

# PSMA Workshop Demo

## Simulation vs Measurement

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## What is and Why use Simulation?

- SPICE: “Simulation Program with Circuit Emphasis”
- LTspice: A popular electronic circuit simulator which is available as a Free download from Linear Technology Corporation at [www.linear.com](http://www.linear.com).
- CMC\_QuickDim.xlsx: A product specific simulation for performance prediction of Common Mode Choke design that use CMC core manufactured by Vacuumschmelze GmbH. Available thru VAC distributors.
- Both programs help circuit designers tweek circuit design and predict circuit performance before actual prototype is constructed.

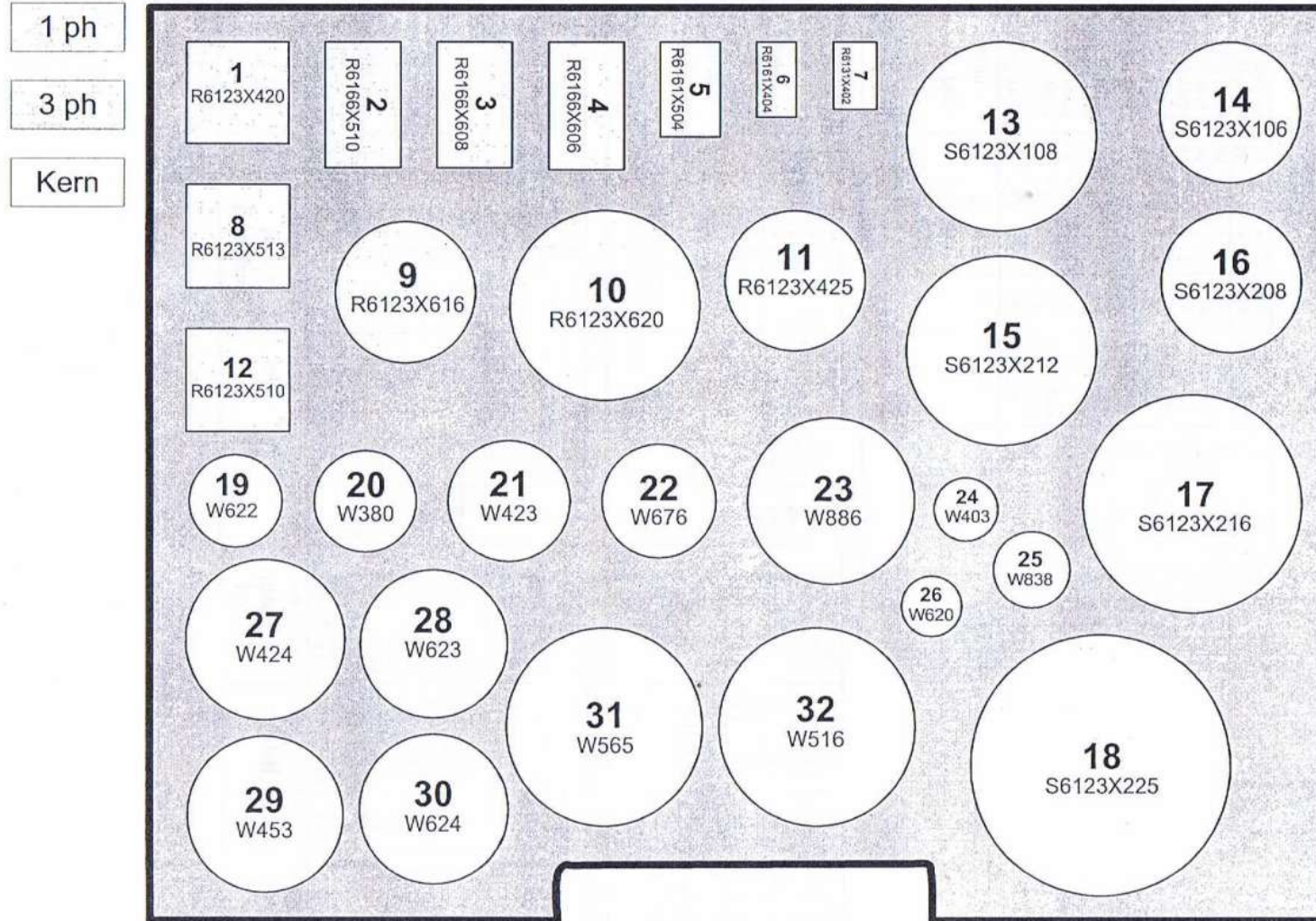
# Tools

- Picoscope 3206B w/ probes and 50  $\Omega$  BNC terminator
- LTspice
- CMC\_QuickDim
- VAC CMC sample kit “EMC-Kit 2004” (focus on 6166-X510, X608, X606, and 6123-X420)
- VAC nanocrystalline core CMC sample kit: “nanocrystalline VITROPERM CORE Sample-Kit” (Focus on W622 and W380)
- VAC nanocrystalline core sample kit: “nanocrystalline VITROPERM Cores for Power Transformer” (Focus on W375)



# CMC Sample Kit

EMC\_Kit\_2004.dsf / J. Beichler [21.04.2004]



## VAC EMC-Kit 2004


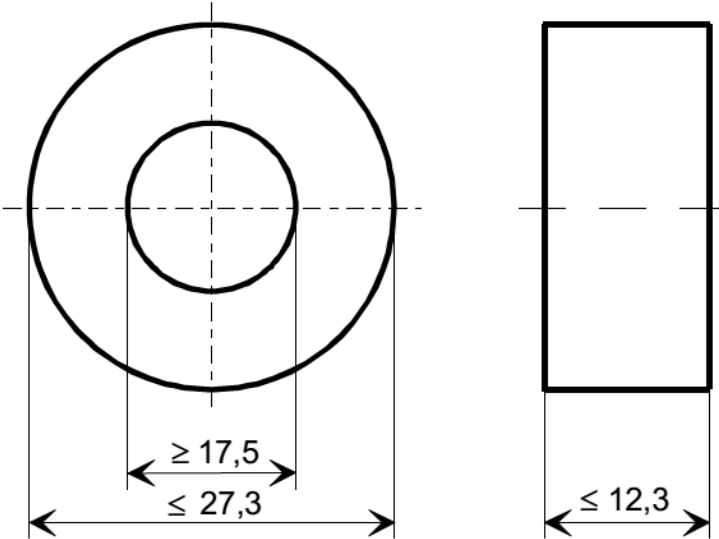
EMC\_Kit\_2004.xls / J. Beichler [23.11.2004]

CMC / 1 Phase														Core											
EMC-Kit No.	Part No.	$I_N$ [A]	Dimensions [mm <sup>3</sup> ]			$U_{N,eff}$ [V]	$U_{P,eff}$ [V]	Design	Z  [Ω] (typically)		L [mH]		$L_{leak}$ [μH]	$I_{unbal}$ [mA] (typically)			Type	Dimensions [mm <sup>3</sup> ]			$A_L$ [μH]				
No.	T6040...		w	d	h				10kHz	100kHz	10kHz	100kHz		DC	10kHz	100kHz		$\varnothing_a$	$\varnothing_i$	h	$\mu_i$	Fix.	10 kHz	100 kHz	Tol [%]
1	5-R6123-X420	20	33	30	20	250	2500	flat	110	410	1,4	0,46	3,7	85	90	170	W622	25	20	10	high	Epoxy	22,5	7,2	-25/+45
2	5-R6166-X510	10	35	21	35	250	2500	upright	650	2800	9,0	2,9	22	34	36	65	W622	25	20	10	high	Epoxy	22,5	7,2	-25/+45
3	5-R6166-X608	8	35	21	35	250	2500	upright	970	4000	13,0	4,1	27	28	30	55	W622	25	20	10	high	Epoxy	22,5	7,2	-25/+45
4	5-R6166-X606	6	35	21	35	250	2500	upright	1600	6000	20,3	6,5	42	23	24	45	W622	25	20	10	high	Epoxy	22,5	7,2	-25/+45
5	5-R6161-X504	4,5	27	17	29	250	2500	upright	1950	6500	28,3	6,9	32	16	18	35	W838	19	15	10	high	Plastic case	36,1	8,8	-25/+45
6	5-R6161-X404	4	23	14	25	250	2500	upright	520	2300	7,3	2,3	15,5	19	20	39	W620	16	12,5	6	high	Epoxy	15,0	4,8	-25/+45
7	5-R6131-X402	2	22	12	25	250	2500	upright	900	3000	12,1	2,8	10,8	15	17	33	W266	16	10	6	high	Plastic case	42,0	l.b.d.	-25/+40
8	5-R6123-X513	13	36	30	23,5	250	2500	flat	650	2900	9,0	2,6	19	34	36	65	W622	25	20	10	high	Epoxy	22,5	7,2	-25/+45
9	5-R6123-X616	16	38	30	24	250	2500	flat	1000	3000	13	2,7	8	33	37	70	W423	30	20	10	high	Plastic case	66	l.b.d.	±30
10	5-R6123-X620	20	53	31		250	2500	flat	375	2750	4,9	3,4	12,9	200	205	300	W453	40	25	15	low	Plastic case	25,0	l.b.d.	-25/+45
11	5-R6123-X425	25	40	24		250	2500	flat	90	620	1,3	0,9	4,2	235	240	360	W358	30	20	10	low	Plastic case	15,5	l.b.d.	-20/+45
12	5-R6123-X510	10	33	30	20	250	2500	flat	690	2900	9,0	2,9	18	34	36	65	W622	25	20	10	high	Epoxy	22,5	7,2	-25/+45

CMC / 3 Phase														Core											
EMC-Kit No.	Part No.	$I_N$ [A]	Dimensions [mm <sup>3</sup> ]			$U_{N,eff}$ [V]	$U_{P,eff}$ [V]	Design	Z  [Ω] (typically)		L [mH]		$L_{leak}$ [μH]	$I_{unbal}$ [mA] (typically)			Type	Dimensions [mm <sup>3</sup> ]			$A_L$ [μH]				
No.	T6040...		$\varnothing$	h					10kHz	100kHz	10kHz	100kHz		DC	10kHz	100kHz		$\varnothing_a$	$\varnothing_i$	h	$\mu_i$	Fix.	10 kHz	100 kHz	Tol [%]
13	5-S6123-X108	8	51	28		500	4000	flat	640	2600	9,4	3,0	18	63	67	125	W624	40	32	15	high	Epoxy	32,5	10,4	-25/+45
14	5-S6123-X106	6	38	27		500	4000	flat	630	3000	8,6	2,8	18	46	48	90	W676	30	25	15	high	Epoxy	26,5	8,5	-25/+45
15	5-S6123-X212	12	51	28		500	2500	flat	320	2700	5,2	3,4	23	140	142	220	W623	40	32	15	low	Epoxy	13,0	8,4	-25/+45
16	5-S6123-X208	8	38	30		500	4000	flat	220	1850	2,9	2,6	10,5	215	220	280	W786	30	20	15	low	Epoxy	15	13,5	-25/+45
17	5-S6123-X216	18	59	28		500	4000	flat	280	2200	4,4	2,9	13,5	200	204	300	W886	45	32	15	low	Epoxy	19,7	12,8	-25/+45
18	5-S6123-X225	25	70	38		500	4000	flat	220	1700	3,5	2,0	12	250	255	380	W565	50	40	20	low	Plastic case	18,0	10,0	-25/+45

Cores										
EMC-Kit No.	Part No.	Dimensions [mm <sup>3</sup> ]			$\mu_i$	Fix.	$A_L$ [μH]			
No.	T6000...	$\varnothing_a$	$\varnothing_i$	h			10 kHz	100 kHz	Tol [%]	
19	4-L2025-W622	25	20	10	high	epoxy	22,5	7,2	-25/+45	
20	6-L2025-W380	25	16	10	high	plastic case	66,0	l.b.d.	-25/+45	
21	6-L2030-W423	30	20	10	high	plastic case	66,0	14,0	±30	
22	4-L2030-W676	30	25	15	high	epoxy	26,5	8,5	-25/+45	
23	4-L2045-W886	45	32	15	low	epoxy	19,7	12,8	-25/+45	
24	6-L2016-W403	16	10	6	high	plastic case	43,0	l.b.d.	-25/+45	
25	6-L2019-W838	19	15	10	high	plastic case	36,1	8,8	-25/+45	
26	4-L2016-W620	16	12,5	6	high	epoxy	15,0	4,8	-25/+45	
27	6-L2040-W424	40	25	15	high	plastic case	109	22,9	±30	
28	4-L2040-W623	40	32	15	low	epoxy	13,0	8,4	-25/+45	
29	6-L2040-W453	40	25	15	low	plastic case	25,0	17,2	-25/+45	
30	4-L2040-W624	40	32	15	high	epoxy	32,5	10,4	-25/+45	
31	6-L2050-W565	50	40	20	low	plastic case	18,0	10,0	-25/+45	
32	6-L2050-W516	50	40	20	high	plastic case	45	l.b.d.	-25/+45	

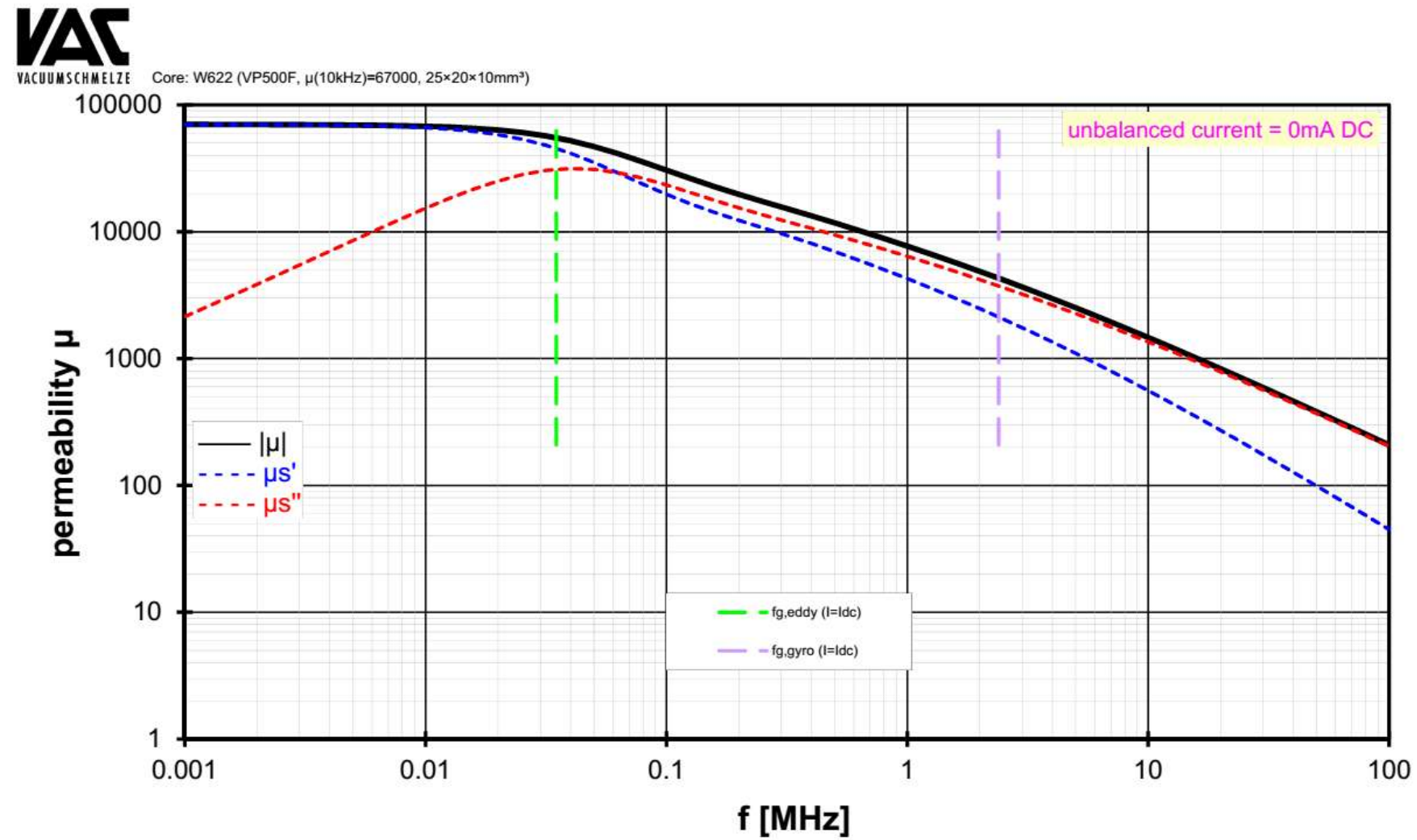
Part No.	I <sub>N</sub> [A]	Dimensions [mm <sup>3</sup> ]			U <sub>N,eff</sub> [V]	U <sub>P,eff</sub> [V]	Design	Z  [Ω] (typically)		L [mH]		L <sub>leak</sub> [μH]	I <sub>unbal</sub> [mA] (typically)			Type
		w	d	h				10kHz	100kHz	10kHz	100kHz		DC	10kHz	100kHz	
T6040...																
5-R6123-X420	20	33	30	20	250	2500	flat	110	410	1,4	0,46	3,7	85	90	170	W622
5-R6166-X510	10	35	21	35	250	2500	upright	650	2800	9,0	2,9	22	34	36	65	W622
5-R6166-X608	8	35	21	35	250	2500	upright	970	4000	13,0	4,1	27	28	30	55	W622
5-R6166-X606	6	35	21	35	250	2500	upright	1600	6000	20,3	6,5	42	23	24	45	W622

	<b>Spezifikation für weichmagnetische Kerne</b> <i>Specification for Soft Magnetic Cores</i>	<b>S-No.:</b> T60004-L2025- <b>W622-51-</b>	
	<b>PK:</b>	<b>Kunde/Customer:</b>	<b>Datum:</b> 10/98 <b>Seite:</b> 1 von 2
<b>Ausführung / Core design:</b> Ringbandkern / <i>Toroidal core:</i>  Kern für stromkomp. Drossel <i>Core for common mode choke</i>  <b>Nennmaße / Nominal Dimensions:</b> 25x20x10 mm  <b>Legierung / Core Material:</b> VITROPERM 500 F  <b>Fixierung / Type of Finish:</b> Fix 350 (Epoxidbeschichtung / <i>Epoxy coated</i> )		<b>Maßbild / Drawing:</b> ohne Maßstab / <i>without scale</i> Maße in mm / <i>Dimensions in mm</i>  	
		Rev.	

These four CMC designs are all based on the same core



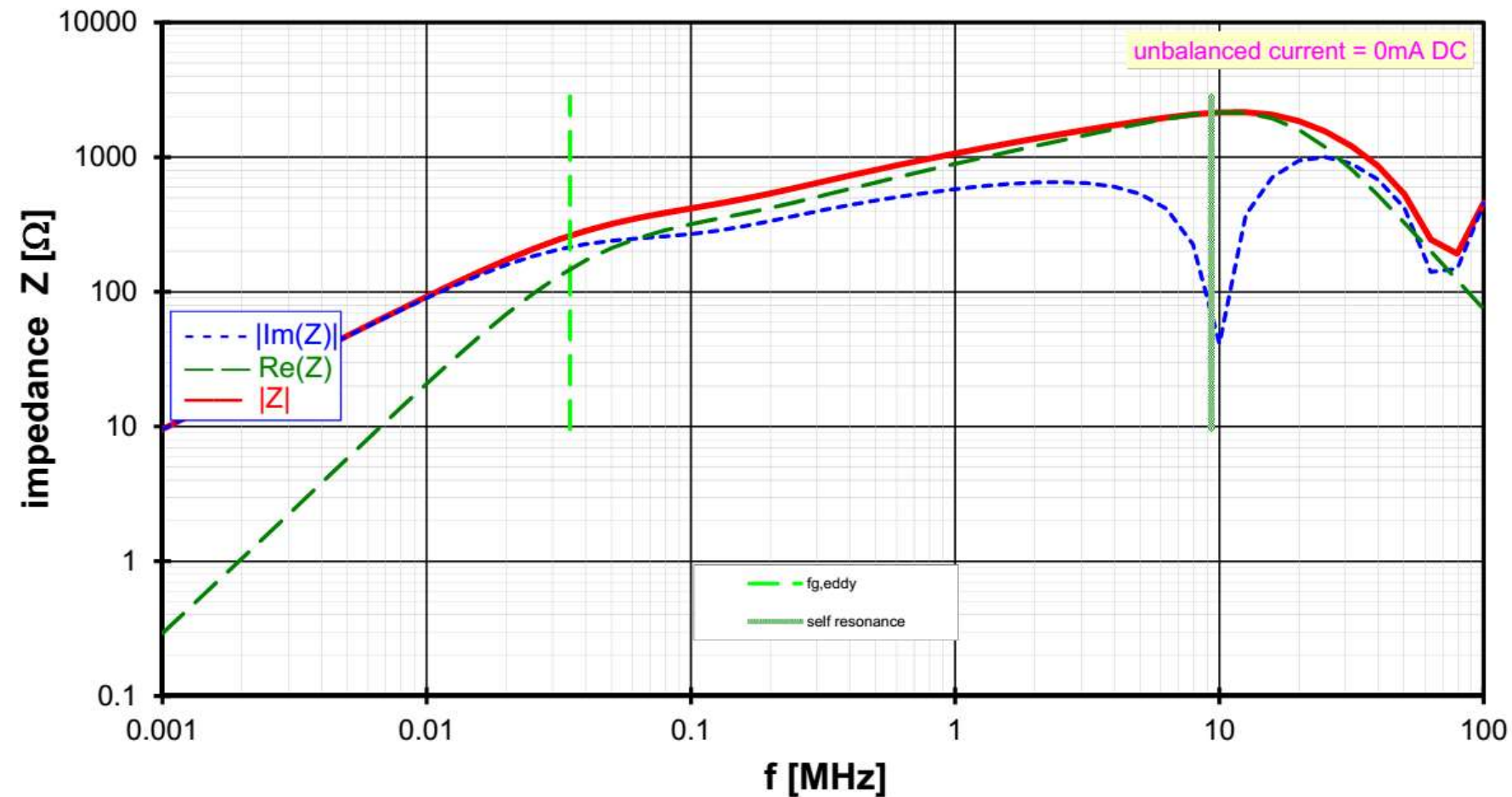
# Perm vs Freq



# Impedance predicted by QuickDim N=8



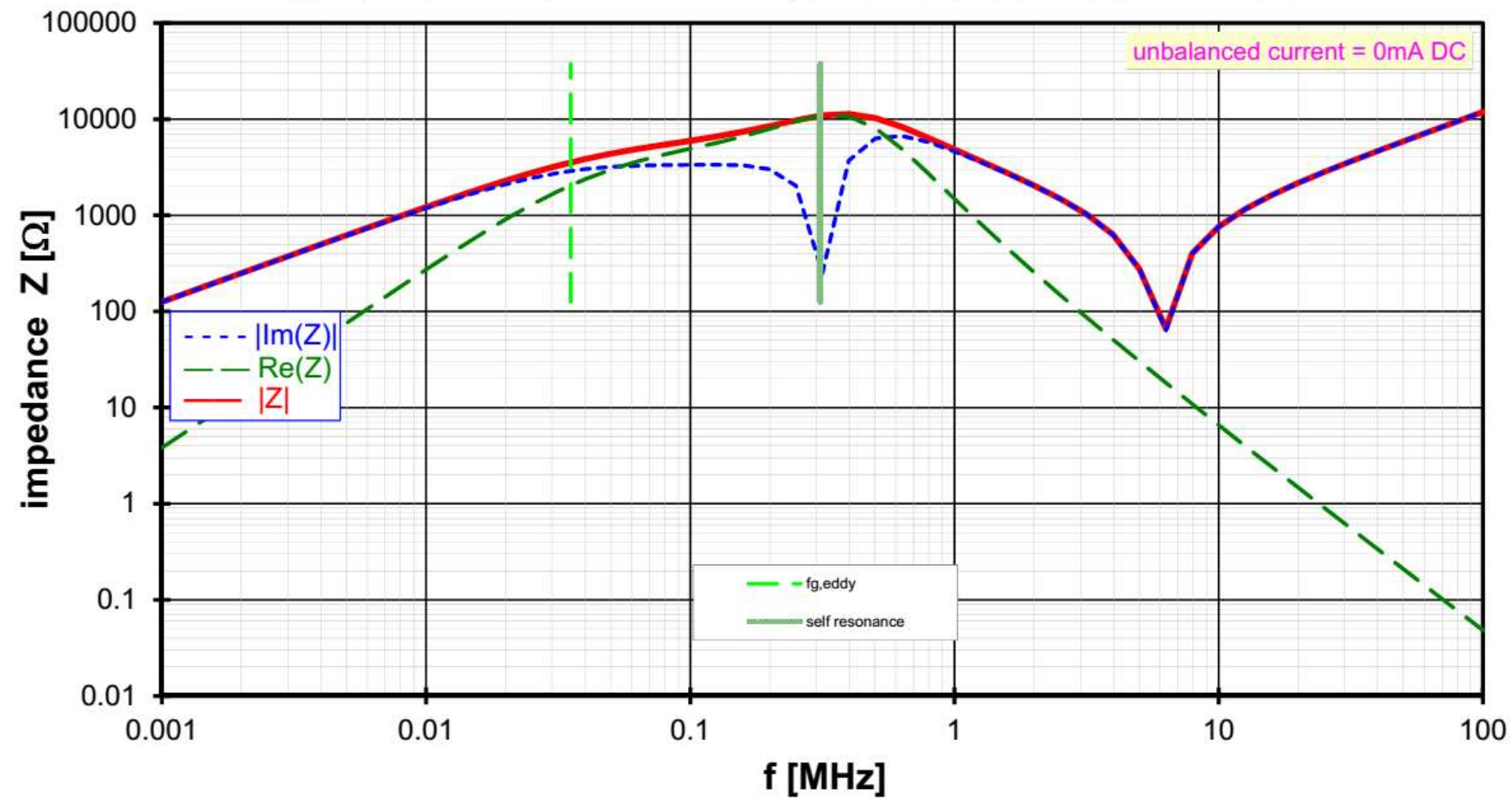
Core: W622 (VP500F,  $\mu(10\text{kHz})=67000$ ,  $25 \times 20 \times 10\text{mm}^3$ ), 2x8 turns / 2.5mm ( $\approx$ AWG10),  $L(10\text{kHz})=1.44\text{mH}$ ;  $I_{\text{cm,max}}(\text{dc})=58.8\text{mA}$ ; Top( $T_a=60^\circ\text{C}$ ,  $I_{\text{eff}}=6\text{A}$ ,  $u^*$ )= $62^\circ\text{C}$



# Impedance predicted by QuickDim N=29



Core: W622 (VP500F,  $\mu(10\text{kHz})=67000$ ,  $25 \times 20 \times 10\text{mm}^3$ ),  $2 \times 29$  turns /  $1.32\text{mm}$  ( $\approx \text{AWG}16$ ),  $L(10\text{kHz})=19\text{mH}$ ;  $I_{\text{cm,max}}(\text{dc})=16.2\text{mA}$ ;  $T_{\text{op}}(T_{\text{a}}=60^\circ\text{C}, I_{\text{eff}}=6\text{A}, "u")=82^\circ\text{C}$



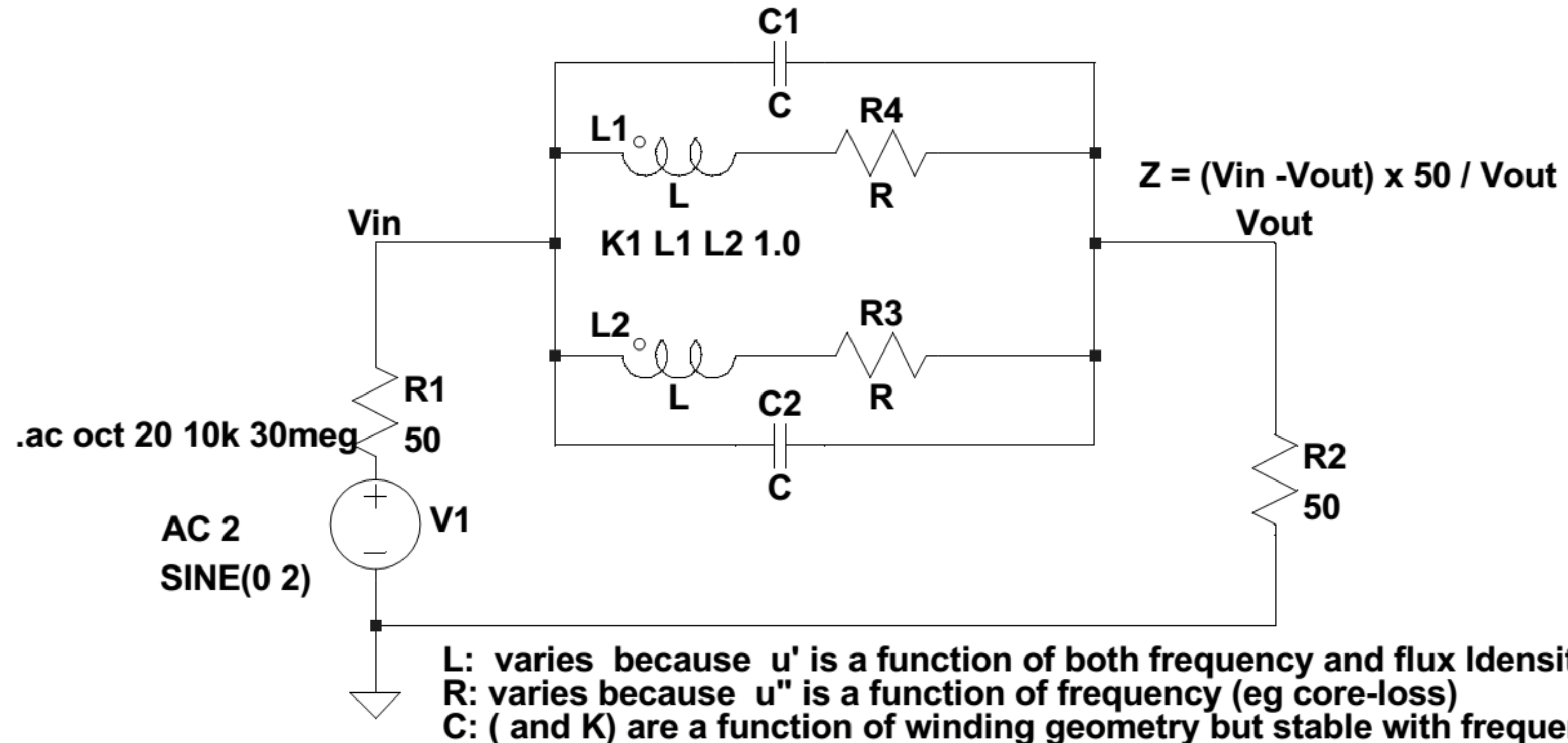


# Typical Numerical Data from QuickDim W622 N=1 and N=10

Reference Lines for  
Impedance |Z|

Ref Line No	Reference Line 1		Reference Line 2	
Title / Description:	Core: W622 (VP500F, $\mu(10\text{kHz})=67000$ , $25 \times 20 \times 10\text{mm}^3$ ), 1 turns / 1.32mm (=AWG16), unbalanced current = 0mA DC		Core: W622 (VP500F, $\mu(10\text{kHz})=67000$ , $25 \times 20 \times 10\text{mm}^3$ ), 10 turns / 1.32mm (=AWG16), unbalanced current = 0mA DC	
	f [MHz]	Z  [ $\Omega$ ]	f [MHz]	Z  [ $\Omega$ ]
← Data	0.001	0.149115196	0.001	14.90994534
	0.001258925	0.187576604	0.001258925	18.75579417
	0.001584893	0.235918471	0.001584893	23.58961936
	0.001995262	0.296652606	0.001995262	29.66259347
	0.002511886	0.372908947	0.002511886	37.28770684
	0.003162278	0.468569542	0.003162278	46.85317416
	0.003981072	0.588413849	0.003981072	58.83698316
	0.005011872	0.738256541	0.005011872	73.82071442
	0.006309573	0.925034596	0.006309573	92.49832952
	0.007943282	1.156754722	0.007943282	115.6710708
	0.01	1.442134276	0.01	144.2118507
	0.012589254	1.78965711	0.012589254	178.9713498
	0.015848932	2.205664997	0.015848932	220.5879062
	0.019952623	2.691189087	0.019952623	269.1713545
	0.025118864	3.23787601	0.025118864	323.8953308
	0.031622777	3.824946626	0.031622777	382.6903279
	0.039810717	4.420953643	0.039810717	442.4138111
	0.050118723	4.993345015	0.050118723	499.8017827
	0.063095734	5.523163531	0.063095734	552.9411957
	0.079432823	6.016089011	0.079432823	602.3850169
	0.1	6.502747093	0.1	651.1952464
	0.125892541	7.029218767	0.125892541	704.0008374

### CMC test for Z vs freq



## Conclusions

- Simulation tools such as LTspice and CMC\_QuickDim can help you quickly understand your design. But breadboard testing is still recommended.
- Magnetic components are difficult to model because of varying levels of frequency dependency of the core.
- Many standard components models are available on the web., so ask your magnetic component manufacturer if they will provide a LTspice model or CMC\_QuickDim plot for your chosen component.