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APPLICATION NOTE 3740

How to Generate Auxiliary Supplies from a Positive Buck DC-DC Converter

Many applications require a low-power supply in addition to the main supply. For reasons of cost, inventory management, or electromagnetic compatibility (EMC), a separate converter may not be appropriate. Consequently, another means of providing extra power rails from the main supply is needed. This application note shows how to use a step-down IC converter's switching action to derive one or more outputs, isolated or non-isolated, quasi-regulated or unregulated.

Introduction

Many applications require a low-power supply in addition to the main supply. A typical example is when an analog front-end amplifier needs ±5V, while the main digital circuitry requires +5V only. For reasons of cost, inventory management, or EMC, a separate -5V converter may not be appropriate. Consequently, another means of providing extra power rails from the main supply is needed.

As a solution to this problem, a step-down IC converter's switching action can be used to derive one or more outputs, isolated or non-isolated, quasi-regulated or unregulated. Auxiliary output currents of 10% to 30% of the main output are perfectly possible. This application note will illustrate this technique using the MAX5035 DC-DC converter.

Step-Down Waveforms

A review of the waveforms found in a working step-down converter will identify the voltage and currents that can be used to generate additional outputs. See Figure 1 below and Example 1 waveforms at the end of this article.

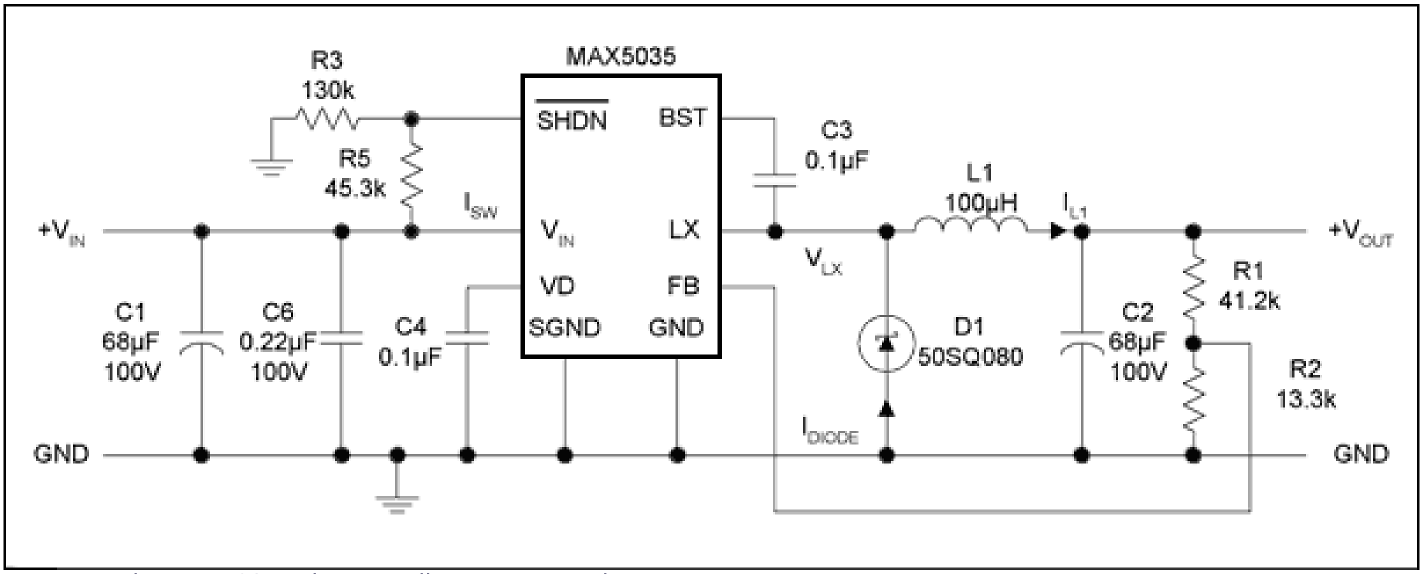

Figure 1. The MAX5035 schematic illustrates step-down converter operation.

There is a switching voltage waveform of amplitude at the LX pin:

V_{LX} = [V_{IN} (max) to -V(diode)] < V_{LX} < V_{IN}(min) -V(diode)]

The voltage across the main inductor during the power cycle (LX connected to V_{IN}) is:

V_{IN}D = [V_{IN} (max) - V_{OUT}] < V_{IN}D < [V_{IN}(min) - V_{OUT}]

Continuous Inductor Current Operation

When the power switch is off, the voltage at the LX connection flies negative, turning on the diode, D1, to ensure that the inductor current continues to circulate. Operation is said to be continuous when the power cycle begins before the circulating current in D1 falls to zero (**Figure 2**).

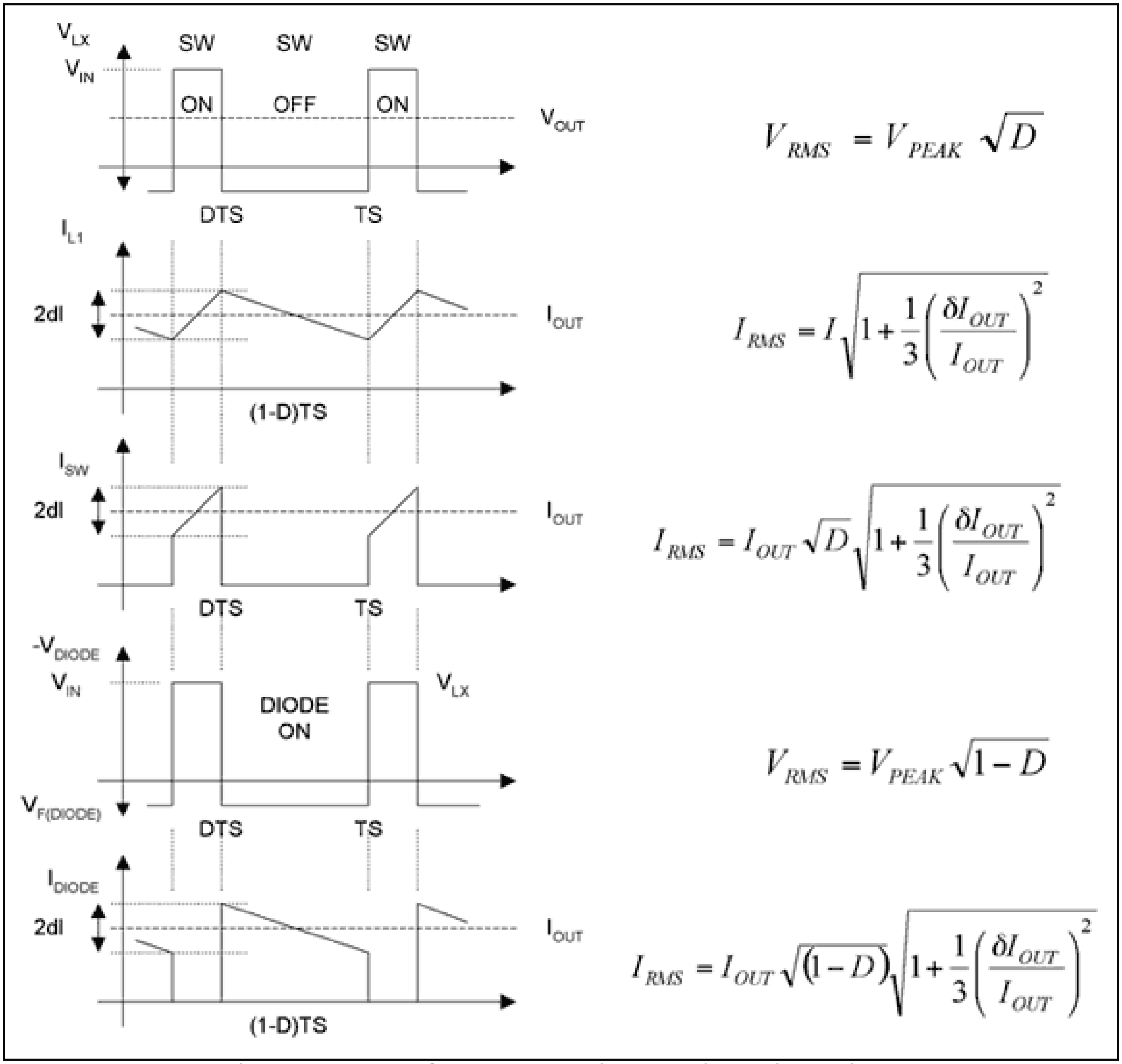

Figure 2. Continuous inductor current waveforms. TS = switching period; D = duty cycle.

Knowing the various RMS currents and voltages associated with the key components, power dissipation can be calculated as follows:

[1] Internal LX switch power dissipation:	$P_{SW} = (I_{SW\_RMS})^2 R_{ON\_SW}$
[2] IC quiescent power dissipation:	$P_{I\_QUIESCENT} = V_{IN} I_{QUIESCENT}$
[3] Schottky diode (D1) power dissipation:	$P_{DIODE} = I_{DIODE\_RMS} V_{DIODE\_FORWARD}$
[4] Load power dissipation:	$P_{LOAD} = R_{LOAD}(I_{LOAD\_RMS})^2$

Definitions

RON_SW—Data sheet on-resistance of the internal power switch (V_{IN} to LX)
RLOAD—Effective resistance connected at the power-supply output.
IQUIESCENT—Quiescent current of the control IC with no switching action.
IDIODE_RMS—Schottky diode (D1) forward RMS current.
VFORWARD—Forward voltage drop across Schottky diode, D1, at rated current.
ILOAD_RMS—RMS load current.

Auxiliary Outputs

Auxiliary outputs can be added to the main step-down by an additional winding on its inductor. The additional output relies on flyback action in the main inductor during the time that the 'catch' Schottky diode (D1 in Fig1) is conducting. Because the diode voltage drop is relatively constant (300mV to 500mV, typically, depending on current), and because the controller regulates the output voltage, the inductor's voltage drop is also relatively constant during the OFF time of the power switch. For the voltage drop to remain consistent, the main inductor should be in continuous conduction throughout the main step-down load range.

The LX pin can also be used to provide a switching input to a discrete charge-pump circuit. For this to remain consistent, the LX pin must be active whenever the additional output is required. You can keep the LX pin active by ensuring that the main step-down output supports a minimum load.

Inductor Selection

Three functions are needed to set the value of the main inductor: the voltage across the inductor, the operating frequency, and the inductor's current ripple. Together, these functions will ensure that adequate energy is stored in the inductor. The inductor's minimum value is determined by the maximum duty cycle and minimum input voltage, and is given by:

$$L_{MIN} = \frac{D_{MAX}(V_{IN\_MIN} - V_{OUT})}{I_{RIPPLE} F_{CLOCK}}$$

$$D_{MAX} = \frac{V_{IN\_MIN}}{V_{OUT}} \qquad I_{RIPPLE} = \% I_{LOAD} \qquad \text{(Continuous operation)}$$

Ripple current is a percentage of output current, and defined as 30% for the MAX5035. Note that the ripple current sets the minimum load current before the onset of discontinuous operation. Because an auxiliary supply increases the peak-current requirements of the power switch, care must be taken to limit the auxiliary power drawn.

For many applications, the Evaluation (EV) kit's standard setup of 100µH and 68µF output filter values will be suitable. These values are retained for the additional supplies. The MAX5035 features fixed, internal type-3 compensation which imposes limitations on the choice of output capacitor. Chose the ESR so that the zero frequency occurs between 20kHz and 40kHz. See the application section of the MAX5035 data sheet for more information.

Auxiliary Output Derived from the Main Inductor's Transformer

The inductor's voltage drop is relatively constant during the power switch's OFF time, because the primary Schottky diode voltage drop is relatively constant (300mV to 500mV, typically, depending on current), and the controller regulates the output voltage. Connecting the secondary rectifier and capacitor so that conduction occurs during the flyback period (diode ON), allows some energy to be tapped off the main inductor. **Figures 3a** and **3b** show two versions of this arrangement. Isolating the auxiliary winding from the main step-down allows flexible connection arrangements. Figure 3a shows the auxiliary output referred to zero volts, and Figure 3b shows the auxiliary output referred to the main positive output. See also waveforms in **Examples 2a** and **2b**.

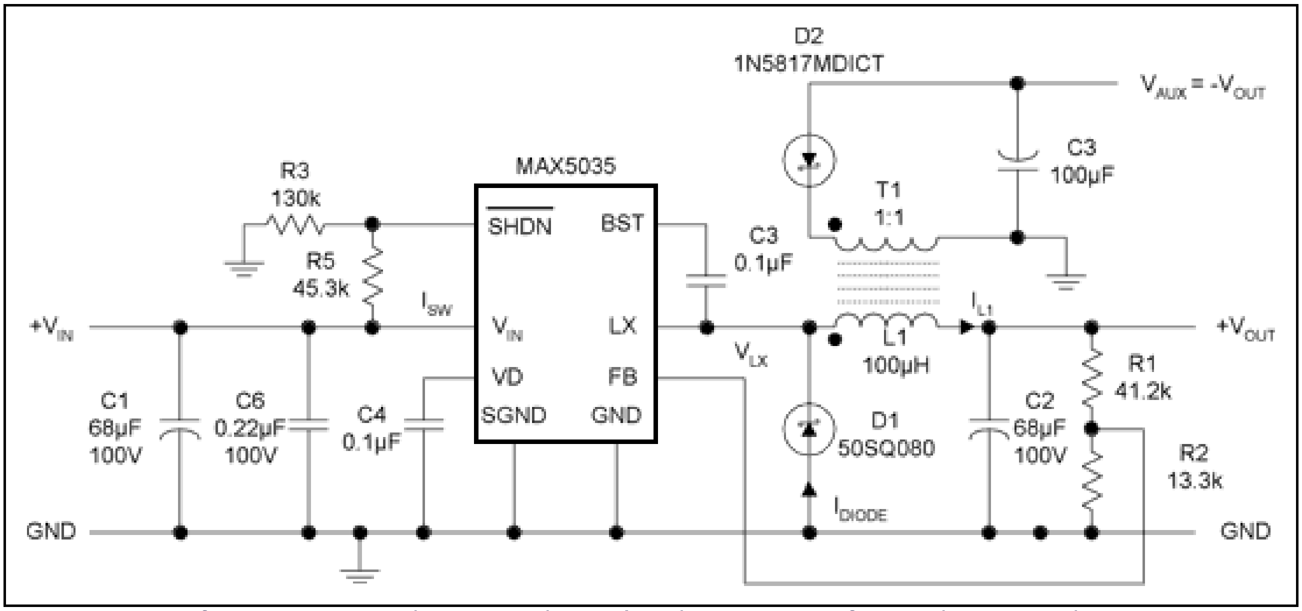

Figure 3a. Transformer serves as the main inductor (auxiliary output referenced to zero volts. T1 = Cooper Bussmann DRQ125-101. (Note the DOT convention for the start of windings.)

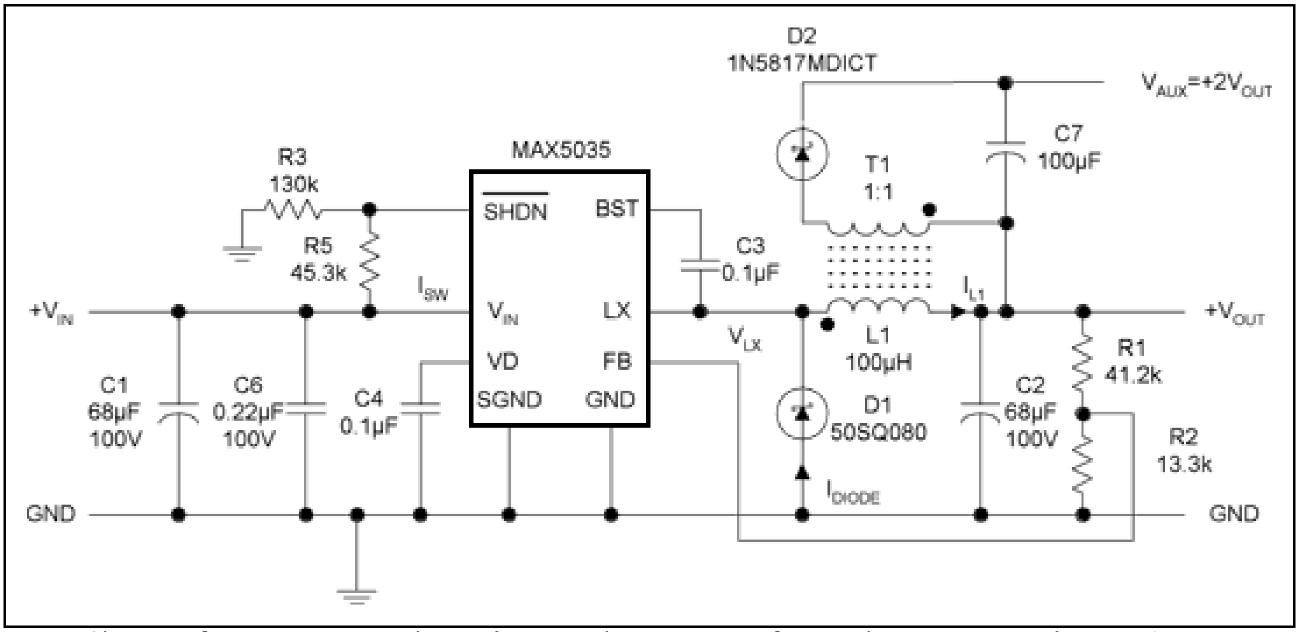

Figure 3b. Transformer as main inductor (+ve auxiliary output referenced to main output). T1 = Cooper Bussmann DRQ125-101. (Note the DOT convention for the start of windings.)

Auxiliary output voltage is given by:

$$V_{AUX} = N2/N1 (V_{OUT} + V_{DIODE1}) - V_{DIODE2}$$

N1 = primary turns and N2 = secondary turns.

This output in Figure 3 is independent of input-voltage changes, as D2 is ON when the internal LX power switch is OFF. Capacitor C7 should be chosen to support the output during the maximum on-time of the power switch. The secondary output suffers a 2% to 3% output variation as the forward voltage drop of D1 varies with temperature and load current. Since N1 and N2 of the transformer are DC-isolated from each another, the extra output may be referenced to any DC voltage.

For a given inductor value, secondary power at the auxiliary output is limited by the onset of discontinuous current in the main primary loop. Restated simply, D1 must remain in conduction at the end of the flyback period. At the onset of discontinuous operation, conduction through D1 becomes zero, and the voltage at LX will show the characteristic decaying 'ring' at a frequency determined by the output inductance and the total stray capacitance at the LX node.

Secondary loading causes a change of primary current at the point of transition when the internal LX switches from on to off. This current step shown in **Figure 4** is given by:

$I_{XTRA} = P_{SEC} (D \times V_{LX})$
D = duty cycle
P_{SEC} = secondary power
V_{LX} = peak voltage excursion at LX

In principle, there is much flexibility in the choice of turns ratio. However, in practice, the availability of standard 1:1 transformers with suitable inductance and peak-current values makes this the most popular choice of turns ratio.

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