

Designing Applications with MCP16331 High-Input Voltage Buck Converter

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INTRODUCTION

The purpose of this document is to help engineers design different low-power applications and provide insight on how simple non-synchronous buck converters can be used to develop solutions for non-typical requirements. The following paragraphs provide examples of converter applications that fulfill a variety of industry requirements.

The solutions provided by Microchip Technology Inc. highlight the use of the MCP16331 Buck (step-down) regulator, which offers the necessary flexibility required in dealing with the increasing range of technological field demands.

MCP16331 OVERVIEW

The MCP16331 is a highly-integrated, high-efficiency, fixed-frequency, step-down DC-DC converter in a popular 6-pin SOT-23 or 8-pin TDFN 2 x 3 package that operates from input voltage sources up to 50V.

Integrated features include a high-side switch, fixed frequency peak current mode control, internal compensation, peak current limit and overtemperature protection. Minimal external components are necessary to develop a complete step-down DC-DC converter power supply.

High converter efficiency is achieved by integrating the current-limited, low-resistance, high-speed N-Channel MOSFET and associated drive circuitry. High-switching frequency minimizes the size of external filtering components, resulting in a small solution size.

The MCP16331 can supply 500 mA of continuous current, while regulating the output voltage from 2.0V to 24V. An integrated, high-performance peak current mode architecture keeps the output voltage tightly regulated, even during input voltage steps and output current transient conditions that are common in power systems.

The EN input is used to turn the device ON and OFF. While OFF, only a few μ A of current are consumed from the input for power shedding and load distribution applications. This pin is internally pulled up, so the device will start even if the EN pin is left floating. Output voltage is set with an external resistive divider.

The main characteristics and features include:

- Up to 96% Efficiency
- Input Voltage Range: 4.4V to 50V
- Output Voltage Range: 2.0V to 24V
- 2% Output Voltage Accuracy
- Qualification: AEC-Q100 Rev. G, Grade 1 (-40°C to +125°C)
- Integrated N-Channel Buck Switch: 600 m Ω
- Minimum 500 mA Output Current Over All Input Voltage Range
 - Up to 1.2A Output Current at 3.3V and 5V V_{OUT}, V_{IN} > 12V, SOT-23 package at +25°C
 - Up to 0.8A Output Current at 12V V_{OUT}, V_{IN} > 18V, SOT-23 package at +25°C ambient temperature
- 500 kHz Fixed Frequency
- Low Device Shutdown Current
- Peak Current Mode Control
- Internal Compensation
- Stable with Ceramic Capacitors
- Internal Soft-Start
- Internal Pull-Up on EN
- Cycle-by-Cycle Peak Current Limit
- Undervoltage Lockout (UVLO):
 - 4.1V to Start
 - 3.6V to Stop
- Overtemperature Protection
- Available Packages: 6-Lead SOT-23, 8-Lead 2x3 TDFN

For further insight and additional information, refer to the MCP16331 Data Sheet – “High-Voltage Input Integrated Switch Step-Down Regulator” (DS20005308) and the MCP16331 User’s Guide – “High-Voltage Input Buck Converter Evaluation Board” (DS50002264) available on Microchip’s website.

APPLICATIONS

Step-Down or Buck Converter

The MCP16331 is a non-synchronous, step-down or buck converter capable of stepping down input voltages, ranging from 4.4V to 50V, down to 2.0V to 24V for $V_{IN} > V_{OUT}$.

The integrated high-side switch is used to chop or modulate the input voltage using a controlled duty cycle for output voltage regulation. High efficiency is achieved by using a low-resistance switch, low forward voltage drop diode, low equivalent series resistance inductor and capacitor. When the switch is turned ON, a DC voltage is applied across the inductor ($V_{IN} - V_{OUT}$), resulting in a positive linear ramp of inductor current. When the switch turns OFF, the applied inductor voltage is equal to $-V_{OUT}$, resulting in a negative linear ramp of inductor current (ignoring the forward voltage drop of the Schottky diode).

For steady-state, continuous inductor current operation, the positive inductor current ramp must equal the negative current ramp, in magnitude. While operating in steady state, the duty cycle of the signal driving the switch must be equal to V_{OUT}/V_{IN} , for constant output voltage regulation, taking into account that the inductor current is continuous, or never reaches zero.

For discontinuous inductor current operation, the steady-state duty cycle will be less than V_{OUT}/V_{IN} , in order to maintain voltage regulation. The average of the chopped input voltage or SW node voltage is equal to the output voltage, while the average of the inductor current is equal to the output current.

The topology of the buck converter can be seen in Figure 1.

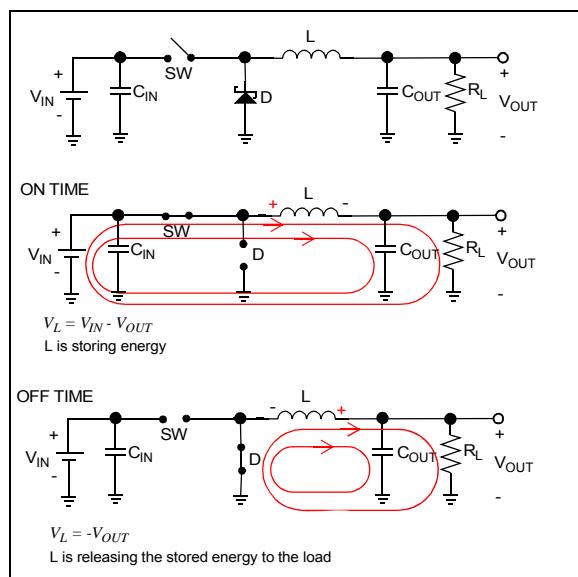


FIGURE 1: Buck Converter Topology.

A non-synchronous buck converter operates in Continuous Inductor Current mode (Figure 2) if the current through the inductor never falls to zero during the commutation cycle. Provided that the inductor current reaches zero, the non-synchronous buck converter operates in Discontinuous Inductor Current mode (Figure 3).

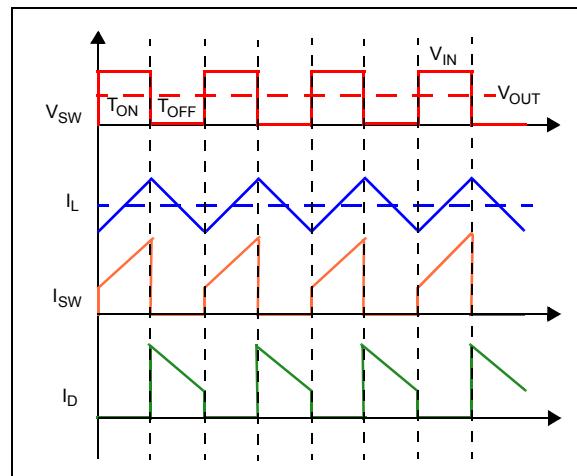


FIGURE 2: Buck Converter Continuous Conduction Mode Waveforms.

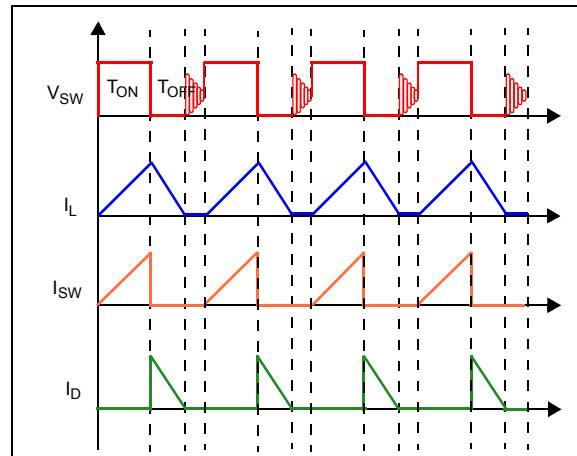


FIGURE 3: Buck Converter Discontinuous Conduction Mode Waveforms.

Figure 4 shows a typical buck converter application, using MCP16331 High Input Voltage Switcher.

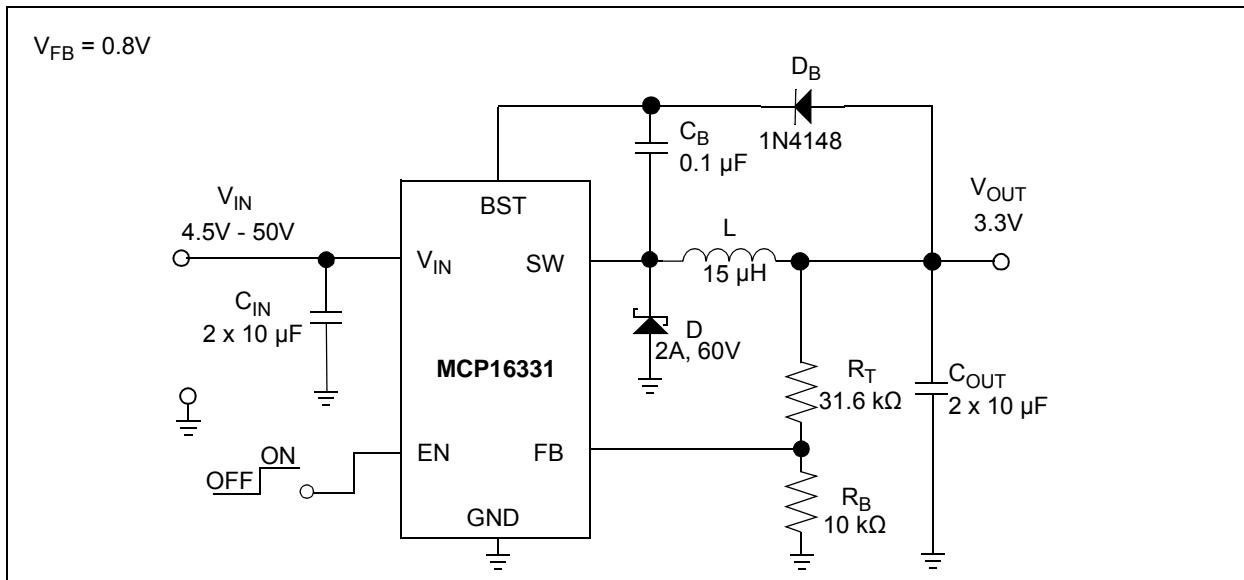


FIGURE 4: MCP16331 Typical Buck Converter Application.

APPLICATIONS

- PIC® MCU/dsPIC® DSC Microcontroller Bias Supply
- 48V, 24V and 12V Industrial Input DC-DC Conversion
- Set-Top Boxes
- DSL Cable Modems
- Automotive
- AC/DC Adapters
- SLA Battery Powered Devices
- AC-DC Digital Control Power Source
- Power Meters
- Consumer
- Medical and Health Care
- Distributed Power Supplies

ADVANTAGES

- Can be used for a large variety of applications
- Easy implementation
- Low component count
- Low price

DRAWBACKS

- This switcher cannot be easily used for other topologies.
- The device cannot be used with external MOSFETS, so there are some limitations related to the maximum operation voltage and current.

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BUCK CONVERTER POWER STAGE DESIGN

In order to build an efficient and competitive power supply that can meet the requirements and industry standards, engineers have to include in the design process the calculation of the external components, based on the input parameters and load requirements of the actual application. In order to do this, there are a few steps that have to be covered.

Tables 1 to 4 introduce all the parameters used for designing the applications presented in this document.

TABLE 1: SYSTEM PARAMETERS

Parameter	Symbol	Unit
Typical Input Voltage	V_{IN}	V
Minimum Input Voltage	V_{INmin}	V
Maximum Input Voltage	V_{INmax}	V
Output Voltage	V_{OUT}	V
Output Current	I_{OUT}	A

TABLE 2: SYSTEM COMPONENTS

Component	Designator	Unit
Inductor	L	μH
Output Capacitor	C_{OUT}	μF
Output Capacitor ESR	$C_{OUT,ESR}$	$m\Omega$
Input Capacitor	C_{IN}	μF
Rectifying Diode	V_D	mV

TABLE 3: SYSTEM BEHAVIOR

Parameter	Designator	Unit
Duty Cycle	D	%
Equivalent Output Voltage	V_{OUT}	V
Equivalent Input Current	I_{IN}	A
Maximum Duty Cycle	D_{MAX}	%
Inductor Ripple Current	I_{Lp-p}	mA
Inductor Peak Current	I_{PEAK}	A
Output Voltage Ripple	V_{OUTp-p}	mV
Output Current	I_{OUT}	mA
Estimated Efficiency	η_{est}	%

TABLE 4: CONVERTER PARAMETERS

Parameter	Designator	Unit
Switching Frequency	f_{SW}	kHz
NMOS switch ON resistance	R_{DSON}	$m\Omega$
Feedback Voltage	V_{FB}	V

Equations 1 to 5 apply only for Continuous Conduction mode.

EQUATION 1: CALCULATING THE INPUT CURRENT

$$I_{IN} = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times \eta_{est}}$$

EQUATION 2: CALCULATING THE DUTY CYCLE

$$D = \frac{V_{OUT} + V_D}{V_{IN} - (I_{OUT} \times R_{DSON})}$$

- Note 1:** For minimum duty cycle, replace V_{IN} with V_{INmax} in the formula above.
2: For maximum duty cycle, replace V_{IN} with V_{INmin} in the formula above.

EQUATION 3: INDUCTOR RIPPLE CURRENT

$$I_{Lp-p} = \frac{(V_{IN} - V_{OUT}) \times D}{f_{SW} \times L}$$

EQUATION 4: INDUCTOR PEAK CURRENT

$$I_{PEAK} = I_{OUT} + \frac{I_{Lp-p}}{2}$$

EQUATION 5: OUTPUT VOLTAGE RIPPLE (APPROXIMATION)

$$V_{OUTp-p} = \frac{I_{Lp-p}}{8 \times f_{SW} \times C_{OUT}}$$

Note: Output voltage ripples due to the neglect of the output capacitance (ceramic capacitors have low ESR).

Rectifying Diode Selection

To reduce losses, Schottky diodes should be used. The forward current rating needed is equal to the maximum output current I_{OUT} . The Schottky diode must have a current rating higher than the inductor peak current limit. Also, the reverse voltage rating has to be higher than the maximum input voltage of the converter. The rectifying diode should also withstand the power dissipation, as shown in [Equation 6](#).

EQUATION 6: RECTIFYING DIODE SELECTION

$$P_D = V_F \times (1 - D) \times I_F$$

Where:

- I_F = Average forward current of the rectifying diode (maximum out current)
- V_F = Diode forward voltage corresponding to forward current
- D = Duty Cycle

Setting the Output Voltage

To calculate the resistive divider values for the MCP16331, in order to obtain the desired output voltage, [Equation 7](#) can be used. R_T is connected between V_{OUT} and the V_{FB} pin and R_B is connected from the V_{FB} input pin to GND.

EQUATION 7: RESISTIVE DIVIDER CALCULATION

$$R_T = R_B \times \left(\frac{V_{OUT}}{V_{FB}} - 1 \right)$$

Where:

$$V_{FB} = 0.8V$$

Using high value resistors minimizes the power loss on the divider (which improves the “no load input current”, but increases the noise).

Using low value feedback resistors provides better accuracy and reduces the noise, but the power losses are higher.

A trade-off between the two cases can be done in order to provide the required V_{OUT} accuracy and also keep the “no load input current” parameter within acceptable ranges, by using [Equation 8](#).

EQUATION 8: RESISTIVE DIVIDER CURRENT

$$I_{Rdiv} = \frac{V_{FB}}{R_B}$$

Inductor Selection

The MCP16331 device features an integrated slope compensation to prevent the bimodal operation of the Pulse Width Modulator (PWM) duty cycle. Internally, half of the inductor current down slope is summed with the internal current sense signal. For the proper amount of slope compensation, it is recommended to keep the inductor down-slope current constant by varying the inductance with V_{OUT} , as shown in [Equation 9](#).

EQUATION 9:

$$K = \frac{V_{OUT}}{L}$$

Where:

$$K = 0.22V/\mu H$$

In [Table 5](#) are presented a few examples of recommended inductor values for typical output voltages, taking into account that K factor should be kept around 0.22V/ μ H.

TABLE 5: RECOMMENDED INDUCTOR VALUES

Output Voltage	K	$L_{STANDARD}$
2.0V	0.20	10 μ H
3.3V	0.22	15 μ H
5V	0.23	22 μ H
12V	0.21	56 μ H
15V	0.22	68 μ H
24V	0.24	100 μ H

MCP16331 Multiple Outputs Buck Converter

In many applications, two or more voltage rails are needed, some of them being galvanically isolated. This kind of task can be accomplished relatively easy, by using the MCP16331 in a multiple outputs buck converter, as shown in Figure 6. Figure 5 reveals a design example that can be implemented for such a request.

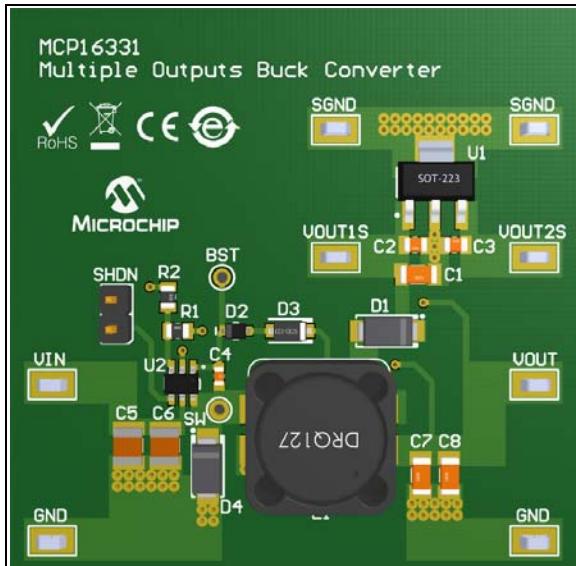


FIGURE 5: MCP16331 Multiple Outputs Buck Converter Design Example.

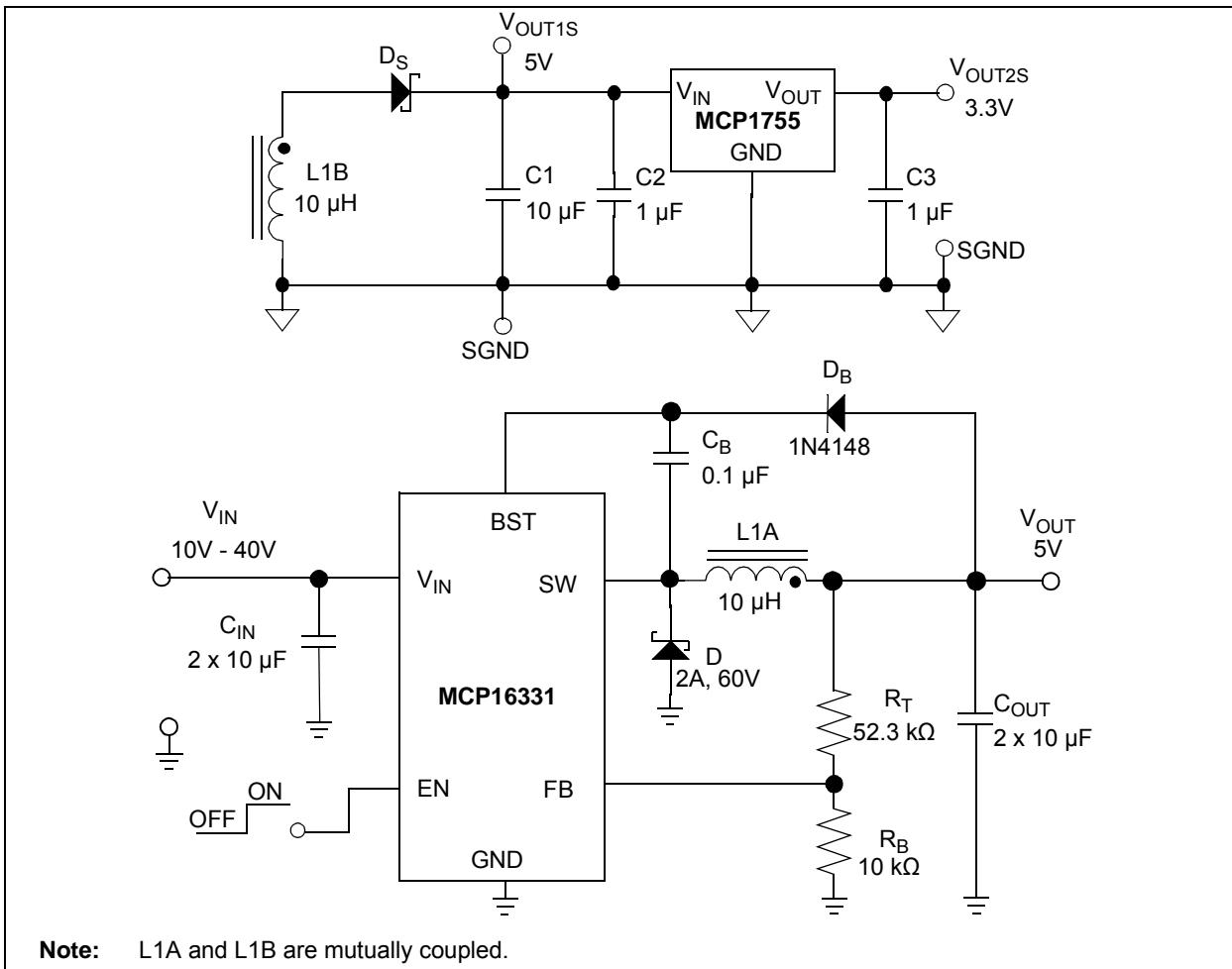


FIGURE 6: Multiple Outputs Buck Converter Example.

FEATURES

- Input Voltage Range: 4.5V to 50V
- Three Outputs (two of them are galvanically isolated from the third one)
- Output Current Capability (10V to 40V input voltage):
 - Up to 400 mA (@ $V_{OUT} = 5V$)
 - Up to 200 mA - combined (@ $V_{OUT1S} = 5V$; $V_{OUT2S} = 3.3V$)
- Switching Frequency: 500 kHz
- Load Regulation: $\leq 5\%$

ADVANTAGES

- Multiple outputs
- Galvanic isolation between outputs

DRAWBACKS

- Needs balancing resistors for keeping the voltage regulation between the outputs
- All the outputs must be charged almost equally when using at least one of them

MULTIPLE OUTPUTS BUCK CONVERTER DESIGN STAGE

Instead of using one chip for each output voltage, the inductor from the typical buck topology was replaced with a 1:1 coupled inductor. By doing this, there are two advantages: one is that an extra output was added to the converter and the second one is that the output has galvanic isolation with respect to the main output. In addition to this, an LDO (Low drop-out voltage regulator) or a linear voltage regulator can be cascaded, as is shown in [Figure 6](#), if the application requires smooth voltage regulation or an extra output.

Consider having a perfect coupled inductor, with each inductor having the same number of windings on a single core, the mutual inductance splits the ripple current equally between the two coupled inductors.

By using a real coupled inductor, the coils do not have equal inductance and the ripple currents will not be exactly the same. Thus, for a desired ripple-current value, the inductance required in a coupled inductor is estimated to be half of what would be needed if there were two separate inductors, as shown in [Equation 10](#).

EQUATION 10:

$$L_{IAmin} = L_{IBmin} = \frac{1}{2} \times \frac{V_{INmin} \times D_{max}}{I_{L1p-p} \times f_{SW}}$$

The accepted ripple current will be chosen to be 30% of the inductor current, both for good transient response and electromagnetic interference (EMI) considerations. For a simpler approach, when choosing the inductor, the values from [Table 5](#) can be used as a reference point, with the remark that they should be halved, for this kind of application.

However, some limitations must be taken into account when using this topology, because there are also drawbacks, regarding the efficiency, voltage difference between outputs, load regulation and so on. Having a 1:1 coupled inductor means that the voltage in the secondary side has almost the same value of the voltage in the primary side and the output voltage of the LDO is lower than each of them.

The most important conditions that should be met, in order to have a functional converter, with a load regulation $\leq 5\%$ are:

- $I_{OUT} > (I_{OUT1S} + I_{OUT2S})$
- $(I_{OUT1S} + I_{OUT2S}) > 10 \text{ mA}$

Where:

- I_{OUT} is the current drawn from V_{OUT}
- I_{OUT1S} is the current drawn from V_{OUT1S}
- I_{OUT2S} is the current drawn from V_{OUT2S}

The primary output voltage equation is identical to a buck converter and is given by [Equation 11](#).

EQUATION 11:

$$V_{OUT} = D \times V_{IN}$$

The secondary output voltage, for a 1:1 inductor ratio, is given by [Equation 12](#).

EQUATION 12:

$$V_{OUT1S} = V_{OUT} - V_F$$

V_F is the forward voltage drop of the rectifying diode from the secondary side. The secondary output (V_{OUT1S}) closely tracks the primary output voltage (V_{OUT}), without the need for additional transformer winding or an optocoupler for feedback.

The peak inductor and switch current during ON-time is given by [Equation 13](#).

EQUATION 13:

$$I_{PEAK} = I_{LIA} + I_{LIB} + \frac{I_{LIAp-p} + I_{LIBp-p}}{2}$$

Since there is no current in the secondary side during T_{ON} , the peak current will be shown in [Equation 14](#).

EQUATION 14:

$$I_{PEAK} = I_{OUT} + I_{OUT1S} + I_{OUT2S} + \frac{LIAp-p}{2}$$

For a better voltage regulation in the secondary side of the converter, an MCP1755 LDO was added, which also provides another output (V_{OUT2S}). Thus, the overall efficiency is pretty high, due to the small difference between V_{OUT1S} and V_{OUT2S} .

MCP16331 Non-Inverting Buck-Boost Converter

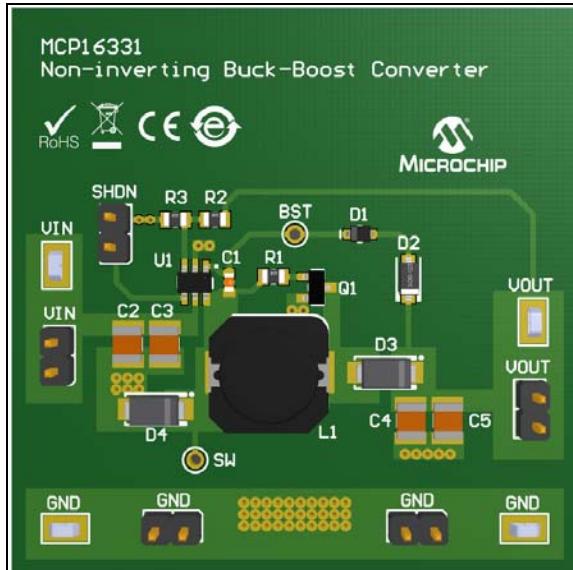


FIGURE 7: MCP16331 Non-Inverting Buck Converter Design Example.

There are several applications (especially in the automotive industry) that require a stable output voltage, obtained from either a lower or a higher input voltage. Regarding this, there are several topologies that can be implemented, both with advantages and drawbacks. [Figure 9](#) shows an example of a non-inverting buck-boost converter, using the MCP16331 buck switcher. For a possible implementation of this topology, please refer to [Figure 7](#).

A conventional non-inverting buck-boost converter uses a single inductor ([Figure 9](#)), but it has an additional MOSFET (Q1) and an additional diode (D2), compared to an inverting buck-boost converter. By turning the internal switch and Q1 ON and OFF simultaneously, the converter operates in Buck-Boost mode, and the duty cycle also complies with [Equation 15](#). The ideal waveforms of a non-inverting buck-boost converter operating in Buck-Boost mode and CCM are

shown in [Figure 8](#). The internal switch and D1 both see a voltage stress of V_{IN} , while Q1 and D2 both see a voltage stress of V_{OUT} .

The internal switch, Q1, D1, D2 and L all see a current stress of $I_{IN} + I_{OUT}$ with inductor ripple current neglected. The relatively large number of power devices and high-current stress in Buck-Boost mode prevent the converter from being very efficient.

The non-inverting buck-boost converter is a cascaded combination of a buck converter followed by a boost converter, the internal switch and Q1 having identical gate-control signals.

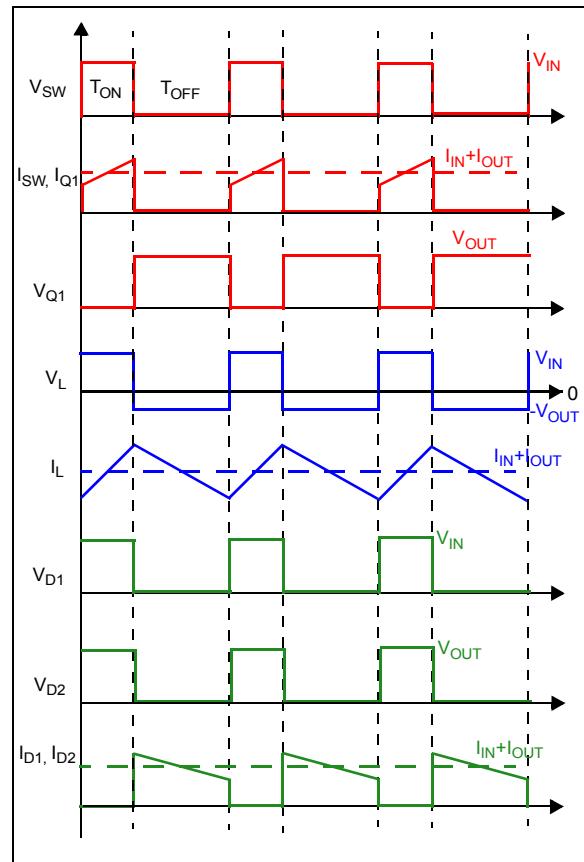


FIGURE 8: MCP16331 Non-Inverting Buck-Boost Converter Waveforms in CCM.

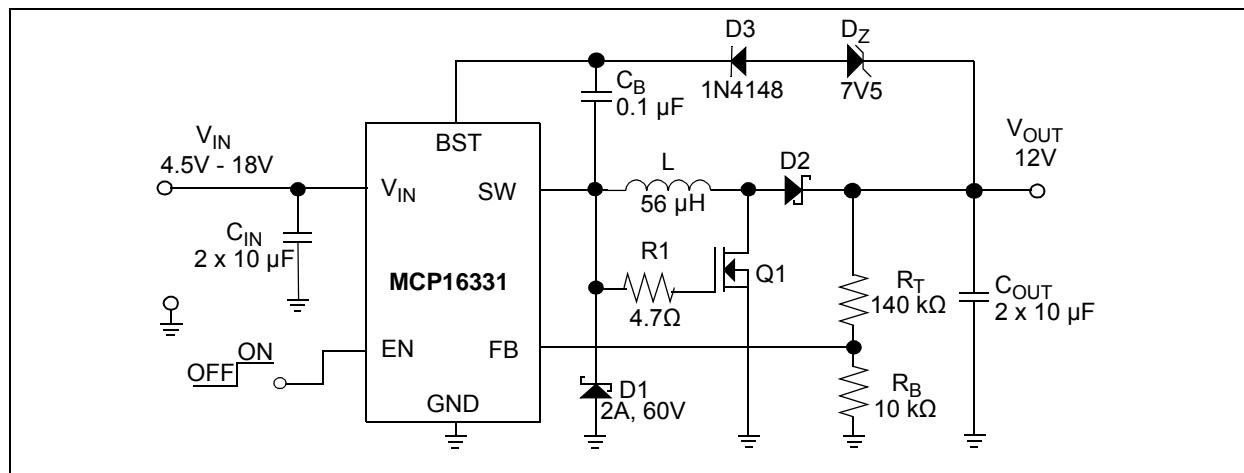


FIGURE 9: MCP16331 Non-Inverting Buck-Boost Converter.

FEATURES

- Input Voltage Range: 4.5V to 18V
- Output Voltage Range (Up to 24V)
- Output Current Capability (9V to 16V input voltage):
 - Up to 500 mA (@ $V_{OUT} = 12V$)
- Switching Frequency: 500 kHz

ADVANTAGES

- Same polarity with respect to V_{IN}
- Single inductor
- No additional control circuitry

DRAWBACKS

- Because Q1 is driven directly from the SW pin, a maximum input voltage of 18V can be used, to avoid damaging transistor's gate.
- For higher input voltages, an additional MOSFET driver can be used to command Q1.

NON-INVERTING BUCK-BOOST CONVERTER DESIGN STAGE

Equations 15 to 21 can be used to calculate the non-inverting buck-boost converter application parameters and inductor's value. Note that the given equations apply for Continuous Conduction mode operation only.

EQUATION 15: DUTY CYCLE

$$D = \frac{V_{OUT} + 2 \times V_D}{V_{IN} + V_{OUT} + 2 \times V_D}$$

EQUATION 16:

$$D_{max} = \frac{V_{OUT} + 2 \times V_D}{V_{INmin} + V_{OUT} + 2 \times V_D}$$

The duty cycle of the non-inverting buck-boost converter can be calculated with the equations above. At minimum input voltage (V_{INmin}), the duty cycle has the maximum value. At maximum input voltage (V_{INmax}), the duty cycle has the minimum value.

EQUATION 17: EQUIVALENT INPUT CURRENT

$$I_{IN} = \frac{V_{OUT} \times I_{OUT}}{V_{IN} \times \eta_{est}}$$

EQUATION 18:

$$I_{INmax} = \frac{V_{OUT} \times I_{OUT}}{V_{INmin} \times \eta_{est}}$$

For non-inverting buck-boost converter, the DC current flowing through L is the sum of input current and output current. The maximum input current (keeping the load and output voltage constant) is at the V_{INmin} , as shown in Equation 18.

EQUATION 19: INDUCTOR RIPPLE CURRENT

$$I_{LP-p} = (I_{IN} + I_{OUT}) \times k$$

Note 1: k takes values between 0.2 to 0.4.

2: k represents a percentage of the inductor current.

The inductor ripple current represents a percentage of the DC current. Depending on the application, this percentage usually represents 20% to 40%. The higher the ripple (coefficient k is higher), the lower the inductor value. The output current capabilities will be lower, as the current ripple will reach the peak current limitation sooner. For lower k coefficient values, the inductor will be higher. The output current will increase as the ripple will be lower requiring more load to hit the current limit. As a result of higher output current, the power dissipation of the device has to be taken into consideration. The converter may enter thermal shutdown before reaching the peak current limit. The requirements of the application will determine the acceptable inductor current ripple range. However, as MCP16331 is a peak current mode control converter, it requires a significant inductor ripple current in order to provide the best transient response. Usually, a k = 30% is a good trade-off between current capabilities and dynamic response.

The inductor's peak current is dependent on the following parameters, as shown in [Equation 20](#):

EQUATION 20: INDUCTOR PEAK CURRENT

$$I_{Lpeak} = I_{IN} + I_{OUT} + \frac{I_{Lp-p}}{2}$$

- Converter's input current
- Converter's output current
- The inductor current ripple which is designed to meet the application requirements

During the design phase, the efficiency of the converter is estimated, in order to simplify all the calculations. The real application results may differ to a small extent, influenced by the component/system tolerances and accuracy of the estimated parameters.

EQUATION 21: INDUCTOR VALUE

$$L = \frac{(V_{IN} + V_{OUT}) \times D_{max}}{I_{Lp-p} \times f_{SW}}$$

The value of the inductor can be calculated using [Equation 21](#), but for a more simple way to design an application like this, the values from [Table 5](#) can be used.

High Inductor Current Ripple

- Advantages
 - Lower inductor value required, lowering application's necessary board space, decreasing overall costs
 - Better dynamic response
- Disadvantages
 - Lower output current capabilities
 - Increased EMI (electromagnetic interference), requiring additional output capacitance

Low Inductor Current Ripple

- Advantages
 - Higher output current capabilities
 - Decreased EMI
- Disadvantages
 - Increased inductor value, bigger package/board size, increased costs
 - Higher thermal stress
 - Slower dynamic response

MCP16331 Inverting Buck-Boost Converter

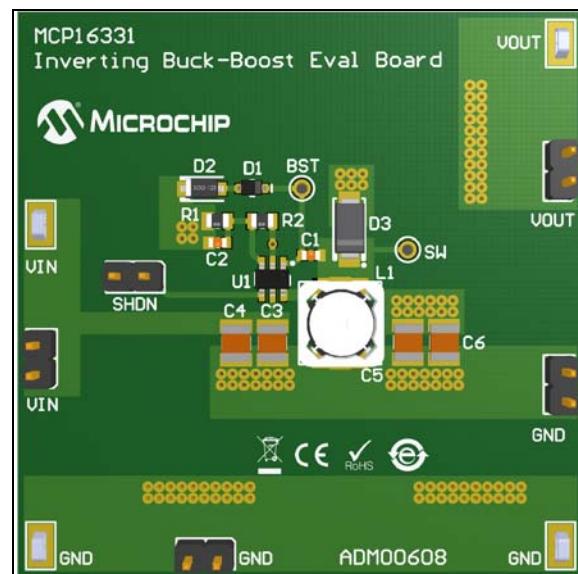


FIGURE 10: MCP16331 Inverting Buck Converter Design Example.

Besides the non-inverting buck-boost converter, generating a negative output voltage from a positive input voltage can be useful, especially for supplying amplifiers. In this case, an inverting buck-boost converter can be implemented, using MCP16331, as shown in [Figure 12](#). This application shows the possibility of using a buck switcher in an inverting buck-boost topology. An example of a possible PCB layout implementation of this converter is shown in [Figure 10](#).

[Figure 12](#) shows that the inductor is connected between SW pin and GND, the anode of the freewheeling diode is connected to V_{OUT} and its cathode is tied to SW, just like in a regular inverting buck-boost configuration.

During operation, when the internal switch is turned ON, the voltage across the inductor is V_{IN} , so the entire load current is supplied by the energy stored in the output capacitor. When the internal switch is turned OFF, the inductor reverses polarity to keep the inductor's current continuous, so the voltage across the inductor is approximately V_{OUT} . While the switch is turned OFF, the inductor supplies current both to the load and to the output capacitor. The waveforms for steady-state, continuous inductor current operation, are shown in [Figure 11](#).

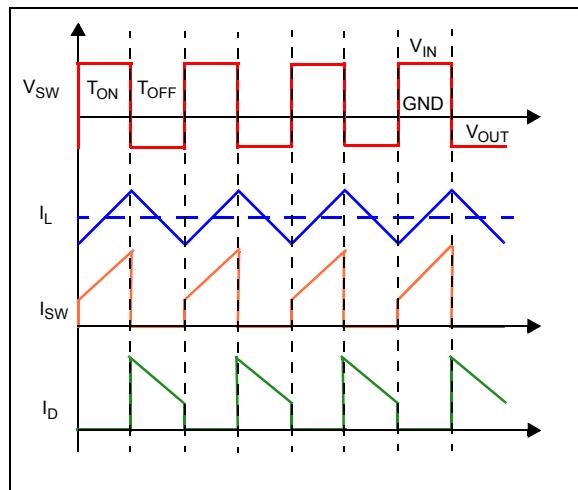


FIGURE 11: MCP16331 Inverting Buck-Boost Converter Waveforms in CCM.

To use the MCP16331 buck switcher in a non-inverting buck-boost topology, the GND pin should be tied to V_{OUT} , so the output capacitor will have the higher voltage potential at GND.

The voltage between the device's V_{IN} pin and GND is $V_{IN} - (-V_{OUT})$, instead of V_{IN} , as in the buck converter, so the following condition (see [Equation 22](#)) should be taken into account when designing such an application.

EQUATION 22:

$$(V_{IN} + |V_{OUT}|) < 50V$$

Thus, for enabling/disabling the device, the same voltage should be applied on EN pin.

For calculating the duty cycle, [Equation 23](#) can be used (considering the electronic components used are ideal).

EQUATION 23:

$$D = \frac{V_{OUT}}{V_{OUT} - V_{IN}}$$

The peak current in the inductor will be calculated as shown in [Equation 24](#).

EQUATION 24:

$$I_{Lpeak} = \frac{I_{OUT}}{1-D} + \frac{I_{LP-p}}{2}$$

For the minimum inductor value, refer to the recommended inductor values in [Table 5](#).

In conclusion, MCP16331 can be used to generate a negative output from a positive voltage source, if the circuit is configured as an inverting buck-boost, but, it must be acknowledged that the GND pin of the switcher should not be tied to the ground of the entire system.

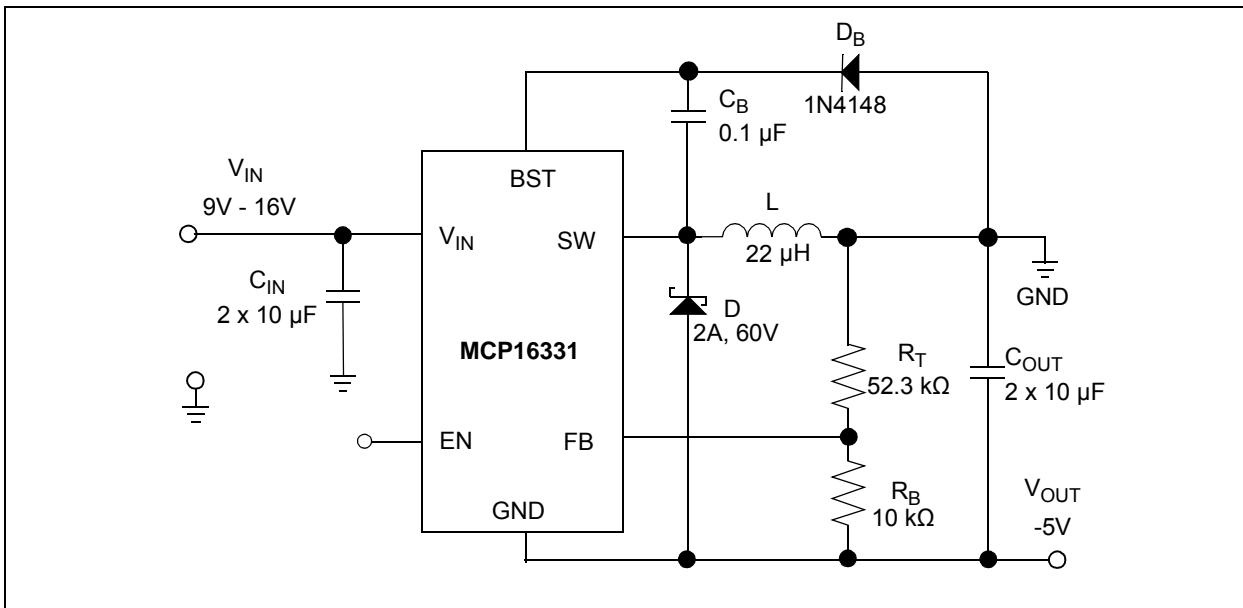


FIGURE 12: MCP16331 Inverting Buck-Boost Application.

FEATURES

- Input Voltage Range: 4.5V to 48V
- Output Voltage Range: up to -24V (inverting)
- Output Current Capability (9V to 16V input voltage):
 - Up to 500 mA (@V_{OUT} = -5V)
- Switching Frequency: 500 kHz

ADVANTAGES

- Can be used for applications in which the input voltage is either higher or lower than the output voltage (without taking into account the polarity of the output voltage)
- Negative polarity with respect to V_{IN}
- Simple implementation, with minimum of components

DRAWBACKS

- The maximum input voltage capability is affected by the output voltage of the converter.

CONCLUSION

This document is a brief introduction into a different way of thinking how to develop a simple and inexpensive solution for various requirements, rather than focusing on obvious approaches.

MCP16331 is a highly-integrated DC-DC converter, designed for step-down regulation, which can be used to develop non-typical applications, such as Multiple Outputs Buck Converter, Inverting or Non-Inverting Buck Converter, with minimal changes within the typical schematic.

However, for each application, there are some limitations and conditions that must be taken into account for a good functionality.

Overall, the information presented here aims to help engineers in designing clever solutions, mainly for applications that require high input voltages.

Note the following details of the code protection feature on Microchip devices:

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- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
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