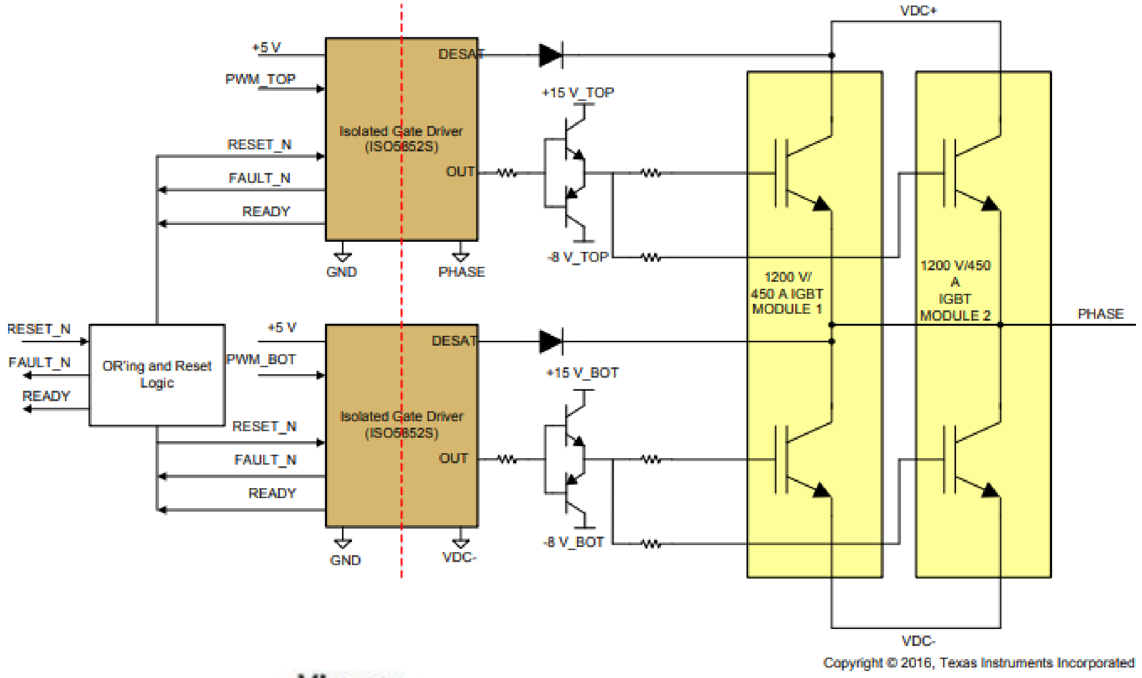
Applications for isolated gate drivers

TIPL 502
TI Precision Labs – Isolated Gate Drivers

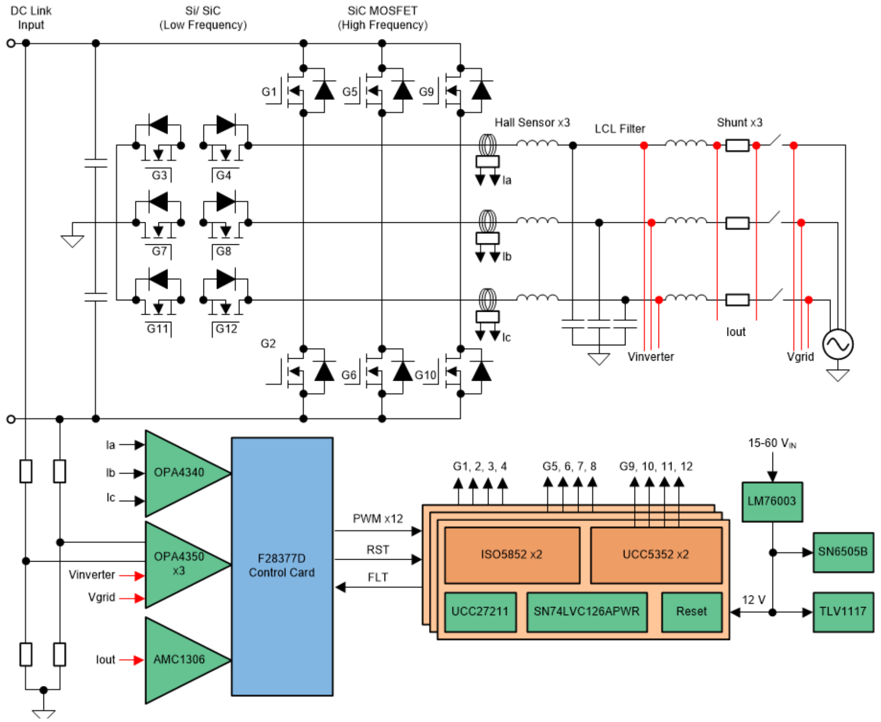
Presented and Prepared by Derek Payne

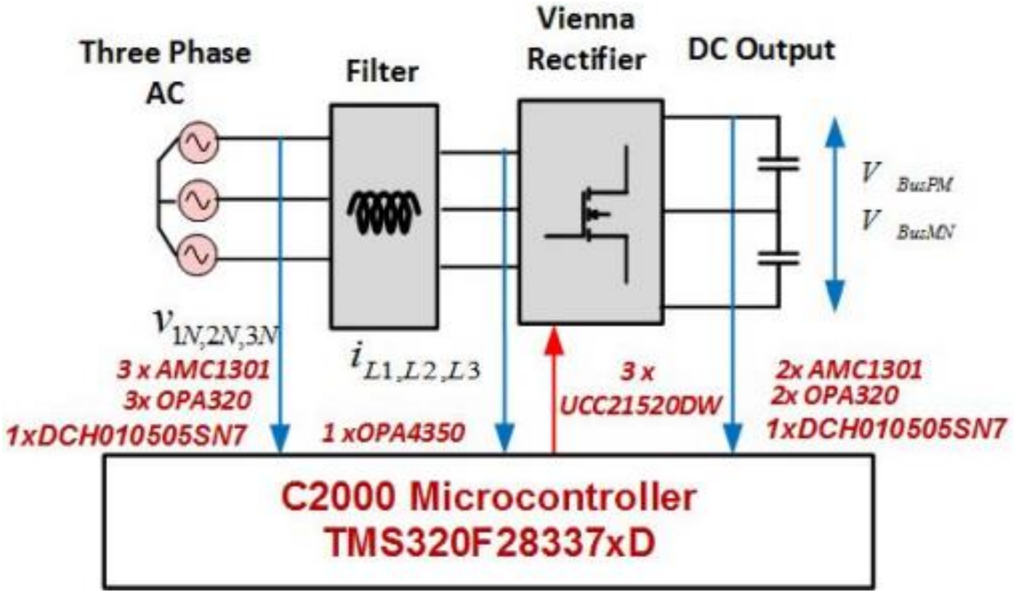
Example Topologies

Traction Inverter

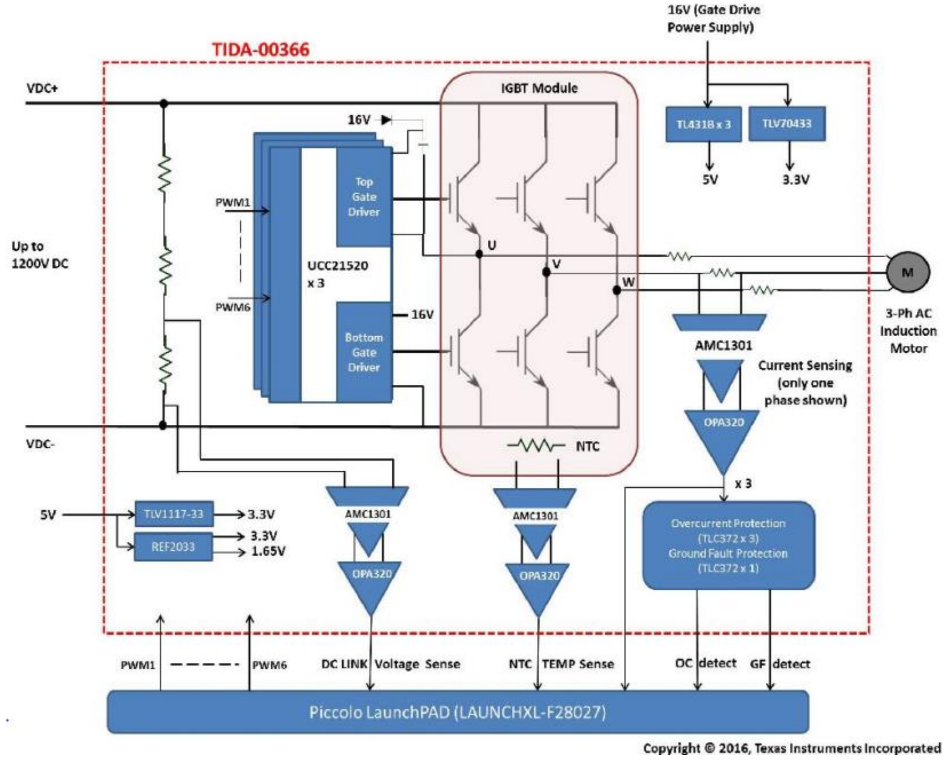


Solar String Inverter



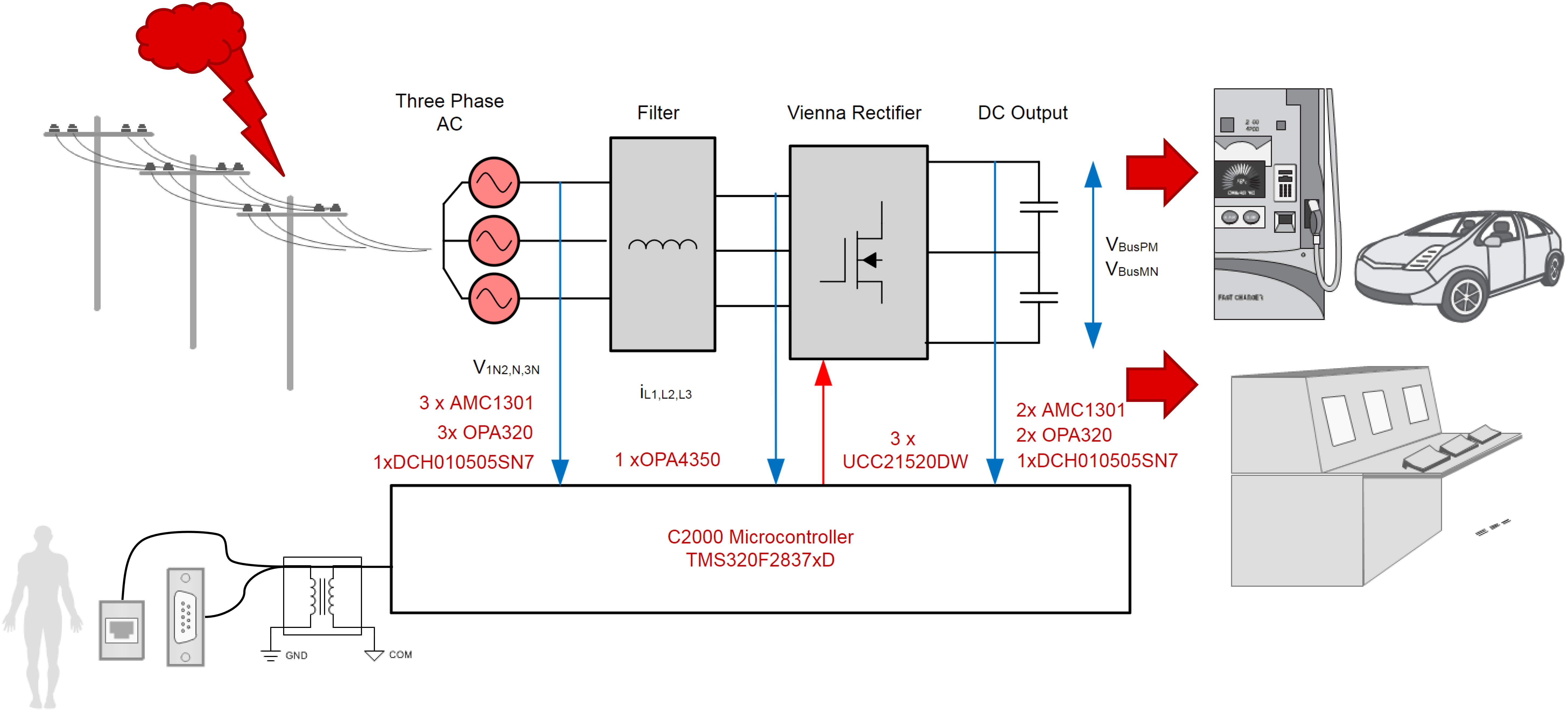


3ϕ PFC

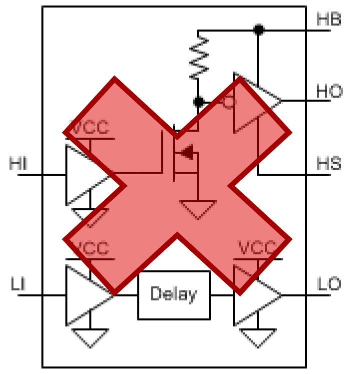


Motor Drive

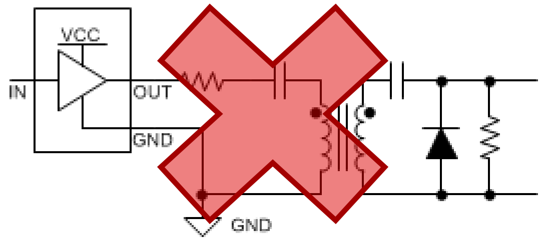
Three Phase Power Factor Correction



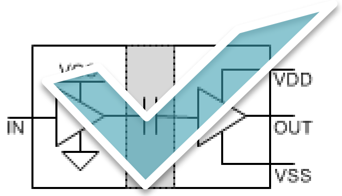
Three Phase Power Factor Correction



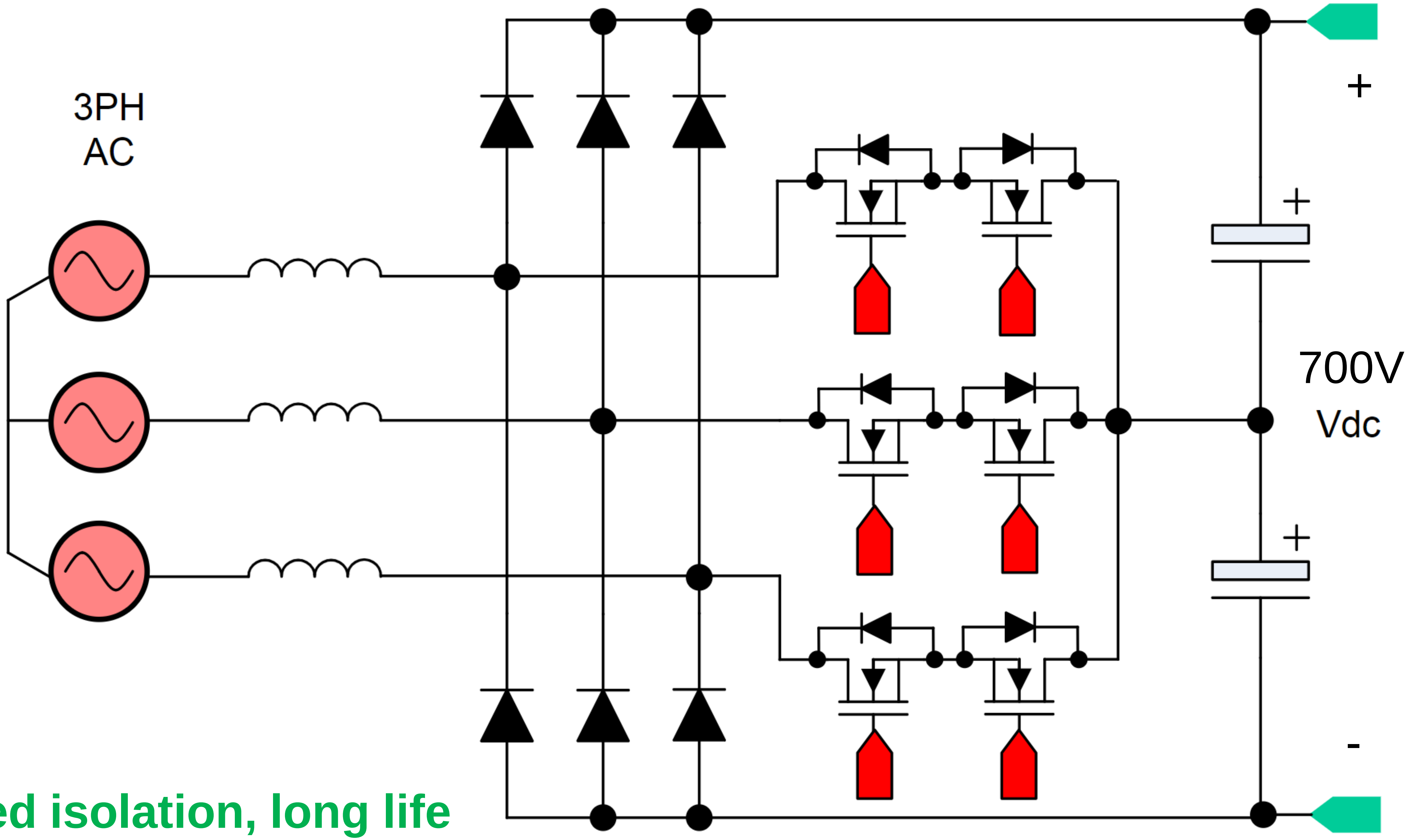
600V Abs. Max



Cost, Space, Effort



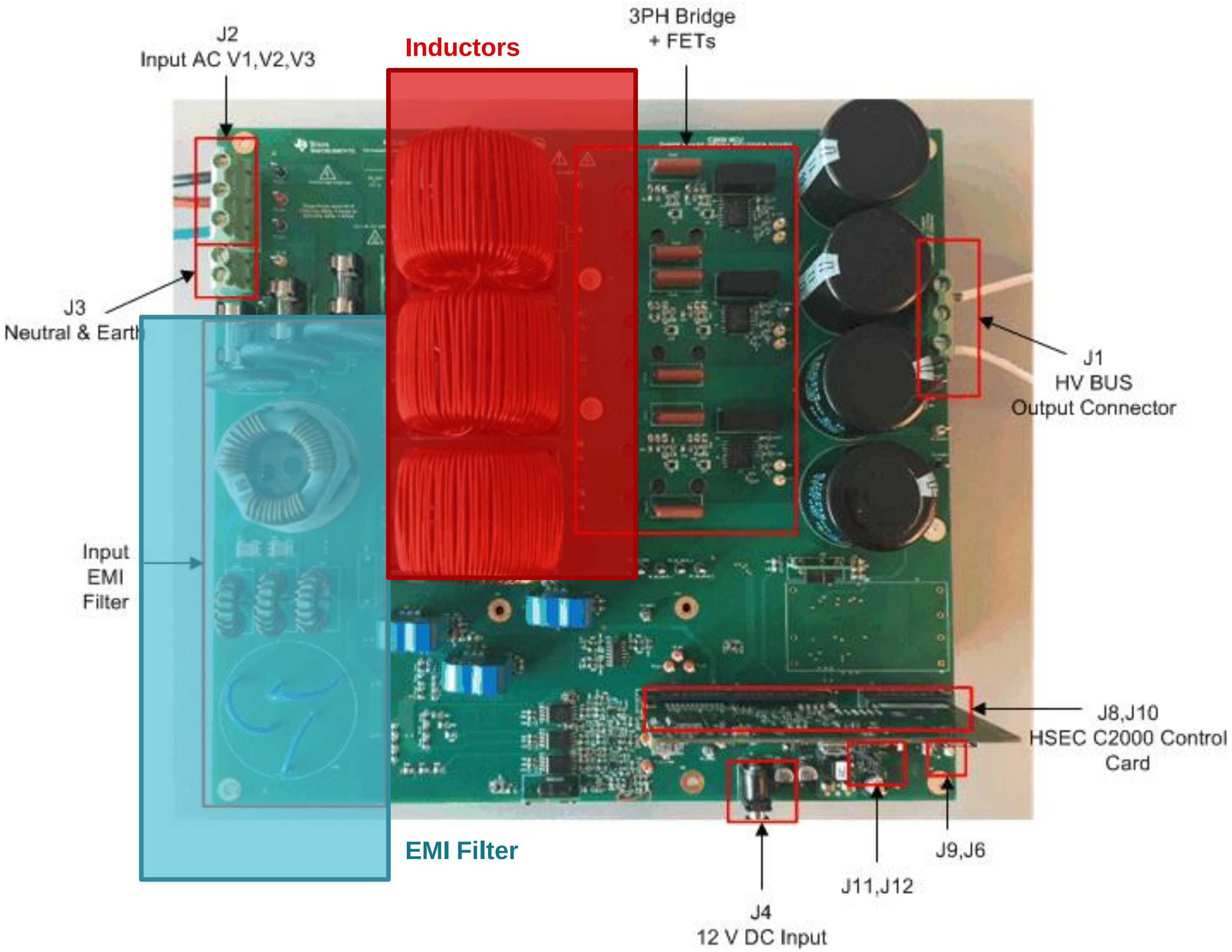
Compact, reinforced isolation, long life



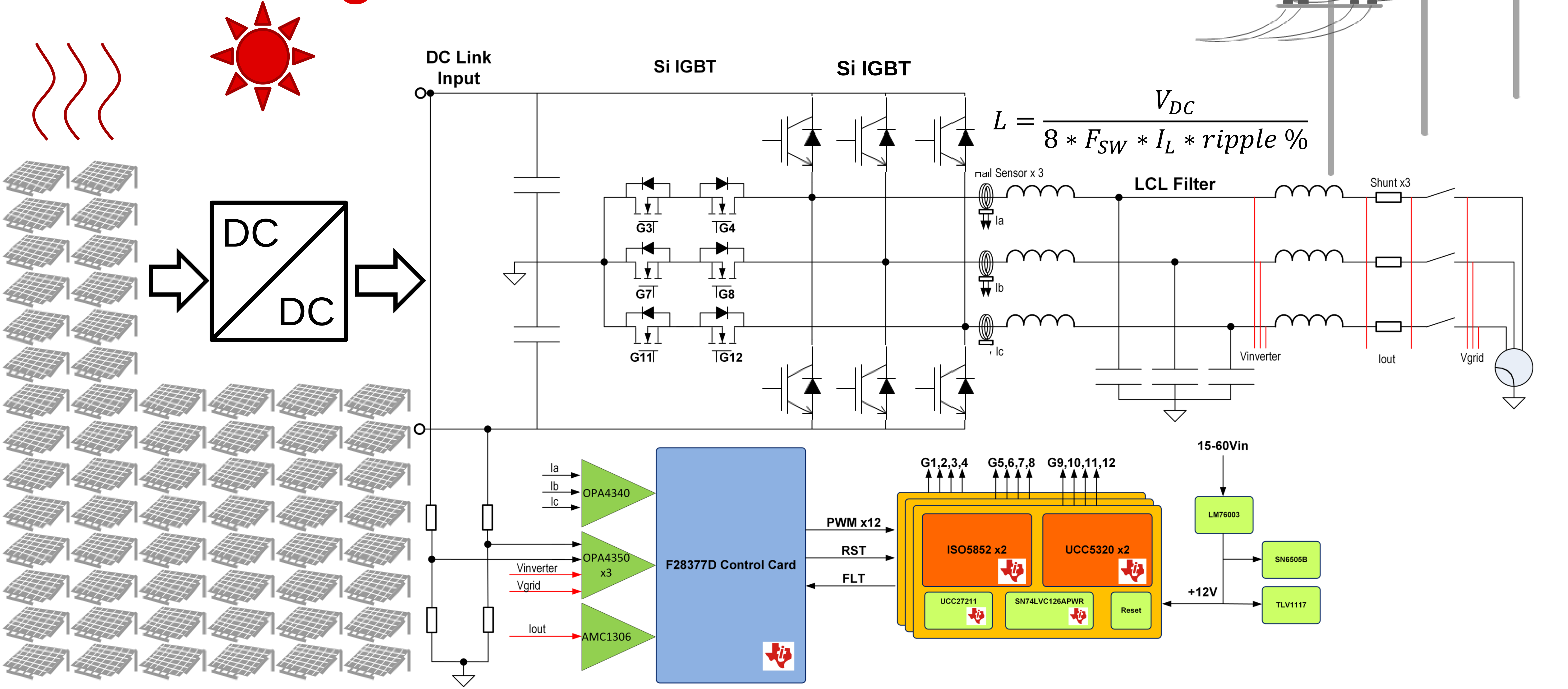
Three Phase Power Factor Correction

- $\Delta i_{pp_{max}} = \dfrac{\frac{V_{bus}}{2} * T_S}{4 * L_i} \Rightarrow L_i = \dfrac{\frac{V_{bus}}{2}}{4 * F_{SW} * \Delta i_{pp_{max}}}$
- Inductor size is inversely proportional to switching frequency
- **Slower F_{SW} => Larger inductors**
- Line filter attenuates fundamental switching frequency and harmonics
- Attenuation at F_{SW} is proportional to filter component size, # of stages
- **Slower F_{SW} => Bigger EMI filter**

Size for F_{SW} / 2

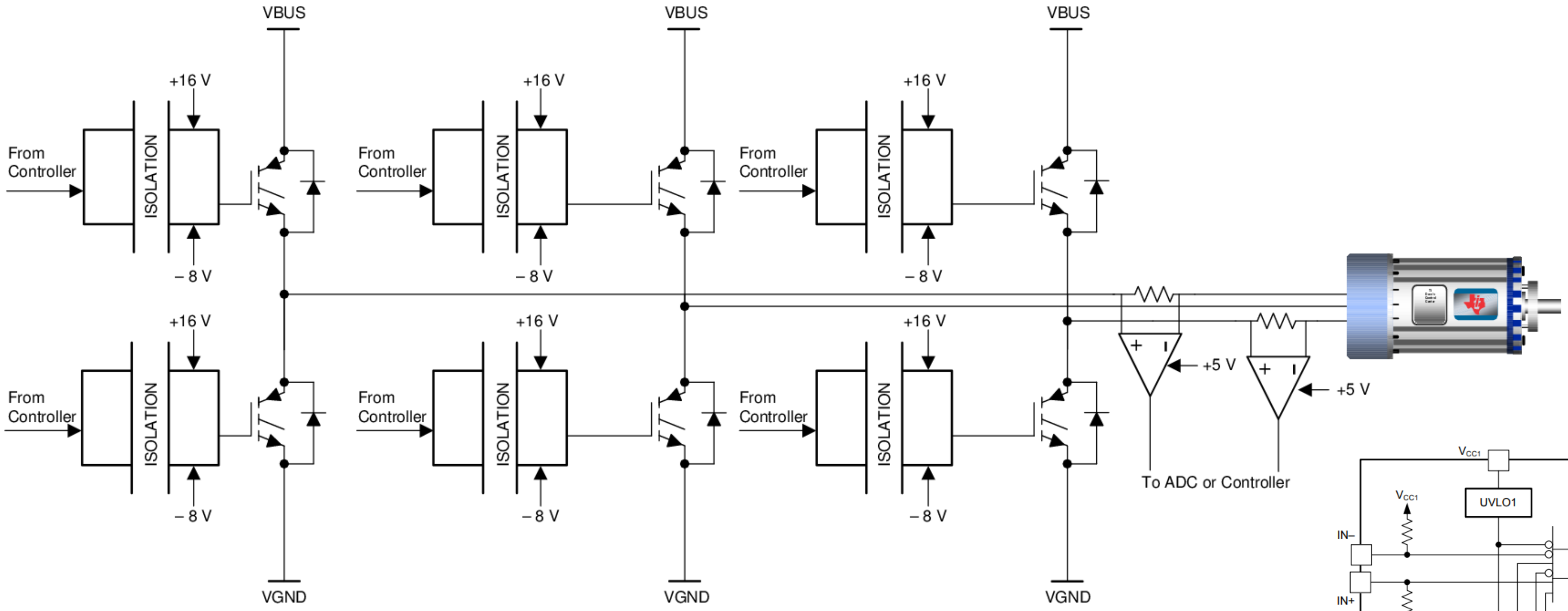


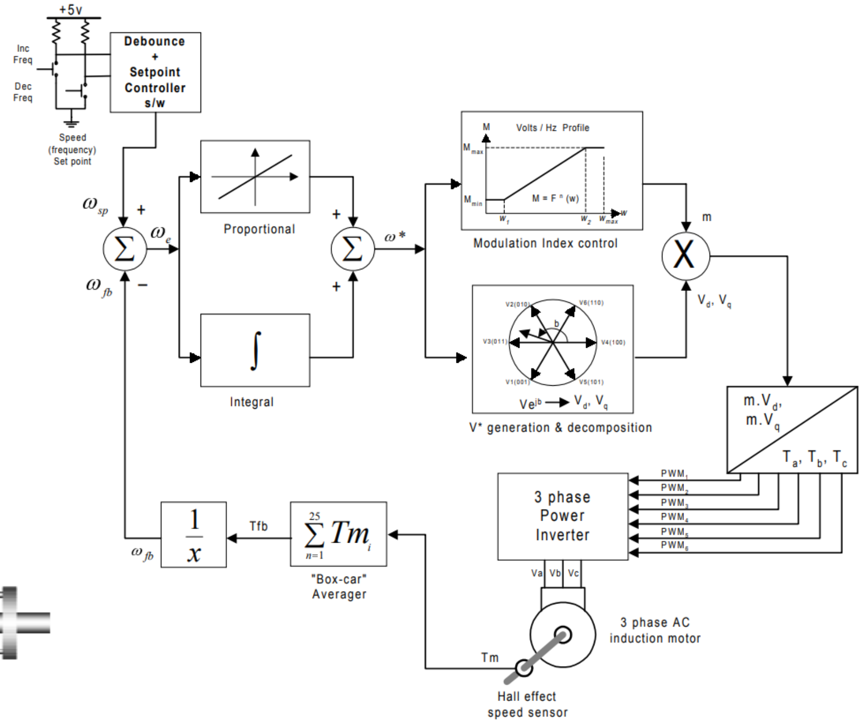
Solar String Inverter

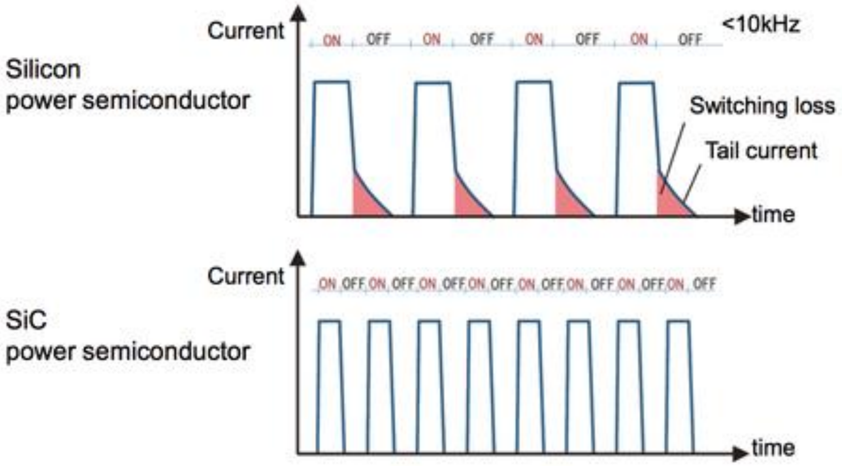


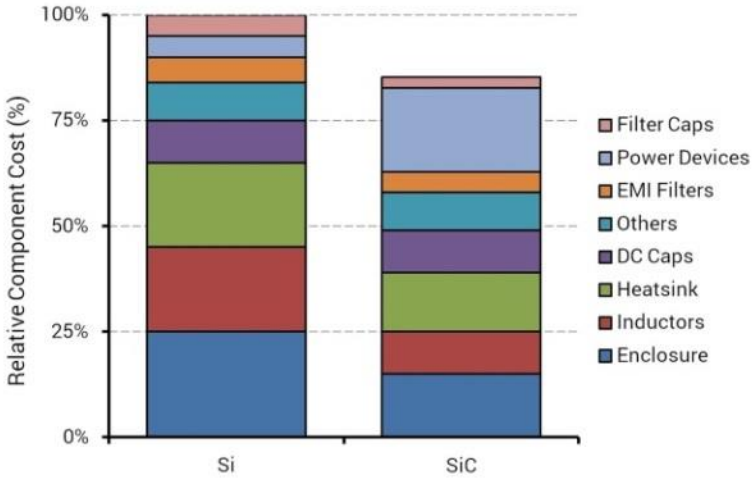
$$L = \frac{V_{DC}}{8 * F_{SW} * I_L * ripple\ \%}$$

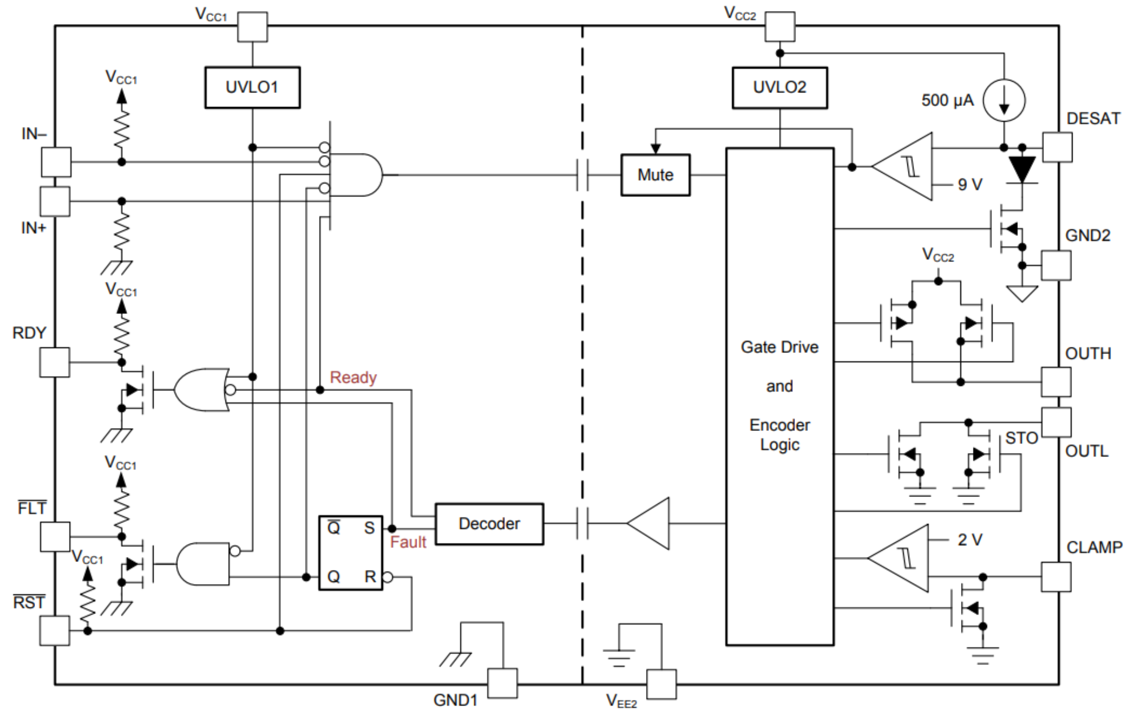
Motor Drive


VBUS
+16 V
From Controller
ISOLATION
– 8 V
VGND
+5 V
To ADC or Controller

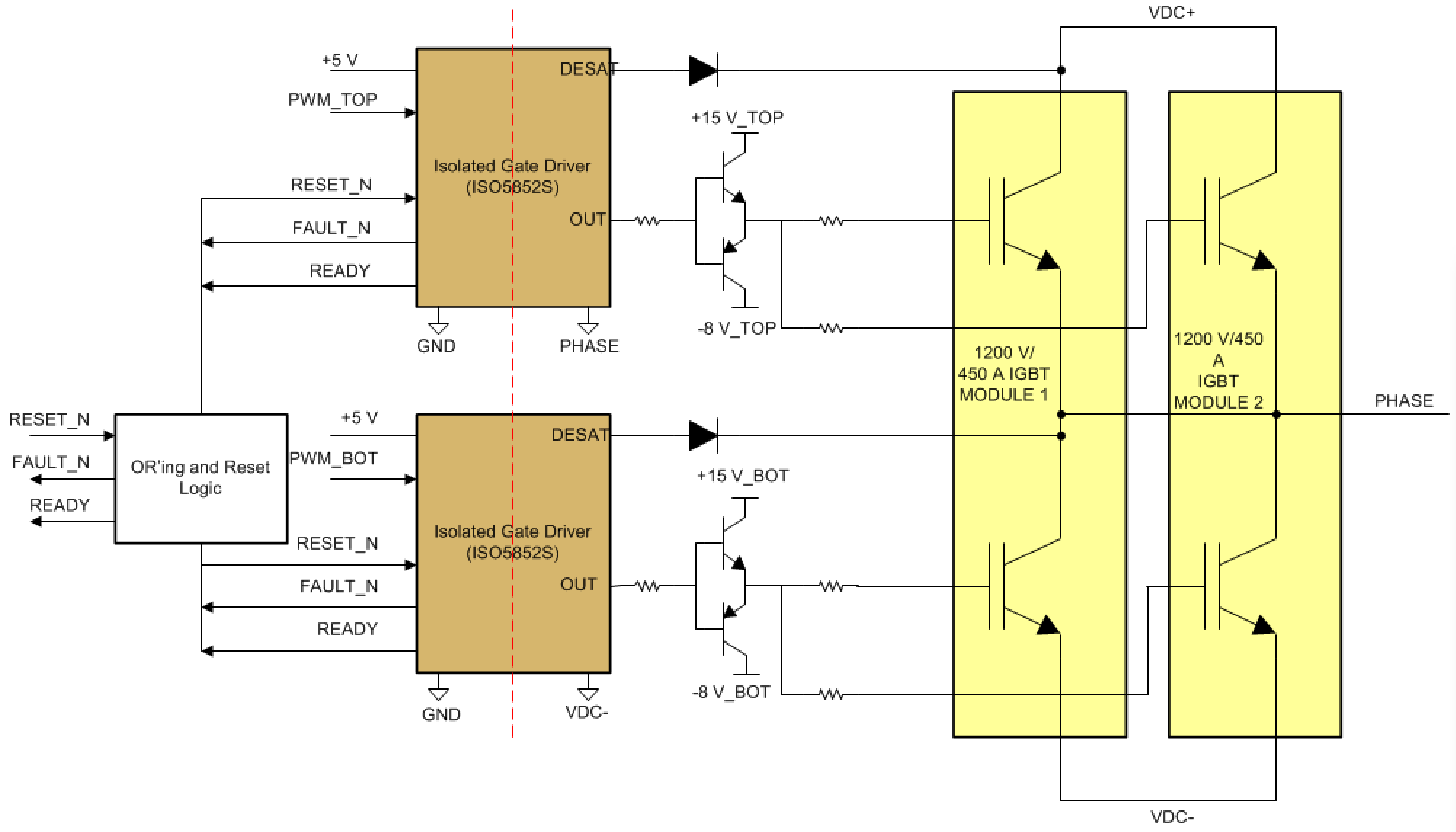

Debounce + Setpoint Controller s/w
Speed (frequency) Set point
Proportional
Integral
Modulation Index control
Volts / Hz Profile
V* generation & decomposition
3 phase Power Inverter
"Box-car" Averager
3 phase AC induction motor
Hall effect speed sensor


Current
Silicon power semiconductor
ON
OFF
<10kHz
Switching loss
Tail current
time
SiC power semiconductor

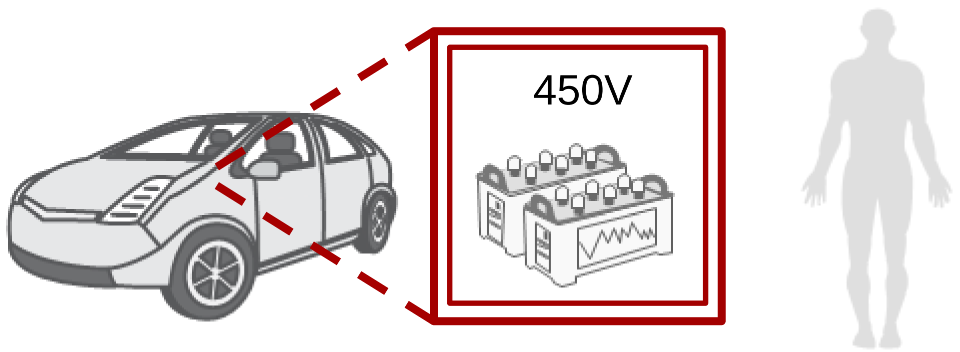

Relative Component Cost (%)
100%
75%
50%
25%
0%
Si
SiC
Filter Caps
Power Devices
EMI Filters
Others
DC Caps
Heatsink
Inductors
Enclosure

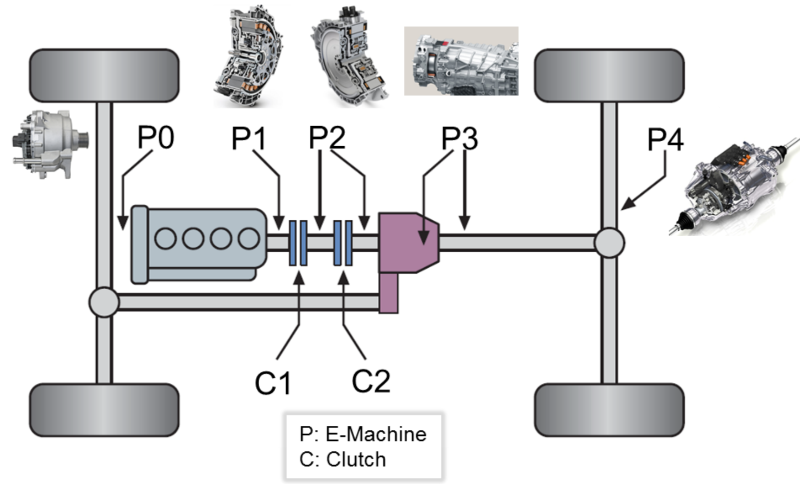

UVLO1
UVLO2
IN–
IN+
RDY
FLT
RST
Ready
Fault
Decoder
Mute
Gate Drive and Encoder Logic
500 µA
DESAT
9 V
GND2
OUTH
STO
OUTL
2 V
CLAMP
GND1

Traction Inverters



Reinforced Isolation





E-MACHINE POSITION	ASIL RATING	COMMENT
P0	ASIL-B/C	Basic level of (48V) hybridization (BSG)
P1	ASIL-B/C	E-Machine at the crankshaft, very limited electric only drive
P2	ASIL-B/C	E-Machine placed in between combustion engine and transmission. Could be used for 48V and HV systems (ISG)
P3	ASIL-C/D	Transmission integrated E-Machine (ISG)
P4	ASIL-C/D	E-Axle, adds electric propulsion to the axle directly. Enables 4(A)WD. Could be used for pure electric vehicles

ASIL rating derived from ISO 26262

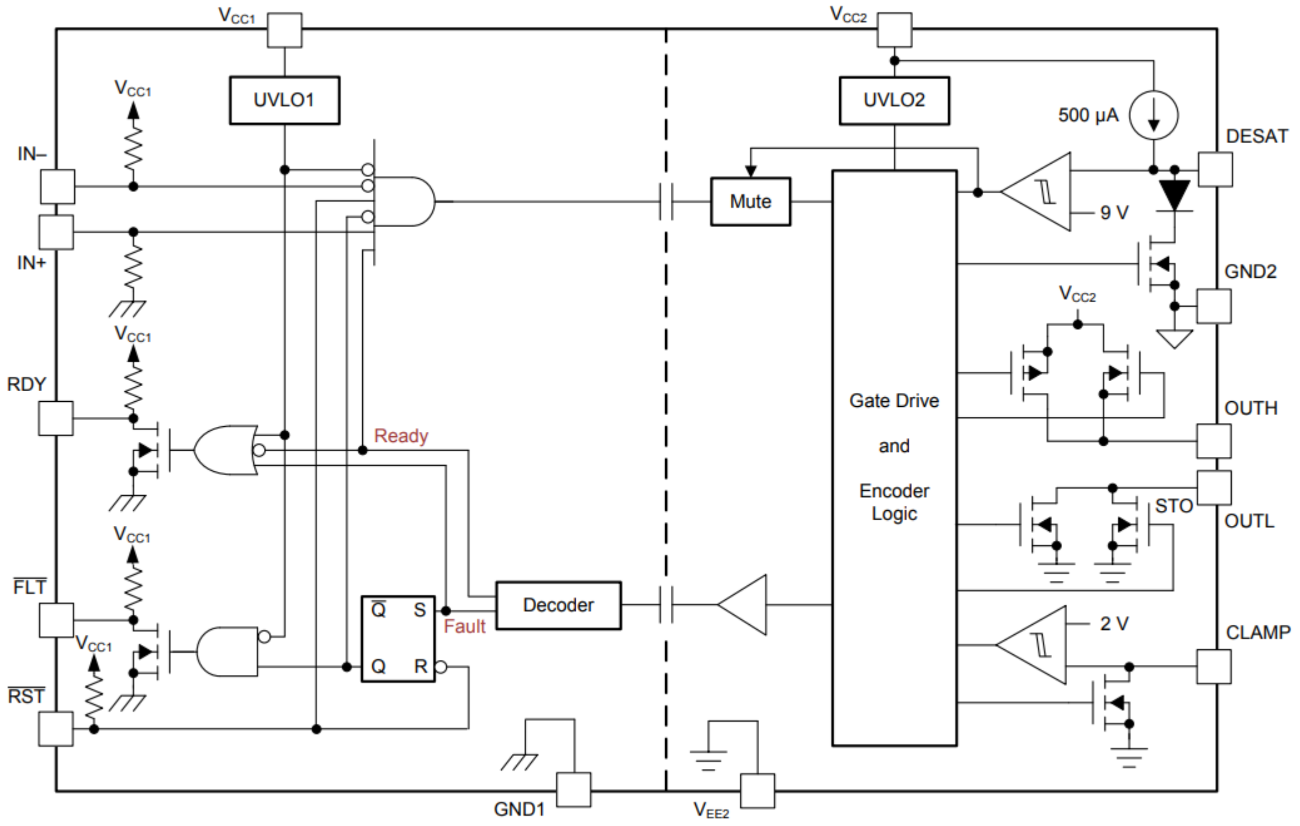
Looking Ahead

7.10 Switching Characteristics

Over recommended operating conditions unless otherwise noted. All typical values are at T_A = 25°C, V_{CC1} = 5 V, V_{CC2} – GND2 = 15 V, GND2 – V_{EE2} = 8 V

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
t_r	Output-signal rise time at OUTH	C_{LOAD} = 1 nF	See Figure 44, Figure 45, and Figure 46	12	18	35	ns
t_f	Output-signal fall time at OUTL	C_{LOAD} = 1 nF		12	20	37	ns
t_{PLH}, t_{PHL}	Propagation Delay	C_{LOAD} = 1 nF			76	110	ns
t_{sk-p}	Pulse skew $\|t_{PHL} – t_{PLH}\|$	C_{LOAD} = 1 nF				20	ns
t_{sk-pp}	Part-to-part skew	C_{LOAD} = 1 nF				30 (1)	ns
$t_{GF\ (IN,/RST)}$	Glitch filter on IN+, IN–, $\overline{RST}$	C_{LOAD} = 1 nF		20	30	40	ns
$t_{DS\ (90\%)}$	DESAT sense to 90% $V_{OUTH/L}$ delay	C_{LOAD} = 10 nF			553	760	ns
$t_{DS\ (10\%)}$	DESAT sense to 10% $V_{OUTH/L}$ delay	C_{LOAD} = 10 nF			2	3.5	µs
$t_{DS\ (GF)}$	DESAT-glitch filter delay	C_{LOAD} = 1 nF			330		ns
$t_{DS\ (\overline{FLT})}$	DESAT sense to $\overline{FLT}$-low delay	See Figure 46				1.4	µs
t_{LEB}	Leading-edge blanking time	See Figure 44 and Figure 45		310	400	480	ns
$t_{GF(RSTFLT)}$	Glitch filter on $\overline{RST}$ for resetting $\overline{FLT}$			300		800	ns
C_I	Input capacitance (2)	V_I = V_{CC1} / 2 + 0.4 × sin (2πft), f = 1 MHz, V_{CC1} = 5 V			2		pF
CMTI	Common-mode transient immunity	V_{CM} = 1500 V, see Figure 47		100	120		kV/µs

(1) Measured at same supply voltage and temperature condition
(2) Measured from input pin to ground.

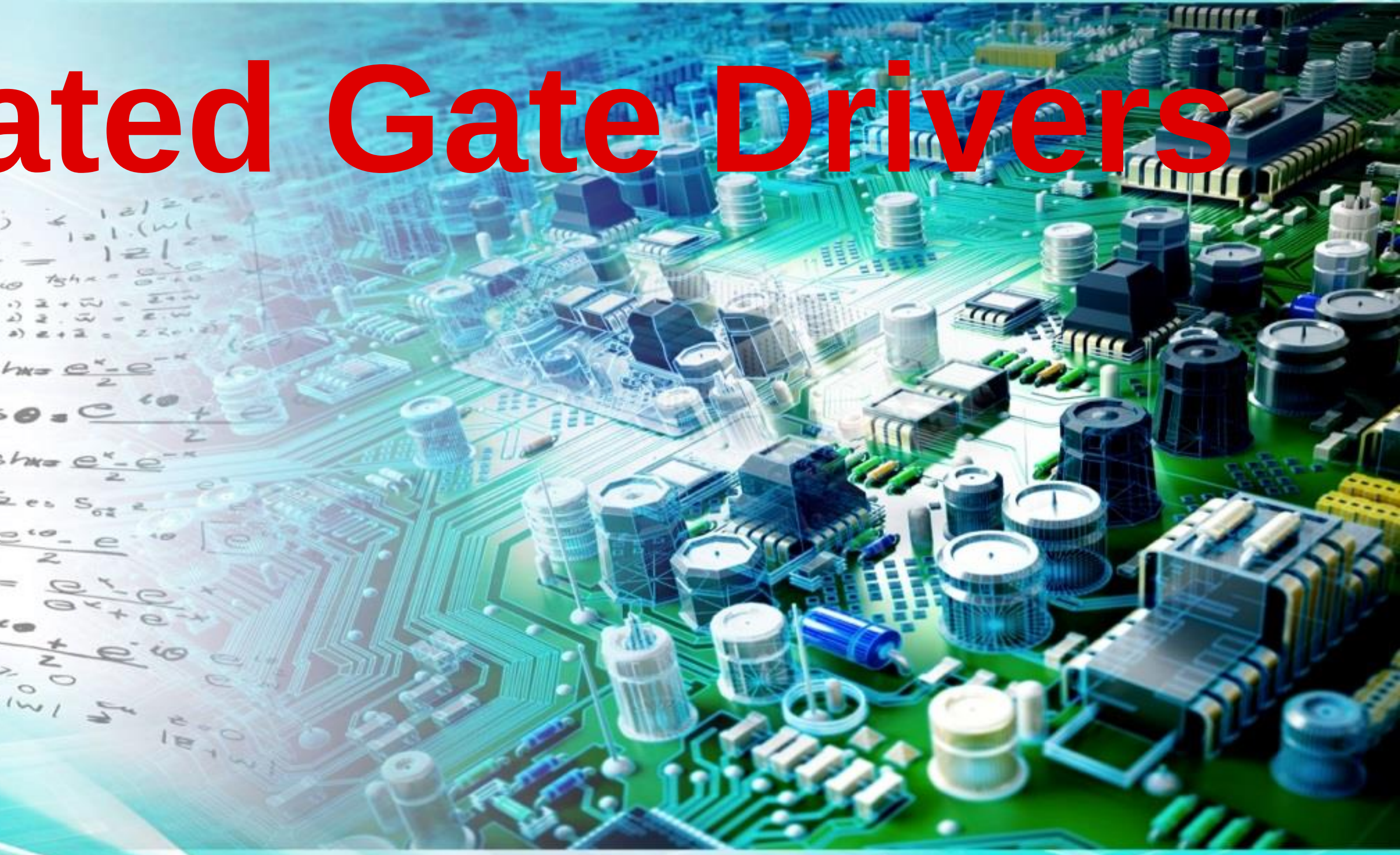


Thanks for your time!
Please try the quiz.

Applications for Isolated Gate Drivers

Multiple Choice Quiz

TI Precision Labs – Isolation



Quiz: Applications for Isolated Gate Drivers

1. __________ must be used for the interface between high voltage and user-accessible circuitry (like connectors or communications ports) to meet many equipment safety standards.
   a. Reinforced isolation
   b. Line drivers
   c. Fiber optics
   d. Low-voltage microcontrollers
2. __________ converts stable, monofrequency AC power to stable, clean DC power; __________ converts stable, clean DC power to stable, monofrequency AC power
   a. Solar string inverters / Motor drives
   b. Power factor correction circuits / Traction inverters
   c. Power factor correction circuits / Solar string inverters
   d. Motor drives perform both functions
3. Thanks to their high voltage ratings and high current capability, __________ have been historically used in switching power systems up to hundreds of kilowatts
   a. Silicon carbide transistors
   b. Insulated-gate bipolar transistors (IGBTs)
   c. Silicon MOSFETs
   d. Gallium nitride transistors

Quiz: Applications for Isolated Gate Drivers

4. **The high-voltage bus in solar string inverter designs has been _________ over time because ___________**
   a. Increasing; it reduces I^2R losses and component size
   b. Increasing; it increases switching frequency
   c. Decreasing; it becomes easier to use inexpensive non-isolated gate drivers
   d. Decreasing; it permits the use of faster, lower-voltage MOSFETs
5. **Silicon carbide MOSFETs are one potential way to improve size, cost, and performance of motor drives and traction inverters. It requires gate drivers that can:**
   a. Operate at automotive temperature ranges of -40°C to 125°C to enable high-temperature applications
   b. Switch with low propagation delay and low pulse width distortion to enable fast switching
   c. Integrate protection features to minimize external component count and cost
   d. Both b and c
6. **Traction inverters help to define the next generation of isolated gate drivers because:**
   a. Automotive ASIL ratings place strict requirements on critical systems, including gate drivers
   b. Size, cost, and heatsinking material constraints emphasize gate drivers with highly-integrated features
   c. Silicon carbide MOSFETs have unique drive requirements compared to IGBTs or MOSFETs
   d. All of the above

Applications for Isolated Gate Drivers

Multiple Choice Quiz – Solutions

TI Precision Labs – Isolation

Quiz: Applications for Isolated Gate Drivers

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   b. Line drivers
   c. Fiber optics
   d. Low-voltage microcontrollers

2. **__________ converts stable, monofrequency AC power to stable, clean DC power; __________ converts stable, clean DC power to stable, monofrequency AC power**
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