# SimSurfing
# DC-DC Converter Design Support Tool
# Operation Manual

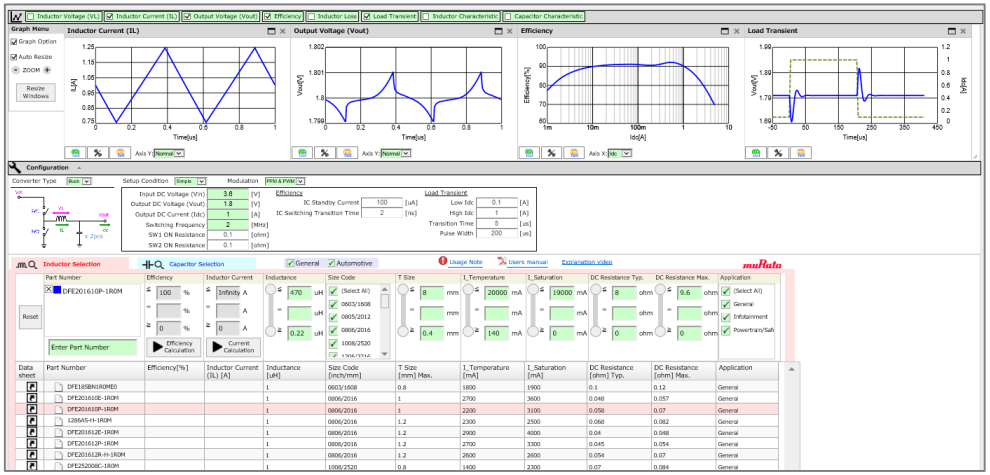

August, 2019

Murata Manufacturing Co., Ltd.

# Index

# 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

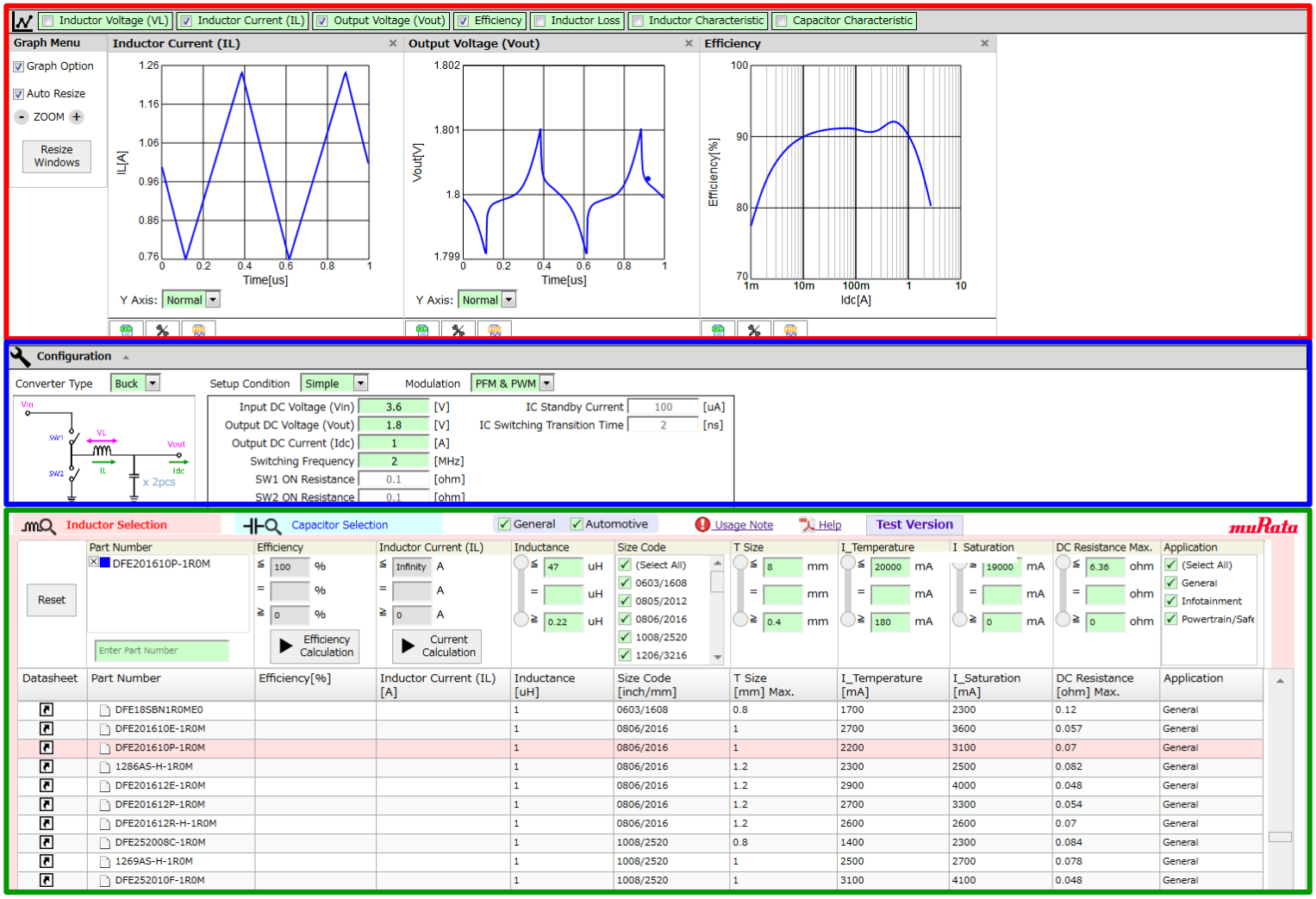
- Characteristics graph of a power inductor displayed by the software

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)



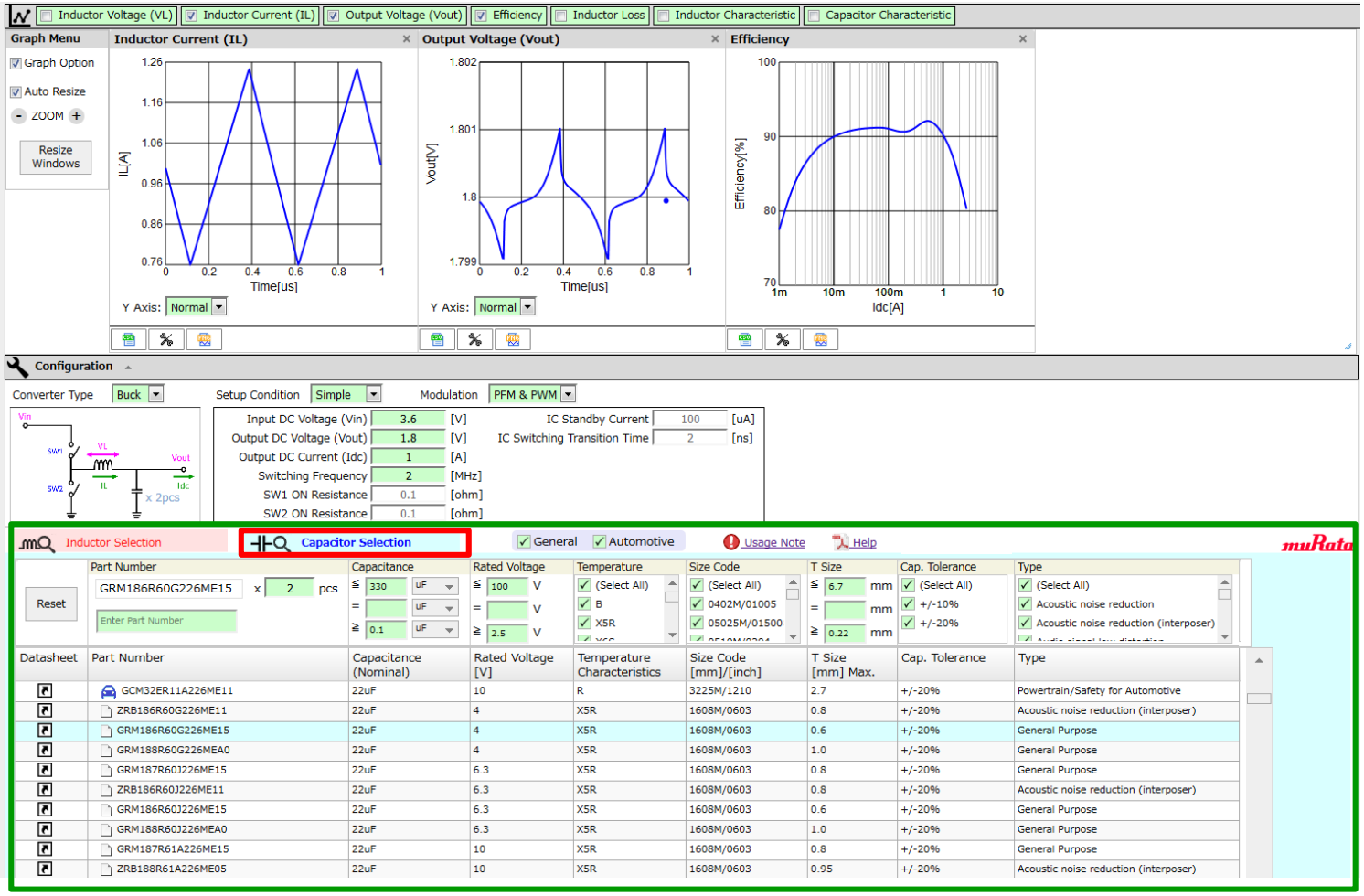

(1) Graph output function

(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)

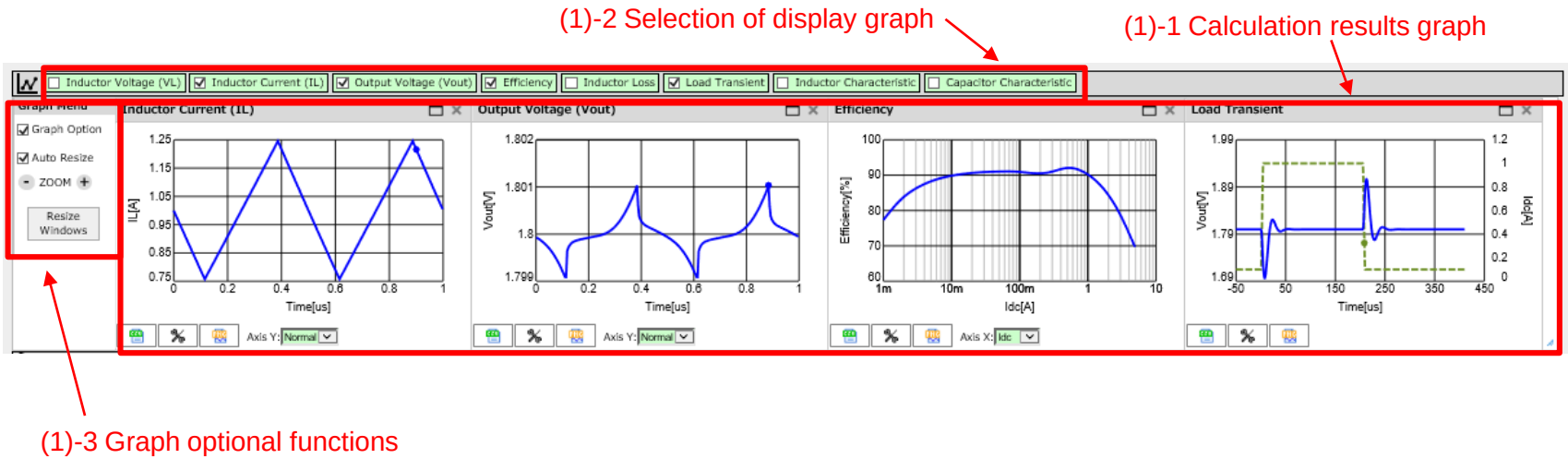
-> A list of power inductors is displayed in (3) functional block of the part number selection.
Changing the tab will display a list of multilayer ceramic capacitors (hereinafter, MLCC).

# 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.

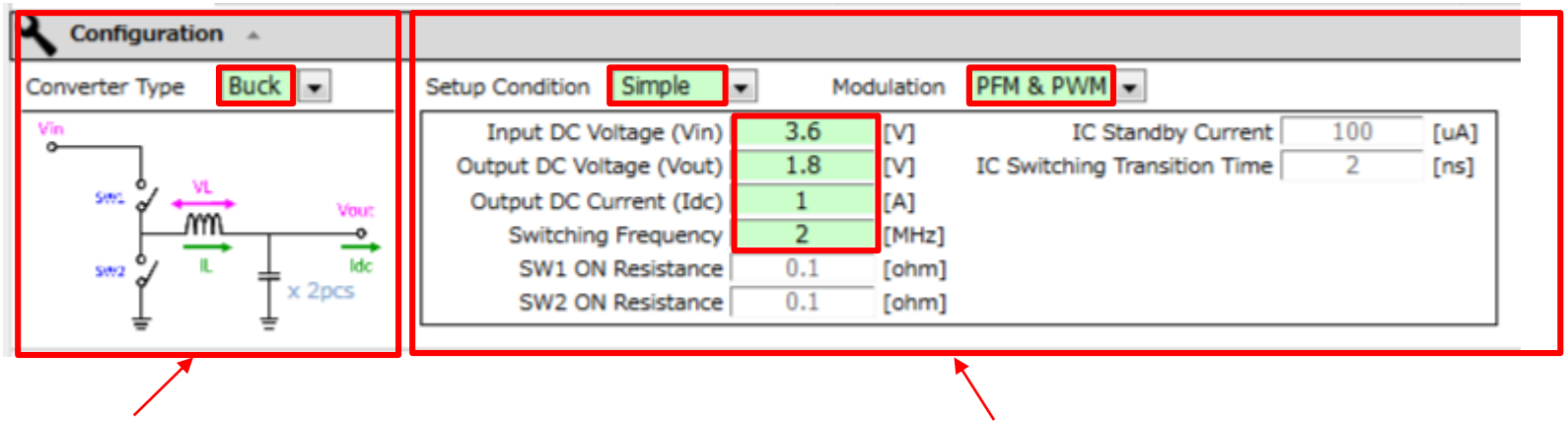
See the following for the detailed operation.
- Examples of use: p.10 to p.19
- Operation of each functional block: p.20 to p.35




<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

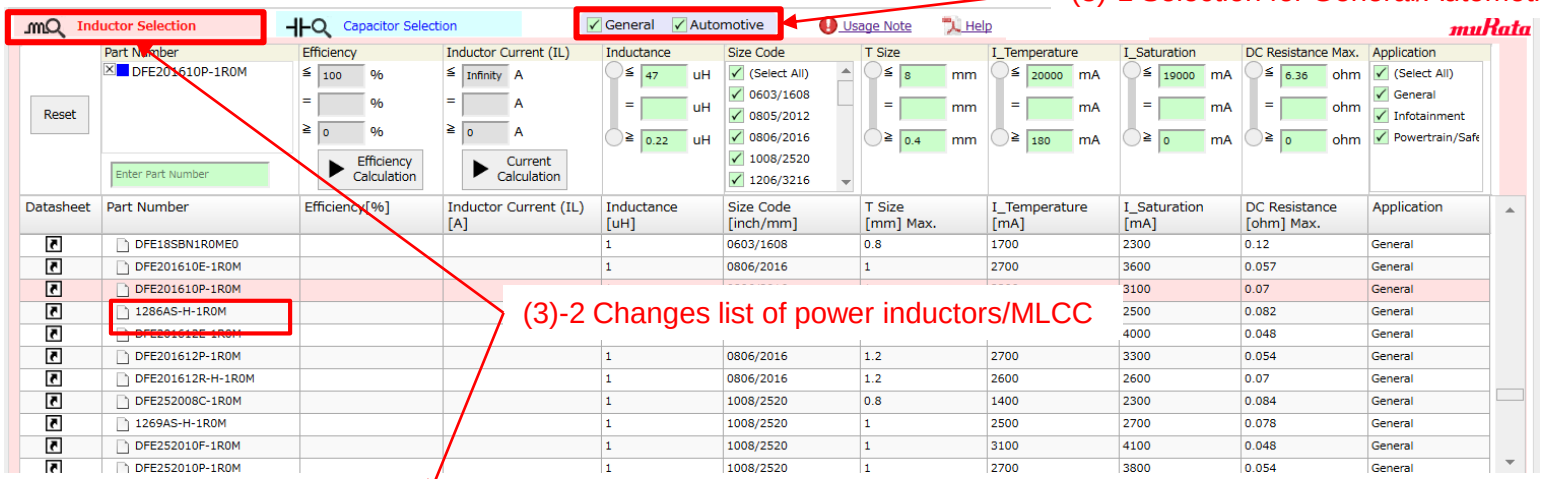
<Default settings>

| | |
|---|---|
| (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] |

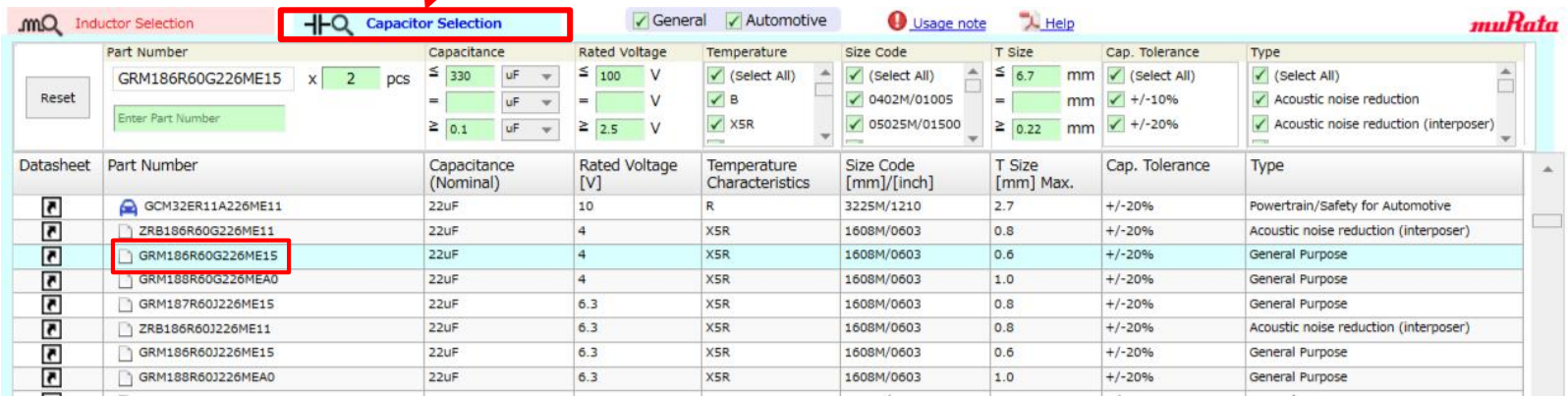
# 2. Quick Operation Guide
## 2-2. How to Use Each Component (3/3)

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

(3)-1 Selection for General/Automotive




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

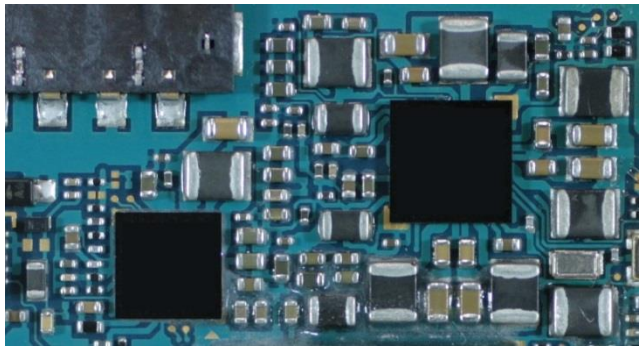



<Default settings>
(3)-1 General/Automotive -> Both checked
(3)-2 Inductor Selection -> Part No.: DFE201610P-1R0M
Capacitor Selection -> Part No.: GRM186R60G226ME15

# 3. Use Cases

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

<Design of DC-DC converters for mobile devices>



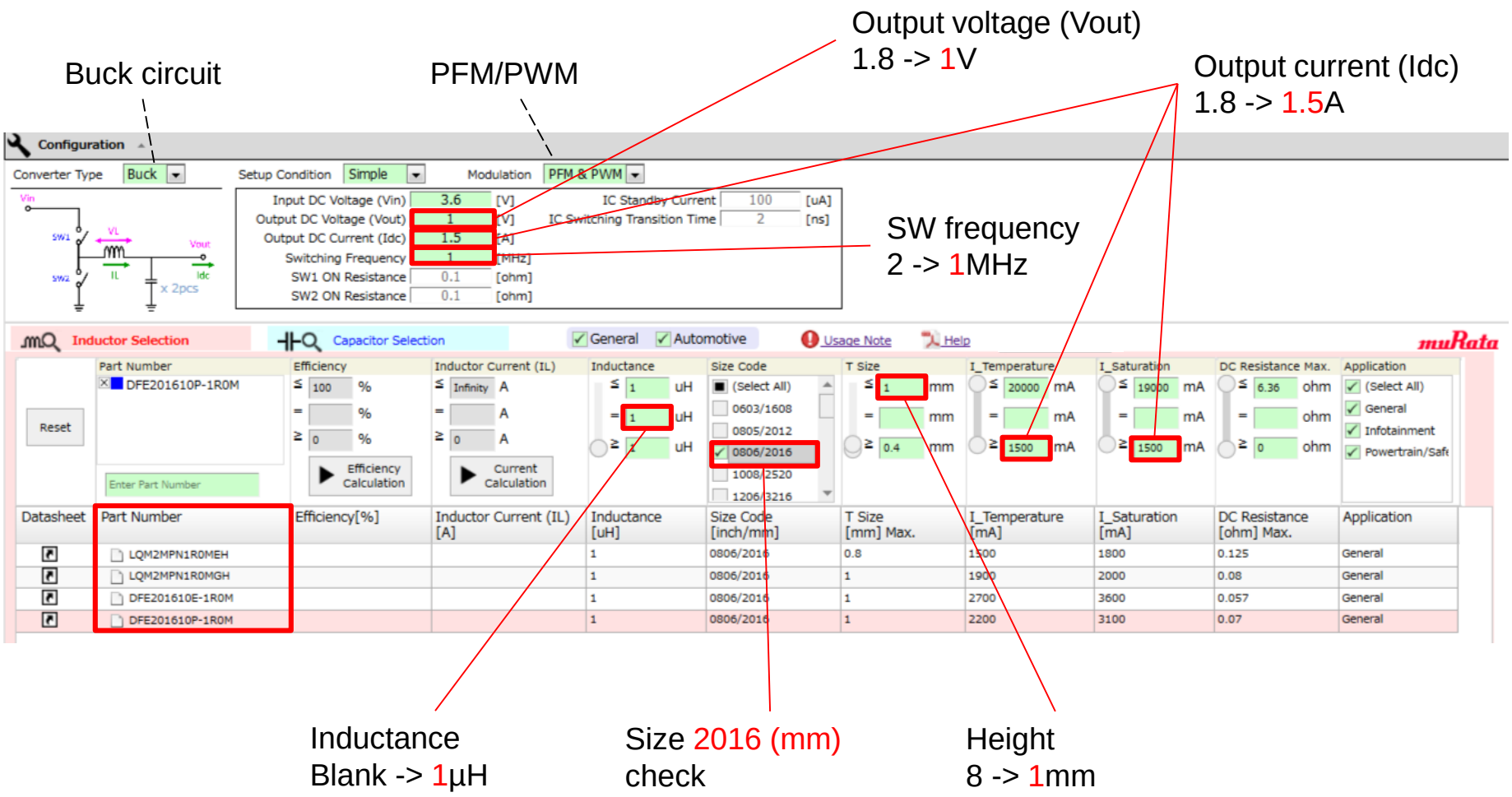
Operating conditions of DC-DC converter:
- Buck circuit
- Low current: PFM, Normal operation: PWM
- Input voltage: 3.6V, Output voltage: 1.0V
- Output current: 1.5A
- Switching frequency: 1MHz

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)

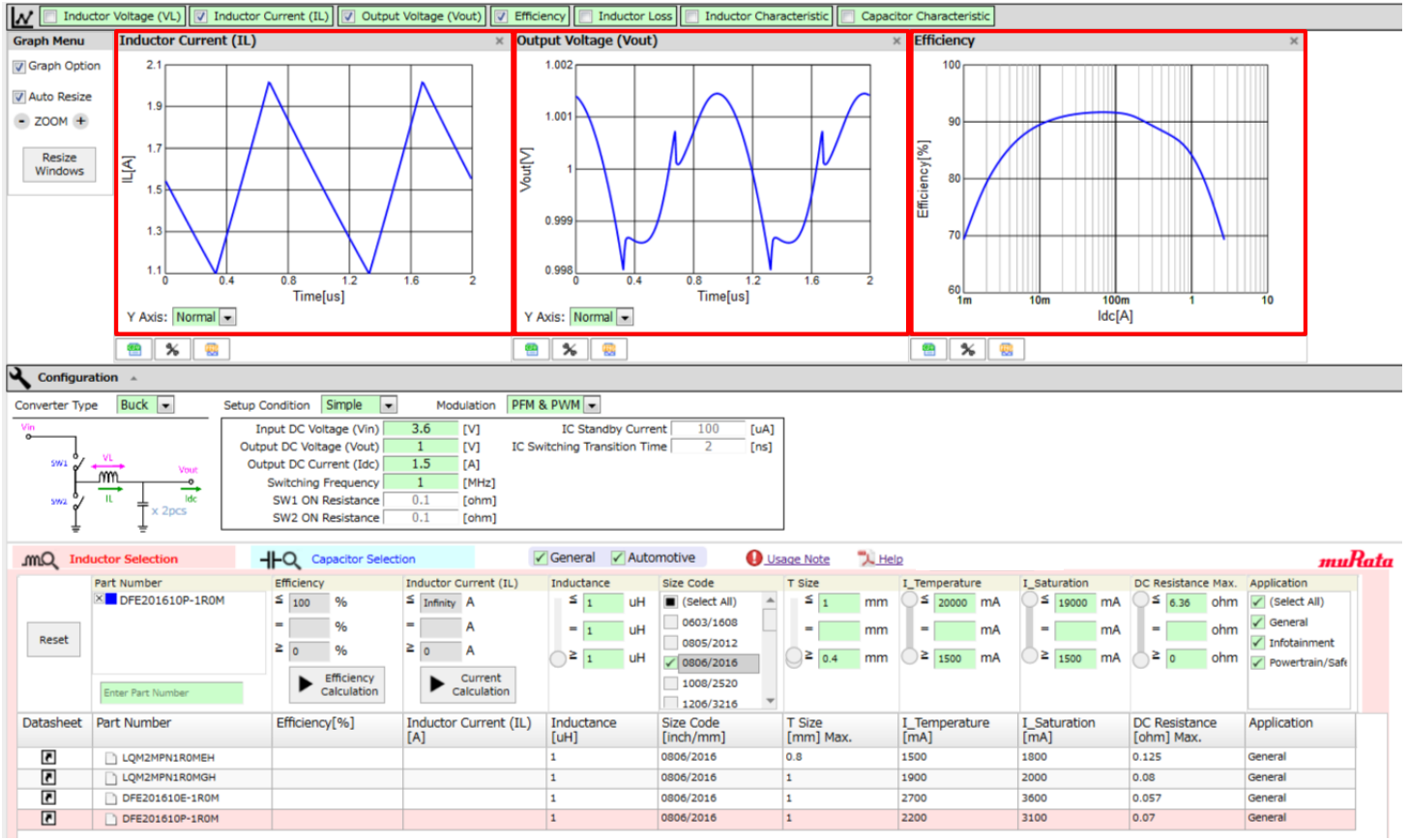
-> Set the conditions on the previous page to narrow down the part number of the power inductors suitable for the conditions.



# 3. Use Cases

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

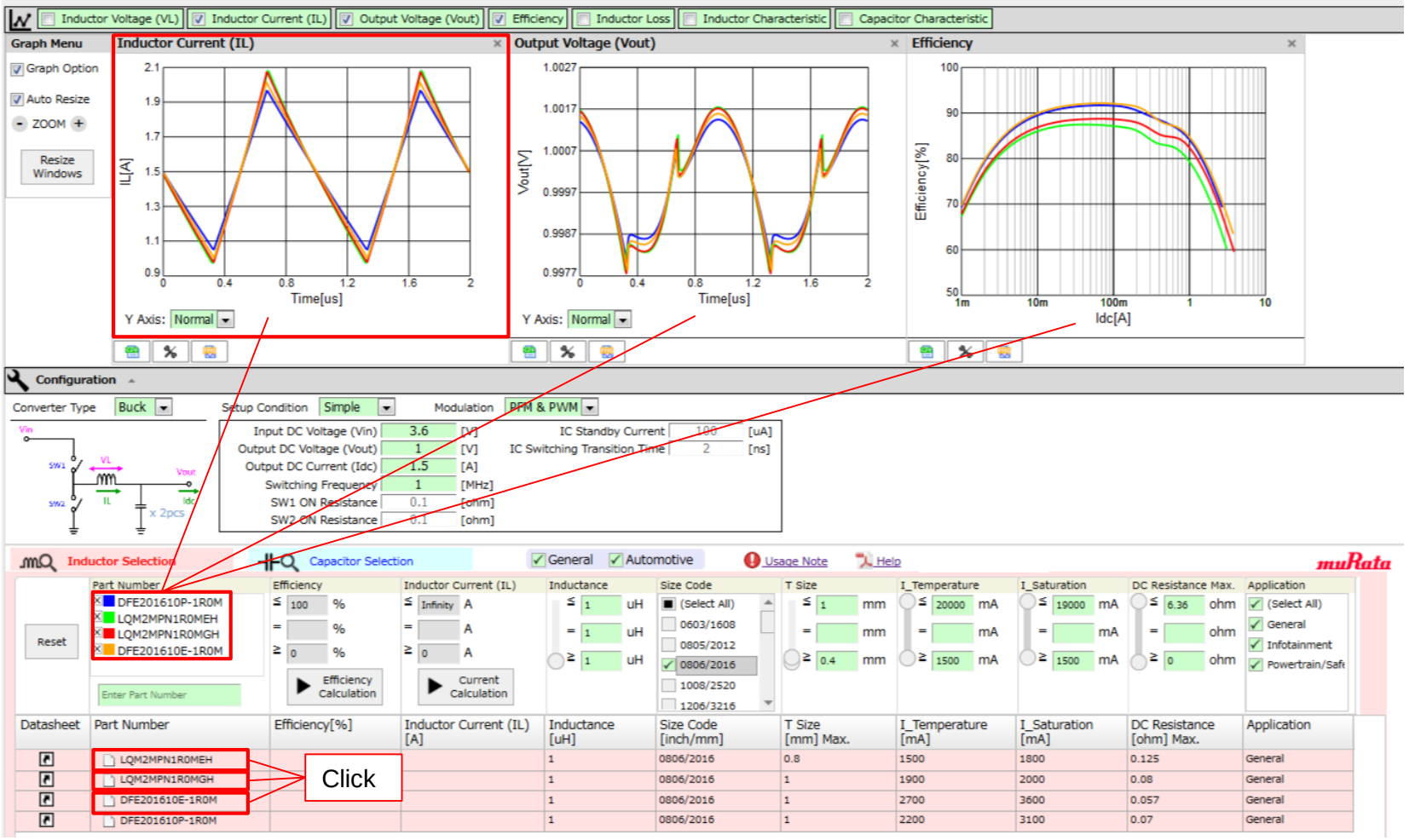
-> While "DFE201610P-1R0M" (and MLCC "GRM186R60G226ME15") are selected, the ripple current, output voltage and efficiency graphs will be displayed.



# 3. Use Cases

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

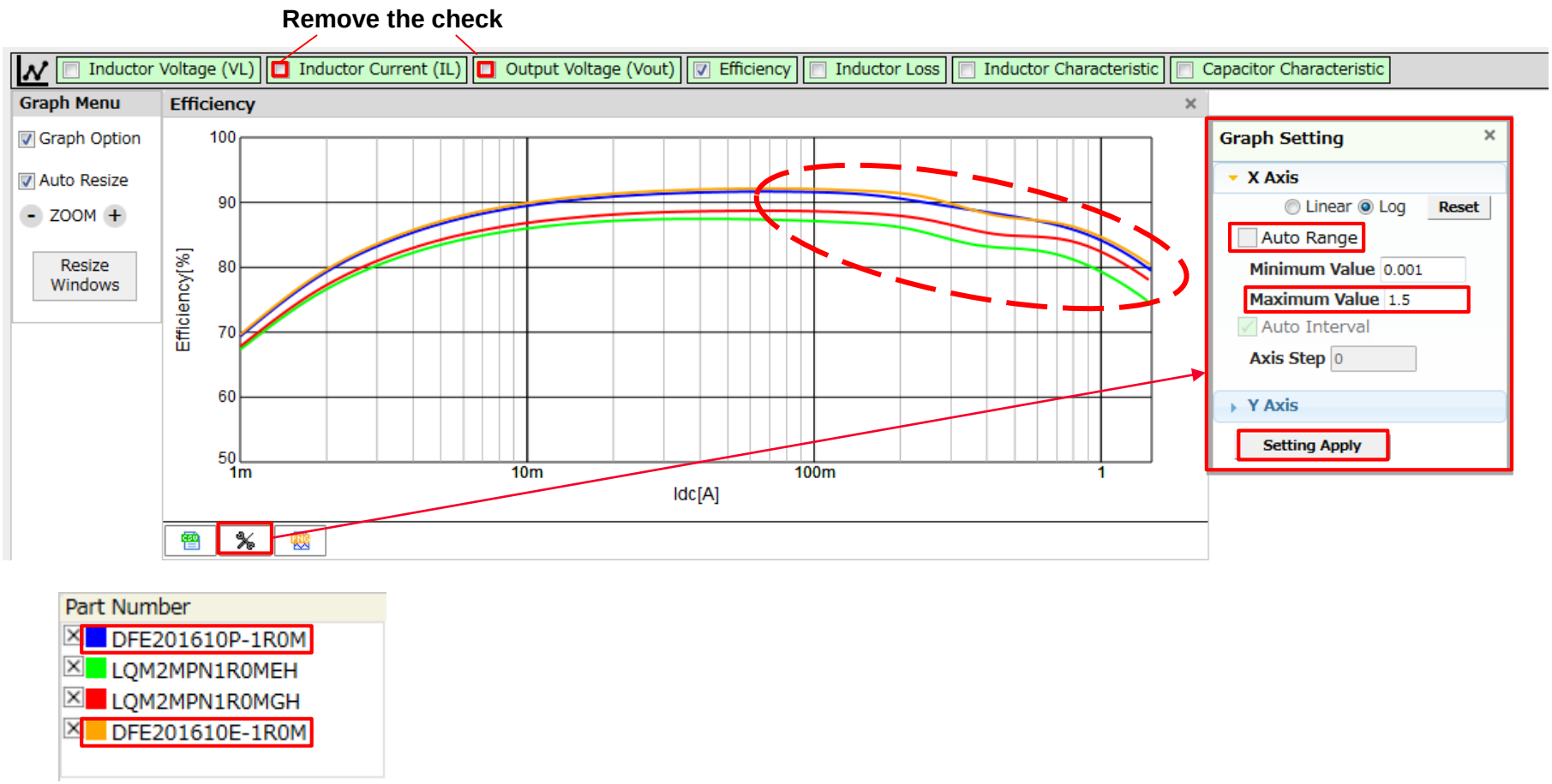
-> The graph shows that there is no great difference in the ripple current for all of the part numbers.
Next, look at the efficiency graph.



# 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)

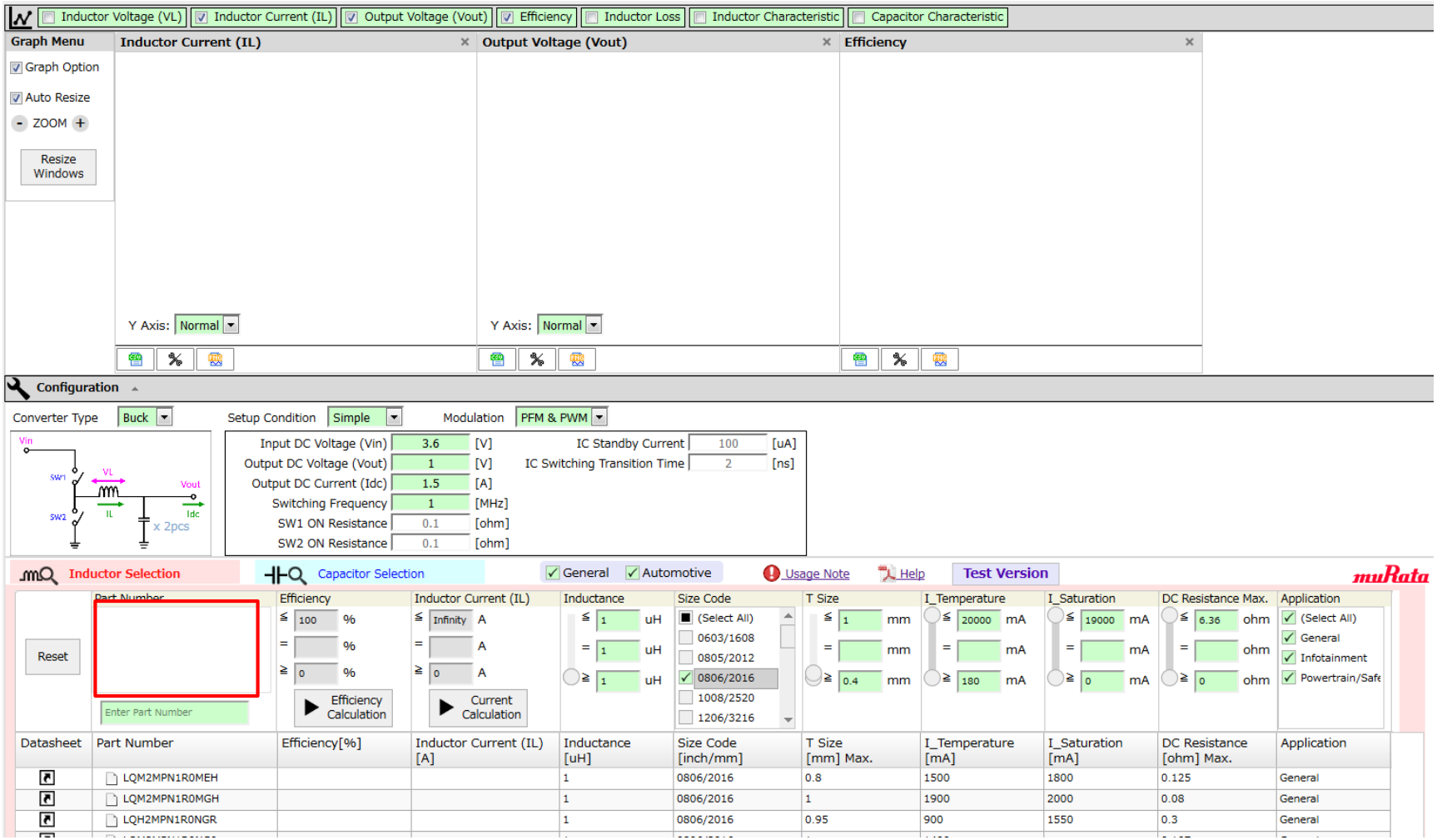
Next, it was determined to evaluate a high frequency DC-DC converter aiming for downsizing.

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 1µH -> 0.47µH

# 3. Use Cases

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

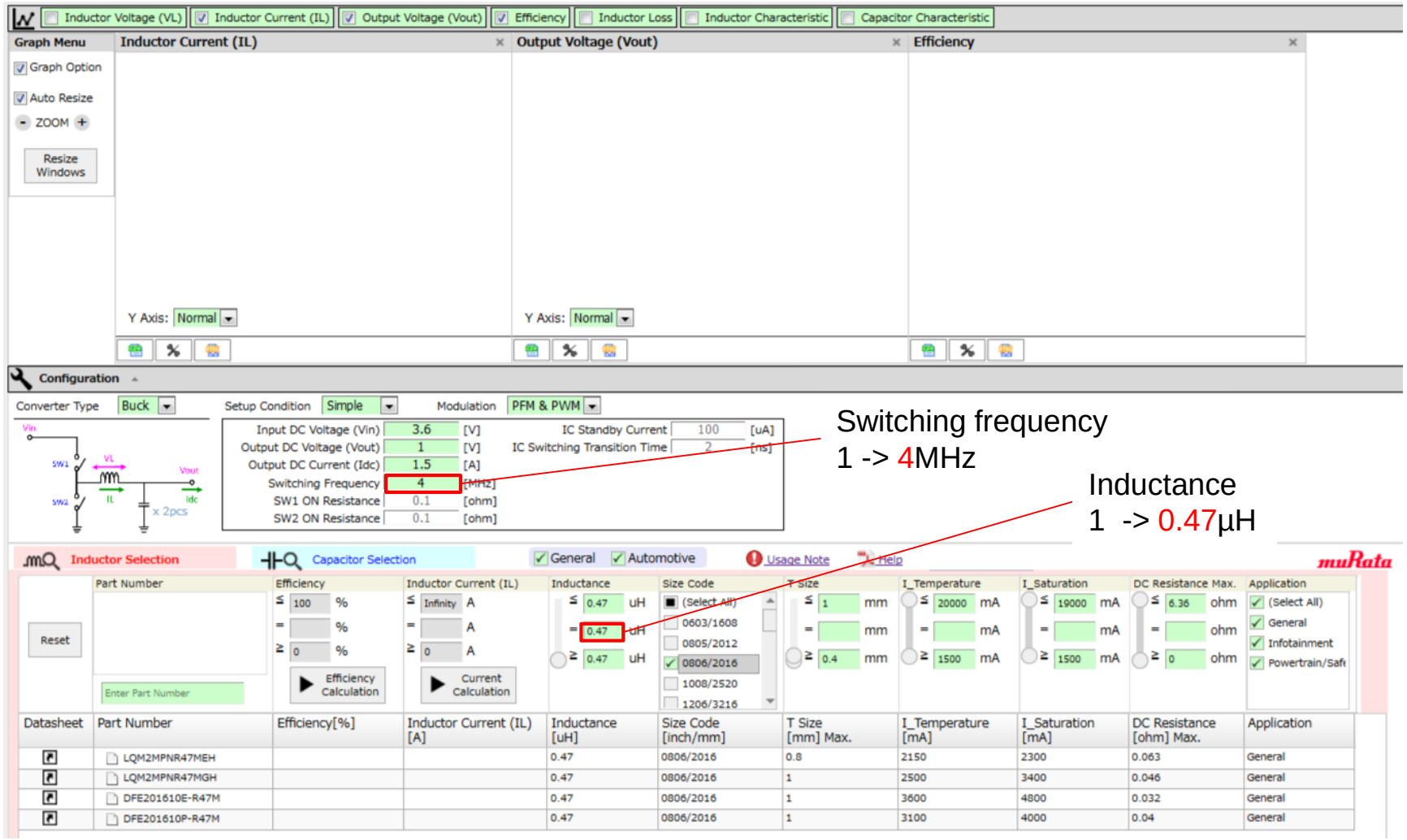
-> Click the ☒ of ☒ LQM2MPN1R0NG0 to delete all the graph curves.



# 3. Use Cases

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

-> Change the inductance and switching frequency.



# 3. Use Cases

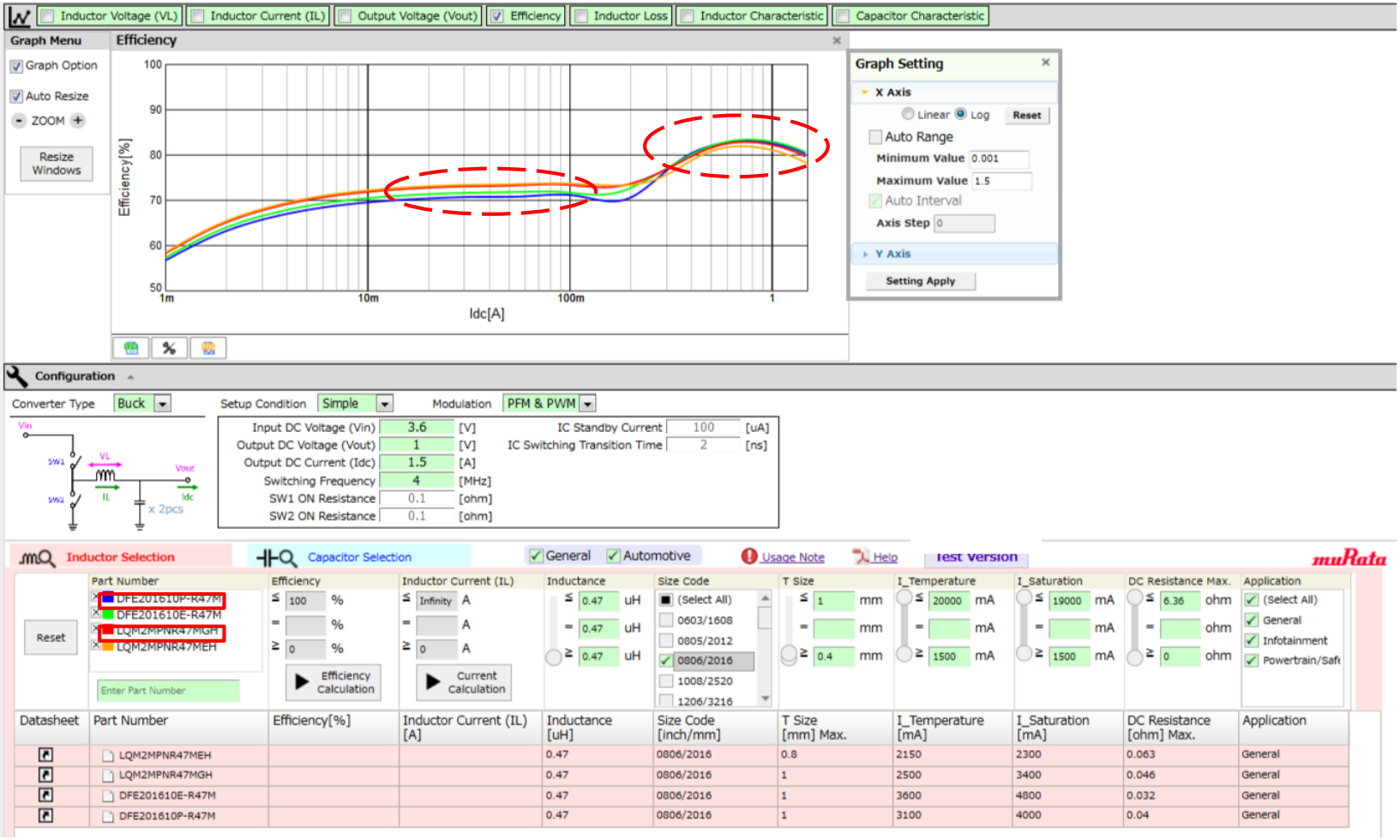
## 3-1. Design of DC-DC Converter for Mobile Devices (9/10)

-> 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

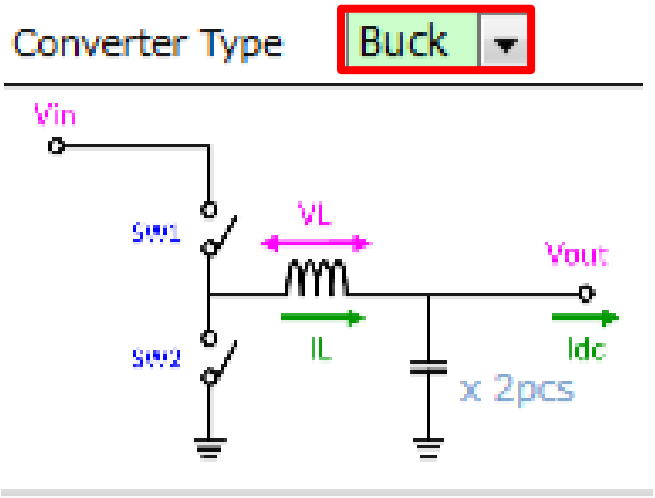
## 3-1. Design of DC-DC Converter for Mobile Devices (10/10)

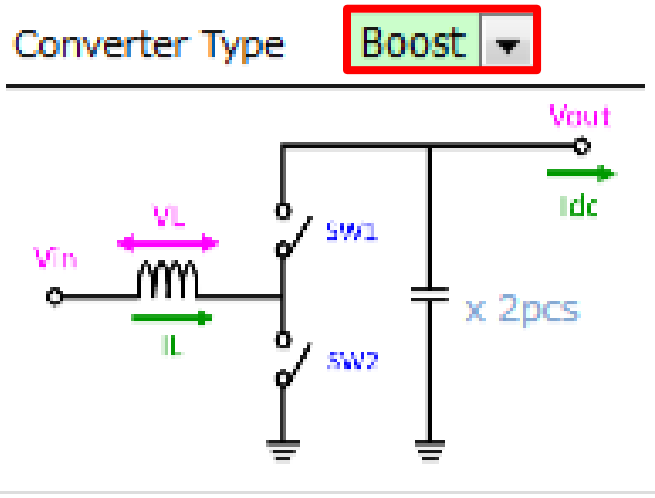
-> The same as p.13, expands the efficiency graph only. In this graph, "DFE201610E-R47M" and "LQM2MPNR47MGH" can be selected as high efficiency power inductors which satisfies the initial conditions.



# 4. Details of Operation

## 4-1. Circuit Selection Field



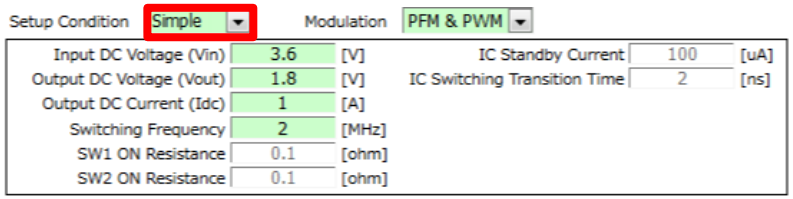



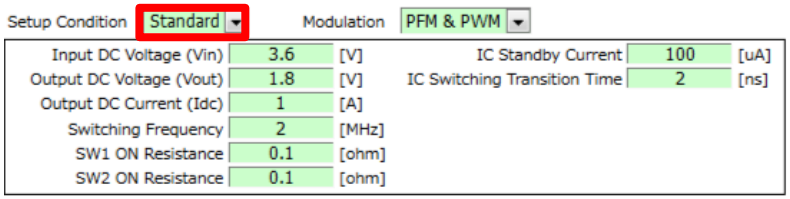

-> Select Buck (Buck type) or Boost (Boost type) as the type of DC-DC converter circuit.

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)




-> 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 |

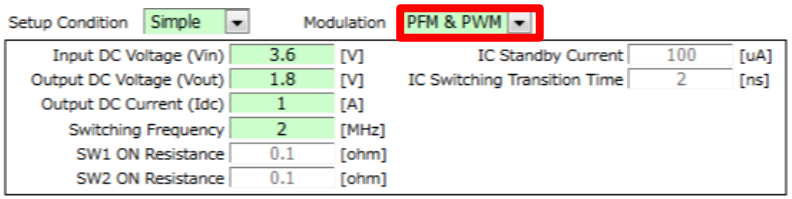
-> Advanced calculation can be set by selecting the Standard mode and entering the basic characteristics of the PMIC (red check mark).

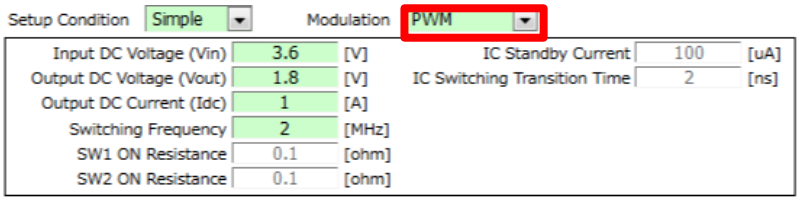
* This function can be used by first selecting the Simple mode to execute the calculation, and then performing a detailed verification of the results in Standard mode.

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)



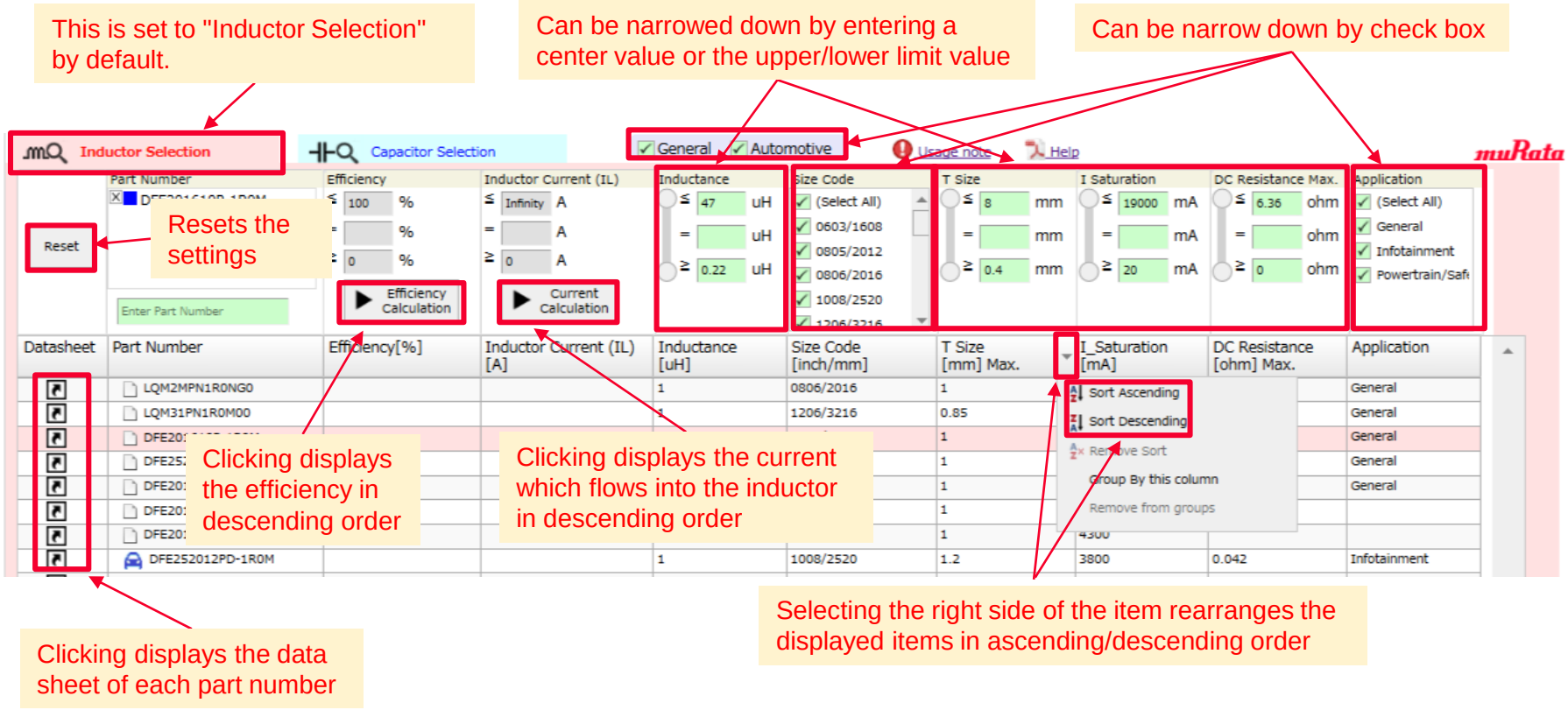

-> As a modulation mode of a circuit, two types of modes including "PFM & PWM" and "PWM" can be selected.

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

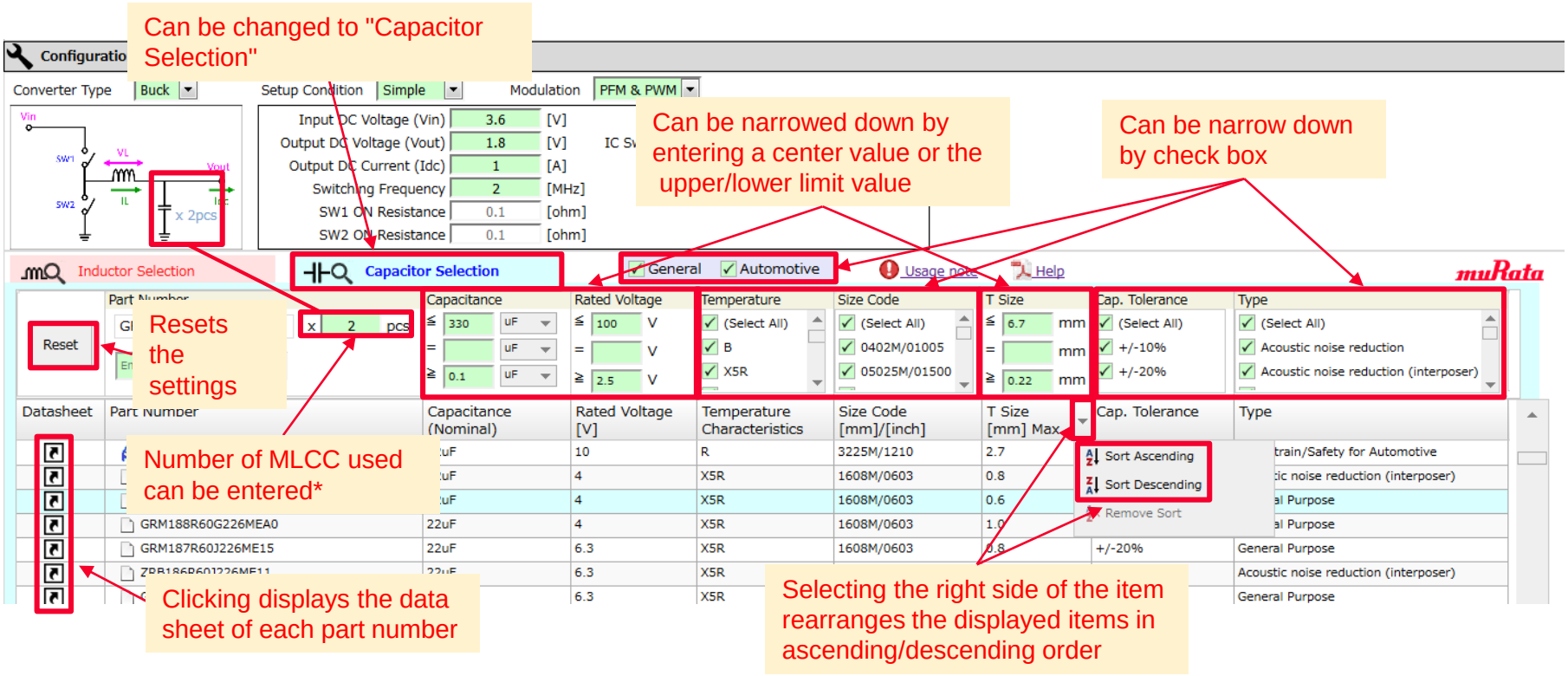
## 4-3. Part Number Selection Function (1/2)




-> 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)



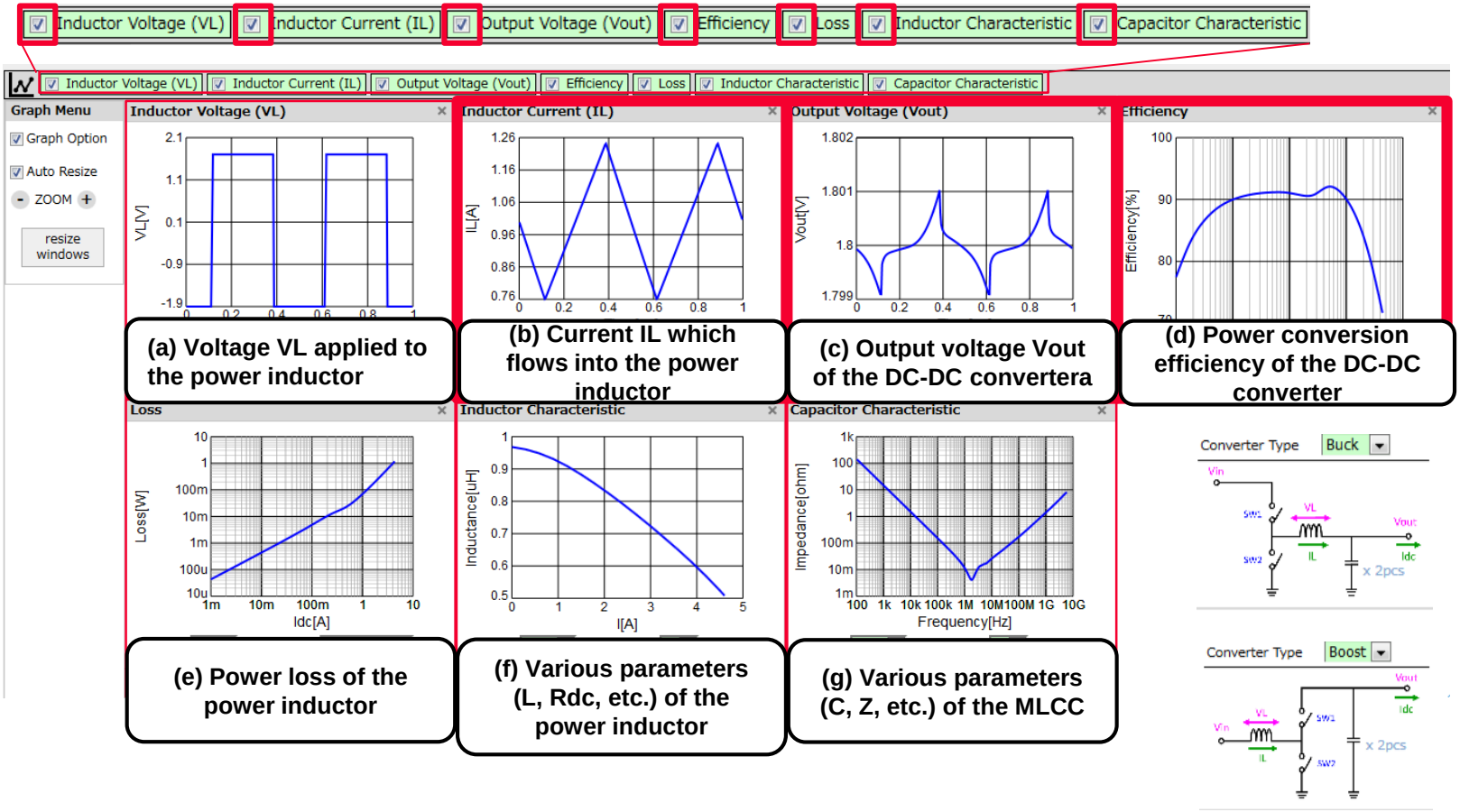

* Irrespective of the "Buck" or "Boost" mode, a number of MLCC used can be entered for one part number.

-> 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)

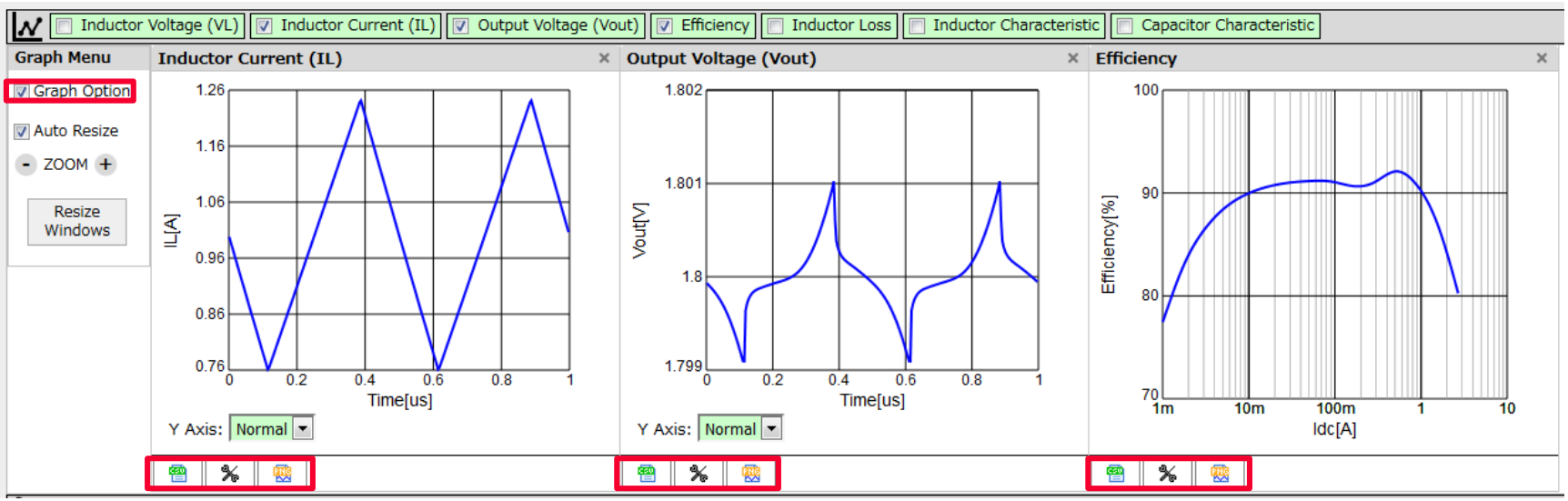
**Check the item(s) to be displayed**




-> 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.

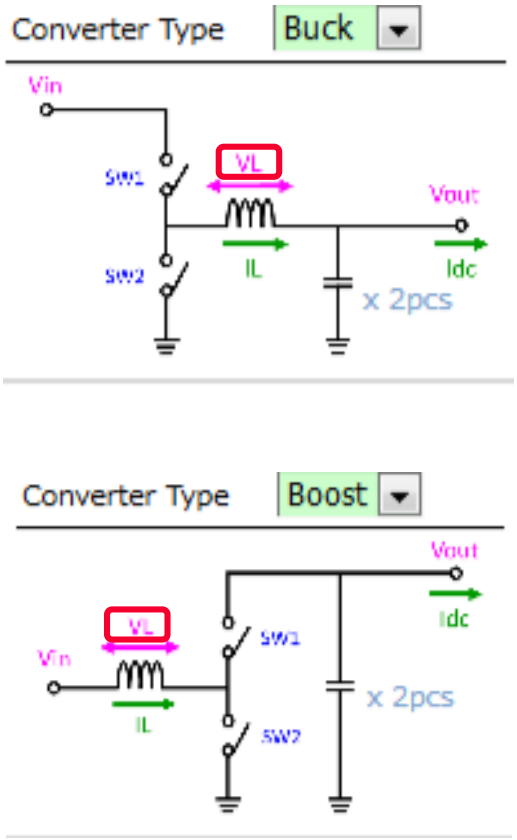
: CSV output : Change of graph settings : Saves image (PNG format)

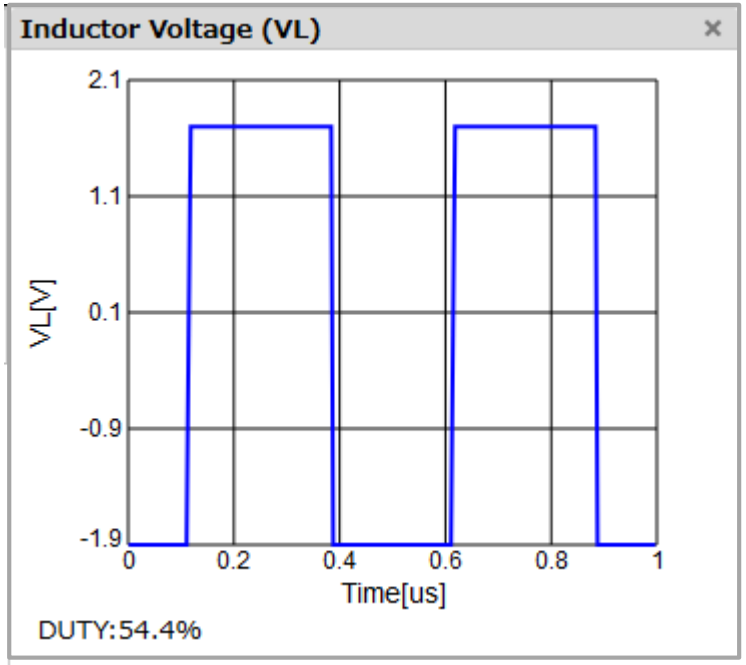
* Unchecking the [Graph Option] will close the buttons.

# 4. Details of Operation

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

(a) Voltage VL applied to the power inductor



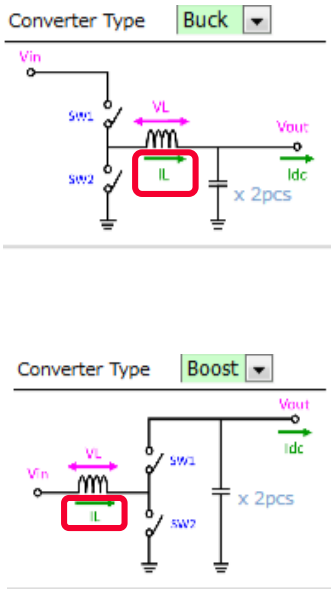



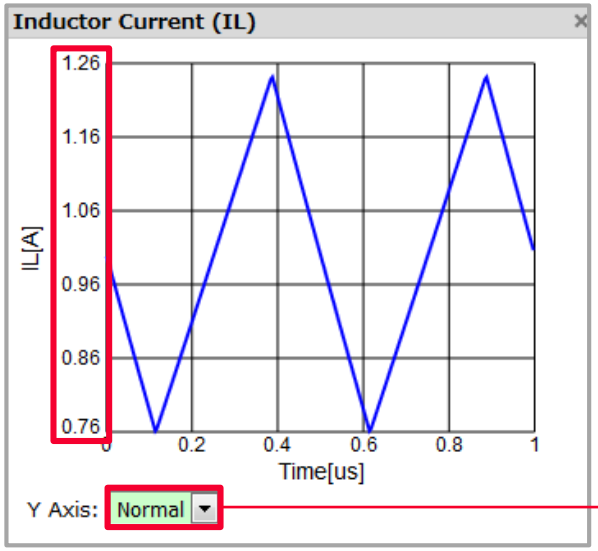

-> The upper/lower limit voltage of VL is determined by the input voltage Vin and the output voltage Vout.
The Duty ratio is determined by the ratio of Vout to Vin and the ON resistance of the IC, etc.

# 4. Details of Operation

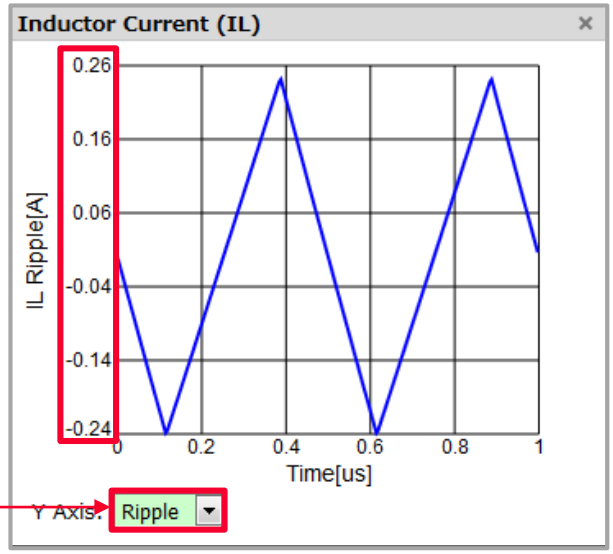
## 4-4. Graph Output Function (4/10)

(b) Current IL 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.

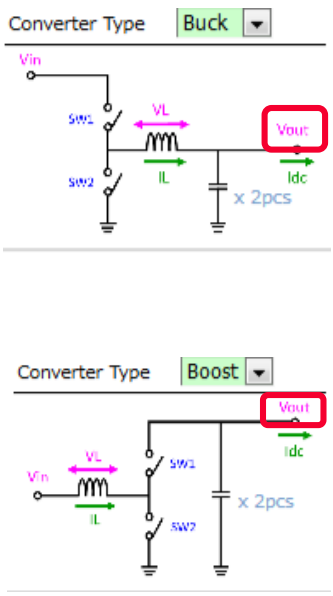
-> The current waveform of IL is displayed as a triangular wave. This is generally called the "ripple current."

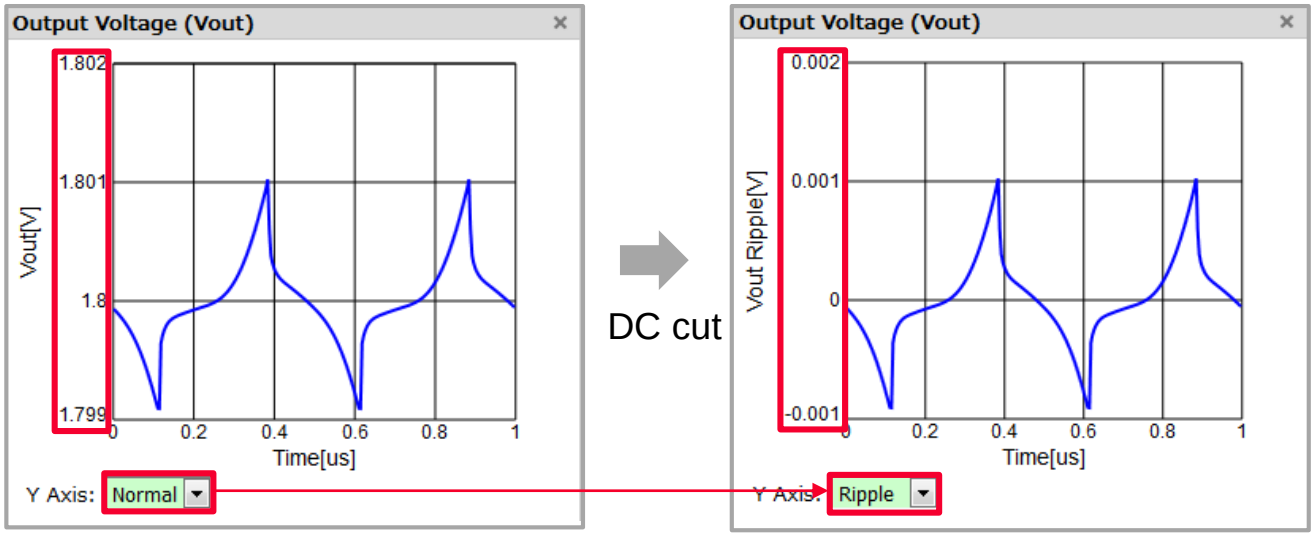
[Notes]
The amplitude of the ripple current is inverse proportion to the L value of the power inductor. When the L value drops the amplitude suddenly increases due to the current bias characteristics of the inductor. This will cause a defect where the DC-DC converter itself does not operate normally,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

# 4. Details of Operation

## 4-4. Graph Output Function (5/10)

(c) Output voltage Vout



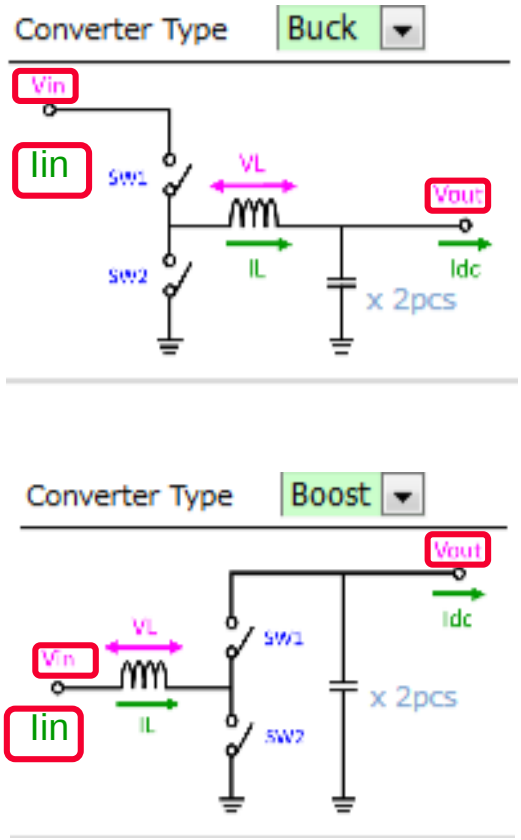

* Setting the Y-Axis from "Normal" to "Ripple" cuts the DC component, and only displays the current amplitude.

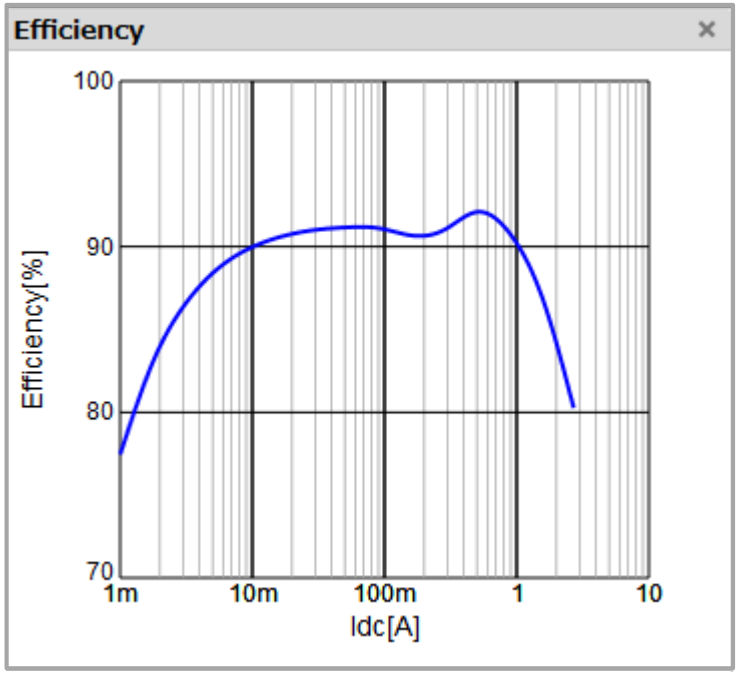
-> The waveform of the output voltage is one of the main performance indexes of a DC-DC converter. This is generally called the "ripple voltage."

[Notes]
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



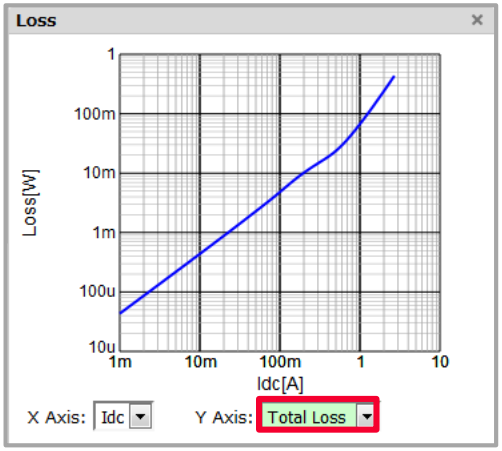



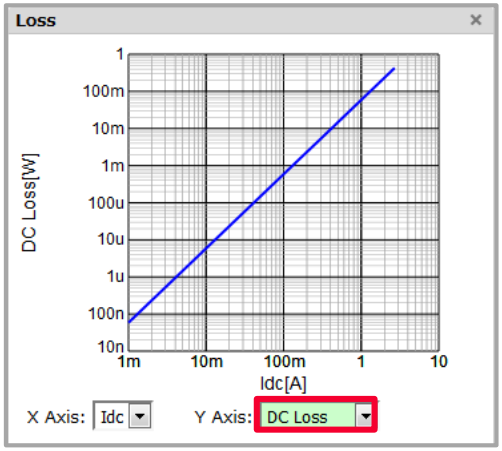

Power conversion efficiency = $\frac{V_{out}I_{dc}}{V_{in}I_{in}} \times 100[\%]$

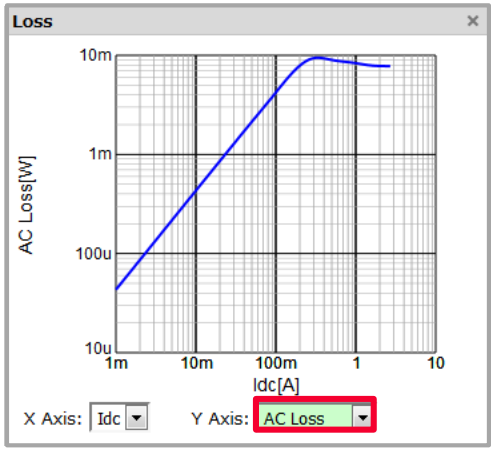
-> The power conversion efficiency is one of the most important performance indexes of a DC-DC converter. Although the efficiency is generally calculated by the above equation, it is calculated from the power loss of the power inductor and the ON resistance of the IC in this software.

# 4. Details of Operation
## 4-4. Graph Output Function (7/10)

(e) Power loss of the power inductor



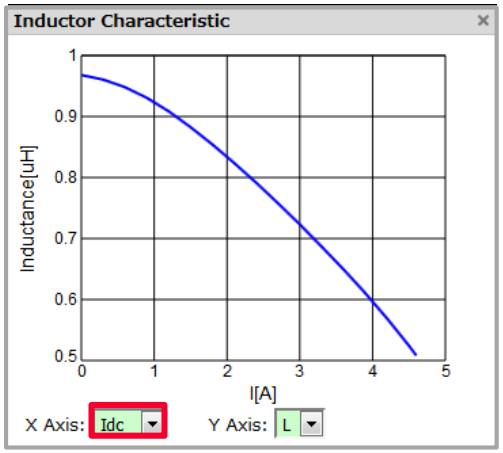

-> The power loss for the Idc of a power inductor can be displayed.

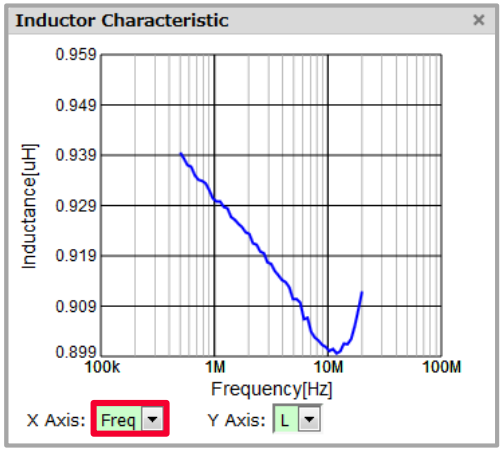
| | |
|---|---|
| Total Loss | Total of the power loss of an inductor (DC Loss + AC Loss) |
| DC Loss | Power loss when DC current is flowing into the inductor |
| AC Loss | Power loss when AC current is flowing into the inductor |

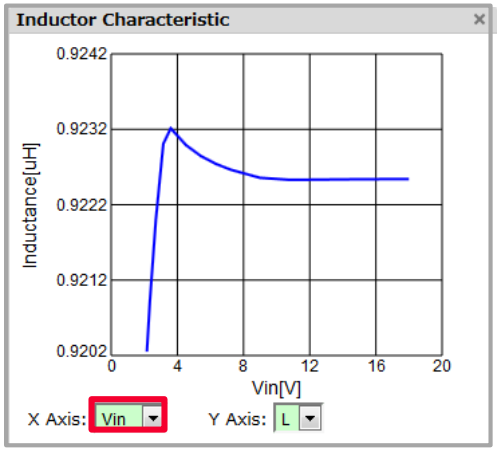
# 4. Details of Operation

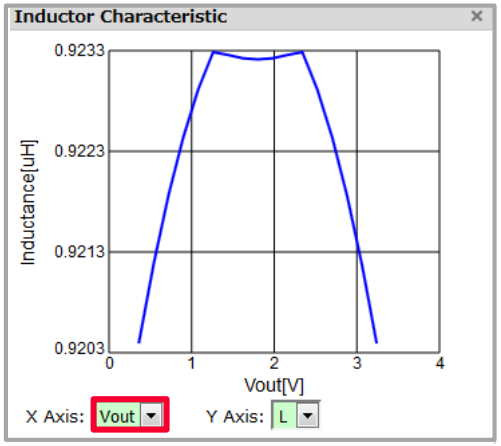
## 4-4. Graph Output Function (8/10)

(f) Various parameters of a power inductor



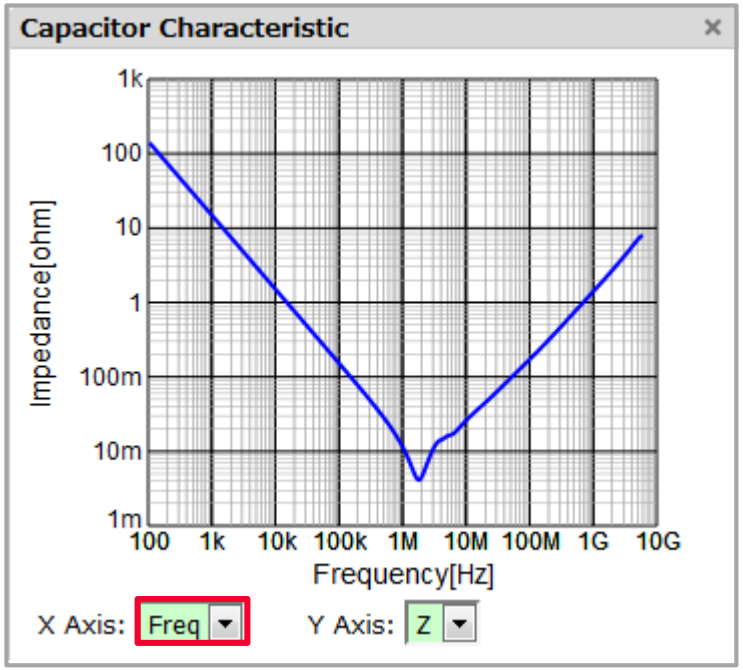



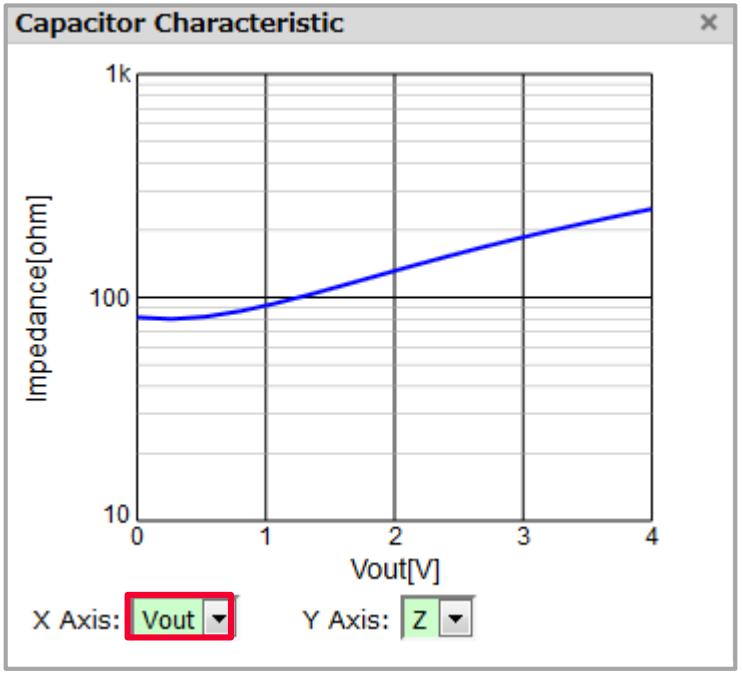

-> A total of 24 characteristics graphs Z/R/X/C/L/Q can be displayed for the Idc/Freq/Vin/Vout in a power inductor.

# 4. Details of Operation

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

(g) Various parameters of MLCC



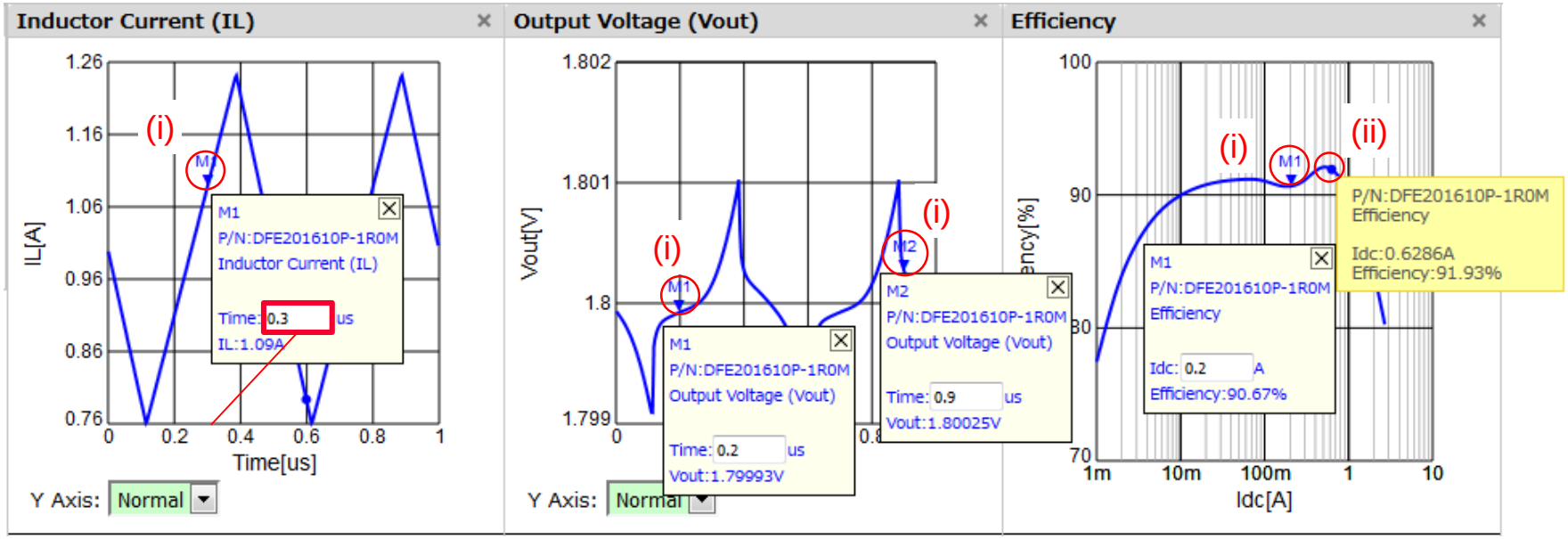




-> A total of 12 characteristics graphs Z/R/X/C/L/Q can be displayed for the Freq/Vout in an MLCC.

# 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.

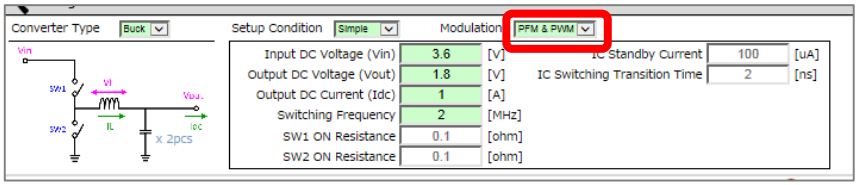
(ii)

- 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

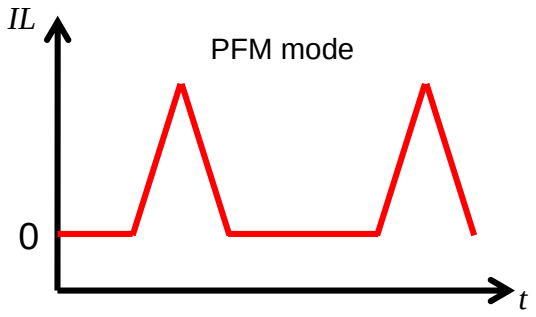
## 4-5. [Supplement] PFM Mode and PWM Mode (1/2)

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

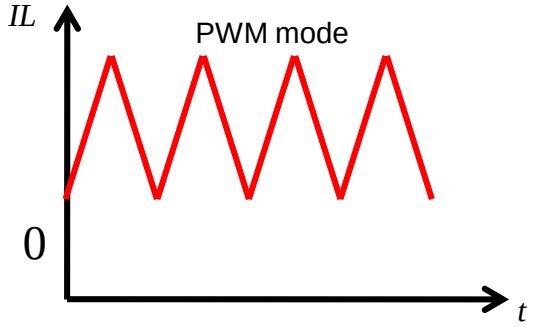



| | |
|---|---|
| **PFM&PWM** | Calculated by automatically switching between PWM and PFM |
| | -> For the purpose of optimization of the efficiency, when the output current Idc is too high the mode is switched to the PWM mode, and when too low, it is switched to the PFM mode (see p.36 for the details).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

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




-> Executes intermittent operation to suppress the switching loss




-> Adjusts the output voltage by the Duty ratio

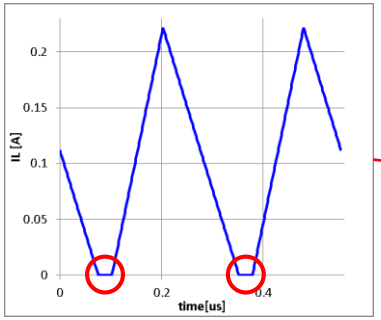
# 4. Details of Operation

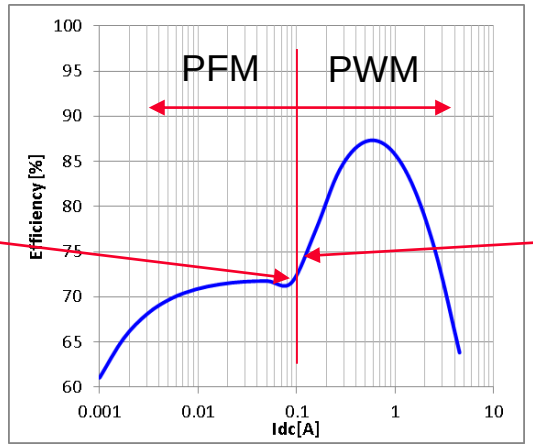
## 4-5. [Supplement] PFM Mode and PWM Mode (2/2)

<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)



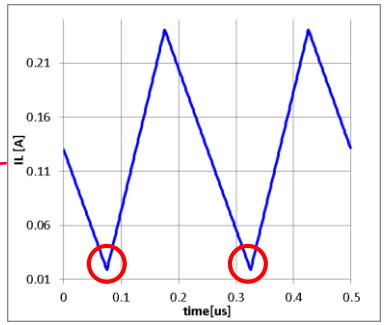




Figure 1
Inductor current waveform
when Idc = 0.09A

Figure 2
Inductor current waveform
when Idc = 0.13A