Introduction of Inductor Selection Tool “MPST" for DC-DC Converters - Detailed Version -

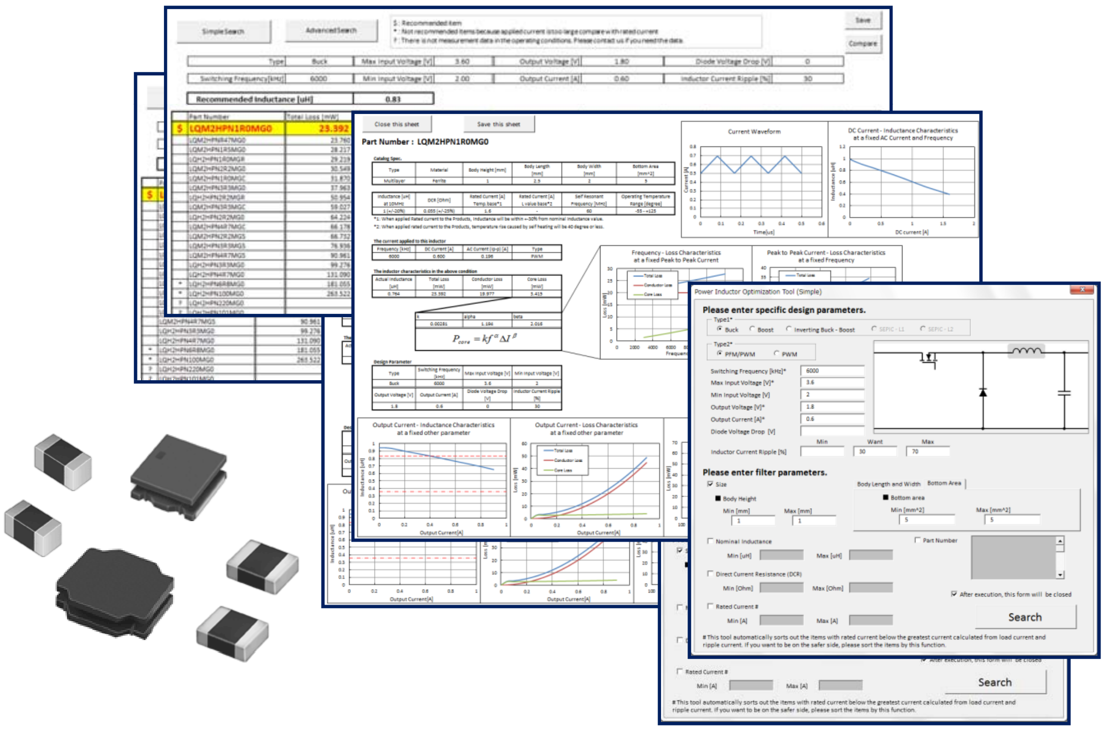
Having trouble selecting power inductors when designing DC-DC converter circuits?

First of all, what is the "ideal" power inductor?

Inductors having the following conditions can be called the ideal inductor.
- Low loss in the target load range
- Having an inductance value with balanced load response and ripple
- Having sufficient bias current characteristics and rated current for the assumed current
- Designable size

However, the "target load range ", "point of load response and ripple balance", "current margin", "designable size" and etc. change according to the application and the design concept of the designer.
In short, the "ideal" power inductor changes with various conditions and requirements.

The Murata Power Inductor Selection Tool (MPST) is a tool to support the process of selecting an ideal power inductor in consideration of these complex factors.



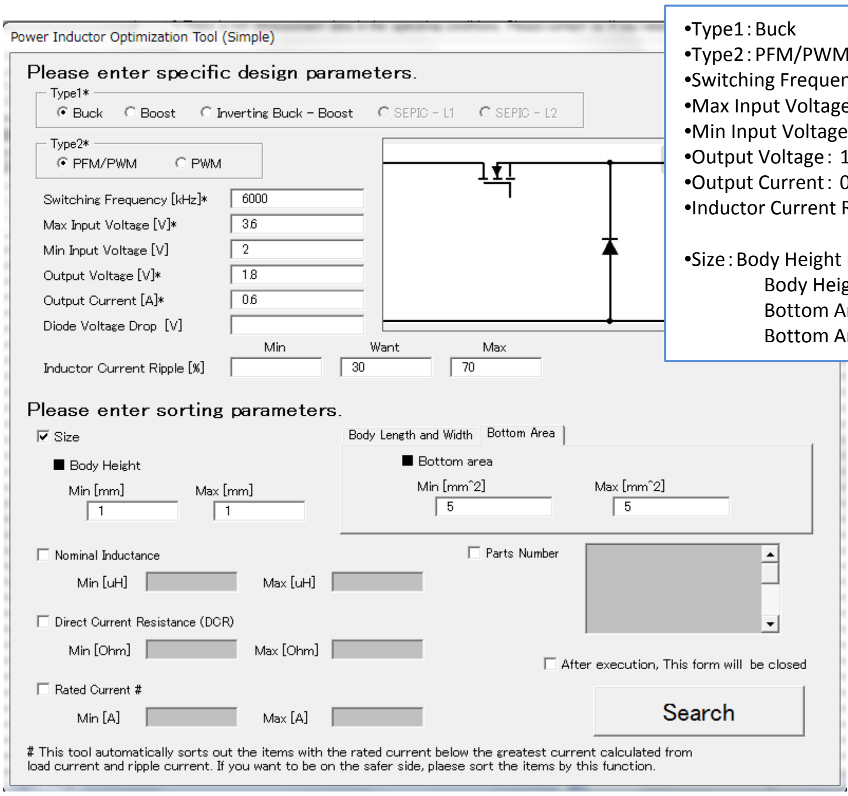
Example of Power Inductor Selection using MPST

* Following shows one example

Assuming a case where a 2.5 x 2.0 x 1.0 mm size conductor is selected for a step-down DC-DC converter for a portable device with 6 MHz operating frequency, 3.6 V input voltage, 1.8 V output voltage and 0.6 A max output current
* Condition focusing on the efficiency at a high load, with an allowable ripple to some extent.

1st step Inputting the Conditions and Searching

Select "Simple Search", input the desired conditions then click "Search" to start the search.



- •Type1 : Buck
- •Type2 : PFM/PWM
- •Switching Frequency : 6000 [kHz]
- •Max Input Voltage : 3.6 [V]
- •Min Input Voltage : 2 [V]
- •Output Voltage : 1.8 [V]
- •Output Current : 0.6 [A]
- •Inductor Current Ripple (Want) : 30%
  (Max) : 70%
- •Size : Body Height min : 1[mm]
  Body Height max : 1[mm]
  Bottom Area min : 5[mm]
  Bottom Area max : 5[mm]

Topics

- This tool supports Buck, Boost and Inverting Buck-Boost.
  The PFM/PWM automatic switching function can also be simulated.
- By specifying the inductor current ripple, the inductance value when the inductor current ripple becomes the ideal value (want) and the Min/Max of the allowable value, will be calculated automatically and reflected in the results.
  * When a value is input in Min/Max, the output results can be sorted to only the components which satisfy the inductor current ripple within the Min/Max value.
- \- The results can be sorted to only the inductors with the desired (want) conditions.
  * Allowable sorting conditions: Size, inductance value, Rdc, rated current, part number

2nd step Confirming the Output Results

Murata's power inductors suitable to the conditions will be displayed in order from the lowest to the highest loss (Total Loss).

Simple Search | Advanced Search

$: Recommended item
* : Not recommended items because applied current is too large compare with rated current
? : There is not measurement data in the operating conditions. Please contact us if you need the data.

Save | Compare

Type	Buck	Max Input Voltage [V]	3.60	Output Voltage [V]	1.80	Diode Voltage Drop [V]	0
Switching Frequency[kHz]	6000	Min Input Voltage [V]	2.00	Output Current [A]	0.60	Inductor Current Ripple [%]	30

Low Loss

Recommended Inductance [uH]	0.83

	Part Number	Total Loss [mW]	Conductor Loss [mW]	Core Loss [mW]	Nominal Inductance [uH]	Actual Inductance [uH]	DCR [Ohm]	Rated Current [A]	Current Ripple [%]	Detail
$	**LQM2HPN1R0MG0**	**23.392**	**19.977**	**3.415**	**1.000**	**0.764**	**0.055**	**1.600**	**32.741**	Detailed Data
	LQM2HPNR47MG0	23.760	14.926	8.833	0.470	0.378	0.040	1.800	66.214	Detailed Data
	LQM2HPN1R5MG0	28.217	25.335	2.882	1.500	0.987	0.070	1.500	25.326	Detailed Data
	LQH2HPN1R0MGR	29.219	25.312	3.908	1.000	1.085	0.070	2.100	23.047	Detailed Data
	LQM2HPN2R2MG0	30.549	28.887	1.662	2.200	1.311	0.080	1.300	19.066	Detailed Data
	LQM2HPN1R0MGC	31.870	28.978	2.892	1.000	0.917	0.080	1.500	27.250	Detailed Data
	LQM2HPN3R3MG0	37.963	36.134	1.829	3.300	1.185	0.100	1.200	21.098	Detailed Data
	LQH2HPN2R2MGR	50.954	48.309	2.645	2.200	1.910	0.134	1.470	13.087	Detailed Data

* The value when the highest load is applied to the inductor with the input conditions will be displayed.

Topics

An evaluation can be performed individually for the core loss and conductor loss. The evaluation of the loss which was conventionally predicted only as an estimate from the DC resistance can now be accurately evaluated.

* Click here for more details on the viewpoint of power inductor loss.

Example:

Part Number	Total Loss [mW]	Conductor Loss [mW]	Core Loss [mW]	Nominal Inductance [uH]	Actual Inductance [uH]	DCR [Ohm]
LQM2HPN1R0MG0	**23.392**	**19.977**	**3.415**	**1.000**	**0.764**	**0.055**
LQM2HPNR47MG0	23.760	14.926	8.833	0.470	0.37	0.040

The overall loss may become lower with a larger DC resistance in some cases.

The values can be seen on the MPST screen without performing an actual evaluation.

The inductance value in an actual use state will be displayed.

Until now, the inductance value in an actual use state (current decreased due to the bias) could only be predicted from the bias current characteristics.
Since the MPST simulation displays the values considering the frequency and current amplitude not only the DC component of the current, more accurate values can be understood.

The inductor current ripple can be evaluated.

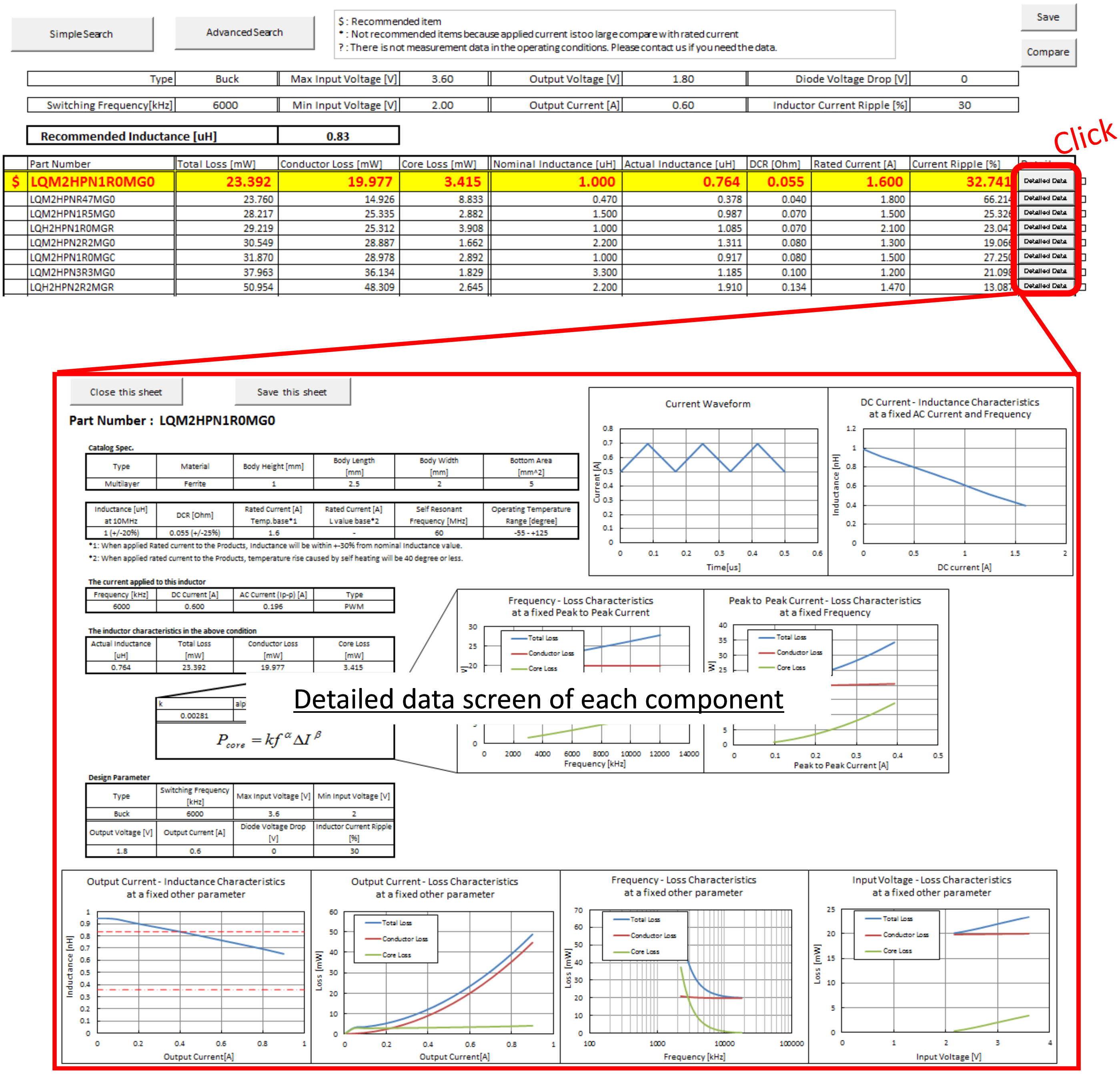
This evaluation allows the selection of inductors from the viewpoint of the ripple voltage and the load response characteristics, not only from the viewpoint of the efficiency.

Relationship between Inductor Current Ripple and Stability & Fast Response

	Ripple Voltage	Fast Response (Load Response Characteristics)
Inductor current ripple **High**	High	Good
Inductor current ripple **Low**	Low	Poor

3rd step Confirming the Detailed Data

When the "Detailed Data" button on the right end of the column is clicked, a detailed data sheet will be displayed for each inductor.



Type	Buck	Max Input Voltage [V]	3.60	Output Voltage [V]	1.80	Diode Voltage Drop [V]	0
Switching Frequency[kHz]	6000	Min Input Voltage [V]	2.00	Output Current [A]	0.60	Inductor Current Ripple [%]	30

Recommended Inductance [uH]	0.83

	Part Number	Total Loss [mW]	Conductor Loss [mW]	Core Loss [mW]	Nominal Inductance [uH]	Actual Inductance [uH]	DCR [Ohm]	Rated Current [A]	Current Ripple [%]
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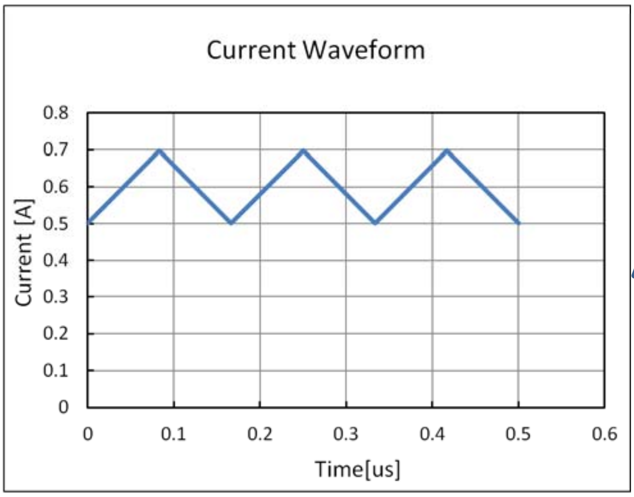
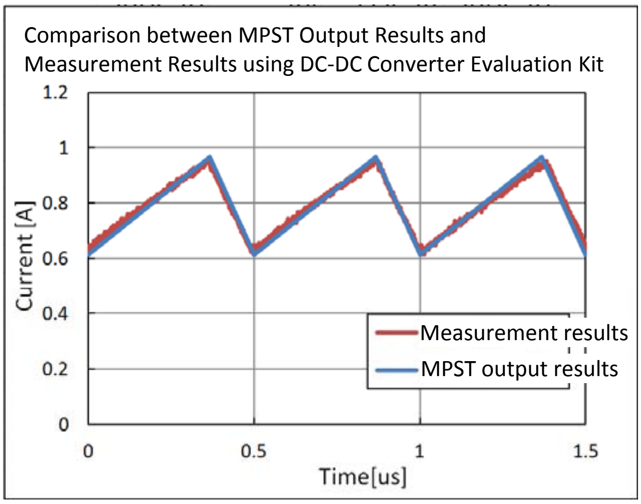
The data required to select inductors, from the basic catalog specifications to graphs of the characteristic fluctuations assuming actual use, will be displayed collectively in one sheet.

<Meanings and Intentions of the Graphs in the Detailed Data Screen>

■Current Wave form

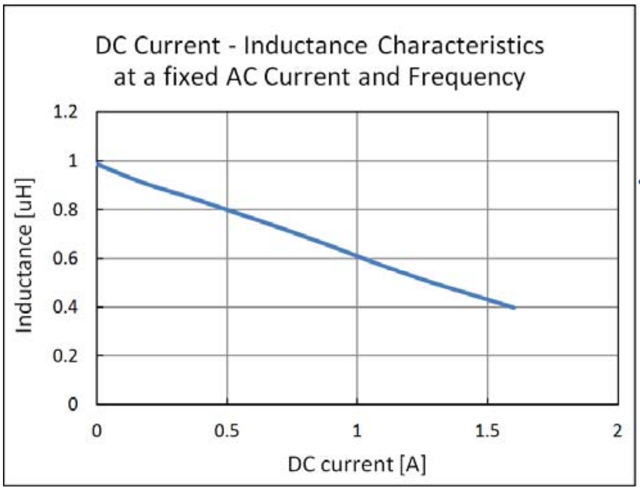


Current waveform flows to an inductor under set conditions

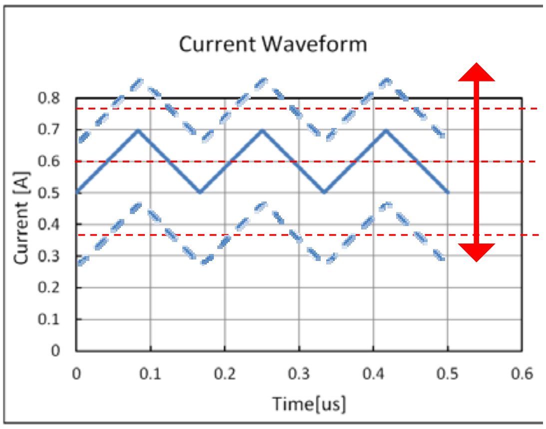


Results extremely close to a measurement can be acquired.

■DC Current – Inductance Characteristics



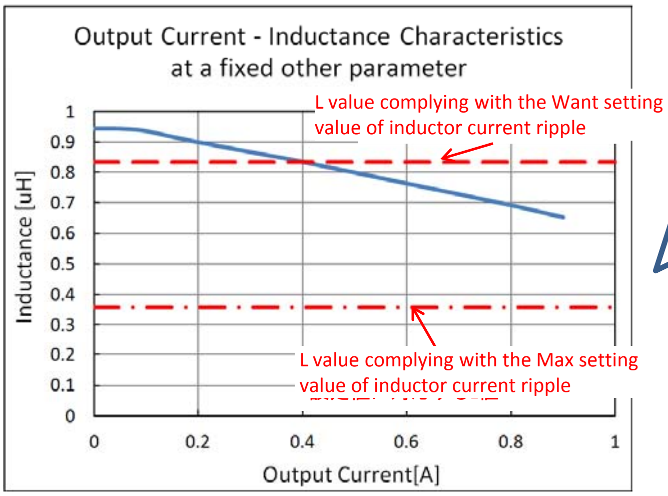
Change of the inductance value when only changing the DC component of the current without changing the current amplitude



This graph shows the change of the inductance value when the triangular wave of the current waveform is moved up and down in parallel.

* The value becomes almost equivalent to the bias current characteristics.

■Output Current – Inductance Characteristics



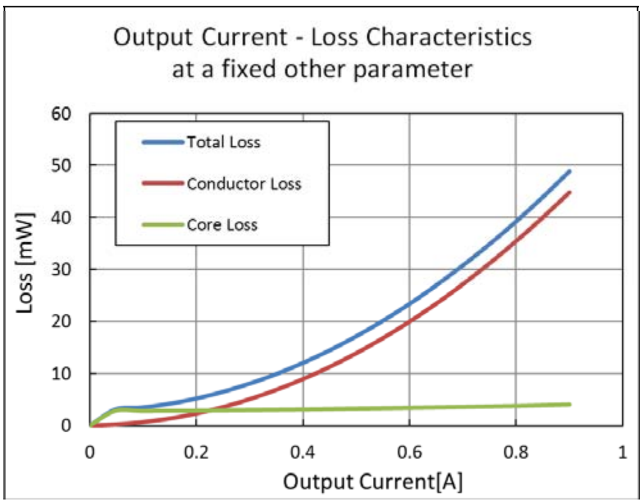
Change of the inductance value when the output current is changed

When the output current is changed, the current amplitude will also change.
The characteristics in consideration of this change are displayed in this graph.
Changes of the inductance value closer to actual conditions than the simple bias current can be evaluated.

Example: Changes of the current amplitude by changing the output current
@LQM2HPN1R0MG0

Output Current [A]	Current Amplitude [A]
0.6	0.196
1.0	0.452
1.4	0.522

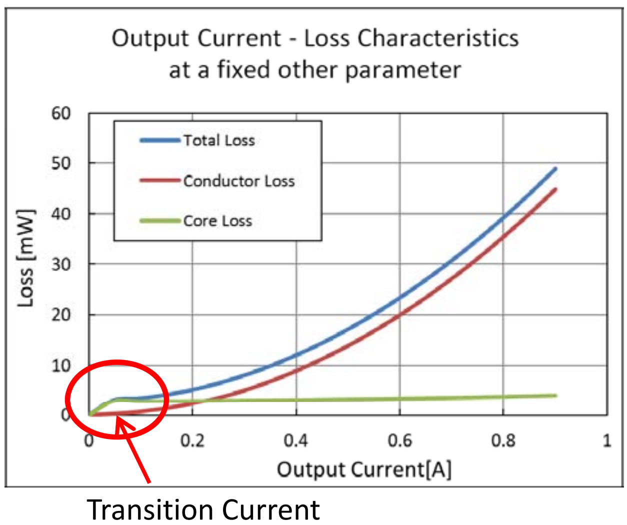
■Output Current – Loss Characteristics



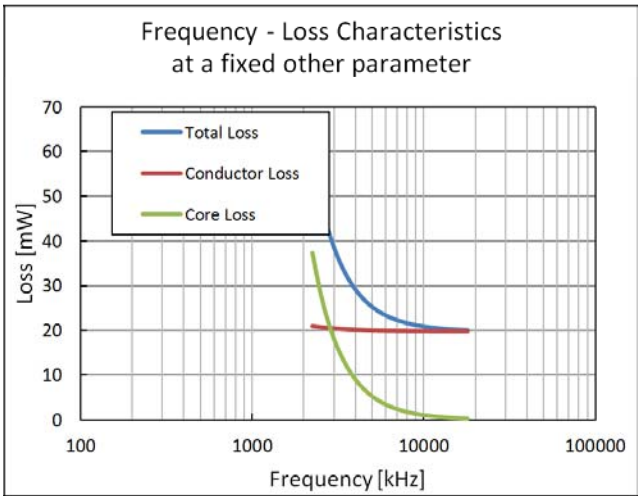
Changes of loss when the output current of the DC-DC converter is changed

Changes of loss from high load to low load can be evaluated.

The current (transition current) which changes from PFM to PWM can also be estimated.



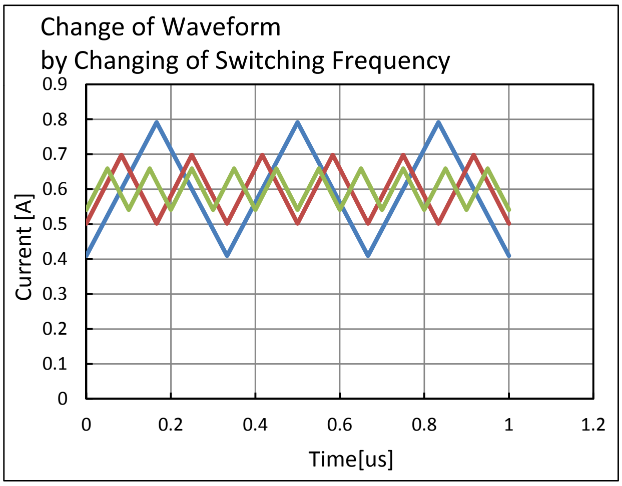
■Frequency –Loss Characteristics



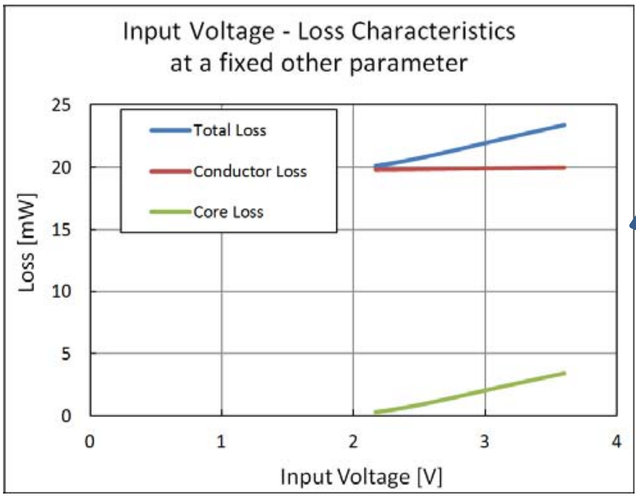
Changes of loss when the switching of a DC-DC converter is changed

When the switching frequency is changed, the current waveform will change greatly. The characteristics in consideration of this change are displayed in this graph.

This can be used as a reference when the IC operating frequency has not been established.



■Input Voltage –Loss Characteristics



Changes of loss when the input voltage of a DC-DC converter is changed

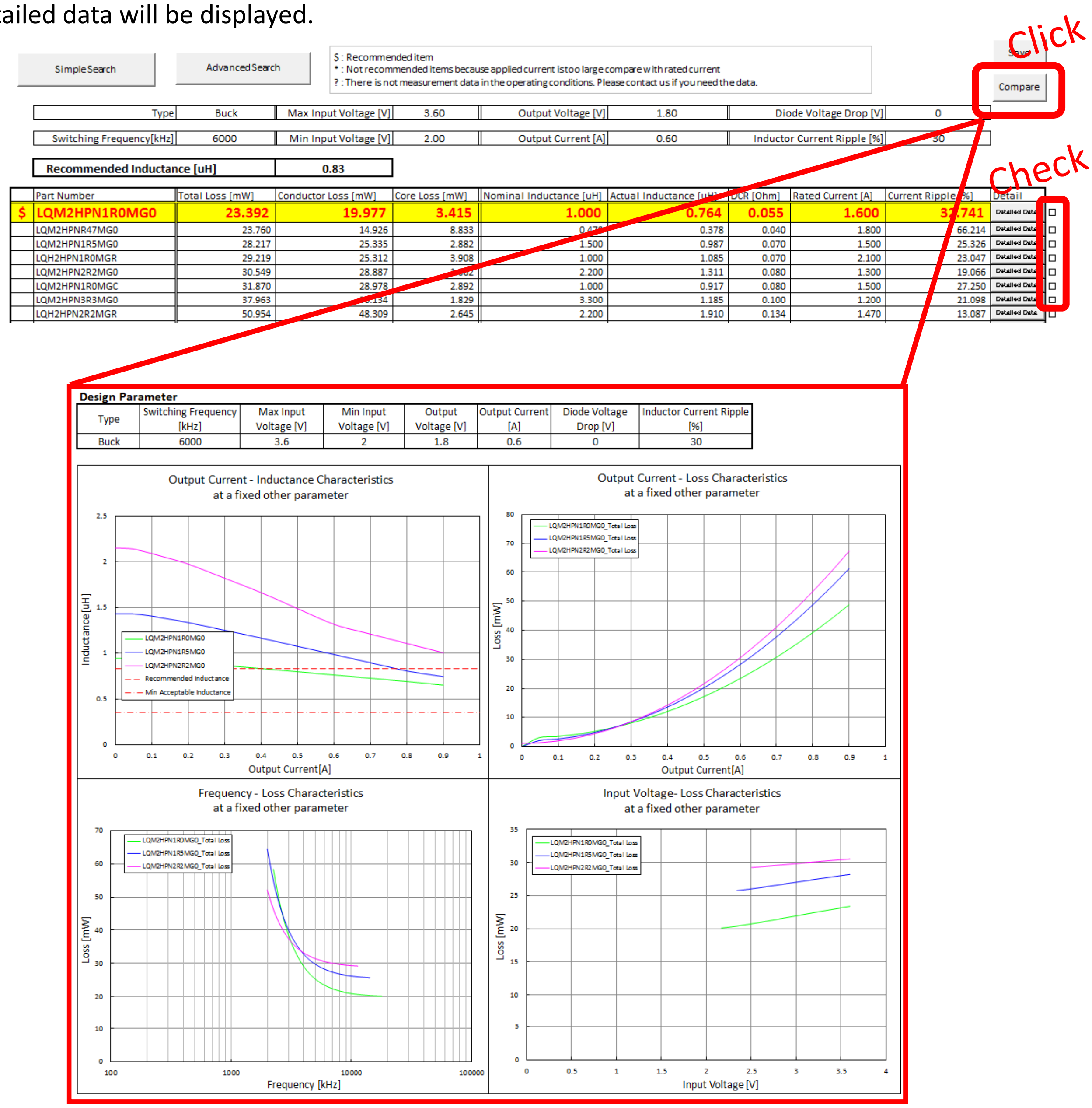
This graph shows the change of loss when the input voltage of a DC-DC converter is changed.
The following cases are assumed for the evaluation.

- When designing portable devices:
  Evaluation of loss when the voltage deteriorates by consumption of a battery

- (For IC designers)
  When setting the reference component of a DC-DC converter IC:
  Evaluation of an inductor ideal for the overall input voltage within the specification range

4th step Comparing the Detailed Data

When a check mark is entered in the check box on the right side end of the inductor and the "Compare" button is clicked to select the characteristic items to be compared, the comparison sheet of the detailed data will be displayed.



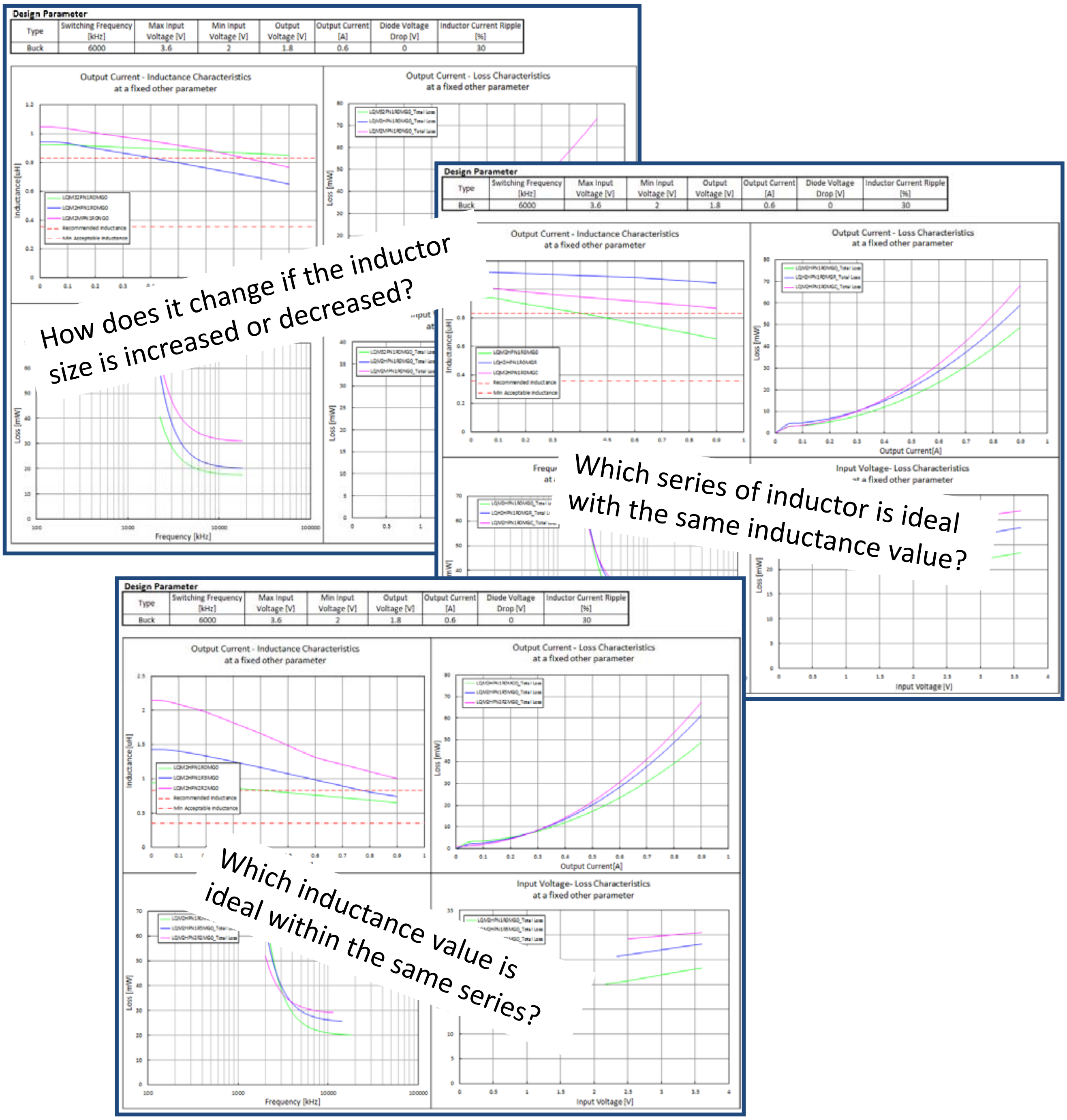
<u>The above graph shows that LQM2HPN1R0MG0 is the most suitable inductor in this example.</u>

Point!

- Even when a current beyond the output current flows, there is a margin to the limit of the inductance value.
- Loss at a high load is superior compared to the other two candidates.
- Even when the input voltage deteriorates, the loss remains the lowest.

* The conclusion changes depending on various conditions, such as when the efficiency is focused on at a low load, or when the ripple must be suppressed.

The ideal power inductor can be selected
by comparing the detailed data from various points of view.



MPST Download Location

Download MPST from the "Design Support Tool" page of Murata's Web site.

MPST (Murata Power Inductor Selection Tool) download page:
http://www.murata.com/products/design_support/mpst/index.html

* MPST is a VBA application (Macro) which operates in Microsoft Excel.
Microsoft® Excel® 2003 or later is required to execute MPST.
In order to execute MPST, it is necessary to validate the execution of the Macro in Microsoft® Excel®. For the method of validating the Macro, refer to the Microsoft® Excel® handling method.
Microsoft and Excel are registered trademarks, or trademarks of Microsoft Corporation in the U.S. and other countries.

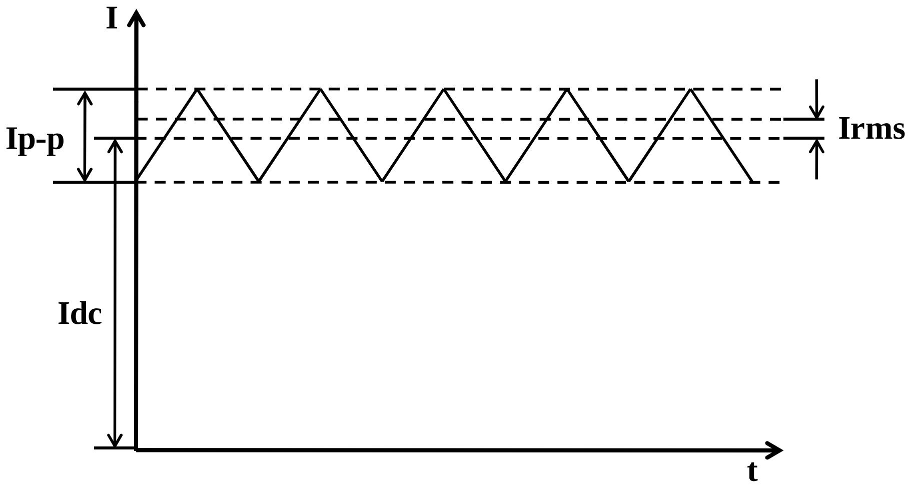
Supplemental Materials

What is an inductor current ripple?

The inductor current ripple refers to the size of the AC component to the DC component of the current which flows into the inductor.

* Keep in mind that the inductor current ripple is different than the "ripple rate" which is often mentioned in the characteristics of DC-DC converters.
The "ripple rate" refers to the size of the noise component (fluctuation of voltage) which appears in the output voltage, and is different from the "Inductor Current Ripple" mentioned here.

$$Ripple = \frac{I_{p-p}}{I_{dc}} [\%]$$



This inductor current ripple becomes the index for setting the derating for the rated current of the IC.

Also, there are the following relationships for the characteristics of DC-DC converters.

Relationship between Inductor Current Ripple and Stability & Fast Response

	Ripple Voltage	Fast Response (Load Response Characteristics)
Inductor current ripple **High**	High	Good
Inductor current ripple **Low**	Low	Poor

Moreover, the characteristics of an inductor are related to the inductance value, and have the following relationships.

Relationship between Inductor Current Ripple and Inductance Value

	インダクタンス値
Inductor current ripple **High**	Low
Inductor current ripple **Low**	High

* For details, refer to the "Inductor Current Ripple (Max)" described on the following page.

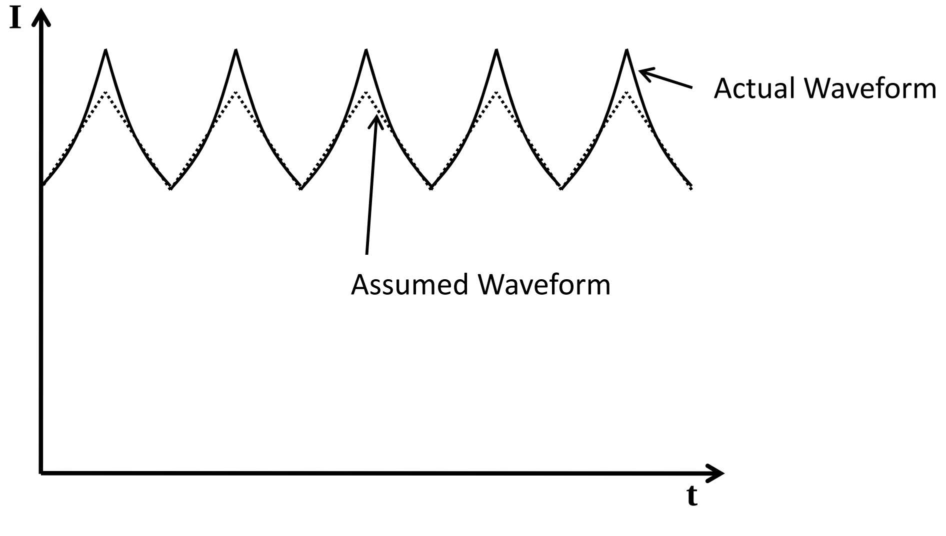
■Inductor Current Ripple（Want）

MPST is structured so that the inductance value which becomes the inductor current ripple is automatically calculated and displayed in the "Recommended Inductance" of the output results, by inputting the ideal value in the "Want" field of the "Inductor Current Ripple" of the input form.

■Inductor Current Ripple（Max）

When an inductor with poor bias current characteristics is used, the inductance value will deteriorate due to the increase in the current (inductor current ripple becomes higher), which causes unstable operation.
In the worst case, there is a risk of causing serious damage to circuits, such as destruction of ICs.
Therefore, the restrictions to "prevent the triangular wave of the amplitude from becoming larger than it is now in the operating state", and the function (Max Inductance Current Ripple) to select components are provided in MPST.
When the "Max Inductance Current Ripple" is specified, inductors in which a current flows more than the current ripple specified at the time of a maximum load (without having the necessary bias characteristics) will be excluded automatically from the search results.

* The "Min Inductance Current Ripple" is the limiting value to prevent a DC-DC converter from having a poor response characteristic due to the inductance being too high.



Current waveform when an inductor having poor characteristics is used for the required bias current characteristics

Viewpoint of Loss in Power Inductors

Inductor loss in a DC-DC converter consists of Core Loss (Pcore) and Conductor Loss (Pcond) as shown below.

$$P = P_{cond} + P_{core}$$

Conductor Loss (Pcond) is the loss which mainly originates in a DC component, and is expressed as follows using the DC resistance (Rdc) and the current DC component (Idc).

$$P_{cond} = R_{DC} I_{DC}{}^{2}$$

Basically, this value can be calculated if the value of the DC resistance is understood. Conventionally, the power inductor loss was only predicted from this value.

On the other hand, the Core Loss (Pcore) is the loss which mainly originates in the AC component, and is expressed as follows using the AC resistance (Rac) and the current AC component (Irms).

$$P_{core} = R_{AC} I_{rms}{}^{2}$$

Since the AC resistance (Rac) and the current AC component (Irms) changes depending on the conditions, such as the frequency, current amplitude, bias current and etc., it was difficult to calculate this value accurately.
Actually, this Core Loss is a component which can not be disregarded, as there are cases where a value larger than the conductor loss is taken in conditions of high frequency and low load.

Murata established a method to accurately evaluate power inductor loss, by measuring the changes in the inductor characteristics caused by the changes of these complicated conditions.
We have constructed an environment where the characteristics of inductors can easily be evaluated, by calculating the values automatically in MPST based on these evaluation results.