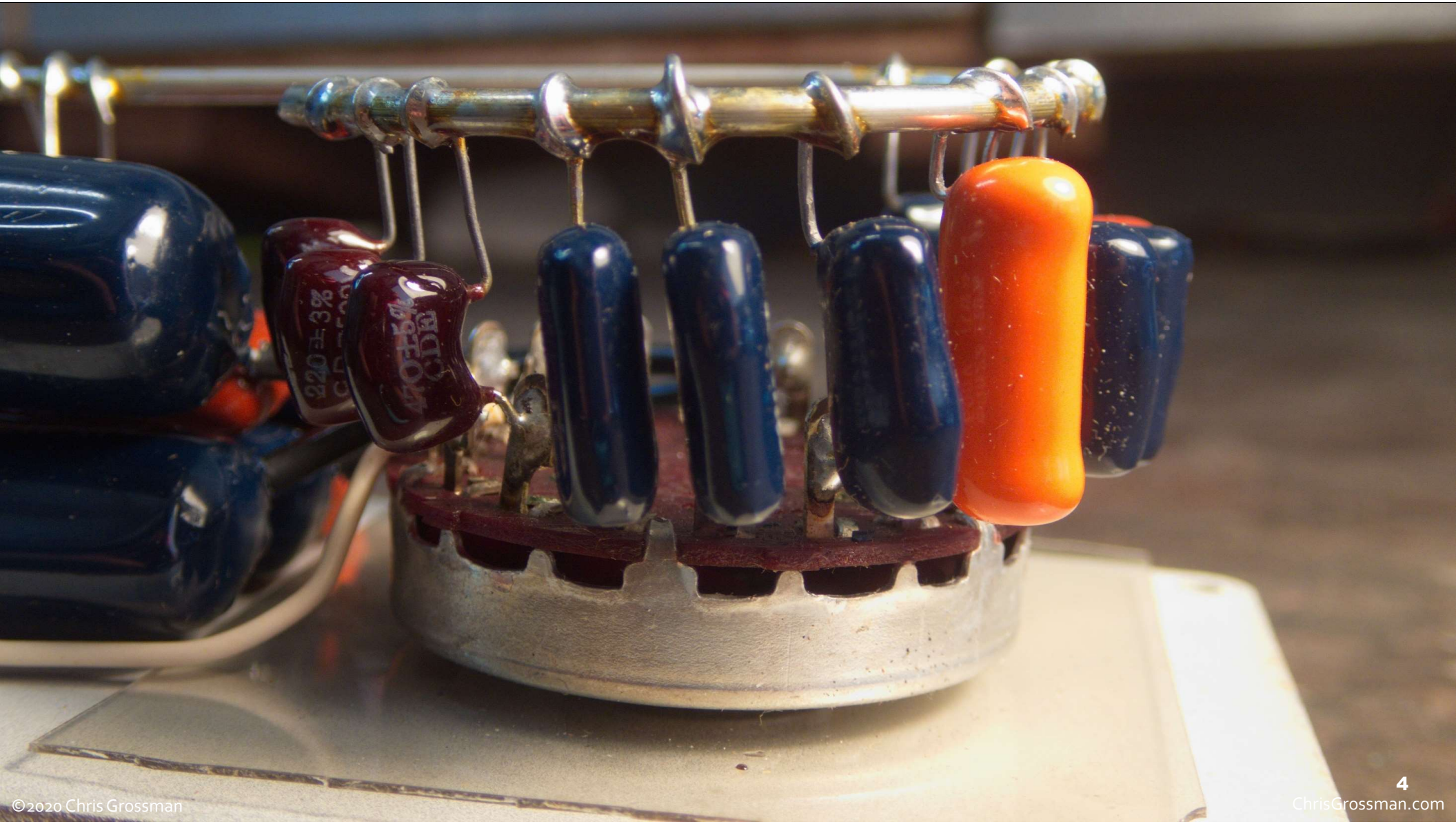
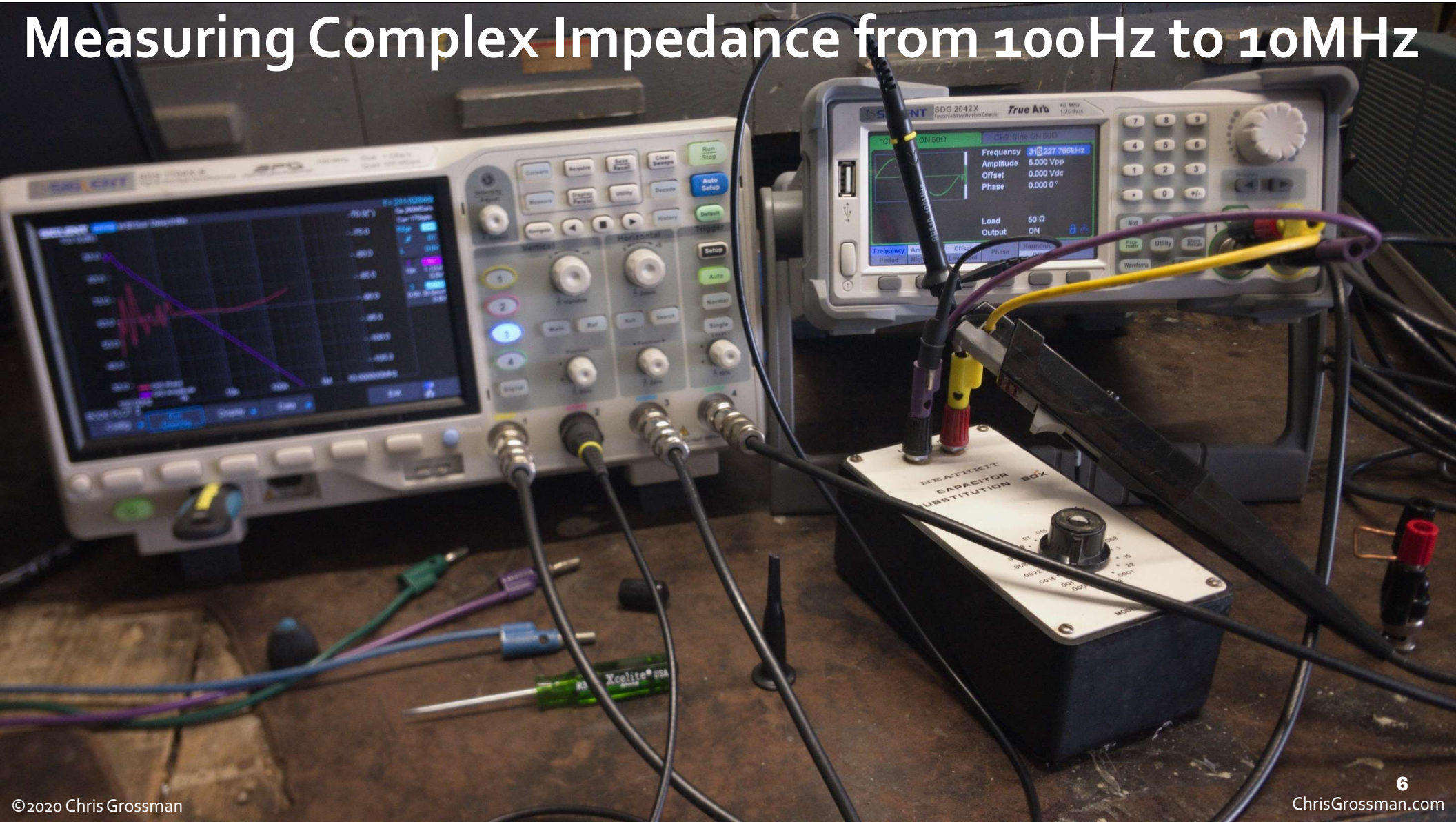


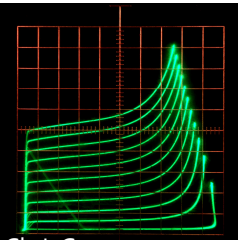
- All capacitors have a tolerance of 10% or better
- All but three are 600V to 1000V film capacitors

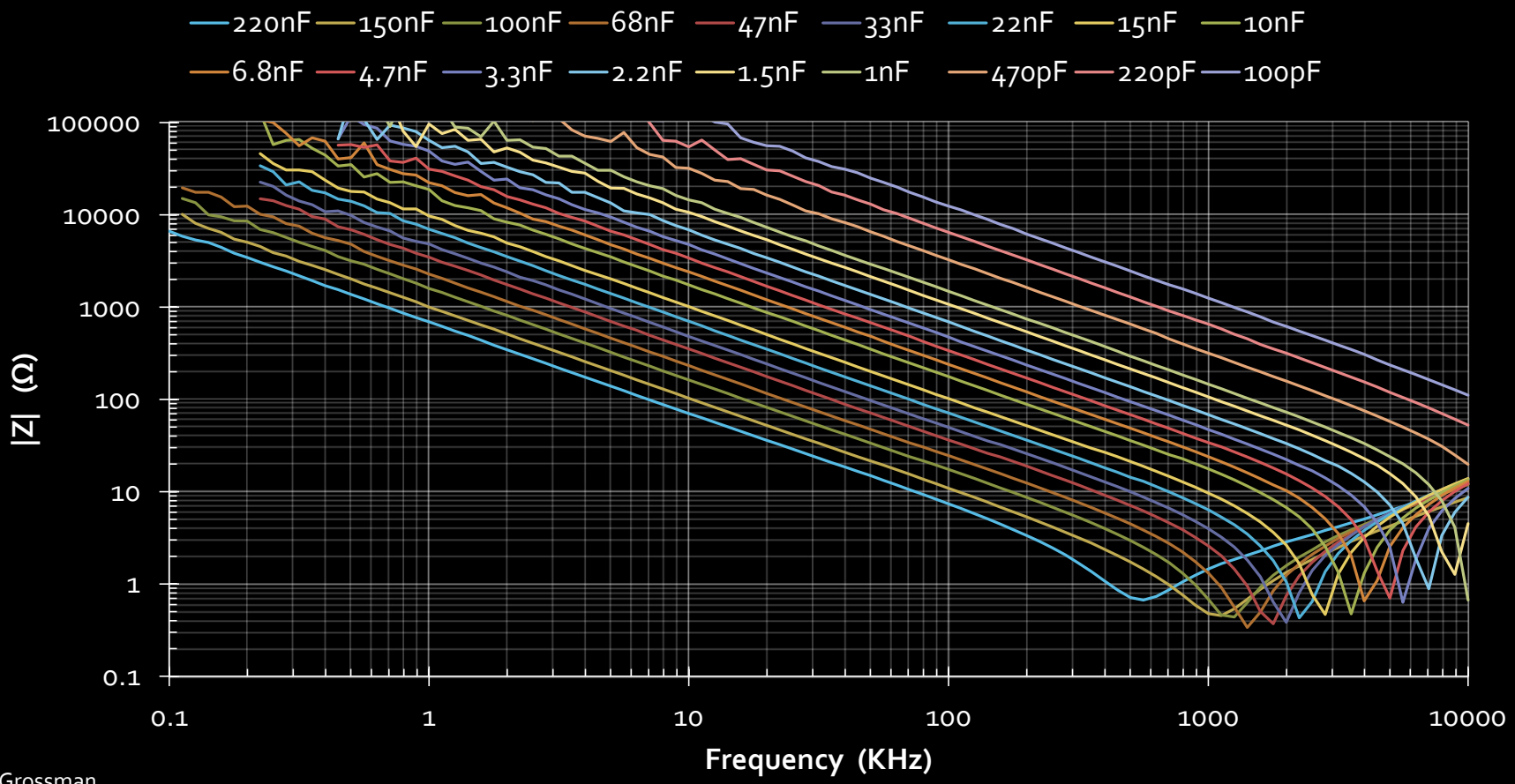


Measuring Complex Impedance from 100Hz to 10MHz

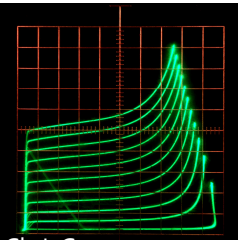


Heathkit IN-3147 Capacitor Substitution Box
|Z| vs. frequency





Heathkit IN-3147 Capacitor Substitution Box Phase(Z) vs. Frequency



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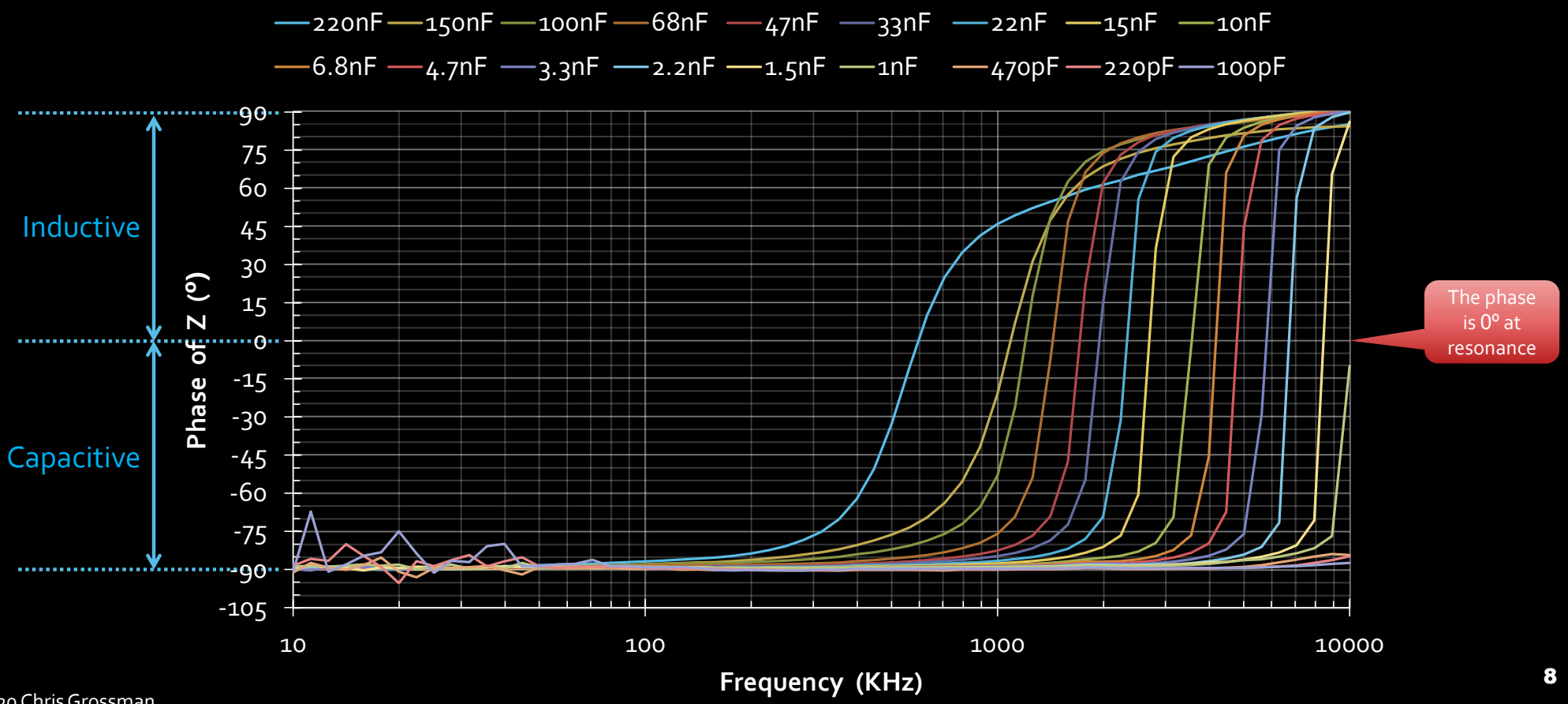
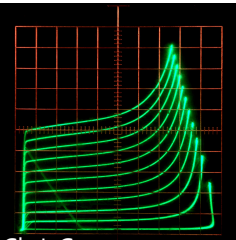
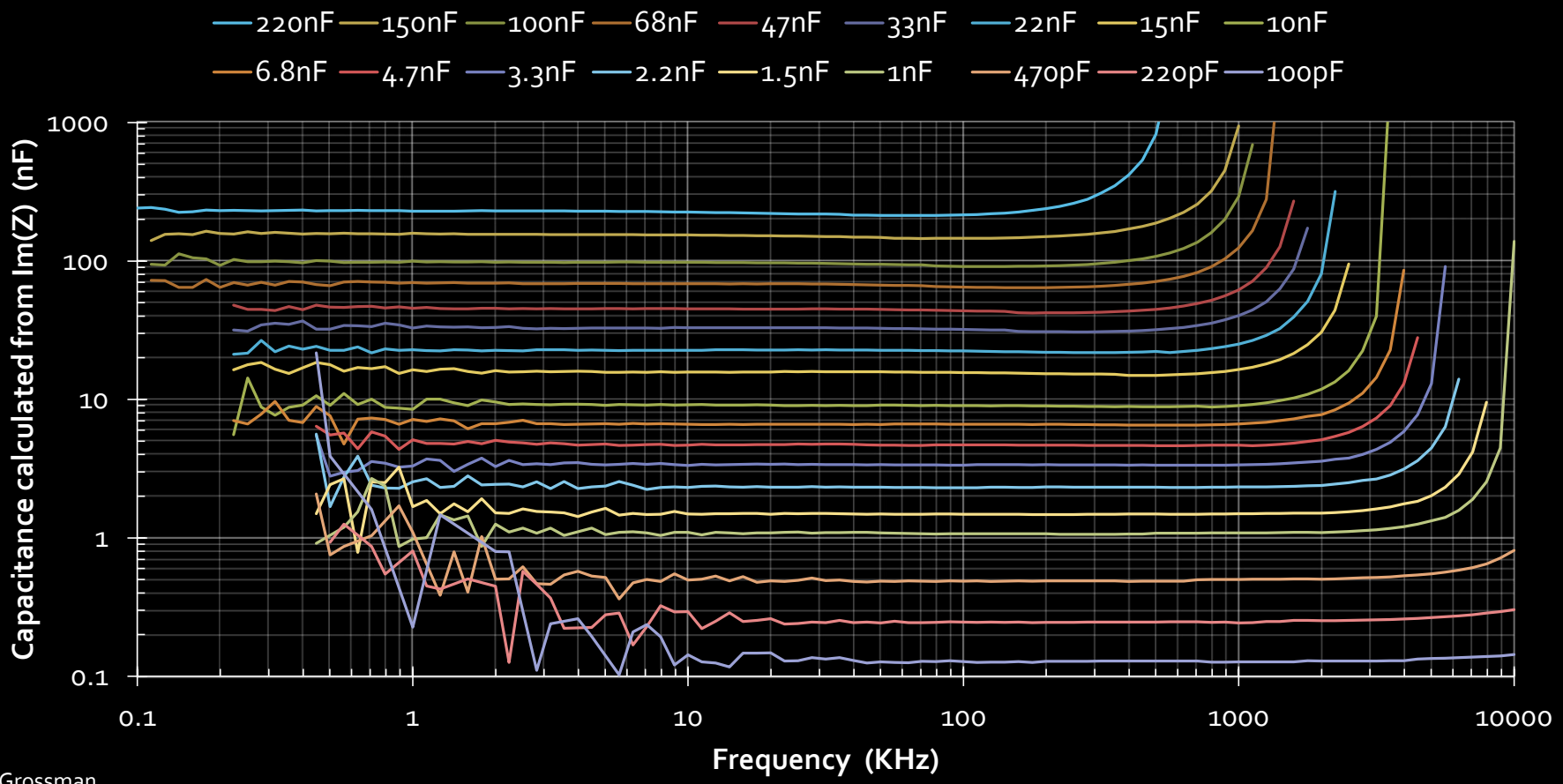
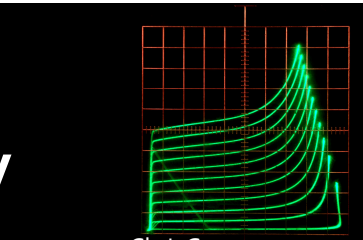


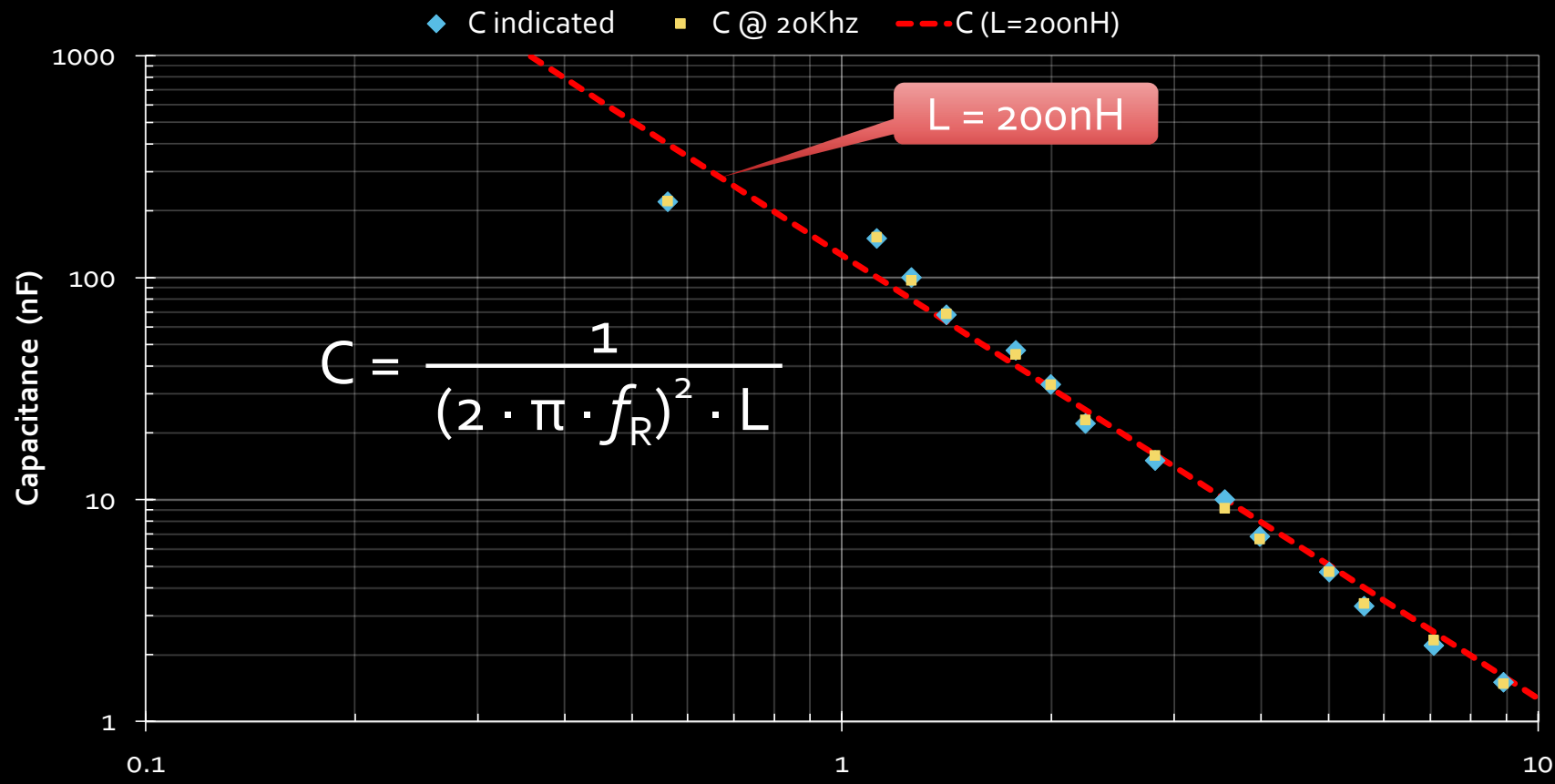
Heathkit IN-3147 Capacitor Substitution Box Measured Capacitance vs. Frequency



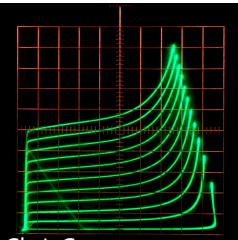


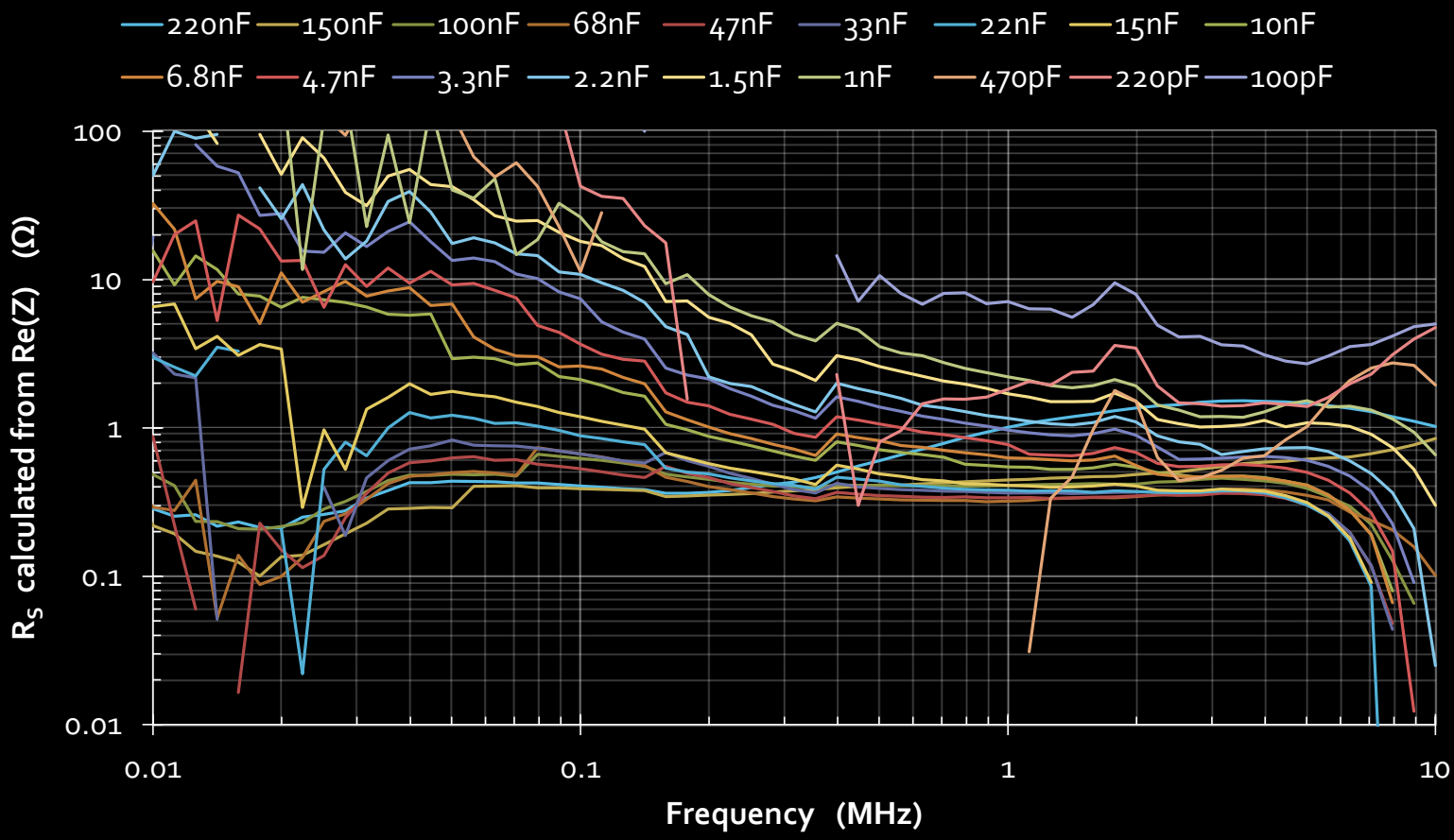
Capacitance vs. Resonant Frequency



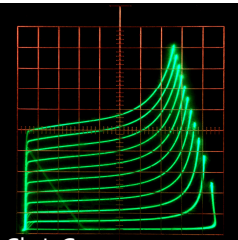


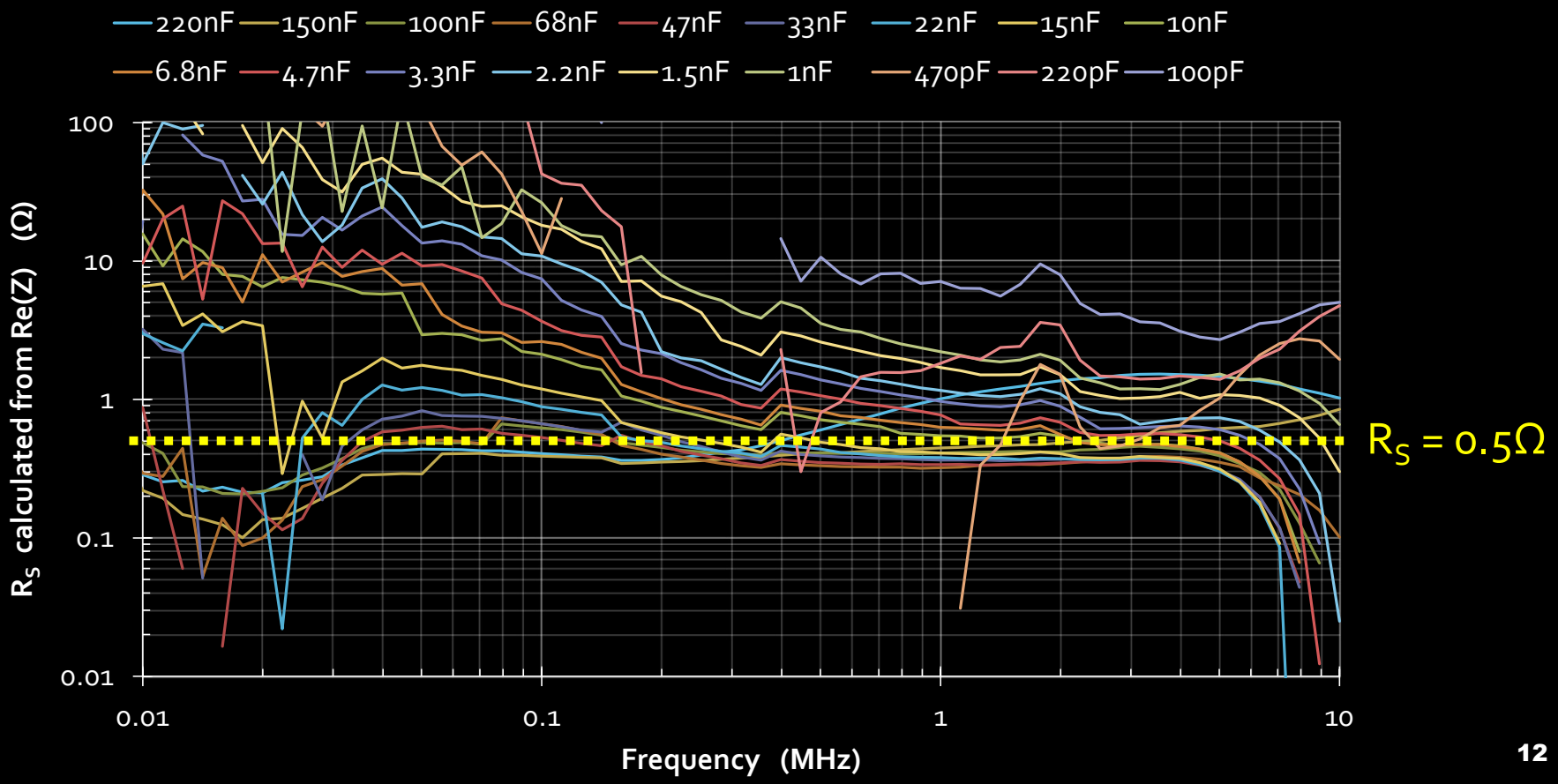
Measured Series Resistance for the Heathkit IN-3147



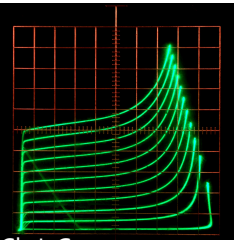


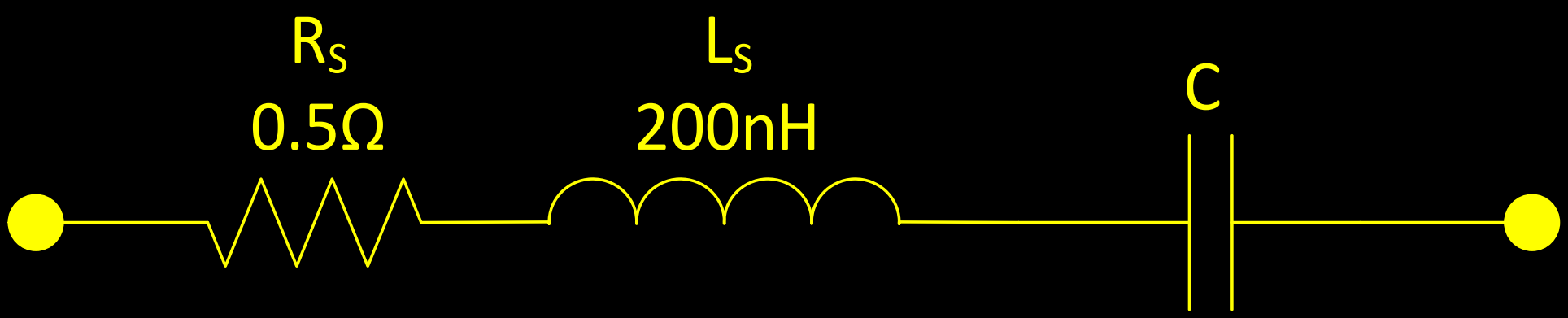
Measured Series Resistance for the Heathkit IN-3147





Heathkit IN-3147 Capacitor Substitution Box Equivalent Circuit





This is the circuit at the terminal posts. Any leads used to connect this to a circuit will have additional inductance.

ZM-11/U 1 KHz LCR Bridge


WINHY
VC 28II
VO. 7
2017-01-14
20000 count - 1pF
DER EE
DE-5000
LCR Meter
10fF
FLUKE
101
6000 count
10pF
UNI-T
U210E
2000 count
1pF
AW Sperry
CM-200
2000 count
100fF
EEVBlog
121GW
50000 count
1pF
ANENG
AN8008
10000 count
1pF
ANENG
AN819A
2000 count
10pF
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Complex AC Measurement @ 100Hz, 120Hz, 1KHz, 10KHz, & 100KHz

Time to charge

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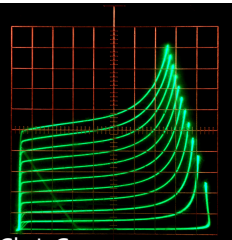
Measured Capacitance in nF



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Meters using the constant current time to charge method

Der EE DE-5000 multi-frequency LCR Meter

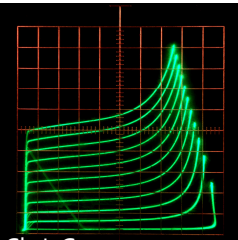
ZM-11/U 1 KHz LCR Bridge

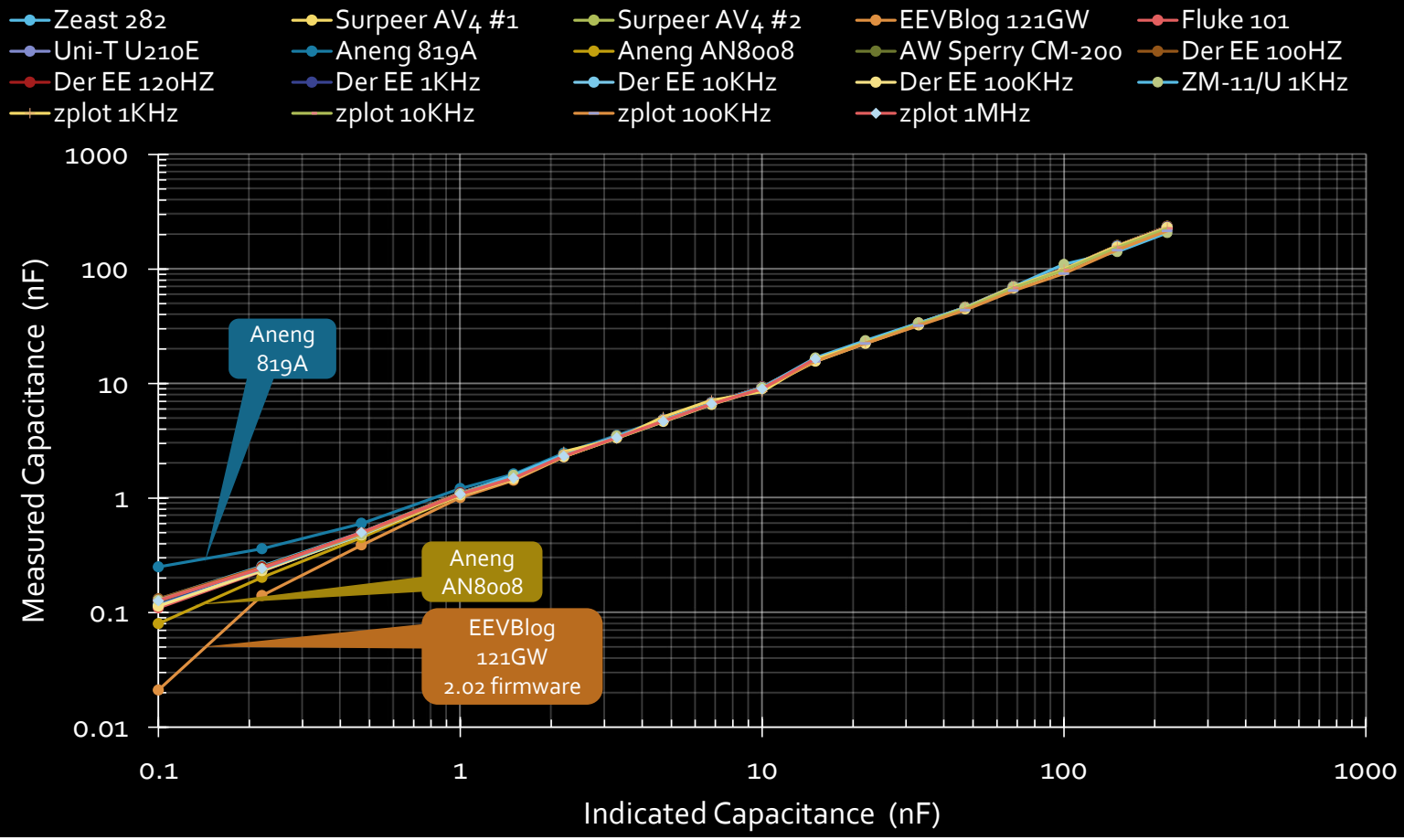
Siglent SDS1104X-E Bode Plot II and a Tek current probe

Meter / C	220nF	150nF	100nF	68nF	47nF	33nF	22nF	15nF	10nF	6.8nF	4.7nF	3.3nF	2.2nF	1.5nF	1nF	470pF	220pF	100pF
Zeast 282	233.7	158.87	100.13	70.07	46.1	33.43	23.16	16.115	9.3	6.793	4.816	3.471	2.387	1.53	1.115	0.502	0.255	0.131
Surpeer AV4 #1	233.7	158.91	100.16	70.08	46.1	33.43	23.16	16.111	9.293	6.785	4.808	3.463	2.379	1.52	1.106	0.492	0.245	0.121
Surpeer AV4 #2	233.6	158.81	100.09	70.04	46.07	33.41	23.15	16.105	9.29	6.785	4.809	3.464	2.381	1.523	1.108	0.495	0.248	0.124
EEVBlog 121GW	232.4	157.5	100.11	69.97	45.93	33.23	22.92	15.85	9.237	6.722	4.734	3.384	2.29	1.429	1.009	0.388	0.141	0.021
Fluke 101	233.4	158.7	100	69.9	46	33.46	23	16	9.23	6.74	4.78	3.45	2.37	1.52	1.1	0.49	0.23	0.11
Uni-T U210E	234	159.5	100.5	70.3	46.3	33.6	23.3	16.18	9.34	6.82	4.83	3.48	2.39	1.529	1.111	0.493	0.247	0.126
Aneng 819A	230	156	99.4	69.5	45.7	33.2	23	16.01	9.32	6.84	4.88	3.54	2.47	1.62	1.21	0.6	0.36	0.25
Aneng AN8008	234.6	159.5	100.5	70.45	46.26	33.54	23.22	16.14	9.293	6.775	4.788	3.435	2.349	1.484	1.065	0.451	0.203	0.08
AW Sperry CM-200	233	159.1	100.3	70.2	46.2	33.5	23.2	16.04	9.26	6.76	4.79	3.45	2.37	1.524	1.105	0.487	0.242	0.125
Der EE 100HZ	233.6	159.05	100.23	70.17	46.14	33.48	23.19	16.136	9.312	6.804	4.826	3.479	2.39	1.529	1.112	0.495	0.25	0.132
Der EE 120HZ	233.6	158.75	100.25	70.12	46.15	33.49	23.2	16.138	9.312	6.8	4.818	3.473	2.386	1.528	1.109	0.492	0.247	0.128
Der EE 1KHz	232.7	158.27	99.72	69.83	45.91	33.3	23.08	16.061	9.267	6.764	4.791	3.45	2.366	1.5112	1.0951	0.4799	0.2363	0.1181
Der EE 10KHz	230.2	156.54	98.67	69.1	45.48	33.01	22.85	15.886	9.16	6.688	4.735	3.408	2.34	1.4947	1.0825	0.4769	0.2334	0.11527
Der EE 100KHz	229.2	154.75	97.37	68.11	44.77	32.48	22.44	15.585	8.975	6.558	4.646	3.343	2.298	1.4656	1.0617	0.4748	0.2319	0.114
ZM-11/U 1KHz	206	141	110	70	46.2	33.9	23.7	16.8	9.21	6.72	4.79	3.48	2.4	1.59	1.09	0.481	0.241	0.129
zplot 1KHz	229.20	158.67	99.81	69.92	45.66	32.78	22.87	16.36	8.467	7.152	5.116	3.300	2.542	#N/A	#N/A	#N/A	#N/A	#N/A
zplot 10KHz	225.55	154.26	97.96	68.45	45.16	33.00	22.65	15.74	9.135	6.609	4.665	3.331	2.315	1.489	1.094	0.497	#N/A	#N/A
zplot 100KHz	215.53	145.96	91.40	64.78	43.73	32.02	22.37	15.63	9.021	6.630	4.703	3.346	2.302	1.483	1.072	0.488	0.246	0.128
zplot 1MHz	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	16.44	9.017	6.648	4.675	3.372	2.329	1.494	1.085	0.501	0.243	0.127

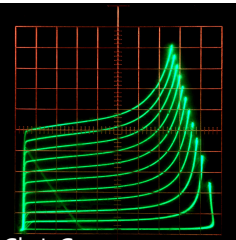
WINHY VC 28II

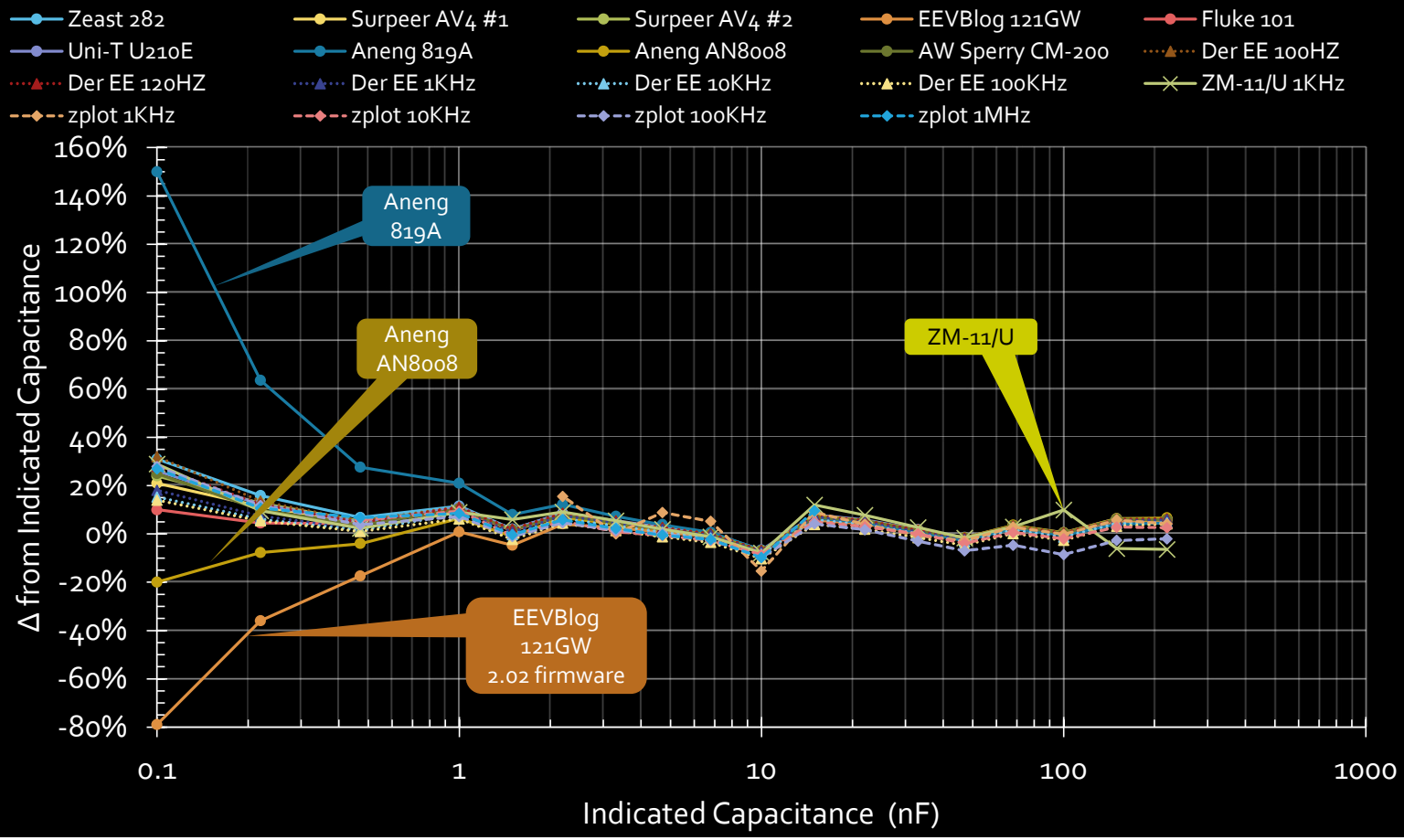
Measured Capacitance vs. Indicated Capacitance
All methods for the Heathkit IN-3147



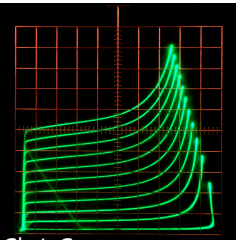


% Difference of the Measurement from the Capacitance Indicated on the Heathkit IN-3147





Conclusion



- Heathkit IN-3147 Capacitor Substitution Box
  - Highly usable range of 100pF to 0.22µF
  - High quality capacitors
  - All values are usable to 200 KHz
  - 500V rating is great for tube circuits
- Capacitance Measurements
  - The impedance sweep is the most informative, but slow and cumbersome to set up
  - Time to charge measurements built into most modern meters work well & are fast and easy
    - Aneng AN8008 , Aneng AN819A, & EEVBlog 121GW were all very disappointing since they do not work well for capacitors below 2nF
  - DER-EE DE-5000 works well, but calibration with leads is slow
  - The ZM-11/U is nice because it measures with applied voltages up to 800V
- Which meters do I regularly use?
  - WINHY VC28II Multimeter
  - DER-EE DE-5000 LCR Meter