High Efficiency Synchronous Buck Converter using optimised Split-Gate RSO MOSFET

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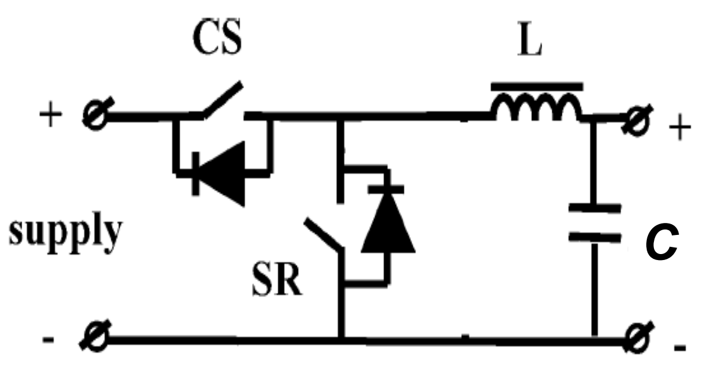
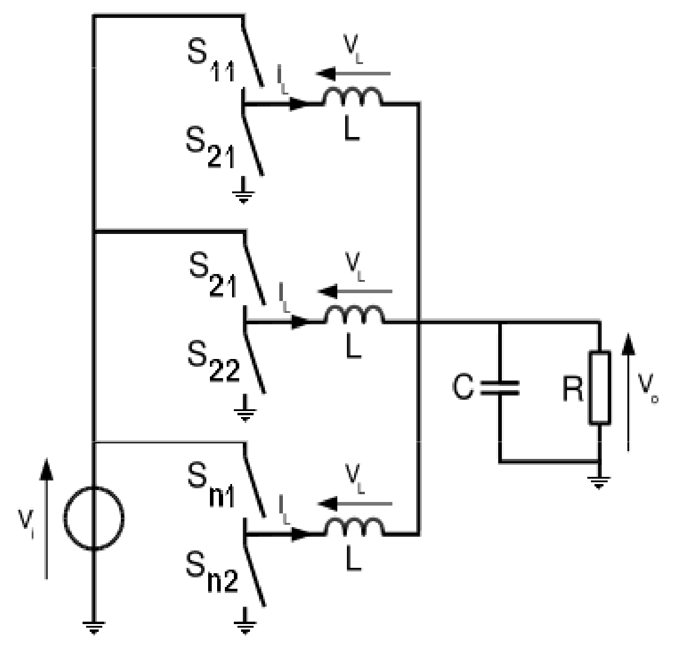
Introduction



Synchronous Step Down/Buck Converter

In this work, we have investigated a Split-Gate RSO (Resurf Stepped Oxide) MOSFET for the application of synchronous buck converter. The device showed a remarkable Figure of Merit (FOM). The efficiency of the device responding in synchronous buck converter circuit confirmed that this device is perfect for this application. Simulations corroborate an impressive improvement of efficiency of the VRM in the 5MHz range. The results show that Split Gate RSO MOSFET can achieve an extremely good FOM of 5.83 mΩnC and the efficiency of the circuit at switching frequency of 5Mhz was as high as 80% which makes Split-Gate RSO MOSFET the ideal switch for this kind of application.



Multiphase buck converter with Synchronous buck circuitry.

DC-DC Buck Converter Requirement on its Switches

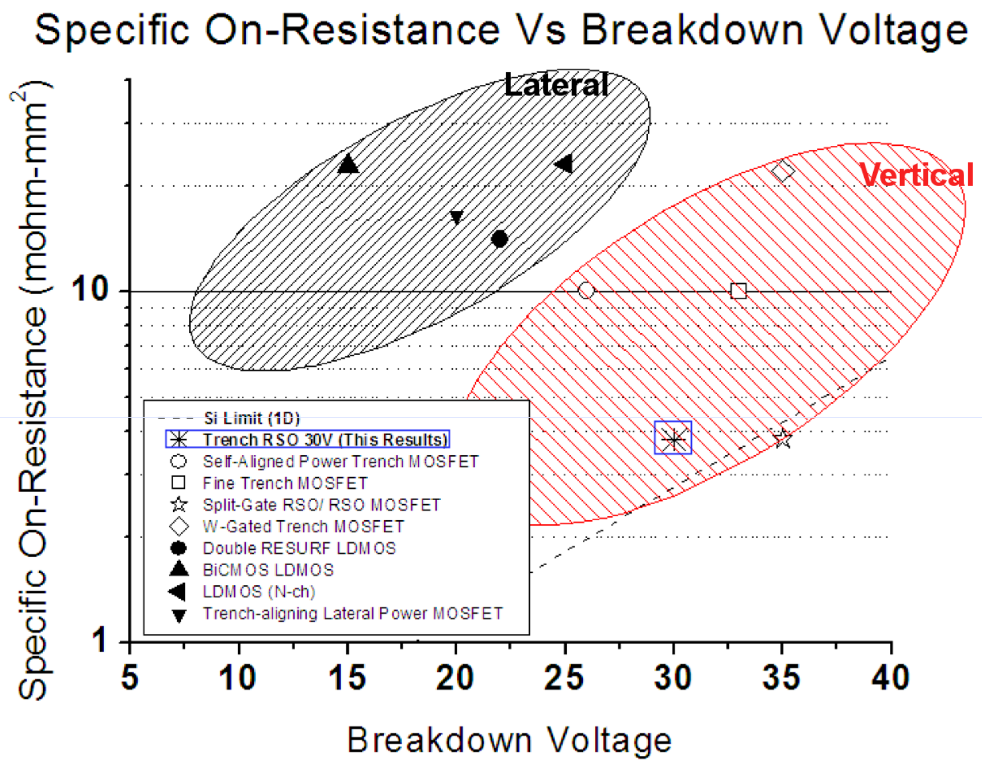
The two power switches in DC-DC converters, high-side and low-side.

High-side – Also known as control switch, requires low turn-on resistance and low gate-to-drain charge. FOM is mΩ×nC.

Low-side – Also known as synchronous rectifier, requires low turn-on resistance and good body diode. FOM is mΩ×mm^2.

This project is looking for application in high switching frequency voltage regulator module.

Vertical vs Lateral MOSFET

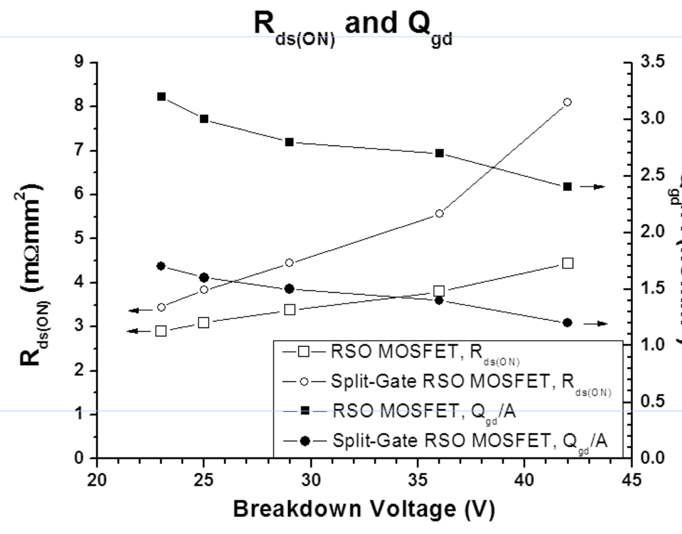


Vertical– Lower on-state resistance, higher switching losses, more expensive to manufacture and harder to integrate due to drain at bottom.

Lateral – Higher on-state resistance, lower switching losses. Easier to integrate because all contact is at the top.

N_{epi} Doping Concentration

Different BV with variation of N-Epi Doping

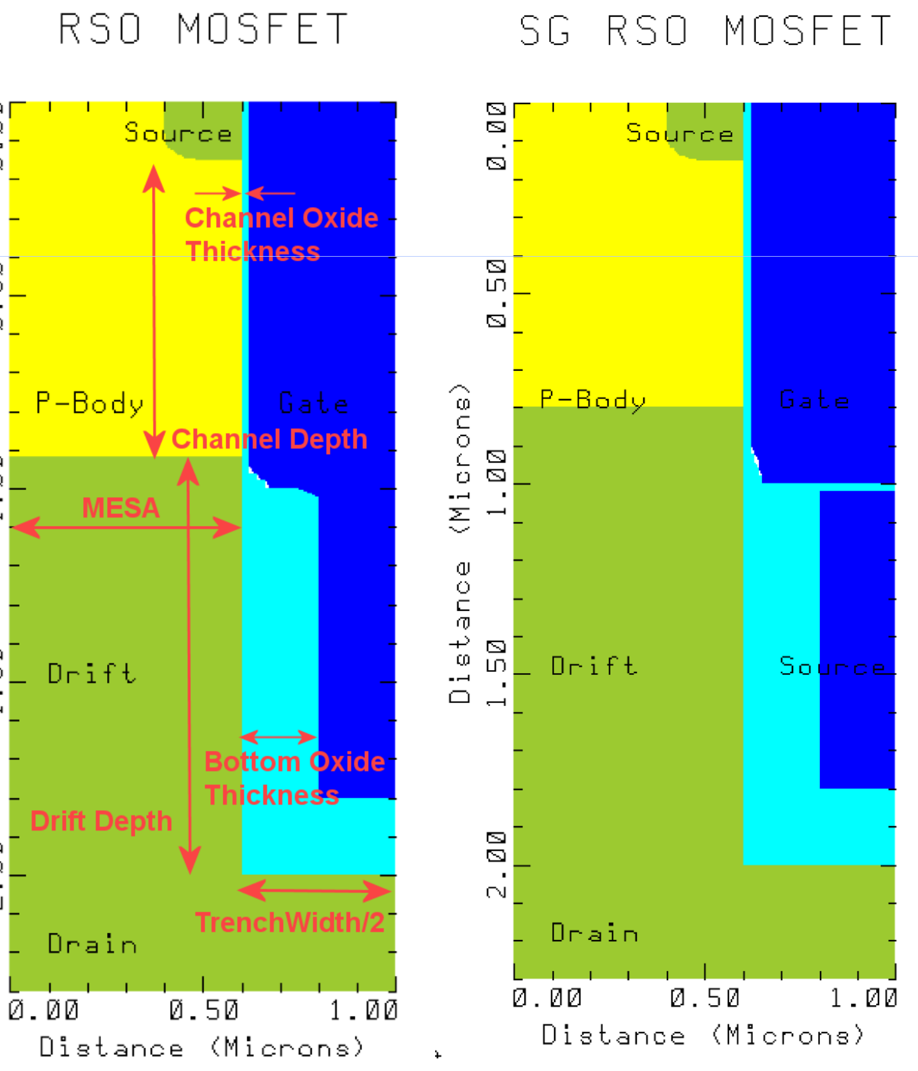


Bottom Oxide Thickness (um)	BV (V)	$R_{ds(ON)}$ (mΩ mm^2)	Q_{gd}/A (nC mm^{-2})	$R_{ds(ON)} \times Q_{gd}$ (mΩ nC)
2.0	29	4.44	1.5	6.66
1.5	31	4.72	1.4	6.61
1.0	33	5.41	1.3	7.03

P-Well Dose (cm^{-2})	BV (V)	$R_{ds(ON)}$ (mΩ mm^2)	Q_{gd}/A (nC mm^{-2})	$R_{ds(ON)} \times Q_{gd}$ (mΩ nC)
5E12	31	4.72	1.4	6.61
4E12	30	4.42	1.6	7.07
3E12	29	4.17	1.7	7.09
2E12	27	3.91	1.8	7.04

Trench Channel Depth (um)	BV (V)	$R_{ds(ON)}$ (mΩ mm^2)	Q_{gd}/A (nC mm^{-2})	$R_{ds(ON)} \times Q_{gd}$ (mΩ nC)
1	30	4.42	1.6	7.07
0.9	34	6.37	1.3	8.19

RSO MOSFET and Split-Gate RSO MOSFET



Published by NXP in ISPSD '07.

RSO MOSFET – Extended trench depth with thicker bottom oxide. Improved on-state resistance. (Figure on the left).

Split-Gate RSO MOSFET – Poly extended into the drift region is spited and is connected to source. Slight decrease in on-state resistance but improve(reduce) in gate-to-drain capacitance/charge.(Figure on the right).

Both of these structures are investigated in TSUPREM4 and MEDICI for their performance.

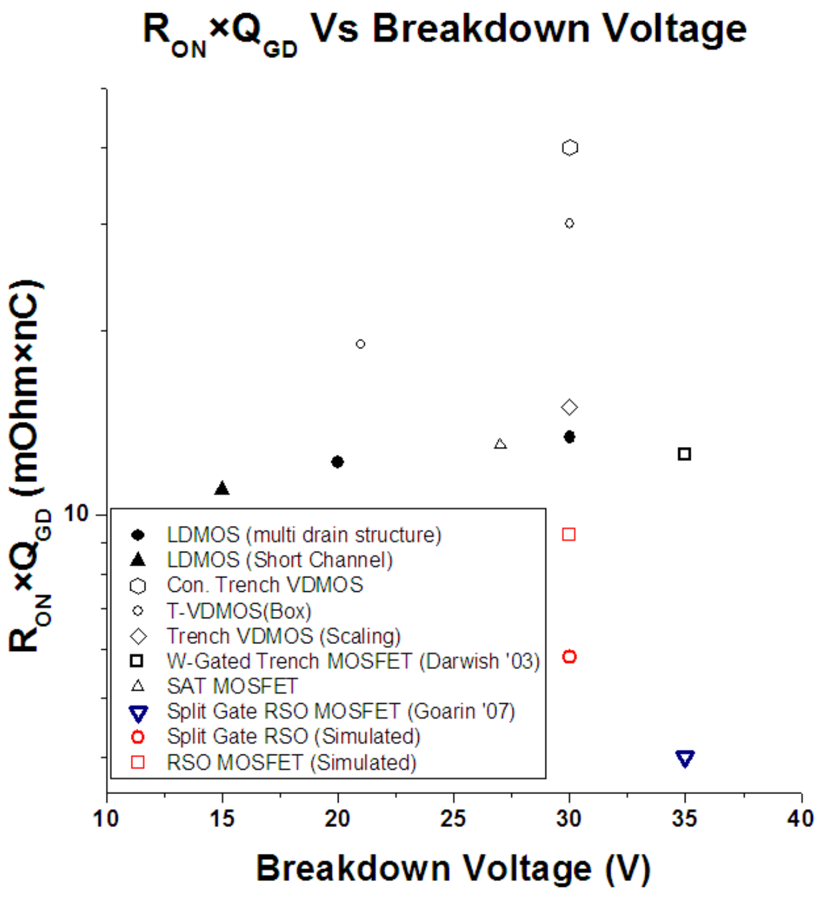
Conclusion

Device modelling Results

Both simulation results is plotted to compare with other literature results. The FOM of these devices is marked in red. At 30V breakdown, the device FOM exhibit exceptionally good even with higher on-state resistance.

The devices is then transferred to Or-Cap circuit simulator to simulate the device in DC-DC circuit level to investigate in its efficiency.

The blue marker is the real Split-Gate RSO MOSFET device from NXP.



Efficiency

Output Characteristic of MEDICI is matched.

V_{in}=12V, V_o=1V

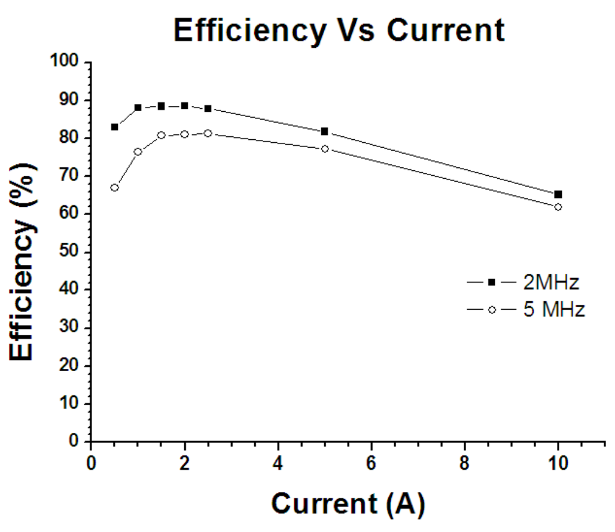
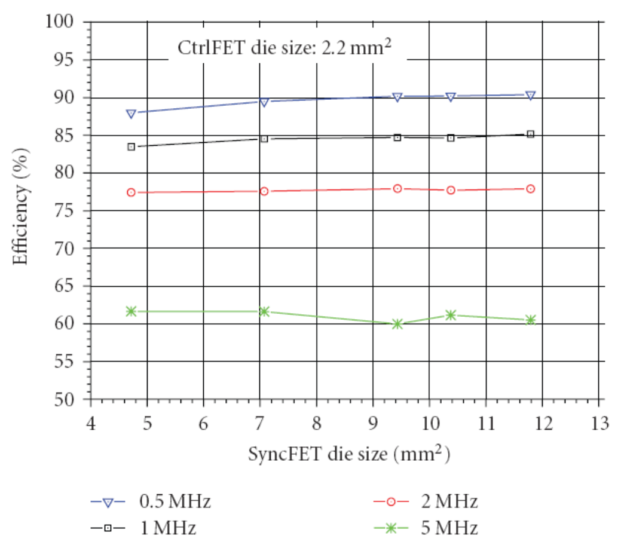


Figure taken from Yali Xiong APEC '07



This plot shows that this device is capable of achieving high efficiency even at high 5MHz switching frequency.

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