

# When and How to Supply an External Bias for Buck Controllers – Part 1



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In multi-rail systems system designers often have to make the choice of where to tap into for the input rail for the buck controllers. Often it is from 12V or 24V rails, however in some cases it's from 5V or 3.3V rails. I will be discussing the need to supplying external bias and its benefits in the first part of this 3 part series.

Well, it comes down to the metal-oxide semiconductor field-effect transistor (MOSFET) curves and operating the MOSFETs in their sweet spots. It also depends on the input voltage. Most controllers are designed for use in a 5V or 12V rail, yet in many cases system designers use the same controllers in lower voltage rails.

If you look at the data sheets of those controllers, the  $V_{IN}$  range checks out OK, but are you really getting the best performance or highest efficiency possible when operating at 3.3V?

Let's use TI's LM27403 as an example. [Figure 1](#) shows the applicable info from the data sheet.

		MIN	NOM	MAX	UNIT
VIN	Input voltage <sup>(2)</sup>	3.0		5.5	V
	VIN tied to VDD	3.0		20	V

Figure 1. LM27403  $v_{IN}$  Range

The minimum  $V_{IN}$  is 3V, so it passes the sanity check for use with a 3.3V rail. Now, let's look at the block diagram for the LM27403, shown in [Figure 2](#).

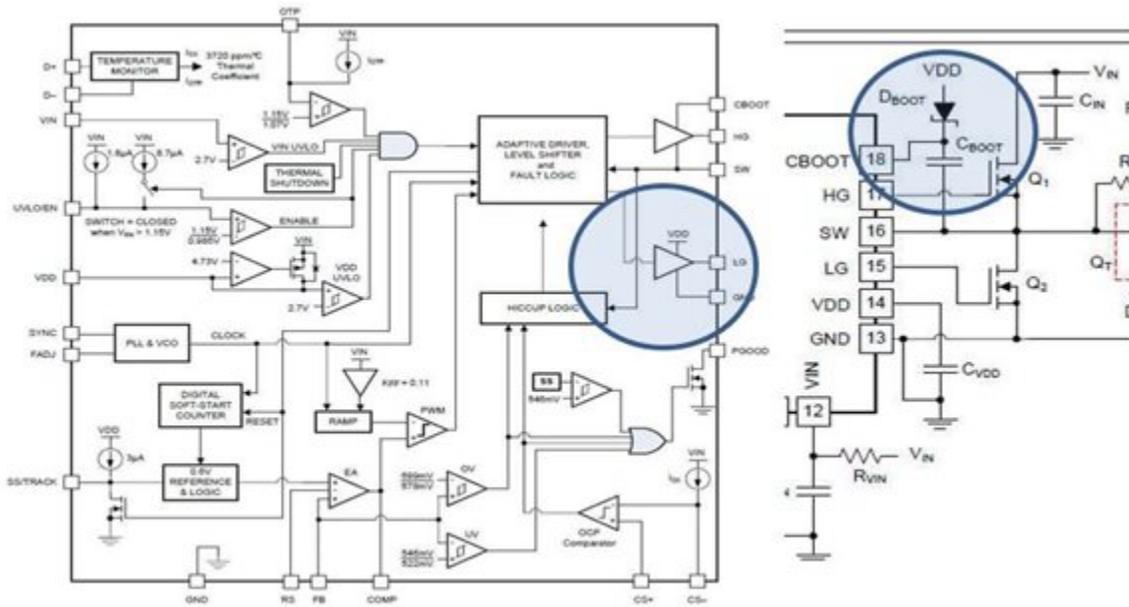


Figure 2. LM27403 block diagram

VDD in [Figure 2](#) powers both the low- and high-side drivers. The supply for the low-side driver is VDD and the supply for the high-side driver is  $C_{BOOT}$ , also known as VDD-Dboot. This means that the low-side FET will see 3.3V for the gate drive and the high-side FET will see 3.3V minus the boot diode drop.

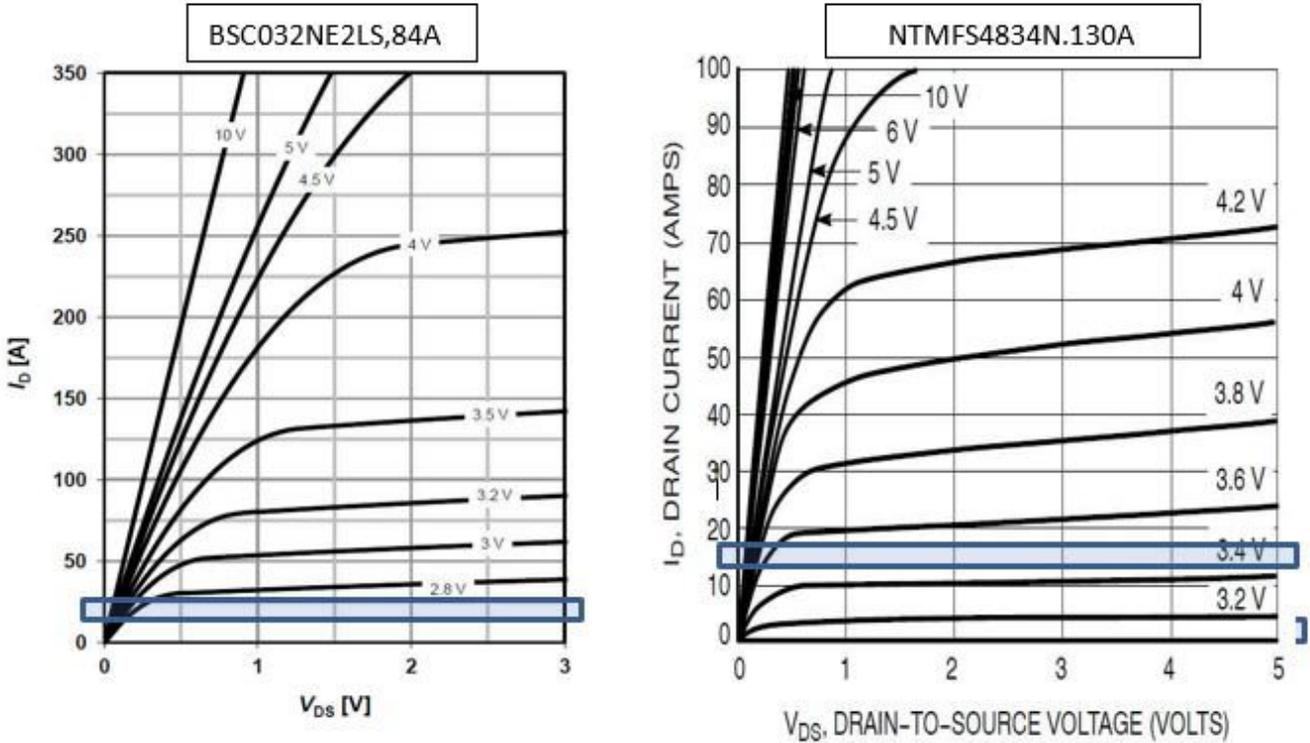
You'll usually want to use controllers when your output-current needs are higher than 5A. Take a 15A application. [Figure 3](#) lists a few random FET choices.

FETS	$I_D$ max	Rdson spec	$I_D$ at $V_{gs}=3V$	Rdson at $V_{gs}=3V$	$I_D$ at $V_{gs}=5V$	Rdson at $V_{gs}=5V$
NTD4806N	76A	10m $\Omega$	<3A	No data	>70A	6m $\Omega$
CSD17308Q3	50A	10m $\Omega$	No data	12m $\Omega$	>30A	8.5m $\Omega$
CSD17304Q3	56A	6m $\Omega$	>30A	9.5m $\Omega$	>30A	6.5m $\Omega$
CSD17309Q3	60A	5m $\Omega$	>30A	6m $\Omega$	>50A	4.5m $\Omega$
CSD17581Q3A	60A	3.2m $\Omega$	No data	10m $\Omega$	>50A	3.7m $\Omega$
NTMFS4834N	130A	4m $\Omega$	10A	25m $\Omega$	>100A	3.5m $\Omega$
BSC032NE2LS	84A	3m $\Omega$	50A	10m $\Omega$	>70A	3.5m $\Omega$
CSD16556Q5B	100A	1m $\Omega$	No data	3m $\Omega$	>70A	1.2m $\Omega$
BSC010NE2LS	100A	1m $\Omega$	75A	3m $\Omega$	>70A	1m $\Omega$
CSD87350Q5D -control fet	40A	5m $\Omega$	No data	8m $\Omega$	>30A	5m $\Omega$
CSD87350Q5D -sync fet	40A	1.2m $\Omega$	No data	2.7m $\Omega$	>30A	2.2m $\Omega$

**Figure 3. FET Choices for a 15A Design**

Referring to [Figure 3](#) and [Figure 4](#) you can see that the  $I_D$  max and Rdson spec columns in the data sheet can be misleading when it comes to operating at 3.3V. Factoring in a 10% tolerance, examine the FET curves (in [Figure 4](#)) for 3V and the drain current in the  $I_D$  at  $V_{gs}=3V$  column in [Figure 3](#). This is the significant parameter that tells you whether a FET can natively support operation at  $V_{IN} = 3.3V$ . For example, the NTMFS4834N will not support a 15A application even though it has a low Rdson number (see the  $I_D$  capability at  $V_{gs} = 3V$  in [Figure 4](#)). This same FET would be OK if you were supplying 5V to the VDD pin of the LM27403. But using FETs that are not designed for a 3.3V application will affect three things:

- The FET won't support the current, and the high  $V_{ds}$  drop will cause high power dissipation or even damage the device.
- Efficiency will be lower than expected due to the sharp increase in Rdson at 3Vgs.
- If the controller uses Rdson for sensing the current limit, the current limit may not function correctly.



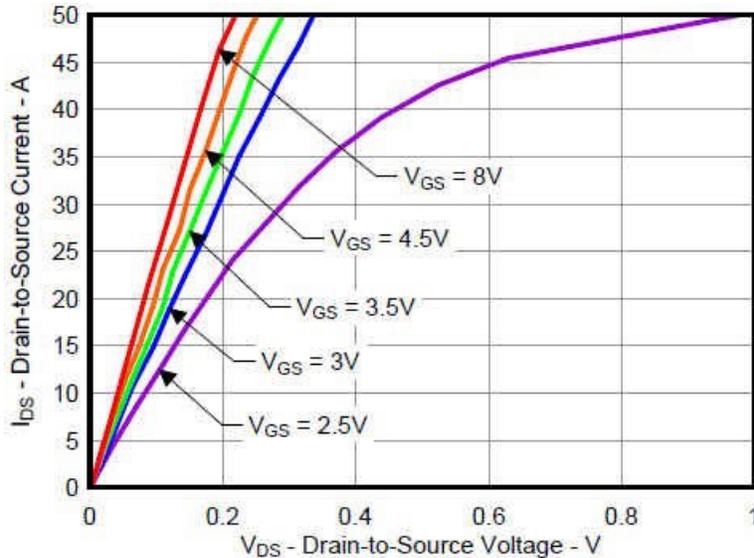
Good choice for a 3.3V input voltage/15A design

Bad choice for a 3.3V input voltage/15A design

**Figure 4. FET Curves Showing  $I_D$  Versus  $V_{DS}$**

Figure 3 indicates that all of the FETs would be fine to use at  $V_{GS} = 5V$ .

Talking about MOSFET data sheets, the CSD17304Q3 and CSD17309Q3 data sheets show my favorite format depicting curves down to lower  $V_{GS}$  levels. Figure 5 shows the curves down to  $V_{GS}$  levels of 2.5V. Kudos to the applications team that did this.



**Figure 5. FET Curve from the CSD17309Q3 Data Sheet**

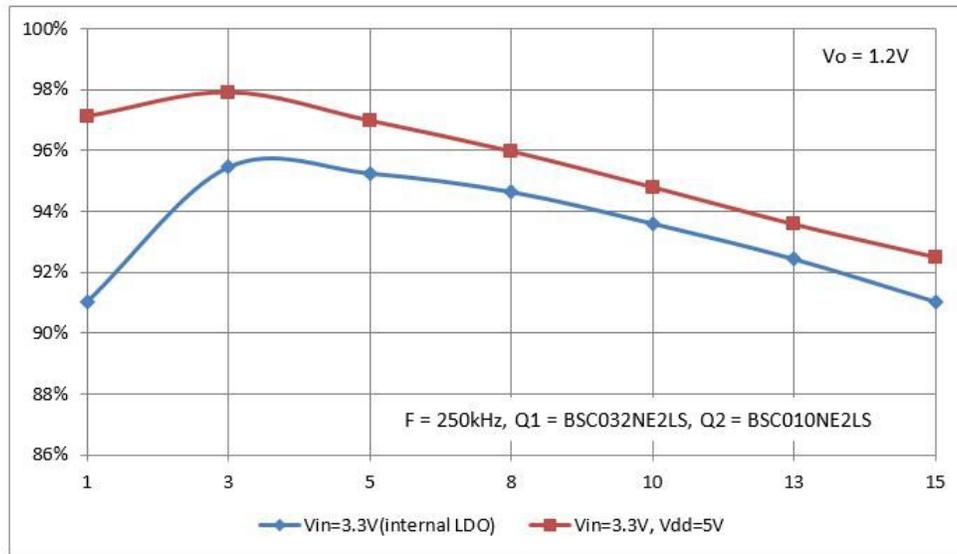
How do you accomplish that practically for a 3.3V rail? This leads me to the question I asked at the beginning of this post; when to use an external bias for controllers.

In some cases external bias is used as an efficiency improvement measure. In other cases external bias makes it practical for the FET to support the current.

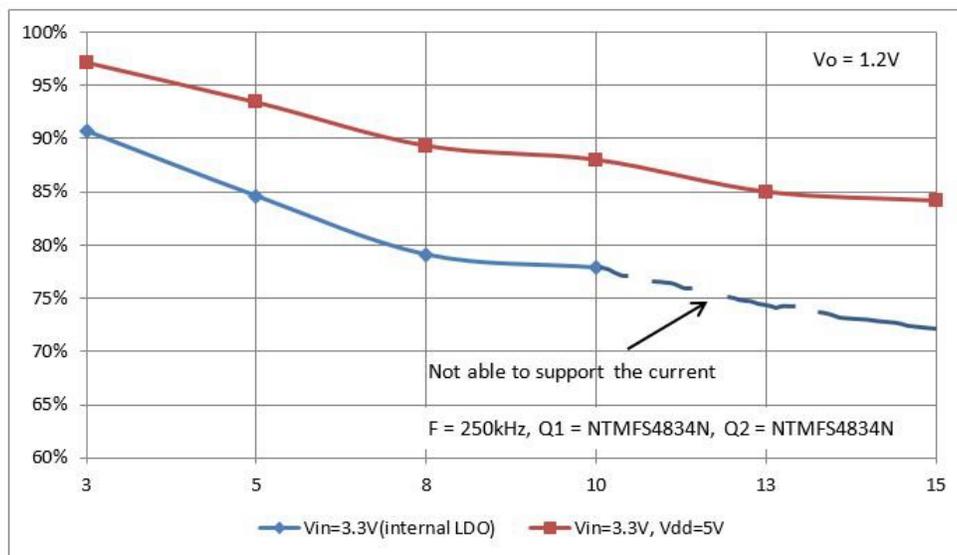
Figure 6 and Figure 7 shows the efficiency improvements for different configurations of VDD with different FETs.

How much current should the bias regulator be capable of supplying? It should be capable of providing the non-switching quiescent current plus the average gate-drive currents ( $I_{BIAS}$ ). You can calculate this using the CSD87350Q5D as an example (see

$$I_{BIAS} = Q_{G(ctrl)} + Q_{G(sync)} \times f_{SW} = 30 \text{ nC} \times 250 \text{ kHz} = 7.5 \text{ mA} \quad (1)$$

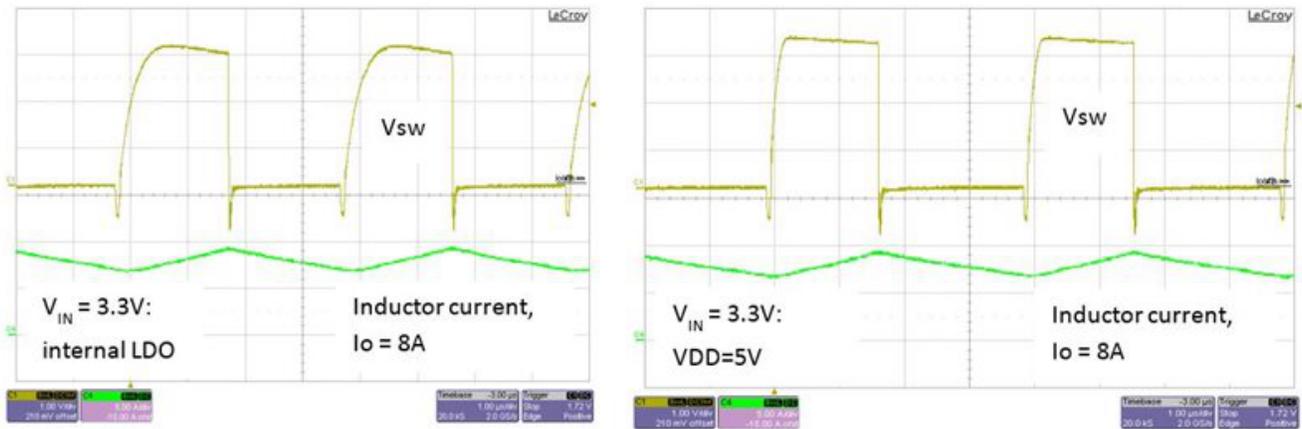


**Figure 6. Efficiency Curves for the LM27403 and BSC032NE2LS/BSC010NE2LS, with Internal and External Bias**



**Figure 7. Efficiency Curves for the LM27403 and NTMFS4834, with Internal and External Bias**

Figure 8 shows the impact of DC bias on the switching waveform, with dc bias the rise times are fast.



**Figure 8. Switching Waveforms with and without DC Bias**

So as you can see, you have to pay careful attention to FET selection in controller designs that run off of a 3.3V rail. By pairing the right FET, you can get a trouble-free design performing at its best; by using a device that flexibly applies external bias, you can optimize your design for cost and highest efficiency.

In the next installment of this series, I'll discuss these two topics:

- Can you apply an external bias voltage to any controller VDD pin or  $V_{IN}$  pin?
- If you don't have a 5V bias rail available in your system, can you generate a 5V bias rail from the DC/DC converter by using a charge pump?

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