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“Simulation of T/S Parameter Production Tolerances”

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“Simulation of T/S Parameter Production Tolerances”

Thiele / Small parameters (T/S), Frequency Response and Power Handling, are the primary evaluation standards for loudspeaker performance.

For production testing, both frequency response and power handling have clear standards and a good engineering basis for those standards.

Thiele / Small parameter standards, however are typically assigned arbitrarily with no consideration of their relationship to the parts’ tolerance specifications that actually cause the parameter variance

- or to the real performance variations!

(System F_3, Tuning, SPL)

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A typical Tolerance Specification for T/S parameters might look like this:

Parameter	Value	Unit	Tolerance
R_e	6	Ohms	+/- 5%
F_o	60.3	Hz.	+/- 10%
Q_{ts}	.575		+/- 10%
Q_{ms}	6.0		+/- 10%
V_{as}	27.27	Liters	+/- 10%

- **How these relate to the Parts Specifications is not considered!**

  (How do parameters change when part values change?)

- **How these relate to the Performance of the speaker is not considered!**

  (What parameters are important for the performance?)

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What we need to do is:

- **Identify which parameters are important for performance.**

- **Identify how part changes affect parameters**

  (especially the important ones)

- **Set <u>parameter tolerances</u> that are based on *reasonable* <u>parts tolerances</u>.**

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Which parameters are important for performance?

Performance is typically defined by:

- **System F_3**
- **Tuning (Q_{tc} for sealed and infinite baffle, F_b for vented)**
- **Sensitivity**

These are not defined by single parameters, rather by ratios of parameters:

- **F_o / Q_{ts} ratio**
- **BL^2 / R_e ratio**

Good control over these ratios, means good control over the performance of the system.

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How do part changes affect parameters?

Speaker parts specifications are typically a combination of dimensions with tolerance values, and part-specific specifications such as DCR (coils), deflection (spiders) Fo (cones), etc.

Changes in parts values typically change more than one parameter.

For example:

Coil DCR affects every parameter

Cone Fo affects Fo, Qts Qes, Vas

Motor Dimensions affect Qe, Qts, BL, SPL

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In fact all of the speaker parts tolerances interact to produce a wide range of variance in the speaker parameters

To accurately calculate parameter variations based on the tolerances of individual parts you need to create a complex matrix of all of the important variables and their tolerances.

Then calculate how these variables affect every parameter through the full range of their tolerances.

Easy Right?

Fortunately….

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“Simulation of T/S Parameter Production Tolerances”

Parameter Tolerance Worksheet

Starting Values	Unit	Value
Sd	cm^2	216.42
BL	Tm	7.798
Mmd	g	15

Enter starting values and part specifications (BOLD values).

All other values are calculated.

Parameters are calculated based on the "Starting Values" and "Standard Part Specifications".

The Sealed Enclosure Predictions are calculated for the entered "Box Volume".

Part Specification	Unit	Standard	+%	-%	+ Value	- Value
Re (coil Dcr)	Ohm	6	5.00%	5.00%	6.30	5.70
Coil Mass	g	2.75				
Front Plate Thickness	mm	6	1.67%	1.67%	0.10	0.10
Front Plate Inside Diameter	mm	28.7	0.35%	0.00%	0.10	0.00
Pole Piece Diameter	mm	24.95	0.00%	0.40%	0.00	0.10
Magnet Outside Diameter	mm	100	0.00%	0.00%	0.00	0.00
Magnet Inside Diameter	mm	45	2.22%	2.22%	1.00	1.00
Magnet material Br Variance			0.00%	0.00%		
Cone Fo	Hz.	45	10.00%	10.00%	49.50	40.50
Cone +1/2 edge Mmd	g	8.6	0.00%	0.00%	8.60	8.60
Spider Deflection	mm	0.62	10.00%	10.00%	0.68	0.56
Mass for Deflection	g	100				
Qms		6.8	10.00%	10.00%	7.48	6.12
Glue Mass	g	1	5.00%	5.00%	1.05	0.95

Parameters	Unit	Standard	+%	-%	+Value	-Value
Re	Ohm	6	5.0%	5.0%	6.30	5.70
Fo	Hz.	60.30	7.6%	7.0%	64.90	56.10
Qes		0.628	23.0%	14.4%	0.772	0.537
Qms		6.8	10.0%	10.0%	7.48	6.12
Qts		0.575	21.7%	14.1%	0.700	0.494
BL	Tm	7.798	1.6%	4.1%	7.93	7.48
BL^2 / Re		10.13	8.7%	12.5%	11.02	8.87
Fo/Qts		104.87	8.3%	11.6%	113.55	92.70
Mmd	g	15	1.3%	1.3%	15.19	14.81
Mms (FA)	g	16.80	1.1%	1.1%	16.99	16.61
Cms	m/N	4.15E-04	14.3%	12.7%	4.74E-04	3.62E-04
Vas	Liters	27.27	14.3%	12.7%	31.17	23.81
SPL 2.83V	dB	92.96	0.7%	1.0%	93.65	92.08
SPL 1W1m	dB	91.71	0.5%	0.7%	92.17	91.04

Sealed Enclosure						
Box Volume	Liter	10				
Qtc		1.110	16.0%	9.7%	1.287	1.002
F3	Hz.	87.82	1.8%	1.9%	89.39	86.17

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“Simulation of T/S Parameter Production Tolerances”

Input values

Starting Values	Unit	Value
Sd	cm^2	216.42
BL	Tm	7.798
Mmd	g	15

Enter starting values and part specifications (BOLD values).

All other values are calculated.

Part Specification	Unit	Standard	+%	-%	+ Value	- Value
Re (coil Dcr)	Ohm	6	5.00%	5.00%	6.30	5.70
Coil Mass	g	2.75				
Front Plate Thickness	mm	6	1.67%	1.67%	0.10	0.10
Front Plate Inside Diameter	mm	28.7	0.35%	0.00%	0.10	0.00
Pole Piece Diameter	mm	24.95	0.00%	0.40%	0.00	0.10
Magnet Outside Diameter	mm	100	0.00%	0.00%	0.00	0.00
Magnet Inside Diameter	mm	45	2.22%	2.22%	1.00	1.00
Magnet material Br Variance			0.00%	0.00%		
Cone Fo	Hz.	45	10.00%	10.00%	49.50	40.50
Cone +1/2 edge Mmd	g	8.6	0.00%	0.00%	8.60	8.60
Spider Deflection	mm	0.62	10.00%	10.00%	0.68	0.56
Mass for Deflection	g	100				
Qms		6.8	10.00%	10.00%	7.48	6.12
Glue Mass	g	1	5.00%	5.00%	1.05	0.95

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“Simulation of T/S Parameter Production Tolerances”

Tolerance Calculations

Parameters are calculated based on the "Starting Values" and "Standard Part Specifications".

The Sealed Enclosure Predictions are calculated for the entered "Box Volume".

Parameters	Unit	Standard	+%	-%	+Value	-Value
Re	Ohm	6	5.0%	5.0%	6.30	5.70
Fo	Hz.	60.30	7.6%	7.0%	64.90	56.10
Qes		0.628	23.0%	14.4%	0.772	0.537
Qms		6.8	10.0%	10.0%	7.48	6.12
Qts		0.575	21.7%	14.1%	0.700	0.494
BL	Tm	7.798	1.6%	4.1%	7.93	7.48
BL^2 / Re		10.13	8.7%	12.5%	11.02	8.87
Fo/Qts		104.87	8.3%	11.6%	113.55	92.70
Mmd	g	15	1.3%	1.3%	15.19	14.81
Mms (FA)	g	16.80	1.1%	1.1%	16.99	16.61
Cms	m/N	4.15E-04	14.3%	12.7%	4.74E-04	3.62E-04
Vas	Liters	27.27	14.3%	12.7%	31.17	23.81
SPL 2.83V	dB	92.96	0.7%	1.0%	93.65	92.08
SPL 1W1m	dB	91.71	0.5%	0.7%	92.17	91.04
Sealed Enclosure						
Box Volume	Liter	10				
Qtc		1.110	16.0%	9.7%	1.287	1.002
F3	Hz.	87.82	1.8%	1.9%	89.39	86.17

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Coil DCR Change of +/- 5 %

Parameter Tolerance Worksheet

Starting Values	Unit	Value
Sd	cm^2	**216.42**
BL	Tm	**7.798**
Mmd	g	**15**

Enter starting values and part specifications (BOLD values).

All other values are calculated.

Parameters are calculated based on the "Starting Values" and "Standard Part Specifications".

The Sealed Enclosure Predictions are calculated for the entered "Box Volume".

Part Specification	Unit	Standard	+%	-%	+ Value	- Value
Re (coil Dcr)	Ohm	**6**	**5.00%**	**5.00%**	6.30	5.70
Coil Mass	g	**2.75**				
Front Plate Thickness	mm	**6**	0.00%	0.00%	**0.00**	**0.00**
Front Plate Inside Diameter	mm	**28.7**	0.00%	0.00%	**0.00**	**0.00**
Pole Piece Diameter	mm	**24.95**	0.00%	0.00%	**0.00**	**0.00**
Magnet Outside Diameter	mm	**100**	0.00%	0.00%	**0.00**	**0.00**
Magnet Inside Diameter	mm	**45**	0.00%	0.00%	**0.00**	**0.00**
Magnet material Br Variance			**0.00%**	**0.00%**		
Cone Fo	Hz.	**45**	**0.00%**	**0.00%**	45.00	45.00
Cone +1/2 edge Mmd	g	**8.6**	**0.00%**	**0.00%**	8.60	8.60
Spider Deflection	mm	**0.62**	**0.00%**	**0.00%**	0.62	0.62
Mass for Deflection	g	**100**				
Qms		**6.8**	**0.00%**	**0.00%**	6.80	6.80
Glue Mass	g	**1**	**0.00%**	**0.00%**	1.00	1.00

Parameters	Unit	Standard	+%	-%	+Value	-Value
Re	**Ohm**	6	5.0%	5.0%	6.30	5.70
Fo	Hz.	60.30	0.4%	0.4%	60.55	60.06
Qes		0.628	5.4%	5.4%	0.662	0.594
Qms		6.8	0.0%	0.0%	6.8	6.8
Qts		0.575	4.9%	5.0%	0.603	0.547
BL	Tm	7.798	0.0%	0.0%	7.80	7.80
BL^2 / Re		10.13	5.3%	4.8%	10.67	9.65
Fo/Qts		104.87	4.8%	4.3%	109.89	100.34
Mmd	g	15	0.9%	0.9%	15.14	14.86
Mms (FA)	g	16.80	0.8%	0.8%	16.94	16.66
Cms	m/N	4.15E-04	0.0%	0.0%	4.15E-04	4.15E-04
Vas	Liters	27.27	0.0%	0.0%	27.27	27.27
SPL 2.83V	dB	92.96	0.6%	0.5%	93.48	92.47
SPL 1W1m	dB	91.71	0.3%	0.3%	92.00	91.43

Sealed Enclosure						
Box Volume	Liter	**10**				
Qtc		1.110	4.9%	5.0%	1.165	1.055
F3	Hz.	87.82	1.5%	1.2%	89.12	86.79

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Cone F_o +/- 10% & Spider Deflection +/- 15%

Parameter Tolerance Worksheet

Starting Values	Unit	Value
Sd	cm^2	216.42
BL	Tm	7.798
Mmd	g	15

Enter starting values and part specifications (BOLD values).

All other values are calculated.

Parameters are calculated based on the "Starting Values" and "Standard Part Specifications".

The Sealed Enclosure Predictions are calculated for the entered "Box Volume".

Part Specification	Unit	Standard	+%	-%	+ Value	- Value
Re (coil Dcr)	Ohm	6	0.00%	0.00%	6.00	6.00
Coil Mass	g	2.75				
Front Plate Thickness	mm	6	0.00%	0.00%	0.00	0.00
Front Plate Inside Diameter	mm	28.7	0.00%	0.00%	0.00	0.00
Pole Piece Diameter	mm	24.95	0.00%	0.00%	0.00	0.00
Magnet Outside Diameter	mm	100	0.00%	0.00%	0.00	0.00
Magnet Inside Diameter	mm	45	0.00%	0.00%	0.00	0.00
Magnet material Br Variance			0.00%	0.00%		
Cone Fo	Hz.	45	10.00%	10.00%	49.50	40.50
Cone +1/2 edge Mmd	g	8.6	0.00%	0.00%	8.60	8.60
Spider Deflection	mm	0.62	15.00%	15.00%	0.71	0.53
Mass for Deflection	g	100				
Qms		6.8	0.00%	0.00%	6.80	6.80
Glue Mass	g	1	0.00%	0.00%	1.00	1.00

Parameters	Unit	Standard	+%	-%	+Value	-Value
Re	Ohm	6	0.0%	0.0%	6.00	6.00
Fo	Hz.	60.30	9.0%	7.9%	65.73	55.57
Qes		0.628	9.0%	7.9%	0.685	0.579
Qms		6.8	0.0%	0.0%	6.8	6.8
Qts		0.575	8.2%	7.2%	0.622	0.533
BL	Tm	7.798	0.0%	0.0%	7.80	7.80
BL^2 / Re		10.13	0.0%	0.0%	10.13	10.13
Fo/Qts		104.87	0.7%	0.8%	104.18	105.67
Mmd	g	15	0.0%	0.0%	15.00	15.00
Mms (FA)	g	16.80	0.0%	0.0%	16.80	16.80
Cms	m/N	4.15E-04	17.8%	15.8%	4.88E-04	3.49E-04
Vas	Liters	27.27	17.8%	15.8%	32.12	22.96
SPL 2.83V	dB	92.96	0.0%	0.0%	92.96	92.96
SPL 1W1m	dB	91.71	0.0%	0.0%	91.71	91.71
Sealed Enclosure						
Box Volume	Liter	10				
Qtc		1.110	1.7%	1.4%	1.129	1.095
F3	Hz.	87.82	1.6%	1.9%	86.45	89.48

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Typical Magnet Part Tolerances

Parameter Tolerance Worksheet

Starting Values	Unit	Value
Sd	cm^2	216.42
BL	Tm	7.798
Mmd	g	15

Enter starting values and part specifications (BOLD values).

All other values are calculated.

Parameters are calculated based on the "Starting Values" and "Standard Part Specifications".

The Sealed Enclosure Predictions are calculated for the entered "Box Volume".

Part Specification	Unit	Standard	+%	-%	+ Value	- Value
Re (coil Dcr)	Ohm	6	0.00%	0.00%	6.00	6.00
Coil Mass	g	2.75				
Front Plate Thickness	mm	6	1.67%	1.67%	0.10	0.10
Front Plate Inside Diameter	mm	28.7	0.17%	0.00%	0.05	0.00
Pole Piece Diameter	mm	24.95	0.00%	0.20%	0.00	0.05
Magnet Outside Diameter	mm	100	0.50%	0.50%	0.50	0.50
Magnet Inside Diameter	mm	45	1.11%	1.11%	0.50	0.50
Magnet material Br Variance			2.00%	2.00%		
Cone Fo	Hz.	45	0.00%	0.00%	45.00	45.00
Cone +1/2 edge Mmd	g	8.6	0.00%	0.00%	8.60	8.60
Spider Deflection	mm	0.62	0.00%	0.00%	0.62	0.62
Mass for Deflection	g	100				
Qms		6.8	0.00%	0.00%	6.80	6.80
Glue Mass	g	1	0.00%	0.00%	1.00	1.00

Parameters	Unit	Standard	+%	-%	+Value	-Value
Re	Ohm	6	0.0%	0.0%	6.00	6.00
Fo	Hz.	60.30	0.0%	0.0%	60.30	60.30
Qes		0.628	11.8%	7.8%	0.702	0.579
Qms		6.8	0.0%	0.0%	6.8	6.8
Qts		0.575	10.7%	7.2%	0.636	0.534
BL	Tm	7.798	4.1%	5.4%	8.12	7.38
BL^2 / Re		10.13	8.4%	10.5%	10.99	9.07
Fo/Qts		104.87	7.7%	9.6%	112.97	94.77
Mmd	g	15	0.0%	0.0%	15.00	15.00
Mms (FA)	g	16.80	0.0%	0.0%	16.80	16.80
Cms	m/N	4.15E-04	0.0%	0.0%	4.15E-04	4.15E-04
Vas	Liters	27.27	0.0%	0.0%	27.27	27.27
SPL 2.83V	dB	92.96	0.4%	0.5%	93.32	92.48
SPL 1W1m	dB	91.71	0.4%	0.5%	92.06	91.23

Sealed Enclosure						
Box Volume	Liter	10				
Qtc		1.110	10.7%	7.2%	1.229	1.031
F3	Hz.	87.82	2.9%	3.1%	90.35	85.10

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“Simulation of T/S Parameter Production Tolerances”

Complete set of Typical Tolerances

Parameter Tolerance Worksheet

Starting Values	Unit	Value
Sd	cm^2	216.42
BL	Tm	7.798
Mmd	g	15

Enter starting values and part specifications (BOLD values).

All other values are calculated.

Parameters are calculated based on the "Starting Values" and "Standard Part Specifications".

The Sealed Enclosure Predictions are calculated for the entered "Box Volume".

Part Specification	Unit	Standard	+%	-%	+ Value	- Value
Re (coil Dcr)	Ohm	6	5.00%	5.00%	6.30	5.70
Coil Mass	g	2.75				
Front Plate Thickness	mm	6	1.67%	1.67%	0.10	0.10
Front Plate Inside Diameter	mm	28.7	0.17%	0.00%	0.05	0.00
Pole Piece Diameter	mm	24.95	0.00%	0.20%	0.00	0.05
Magnet Outside Diameter	mm	100	0.50%	0.50%	0.50	0.50
Magnet Inside Diameter	mm	45	0.00%	0.00%	0.00	0.00
Magnet material Br Variance			1.00%	1.00%		
Cone Fo	Hz.	45	10.00%	10.00%	49.50	40.50
Cone +1/2 edge Mmd	g	8.6	0.00%	0.00%	8.60	8.60
Spider Deflection	mm	0.62	15.00%	15.00%	0.71	0.53
Mass for Deflection	g	100				
Qms		6.8	10.00%	10.00%	7.48	6.12
Glue Mass	g	1	2.00%	2.00%	1.02	0.98

Parameters	Unit	Standard	+%	-%	+Value	-Value
Re	Ohm	6	5.0%	5.0%	6.30	5.70
Fo	Hz.	60.30	9.5%	8.3%	66.04	55.31
Qes		0.628	24.8%	17.4%	0.784	0.519
Qms		6.8	10.0%	10.0%	7.48	6.12
Qts		0.575	23.4%	16.9%	0.709	0.478
BL	Tm	7.798	2.7%	4.0%	8.01	7.49
BL^2 / Re		10.13	11.1%	12.2%	11.26	8.89
Fo/Qts		104.87	10.3%	11.2%	115.70	93.09
Mmd	g	15	1.0%	1.1%	15.16	14.84
Mms (FA)	g	16.80	0.9%	0.9%	16.96	16.64
Cms	m/N	4.15E-04	17.8%	15.8%	4.88E-04	3.49E-04
Vas	Liters	27.27	17.8%	15.8%	32.12	22.96
SPL 2.83V	dB	92.96	0.8%	0.9%	93.73	92.11
SPL 1W1m	dB	91.71	0.6%	0.7%	92.25	91.06

Sealed Enclosure						
Box Volume	Liter	10				
Qtc		1.110	16.0%	11.6%	1.288	0.981
F3	Hz.	87.82	2.5%	1.4%	90.02	86.56

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“Simulation of T/S Parameter Production Tolerances”

Complete set of Typical Tolerances – Better Coil

Parameter Tolerance Worksheet

Starting Values	Unit	Value
Sd	cm^2	216.42
BL	Tm	7.798
Mmd	g	15

Enter starting values and part specifications (BOLD values).

All other values are calculated.

Parameters are calculated based on the "Starting Values" and "Standard Part Specifications".

The Sealed Enclosure Predictions are calculated for the entered "Box Volume".

Part Specification	Unit	Standard	+%	-%	+ Value	- Value
Re (coil Dcr)	Ohm	6	2.00%	2.00%	6.12	5.88
Coil Mass	g	2.75				
Front Plate Thickness	mm	6	1.67%	1.67%	0.10	0.10
Front Plate Inside Diameter	mm	28.7	0.17%	0.00%	0.05	0.00
Pole Piece Diameter	mm	24.95	0.00%	0.20%	0.00	0.05
Magnet Outside Diameter	mm	100	0.50%	0.50%	0.50	0.50
Magnet Inside Diameter	mm	45	0.00%	0.00%	0.00	0.00
Magnet material Br Variance			1.00%	1.00%		
Cone Fo	Hz.	45	10.00%	10.00%	49.50	40.50
Cone +1/2 edge Mmd	g	8.6	0.00%	0.00%	8.60	8.60
Spider Deflection	mm	0.62	15.00%	15.00%	0.71	0.53
Mass for Deflection	g	100				
Qms		6.8	10.00%	10.00%	7.48	6.12
Glue Mass	g	1	2.00%	2.00%	1.02	0.98

Parameters	Unit	Standard	+%	-%	+Value	-Value
Re	Ohm	6	2.0%	2.0%	6.12	5.88
Fo	Hz.	60.30	9.2%	8.1%	65.88	55.44
Qes		0.628	20.9%	14.6%	0.760	0.536
Qms		6.8	10.0%	10.0%	7.48	6.12
Qts		0.575	19.9%	14.3%	0.689	0.493
BL	Tm	7.798	2.7%	4.0%	8.01	7.49
BL^2 / Re		10.13	7.7%	9.7%	10.91	9.16
Fo/Qts		104.87	7.2%	8.9%	112.45	95.54
Mmd	g	15	0.5%	0.5%	15.08	14.93
Mms (FA)	g	16.80	0.4%	0.4%	16.88	16.73
Cms	m/N	4.15E-04	17.8%	15.8%	4.88E-04	3.49E-04
Vas	Liters	27.27	17.8%	15.8%	32.12	22.96
SPL 2.83V	dB	92.96	0.5%	0.6%	93.41	92.40
SPL 1W1m	dB	91.71	0.4%	0.5%	92.07	91.23

Sealed Enclosure						
Box Volume	Liter	10				
Qtc		1.110	12.8%	8.8%	1.252	1.012
F3	Hz.	87.82	1.3%	1.0%	88.99	86.98

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Summary using Tolerance Worksheet:

Using Q_{ts}, Q_{es} and V_{as} for QC parameters can be misleading and cause unnecessary failures.

Coil R_e has a large affect on important parameters and improving tolerance can greatly improve total speaker tolerances.

Large Changes in Cone F_o and Spider Deflection have little affect on important parameters.

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Performance – Based T/S Tolerance Model based on Part Tolerances

Parameter	Value	Unit	Tolerance
R_e	6	Ohms	+/- 2%
F_o	60.3	Hz.	+/- 10%
Fo/Q_{ts} Ratio	105		+/- 10%
BL^2/ R_e Ratio	10.13		+/- 10%

These values can easily be achieved with reasonable part tolerances

(Coil tolerances have to be improved from the +/- 5% DCR standard)

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Questions, Comments?

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