



*Global Design Infrastructure Innovation*

# Parametric passive spice model and importance of DC bias models

2020.10.3

<http://www.modech.com/>

- 1. Passive device specifications described in the data sheet
- 2. Relationship between important characteristics of inductor & capacitor and circuit characteristics
- 3. Improved design flow proposal using the parametric passive model

Passive device specifications described  
in the data sheet

# Data sheet of passive device(inductor)

The important inductor specifications for modeling in the datasheet are as following.

TAIYO YUDEN LB Series

■ 製品特性表

インダクタンス Inductance	1.0 uH ± 20 %
ケースサイズ (EIA/JIS)	0603/1608
定格電流 (max)	0.16 A
DC resistance(typ.)	0.221 Ω
DC resistance(max.)	0.17 Ω
Measured frequency of parameter	96 MHz
Resonance frequency	100 MHz
Operating temperature range	-40 to +105 °C (Including-self-generated heat)
Temperature change rate of inductance	± 20 %
	Yes
REACH対応 (205 物質)	Yes
ハロゲンフリー	Yes
適用はんだ付け法	Reflow

TAIYO YUDEN MC Series

■ 製品特性表

インダクタンス Inductance	1.0 uH ± 20 %
ケースサイズ (EIA/JIS)	0504/1210
定格電流 (max)	1.1 A
DC bias current(Max.)	1.5 A (ΔL=30%)
DC bias current(Typ.)	1.7 A (ΔL=30%)
温度上昇許容電流 (max)	1.1 A (ΔT=40°C)
温度上昇許容電流 (typ)	1.2 A (ΔT=40°C)
DC resistance(max.)	0.179 Ω
DC resistance(typ.)	0.157 Ω
Measured frequency of parameter	96 MHz
Operating temperature range	-40 to +125 °C (Including-self-generated heat)
RoHS指令対応 (10 物質)	Yes
REACH対応 (205 物質)	Yes
適用はんだ付け法	Reflow

The datasheet describes many important specification for modeling

The important inductor specifications for modeling in the datasheet are as following.

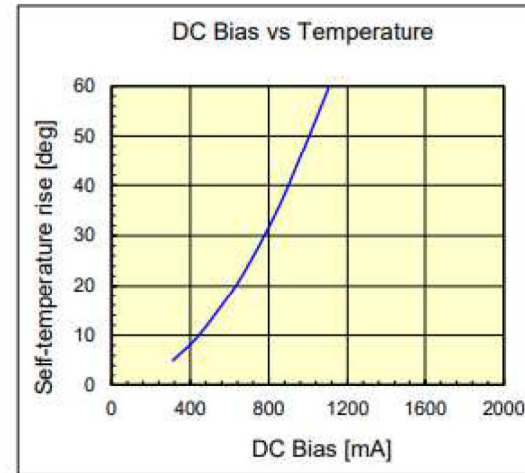
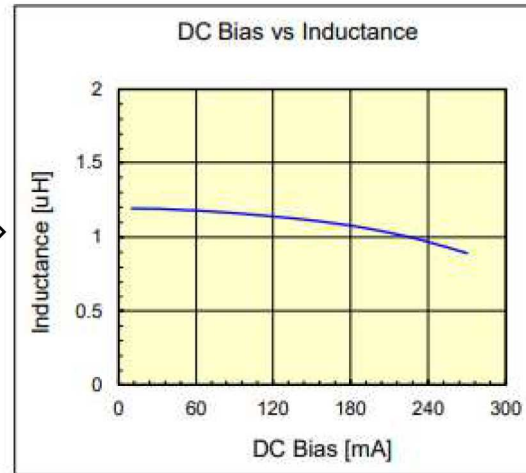
- inductance  
The inductance specification is determined by treating many factors of variation.
- DC resistance  
It is the specification that determines the resistance at DC(0Hz).  
AC resistance is higher than DC resistance due to skin effect and iron loss.
- Resonance frequency  
In the frequency band higher than the resonance frequency, the inductor operates as a capacitor.
- Operating temperature range  
The operating temperature range is guaranteed by the manufacturer.  
Temperature change is a factor of inductance variation
- Measured frequency of parameter  
The manufacturer guarantees inductance and Q value for this frequency
- DC bias current  
The value of the inductor changes depending on the DC bias current.

# Data sheet of passive device(inductor)

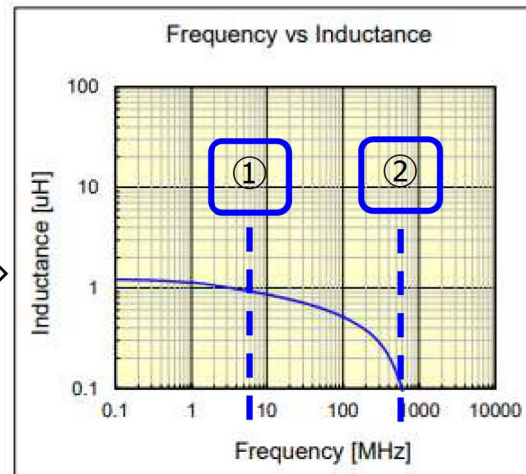
The important inductor specifications for modeling in the datasheet are as following.

TAIYO YUDEN LB Series

DC bias current dependence



① Measured frequency of parameter  
② Resonance frequency



# Data sheet of passive device(capacitor)

The important capacitor specifications for modeling in the datasheet are as following.

TAIYO YUDEN  
Multilayer ceramic capacitors for high frequencies

■ 製品特性表

静電容量 <b>Capacitance</b>	10 pF ± 2 %
ケースサイズ (EIA/JIS)	008004/0201
定格電圧	16 V
Q (min)	50 at 1GHz
Capacitance fluctuation due to temperature change(EIA)	± 2 %
Operating temperature range(EIA)	0 ~ 100 °C
Capacitance fluctuation due to temperature change(JIS)	± 2 %
Operating temperature range(JIS)	0 ~ 100 °C
Temperature coefficient of capacitance	± 20 ppm/°C
高温負荷 (% 定格電圧)	200 %
<b>Insulation resistance</b>	10 GΩ
RoHS指令対応 (10 物質)	Yes
REACH対応 (205 物質)	Yes
ハロゲンフリー	Yes
適用はんだ付け法	Reflow

TAIYO YUDEN  
High dielectric constant multilayer ceramic capacitor

■ 製品特性表

静電容量 <b>Capacitance</b>	4.7 uF ± 20 %
ケースサイズ (EIA/JIS)	0201/0603
定格電圧	2.5 V
tan δ (max)	10 %
Capacitance fluctuation due to temperature change(EIA)	± 20 %
Operating temperature range(EIA)	-55 ~ 125 °C
Insulation resistance	20 MΩ・μF
RoHS指令対応 (10 物質)	Yes
REACH対応 (205 物質)	Yes
ハロゲンフリー	Yes
適用はんだ付け法	Reflow

The datasheet describes many important specification for modeling

The important capacitor specifications for modeling in the datasheet are as following.

- Capacitance  
The inductance specification is determined by taking into account many factors of variation.
  - Insulation resistance  
It is the specification that determines the resistance at DC(0Hz).
  - Q,  $\tan\delta$   
Q and  $\tan\delta$  are parameters representing the loss component in alternating current
  - Resonance frequency  
In the frequency band higher than the resonance frequency, the capacitor operates as an inductor.
- 
- Operating temperature range  
The operating temperature range is guaranteed by the manufacturer.  
Temperature change is a factor of inductance variation
- 
- DC bias voltage  
The value of the capacitor changes depending on the DC bias voltage.
  - Temperature change dependence  
Temperature change dependence of capacitance is specified by EIA and JIS.

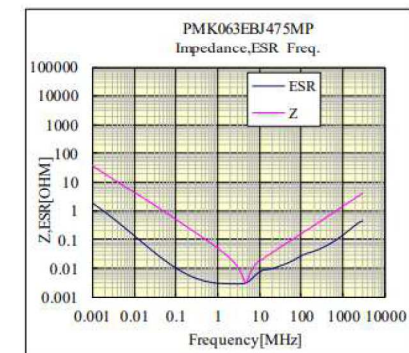
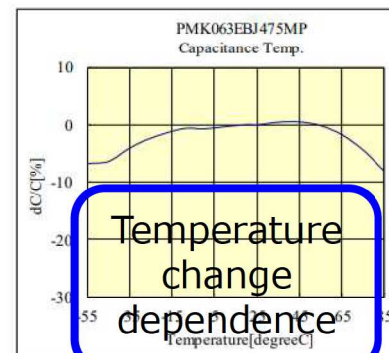
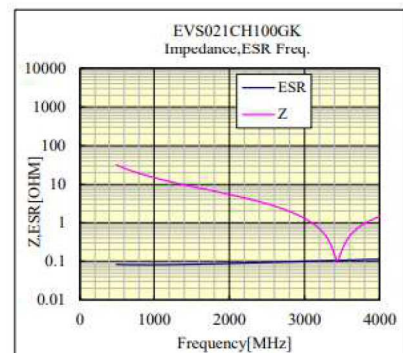
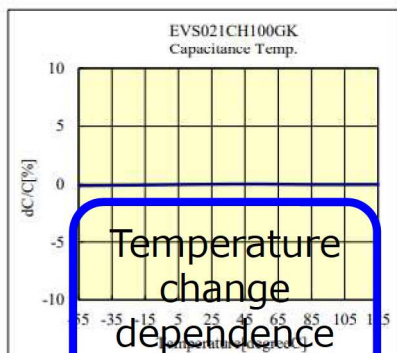
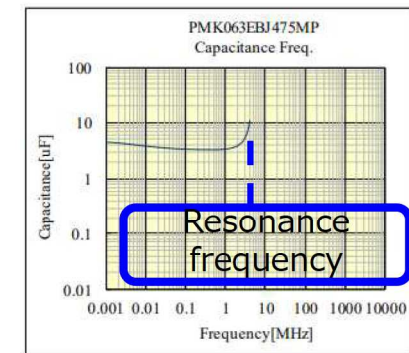
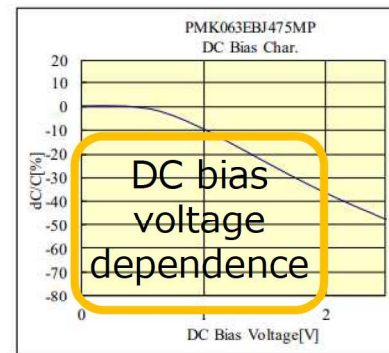
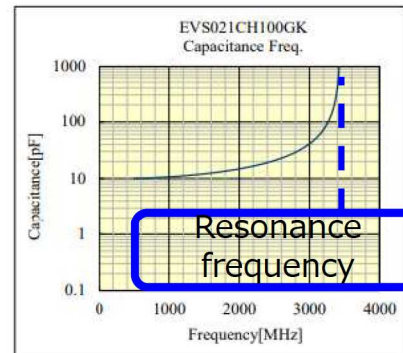
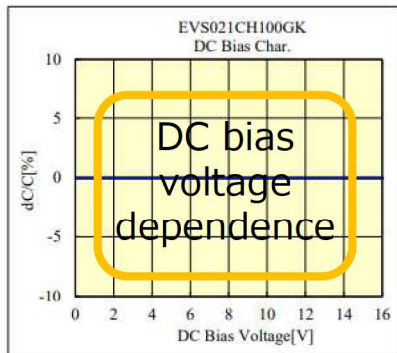


# Data sheet of passive device(capacitor)

The important capacitor specifications for modeling in the datasheet are as following.

TAIYO YUDEN  
Multilayer ceramic capacitors for high frequencies

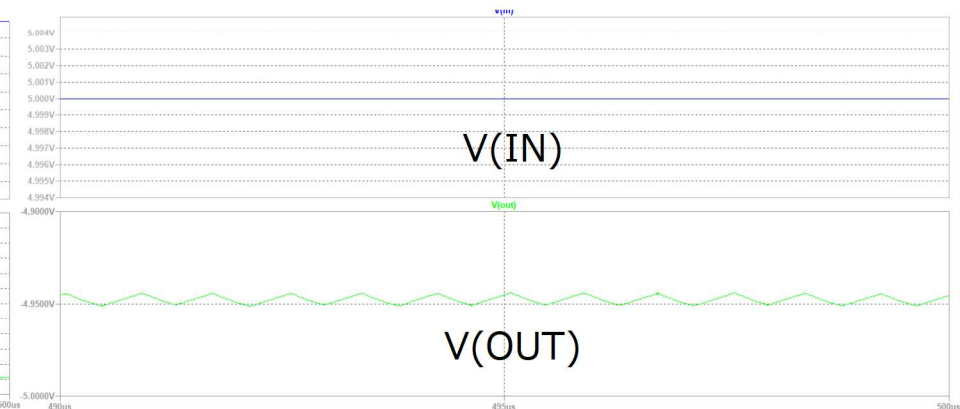
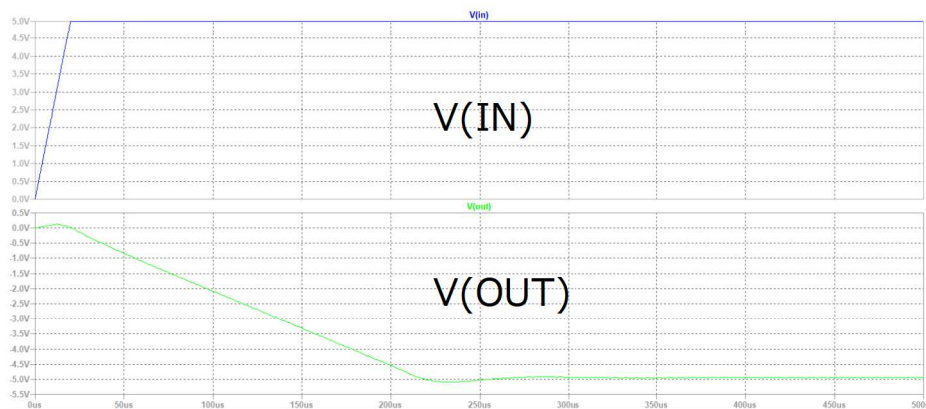
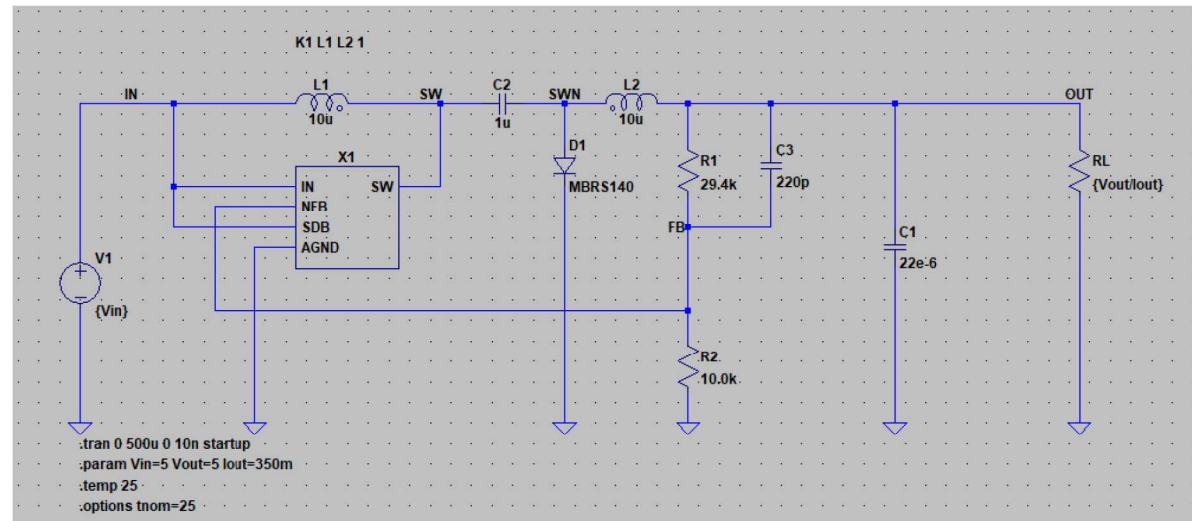
TAIYO YUDEN  
High dielectric constant multilayer ceramic capacitor



# Relationship between important characteristics of inductor&capacitor and circuit characteristics

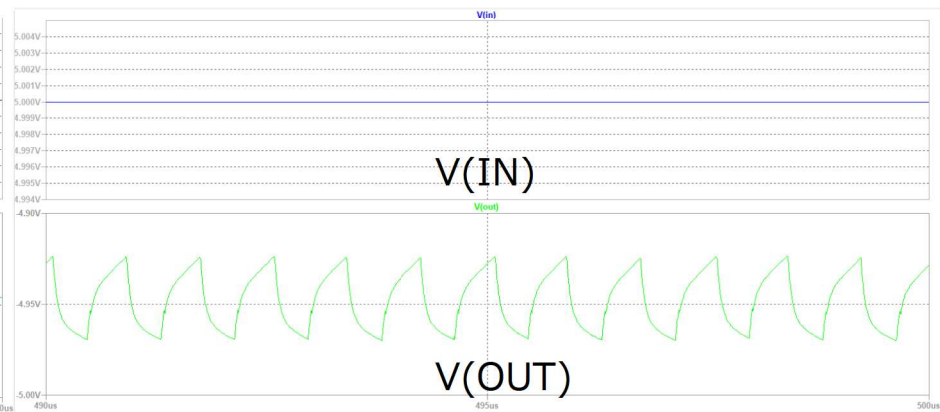
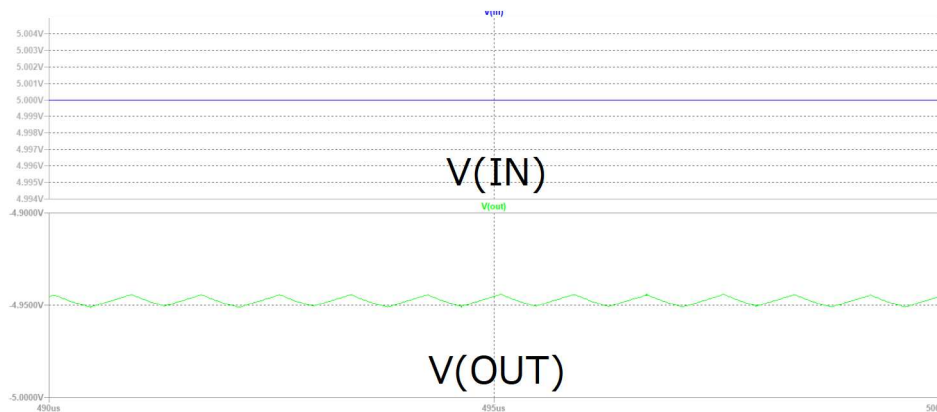
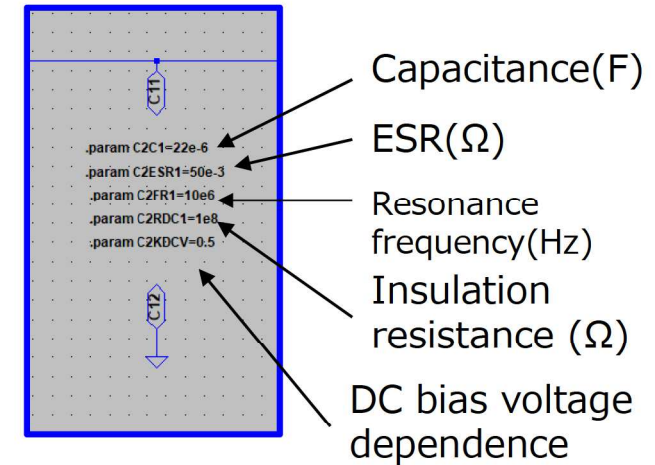
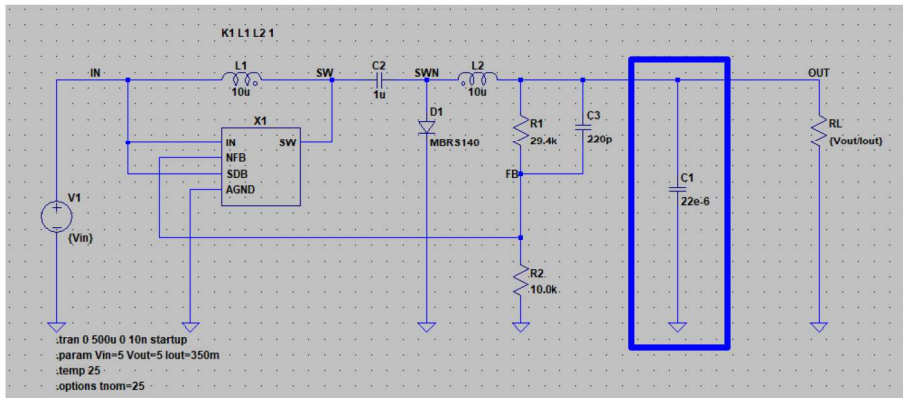
# Relationship between important characteristics of inductor&capacitor and circuit characteristics

The test circuit of DC/DC convertor is as following



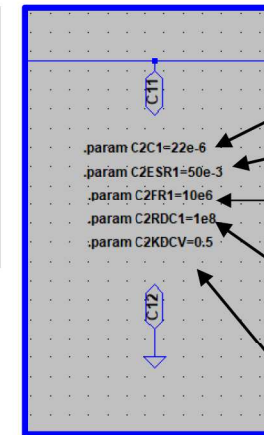
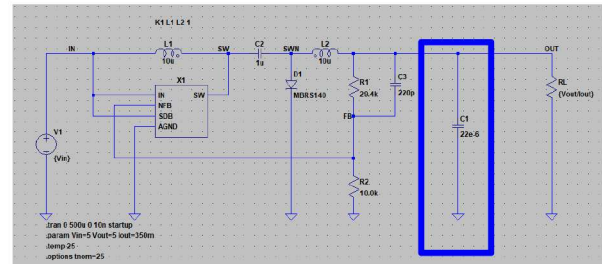
# Relationship between important characteristics of capacitor and circuit characteristics

The output voltage ripple has increased as the ideal capacitor model has been changed to the MoDeCH parametric passive spice model.



# Relationship between important characteristics of capacitor and circuit characteristics

The high frequency noise of the output voltage increased as the resonance frequency parameter decreased.



Capacitance(F)

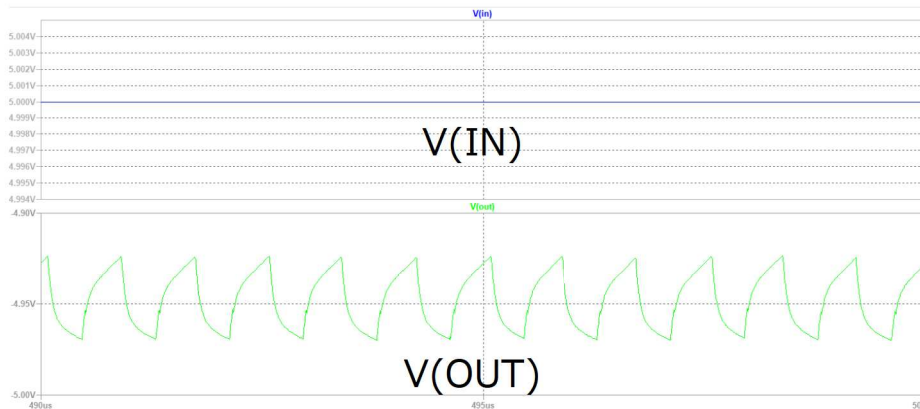
ESR( $\Omega$ )

Resonance frequency(Hz)

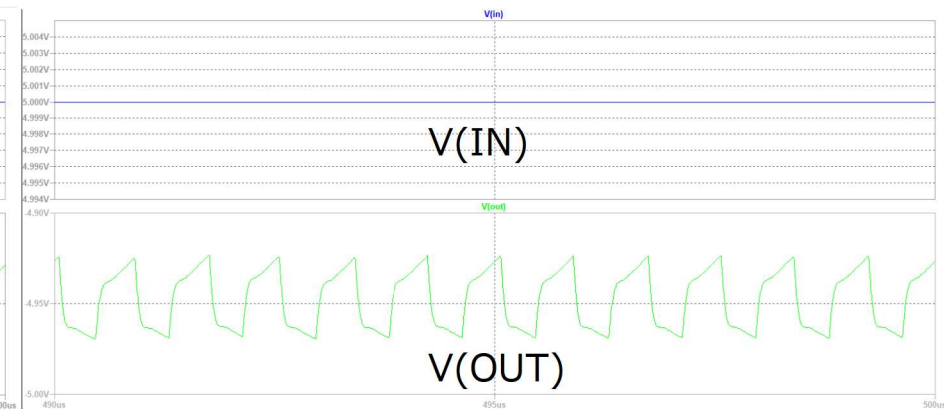
Insulation resistance ( $\Omega$ )

DC bias voltage dependence

Resonance frequency:10MHz

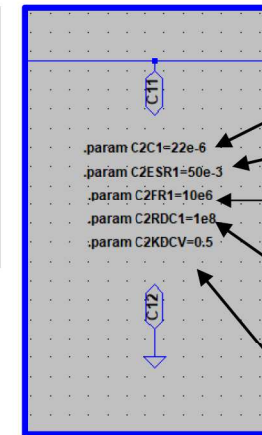
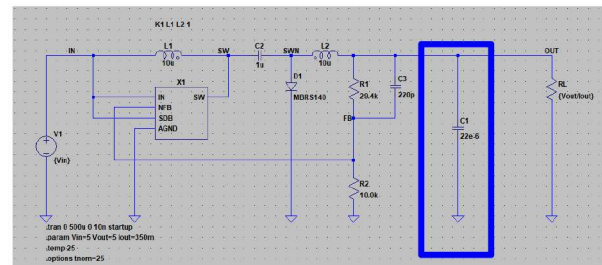


Resonance frequency:1MHz



# Relationship between important characteristics of capacitor and circuit characteristics

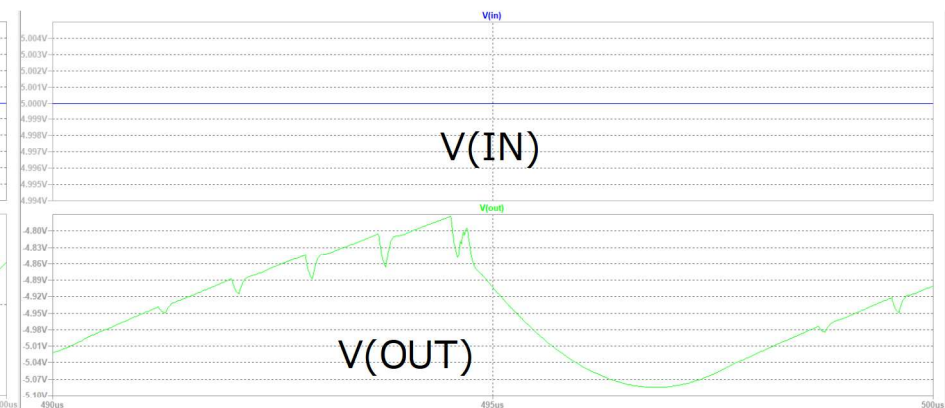
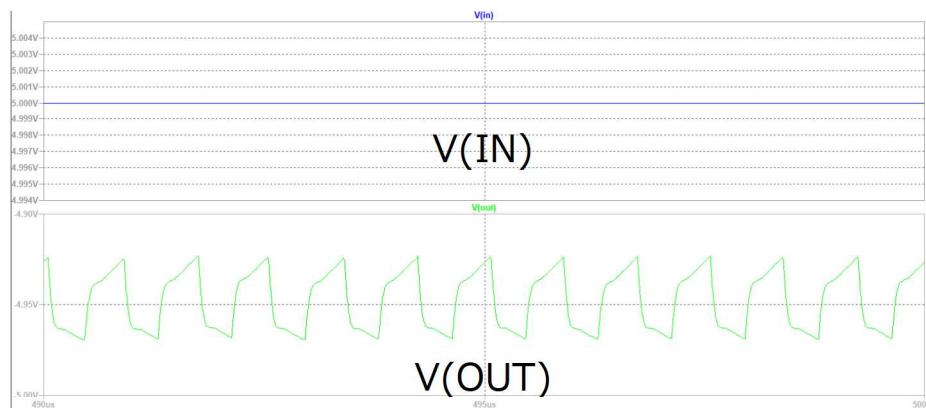
The low frequency noise of the output voltage increased with increasing voltage-dependent parameters.



- Capacitance(F)
- ESR( $\Omega$ )
- Resonance frequency(Hz)
- Insulation resistance ( $\Omega$ )
- DC bias voltage dependence

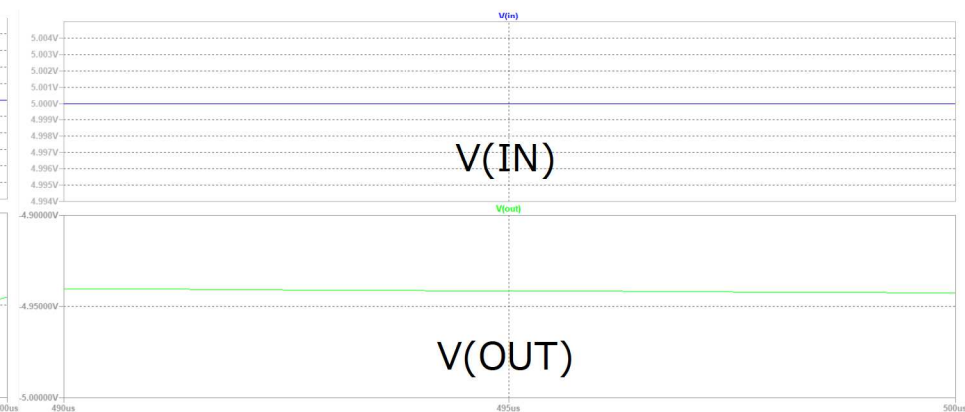
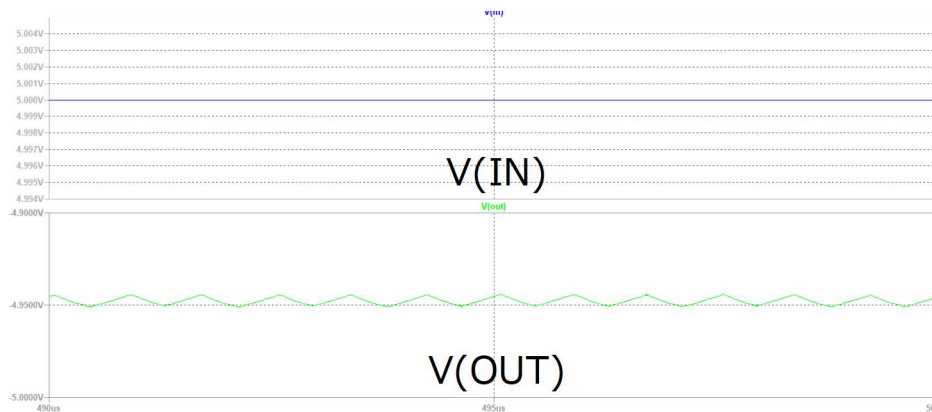
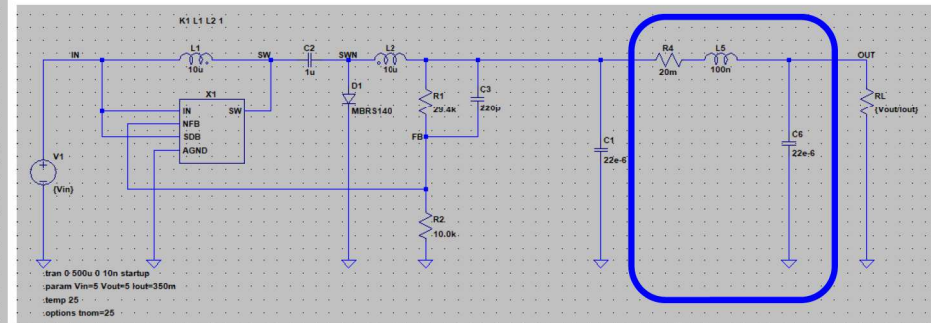
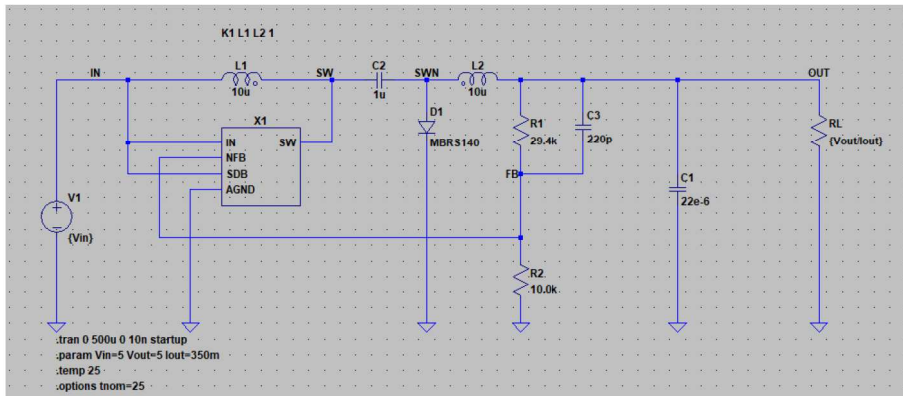
DC bias voltage dependence parameter:0.5

DC bias voltage dependence parameter: 0.6



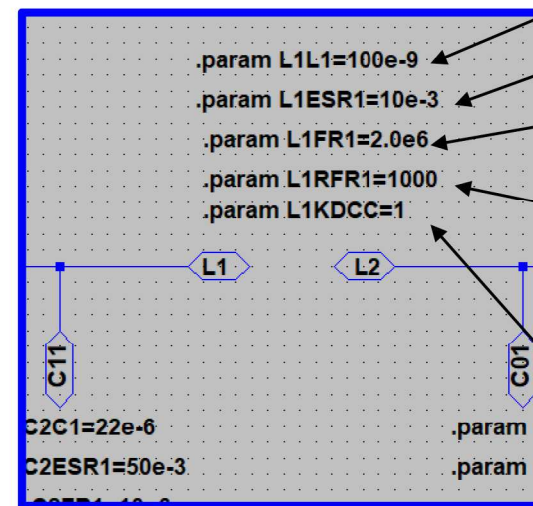
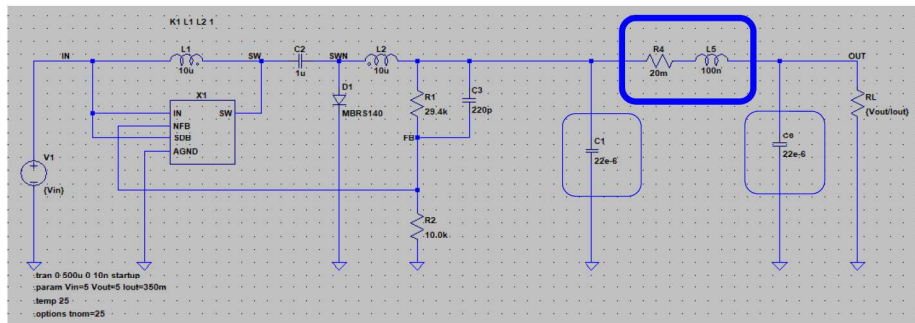
# Relationship between important characteristics of inductor and circuit characteristics

Inductor and capacitor models have been added to the circuit to test parametric spice model of inductor.

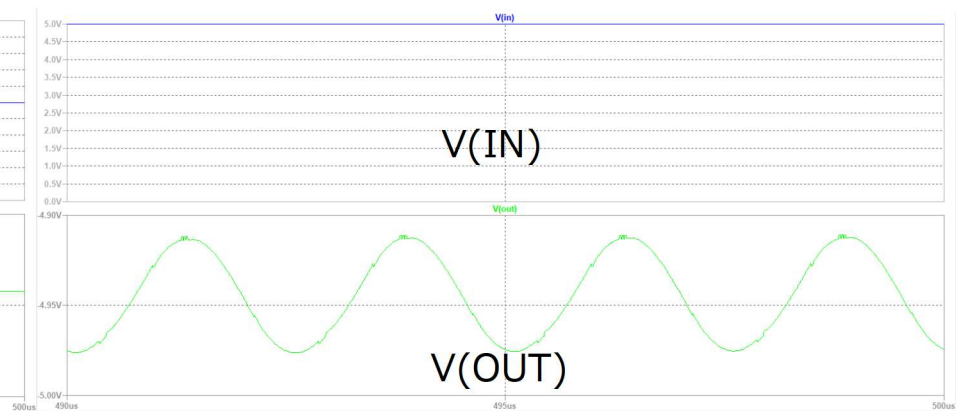
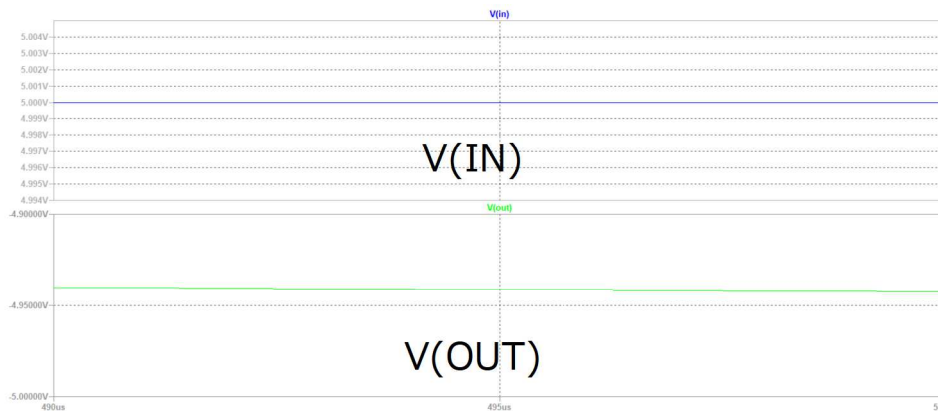


# Relationship between important characteristics of inductor and circuit characteristics

The ideal inductor model has been changed to a MoDeCH parametric passive spice model, so noise is superimposed on the output voltage.



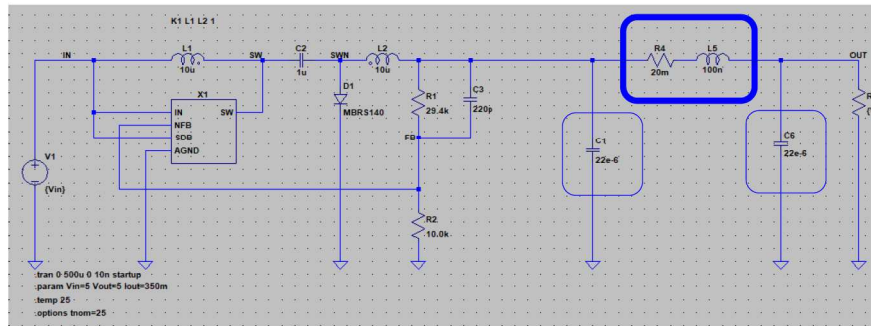
- Inductance(H)
- ESR( $\Omega$ )
- Resonance frequency(Hz)
- Impedance at resonance frequency( $\Omega$ )
- DC bias current dependence





# Relationship between important characteristics of inductor and circuit characteristics

The high frequency noise of the output voltage changed as the resonance frequency parameter decreased.

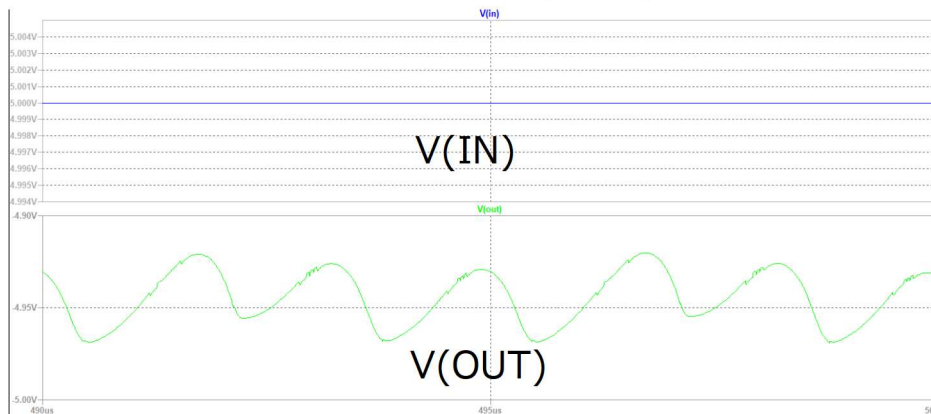


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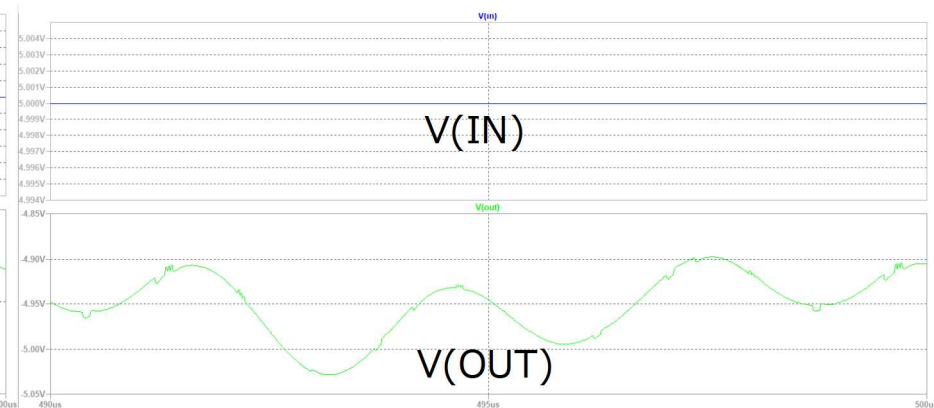
.param L1L1=100e-9
.param L1ESR1=10e-3
.param L1FR1=2.0e6
.param L1RFR1=1000
.param L1KDCC=1
    
```

- Inductance(H)
- ESR( $\Omega$ )
- Resonance frequency(Hz)
- Impedance at resonance frequency( $\Omega$ )
- DC bias current dependence

Resonance frequency: 2MHz

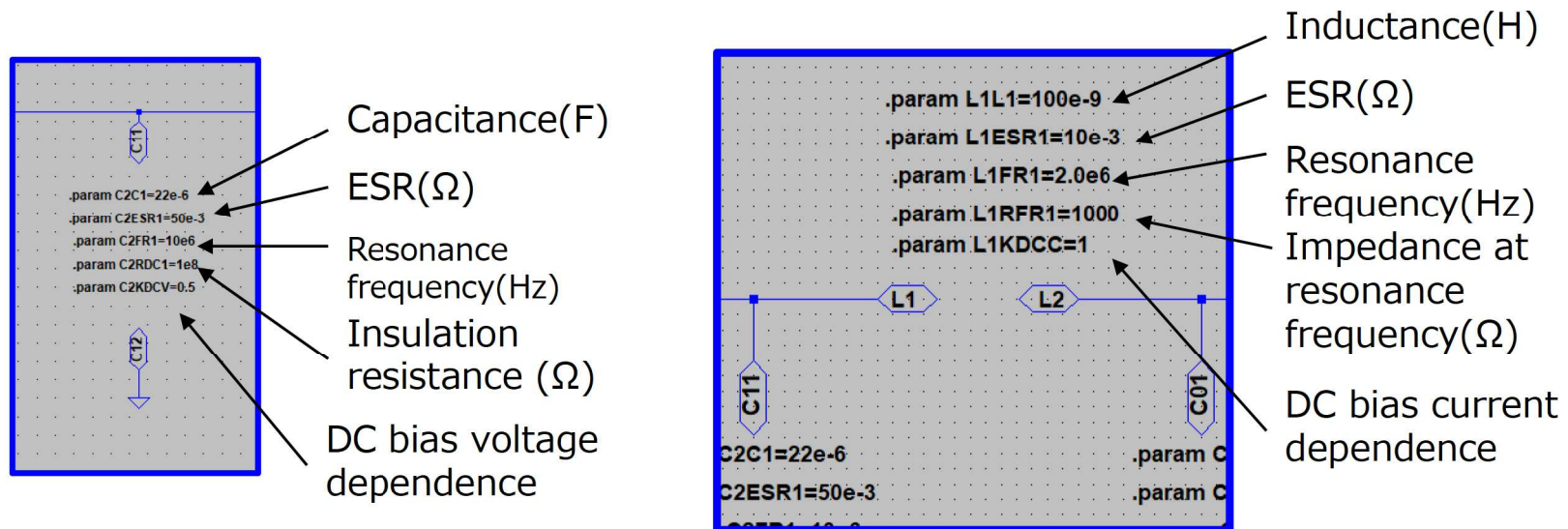


Resonance frequency: 1MHz



# Relationship between important characteristics of inductor and circuit characteristics

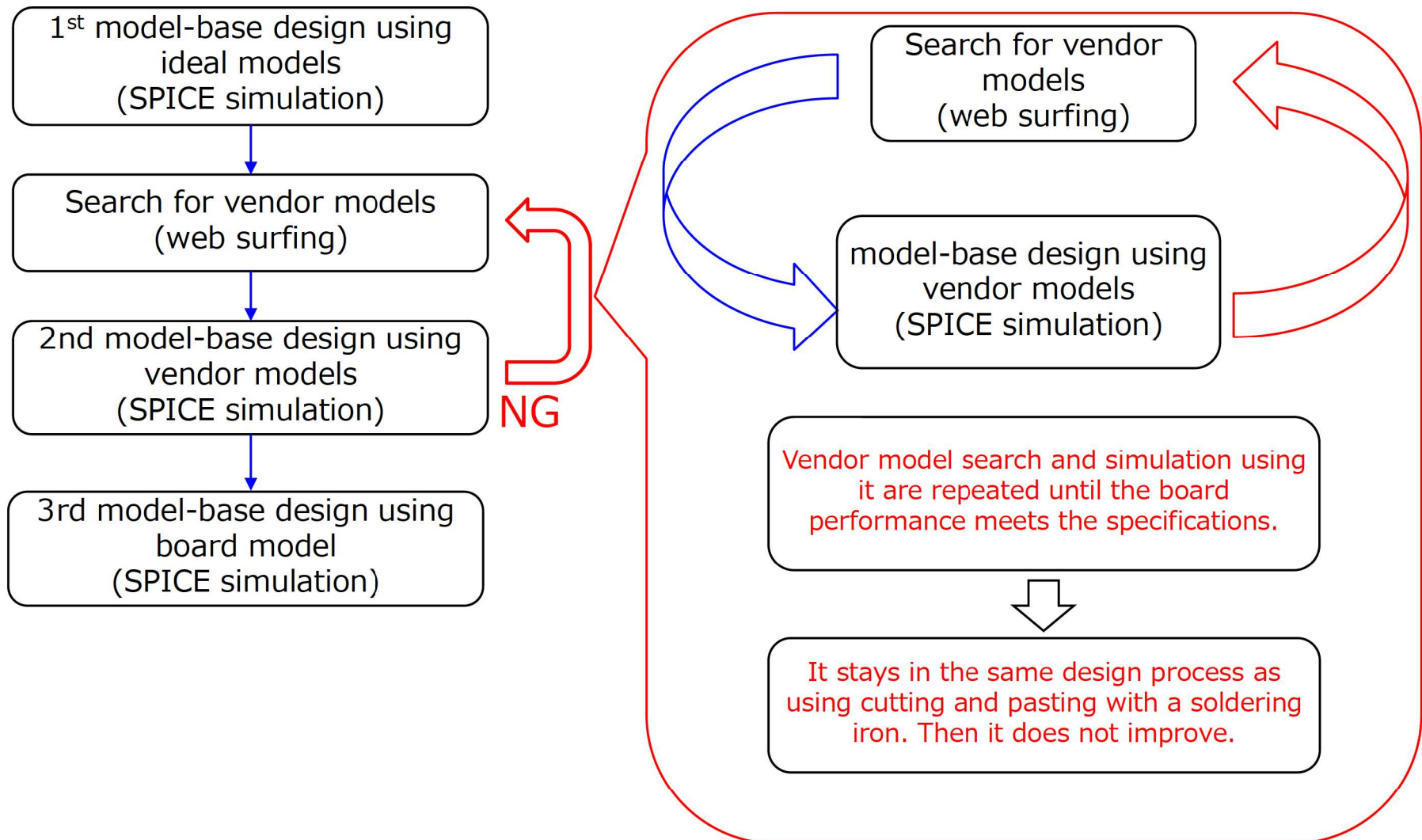
The parametric passive spice model used in this seminar will be sold on the MoDeCH Model On! Search web site. The parameters that can be changed are as follows.



# Improved design flow proposal using the parametric passive model

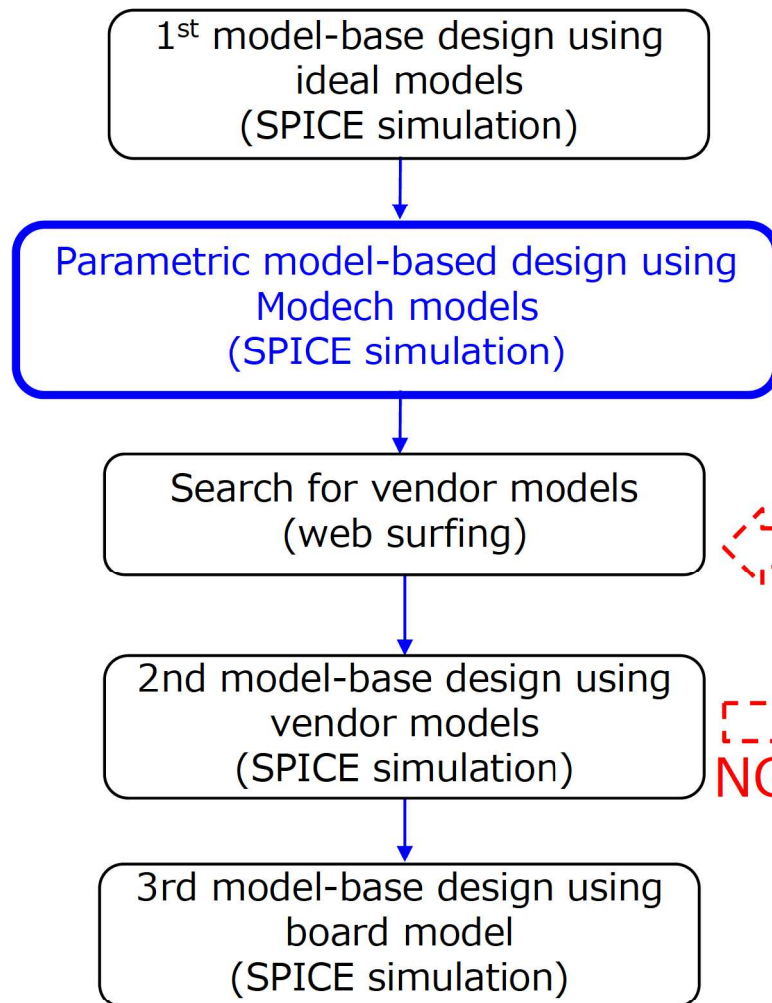
# Design flow issues for model-based design

Design flow issues for model-based design

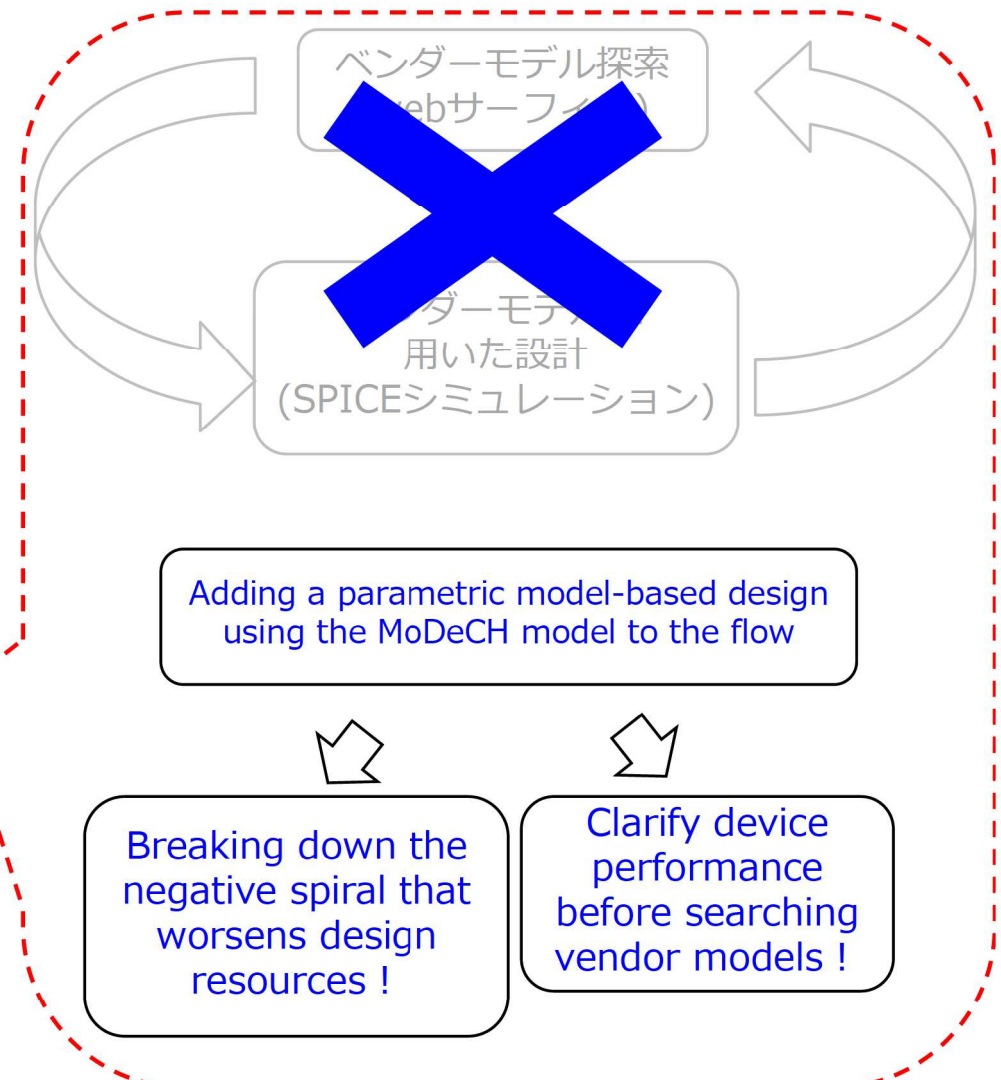


# Improved design flow proposal by parametric model-based design

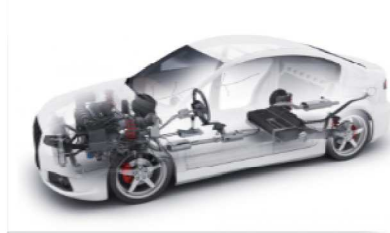
parametric model-based design



NG



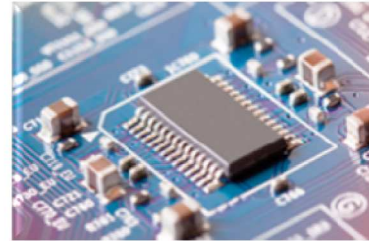
- This seminar introduced the specifications of passive devices described in the data sheet.
- The relationship between the important characteristics of inductors&capacitors and the characteristics of DC / DC converters has been verified.
- The importance of parametric model-based design has been introduced in this paper.



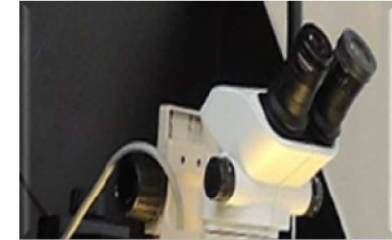
Automotive, Industrial equipment



Power devices



SPICE simulation models



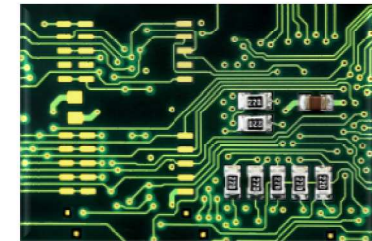
Design support



Software for model-based design



<http://www.modech.com/>



SPICE simulation models

