



SimSurfing DC-DC Converter Design Support Tool Operation Manual

August, 2019
Murata Manufacturing Co., Ltd.

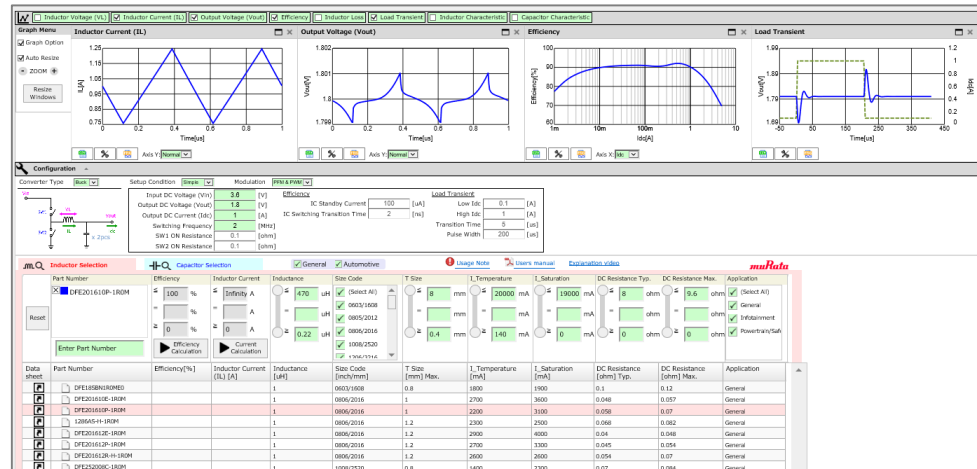


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1. About This Tool

1-1. Outline

- This tool supports the selection of power inductors and multilayer ceramic capacitors of Murata suitable for the desired operating conditions of DC-DC converter circuits.



[Basic Function]

The following outputs can be acquired by selecting the circuit of a DC-DC converter, entering each operating condition, and selecting the part number of a power inductor.

Ripple current	-> Inductor Current - Time
Output voltage	-> Output Voltage - Time
Efficiency	-> Efficiency - Output Current

Power inductors suitable for a DC-DC converter can be narrowed down based on these outputs.

1. About This Tool

1-2. Notes for Use



- Characteristics graph of a power inductor displayed by the software

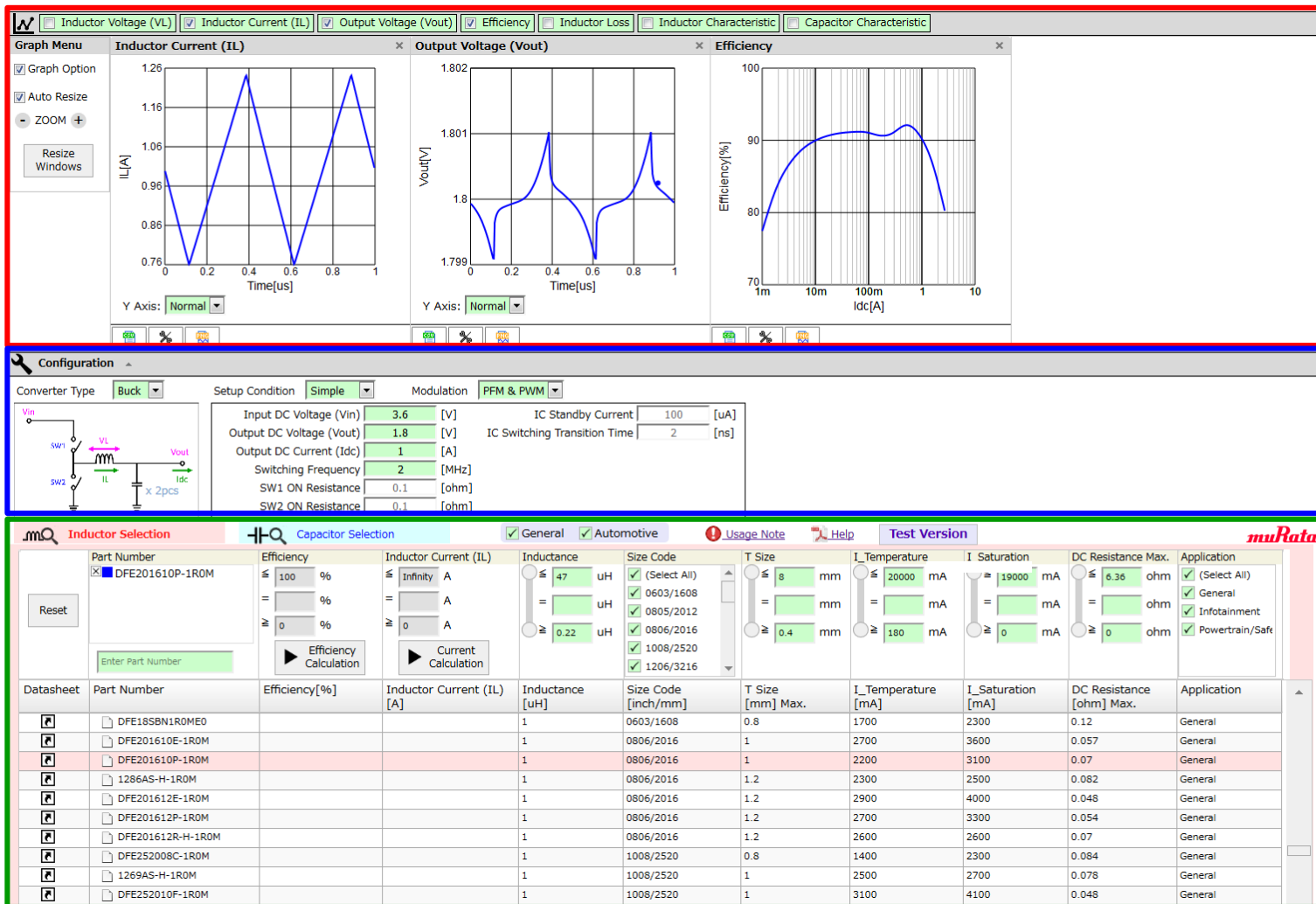
Each of the measurement systems differs in the following data measurements.

- ✓ Characteristics data of the power inductor used by the tool (see p.32)
- ✓ Characteristics data used in the power inductors of the SimSurfing characteristics viewer

Note that a difference may occur between both characteristics data due to the above differences.

2. Quick Operation Guide

2-1. Screen Configuration (1/2)



(1)
Graph
output
function

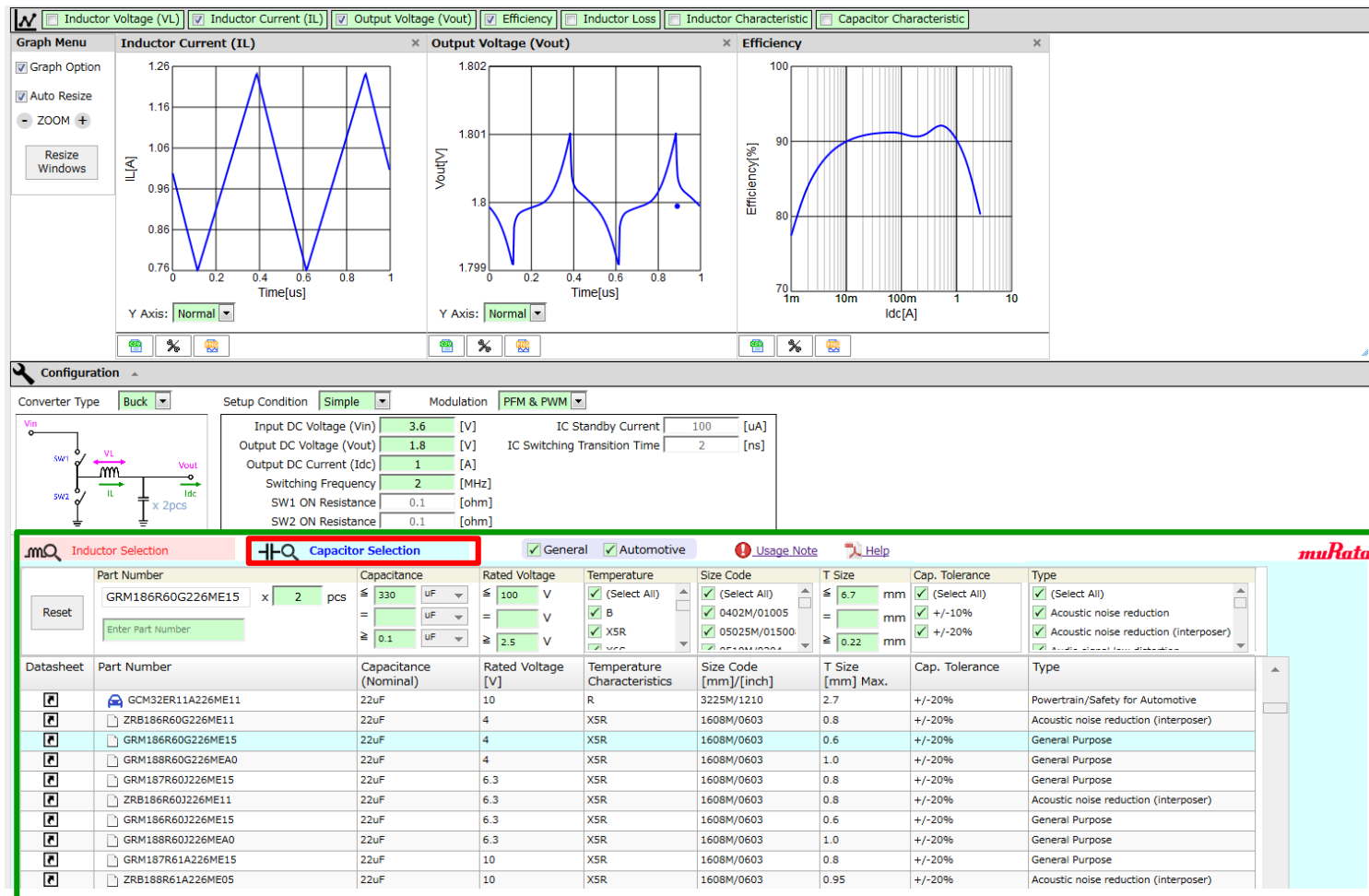
(2)
Circuit
selection
field /
input function
of circuit
operating
conditions

(3)
Part number
selection
function
(Power
inductor)

-> The screen consists of three functional blocks including (1) Graph output, (2) Circuit selection field / input of circuit operating conditions, and (3) part number selection.

2. Quick Operation Guide

2-1. Screen Configuration (2/2)



(3)
Part number
selection
function
(MLCC)

-> A list of power inductors is displayed in (3) functional block of the part number selection. Changing the tab will display a list of multilayer ceramic capacitors (hereinafter, MLCC).

2. Quick Operation Guide

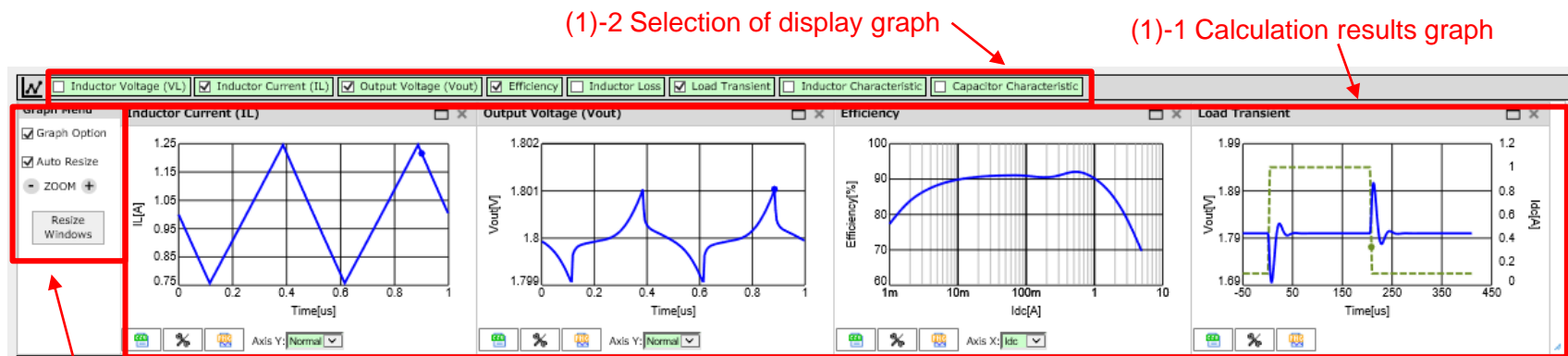
2-2. How to Use Each Component (1/3)

(1) Graph output function

-> The graphs of (1)-1 are output based on the settings and various conditions indicated p.8 and p.9. Changing these settings and conditions allows for the basic operation of the software.

See the following for the detailed operation.

- Examples of use: p.10 to p.19
- Operation of each functional block: p.20 to p.35



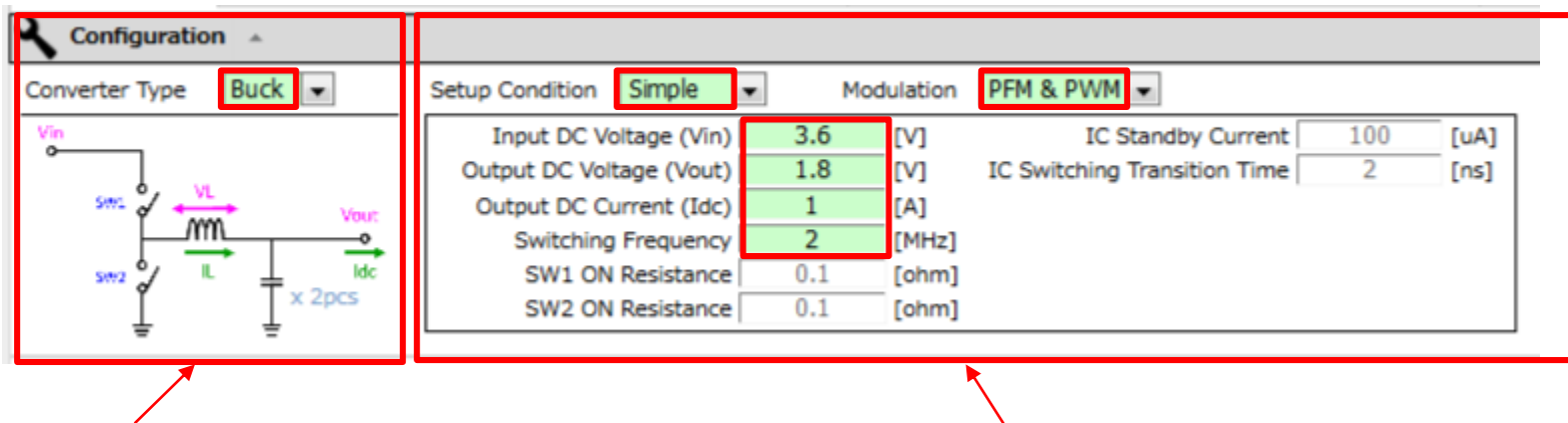
<Default settings>

- (1)-1 and (1)-2 display graph -> <Inductor Current (IL)>, <Output Voltage (Vout)>, <Efficiency>
- (1)-3 Graph Options -> Not checked

2. Quick Operation Guide

2-2. How to Use Each Component (2/3)

(2) Input function of circuit selection field / circuit operating conditions



(2)-1 Selection of DC-DC converter circuit

(2)-2 Input of circuit operating conditions

<Default settings>

(2)-1 Convert Type

-> <Buck>: Buck circuit

(2)-2 Setup Condition

-> <Simple>:

Modulation

-> <PFM&PWM>

- Input DC Voltage (Vin)

-> 3.6 [V]

- Output DC Voltage (Vout)

-> 1.8 [V]

- Output DC Current (Idc)

-> 1 [A]

- Switching Frequency

-> 2 [MHz]

2. Quick Operation Guide

2-2. How to Use Each Component (3/3)

(3) Part number selection function (Power inductors/MLCC)

(3)-1 Selection for General/Automotive

Part Number	Efficiency [%]	Inductor Current (IL) [A]	Inductance [uH]	Size Code [inch/mm]	T Size [mm] Max.	I Temperature [mA]	I Saturation [mA]	DC Resistance [ohm] Max.	Application
DFE18SBN1R0ME0			1	0603/1608	0.8	1700	2300	0.12	General
DFE201610E-1R0M			1	0806/2016	1	2700	3600	0.057	General
DFE201610P-1R0M							3100	0.07	General
1286AS-H-1R0M							2500	0.082	General
DFE201612P-1R0M			1	0806/2016	1.2	2700	3300	0.054	General
DFE201612R-H-1R0M			1	0806/2016	1.2	2600	2600	0.07	General
DFE252008C-1R0M			1	1008/2520	0.8	1400	2300	0.084	General
1269AS-H-1R0M			1	1008/2520	1	2500	2700	0.078	General
DFE252010F-1R0M			1	1008/2520	1	3100	4100	0.048	General
DFE252010P-1R0M			1	1008/2520	1	2700	3800	0.054	General

(3)-2 Changes list of power inductors/MLCC

Part Number	Capacitance [uF]	Rated Voltage [V]	Temperature Characteristics	Size Code [mm]/[inch]	T Size [mm] Max.	Cap. Tolerance	Type
GCM32ER11A226ME11	22uF	10	R	3225M/1210	2.7	+/-20%	Powertrain/Safety for Automotive
ZRB186R60G226ME11	22uF	4	X5R	1608M/0603	0.8	+/-20%	Acoustic noise reduction (interposer)
GRM186R60G226ME15	22uF	4	X5R	1608M/0603	0.6	+/-20%	General Purpose
GRM188R60G226MEA0	22uF	4	X5R	1608M/0603	1.0	+/-20%	General Purpose
GRM187R60J226ME15	22uF	6.3	X5R	1608M/0603	0.8	+/-20%	General Purpose
ZRB186R60J226ME11	22uF	6.3	X5R	1608M/0603	0.8	+/-20%	Acoustic noise reduction (interposer)
GRM186R60J226ME15	22uF	6.3	X5R	1608M/0603	0.6	+/-20%	General Purpose
GRM188R60J226MEA0	22uF	6.3	X5R	1608M/0603	1.0	+/-20%	General Purpose

<Default settings>

(3)-1 General/Automotive -> Both checked

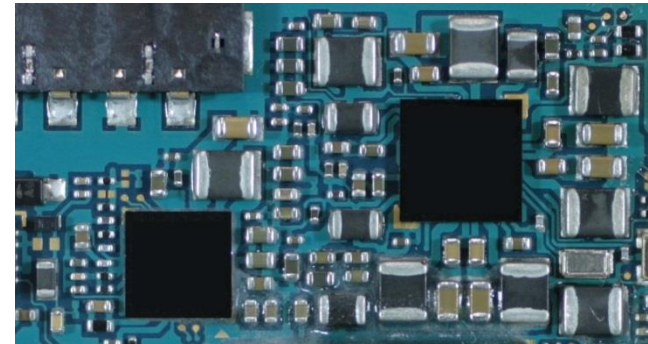
(3)-2 Inductor Selection -> Part No.: DFE201610P-1R0M

Capacitor Selection -> Part No.: GRM186R60G226ME15

3. Use Cases

3-1. Design of DC-DC Converter for Mobile Devices (1/10)

<Design of DC-DC converters for mobile devices>



Operating conditions of DC-DC converter:

- Buck circuit
- Low current: PFM, Normal operation: PWM
- Input voltage: 3.6V, Output voltage: 1.0V
- Output current: 1.5A
- Switching frequency: 1MHz

I want to select a power inductor with an inductance of 1.0μH, size 2016 (mm) / height 1.0 mm max in which the efficiency and ripple are optimized for a DC-DC converter with the above conditions.

3. Use Cases

3-1. Design of DC-DC Converter for Mobile Devices (2/10)

-> Set the conditions on the previous page to narrow down the part number of the power inductors suitable for the conditions.

Buck circuit **PFM/PWM**

Output voltage (Vout)
1.8 -> **1V**

Output current (Idc)
1.8 -> **1.5A**

SW frequency
2 -> **1MHz**

The screenshot shows the muRata Inductor Selection tool. The top section is the 'Configuration' panel, which includes a circuit diagram of a buck converter, a 'Setup Condition' dropdown set to 'Simple', and a 'Modulation' dropdown set to 'PFM & PWM'. The configuration table is as follows:

Parameter	Value	Unit
Input DC Voltage (Vin)	3.6	[V]
Output DC Voltage (Vout)	1	[V]
Output DC Current (Idc)	1.5	[A]
Switching Frequency	1	[MHz]
SW1 ON Resistance	0.1	[ohm]
SW2 ON Resistance	0.1	[ohm]
IC Standby Current	100	[uA]
IC Switching Transition Time	2	[ns]

The bottom section is the 'Inductor Selection' panel, which shows a search for 'DFE201610P-1R0M'. The search results table is as follows:

Part Number	Efficiency	Inductor Current (IL)	Inductance	Size Code	T Size	I Temperature	I Saturation	DC Resistance Max.	Application
DFE201610P-1R0M	100 %	Infinity A	1 uH	0806/2016	1 mm	20000 mA	19000 mA	6.36 ohm	(Select All)
LQM2MPN1R0MEH				0803/1608					General
LQM2MPN1R0MGH				0805/2012					Infotainment
DFE201610E-1R0M				1008/2520					Powertrain/Safety
DFE201610P-1R0M				1206/3216					

Red boxes highlight the following values in the search results table:

- Inductance: 1 uH
- Size Code: 0806/2016
- T Size: 1 mm
- I Temperature: 1500 mA
- I Saturation: 1500 mA

Red arrows point from the configuration panel to the search results table, indicating the following values:

- Output voltage (Vout): 1V
- Output current (Idc): 1.5A
- SW frequency: 1MHz

Inductance
Blank -> **1μH**

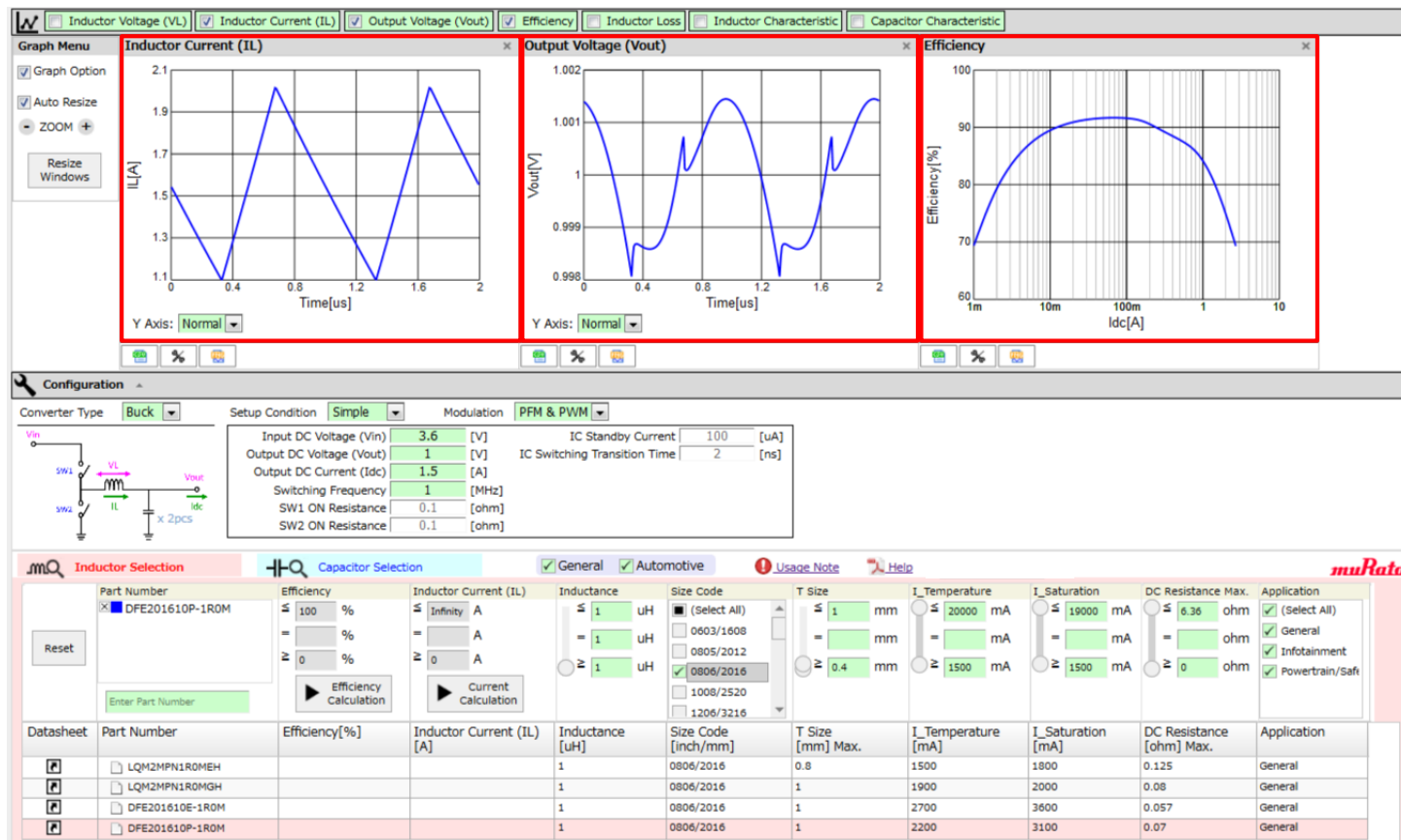
Size **2016 (mm)**
check

Height
8 -> **1mm**

3. Use Cases

3-1. Design of DC-DC Converter for Mobile Devices (3/10)

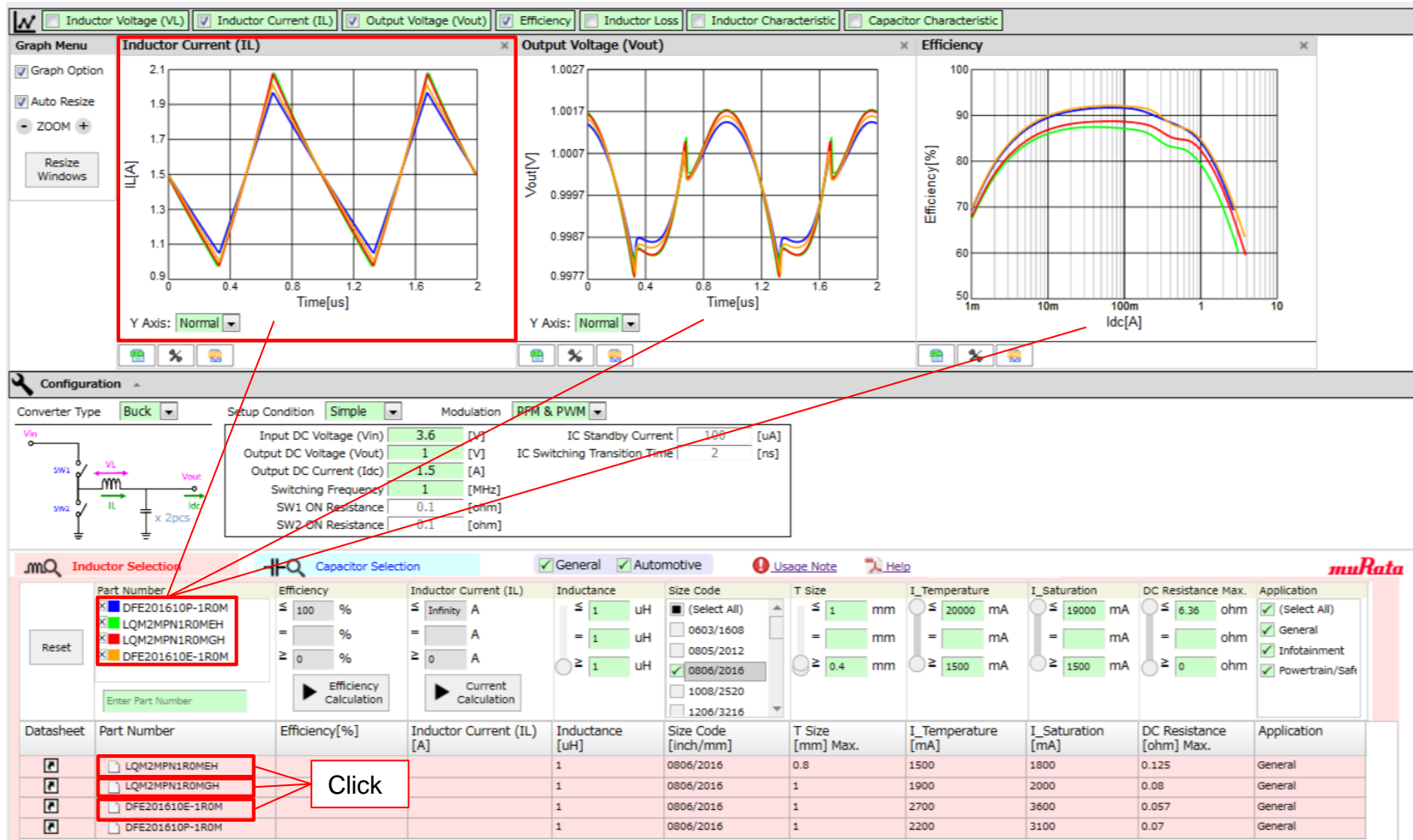
-> While "DFE201610P-1R0M" (and MLCC "GRM186R60G226ME15") are selected, the ripple current, output voltage and efficiency graphs will be displayed.



3. Use Cases

3-1. Design of DC-DC Converter for Mobile Devices (4/10)

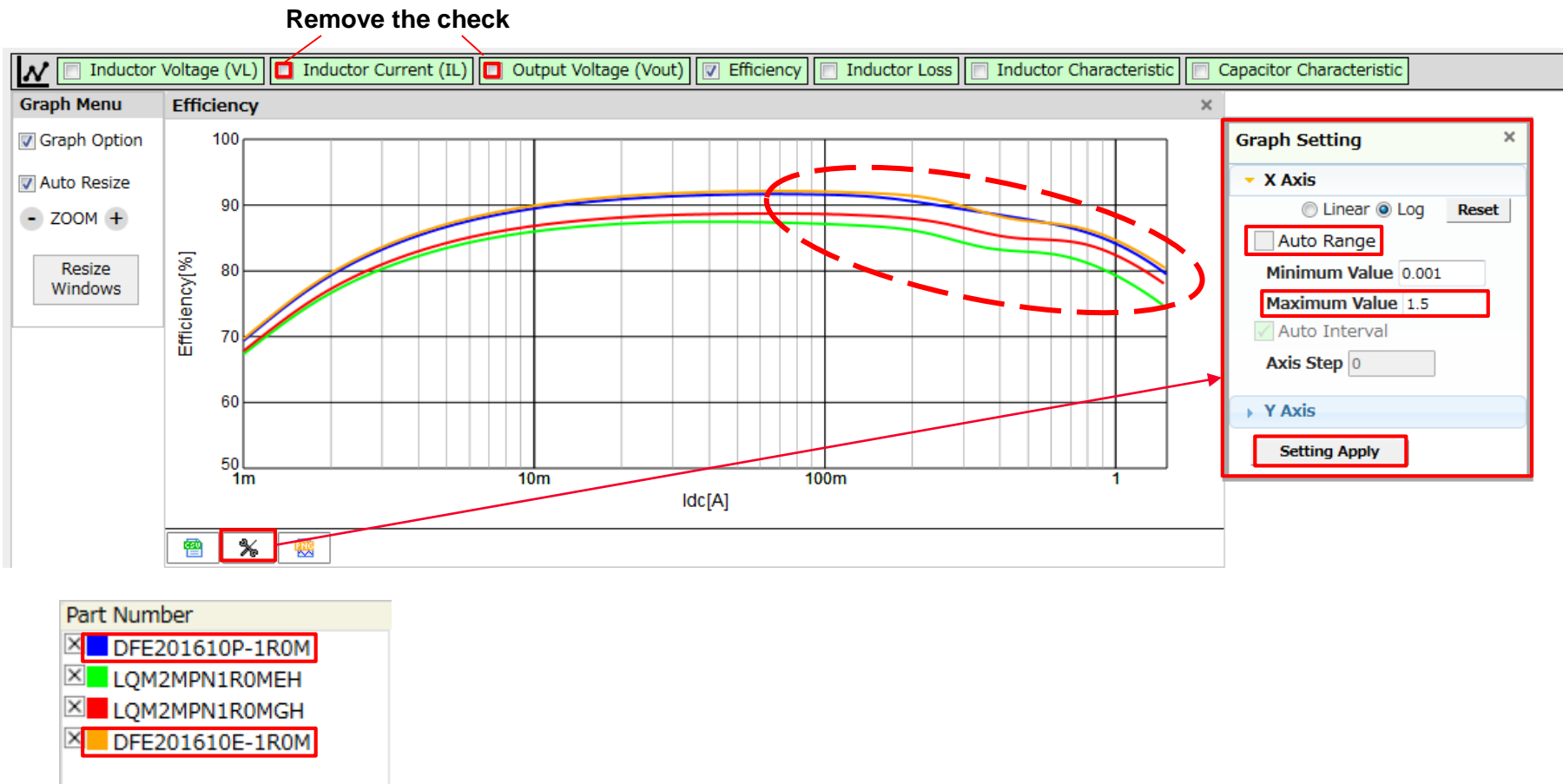
-> The graph shows that there is no great difference in the ripple current for all of the part numbers. Next, look at the efficiency graph.



3. Use Cases

3-1. Design of DC-DC Converter for Mobile Devices (5/10)

-> Expands the efficiency graph only. In this graph, "DFE201610P-1R0M" and "DFE201610E-1R0M" can be selected as a high efficiency power inductor which satisfies the initial conditions.



3. Use Cases

3-1. Design of DC-DC Converter for Mobile Devices (6/10)





Next, it was determined to evaluate a high frequency DC-DC converter aiming for downsizing.

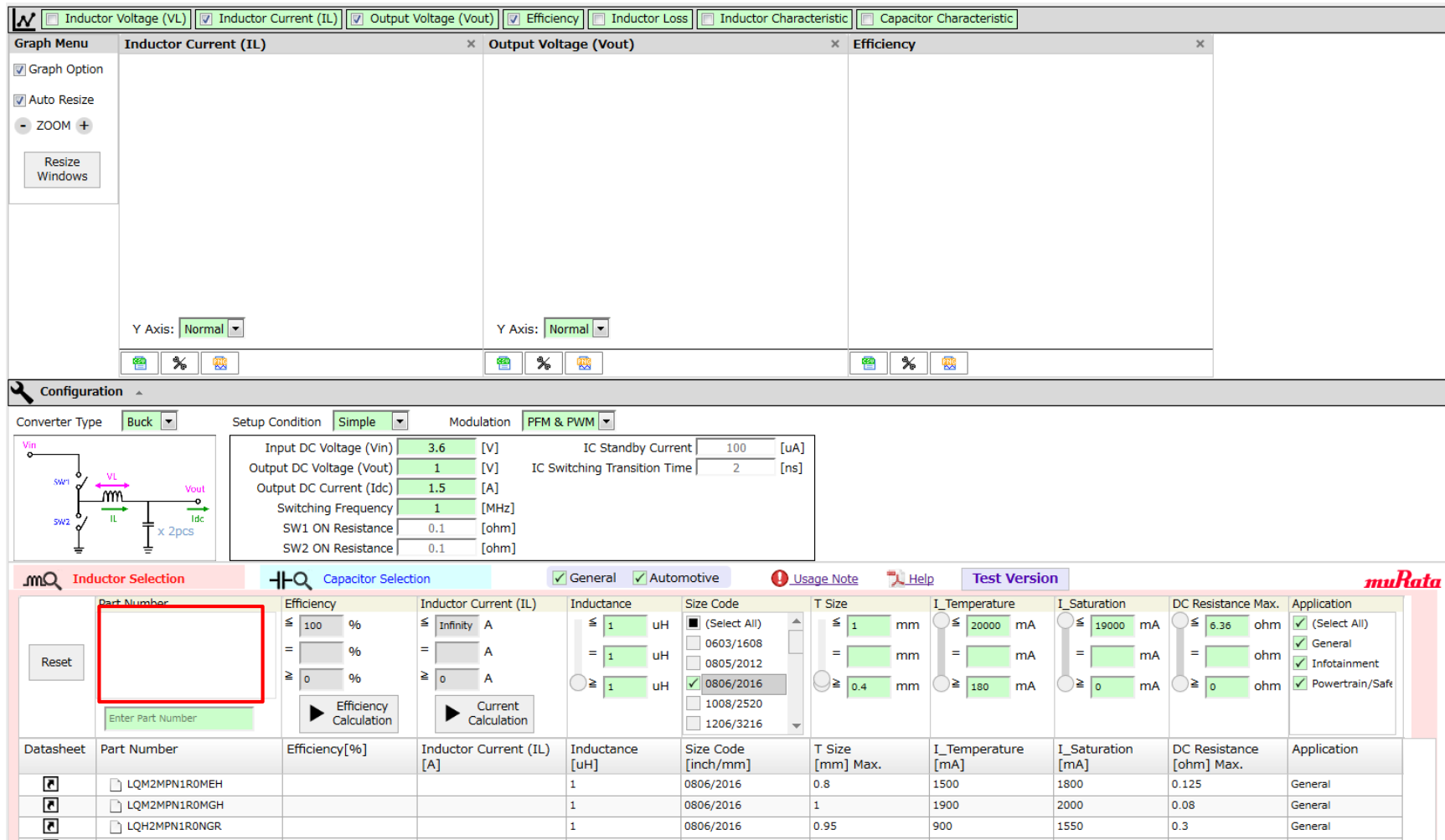
I want to select a power inductor in which the efficiency and ripple current are optimized when some of the conditions are changed as follows.

- Switching frequency 1MHz -> 4MHz
- Inductance 1 μ H -> 0.47 μ H

3. Use Cases

3-1. Design of DC-DC Converter for Mobile Devices (7/10)

-> Click the  of  to delete all the graph curves.



The screenshot displays the Murata Powertrain Design Tool interface. At the top, the 'Graph Menu' includes checkboxes for Inductor Voltage (VL), Inductor Current (IL), Output Voltage (Vout), Efficiency, Inductor Loss, Inductor Characteristic, and Capacitor Characteristic. Below this, three graph windows are visible: Inductor Current (IL), Output Voltage (Vout), and Efficiency. Each graph has a 'Y Axis' dropdown set to 'Normal' and a 'Zoom' button. The 'Configuration' section at the bottom left shows the 'Converter Type' set to 'Buck' and 'Modulation' set to 'PFM & PWM'. The 'Setup Condition' is 'Simple'. The 'Inductor Selection' table is highlighted with a red box around the 'Part Number' column. The 'Capacitor Selection' section is also visible. The 'Usage Note' and 'Test Version' buttons are present. The 'Application' column in the table is checked for 'General', 'Infotainment', and 'Powertrain/Safe'.

Part Number	Efficiency	Inductor Current (IL)	Inductance	Size Code	T Size	I Temperature	I Saturation	DC Resistance Max.	Application
LQM2MPN1R0MEH	100 %	Infinity A	1 uH	0806/2016	0.8	1500	1800	0.125 ohm	General
LQM2MPN1R0MGH	100 %	Infinity A	1 uH	0806/2016	1	1900	2000	0.08 ohm	General
LQH2MPN1R0NGR	100 %	Infinity A	1 uH	0806/2016	0.95	900	1550	0.3 ohm	General

3. Use Cases

3-1. Design of DC-DC Converter for Mobile Devices (8/10)

-> Change the inductance and switching frequency.

Configuration

Converter Type: **Buck** | Setup Condition: **Simple** | Modulation: **PFM & PWM**

Input DC Voltage (Vin): 3.6 [V] | IC Standby Current: 100 [uA]
Output DC Voltage (Vout): 1 [V] | IC Switching Transition Time: 2 [ns]
Output DC Current (Idc): 1.5 [A]
Switching Frequency: **4** [MHz] (changed from 1)
SW1 ON Resistance: 0.1 [ohm]
SW2 ON Resistance: 0.1 [ohm]

Inductor Selection

Part Number	Efficiency	Inductor Current (IL)	Inductance	Size Code	T Size	I Temperature	I Saturation	DC Resistance Max.	Application
LQM2MPNR47MEH	≤ 100 %	≤ Infinity A	≤ 0.47 uH	0603/1608	≤ 1 mm	≤ 20000 mA	≤ 19000 mA	≤ 6.36 ohm	General
LQM2MPNR47MGH	≤ 100 %	≤ Infinity A	≤ 0.47 uH	0805/2012	≤ 1 mm	≤ 20000 mA	≤ 19000 mA	≤ 6.36 ohm	General
DFE201610E-R47M	≤ 100 %	≤ Infinity A	≤ 0.47 uH	1008/2520	≤ 0.4 mm	≤ 1500 mA	≤ 1500 mA	≤ 0 ohm	Infotainment
DFE201610P-R47M	≤ 100 %	≤ Infinity A	≤ 0.47 uH	1206/3216	≤ 0.4 mm	≤ 1500 mA	≤ 1500 mA	≤ 0 ohm	Powertrain/Saf

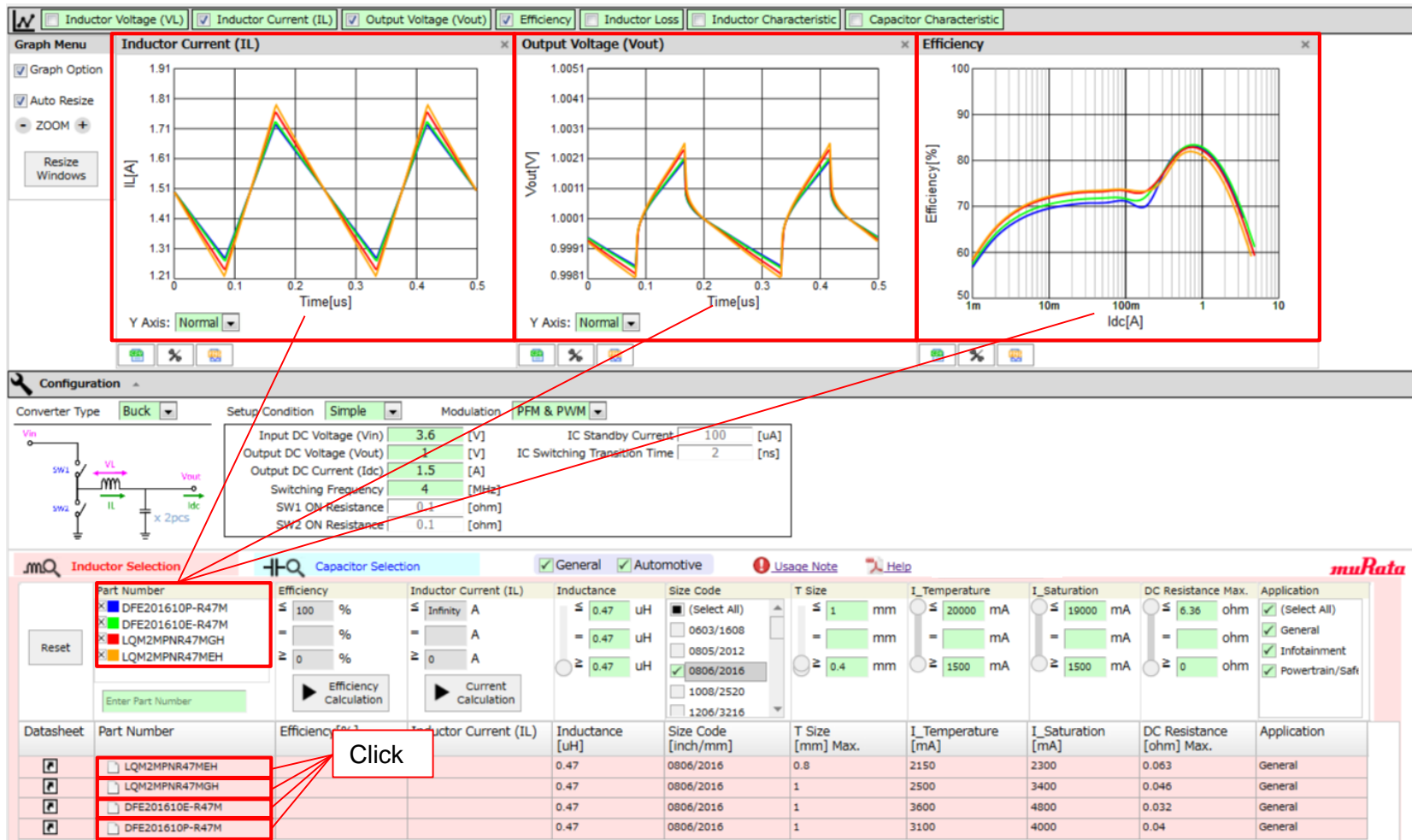
Annotations:

- Switching frequency 1 -> 4MHz
- Inductance 1 -> 0.47uH

3. Use Cases

3-1. Design of DC-DC Converter for Mobile Devices (9/10)

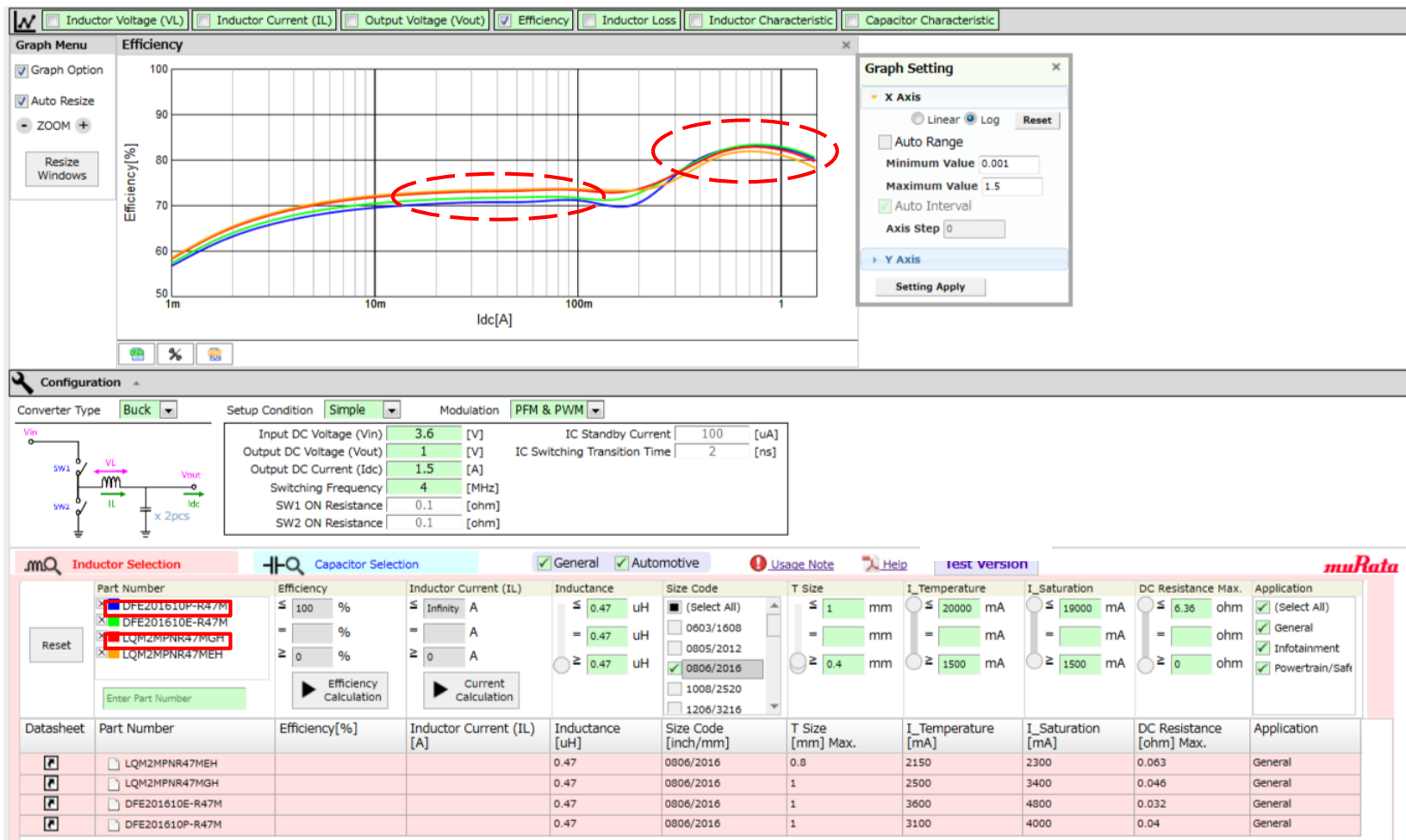
-> The graph shows that there is no great difference in the ripple current for all of the part numbers in this case as well. Similarly, look at the efficiency graph.



3. Use Cases

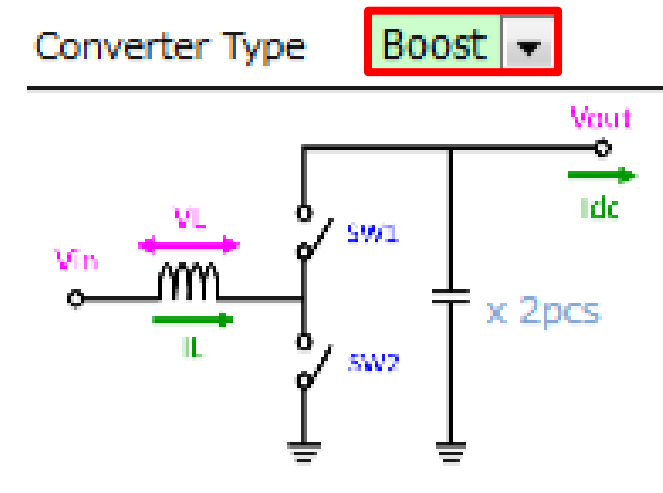
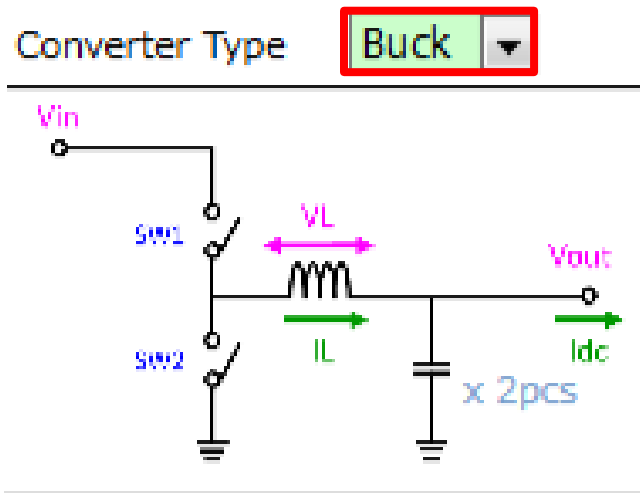
3-1. Design of DC-DC Converter for Mobile Devices (10/10)

-> The same as p.13, expands the efficiency graph only. In this graph, "DFE201610E-R47M" and "LQM2MPNR47MGH" can be selected as high efficiency power inductors which satisfies the initial conditions.



4. Details of Operation

4-1. Circuit Selection Field



-> Select Buck (Buck type) or Boost (Boost type) as the type of DC-DC converter circuit.

The operation when "Buck" is selected is described in the following.

4. Details of Operation

4-2. Input Function of Circuit Operating Conditions (1/3)

Setup Condition **Simple** Modulation **PFM & PWM**

Input DC Voltage (Vin)	3.6	[V]	IC Standby Current	100	[uA]
Output DC Voltage (Vout)	1.8	[V]	IC Switching Transition Time	2	[ns]
Output DC Current (Idc)	1	[A]			
Switching Frequency	2	[MHz]			
SW1 ON Resistance	0.1	[ohm]			
SW2 ON Resistance	0.1	[ohm]			

Setup Condition **Standard** Modulation **PFM & PWM**

Input DC Voltage (Vin)	3.6	[V]	IC Standby Current	100	[uA]
Output DC Voltage (Vout)	1.8	[V]	IC Switching Transition Time	2	[ns]
Output DC Current (Idc)	1	[A]			
Switching Frequency	2	[MHz]			
SW1 ON Resistance	0.1	[ohm]			
SW2 ON Resistance	0.1	[ohm]			

-> There are two types of modes including "Simple" and "Standard" as the input items. The table below shows the items that can be input in each mode.

Input item	Input unit	Mode		Remarks
		Simple	Standard	
Input DC Voltage (Vin)	V	✓	✓	
Output DC Voltage (Vout)	V	✓	✓	
Output DC Current (Idc)	A	✓	✓	"Iout" is indicated depending on the IC
Switching Frequency	MHz	✓	✓	
SW1 ON Resistance	Ω	-	✓	ON resistance of IC, etc.
SW2 ON Resistance	Ω	-	✓	ON resistance of IC, etc.
IC Standby Current	μA	-	✓	Self-consumption current of PMIC
IC Switching Transition Time	ns	-	✓	Time for SW to be in ON state

4. Details of Operation

4-2. Input Function of Circuit Operating Conditions (2/3)

Input item	Input unit	Mode		Remarks
		Simple	Standard	
Input DC Voltage (Vin)	V	✓	✓	
Output DC Voltage (Vout)	V	✓	✓	
Output DC Current (Idc)	A	✓	✓	"Iout" is indicated depending on the IC
Switching Frequency	MHz	✓	✓	
SW1 ON Resistance	Ω	-	✓	ON resistance of IC, etc.
SW2 ON Resistance	Ω	-	✓	ON resistance of IC, etc.
IC Standby Current	μA	-	✓	Self-consumption current of PMIC
IC Switching Transition Time	ns	-	✓	Time for SW to be in ON state

-> Advanced calculation can be set by selecting the Standard mode and entering the basic characteristics of the PMIC (red check mark).

* This function can be used by first selecting the Simple mode to execute the calculation, and then performing a detailed verification of the results in Standard mode.

The operation when Simple mode is selected is described in the following.

4. Details of Operation

4-2. Input Function of Circuit Operating Conditions (3/3)

Setup Condition	Simple	Modulation	PFM & PWM		
Input DC Voltage (Vin)	3.6	[V]	IC Standby Current	100	[uA]
Output DC Voltage (Vout)	1.8	[V]	IC Switching Transition Time	2	[ns]
Output DC Current (Idc)	1	[A]			
Switching Frequency	2	[MHz]			
SW1 ON Resistance	0.1	[ohm]			
SW2 ON Resistance	0.1	[ohm]			

Setup Condition	Simple	Modulation	PWM		
Input DC Voltage (Vin)	3.6	[V]	IC Standby Current	100	[uA]
Output DC Voltage (Vout)	1.8	[V]	IC Switching Transition Time	2	[ns]
Output DC Current (Idc)	1	[A]			
Switching Frequency	2	[MHz]			
SW1 ON Resistance	0.1	[ohm]			
SW2 ON Resistance	0.1	[ohm]			

-> As a modulation mode of a circuit, two types of modes including "PFM & PWM" and "PWM" can be selected.

When "PFM & PWM" is selected, the efficiency is calculated by automatically switching between PWM and PFM. See p.36 for the details.

The operation when "PFM & PWM" is selected is described in the following.

4. Details of Operation

4-3. Part Number Selection Function (1/2)

This is set to "Inductor Selection" by default.

Can be narrowed down by entering a center value or the upper/lower limit value

Can be narrow down by check box

Resets the settings

Efficiency Calculation

Current Calculation

Inductance

Size Code

T Size

I Saturation

DC Resistance Max.

Application

Clicking displays the efficiency in descending order

Clicking displays the current which flows into the inductor in descending order

Clicking displays the data sheet of each part number

Selecting the right side of the item rearranges the displayed items in ascending/descending order

Part Number	Efficiency	Inductor Current (IL)	Inductance	Size Code	T Size	I Saturation	DC Resistance Max.	Application
LQM2MPN1R0NG0			1	0806/2016	1			General
LQM31PN1R0M00			1	1206/3216	0.85			General
DFE2012PD-1R0M			1	1008/2520	1.2	3800	0.042	Infotainment

-> The part number of the power inductors can be narrowed down by the specifications of inductance, size code, thickness, saturation current, maximum DC resistance and application. Clicking also displays the data sheet of each part number.

4. Details of Operation

4-3. Part Number Selection Function (2/2)

Configuration

Converter Type: Buck Setup Condition: Simple Modulation: PFM & PWM

Input DC Voltage (Vin): 3.6 [V]
Output DC Voltage (Vout): 1.8 [V]
Output DC Current (Idc): 1 [A]
Switching Frequency: 2 [MHz]
SW1 ON Resistance: 0.1 [ohm]
SW2 ON Resistance: 0.1 [ohm]

Can be changed to "Capacitor Selection"

Can be narrowed down by entering a center value or the upper/lower limit value

Can be narrow down by check box

Inductor Selection Capacitor Selection

Reset

Resets the settings

Number of MLCC used can be entered*


Clicking displays the data sheet of each part number

General Automotive Usage note Help

Part Number	Capacitance	Rated Voltage	Temperature	Size Code	T Size	Cap. Tolerance	Type
GRM188R60G226ME0	22uF	4	X5R	1608M/0603	1.0	+/-20%	General Purpose
GRM187R60J226ME15	22uF	6.3	X5R	1608M/0603	0.8	+/-20%	Acoustic noise reduction (interposer)
ZDR186A01226ME11	22uF	6.3	X5R	1608M/0603	0.8	+/-20%	General Purpose

Selecting the right side of the item rearranges the displayed items in ascending/descending order

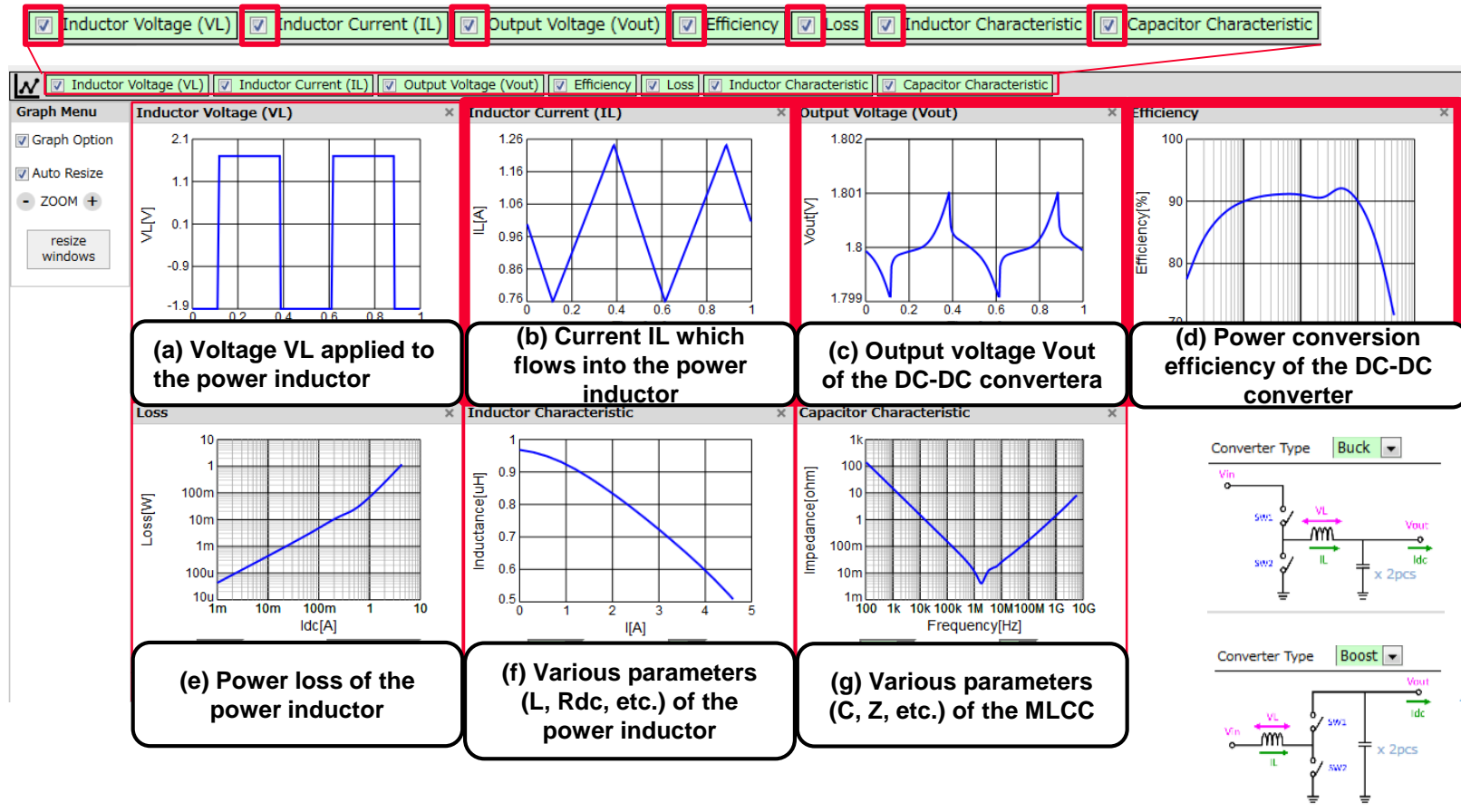
* Irrespective of the "Buck" or "Boost" mode, a number of MLCC used can be entered for one part number.

-> The part number of the MLCC can be narrowed by specifications of the capacitance, rated voltage, temperature characteristics, size code, thickness, capacitance tolerance, and type.
Clicking  also displays the data sheet of each part number.

4. Details of Operation

4-4. Graph Output Function (1/10)

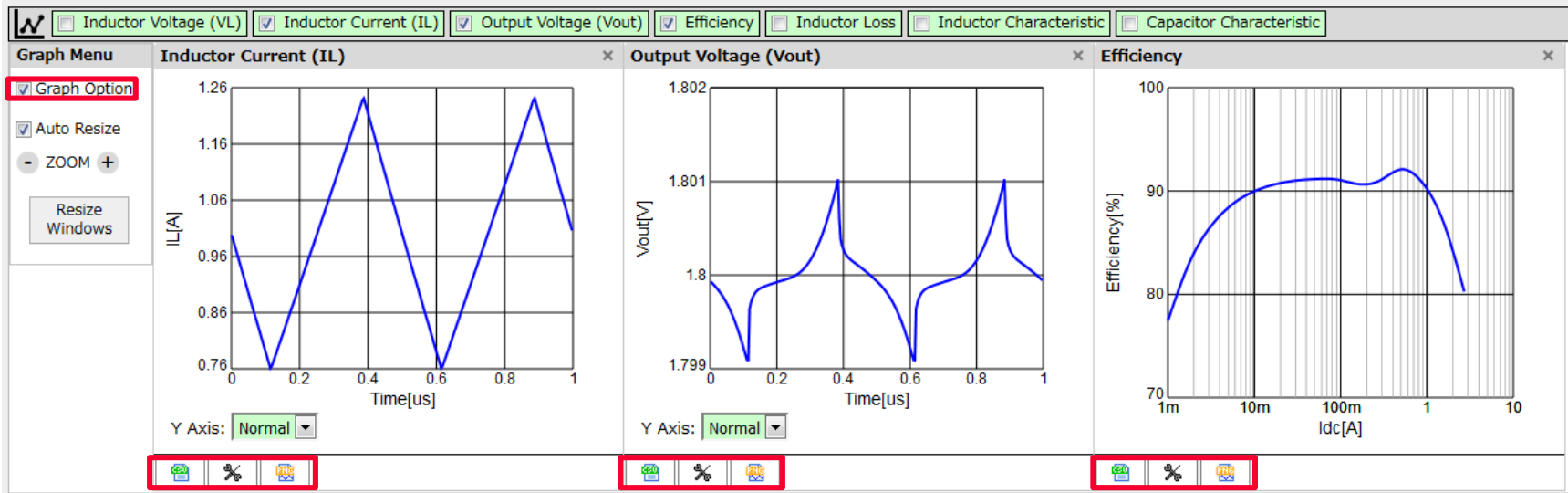
Check the item(s) to be displayed



-> Clicking the part number of the power inductor displays seven types of graphs including the ripple current (IL - Time), output voltage (Vout - Time), and efficiency (Efficiency - Idc).

4. Details of Operation

4-4. Graph Output Function (2/10)



-> are functions common to all graphs. Clicking each button enables the following operations.

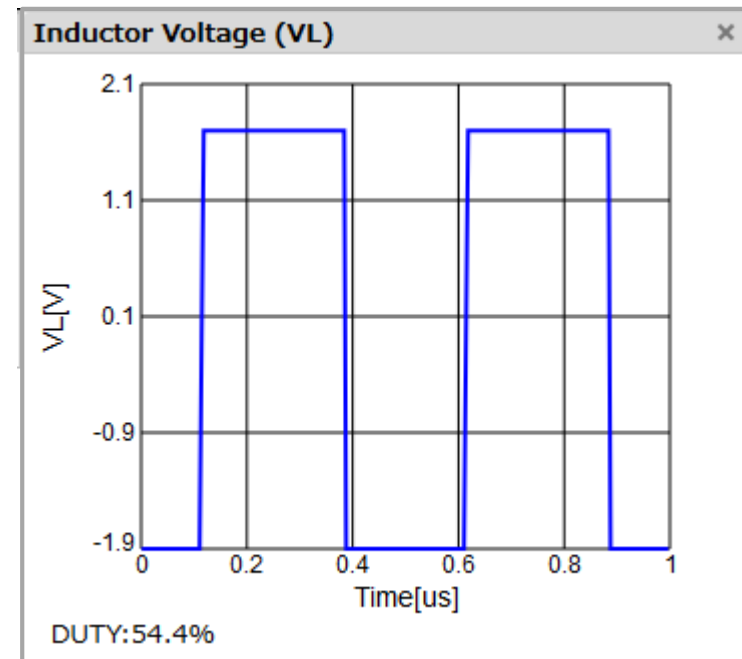
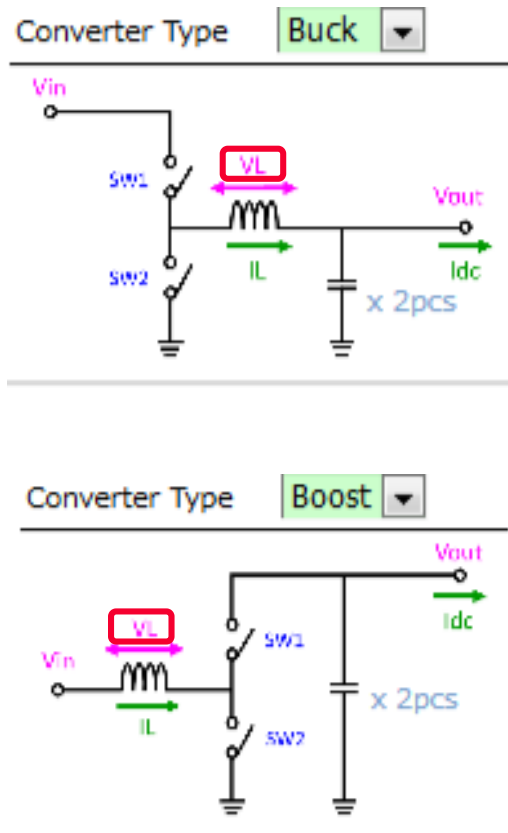
: CSV output : Change of graph settings : Saves image (PNG format)

* Unchecking the [Graph Option] will close the buttons.

4. Details of Operation

4-4. Graph Output Function (3/10)

(a) Voltage V_L applied to the power inductor

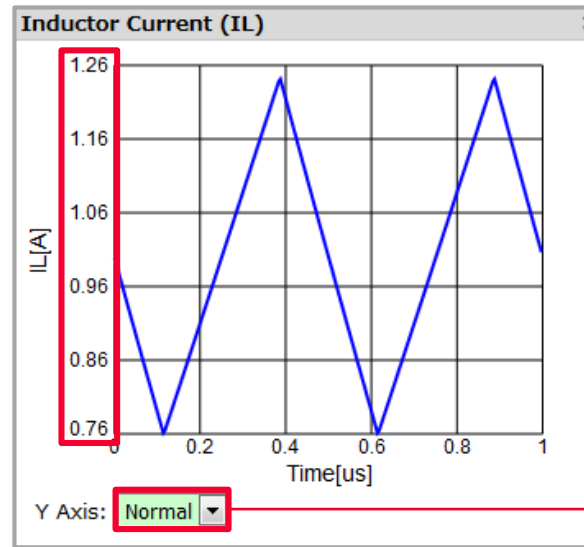
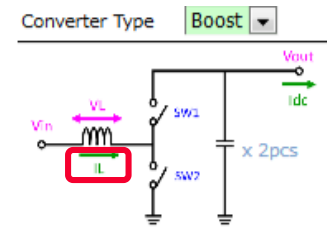
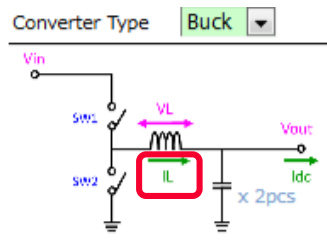


-> The upper/lower limit voltage of V_L is determined by the input voltage V_{in} and the output voltage V_{out} .
The Duty ratio is determined by the ratio of V_{out} to V_{in} and the ON resistance of the IC, etc.

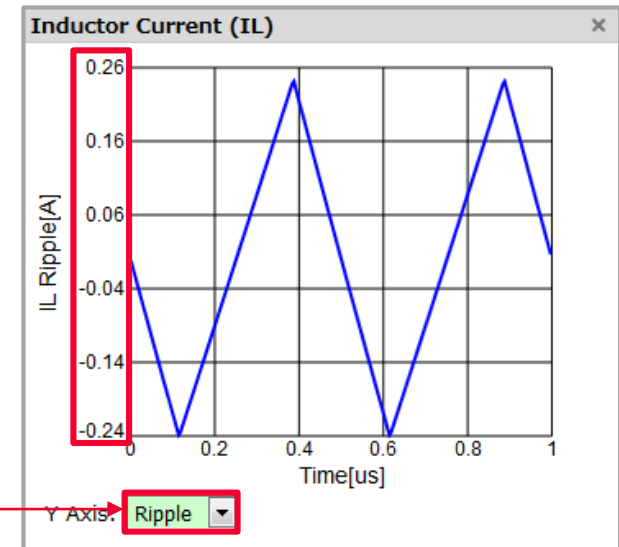
4. Details of Operation

4-4. Graph Output Function (4/10)

(b) Current I_L which flows into the power inductor



DC cut



* Setting the Y-Axis from "Normal" to "Ripple" cuts the DC component, and only displays the current amplitude.

-> The current waveform of I_L is displayed as a triangular wave. This is generally called the "ripple current."

[Notes]

The amplitude of the ripple current is inverse proportion to the L value of the power inductor. When the L value drops the amplitude suddenly increases due to the current bias characteristics of the inductor. This will cause a defect where the DC-DC converter itself does not operate normally, etc.

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Converter Type **Buck**

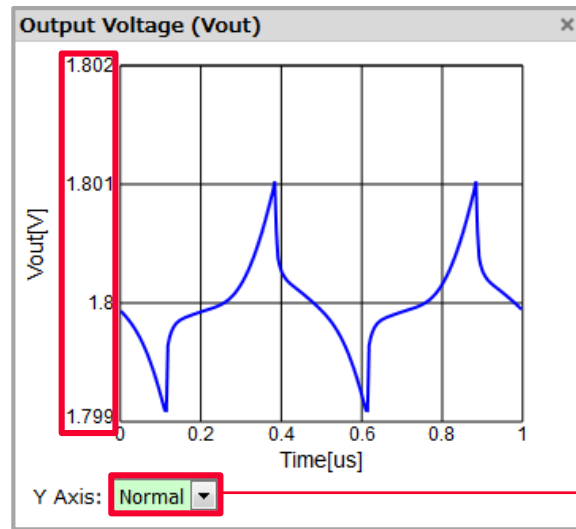
Input: V_{in}

Switches: SW1, SW2

Inductor: L (Voltage: V_L , Current: I_L)

Capacitor: C (x 2pcs)

Output: V_{out} , I_{dc}



Output Voltage (Vout)

Vout Ripple[V]

Time[us]

Y Axis: Ripple

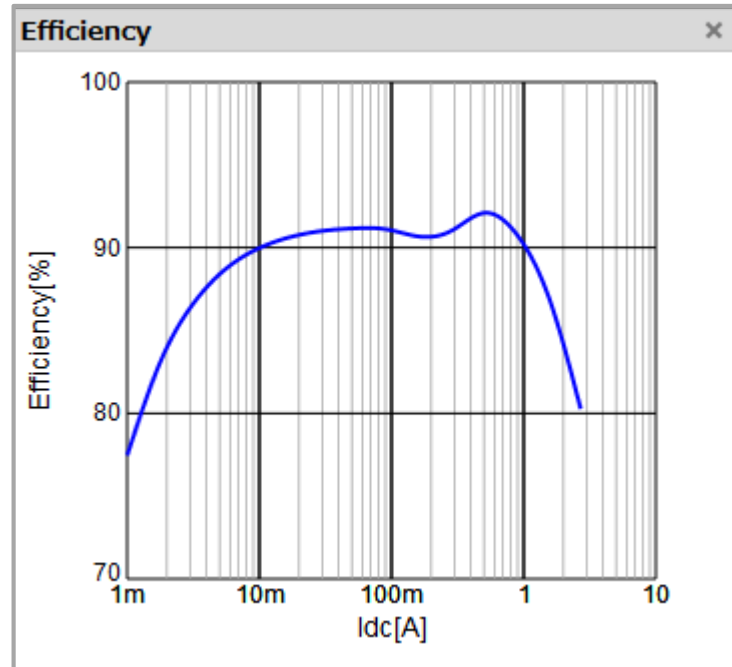
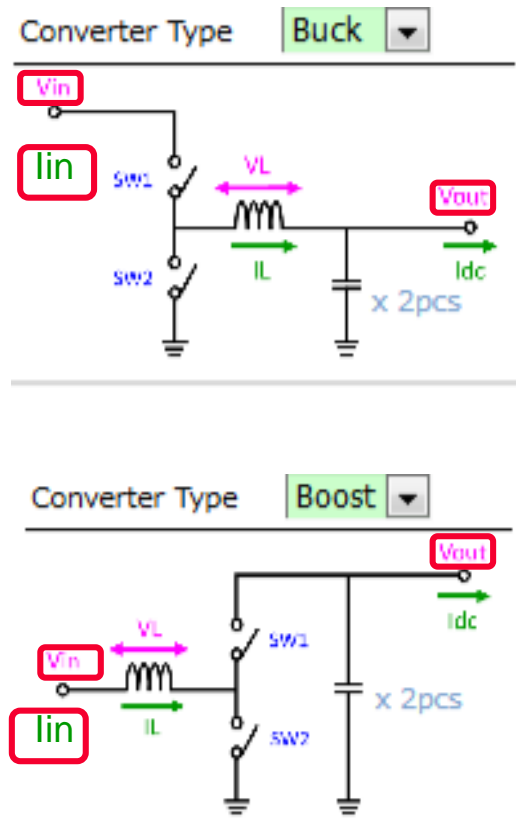
-> The waveform of the output voltage is one of the main performance indexes of a DC-DC converter. This is generally called the "ripple voltage."

It is necessary to set the ripple voltage low enough according to the IC specification so that an IC with a load does not malfunction.

4. Details of Operation

4-4. Graph Output Function (6/10)

(d) Power conversion efficiency



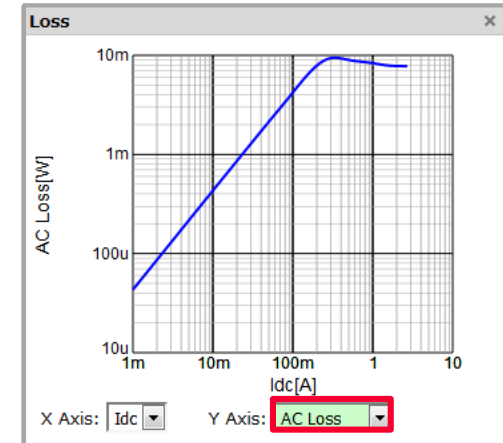
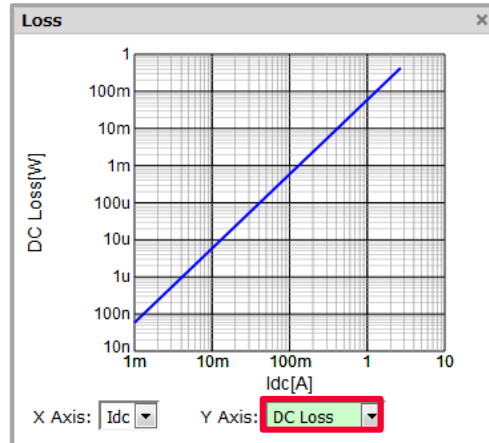
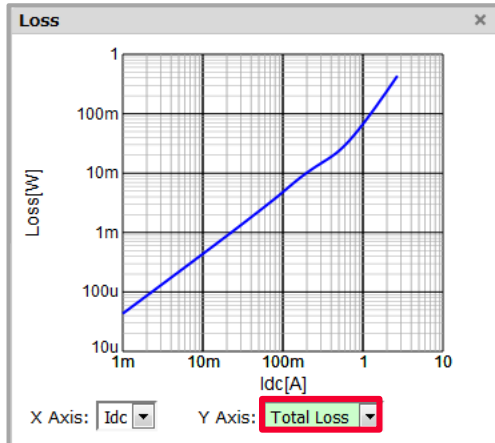
$$\text{Power conversion efficiency} = \frac{V_{out}I_{dc}}{V_{in}I_{in}} \times 100[\%]$$

-> The power conversion efficiency is one of the most important performance indexes of a DC-DC converter. Although the efficiency is generally calculated by the above equation, it is calculated from the power loss of the power inductor and the ON resistance of the IC in this software.

4. Details of Operation

4-4. Graph Output Function (7/10)

(e) Power loss of the power inductor



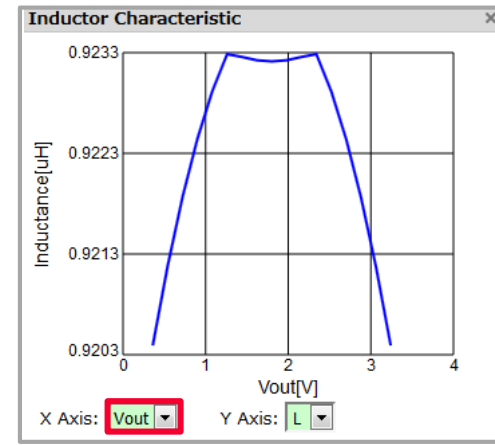
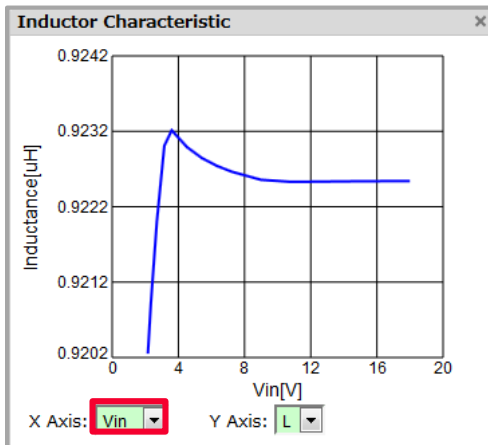
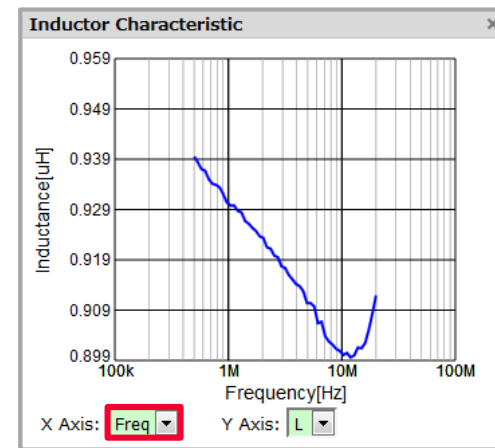
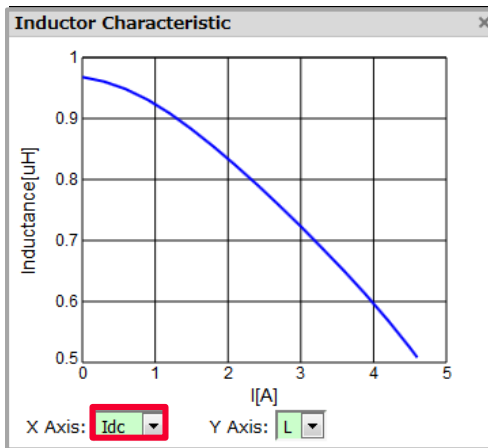
-> The power loss for the Idc of a power inductor can be displayed.

Total Loss	Total of the power loss of an inductor (DC Loss + AC Loss)
DC Loss	Power loss when DC current is flowing into the inductor
AC Loss	Power loss when AC current is flowing into the inductor

4. Details of Operation

4-4. Graph Output Function (8/10)

(f) Various parameters of a power inductor

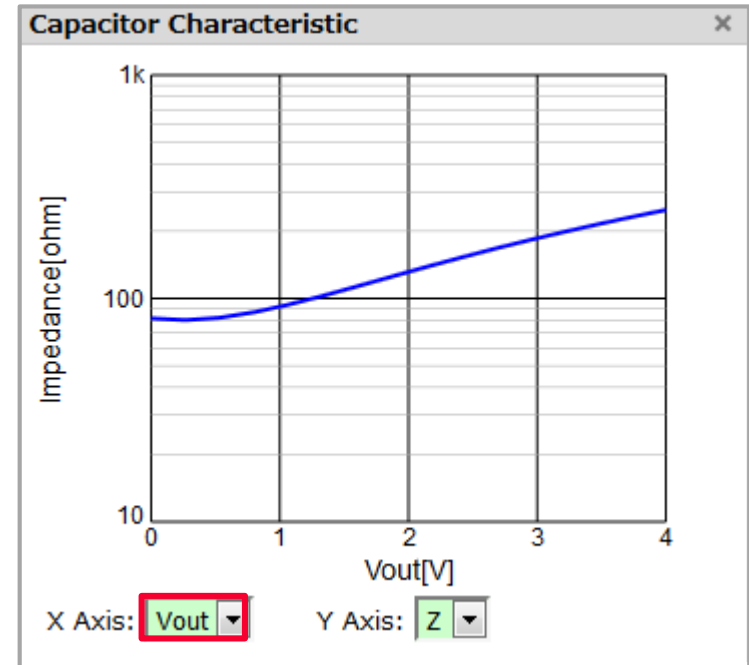
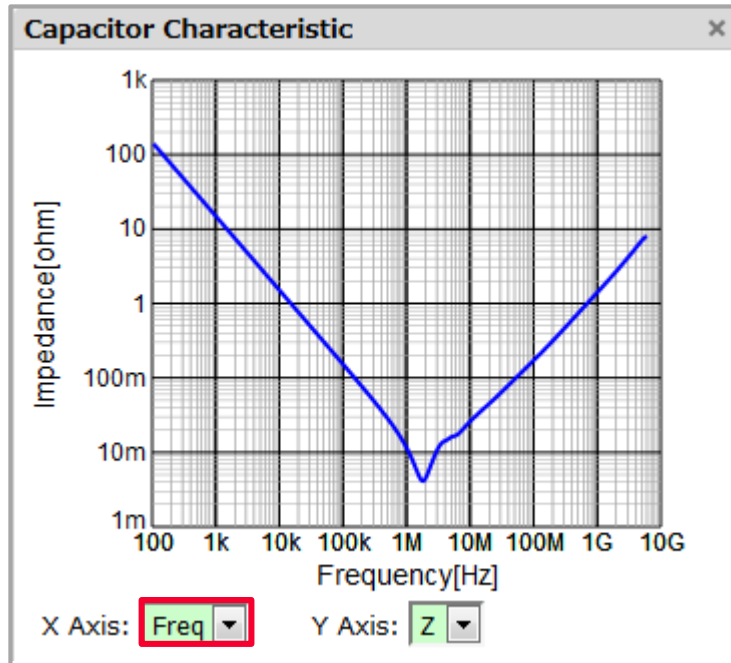


-> A total of 24 characteristics graphs Z/R/X/C/L/Q can be displayed for the Idc/Freq/Vin/Vout in a power inductor.

4. Details of Operation

4-4. Graph Output Function (9/10)

(g) Various parameters of MLCC

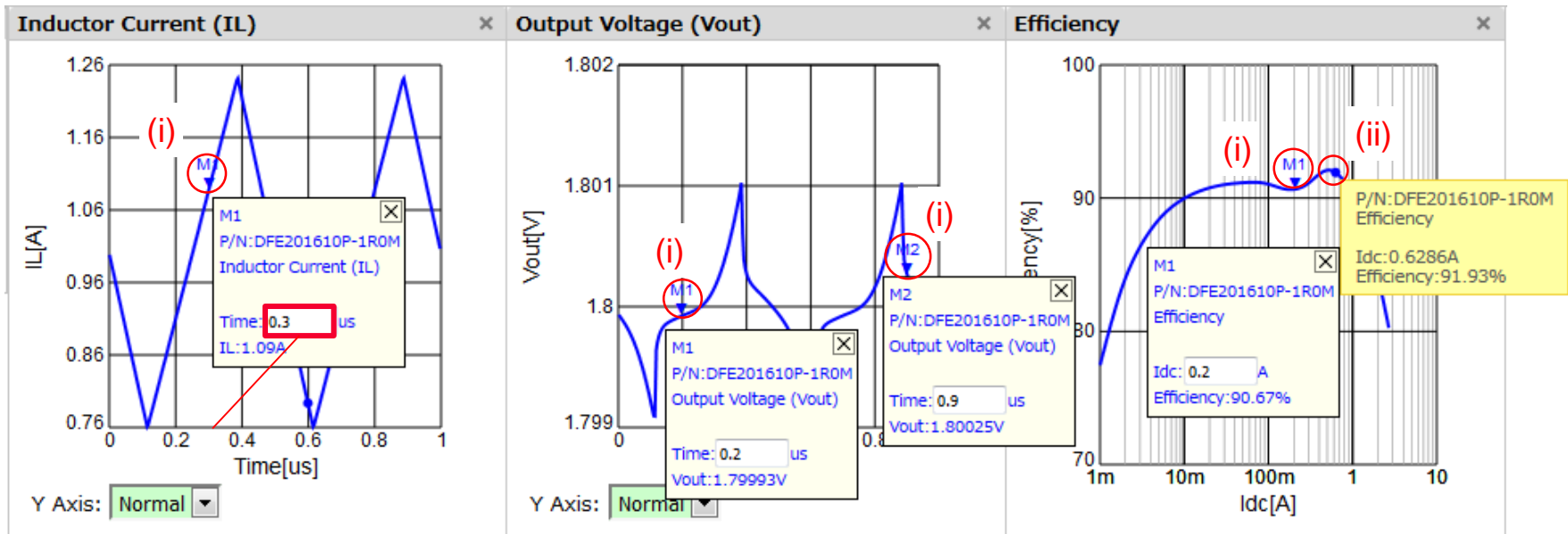


-> A total of 12 characteristics graphs Z/R/X/C/L/Q can be displayed for the Freq/Vout in an MLCC.

4. Details of Operation

4-4. Graph Output Function (10/10)

-> A marker function can be used.

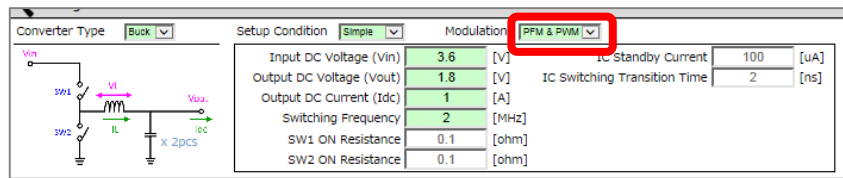


- (i)
- Clicking on the characteristics curve displays the marker.
 - Entering the horizontal axis allows the marker to be moved to a specified location.
 - Multiple markers can be displayed. Clicking a marker or clicking the upper right of a marker ☐ box deletes the marker.
- (ii)
- Placing the mouse pointer on the characteristics curve displays the numerical value of the vertical/horizontal axes in the specified location.

4. Details of Operation

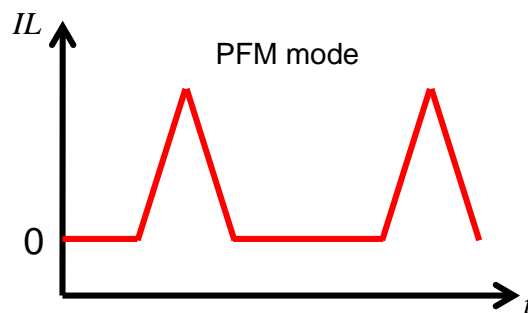
4-5. [Supplement] PFM Mode and PWM Mode (1/2)

In the Modulation item of the software, the operation mode can be changed between "PFM & PWM" and "PWM."

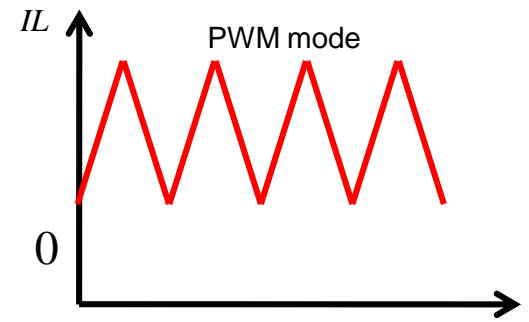


PFM&PWM	Calculated by automatically switching between PWM and PFM
	-> For the purpose of optimization of the efficiency, when the output current Idc is too high the mode is switched to the PWM mode, and when too low, it is switched to the PFM mode (see p.36 for the details).
PWM	Calculated in the PWM mode only in the entire Idc range

* Waveform image of the current (I_L) which flows into an inductor



-> Executes intermittent operation to suppress the switching loss



-> Adjusts the output voltage by the Duty ratio

4. Details of Operation

4-5. [Supplement] PFM Mode and PWM Mode (2/2)

<When "PFM & PWM" is selected>

The efficiency is calculated by automatically switching between PWM and PFM based on the following distinction method.

- PFM mode when the lower limit current of the IL which flows into an inductor becomes 0A state (Figure 1)
- PWM mode when the lower limit current of the IL becomes larger than 0A state (Figure 2)

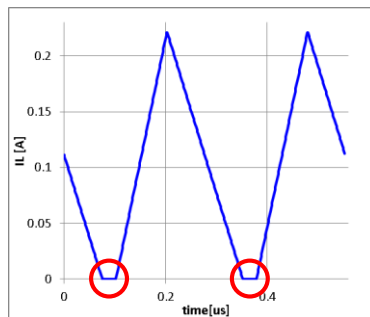


Figure 1
Inductor current waveform
when $I_{dc} = 0.09A$

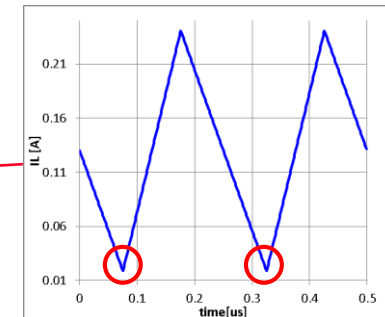
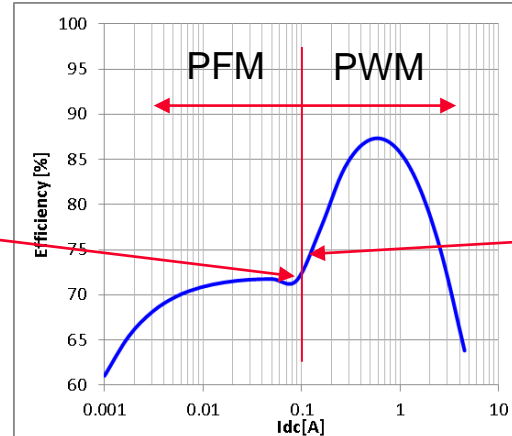


Figure 2
Inductor current waveform
when $I_{dc} = 0.13A$