# MTAN17819 - Inductor Selection Guide for Buck Converters

## Abstract

This application note gives the guideline needed to design the power stage of a buck converter. Switched mode power converters are very prominent in industry today, and provide high efficiency solutions for a wide range of applications. The buck converter is used to step a voltage down from a higher level to a lower level. The design of the power converter must be optimized to maximize performance and to meet customer requirements. It is important to understand the fundamentals of the buck converter and how to appropriately select the components.

## Buck Converter Basics

A buck converter (step-down converter) is a DC-to-DC power converter which steps down voltage (while stepping up current) from input supply to output load. The Buck Converter is used in power converter circuits where the DC output voltage needs to be lower than the DC input voltage. Switching converters (such as buck converters) provide much greater power efficiency as DC-to-DC converters than linear regulators, which are simpler circuits that lower voltages by dissipating power as heat, but do not step up output current. Efficient power conversion extends battery life, reduces heat, and allows for smaller gadgets to be built.

The basic operation of the buck converter has the current in an inductor controlled by two switches (usually a switch and a diode). The conceptual model of the buck converter is best understood in terms of the relation between current and voltage of the inductor. Some converters have the diode replaced by a second switch integrated into the converter known as synchronous converters. Fig.1 shows the basic configuration of buck converter:

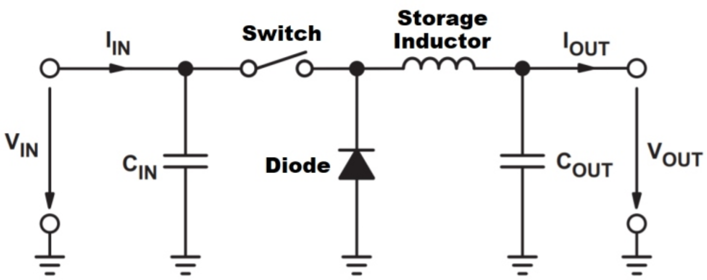


*Figure 1 - Basic Configuration of Buck Converter*

## Essential Parameters for Buck Converter's Storage Inductor Selection

The following four parameters are needed for calculation:
1. Input voltage range: $V_{IN}$ (min) and $V_{IN}$ (max)
2. Output voltage: $V_{OUT}$
3. Max. output current: $I_{OUT}$(max)
4. Switching Frequency of Switching regulator IC used to build buck converter: $f_{sw}$

## Calculations for selecting components of Buck Converter

### *STEP 1 - Calculation of Duty Cycle*

The initial step to calculate the duty cycle (D) for the max. input voltage.

$$\text{Max. Duty Cycle, } D = \frac{V_{out}}{V_{in(max)} \times \eta} \quad \text{.... equation [1]}$$

where,
$V_{IN(max)}$ = max. input voltage
$V_{OUT}$ = output voltage
η = efficiency of the buck converter (example: 95%)

## *STEP 2 - Selection of core material of Inductor based on switching frequency used in Buck Converter*

**Switching Frequency** - The rate at which the DC voltage is switched on and off during the pulse width modulation process in a switching power supply. Increased switching frequency reduces size of associated components such as the inductors, transformers, resistors and capacitors in addition to reduced space requirements on the board and footprints. The switching frequency directly affects the power dissipation in switching elements such as the diode & switch; the inductive and capacitive parasitic elements, and the electromagnetic interference EMI. As demand for higher power densities increase, the frequencies increase, but so do the associated losses such as the switching losses that occur every time the device turns on. These losses therefore put a limit on the practical maximum switching frequency of converter.

Suitable core materials based on switching frequencies:

- **Switching frequency < 150 kHz:** *Iron powder, MnZn and other ferrite mixture*
- **Switching frequency 150 KHz to 1 MHz:** *NiZn, MnZn and other ferrite mixture*
- **Switching frequency > 1 MHz:** *NiZn, Ceramic and other ferrite mixture*

## *STEP 3 - Calculation of Storage Inductor value and its electrical parameters*

An inductor is a passive electronic component that stores energy in the form of a magnetic field. The inductance is directly proportional to the number of turns in the coil. Inductance also depends on the radius of the coil and on the type of core material around which the coil is wound. The inductance value for buck converter can be calculated by using formula given below:

$$\text{Inductance, } L = \frac{[\,V_{in(max)} - V_{out}\,] \times [\,V_{out} + V_D\,]}{[\,V_{in(max)} + V_D\,] \times I_{out} \times 0.3 \times f_{sw}\,]} \quad \text{.... equation [2]}$$

where,
$V_{IN(max)}$ = max. input voltage
$V_{OUT}$ = output voltage
$V_D$ = forward voltage drop across diode
$I_{out}$ = output current
Ripple current factor = 0.2 to 0.4 (taken as 0.3 in this example)
$f_{sw}$ = switching frequency of the converter

*The ripple current is essential in determining the core losses. It is an important parameter for minimizing the power loss of the power inductor.*
*Lower Inductance value - Higher ripple current*
*Higher Inductance value - Smaller ripple current*

**Rated Current of Inductor, $I_R$-** The maximum current the gauge of wire used in the inductor can handle at the rated temperature range. It refers to temperature rise (self-heating of Inductor). Normally, the self heating of inductor range from 20 °C to 40 °C (check datasheet of inductor)

**Saturation Current of Inductor, $I_{SAT}$ -** The point where the magnetic field no longer increases proportionally with an increase in current. The core has become 'saturated'. It refers to decrease in Inductance value of Inductor. Generally, the percentage loss of inductance range from 10% to 40% (check datasheet of inductor)

Nominal current of the inductor, $I_N = I_{out}$

Recommended Inductor's rated current for Buck Converter, $I_{max} = 1.5 \times I_N$ ....equation [3]

**DC Resistance of Inductor, $R_{DC}$ -** The amount of resistance an inductor can offer when a DC signal of 0Hz is passed through it. In practice all inductors will have a small value of DCR associated with it. This is a main parameter for minimizing the power loss of the power inductor. Practically, Higher the inductance causes higher DC resistance in same size Inductors. To minimize the DC resistance, shielded inductors or flat wire inductors are recommended.

**EMC Consideration while selecting Inductors for Buck Converter**
It is highly recommended to choose magnetically shielded inductors like MTSRI, MTSMPI, MTHCMI for critical applications where EMI/EMC consideration is necessary. It is not recommended to route conducting tracks under the inductors & do not place any critical circuit PCBs directly above the inductors.


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## STEP 4 - Calculate Inductor Ripple Current

Inductor ripple current can be calculated by using below equation:

$$\text{Inductor Ripple Current, } \Delta I_L = \frac{(V_{in} - V_{out}) \times D}{f_{sw} \times L} \qquad \text{.... equation [4]}$$

where,
$V_{IN(max)}$ = max. input voltage
$V_{OUT}$ = output voltage
D = duty cycle
$f_{sw}$ = min. switching frequency of the converter
L = selected inductor value

## STEP 5 - Diode Selection

Schottky diodes have much higher peak current rating than average rating. To reduce power losses, Schottky diodes are recommended. The forward current rating required is equal to the maximum output current:

Average forward current of the rectifier diode, $I_F = I_{out(max)} \times (1 - D)$ ....equation [5]

## STEP 6 - Setting of Output Voltage

Voltage divider circuit can be used to set the output voltage of buck converter. It is normally integrated in fixed output converters.

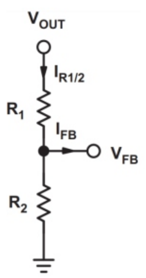



*Figure 2 - Divider circuit for output voltage*

$$R_2 = \frac{V_{FB}}{I_{R1/2}} \qquad \text{....equation [6]}$$

$$R_1 = R_2 \times \left( \frac{V_{out}}{V_{FB}} - 1 \right) \qquad \text{....equation [7]}$$

where,
$R_1$,$R_2$ = resistive divider, see Figure 2
$V_{FB}$ = feedback voltage
$I_{R1/2}$ = current through the resistive divider to ground
$V_{OUT}$ = output voltage

## STEP 7 - Selection of Input Capacitor

It is recommended to use low ESR capacitor and the dielectric material of input capacitor should be X7R or NPO to reduce the losses. The value of input capacitor can be increases to reduce the input voltage ripples.

## STEP 8 - Calculation for Output Capacitor

The output capacitor $C_{OUT}$ maintains the regulated output voltage during the times when the inductor current is higher or lower than the output current. The value of output capacitor can be adjusted to get desired output by using given equation:

$$\text{Output Capacitance, } C_{out(min)} = \frac{\Delta I_L}{8 \times f_{sw} \times \Delta V_{out}} \qquad \text{....equation [8]}$$

where,
$C_{OUT(min)}$ = minimum output capacitance
$\Delta I_L$ = inductor ripple current
$f_{sw}$ = switching frequency of the converter
$\Delta V_{OUT}$ = desired output voltage ripple

# POWER INDUCTORS

## THT POWER INDUCTORS


MTDR Series
THT Drum Inductors


MTTI Series
Toroidal Inductors


MTSDR Series
THT Shield Inductors

## TINY SMD POWER INDUCTORS


MTMPI Series
Multilayer Inductors


MTWWI Series
Wire Wound Inductor


MTPQ Series
Tiny Power Inductors

## SMD UNSHIELDED POWER INDUCTORS


MTSNR Series
Glued Shield Inductor


MTUPI Series
SMD Power Inductors


MTDS Series
HC Power Inductors

## SMD SHIELDED POWER INDUCTORS


MTSLC Series
SMD Power Inductors

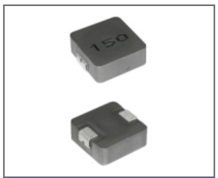

MTSRI Series
Shielded Inductors


MTSUPI Series
SMD Power Inductors

## HIGH CURRENT INDUCTORS

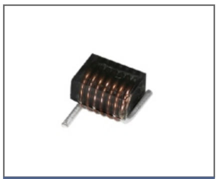

MTSER Series
Flat Wire Inductors

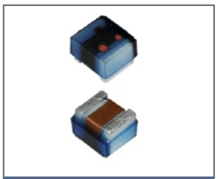

MTHCSI Series
SMD Power Inductors


MTSMPI Series
HC SMD Inductors


MTHCMI Series
HC Cube Inductors

## RF INDUCTORS


MTAIR Series
SMD Air Coils


MTRFI Series
SMD RF Inductors

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