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AND8170/D

Small, Simple, PWM Buck Controller Can Replace High Current LDOs

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APPLICATION NOTE

Modern electronic systems require a host of different regulated voltages to power their various subsystems. The number of voltage levels needed on boards has risen as new generations of processors, memory, etc., have been introduced with lower voltage requirements. Also, the required voltage keeps decreasing so designers must include 5.0 V, 3.3 V and other voltage as low as 1.0 V. The trend in distributed power architectures is to design individual, nonisolated, Point−Of−Load (POL) converters to supply power to each individual load. A power supply usually exists for 5.0 V and 3.3 V, but generating additional lower voltages often requires additional post−regulators.

Low dropout, linear regulators, or LDOs, are typically used for post−regulation because they are easily implemented and provide a relatively noise−free power source. However, for higher currents, such as 1.0 A and above, LDOs take up a great deal of space and can dissipate too much power and thus heat. For low dropout applications where you need another voltage rail, and you already have a 5.0 V or 3.3 V rail, a simple PWM buck converter provides a more efficient choice than a linear regulator.

One example would be a 3.3 V rail from an existing 5.0 V rail. For a 1.0 A load, an LDO could be used as a post−regulator, but the best−case efficiency would be 3.3 V/5.0 V which equates to approximately **66%**. Also, the LDO dissipates **1.7 W**. Another example is a 2.5 V power rail derived from an existing 3.3 V rail. For a 1.0 A load, the best−case efficiency would be 2.5 V/3.3 V which equates to approximately **76%**. The power dissipation is **0.8 W**. For the 3.3 V example, a linear regulator would have to come in a TO−220 or D^{2}PAK package (∼23 mm x 11 mm, and 4.8 mm high). If the circuit in question cannot dissipate power efficiently (for instance, enclosed systems with little or no airflow) the heat given off by an LDO can exceed the thermal budget of the system.

Alternatively, the circuit in Figure 1 shows a simple, five pin (Thin SOT−23−5), buck controller. For the design that provides 2.5 V at 1.0 A from a 3.3 V input, the efficiency is **88% at 1.0 A**. The output ripple voltage for this circuit is 30 mVp−p. This circuit also does not require external compensation and can be disabled to shut off the load with its chip enable (CE) pin. All of this makes this solution about as simple to implement as it's rival, the LDO.

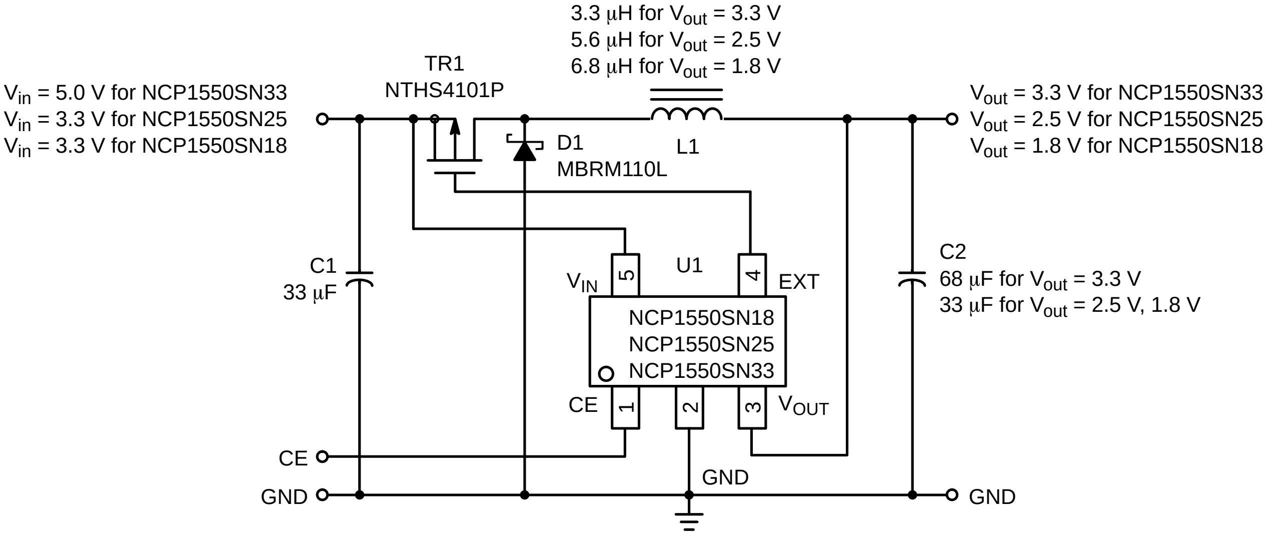

Figure 1. Simple Buck Controller for Converting 1.8, 2.5, or 3.3 V from 3.3 or 5.0 V

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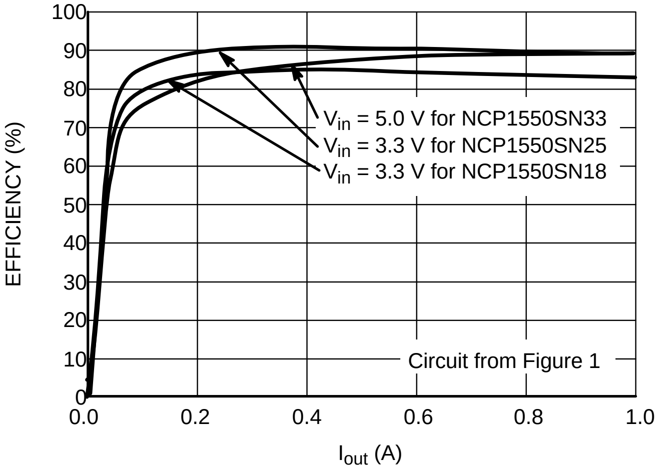

Figure 2. NCP1550 Efficiency vs. I_{out}

Proper passive component selection helped raise the system's overall efficiency. The MOSFET used (NTHS4101P) has a typical $R_{DS(on)}$ of around 20 mΩ at the designed operating point and comes in a very small but thermally efficient ChipFET package. The Schottky used (MBRM110L) is a 10 V device which offers lower V_F than most comparable 20 V devices. Figure 4 shows how the 10 V Schottky platform compares to other typical 20 V platforms. More information about this product family can be found in the application note AND8083/D, "Efficiency Improvements Using 10 V Schottky Diodes" from ON Semiconductor.

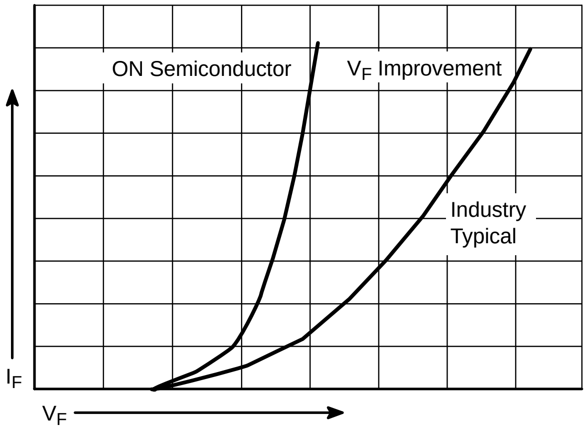

Figure 4. 10 V Schottky V_F vs. Typical Competition

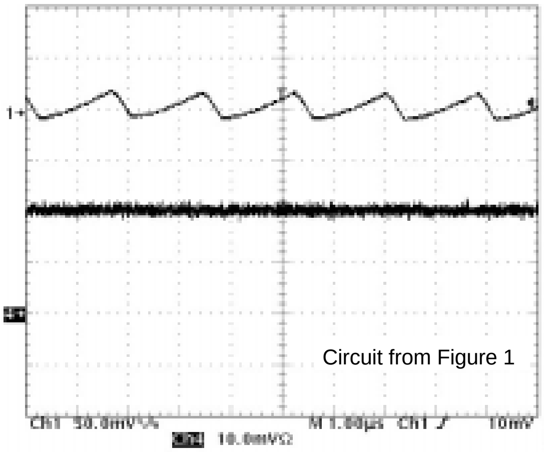

Figure 3. Output Ripple at V_{in} = 3.3 V, V_o = 2.5 V @ 1.0 A (C4 = 500 mA/div)

The 10 V Schottky starts showing its benefits as the duty cycle of the circuit decreases and it conducts more current. For instance, since voltage levels continue to lower, a 1.8 V rail may be necessary. This solution still outperforms the LDO. For instance, if you wanted to supply 1.8 V at 1.0 A from the 3.3 V rail, an LDO would have a best−case efficiency of 1.8 V/3.3 V which equates to approximately **55%** with a power dissipation of **1.5 W**. The circuit from Figure 1 with the above conditions has an efficiency of **83% at 1.0 A**.

On another note, buck converters draw less current from input power sources than LDOs. An LDO's input current is the same as its output current, but a buck converter's input current is a function of the efficiency of the converter. For instance, for the 1.8 V, 1.0 A converter mentioned previously, which has an efficiency of 83%, $I_{in} = (Vo*Io)/\eta*V_{in}$. Therefore, I_{in} = 660 mA which equates to a 34% savings in input current from the LDO solution. For the 2.5 V and 3.3 V solutions, which have efficiencies at their given conditions of 88%, the input current equates to 860 mA and 750 mA respectively. This reduction in input current helps keep the power budget of the existing bus converters down which can equate to smaller size, better performance, and lower cost.

Finally, the user can scale this design to higher currents up to 2.0 A by adjusting the transistor, diode, inductor, and capacitor accordingly. More details on the components required for 2.0 A operation can be found in the NCP1550 data sheet. This solution provides a good replacement for LDOs when one requires high currents, low dropout, and good thermal performance, i.e. efficiency, without adding much complexity.

Table 1. Bill of Materials for Circuit from Figure 1

1.8 V Version

Designator	Qty	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number
U1	1	PFM/PWM Step−Down DC−DC Controller	1.8 Vout, 600 kHz	NA	Thin SOT−23−5	ON Semiconductor	NCP1550SN18T1
D1	1	Schottky Power Rectifier	1.0 A, 10 V	NA	POWERMITE®	ON Semiconductor	MBRM110LT3
TR1	1	Power MOSFET	1.0 A, 20 V	NA	ChipFET™	ON Semiconductor	NTHS4101PT1
C1, C2	2	Low Profile Tantalum Chip Capacitor	33 μF, 10 V	10%	6032−28	Kemet	T491C336K010AS
L1	1	SMD Power Inductor	6.8 μH, 1.36 A	20%	6.0 x 6.4 x 2.5 mm	Sumida	CDC5D236R8

2.5 V Version

Designator	Qty	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number
U1	1	PFM/PWM Step−Down DC−DC Controller	2.5 Vout, 600 kHz	NA	Thin SOT−23−5	ON Semiconductor	NCP1550SN25T1
D1	1	Schottky Power Rectifier	1.0 A, 10 V	NA	POWERMITE®	ON Semiconductor	MBRM110LT3
TR1	1	Power MOSFET	1.0 A, 20 V	NA	ChipFET™	ON Semiconductor	NTHS4101PT1
C1, C2	2	Low Profile Tantalum Chip Capacitor	33 μF, 10 V	10%	6032−28	Kemet	T491C336K010AS
L1	1	SMD Power Inductor	5.6 μH, 1.44 A	20%	6.0 x 6.4 x 2.5 mm	Sumida	CDC5D235R6

3.3 V Version

Designator	Qty	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer Part Number
U1	1	PFM/PWM Step−Down DC−DC Controller	3.3 Vout, 600 kHz	NA	Thin SOT−23−5	ON Semiconductor	NCP1550SN33T1
D1	1	Schottky Power Rectifier	1.0 A, 10 V	NA	POWERMITE®	ON Semiconductor	MBRM110LT3
TR1	1	Power MOSFET	1.0 A, 20 V	NA	ChipFET™	ON Semiconductor	NTHS4101PT1
C1	1	Low Profile Tantalum Chip Capacitor	33 μF, 10 V	10%	6032−28	Kemet	T491C336K010AS
C2	1	Low ESR Tantalum Chip Capacitor	68 μF, 10 V	10%	7343−31	Kemet	T494D686K010AS
L1	1	SMD Power Inductor	3.3 μH, 1.90 A	20%	6.0 x 6.4 x 2.5 mm	Sumida	CDC5D233R3

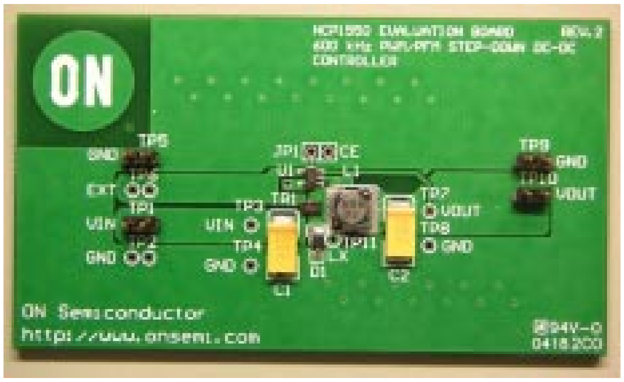

Figure 5. NCP1550 Evaluation Board

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