TI Webinar Series

Using Isolated Gate Drivers for MOSFET, IGBT and SiC applications

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This webinar is intended to provide

✓An understanding of an isolated driver

✓A guideline on how to and when to identify an isolated driver and the type of driver depending on the power switch and application

X This webinar is not intended to discuss details on isolation technology – That will be discussed in a webinar on October 20th, 2017.

Motivation in power management

Optimal Power Solution

Agenda

- Isolation:
  - Definition, why isolate, how to isolate and applications
- Concept of power electronics and definition of a gate driver
- Types of gate driver
- Motivation for an isolated gate driver
  - Walking through an example application
- Types of isolation techniques, terminology and standards
- Isolated gate driver requirements
- MOSFET vs IGBT isolated gate driver and applications
- Wide band gap semiconductors
  - Value of SiC and gate driver requirements
- More information on TI isolated gate driver family and isolation

What is Isolation

A means of transporting data & power between a high voltage and a low voltage circuit while preventing:

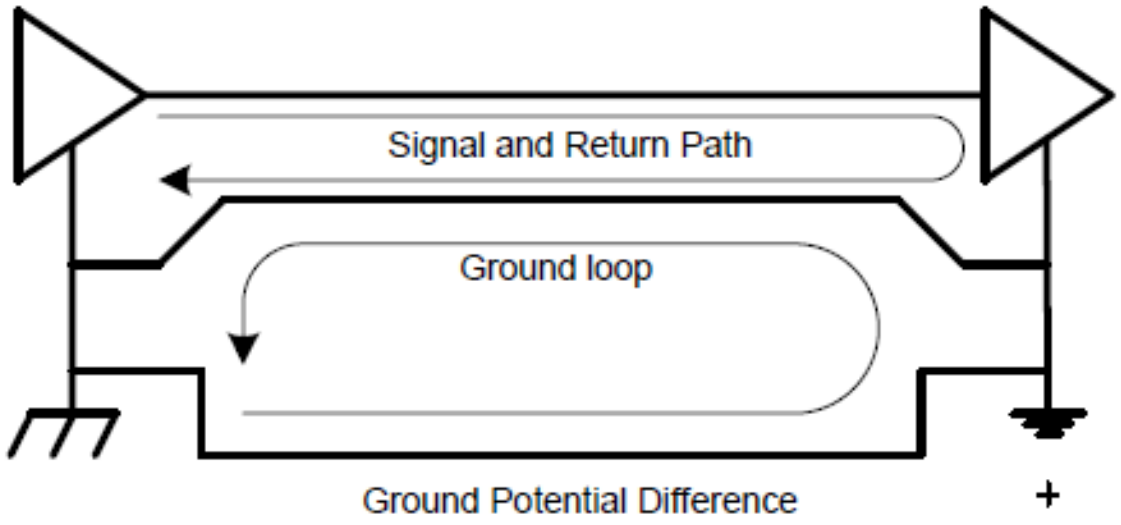
- Hazardous DC or
- Uncontrolled transient current from flowing in between the two circuits.

Why isolate?

- To protect from and safely withstand high voltage surges that would damage equipment or harm humans
- To protect expensive controllers – intelligent systems
- To tolerate large ground potential differences and disruptive ground loops in circuits that have high energy or are separated by large distance
- To communicate reliably with high side components in high-voltage high performance solutions

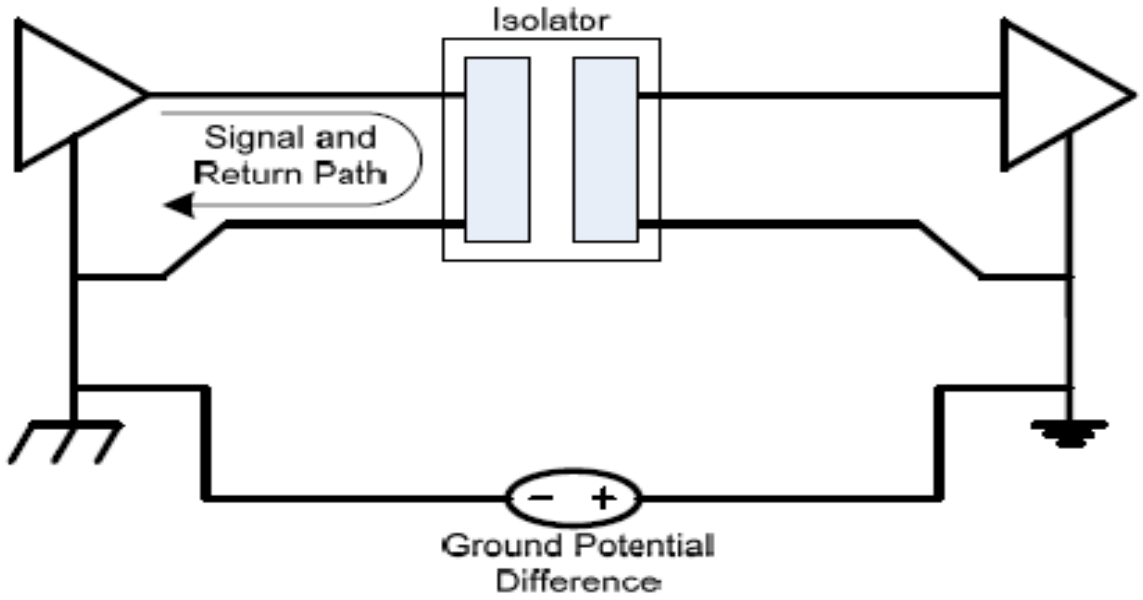
When to use isolation?

- More than one conductive path between two circuits creates a ground-loop
- Multiple ground paths can lead to unintended compensation currents



How to isolate?

- Ground loops can be broken by
  - Disconnecting the grounds
  - Common-mode chokes
  - Frequency selective grounding
  - Differential amplifiers
  - Galvanic isolators



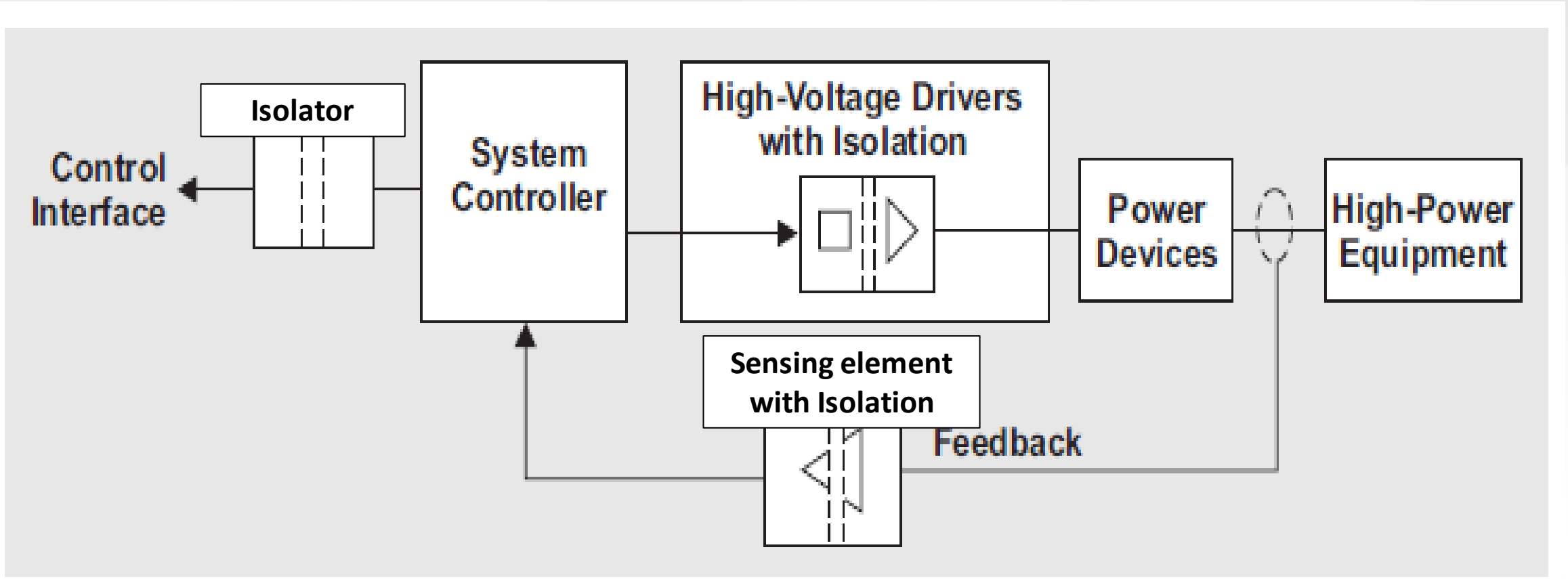
Only galvanic isolation provides protection for very large potential differences

Applications

For switched-mode power electronic applications involved in high-power and high-voltage conversion

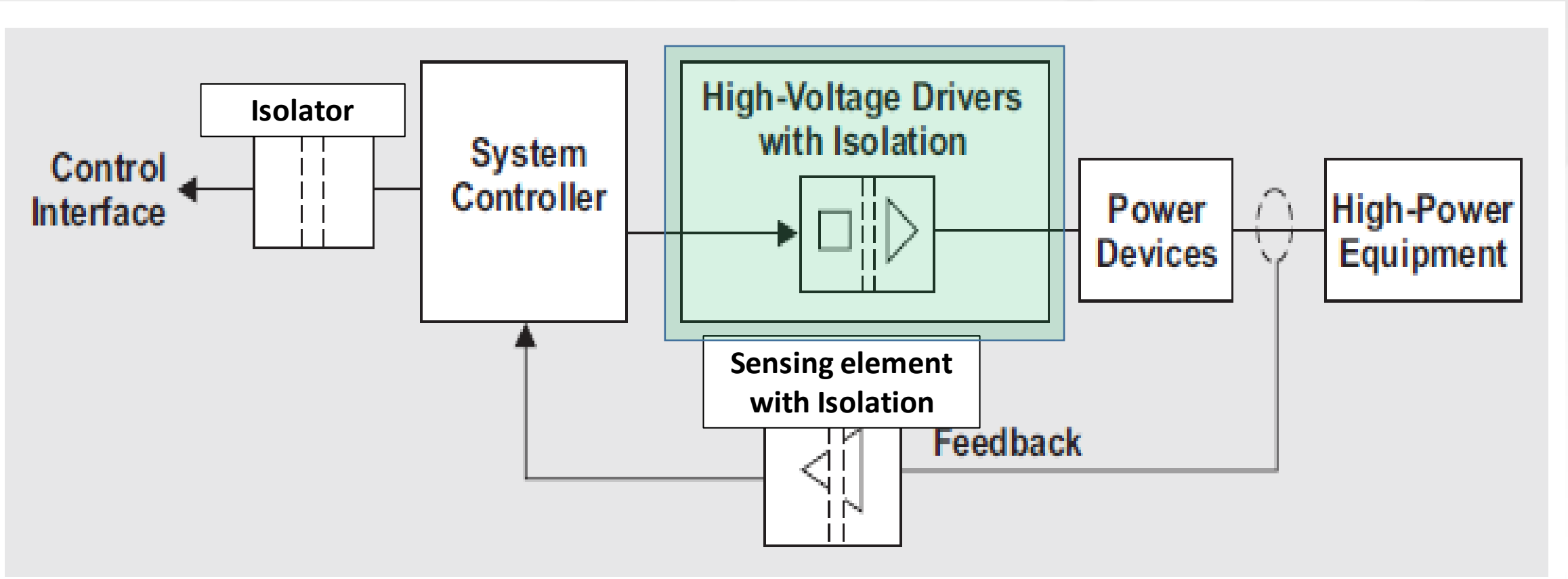
A conceptual power drive system block diagram

Electronic devices and integrated circuits (ICs) used for isolation are called isolators



A conceptual power drive system block diagram

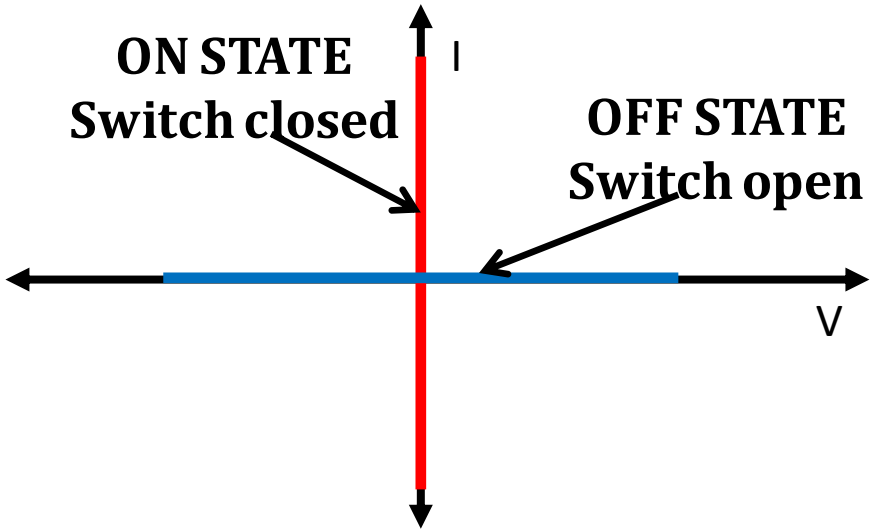
Electronic devices and integrated circuits (ICs) used for isolation are called isolators



Let us take a step back and understand

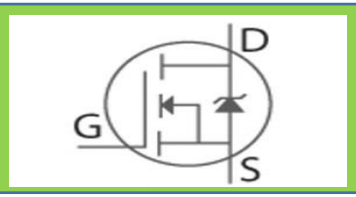
- The concept of power electronics
- What is a gate driver

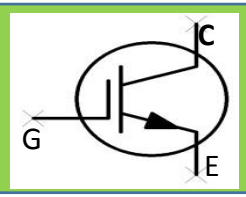
‘Power Switch’ - Fundamental Component in Power Electronics

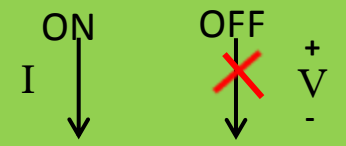


Ideal switch:
Blocking loss, $P_{OFF} = V_{OFF} \times I_{OFF} = 0$
Conduction loss, $P_{ON} = V_{ON} \times I_{ON} = 0$
4 quadrant operation

Power Switches control flow of current in power electronic circuits by operating in 2 states (ON/OFF)

MOSFET 

IGBT 

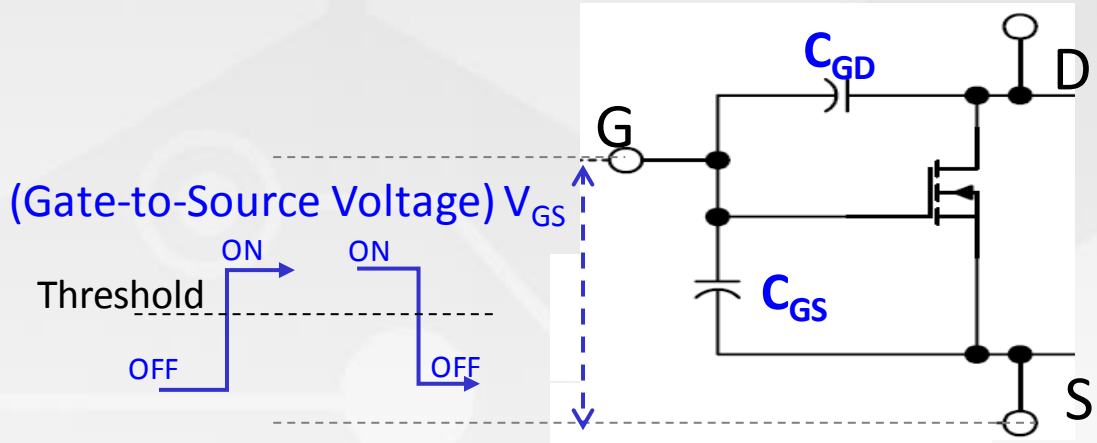


- GATE (G) terminal controls ON/OFF status of switch
- Modern Power Electronics dominated by Switch Mode Power conversion

How does GATE terminal of a Power Switch Work ?

Let's take example of a power MOSFET

- GATE terminal controls ON/OFF state of MOSFET
- VGS = Voltage Between Gate & Source
- To turn ON: Apply a positive voltage,
- V_{GS} > Threshold level
- To turn OFF: V_{GS} < Threshold level
- GATE is a capacitive input, high-impedance terminal
- 2 parasitic capacitors inside MOSFET internal structure (C_{GS}, C_{GD})



Now, about Gate Drivers….

What is a Gate Driver

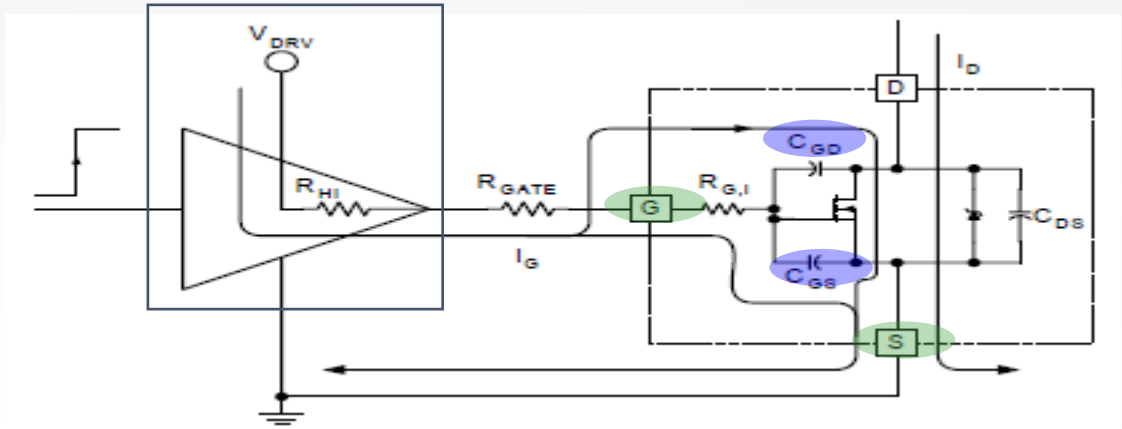
It is a power amplifier that accepts a low-power input from a controller IC and produces the appropriate high-current gate drive for a power MOSFET

Gate Driver device applies voltage signal (V_{GS}) between Gate (G) & Source (S) of power MOSFET, while providing a high-current pulse

➔To charge/discharge C_{GS}, C_{GD} QUICKLY

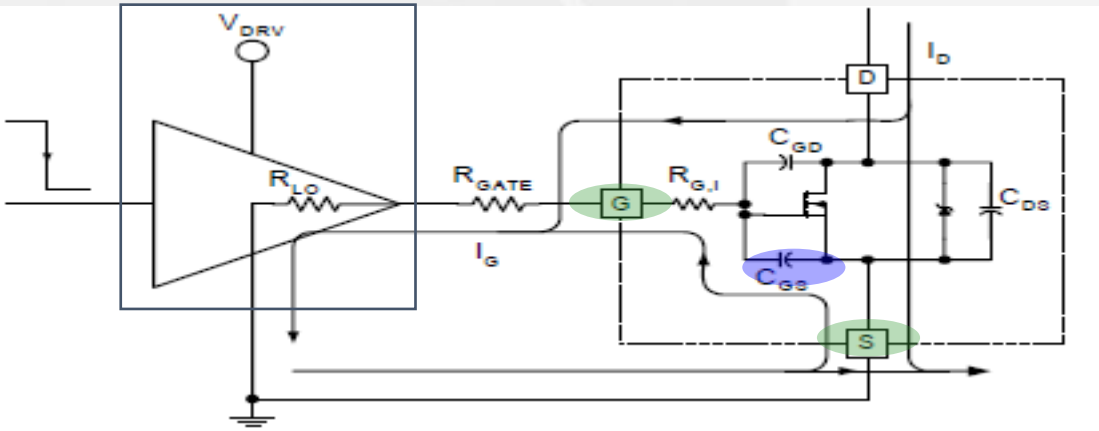
➔To switch ON/OFF power MOSFET QUICKLY

Gate Driver



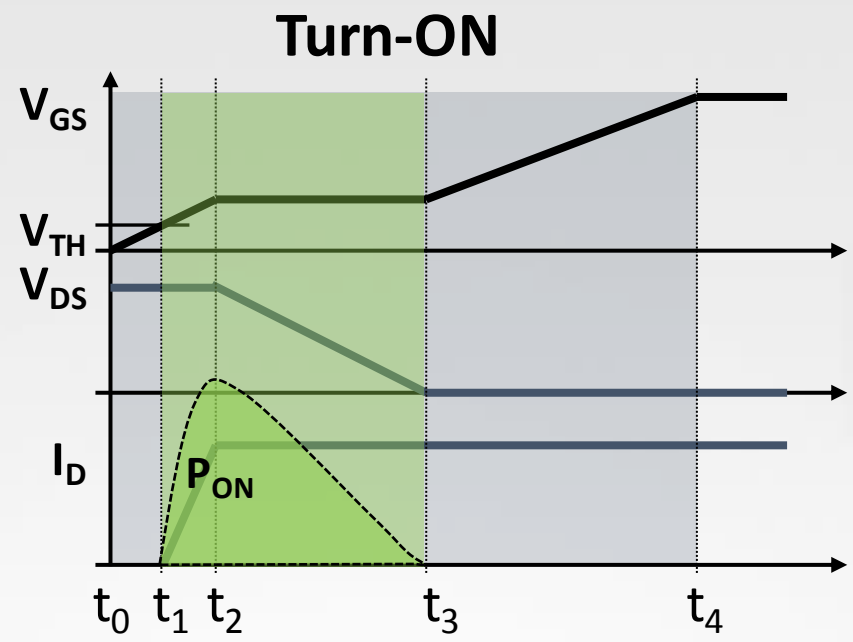
Switch Turn-On

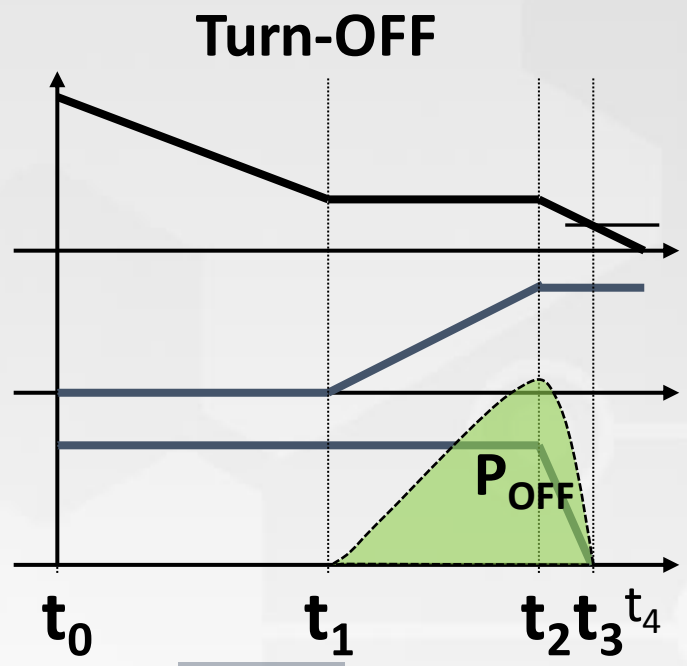
Gate Driver



Switch Turn-Off

Why are Gate Drivers Necessary in Power Electronics?



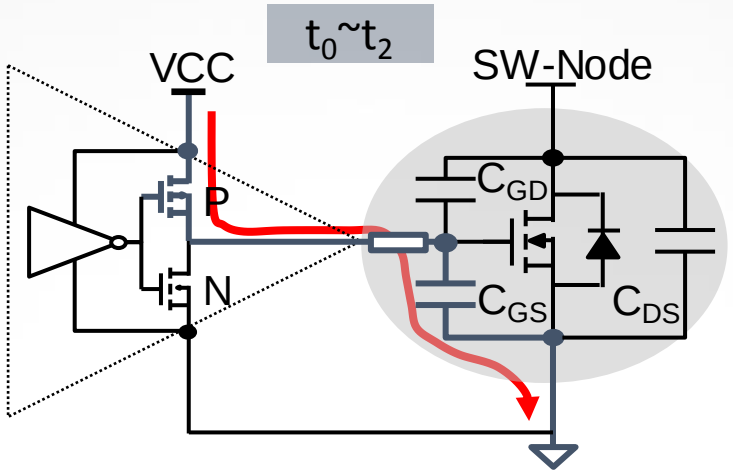


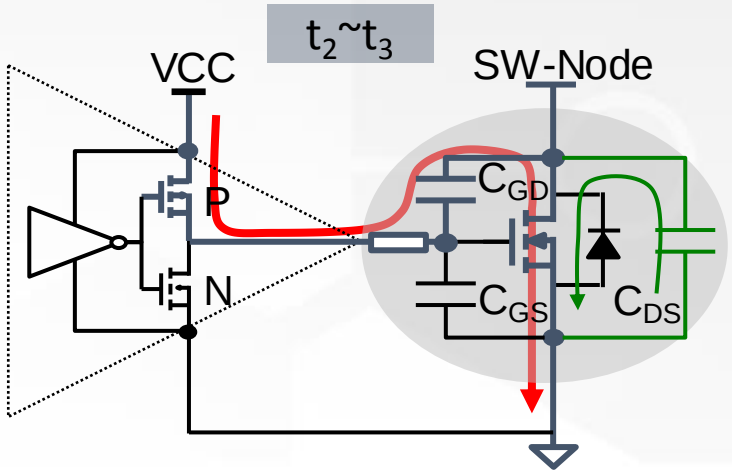
Switching On Loss

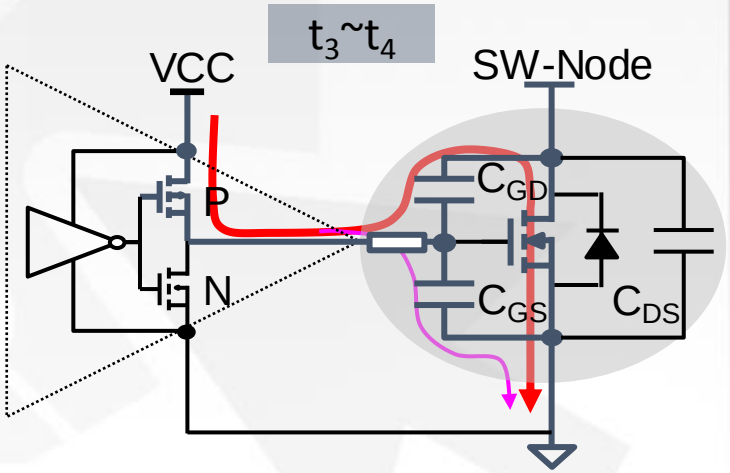
$$\int_{t_1}^{t_3} V_{DS}(t) \cdot I_D(t) dt + E_{OSS}$$

$$t_{1\sim3} \propto \frac{1}{I_{Drv}}$$

Stronger Driver → lower switching loss





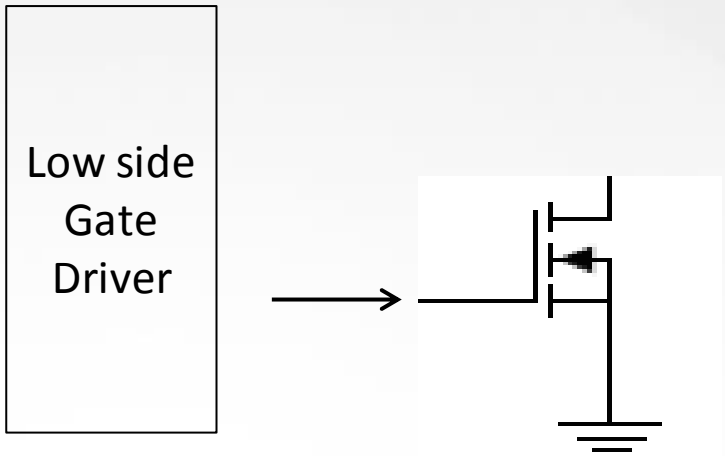


Fast charge/discharge of C_{GS}, C_{GD} reduces power loss in time intervals

Types of Gate Drivers – Based on Switch Position/Arrangement

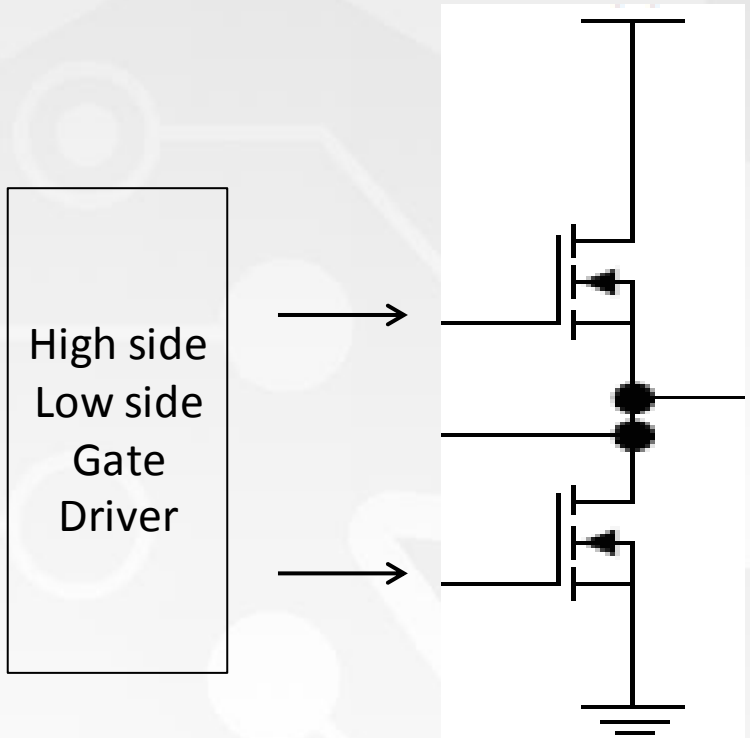
1. Low Side Drivers

Used to Drive GND referenced switches



2. High side-Low Side Drivers

Used to Drive 2 switches connected in Bridge Arrangement

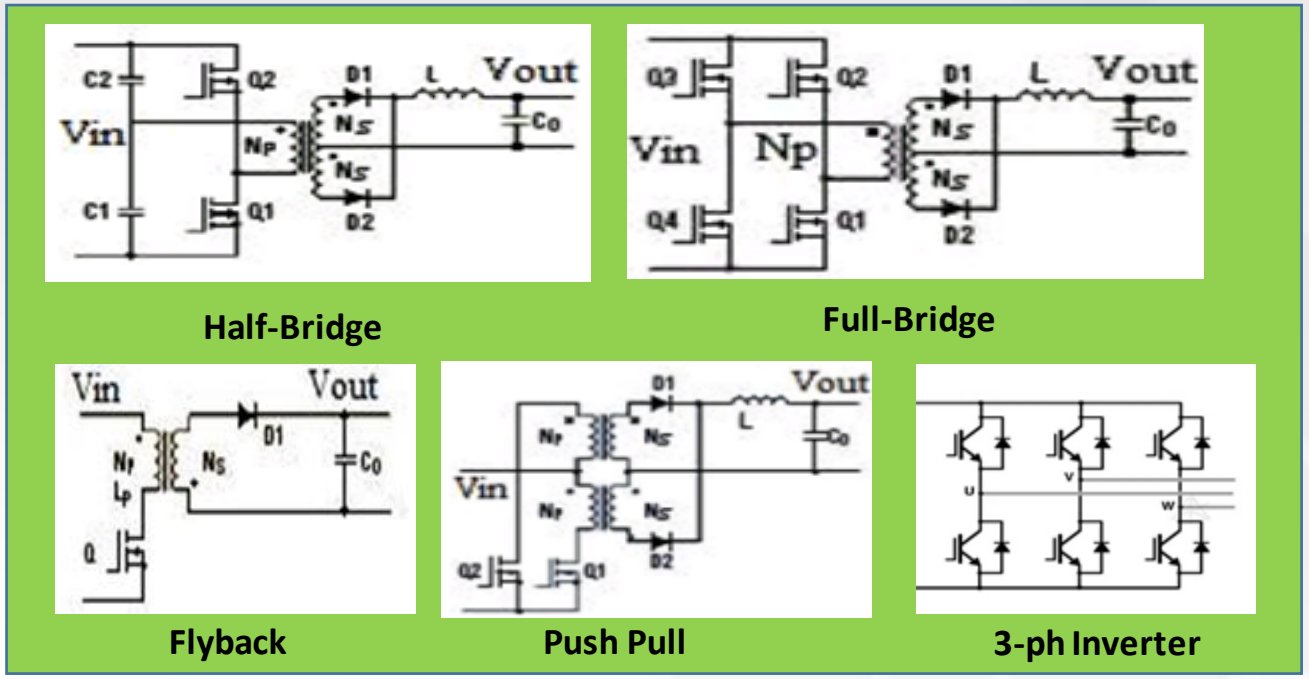


Topologies in switched mode power electronics

Input (V_{IN}, I_{IN}, P_{IN})

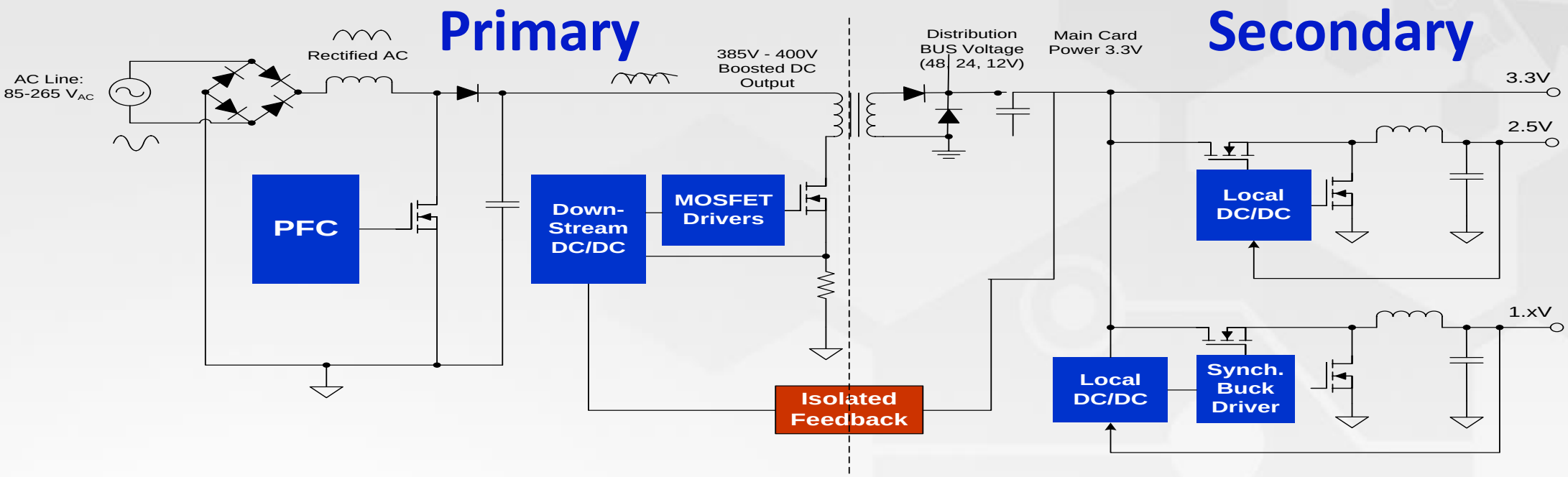
Switch Mode Power Converter

Output (V_{OUT} I_{OUT}, P_{OUT})



Lets look at a power supply application

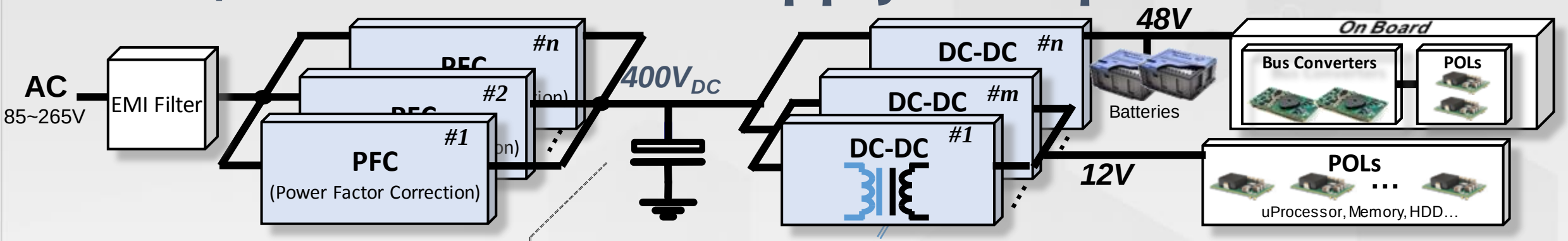
Power Supply application



There is high voltage involved on the primary side of DCDC

PFC Boost	PWM	Local POL Regulators
Reduces Harmonic Content, lowers peak current and makes load look Resistive	PWM is main loop to regulate Vo, provides proper duty cycle	PWM is main loop to regulate Vo, provides proper duty cycle

Server / Telecom Power Supply example



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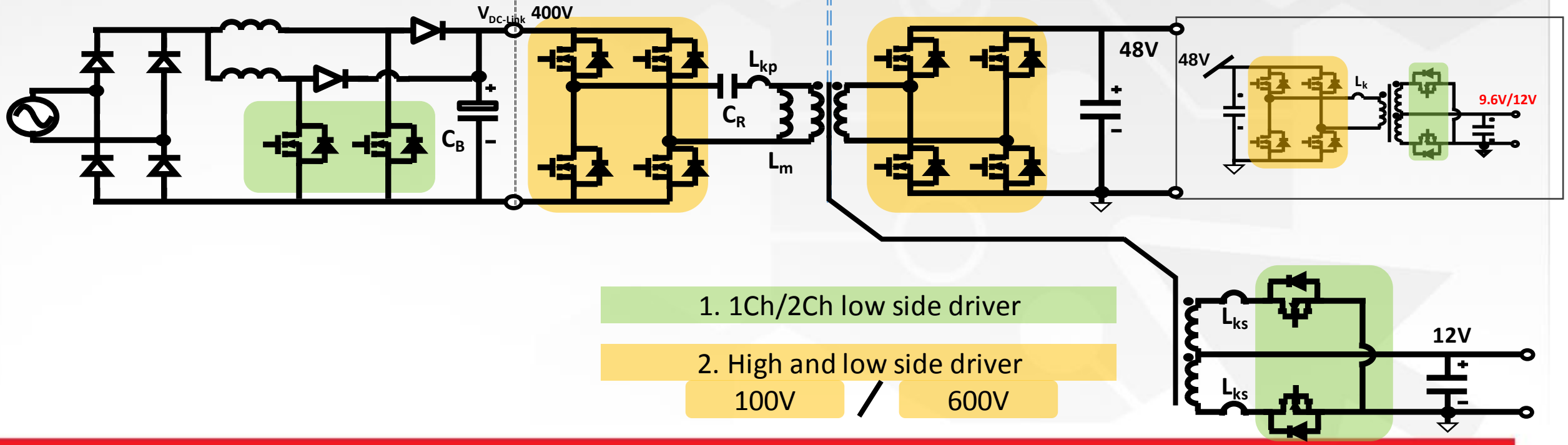


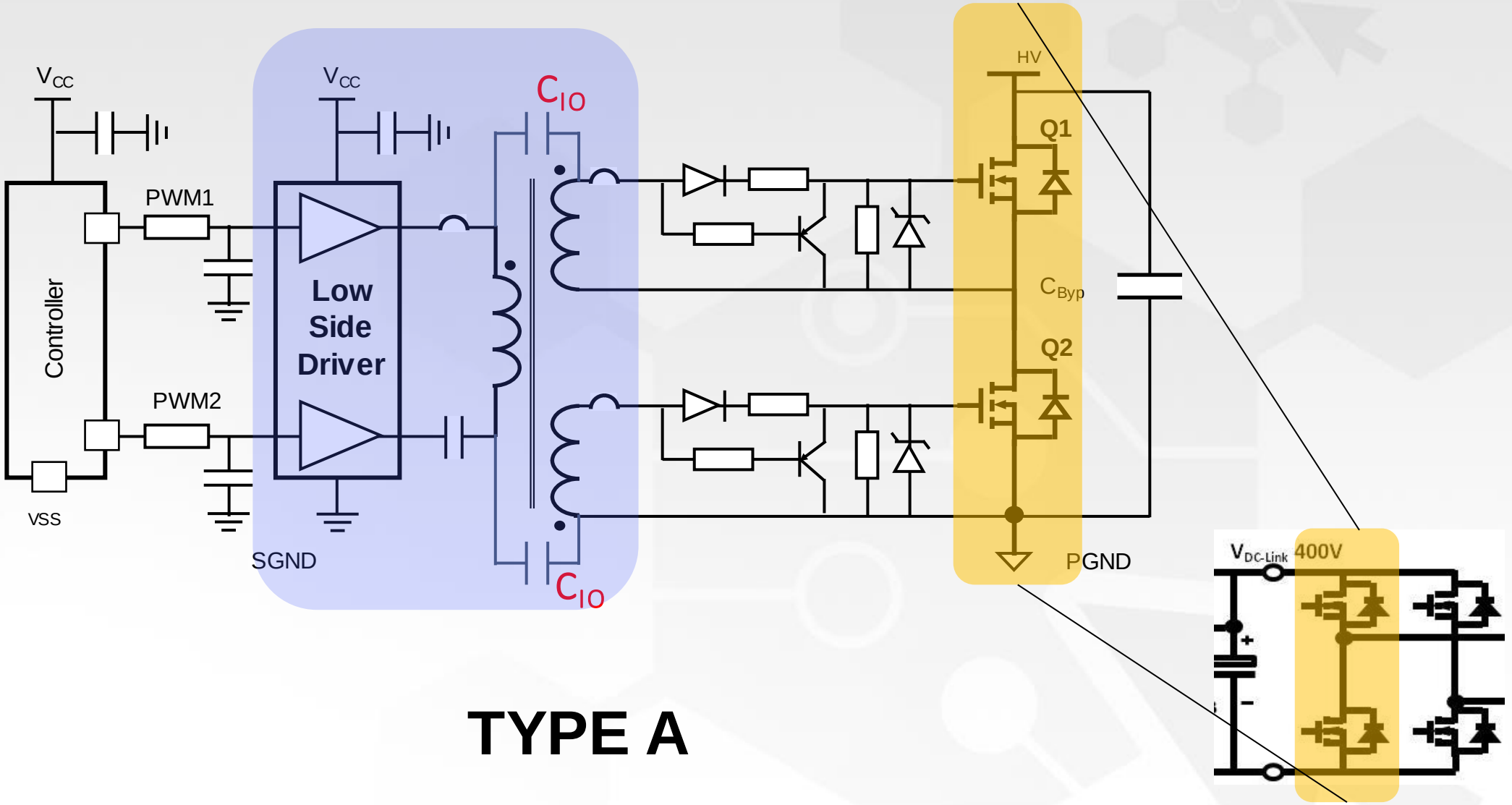
1. 1Ch/2Ch low side driver

2. High and low side driver

100V / 600V

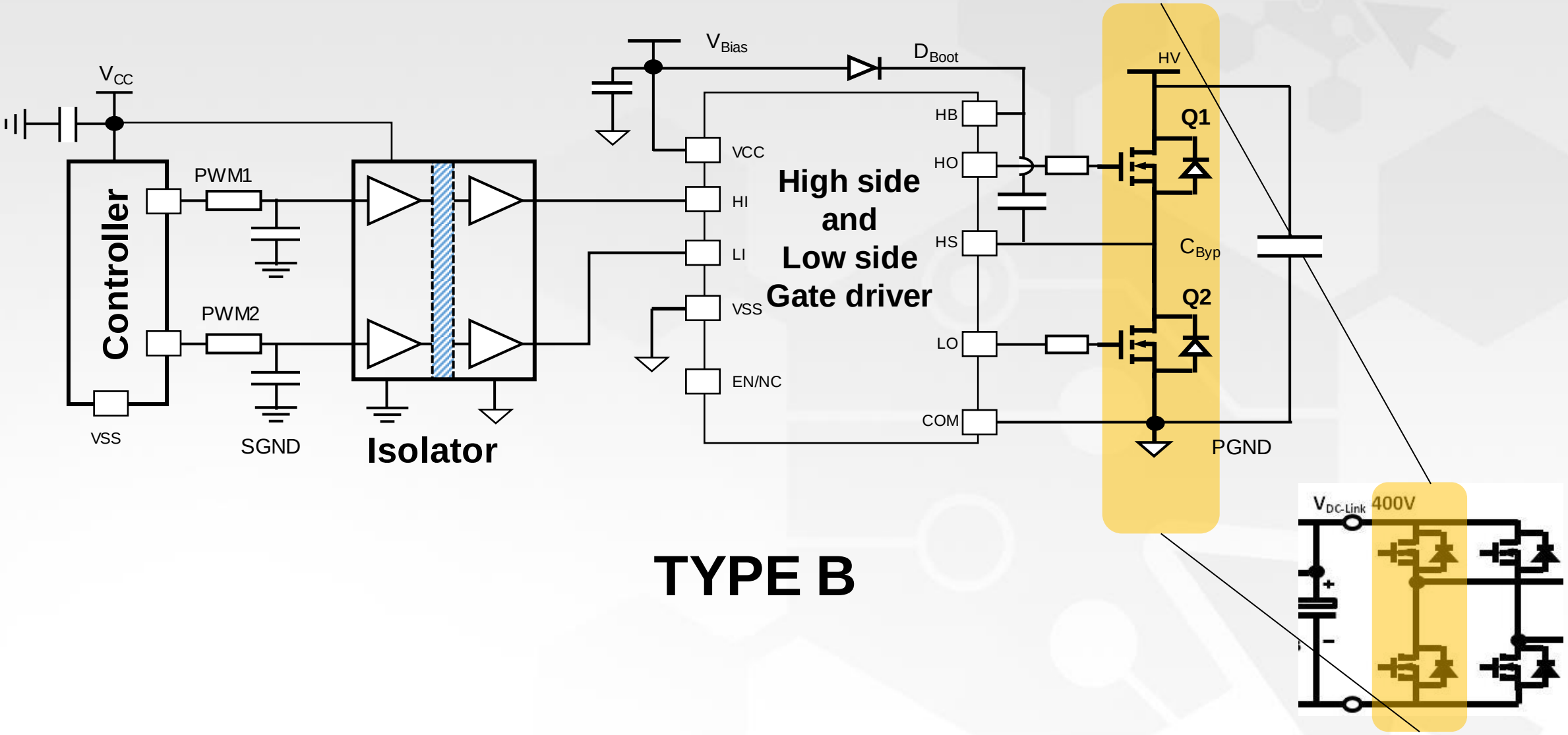
Based on the positioning/placement of the controller, isolation is required between the controller and the driver

Traditional method of isolation: Transformer



TYPE A

Consider an Isolator + Driver



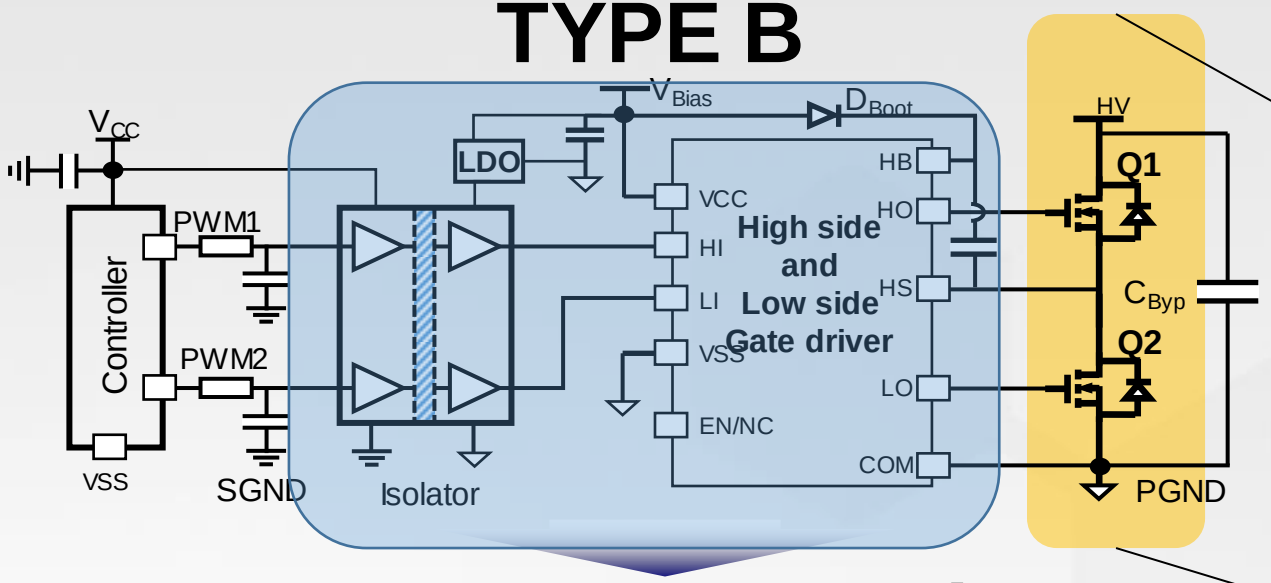
TYPE B

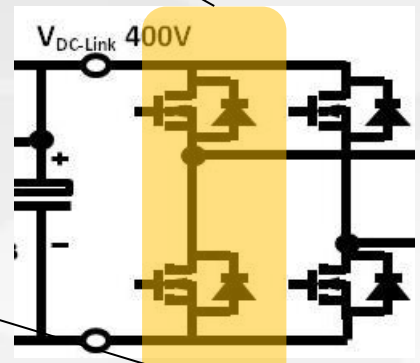
Comparison between Gate Drive Transformer & High & Low Side Driver with isolator

	Type A	Type B
T_{Prop}	≈20ns	≈100ns
Bias Power	NO	Yes
C_{IO}	≥10pF	≤1pF
Parasitics	Large (L_{LK})	Very small
Overshoot	Large	Small
Size	Bulky	Small

Trending towards integration: Isolated gate driver

TYPE B





TYPE C: ISO Driver

- ✓ CMTI>100V/ns
- ✓ 5kVrms reinforced isolation
- ✓ T_{Prop}: 25ns Typ.
- ✓ Match./$_{TPWD}$ < 5ns
- ✓ 110mm²

Trending towards integration: Isolated gate driver

TYPE A

		W (mm)	L (mm)	H (mm)	Area (mm²)	Vol (mm³)
Type A	UCC27324	5	6.2	1.75	31	54.25
	GA3550-BL	17.4	24.13	10	420	4200
				SUM	451	4254

TYPE B

Type B	ISO7520C	10.5	10.6	2.65	111.3	295
	UCC27714	8.75	6.2	1.75	54.25	95
	MURS360	8.1	6.1	2.4	49.41	119
				SUM	215	509

PCB Area Reduction – 76%

TYPE C: ISO Driver (UCC21520)

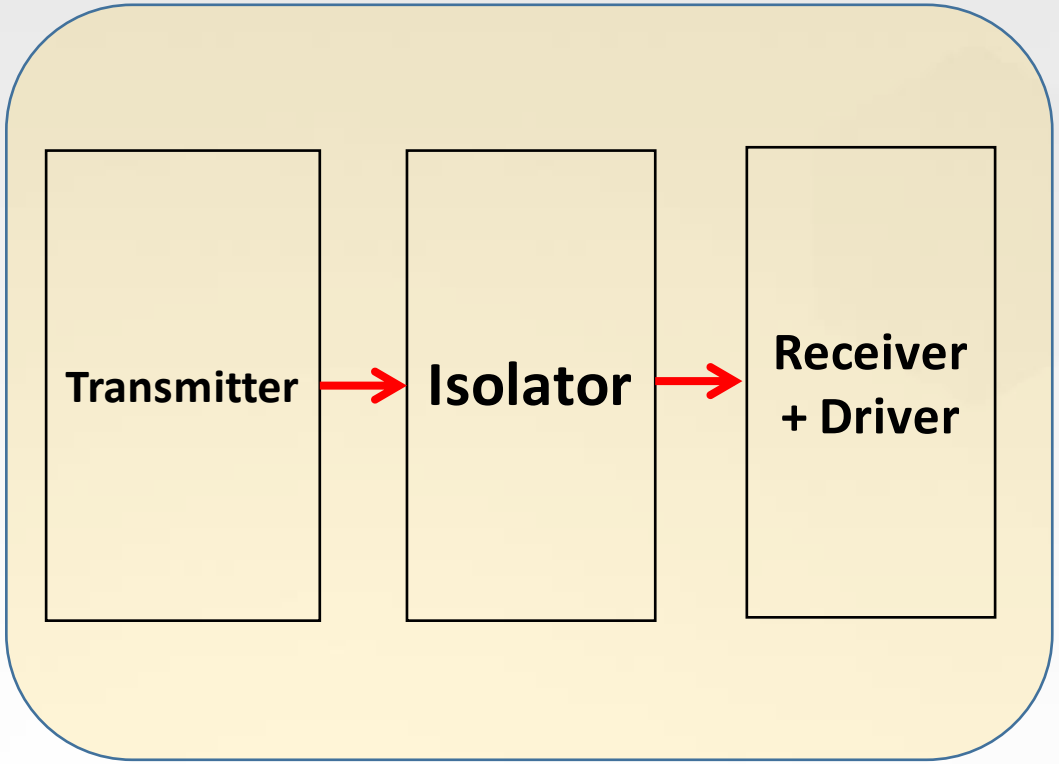
- ✓ CMTI>100V/ns
- ✓ 5kVrms reinforced isolation
- ✓ T_{Prop}: 25ns Typ.
- ✓ Match./$_{TPWD}$ < 5ns
- ✓ 110mm²

Why is driver + isolation integration trend important?

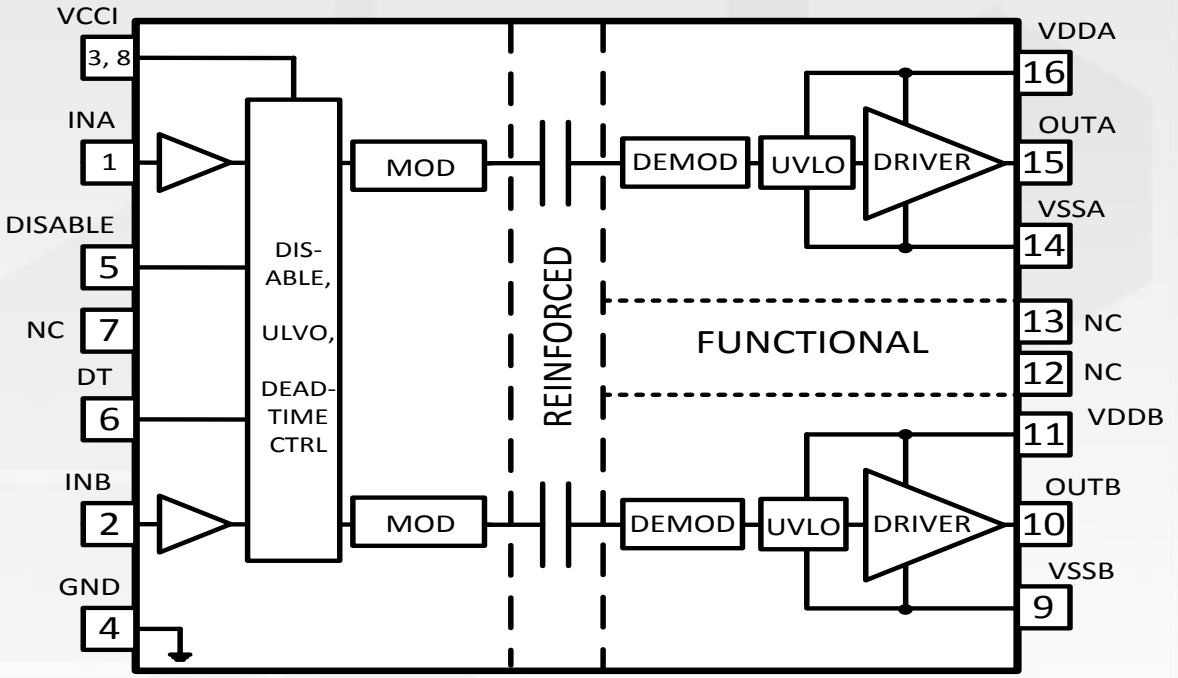
- Adding isolation is becoming mandatory as part of regulatory compliance
- System solutions becoming smaller in size
  - Datacenters – space limited – but more storage
  - Telecom bay stations and RRUs – Higher data transactions
- Higher efficiency
  - Switching to higher voltages
  - More intelligence to systems → More protection of controls
- Higher performance density
- Isolation robustness
- Availability of high voltage devices
  - Wide band gap devices – SiC, GaN

Construction of an isolated gate driver

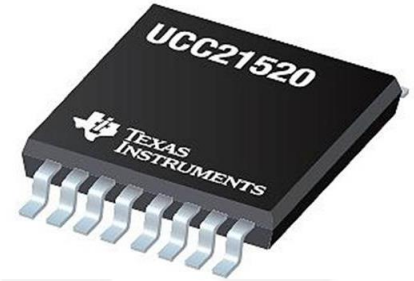
Multichip module



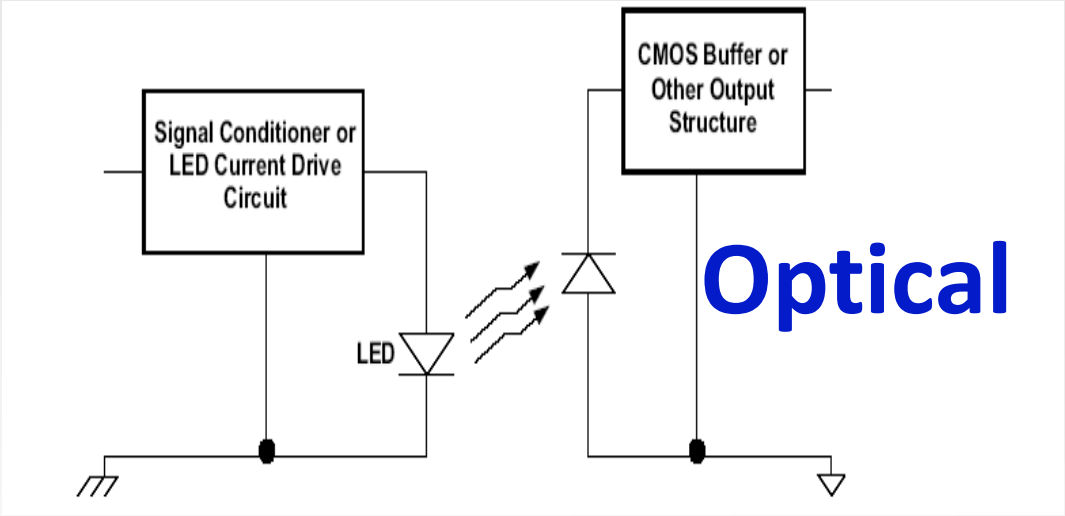
UCC21520



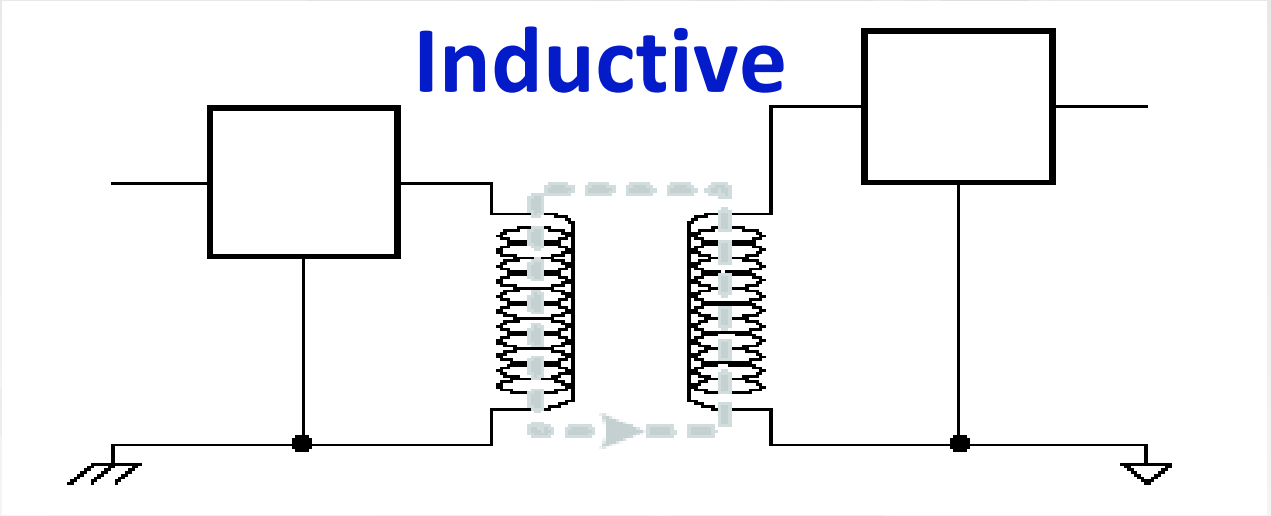
[Visit the UCC21520 webpage]



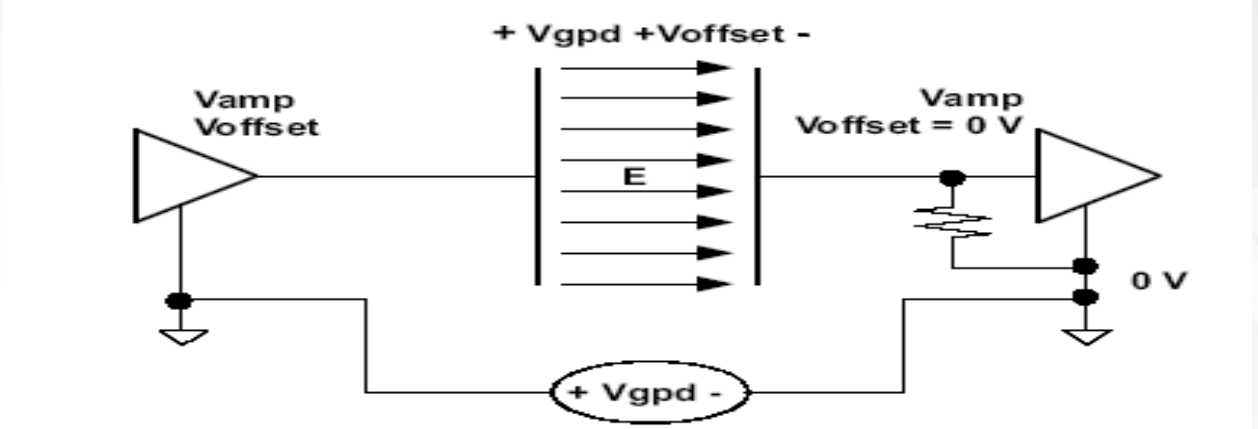
Types of isolation methods



Optical



Inductive

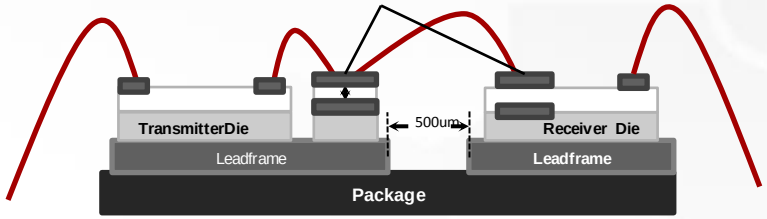


Capacitive

TI uses Capacitive Isolation Technology

- ✓**SiO_2 is the most stable dielectric over temperature and moisture**
- ✓Highest lifetime in the industry, >1.5 kV_{RMS} for 40 years
  - ✓Superior transient protection for harsh environments, >12.8kV
- ✓**Leverage advantages of TI's process technology**
  - ✓Manufacturing repeatability leading to tight part-to-part skew
  - ✓Integration path with many other circuits
  - ✓No wear out mechanisms, low defect levels, high MTBF

Series cap



Value of Capacitive isolation

Higher power density, enabling smaller solutions

High drive currents reduces switching losses with a rise time of 6ns and fall time of 7ns for a 1.8nF load for high frequency switch mode power applications (UCC21520)

Isolation robustness

Best-in-class surge protection of 12.8kVand noise immunity greater than 100V/ns with integrated dead-time control is ideal for safety-critical applications.

Low power consumption

Reduced standby power as low as 1milliamps (mA) helps increase energy efficiency and increase the life of the device.

Levels of Isolation

- **Functional Isolation**
  - Functional Isolation is necessary for the proper operation of a product. There is no need for protection against electric shock
- **Basic Isolation**
  - Basic Isolation is single level of isolation providing basic protection against electric shock
- **Reinforced Isolation**
  - A single insulation system that provide electrical shock protection equal to double insulation
- **Supplementary Isolation**
- **Double Isolation**

Standards that apply to Isolated drivers

- Component level Standards:
  - IEC 60747-5-5 (VDE 0884-5-5) .
  - VDE 0884-10 / VDE 0884-11
  - IEC 60747-17
  - UL 1577
  - ---

TI Isolated gate drivers must pass

- System Level / End Equipment Standards
  - IEC 61800-5-1, safety requirements for adjustable speed drives
  - IEC 60601-1, Medical equipment standard
  - IEC 61010-1, safety standard for measurement, control and Lab equipment
  - IEC 60950-1, Telecom equipment standard
  - ISO 6469-3, Electric Vehicle Safety Standard
  - ….

Customer boards and systems must pass – TI Isolated gate drivers should enable

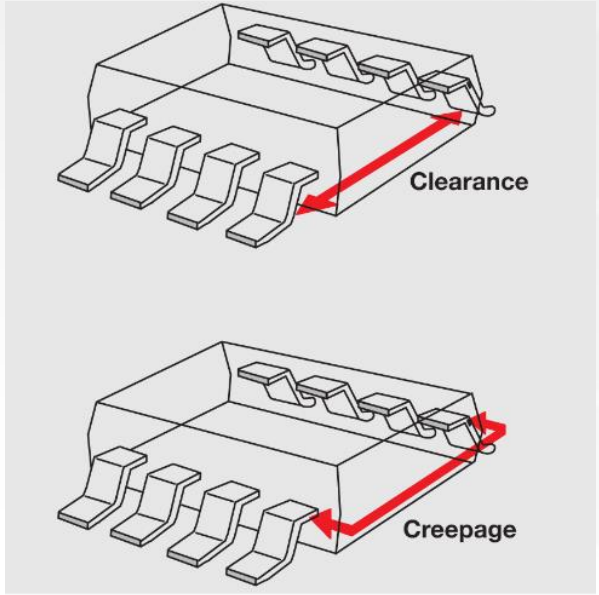
Common Isolation Terminologies

- Isolation Rating Voltage (Vrms) : Viso
- Working/Operating/Repetitive Voltage (Vrms)
- Impulse or Surge Voltage (Vpk): Viosm
- Channel to channel voltage

- Tracking
- Comparative Tracking Index (CTI)

CTI	Material Group
600 <= CTI	I
400 <= CTI < 600	II

- Creepage Distance
- Clearance



- Pollution Degree 1
- Pollution Degree 2
- Pollution Degree 3

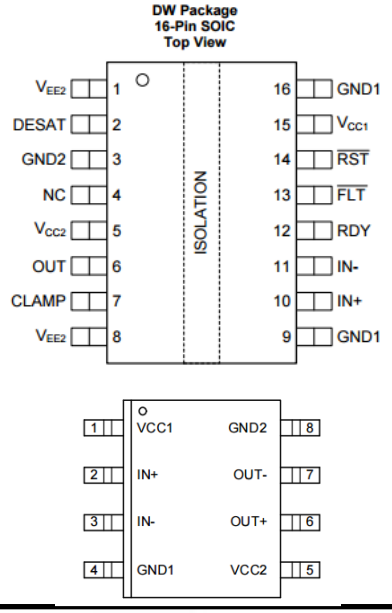
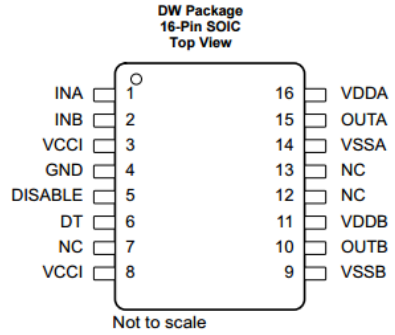
Details on these terminologies to be discussed in the Oct 20th webinar offered on isolation

Key requirements for an isolated driver

In addition to understanding the levels of isolation…. It is important to find out about the driver functionalities:

- **Propagation delay**
- **Common Mode Transient Immunity (CMTI)**
- **Rise time/fall time**
- **Maximum driver side supply voltage**
- **UVLO**
- **Channel to channel delay**
- **Protection schemes**
- **Dead time control and overlap**
- **Enable/disable features**

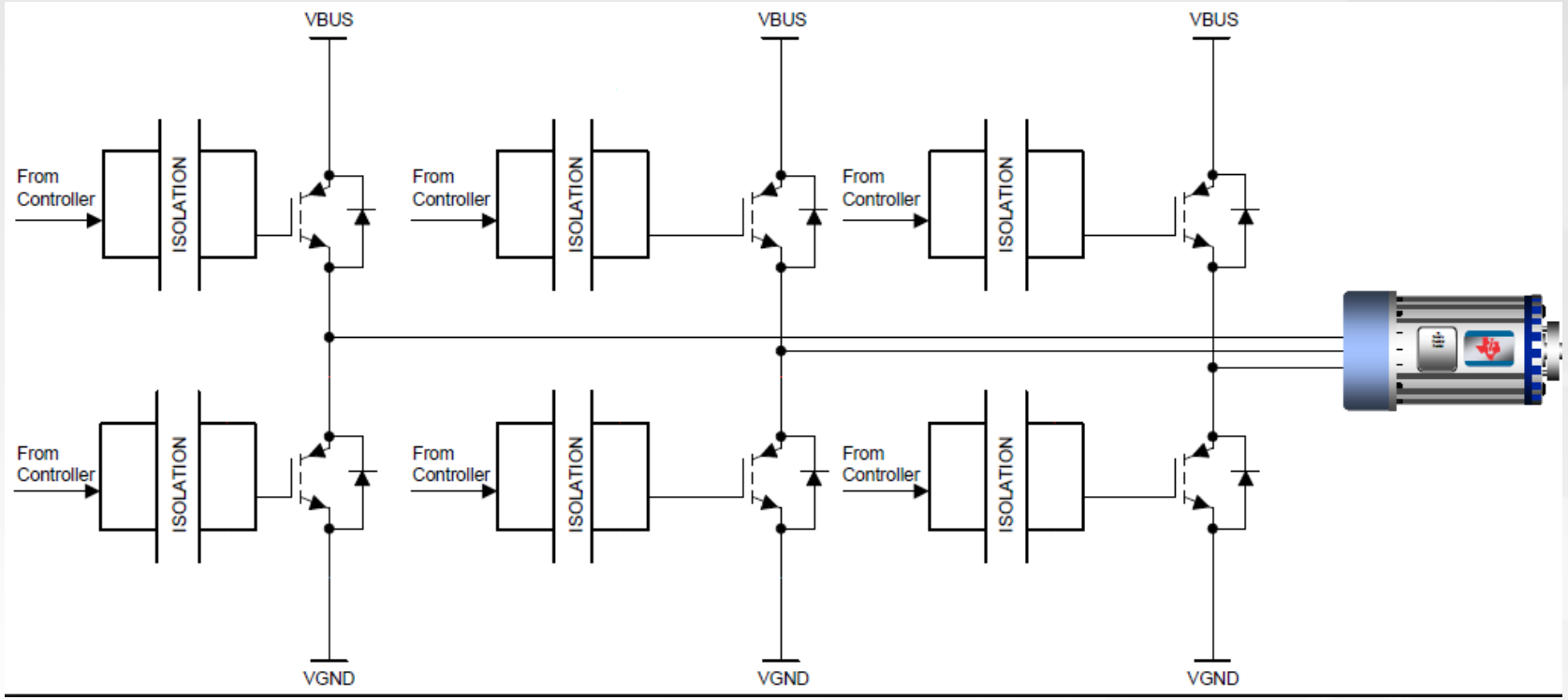
Type of isolated gate drivers

Type	Single	Dual
Power switch	MOSFET, IGBT	MOSFET
Pinouts	8, 16, 24, 32	16 (for SOIC), 13,14
Type of isolation	Basic and Reinforced	Basic and Reinforced
Package type	SOIC (narrow and wide)	SOIC (narrow & wide), LGA
Protection features	Yes (for 16, 24 and 32 pins)	No
Examples		

Comparison between MOSFET and IGBT iso drivers

Power Switch	MOSFET	IGBT
Switching frequencies	High (>20 kHz)	Low to Medium (5-20kHz)
# Channels	Single and Dual	Single
Protection	No	Yes – Desaturation, Miller Clamping
Max Vdd (power supply)	20V	30V
Vdd range	0-20V	-10 to 20V
Operating Vdd	10-12V	12-15V
UVLO	8V	12V
CMTI	50-100V/ns	<50V/ns
Propagation delay	Smaller the better (<50ns)	High (not critical)
Rail Voltage	Up to 650V	>650V
Typical Applications	Power supplies – Server, datacom, telecom, factory automation, onboard and offboard chargers, solar u-inverters and string inverters (<3kW), 400-12V DCDC - Auto	Moto drives (AC machines), UPS, Solar central and string power inverters (>3kW), Traction inverters for auto

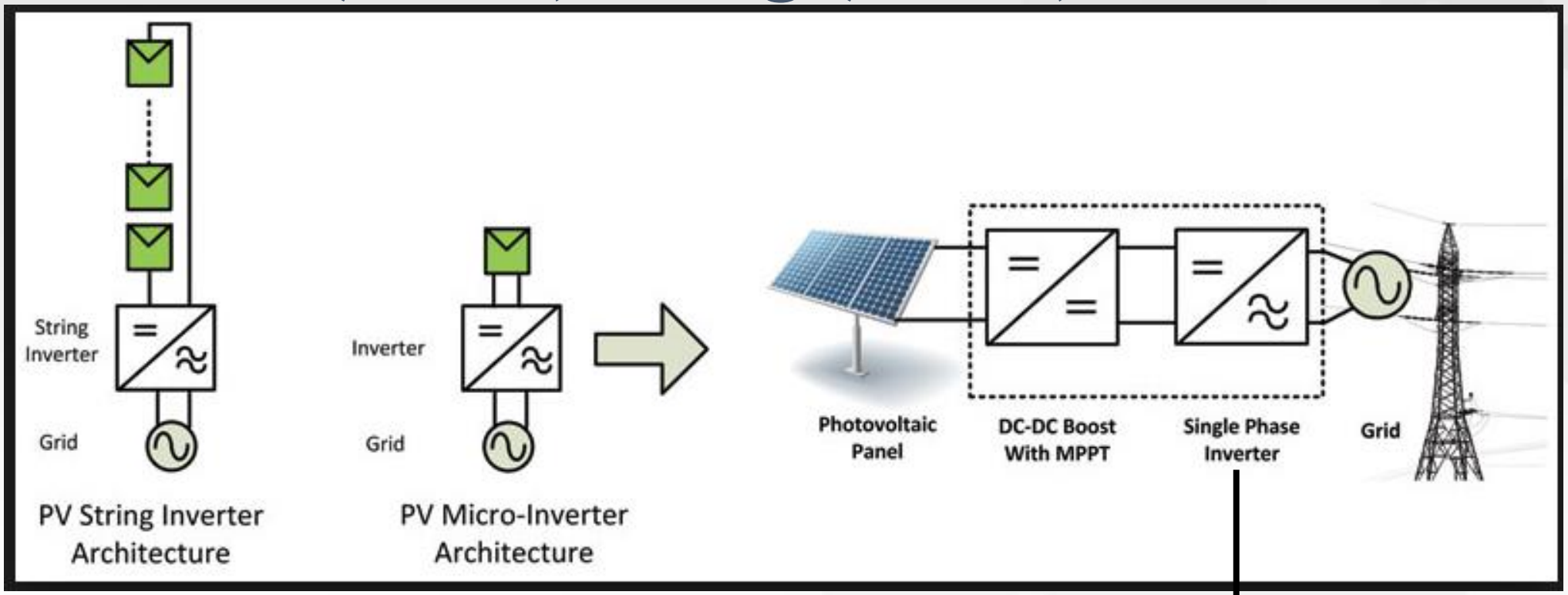
Motor drive application



Gate driver options:

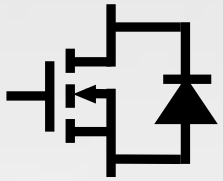
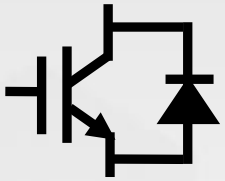
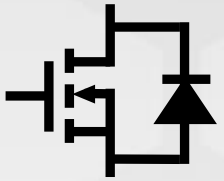
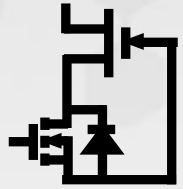
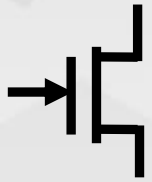
- 6 single channel iso drivers with no protection (8pin) and usually reinforced
- 6 single channel iso drivers with protection (DESAT, Miller clamp or split output) (16 pin)
- 3 single channel iso drivers for high side only (8 or 16 pin) along with 3 non isolated drivers

Solar micro (300W)/string (<3kW) inverter

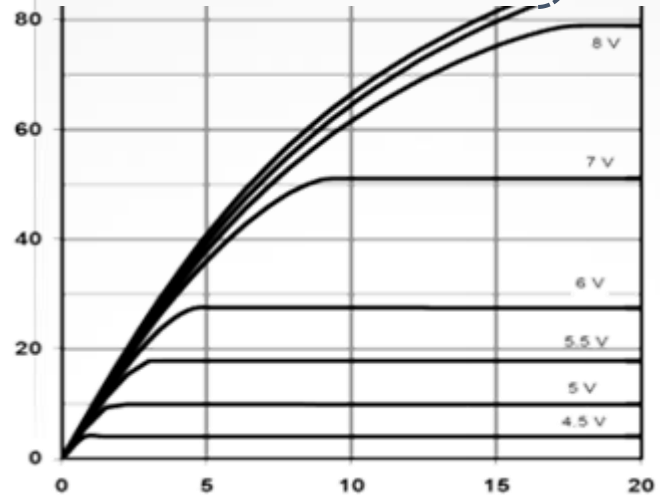


Usually MOSFET single inverters needing isolated (basic or reinforced) drivers

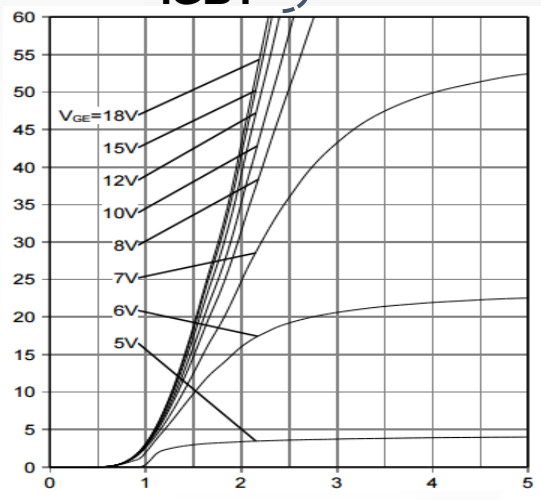
State-of-the-art Power Semiconductors (Wide Band Gap)

	Si-MOSFET	IGBT	SiC-MOSFET	GaN	
					
				Nom-ON	Nom-OFF
Voltage Ratings	20~650V	≥650V	≥650V	≤650V	
Optimal V_{GS} Max.Limit	0~15V (±20V)	-10~15V (-10~20V)	-5~20V (-5~25V)	-5~10V (±18V)	-4~6V (-10~7V)

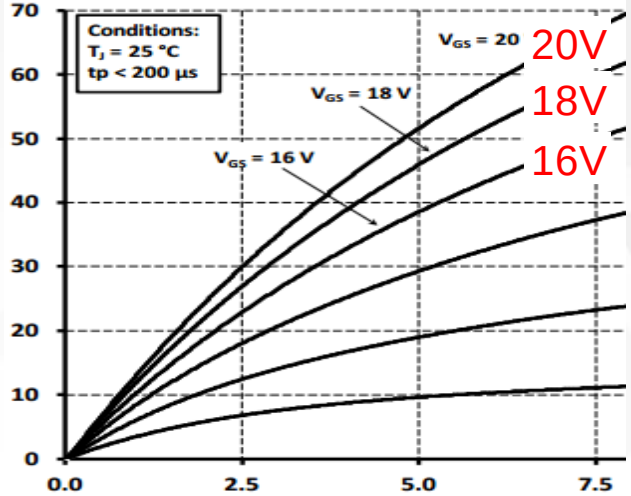
Si-MOSFET 10V



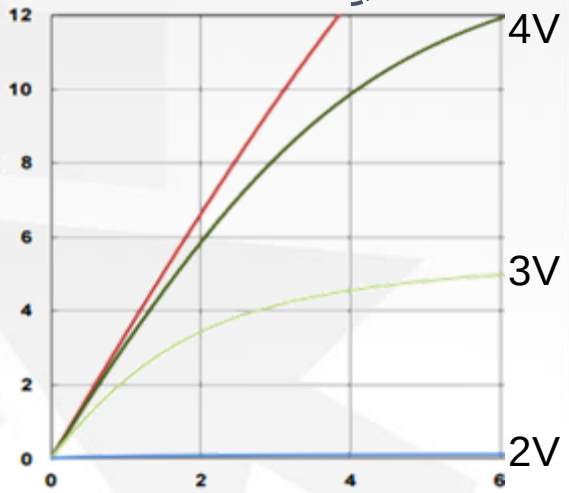
IGBT 12V



SiC-MOSFET



GaN 5V



- I-V curves are from datasheets of Infineon, CREE, EPC

Value of Silicon carbide in high voltage & high power applications

- ✓High power density – 10x more than Silicon
  - ✓High current density
- ✓High breakdown voltage
- ✓Drive higher current in a reduced footprint
- ✓High thermal conductivity
- ✓High mobility – ability to switch at high frequencies

Comparison of SiC to MOSFET and IGBT iso drivers

Power Switch	MOSFET	IGBT	SiC
Switching frequencies	High (>20 kHz)	Low to Medium (5-20kHz)	High (>50 kHz)
# Channels	Single and Dual	Single	Single and Dual
Protection	No	Yes – Desaturation, Miller Clamping	Yes – Current sense, Miller Clamping
Max Vdd (power supply)	20V	30V	30V
Vdd range	0-20V	-10 to 20V	-5 to 25V
Operating Vdd	10-12V	12-15V	15-18V
UVLO	8V	12V	12-15V
CMTI	50-100V/ns	<50V/ns	>100V/ns
Propagation delay	Smaller the better (<50ns)	High (not critical)	Smaller the better (<50ns)
Rail Voltage	Up to 650V	>650V	>650V
Typical Applications	Power supplies – Server, datacom, telecom, factory automation, onboard and offboard chargers, solar u-inverters and string inverters (<3kW), 400-12V DCDC - Auto	Moto drives (AC machines), UPS, Solar central and string power inverters (>3kW), Traction inverters for auto	PFC – Power supplies, Solar inverters, DCDC for EV/HEV and traction inverters for EV, Motor drives, Railways

Note: Blue font highlights similarities

TI isolated gate driver family

All families support MOSFETs, SiC MOSFETs, IGBTs

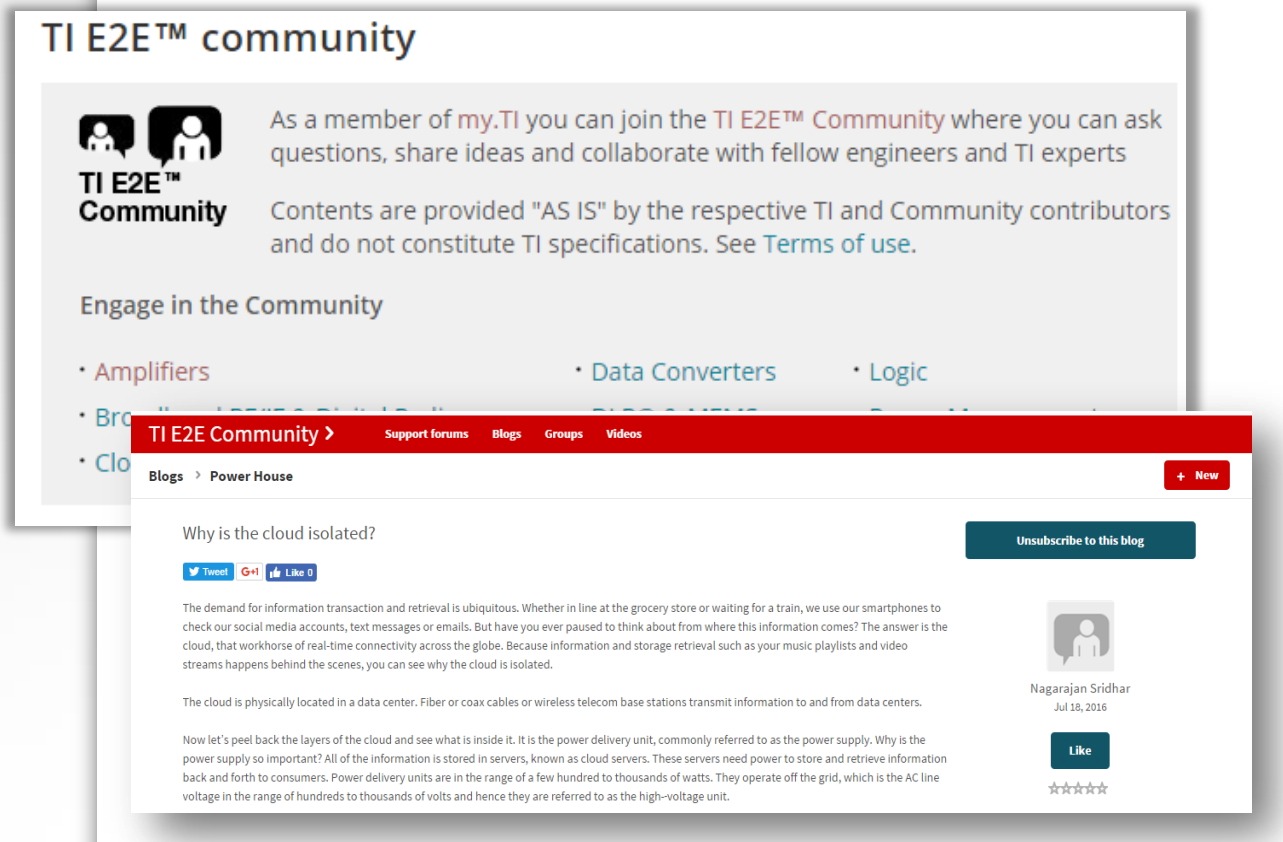
Driver Type	**ISO*****			**UCC*****
# Channels	1			2, 1
DESAT, Soft Turn-off, Miller clamp	Yes			No (yes for Miller Clamp)
SiC support	Yes			Yes
Withstand Isolation voltage (V_{ISO})	5.7kVrms / 8kVpk		5.7kVrms / 8kVpk 3kVrms / 4242kVpk	5.7KVrms/8kVpk
ISO working voltage (V_{IOWM})	1.5kVrms / 2.121kVpk	1kVrms / 1.42kVpk	1.5kVrms / 2.121kVpk 850Vrms/1.2kVpk	1.5kVrms / 2.121kVpk
CMTI (Min)	100kV/µs			100kV/µs
Supply type	Unipolar, Bipolar			Unipolar, Bipolar
Peak drive current	2.5A/5A		17A	4A/6A 8A/12A - with Parallel Channels
Rising and Falling time	20ns/20ns @1.0nF		10ns/10ns @ 1nF	6ns/7ns @1.8nF
VCC, Input	2.25V to 5.5V		3V to 18V	3V to 18V
VDD, Output	15V to 30V		15V to 35V	9.2V to 25V
VDD, quiescent current	3.6mA		1mA	1mA
Propagation delay (Typ)	76ns		50ns	19ns
Protection	UVLO, Power ready indication, Fault Feedback		UVLO	UVLO, Disable, Programmable Dead Time
Packages	SOIC-16 (>8mm Creepage)		SOIC-8 (>4mm, >8.5mm Creepage)	SOIC -16 (**Wide Body**)
Devices	ISO5851 ISO5852S (split O/P)	ISO5451 ISO5452 (split O/P)	ISO53xx	UCC21520

Discover more about isolation

Parameter	Definition	Relevance
Basic Isolation	Isolation that can provide protection against high voltage as long as the barrier is intact.	Basic isolation needs to be coupled with another insulation barrier, if human access is possible.
Reinforced Isolation	Isolation that is equivalent to two basic isolation barriers in series.	Reinforced isolation by itself is sufficient as a safety barrier against high voltage.
V_{IOTM}	The sinusoidal voltage isolator can tolerate for 60sec (defined in pk)	Tolerance to temporary overvoltage on supplies due to load changes, arcing etc.
V_{ISO}	The sinusoidal voltage isolator can tolerate for 60sec (defined in rms)	
V_{IORM}	Maximum periodic voltage that the isolator has to handle on a continuous basis throughout its operating life (defined in pk)	The voltage that the isolator has to handle as part of normal operation (for eg. an isolated gate driver sees a pk voltage equal to the DC bus voltage).
V_{IOWM}	Maximum continuous working voltage that the isolator has to on a continuous basis throughout its operating life (defined in rms)	
V_{SURGE}	Maximum peak voltage of the 1.2us/50us standard surge waveform that the isolator can handle.	Represents direct and indirect lightning strikes. Min 10kV required for reinforced isolation.
Creepage	Minimum distance from pins on side 1 to side 2 along the surface of the package	Limits working voltage or continuous voltage due to degradation along package surface (called tracking)
Clearance	Minimum distance from pins on side 1 to side 2 through the air	Limits peak voltages and surge voltages in system environment due to air breakdown
CMTI	The maximum rate of change of ground potential difference (GND1-GND2) that the isolator can withstand without bit errors	Indicates robustness of isolator to ground noise. Very important in gate-drive applications

- Reliability and isolation resources:
  - High-voltage reinforced isolation: Definitions and test methodologies
  - High-voltage isolation quality and reliability for AMC130x
- Understanding isolation terminology and relevance
- Discover our isolation glossary
- Watch part one and two of our introduction to digital isolation video series
- Join the TI E2E™ Community Isolation forum

Helpful information for readers: UCC21520



- View the UCC21520 datasheet.
- Download the application note, "UCC21520: A Universal Isolated Gate Driver with Fast Dynamic Response."
- Watch videos about the value of an isolated driver and dynamic performance of an isolated driver.
- Learn more about TI's gate driver portfolio and find technical resources.
- Read the Power House blog post, "Why is the cloud isolated?"
- Join the TI E2E™ Community Power Management forum

Thank you