How to Design Multi-kW Converters for Electric Vehicles

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Part 2:	Introduction to Battery Charging
Part 3:	Power Factor and Harmonic Currents
Part 4:	Power Factor Correction
Part 5:	The Phase Shifted Full Bridge
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Part 8:	MOSFET gate driver considerations and References

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Gate Driver Transformers

Advantages

- Primary/Secondary Isolation
- Simple (in theory)
- Zero Quiescent Current
- No start-up delay
- No bootstrap cap to charge
- Robust

Disadvantages

- High Component count
- Bulky in comparison to IC
- Need drivers to drive primary
- Need series Cap to prevent DC current
- Prone to saturation if not driven correctly

Tradeoff -

Good Pri/Sec coupling:

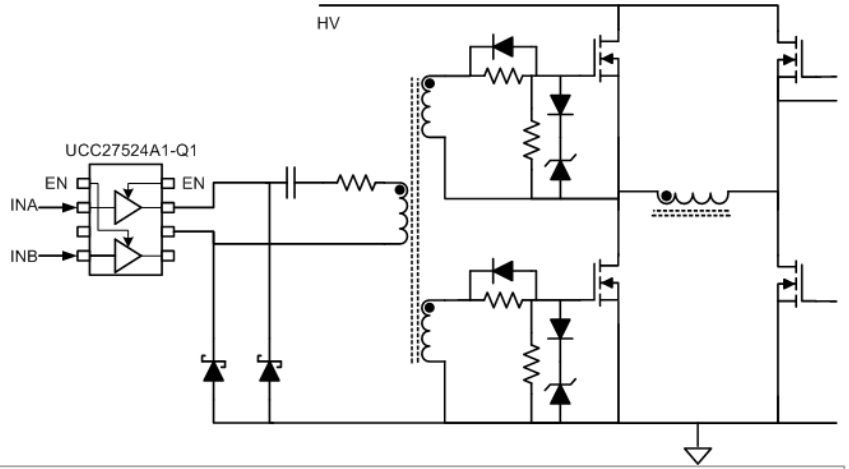
Low leakage inductance, High pri/sec capacitance

Large CM currents, can ‘upset’ driver

Poor Pri/Sec coupling:

Large leakage inductance, low pri/sec capacitance

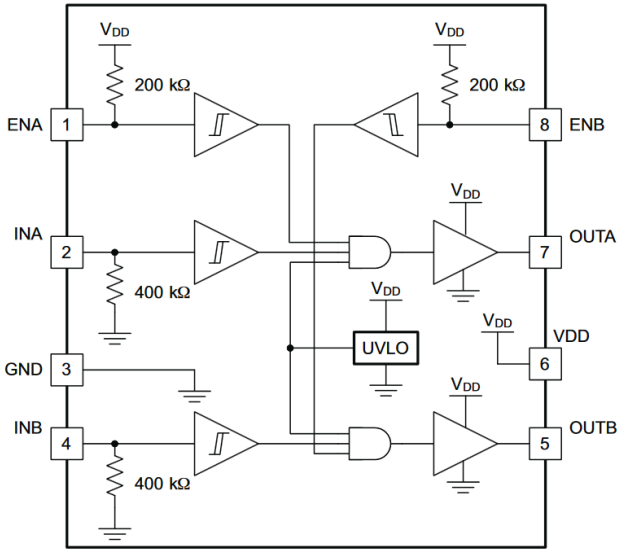
Large spikes due to leakage – must be clamped



Gate Driver Considerations

- MOSFET gate appears as a capacitor (to a good first approximation)
- Aim is to reduce MOSFET switching losses
- Drive MOSFET gate correctly –
  - Keep MOSFET OFF when it is supposed to be OFF
  - Keep MOSFET ON when it is supposed to be ON

- MOSFET turn-on and turn-off times must be minimised
- Needs a low impedance source
- High peak currents (4A to 5A typ) but Low average currents



Driver may or may not have to cross an isolation barrier

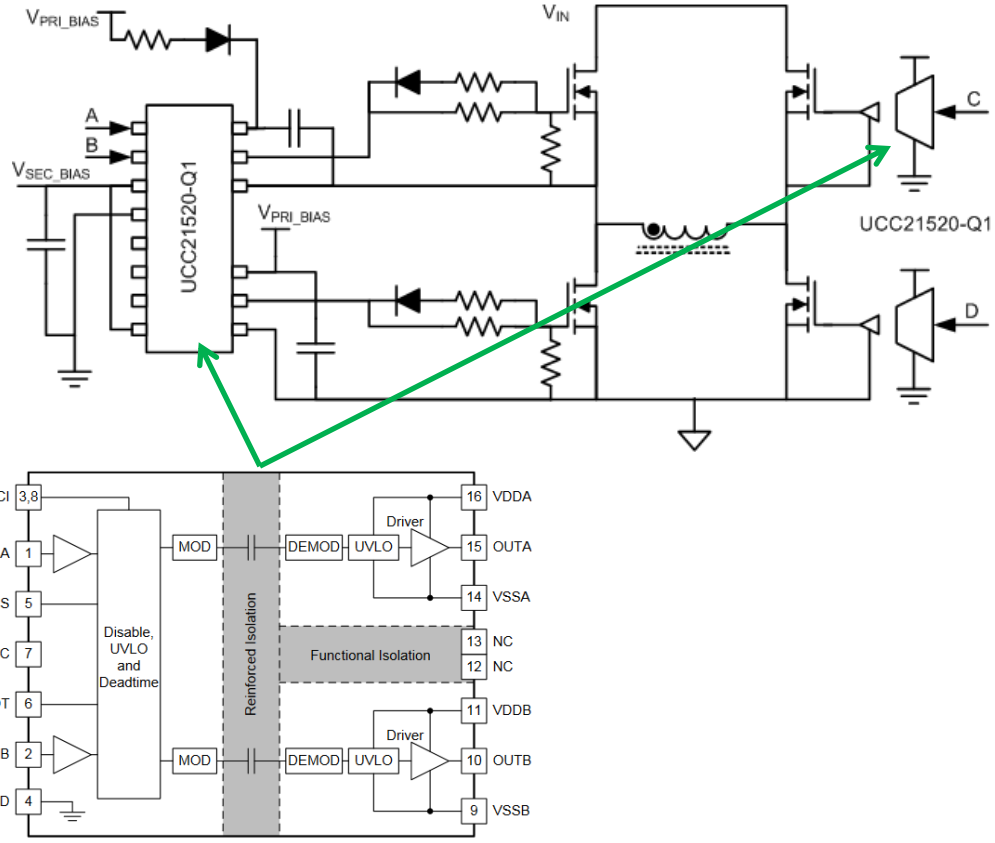
Low side Driver – MOSFET is Ground referenced

High side Driver – MOSFET is not Ground referenced

On Board Charger: Isolated Driver, Option 1

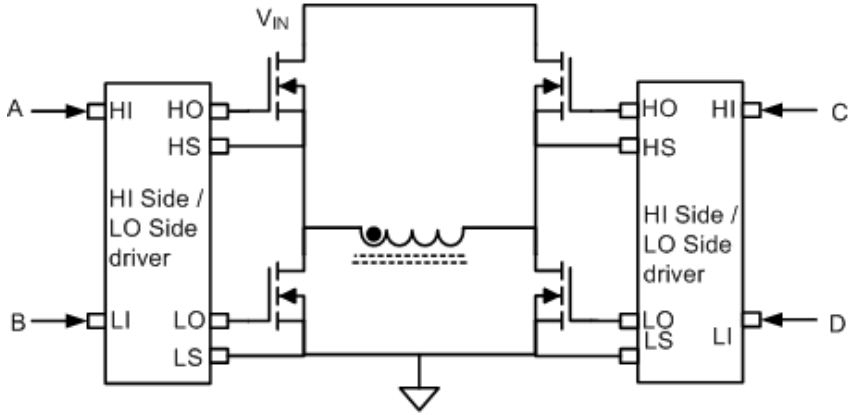
- Primary/Secondary Isolation
- Switching of Primary side MOSFETs
- High Side and Low Side outputs needed
- 4 isolated outputs in total
- 2 high side drives, 2 low side drives
- Isolation to 5.7kV$_{RMS}$

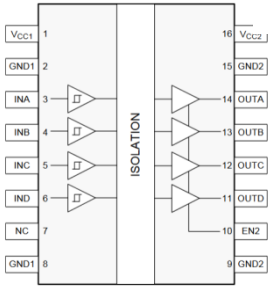
- 2 x UCC21520-Q1, 4A, 6 A driver
- Low Propagation Delays
- Good Propagation Delay Matching
- Adjustable Dead Time
- Safety Features, UVLO etc.
- As with all drivers, PCB layout is critical



On Board Charger: Isolated Driver, Option 2

- Pri/Sec Isolation
- ISO7740-Q1 provides pri/sec isolation
  - 5kV RMS
- 0/10V signal from UCC28951-Q1 needs attenuation (2:1) to meet ISO7740-Q1 input level.
- Gate drivers drive the MOSFETs
- ISO7740FQDWQ
- F option – outputs default LOW !



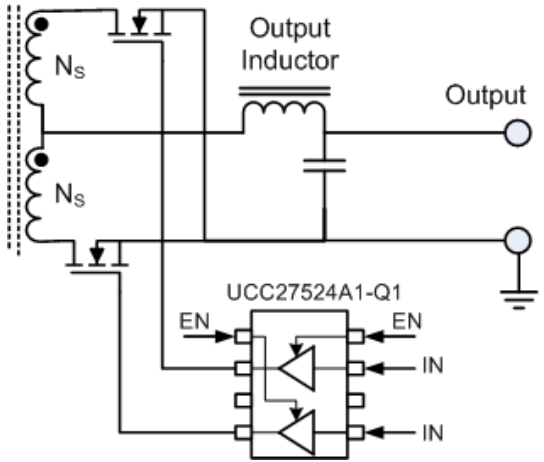


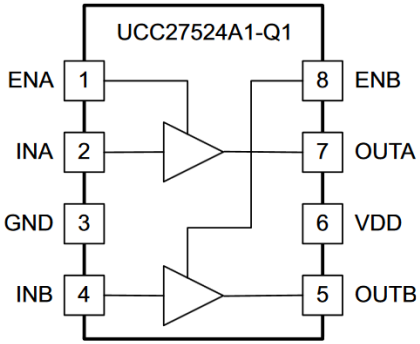
ISO7740F-Q1

UCC27524A1-Q1 Gate Driver IC

- UCC27524A1-Q1 Dual 5-A High-Speed, Low-Side Gate Driver
  - Drive SRs
  - Drive Primary Side MOSFETs
- Two independent channels
- Independent enable on each channel
- Fast, matched rise and fall times
- Outputs LOW when inputs floating

- SRs are large rectifier MOSFETs.
  - Up to 5A peak for fast turn-on and turn-off





Design Resources

- Power factor correction (PFC) controller
  - http://www.ti.com/lsds/ti/power-management/power-factor-correction-overview.page
- Isolated DC/DC controller
  - http://www.ti.com/lsds/ti/power-management/pwm-resonant-controller-overview.page
- TI Reference designs
  - http://www.ti.com/general/docs/refdesignsearchresults.tsp
- Technical Support at TI E2E™ Community
  - https://e2e.ti.com/
- High Volt Interactive Training Series
  - https://training.ti.com/high-voltage-training
- Power Topologies Quick Reference Guide
  - http://www.ti.com/lit/ug/slyu032/slyu032.pdf
- Power Topologies Handbook
  - https://www.ti.com/seclit/ug/slyu036/slyu036.pdf
- Power Supply Design Seminars
  - http://www.ti.com/ww/en/power-training/login.shtml?DCMP=pwr-psds-archive&HQS=pwr-psds-archive-psds
- Power Stage Designer™
  - http://www.ti.com/tool/powerstage-designer?DCMP=powerstagedesigner&HQS=powerstagedesigner
- Introduction to Power Electronics
  - https://training.ti.com/introduction-power-electronics?HQS=pwr-null-null-pentonever-asset-tr-null-wwe

References

Ref 1: Fundamentals of Power Electronics, Erickson and Maksimovic; Springer 2001, Table 18.3, summary of rectifier current stresses.

Ref 2: Analytic Expressions for currents in the CCM PFC stage, http://www.ti.com/lit/ml/slyy131/slyy131.pdf , Gillmor.

Ref 3: Predicting output-capacitor ripple in a CCM boost PFC circuit, https://e2e.ti.com/blogs_/b/powerhouse/archive/2016/06/14/predicting-output-capacitor-ripple-in-a-ccm-boost-pfc-circuit Gillmor

Ref 4: SLUP279 An Interleaving PFC Pre-Regulator for High-Power Converters. O'Loughlin

Ref 5: Capacitor Ripple current in an interleaved PFC converter, Pratt and Jinsong, IEEE transactions on Power Electronics, Vol 24, No 6 June 2009.

Ref 6: http://www.ti.com/lit/an/slua479b/slua479b.pdf Interleaved PFC design review. O'Loughlin

Blog: Are-you-ready-for-totem-pole-pfc

GaN FET-Based CCM Totem Pole Bridgeless PFC

Magnetics Design Handbook, Dixon.

Understanding the basics of flyback converter design

Synchronizing Three or More UCC28950 PSFB Controllers http://www.ti.com/lit/an/slua609/slua609.pdf

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Thank You

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