



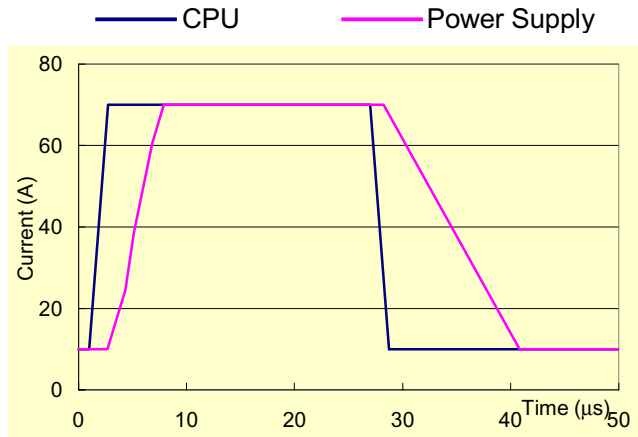
## Example of simulation

**SP-AL can replace MLCC!**  
 3 pcs of EEFC0D0101R(2V100 $\mu$ F) can replace 30 pcs of MLCC 6.3V10 $\mu$ F Y5V 1206.

### Circuit conditions

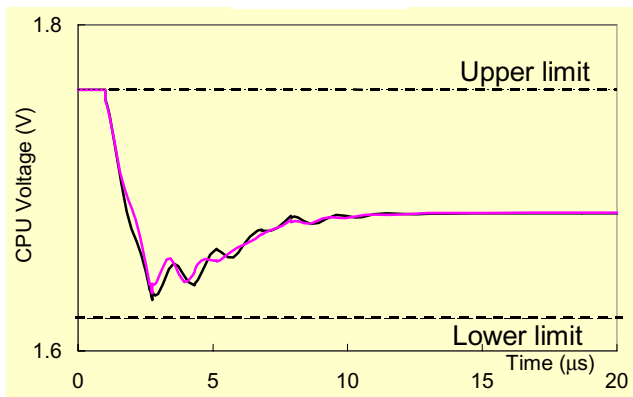
- Vin 11.4V
- Vout 1.75V
- I<sub>p-p</sub> 60A  
(I<sub>max</sub>:70A I<sub>min</sub>:10A)
- CPU slew rate 40A/ $\mu$ s
- V<sub>p-p</sub> 140mV  
(Transient Resp. +/-25mV)
- Switching Freq. 200kHz x3phase(=600kHz)
- Inductance 1.1 $\mu$ H
- Target CPU **Desktop P4 Northwood**

### Current behavior of CPU and Power Supply

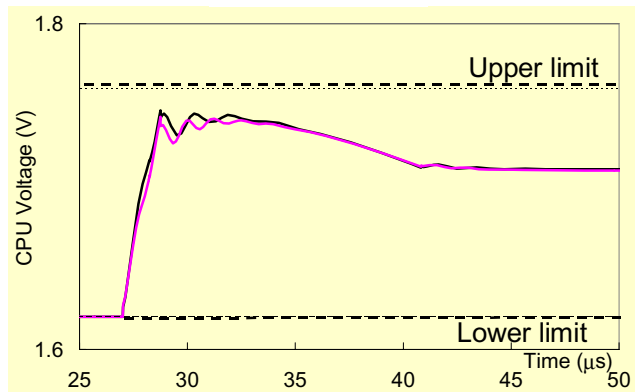


### Transient response simulation results

#### Droop



#### Overshoot



Line	Capacitor solution	Droop	Overshoot
	Bulk Capacitors: (A-FJ6.3V1500 $\mu$ F x8 + OS 4V510 $\mu$ F x4)		
—	Bulk Capacitors + MLCC1206(Y5V)10 $\mu$ F x38	129mV	127mV
—	Bulk Capacitors + SP-Cap CD2V100 $\mu$ F x3 + MLCC1206(Y5V)10 $\mu$ F x8	125mV	123mV



## Transient Response Simulation

### Application Example (CPU)

#### Trend of CPU (Central Processing Unit) used in personal computers

- CPUs continue to follow Moore's Law of doubling operating frequency every 18 months. Today' CPUs are operating above Ghz frequencies. The Ghz-plus CPUs are characterized by increased power, high operating DC current and current slew rate requirements, and a challenging voltage margin.

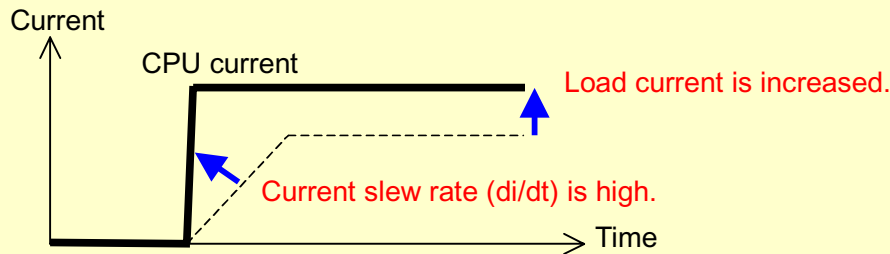
- To reduce energy consumption:
  - CPU stop clock operation is used.
  - CPU drive voltage is lowered.

- In order to reduce power consumption, a switching operation (ON and OFF) is repeated frequently by the CPU stop clock operation.

- A large voltage fluctuation occurs in the CPU drive power line.

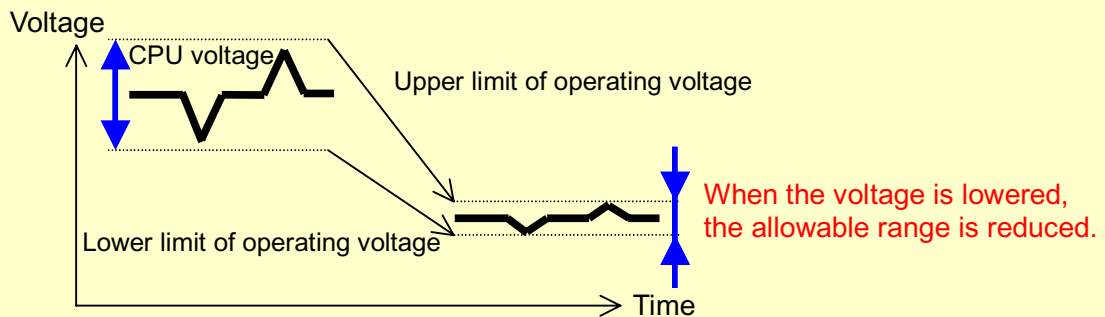
- Load current when CPU is operated (ON) is increased.

- As the CPU computing and operational demand vary, the current demands for the CPU can change very rapidly and require current slew rates of hundreds of amps within a few micro seconds.



- Reduction in CPU drive voltage

- The allowable voltage fluctuation range for CPU operation becomes tighter.

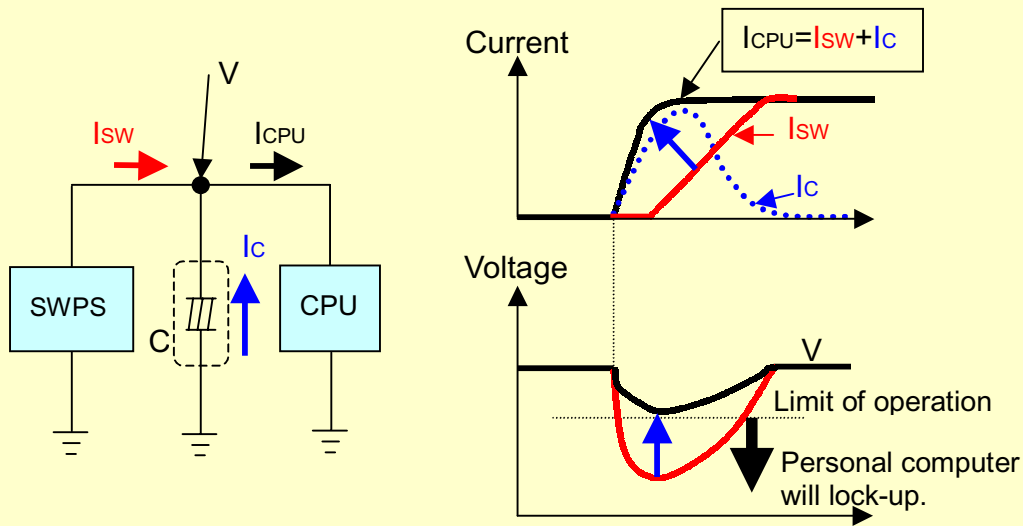


Today's CPUs can require current slew rates of hundreds of amps per micro second. The resulting current surge can create unacceptable spikes in the voltage which must be suppressed within the operating voltage margin before any damage is done to the CPU.

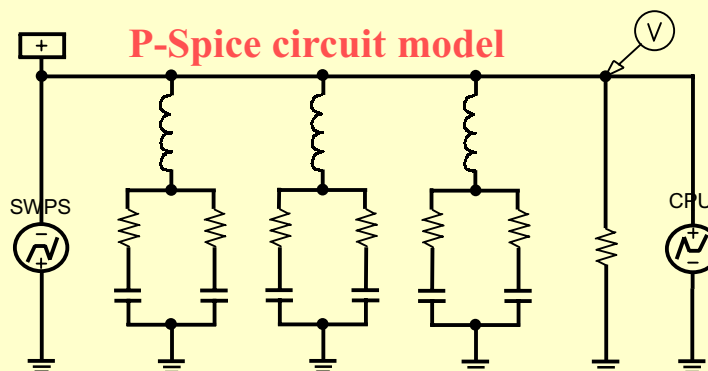


The performance requirements for bulk capacitors have increased due to the increase in the transient response and power requirements of the CPU.

- A capacitor functions as a buffer to supply an instantaneous current at a stable voltage.



This transient response simulation presents the optimum idea of capacitor pick up for power supply design.





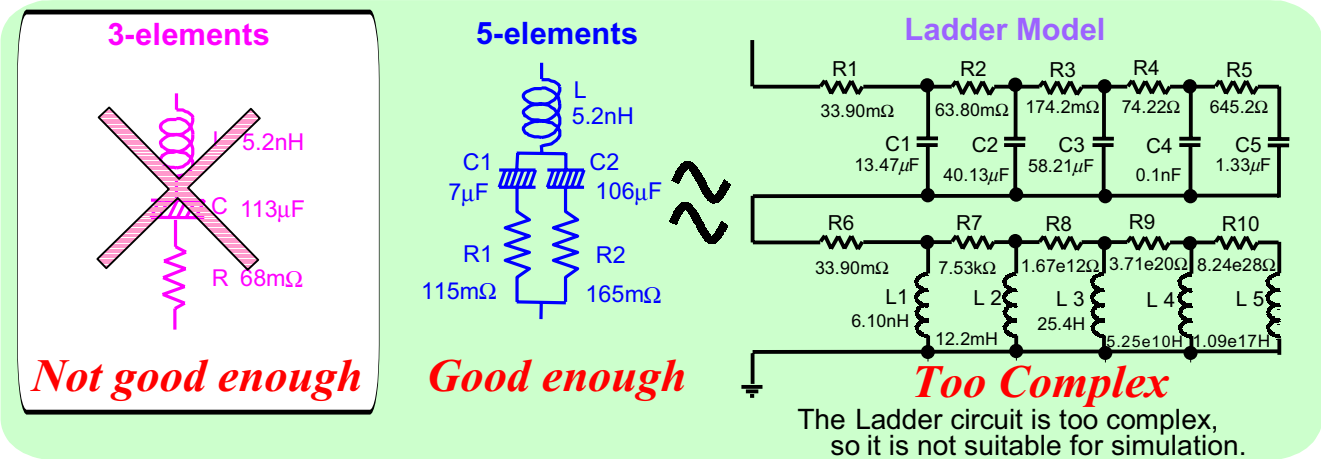
## Simulation method

For the simulation of CPU transient response characteristics, a capacitor-equivalent circuit model must be created and the circuit conditions must be set up.

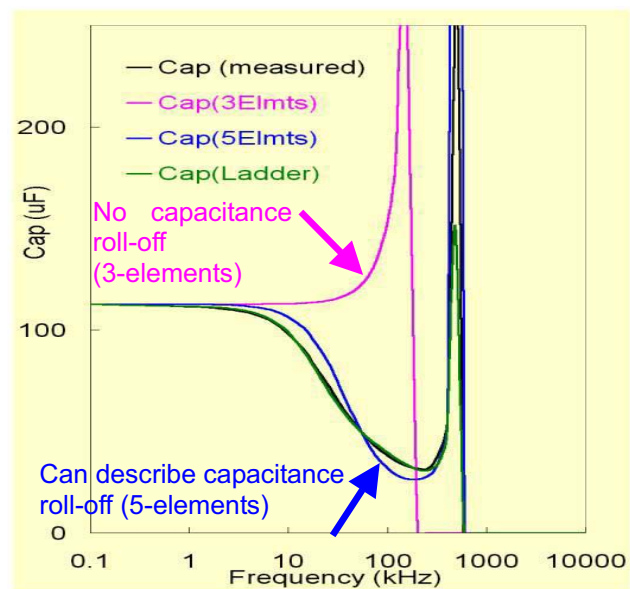
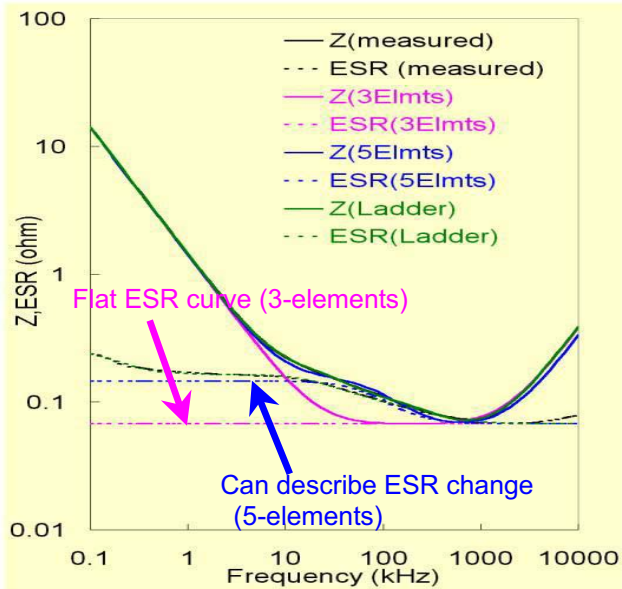
In order to simulate the transient response characteristics of a capacitor, an equivalent circuit model is needed that is capable of indicating the variation in ESR\* and the reduction in capacitance in the high frequency range.

\* ESR: Equivalent Series Resistance

Example of a reproduction of frequency characteristics using an equivalent circuit model



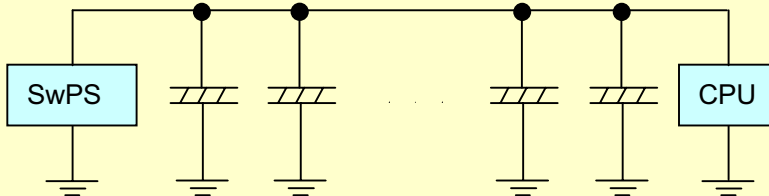
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## Setting of circuit conditions

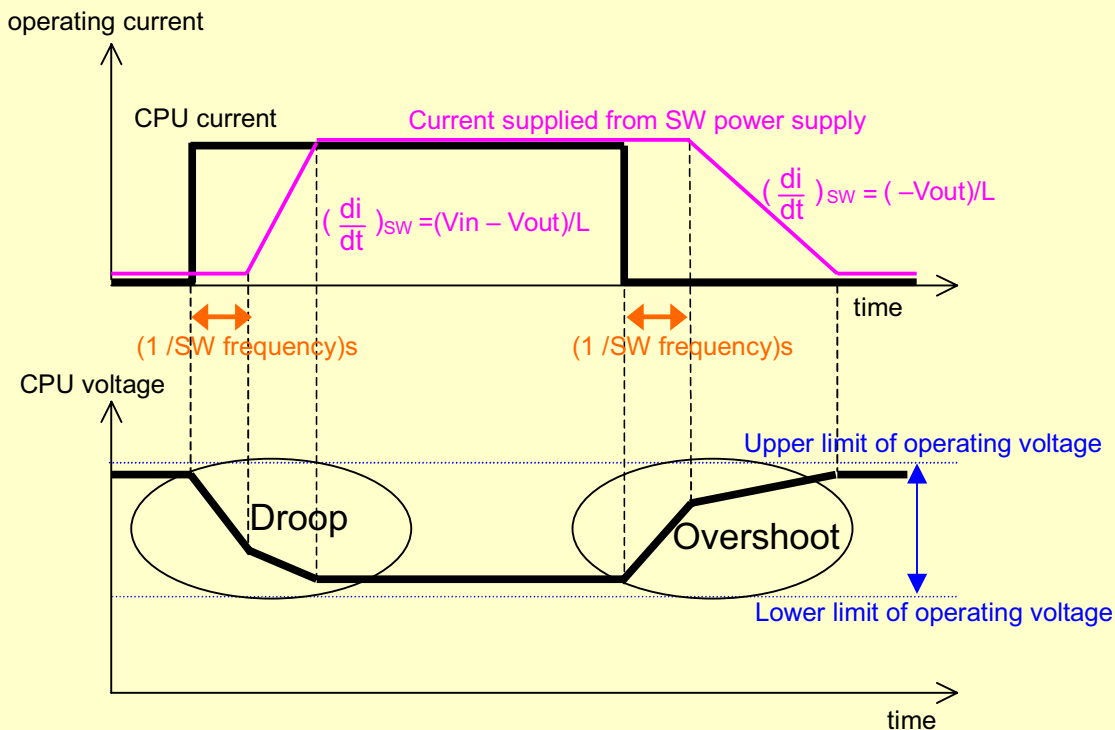
Circuit condition: Put capacitors in parallel between power supply and CPU as described below.



The number of capacitors is calculated using a P Spice circuit simulator under the following conditions of the application.

- Operating current and ramp up time ( $di/dt$ ) of CPU conditions.
- Operating voltage and range of CPU.
- Switching frequency and phase of SW power supply.
- Inductance of PCC (Power Choke Coil) of SW power supply.
- Min. input voltage of SW power supply.

When CPU voltage varies and current is managed, CPU performance is optimized.



It takes time for the SW power supply to respond to the CPU when it turns on  
 → Capacitors are necessary to smoothly transfer the voltage from the CPU start-up.

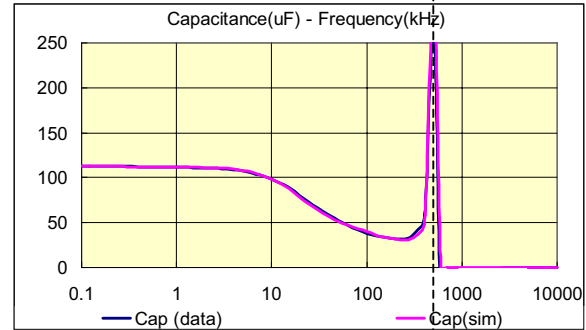
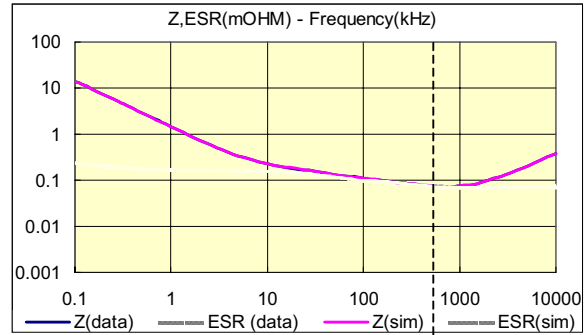
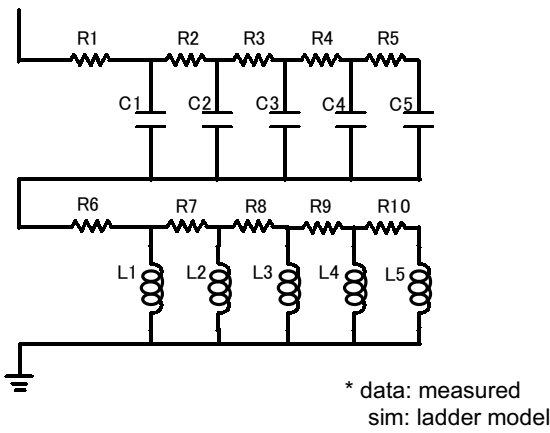


*Estimation of capacitance-frequency characteristics using the Ladder model*

LCR meters are unable to measure capacitance at the resonance point frequencies and above. Using an LCR 20-element ladder model, we propose estimating the behavior of the measured capacitance-frequency characteristics around the point of resonance.

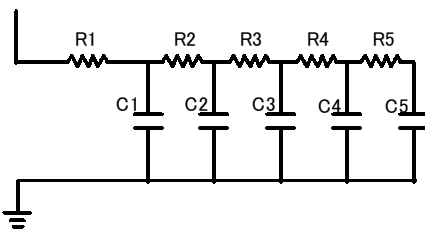
Ref. Low ESR Tantalum (D-size 10V100uF)

Creation of the capacitance-frequency characteristics excluding the effects of inductance

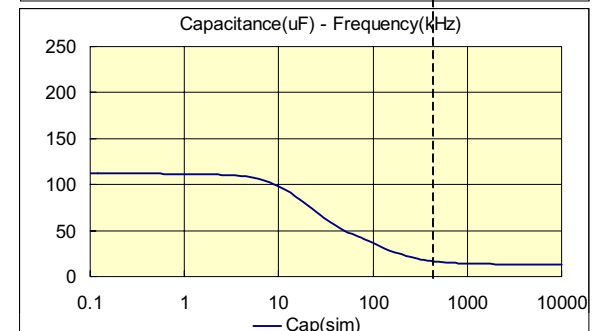
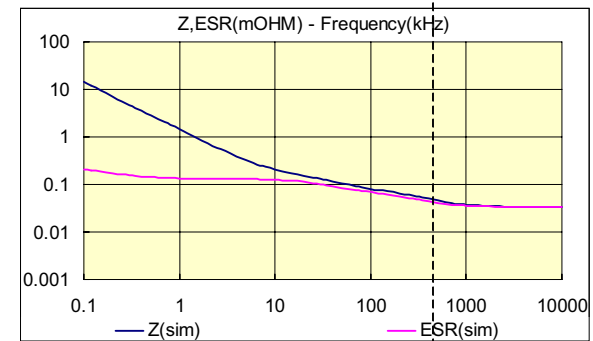


Resonance Point

Removal of the R-L circuit



Estimation of capacitance characteristics at high frequency



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