Application Note
AN-LV-11-2013-V1.0-EN-059

Selecting P-channel MOSFETs for Switching Applications

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Edition 2013-11-26
Published by
Infineon Technologies Austria AG
9500 Villach, Austria

AN-LV-10-2013-V1.0-EN-059
Revision History: 13-11-25, V1.0
Subjects: Application Note initialized

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1 Introduction

P-channel MOSFETs are often used for load switching. The simplicity of P-channel solutions on the high side makes them equally attractive for applications such as Low-Voltage Drives and non-isolated Point of Loads in systems where space is at a premium. The main advantage of a P-channel MOSFET is the simplified gate driving technique in the high side switch position and often reduces the overall cost. This application note discusses the advantages of P-channel MOSFETs as a high side switch in these applications.

2 Comparison between P-channel and N-channel MOSFETs in an application

The source voltage of an N-channel MOSFET when used as a high side switch will be at a higher potential with respect to ground. Thus, to drive an N-channel MOSFET an isolated gate driver or a pulse transformer must be used. The driver requires an additional power supply whilst the transformer can sometimes produce incorrect conditions. However, this is not the case with P-channel. It is easy to drive a P-channel high side switch with a very simple level shifter circuit. Doing this simplifies the circuit and often reduces the overall cost.

However, the point to be noted here is that it is not possible to achieve the same $R_{DS(on)}$ performance for a P-channel MOSFET as for an N-channel with the same chip size. As the mobility of the carriers in an N-channel is approximately 2 to 3 times higher than that of a P-channel, for the same $R_{DS(on)}$ value, the P-channel chip must be 2 to 3 times the size of the N-channel. Because of the larger chip size, the P-channel device will have a lower thermal resistance and a higher current rating but its dynamic performance will be affected proportionally by the chip size.

So, in a low frequency application where the conduction losses are prominent, a P-channel MOSFET should have a comparable $R_{DS(on)}$ to that of an N-channel. In this case, the P-channel MOSFET chip area will be larger than that of the N-channel.

Also, in high frequency applications where the switching losses are dominant, a P-channel MOSFET should have similar total gate charges to that of an N-channel. In this case, a P-channel MOSFET has a similar chip size but a lower current rating than that of an N-channel.

Thus a suitable P-channel MOSFET must be carefully selected taking into consideration the appropriate $R_{DS(on)}$ and gate charge.

3 Choosing a P-channel MOSFET for an application

There are several switching applications that can benefit from the use of P-channel MOSFETs such as Low-Voltage Drives and non-isolated Point of Loads. In these applications the key parameters driving the MOSFET selection are device on-resistance ($R_{DS(on)}$) and the gate charge (Q_G). One or other of these parameters becomes more important depending on the switching frequency in the application.

3.1 Low-Voltage Drives

In Low-Voltage Drive applications the N-channel MOSFETs are often used in a full-bridge or B6-bridge configuration with the motor and a DC source. The trade-off for the advantages offered by N-channel devices is the increasing gate driver design complexity. A gate driver of an N-channel high side switch requires a bootstrap circuit that produces a gate voltage above the motor voltage rail or an isolated power supply to turn it on. Greater design complexity usually results in increased design effort and greater space consumption.

Figure 3.1 below shows the difference between the circuit with complementary MOSFETs and the circuit with N-channel ones. In this configuration, when the high side switch is realized with a P-channel MOSFET, the driver design will be simplified enormously. No charge pump is required for driving the high side switch; it can easily be driven by the MCU via a level shifter. In Low-Voltage Drive applications the N-channel MOSFETs are often used in a full-bridge or B6-bridge configuration with the motor and a DC source. The trade-off for the advantages offered by N-channel devices is the increasing gate driver design complexity. A gate driver of an N-channel high side switch requires a bootstrap circuit that produces a gate voltage above the motor voltage rail or an isolated power supply to turn it on. Greater design complexity usually results in increased design effort and greater space consumption.

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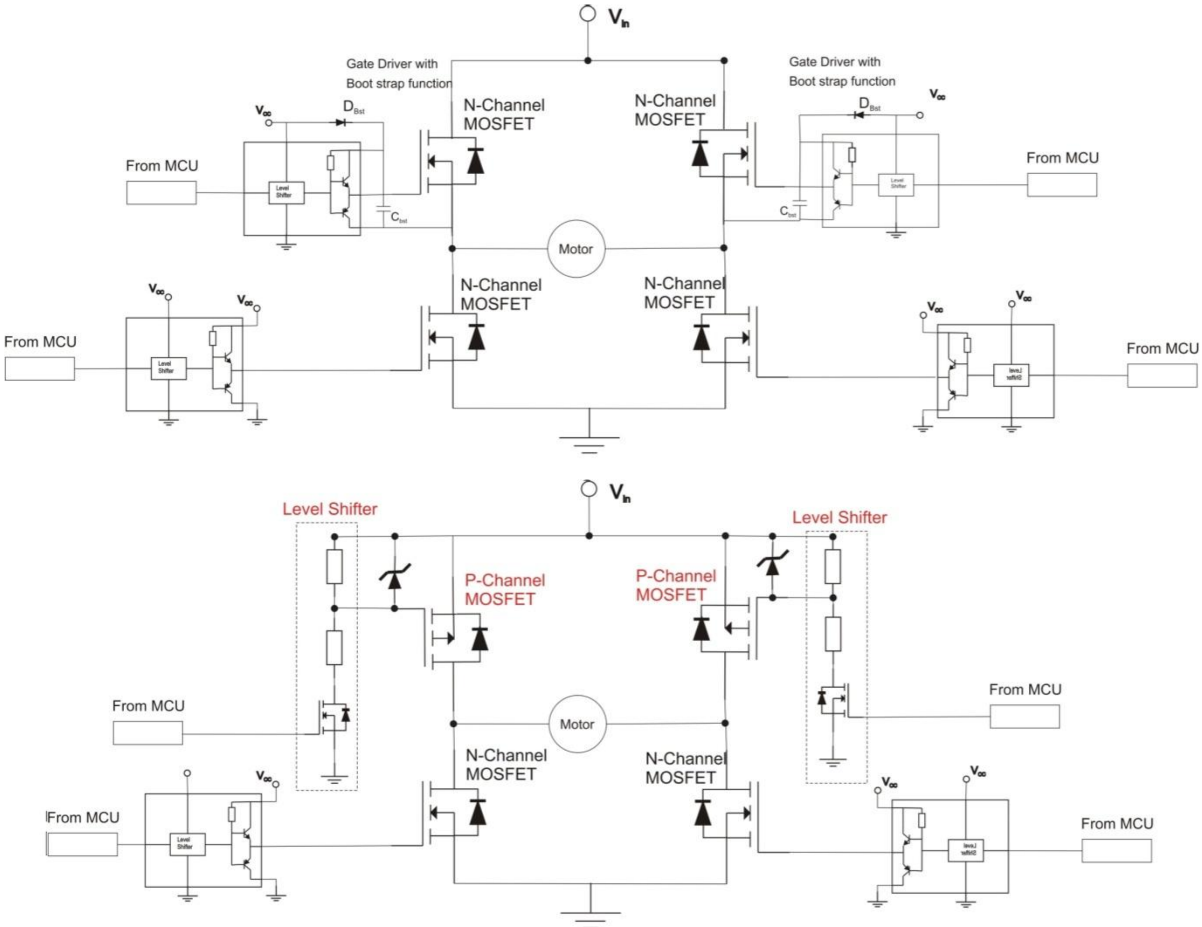

Figure 3.1: Low-Voltage drive application circuit

Generally the switching frequencies in a Low-Voltage Drive application will be between 10 to 50kHz. At these frequencies, most of the power dissipation of a MOSFET is dominated by conduction losses due to the high currents of the motor.

Thus, in this application a P-channel MOSFET with comparable $R_{DS(on)}$ has to be selected to get the maximum advantage of using a P-channel. This can be explained by considering an example of a 30W Low-Voltage Drive powered by a 12V battery. For a high side P-channel MOSFET there can be two options - one with comparable $R_{DS(on)}$ as that of the low side N-channel and one with comparable gate charges. Table 3.1 below shows the parts considered for the full bridge Low-Voltage Drive with similar $R_{DS(on)}$ and with similar gate charges as that of the N-channel MOSFET on the low side.

	Package	$V_{DS,max}$ [V]	$R_{DS(on),max}$ [mΩ]	$I_{D,max}$ [A]	Q_G [nC]	$P_{tot,max}$ [W]	$R_{th,JC}$ [K/W]
BSZ088N03LS G	S3O8	30	8.8	40	16.0	35	3.6
BSZ086P03NS3 G	S3O8	-30	8.6	-40.0	43.2	69	1.8
BSZ180P03NS3 G	S3O8	-30	18.0	-39.6	20.0	40	3.1

Table 3.1: Parts considered for the application

The losses of the MOSFETs in the application are shown in Table 3.2 below.

	BSZ088N03LS G	BSZ086P03NS3 G	BSZ180P03NS3 G
Conduction Losses [mW]	220	215	450
Switching Losses [mW]	14.1	33.9	22.0
Total MOSFET Losses [mW]	234.1	248.9	472.0

Table 3.2: MOSFET losses in the application

From Table 3.2: MOSFET losses in the application it is clear that the total power losses are dominated by the conduction losses as shown in the pie chart below. It is also clear that if the P-channel MOSFET is chosen with similar gate charges as that of the N-channel the switching losses will be comparable but the conduction losses will be too high. Thus for the applications with low switching frequencies the high side P-channel MOSFET has to have a comparable $R_{DS(on)}$ as that of the low side N-channel.

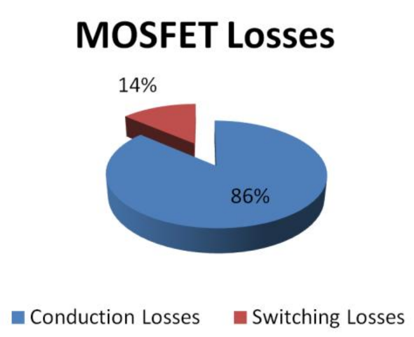

Figure 3.2: MOSFET losses in the application

3.2 Non-isolated Point of Loads

Low power non-isolated Point of Loads where the output power is less than 10W, represents one of the biggest design challenges. Size must be kept to a minimum while maintaining an acceptable level of efficiency.

One common way to reduce converter size is to specify a higher operating frequency. Faster switching means a smaller inductor can be used. Schottky diodes are sometimes used for synchronous rectification in these circuits but MOSFETs are a better choice as output voltages decrease, since the voltage drop can be significantly less than with a diode.

An additional space-saving technique is to replace the high side N-channel MOSFET with a P-channel. The P-channel approach eliminates the need for complex additional circuitry to drive the gate, as required when a N-channel MOSFET is used on the high side. Figure 3.2 below shows the basic circuit diagram of a buck converter with a P-channel MOSFET on the high side.

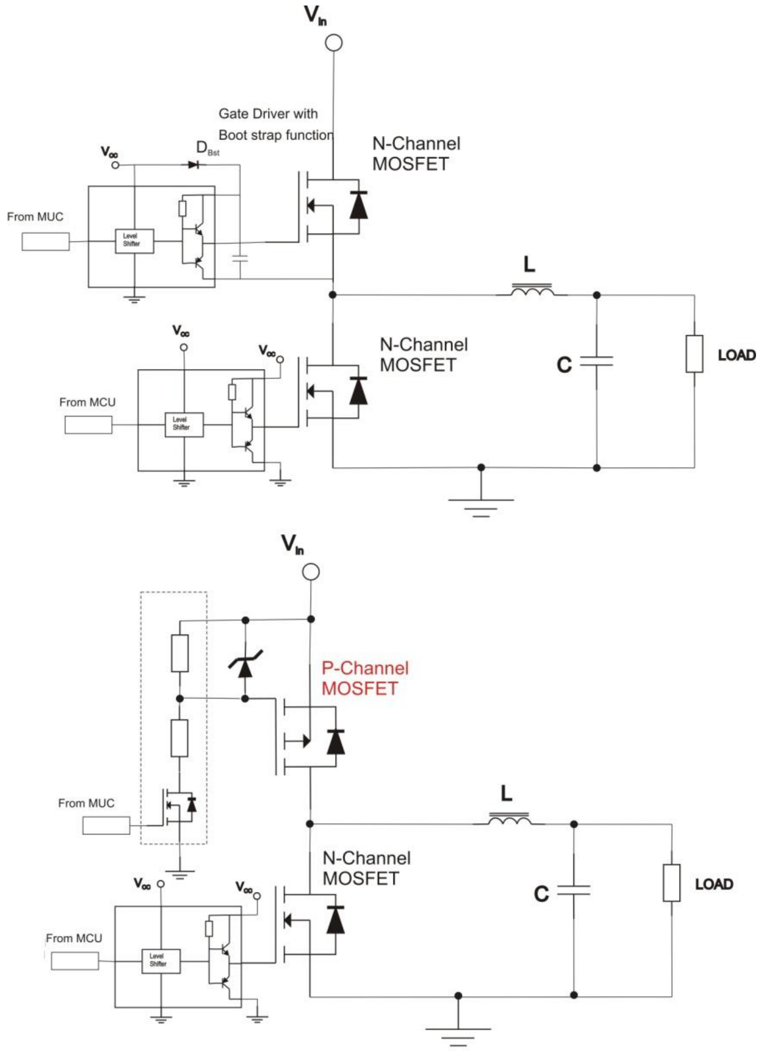

Figure 3.3: Buck converter circuit

Generally the switching frequencies in non-isolated Point of Load applications will be around 500kHz even sometimes up to 2MHz. In contradiction to previous applications, at these frequencies, the dominating loss component is the switching loss. Figure 3.3 below shows the loss contribution of the MOSFET in a 3 watt non-isolated Point of Load application operating at 1MHz.

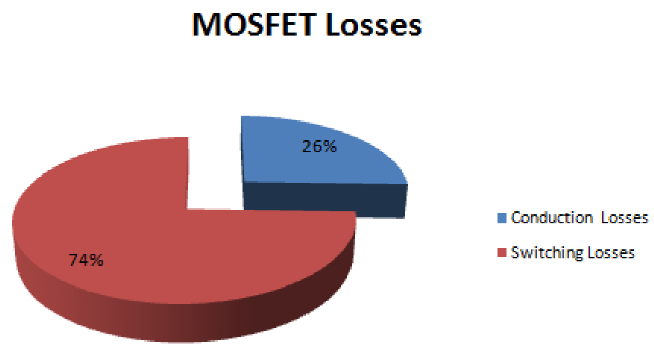

Figure 3.4: MOSFET losses in low power Buck Converters

Thus a high side P-channel MOSFET with comparable gate charge to that of the low side N-channel MOSFET has to be selected.

4 Conclusion

Using a P-channel MOSFET clearly offers designers benefits in terms of easier, more reliable and more optimized circuit design. For given applications, the trade-off between $R_{DS(on)}$ and Q_G must be evaluated when selecting a P-channel MOSFET in order to achieve optimal performance.

Infineon offers a wide range of P-channel MOSFETs both in small signal and power packages.

Table 4.1 & Table 4.2 below shows the Infineon P-channel MOSFET portfolio.

	Package	$V_{DS,max}$ [V]	$R_{DS(on),max}$ [mΩ]	$I_{D,max}$ [A]	$P_{tot,max}$ [W]	Q_G [nC]	$R_{th,JC}$ [K/W]
SPB08P06P G	D2PAK (TO-263)	-60	300	-8.8	42	-10	3.6
SPB18P06P G	D2PAK (TO-263)	-60	130	-18.6	80	-22	1.85
SPB80P06P G	D2PAK (TO-263)	-60	23	-80	375	-115	0.4
SPD04P10P G	DPAK (TO-252)	-100	1000	-4	38	-9	3.9
SPD04P10PL G	DPAK (TO-252)	-100	850	-4.2	38	-12	3.9
SPD15P10P G	DPAK (TO-252)	-100	240	-15	128	-37	1.17
IPD042P03L3 G	DPAK (TO-252)	-30	4.2	-70	150	-131	1
SPD08P06P G	DPAK (TO-252)	-60	300	-8.83	42	-10	3.6
SPD09P06PL G	DPAK (TO-252)	-60	250	-9.7	42	-14	3.6
SPD18P06P G	DPAK (TO-252)	-60	130	-18.6	80	-22	1.85
SPD30P06P G	DPAK (TO-252)	-60	75	-30	125	-32	1.2
IPD068P03L3 G	DPAK (TO-252)	-30	6.8	-70	100	-68	1.5
SPD15P10PL G	DPAK (TO-252)	-100	200	-15	128	-47	1.17
SPD50P03L G	DPAK 5pin (TO-252 5pin)	-30	7	-50	150	-95	1
BSZ086P03NS3 G	S3O8	-30	8.6	-40	69	-43.2	1.8
BSZ086P03NS3E G	S3O8	-30	8.6	-40	69	-43.2	1.8
BSZ120P03NS3E G	S3O8	-30	12	-40	52	-30	2.4
BSZ180P03NS3E G	S3O8	-30	18	-39.6	40	-20	3.1
BSZ180P03NS3 G	S3O8	-30	18	-39.6	40	-20	3.1
BSZ120P03NS3 G	S3O8	-30	12	-40	52	-30	2.4
BSO130P03S	SO-8	-30	13	-11.3	1.56	-61	110
BSO613SPV G	SO-8	-60	130	-3.44	2.5	-20	100
BSO080P03NS3 G	SO-8	-30	8	14.8	1.6	-61	110
BSO201SP H	SO-8	-20	12.9	-14.9	2.5	-66	110
BSO207P H	SO-8	-20	70	-5.7	1.6	-12	110
BSO303P H	SO-8	-30	21	-8.2	2	-36	110
BSO303SP H	SO-8	-30	21	-9.1	1.56	-40	110
BSO211P H	SO-8	-20	110	-4.6	1.6	-8	110
BSO301SP H	SO-8	-30	8	-14.9	1.79	-102	110
BSO080P03S H	SO-8	-30	8	-14.9	1.79	-102	110
BSO200P03S H	SO-8	-30	20	-9.1	1.56	-40	110
BSO203P H	SO-8	-20	34	-8.2	2	-32.4	110
BSO203SP H	SO-8	-20	34	-9	2.35	-33.6	110
BSO080P03NS3E G	SO-8	-30	8	14.8	1.6	-61	110
BSO130P03S H	SO-8	-30	13	-11.7	1.56	-61	110
BSC080P03LS G	SuperSO8	-30	8	-30	89	-92	50
BSC130P03LS G	SuperSO8	-30	13	-22.5	69	-54.9	1.8
BSC200P03LS G	SuperSO8	-30	20	-12.5	63	-36.4	2
BSC030P03NS3 G	SuperSO8	-30	3	-100	125	-137	1
BSC060P03NS3E G	SuperSO8	-30	6	-100	83	-61	1.5
BSC084P03NS3 G	SuperSO8	-30	8.4	-78.6	69	-43	1.8
BSC084P03NS3E G	SuperSO8	-30	8.4	-78.6	69	-43	1.8
SPP08P06P H	TO-220	-60	300	-8.8	42	-10	3.6
SPP15P10PL H	TO-220	-100	200	-15	128	-47	1.17
SPP18P06P H	TO-220	-60	130	-18.6	80	-22	1.85
SPP80P06P H	TO-220	-60	23	-80	340	-115	0.4
SPP15P10P H	TO-220	-100	240	-15	128	-37	1.17

Table 4.1: P-channel Power MOSFET portfolio

	Package	$V_{DS,max}$ [V]	$R_{DS\ (on),max}$ [mΩ]	$I_{D,max}$ [A]	$P_{tot,max}$ [W]	Q_G [nC]	$R_{th,JC}$ [K/W]
SPB08P06P G	D2PAK (TO-263)	-60	300	-8.8	42	-10	3.6
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SPD09P06PL G	DPAK (TO-252)	-60	250	-9.7	42	-14	3.6
SPD18P06P G	DPAK (TO-252)	-60	130	-18.6	80	-22	1.85
SPD30P06P G	DPAK (TO-252)	-60	75	-30	125	-32	1.2
IPD068P03L3 G	DPAK (TO-252)	-30	6.8	-70	100	-68	1.5
SPD15P10PL G	DPAK (TO-252)	-100	200	-15	128	-47	1.17
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BSO211P H	SO-8	-20	110	-4.6	1.6	-8	110
BSO301SP H	SO-8	-30	8	-14.9	1.79	-102	110
BSO080P03S H	SO-8	-30	8	-14.9	1.79	-102	110
BSO200P03S H	SO-8	-30	20	-9.1	1.56	-40	110
BSO203P H	SO-8	-20	34	-8.2	2	-32.4	110
BSO203SP H	SO-8	-20	34	-9	2.35	-33.6	110
BSO080P03NS3E G	SO-8	-30	8	14.8	1.6	-61	110
BSO130P03S H	SO-8	-30	13	-11.7	1.56	-61	110
BSC080P03LS G	SuperSO8	-30	8	-30	89	-92	50
BSC130P03LS G	SuperSO8	-30	13	-22.5	69	-54.9	1.8
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SPP80P06P H	TO-220	-60	23	-80	340	-115	0.4
SPP15P10P H	TO-220	-100	240	-15	128	-37	1.17

Table 4.2: P-channel Small Signal MOSFET portfolio