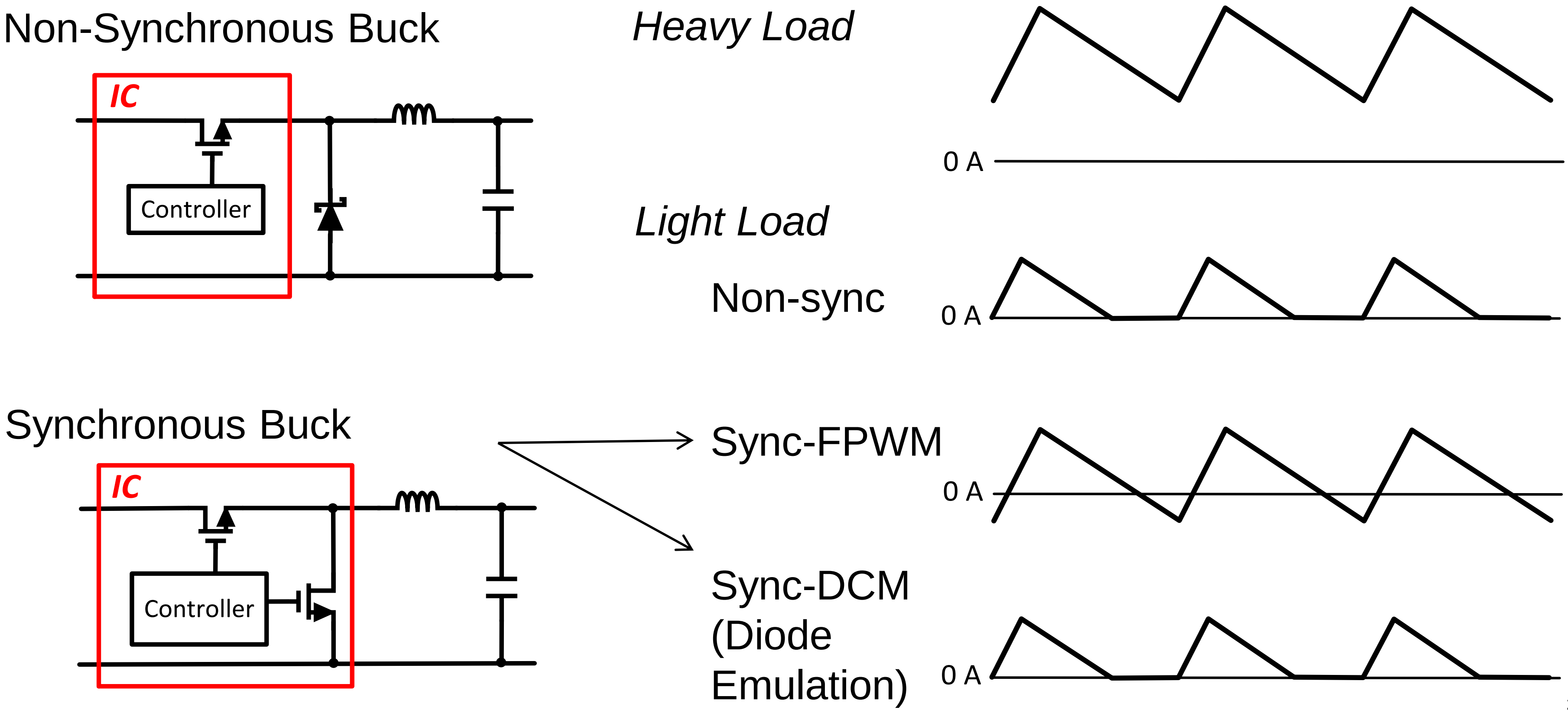
Comparing Synchronous to Non-Synchronous Converters

Comparing Size, Cost, Efficiency, & More

Anston Lobo

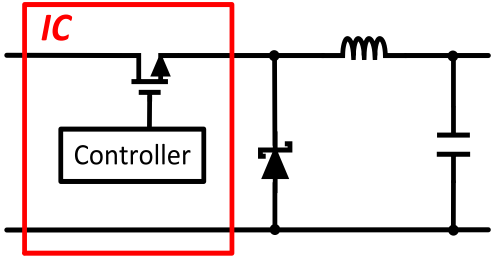
Texas Instruments

Synchronous and non-synchronous buck

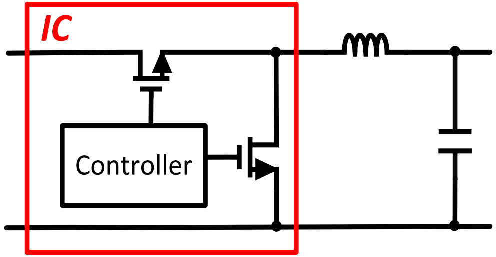


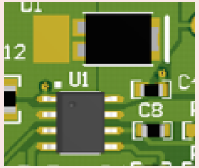
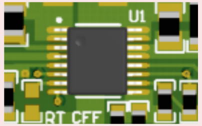
Comparison – Solution size & cost

Non-Synchronous Buck



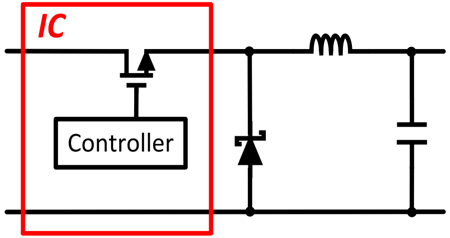
Synchronous Buck



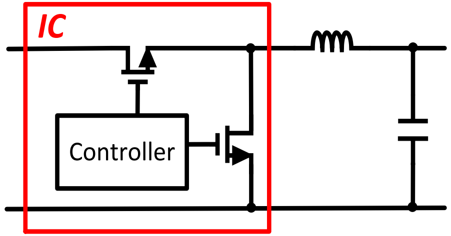
	Non-Sync	Sync
Solution Size	**Larger** IC + Power Diode	**Smaller** Both FETs Integrated
Layout		
Cost	**IC costs less + Diode cost**	**IC costs more**
Other Considerations		▪ *Integrated sync rectifier* ▪ *More Sophisticated controller & driver* ▪ *Needs a thermally optimized package*

Comparison – Ease of use

Non-Synchronous Buck



Synchronous Buck



	Sync	Non-Sync
Design	**Easier**	**Need to select Schottky diode**
External Diode	No need	Selection Considerations ➢ Reverse voltage rating V_R $>V_{IN}$ max ➢ Forward current rating I_{FWD} >Load max + Iripple/2 ➢ Forward voltage drop V_{FWD}, over current and temp Conduction loss = $V_{FWD} * I_{FWD}$ ➢ Reverse leakage current over temp Loss = V_{IN}* Ileak ➢ Parasitic capacitance Switching loss ➢ Package for heat dissipation ➢ Size increase with V_R and I_F

Power diode example – DIODES B340, 40V 3A

B320/B330/B340

V_{RRM} (V)	I_O (A)	V_F max (V)	I_R max (mA)
20/30/40	3.0	0.5	0.5

V_{FWD}

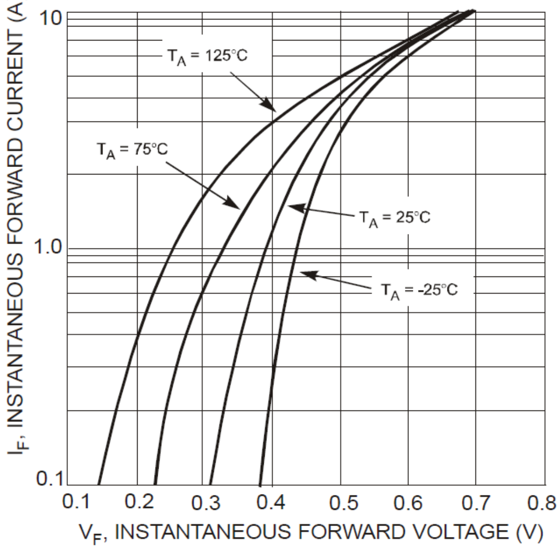


Fig. 1 Typical Forward Characteristics - B320B thru B340B

$I_{REVERSE}$

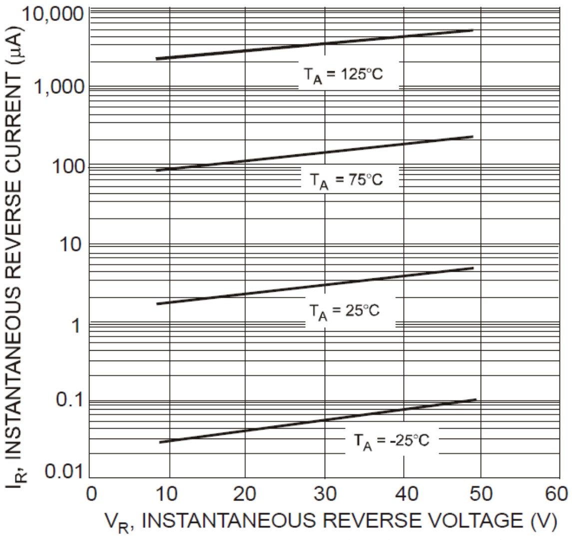
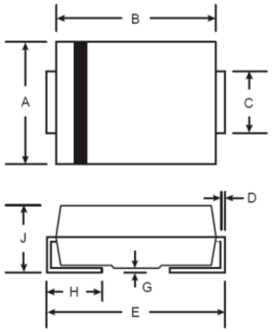


Fig. 3 Typical Reverse Characteristics, B320B thru B340B

Package

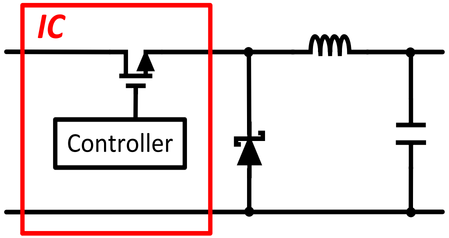


SMC		
Dim	Min	Max
A	5.59	6.22
B	6.60	7.11
C	2.75	3.18
D	0.15	0.31
E	7.75	8.13
G	0.10	0.20
H	0.76	1.52
J	2.00	2.50
All Dimensions in mm		

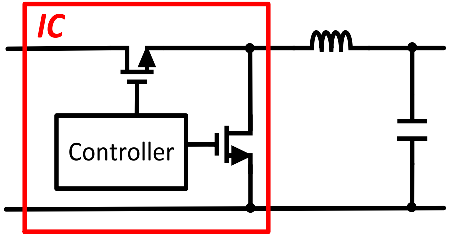
5.59mm×6.6mm

Comparison – Layout to optimize EMI

Non-Synchronous Buck

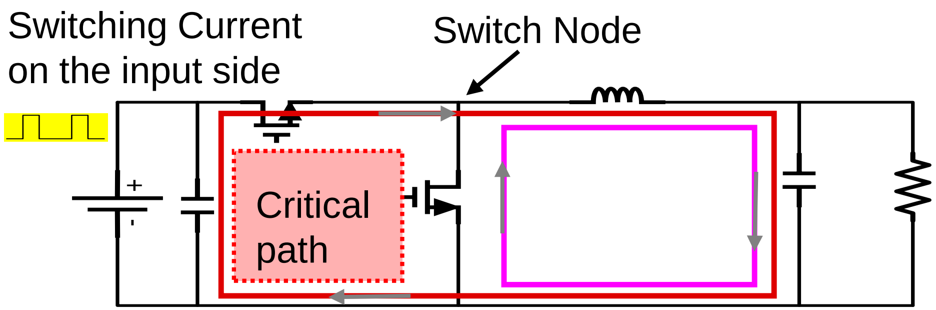


Synchronous Buck

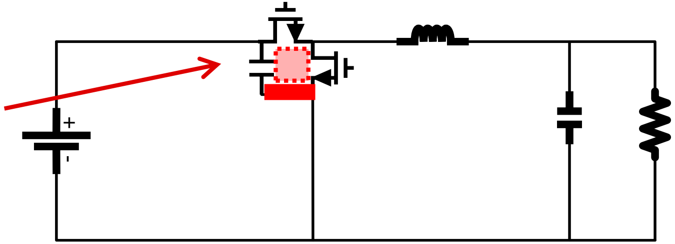


For Any Buck Converter

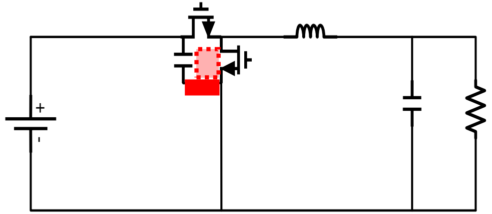
Reduce Critical Path Area → Reduce EMI



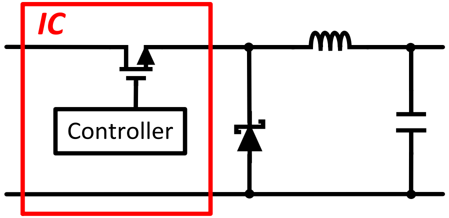
Key of PCB
Layout



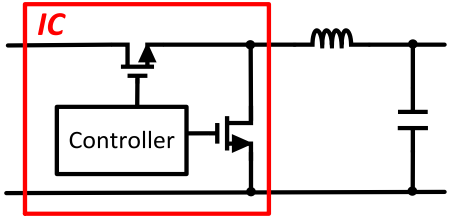
Comparison – Layout to optimize EMI

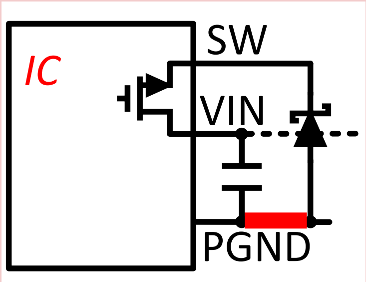
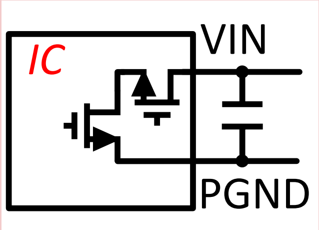


Non-Synchronous Buck



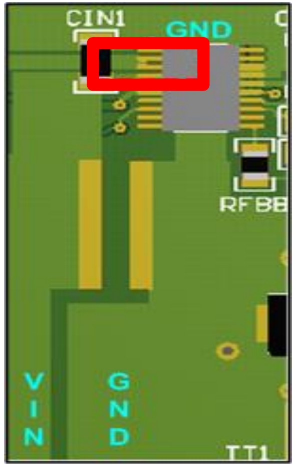
Synchronous Buck

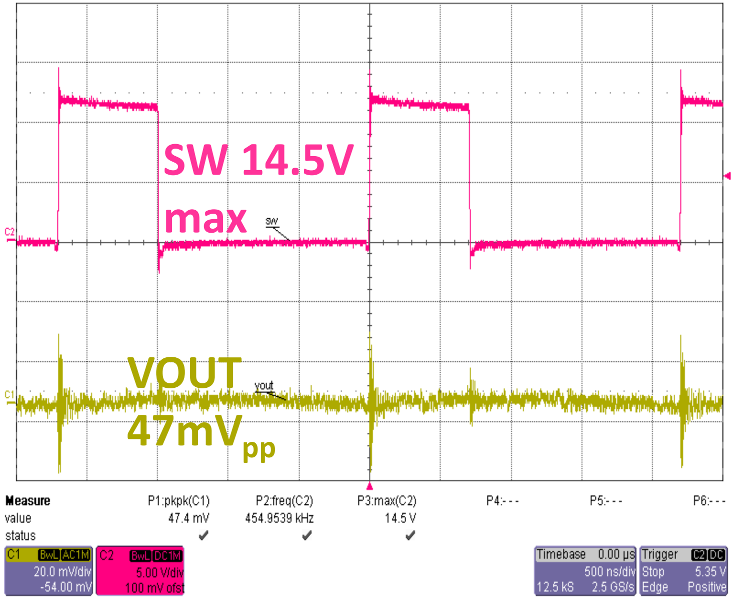


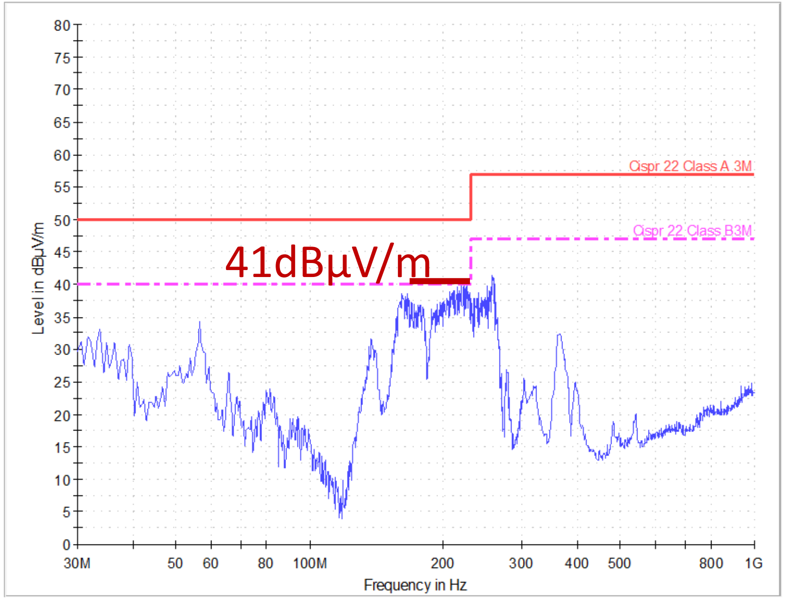
<table>
<tr><th></th><th>Non-Sync</th><th>Sync</th></tr>
<tr><td>Layout for EMI</td><td>Harder to optimize EMI by layout
(Depends on pin out of IC)

</td><td>Easier
(Depends on pin out of IC)

</td></tr>
</table>

EMI mitigation by PCB layout

Critical Path Area Reduction



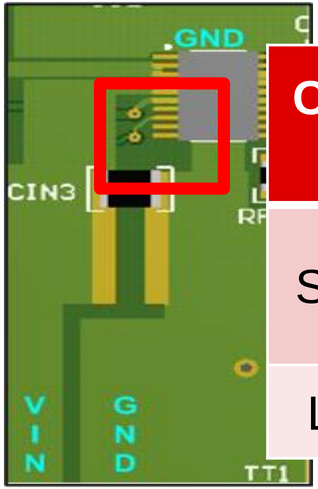


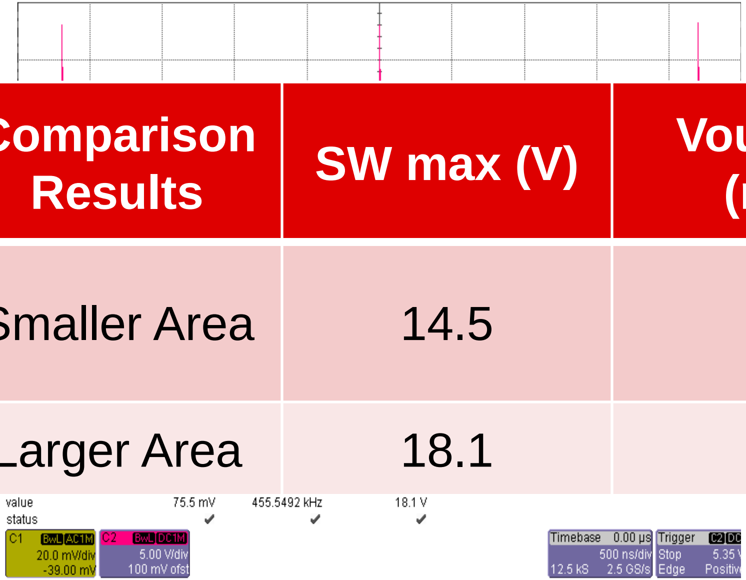


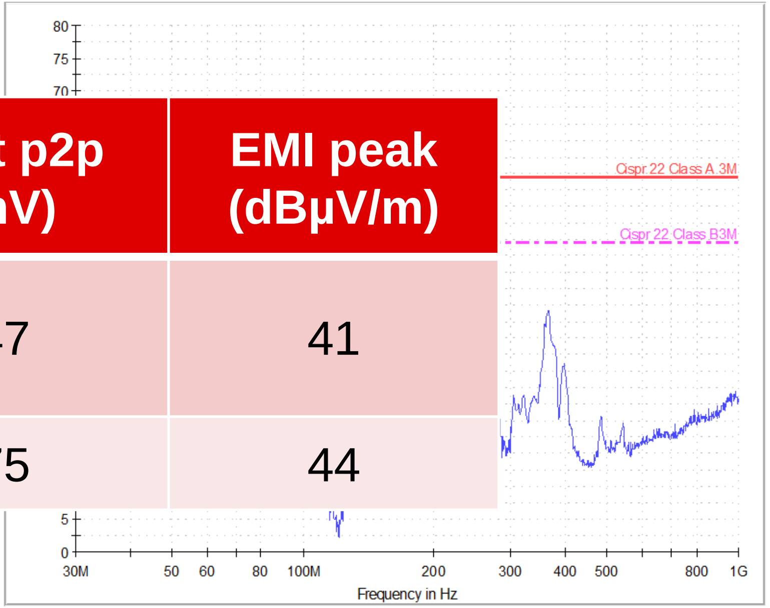
Texas Instruments

EMI mitigation by PCB layout

Critical Path Area Reduction



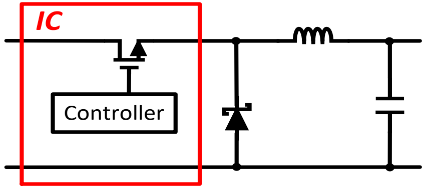


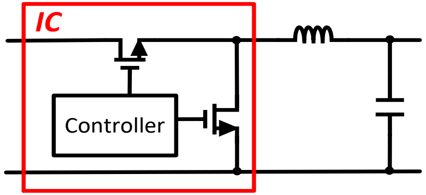


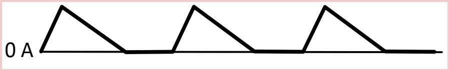
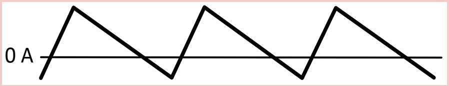
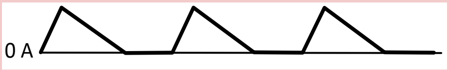
Comparison Results	SW max (V)	Vout p2p (mV)	EMI peak (dBµV/m)
Smaller Area	14.5	47	41
Larger Area	18.1	75	44

Now shown with single C_{IN} with 2.5 times larger area

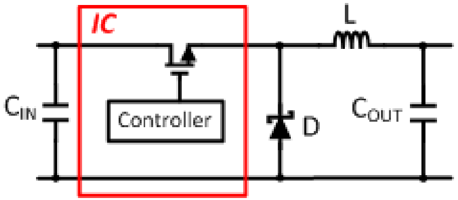
Comparison – Light load efficiency

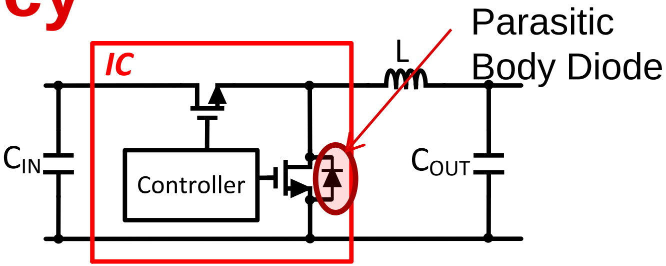


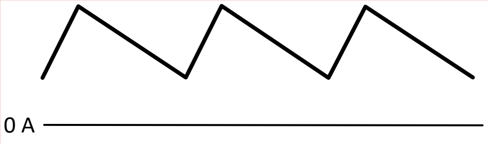
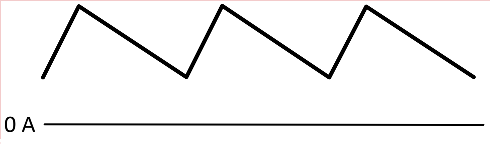


	Non-Sync	Sync - FPWM	Sync - DCM
Light Load Current Waveform			
Negative Current?	No	Yes	No
HS Conduction Losses	Lower I_{RMS} HS: $(I_{RMS\text{-}HS}^2)*R_{ON\text{-}HS}*D$	Higher I_{RMS} HS: $(I_{RMS\text{-}HS}^2)*R_{ON\text{-}HS}*D$	Lower I_{RMS} HS: $(I_{RMS\text{-}HS}^2)*R_{ON\text{-}HS}*D$
LS Conduction Loss	Diode: $I_{Diode}*V_F*t_{Diode}*f_S$	LS: $(I_{RMS\text{-}LS}^2)*R_{ON\text{-}LS}*(1\text{-}D)$	LS: $(I_{RMS\text{-}LS}^2)*R_{ON\text{-}LS}*t_{LS}*f_S$
Switching Frequency	Reduced at very light load	Constant over load	Reduced at very light load
Switching Losses	Less	More	Less

Comparison – Heavy load efficiency

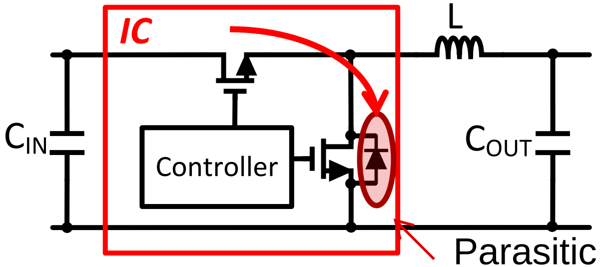




	Non-Sync	Sync – FPWM and DCM
Heavy Load Current Waveform		
Low Side Conduction Losses	**Diode: $I_{Diode}*V_F*(1-D)$**	**LS: $(I_{RMS-LS}^2)*R_{ON-LS}*(1-D)$**
HS FET Switching Losses	**Less** **$\frac{1}{2}*(V_{IN}*I_{OUT})*(t_{rise}+t_{fall})*fs$**	**More** **$\frac{1}{2}*(V_{IN}*I_{OUT})*(t_{rise}+t_{fall})*fs + Qrr*fs*V_{IN}$** **Qrr: LS Body diode Reverse recovery charge**

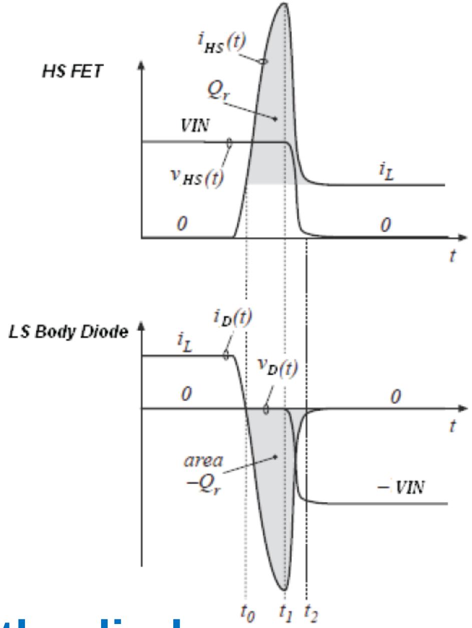
Comparison – Efficiency

Synchronous Buck

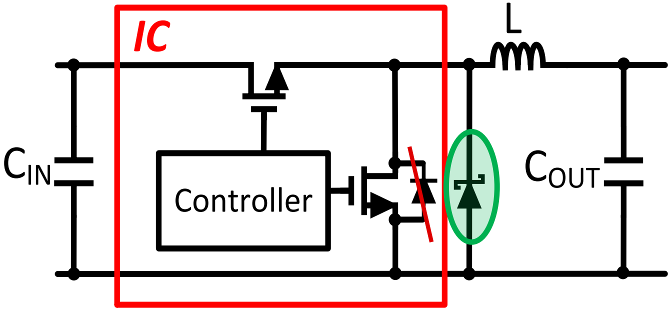


Parasitic Body Diode

- Conduct during dead-time
- Reverse Recover Charge increases switching loss
- Increase ringing in SW node



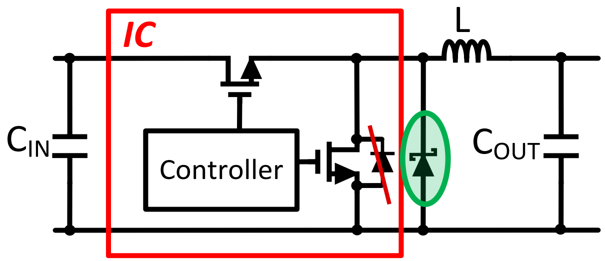
To have the best of both worlds



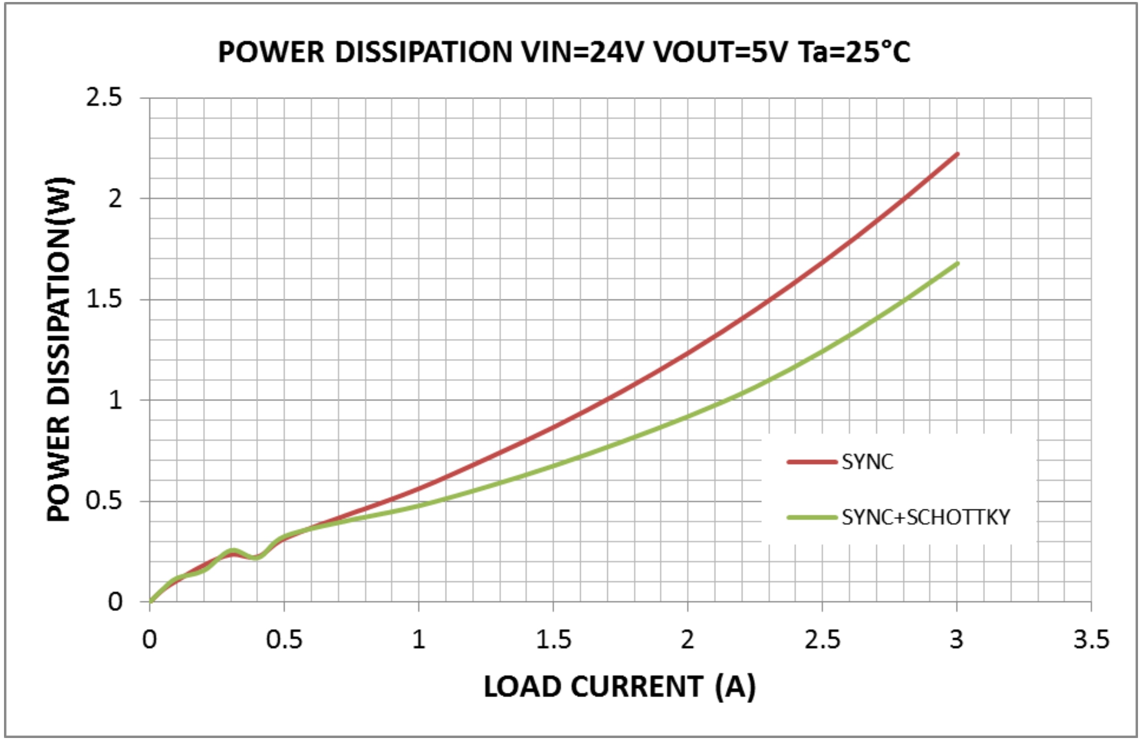
Parallel a SMALL Schottky diode

- Bypass body diode during dead-time
- No reverse recover charge
- Current rating can be a fraction of the power diode for a non-sync buck – only conducts during deadtime

Efficiency improvement with small Schottky



Improvement depends on switching loss from Qrr

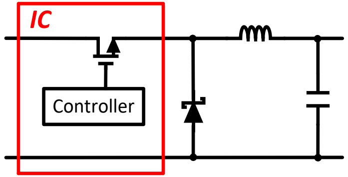


Comparison – Efficiency summary

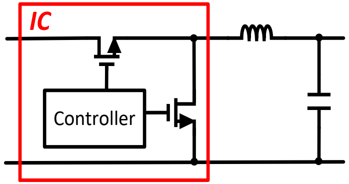
	Non-Sync	Sync-FPWM	Sync-DCM	Sync + Small Schottky
Light Load Efficiency	Better	Worse	Better	Better
Heavy Load Conduction Losses	More	Less	Less	Less
Heavy Load Switching Losses	Less	More	More	Less
Fixed Switching Frequency	No	Yes	No	No
Lower V_{OUT}	Worse (V_F)	Better	Better	Better

Comparison – Thermal performance

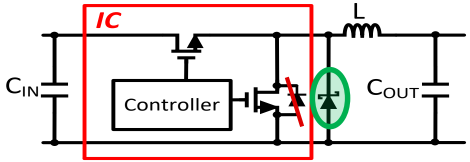
Non-Synchronous Buck

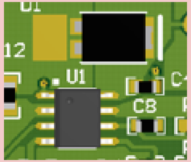
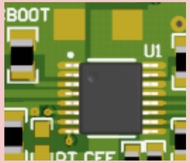
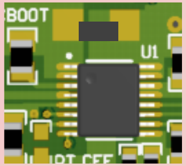
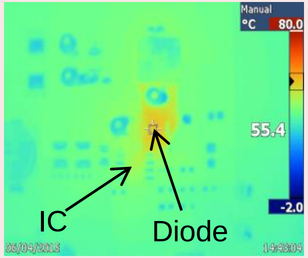
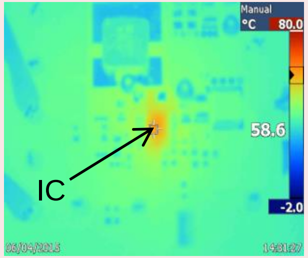
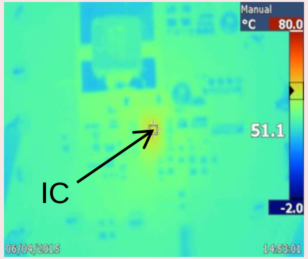


Synchronous Buck

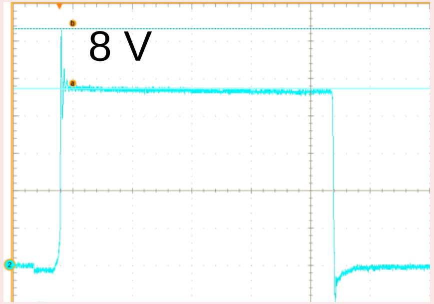
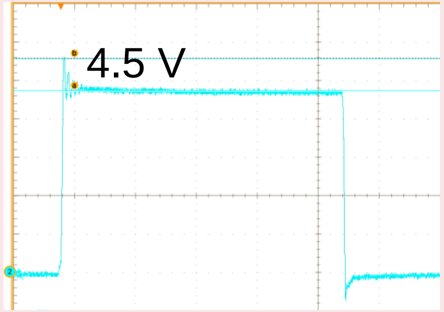
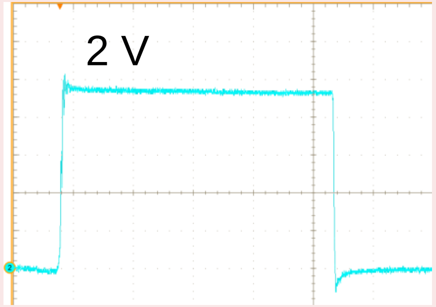
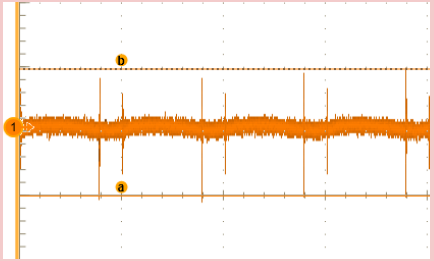
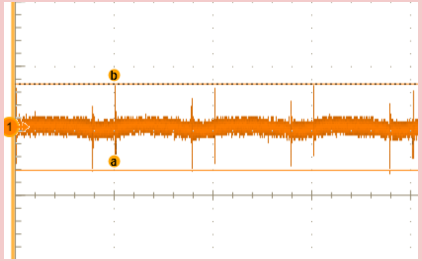
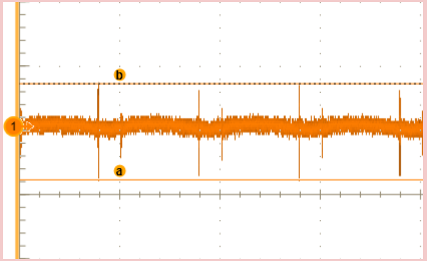


Synchronous + small Schottky

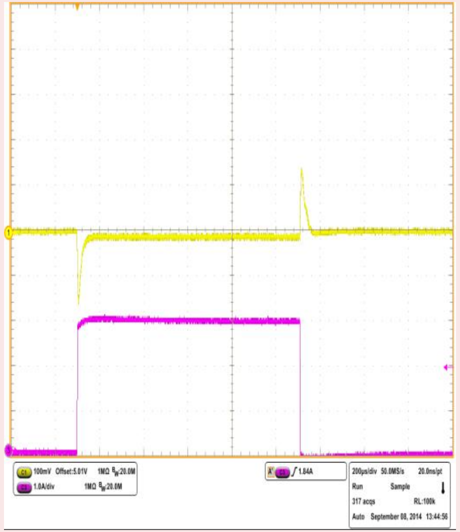
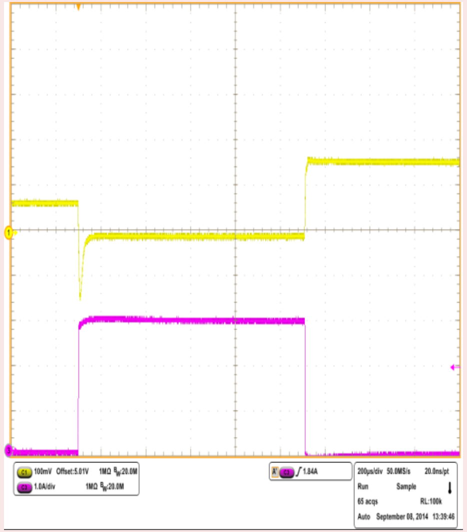


	Non-Sync	Sync	Sync + Small Schottky
Thermal	**Better** Two packages LMR14030 	**Harder** One package LM43603 	**Loss and heat reduced by Schottky diode** LM43603 
Example **V_{IN} = 24V** **V_{OUT} = 5V** **Load = 3A** **500kHz**			

Comparison – Noise

	Sync	Non-Sync	Sync + Small Schottky
V_{OUT} Spike	More - Body diode reverse recovery	Less - Schottky diode	Less – small Schottky diode
SW Ringing Peak V_{IN} = 24V V_{OUT} = 5V Load = 3A 500kHz			
V_{OUT} Spikes V_{IN} = 24V V_{OUT} = 5V Load = 3A 500kHz			

Comparison – Unloading transient

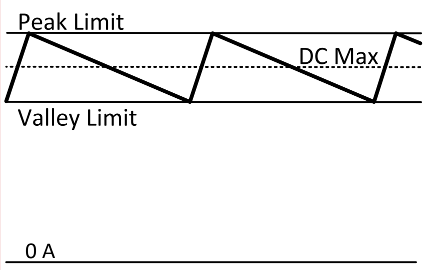
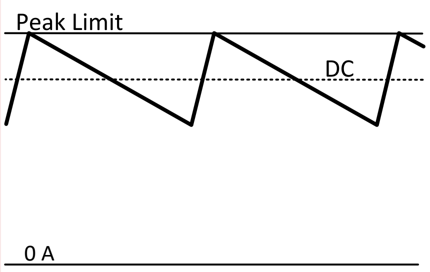
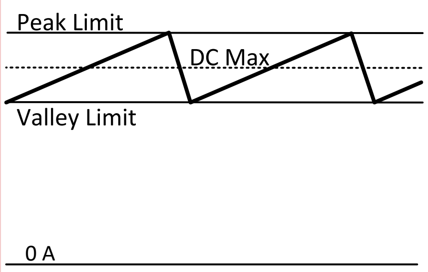
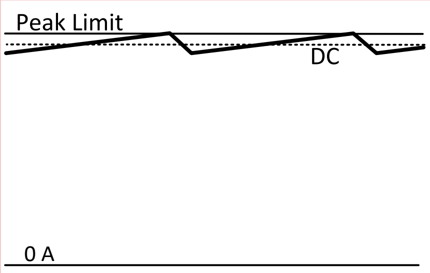
	Sync-FPWM	Sync-DCM	Non-Sync
Unloading Transient Overshoot	**Good** Allow neg current to discharge C_{OUT}	**Worse** Depend on load to discharge C_{OUT}	**Worse** Depend on load to discharge C_{OUT}
Example V_{IN} = 8V V_{OUT} = 5V Load = 3A F_S=2.2MHz LM53603 set at FPWM and DCM modes			Same as Sync-DCM

Texas Instruments

Comparison – Controllability

	Non-Sync	Sync
Controllability	Limited Only controls one FET	Better Controls both FETs Info from both FETs
Current Limit	Peak current only	Peak current Valley current Average current (depends on controller)
OVP	Cannot actively pull down V_{OUT}	Can actively pull down V_{OUT} (depends on controller)
Control architecture		More options

Comparison – Current limit

	Sync	Non-Sync
DC current limiting	Control of Peak current and Valley current → **more accurate DC current limiting**	Only has control of Peak current DC current limit depends on ripple
Fast slew rate	 5A 4A 3A	 5A
Slow slew rate	 5A 4A 3A	 5A

Comparison – Summary

	Non-Synchronous	Synchronous
Size / Ease of use	Larger size	Smaller size, Easier to Use
Light Load Efficiency	Better	Worse with FPWM, better with DCM
Heavy Load Efficiency	More conduction loss Less switching loss	Less conduction loss More switching loss due to reverse recovery Adding small Schottky gives highest efficiency
Lower V_{OUT}	Lower Efficiency (V_F/V_{OUT})	Higher Efficiency
Thermal	Better with two packages	Harder with one package Adding small Schottky reduces power loss a lot
Fixed F_{SW}	No	Yes with FPWM, No with DCM
Noise	less	More, due to body diode reverse recover charge Adding small Schottky diode reduces noise a lot
Unloading Transient	Worse	Good with FPWM, worse with DCM
Controllability	No LS control	More control flexibility

For more information, visit www.simpleswitcher.com