DC/DC Converters for IGBT, SiC, GaN and other Gate Drivers

Florian Boess, Business Development Manager, RECOM Electronic GmbH & Co. KG
on behalf of Rutronik Netherlands, 20. June 2017

RECOM Electronic main facts:

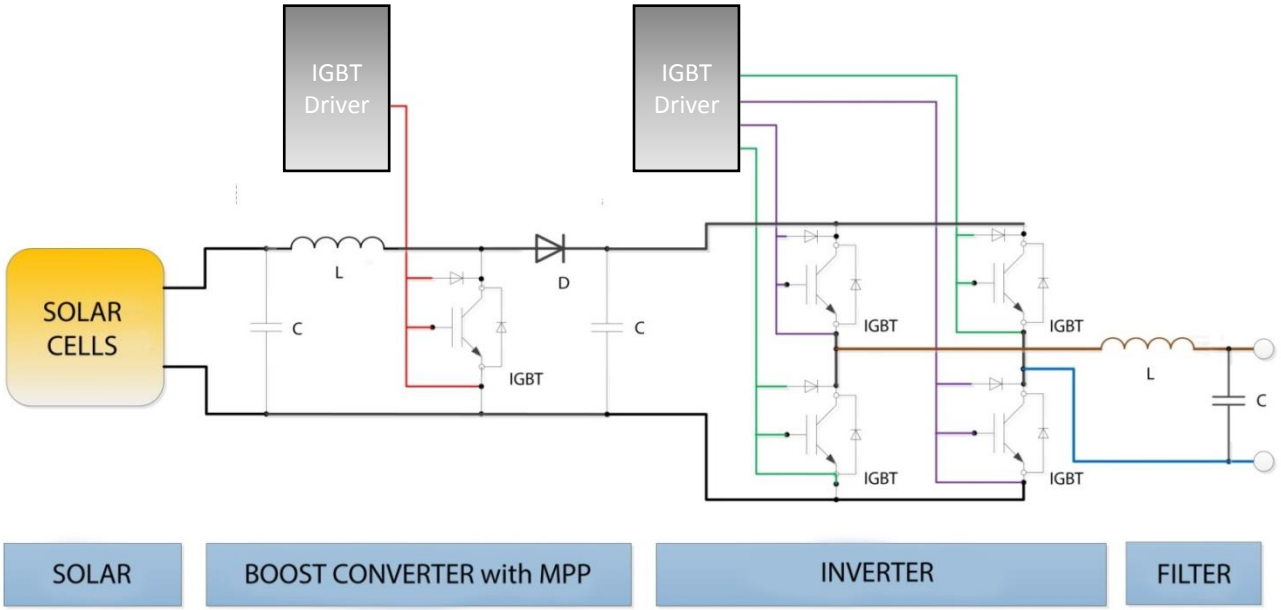
- Since 43 years on the market with DC/DC-Converters
- More than 30.000 products available in a huge partner network
- Own development and production in 3 fabs in Taiwan and China
- Isolated DC/DC-Converters from 0,25W up to 240Watt
- R-78 non isolated Switching regulator series up to 5A Iout
- AC/DC-Power Supplies from 1W up to 480W (Din Rail)
- New own EMC Lab for testing, special seminars and customers
- 3 to 7 years warrenty for the products
- Fully certified and qualified towards UL, EN, CE, ENEC etc.
- Industrial, Medical, new Energy, IoT / Sensors, Lighting, Railway etc.

Introduction

- Typical High Speed / High Power Switching Applications
- IGBT Construction and Gate Drive
- SiC Construction and Gate Drive
- Choosing the right DC/DC converter
- Other Drivers / GaN Technology
- Summary

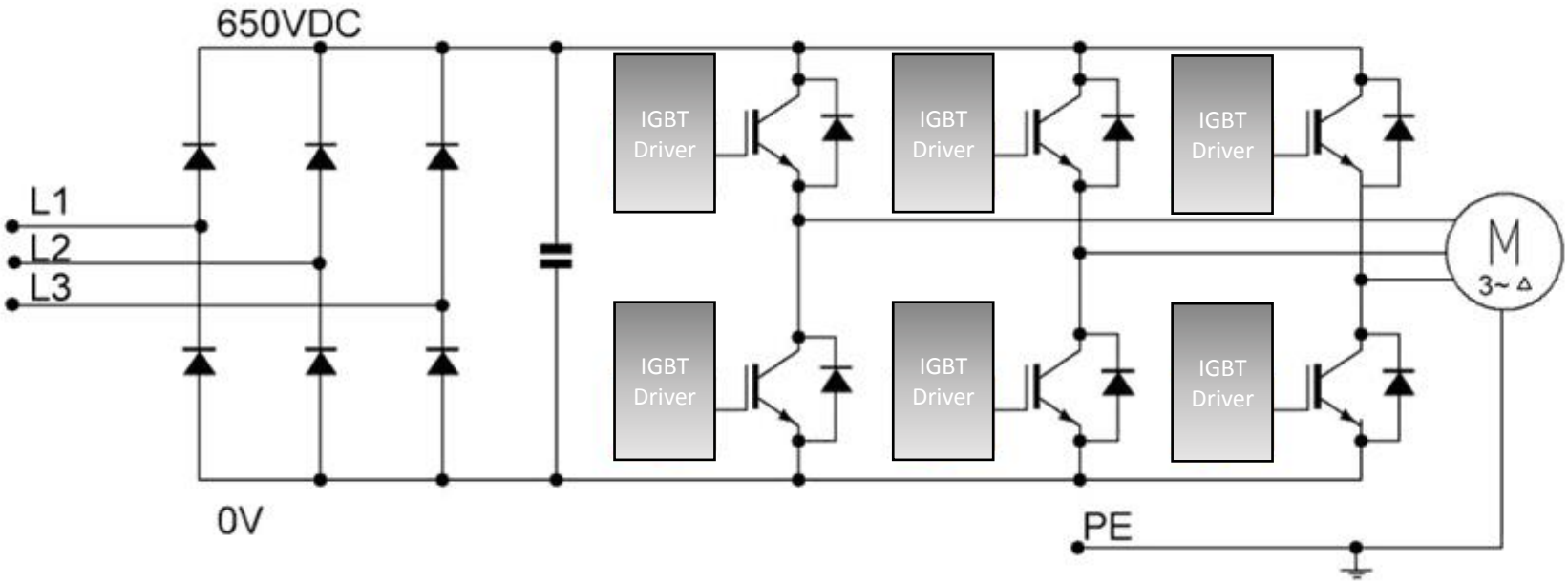
Introduction

- **Typical High Speed / High Power Switching Applications: Solar Inverter**



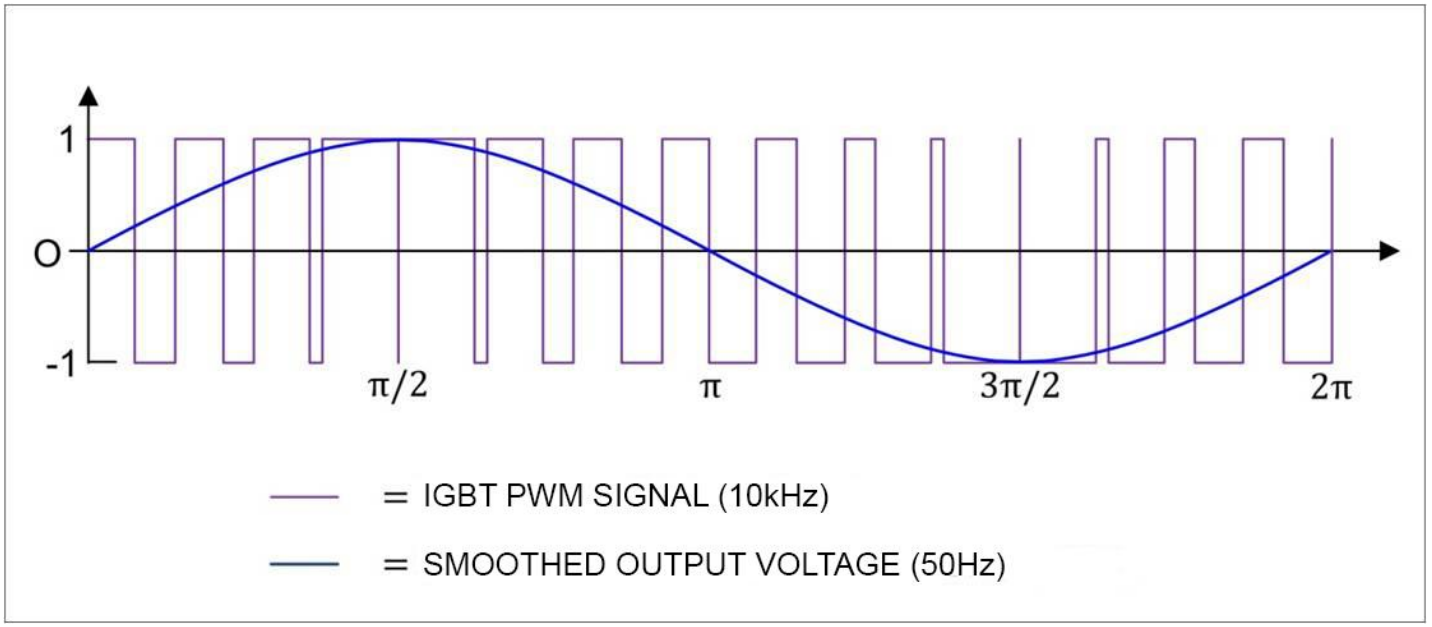
Introduction

- **Typical High Speed / High Power Switching Applications: Motor Controller**



Introduction

- **Typical High Speed / High Power Switching Applications: PWM Power control**

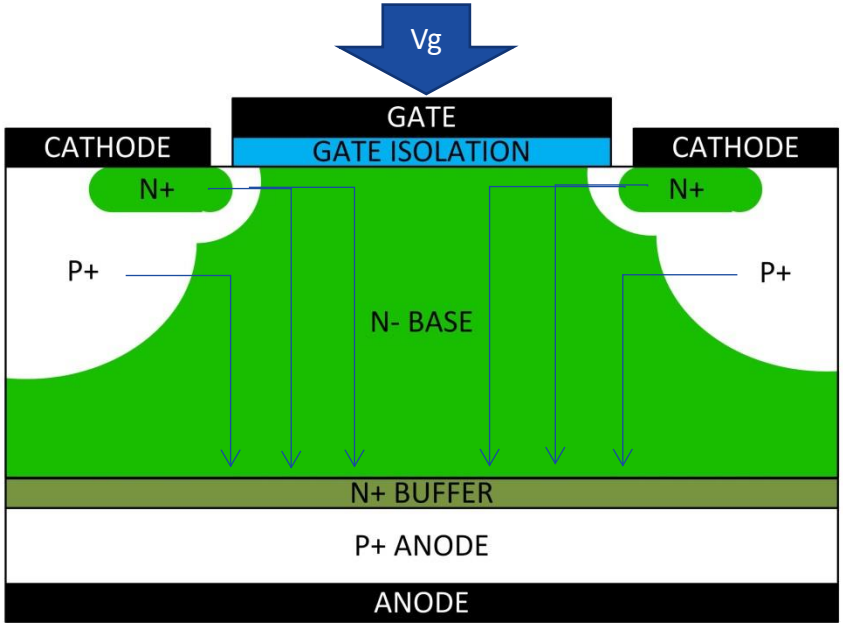


Introduction

- **Typical High Speed / High Power Switching Applications: Typical Requirements**
  - **High Voltage and Current**
  - **Fast turn on**
  - **Fast turn off**
  - **Reliable switching**
  - **Keep di/dt in check**
  - **Keep dv/dt in check**

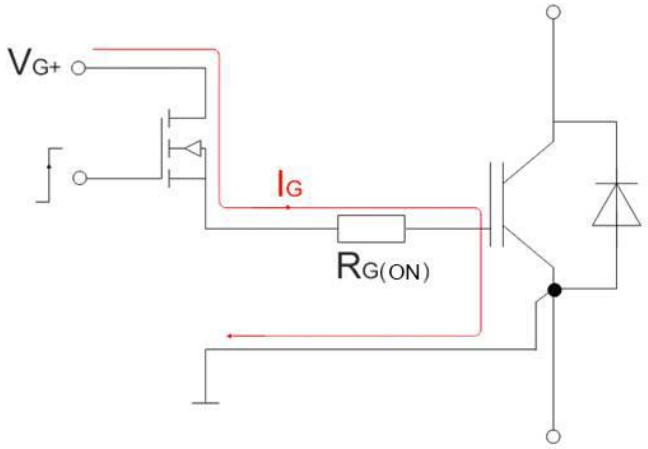
Introduction to IGBT and SiC

IGBT Construction

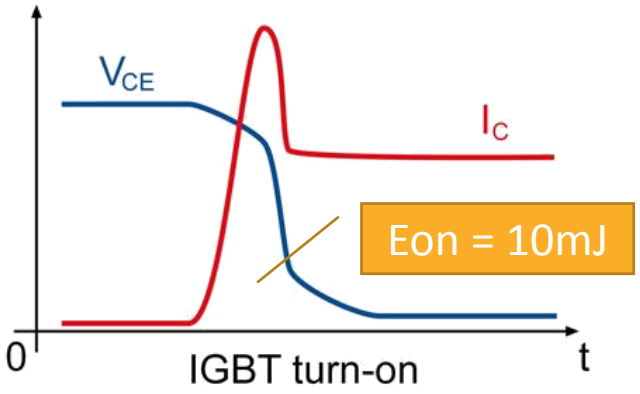


Introduction to IGBT and SiC

Turn On Gate Drive: IGBT



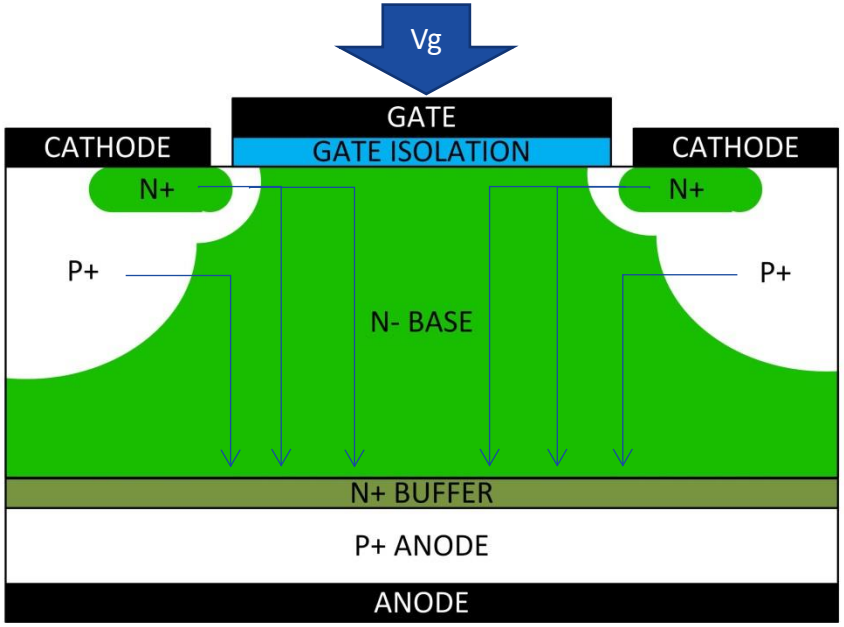
Gate Current at Turn ON



- Switching behaviour determined by gate capacitance
- Threshold +3V approx, but +15 needed for reliability
- Switching speed determined by gate resistor $R_{G(ON)}$ and V_{G+} Voltage

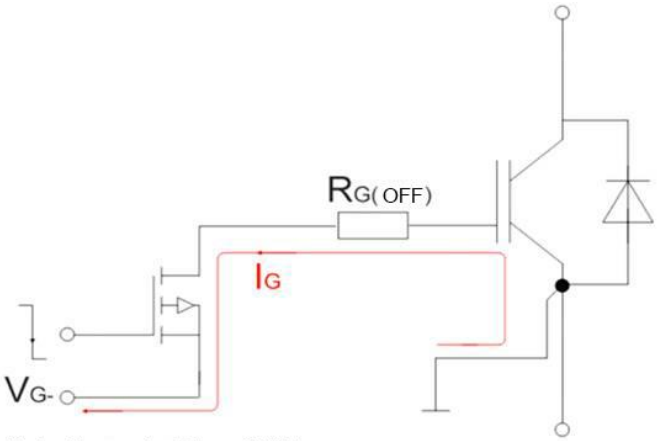
Introduction to IGBT and SiC

IGBT Construction

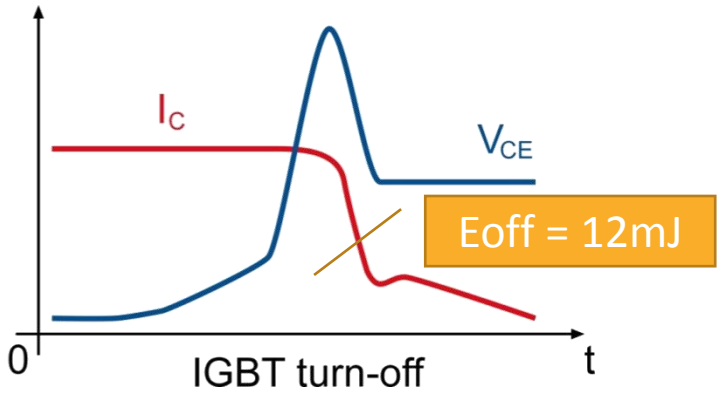


Introduction to IGBT and SiC

Turn Off Gate Drive: IGBT



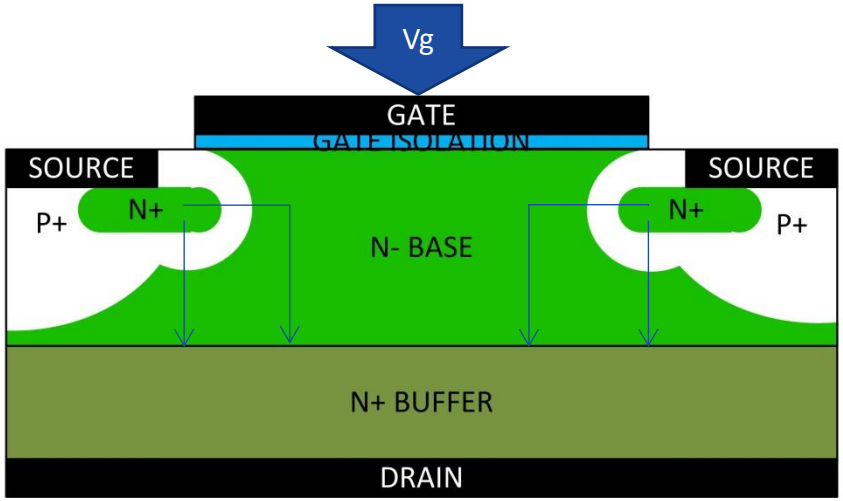
Gate Current at Turn OFF



- Long tail-off (due to recombination time)
- Threshold +3V approx, but -9V needed for speed
- Switching speed determined by gate resistor $R_{G(ON)}$ and V_{G-} Voltage

Introduction to IGBT and SiC

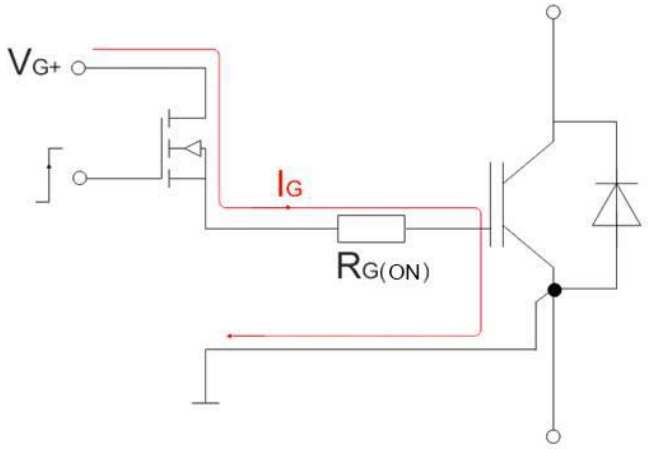
SIC Construction



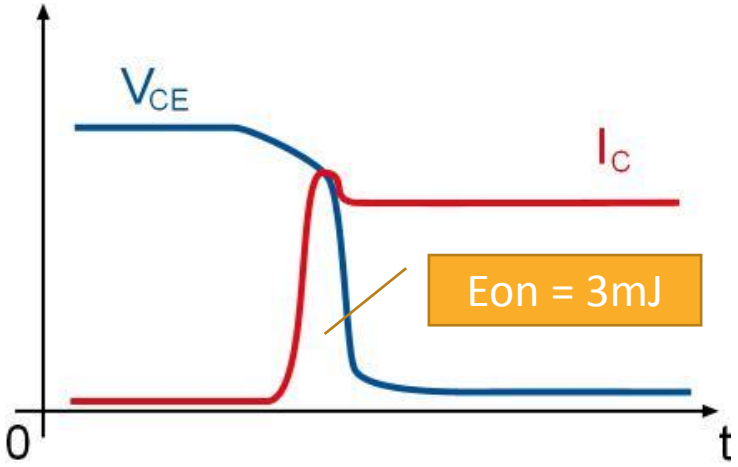
- 10x higher dielectric breakdown than Si (thinner layers = lower resistance)
- 3x better thermal conductivity (higher power rating)

Introduction to IGBT and SiC

Turn On Gate Drive: SIC



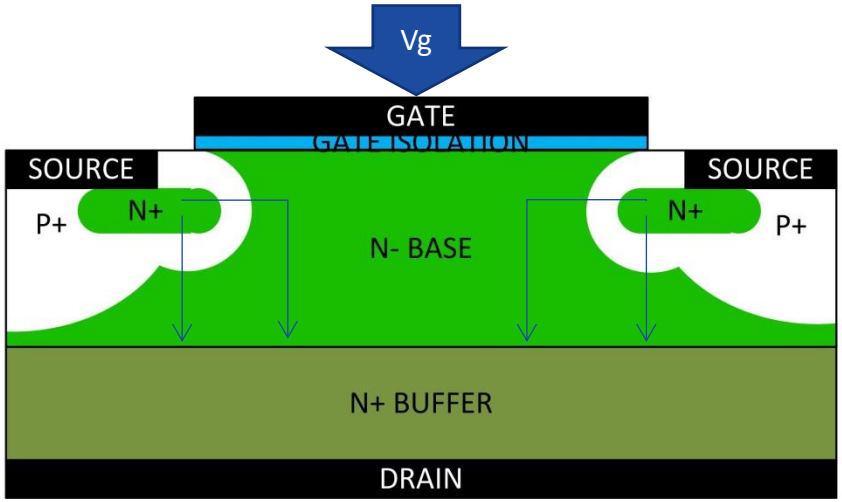
Gate Current at Turn ON



- Significantly lower switching dissipation
- No threshold voltage, but 18-20V needed to switch higher currents
- Switching speed mainly determined by gate resistor $R_{G(ON)}$

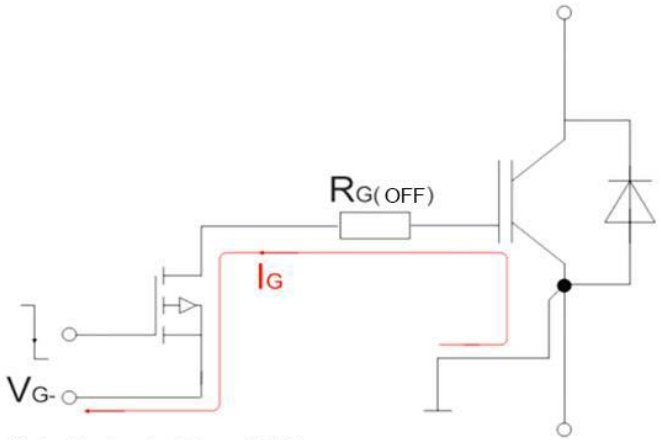
Introduction to IGBT and SiC

SIC Construction

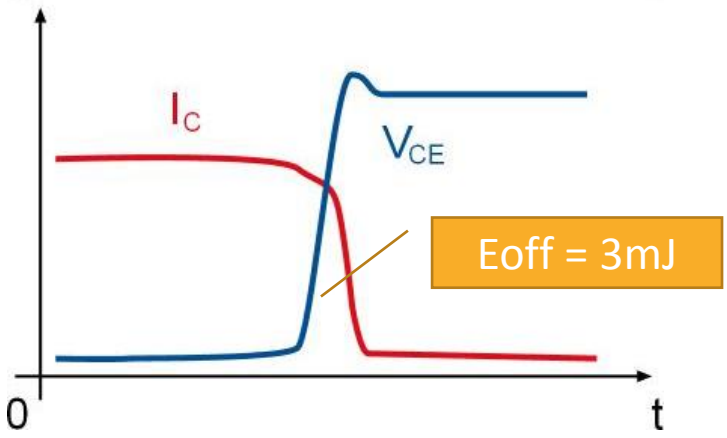


Introduction to IGBT and SiC

Turn Off Gate Drive



Gate Current at Turn OFF

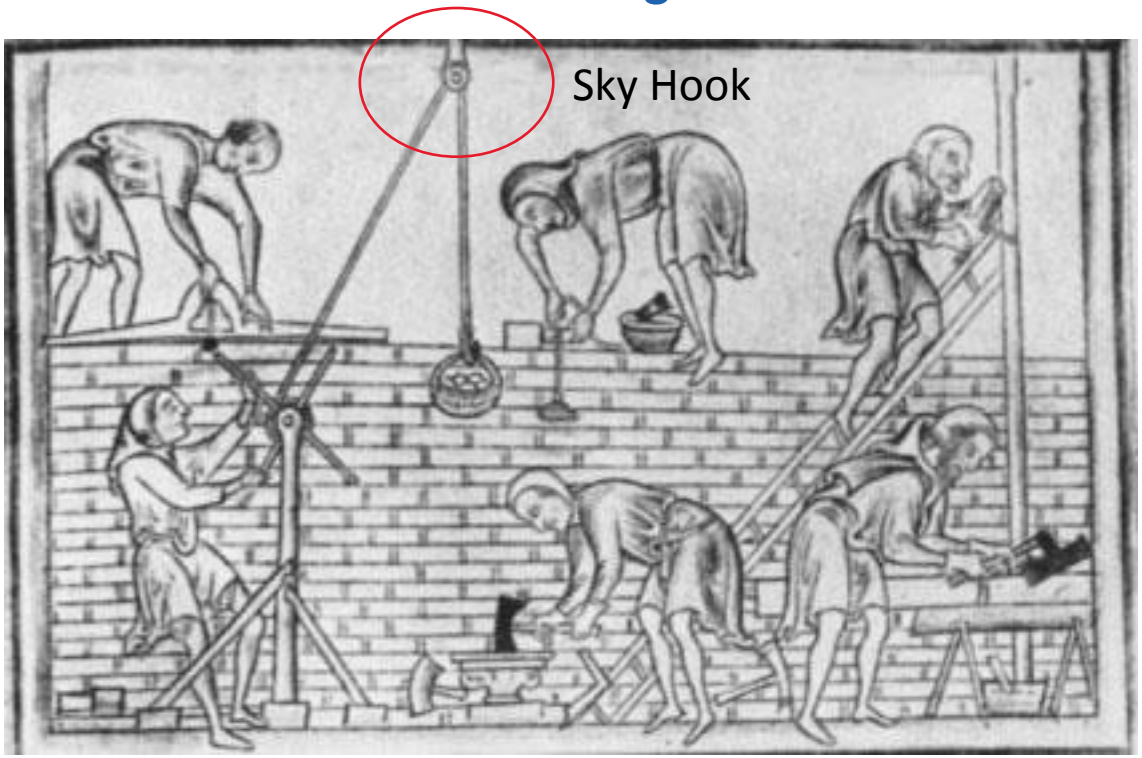


- On and Off switching behaviour very similar (no tail current)
- Threshold 0V, but -5V needed for reliabilty
- Switching speed mainly determined by gate resistor $R_{G(OFF)}$

Introduction to IGBT and SiC

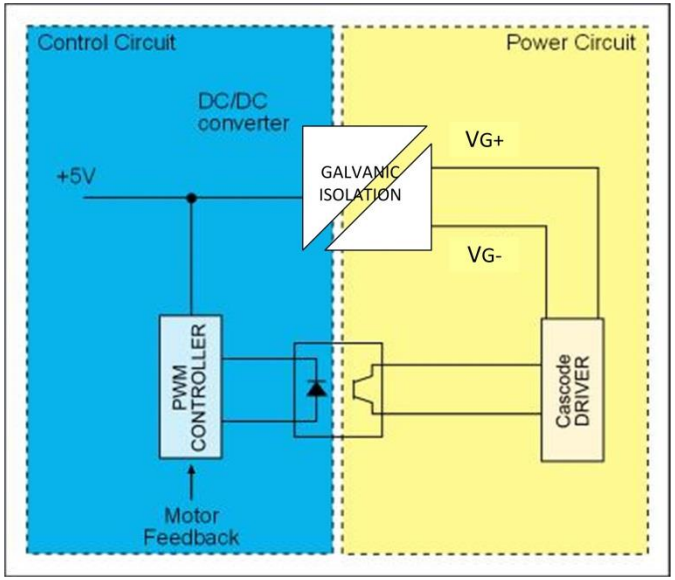
Gate Driver - Where do these voltages come from?

In Mediaeval times, illustrators often drew in a a „skyhook“ rather than explain how things were supported.
The same with some IC manufacturers today!



Introduction to IGBT and SiC

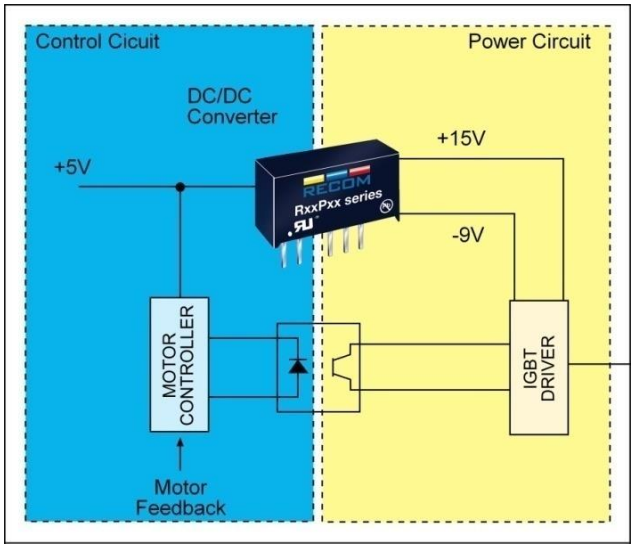
An isolated DC/DC converter is needed to power the gate driver (electronic skyhook):



Choosing the right DC/DC converter

IGBT Gate Driver

Very little power is needed:



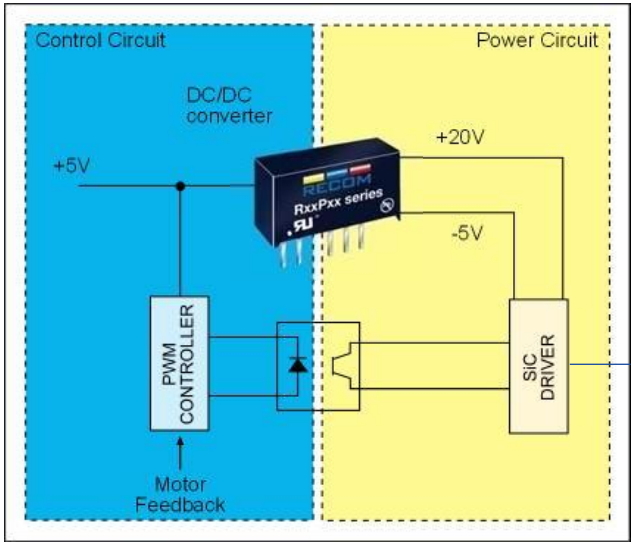
$$P_{gate} = P_{driver} + \left(Q_{gate} f_{sw} \Delta_{V_{gate}}\right) + \left(C_{ge} f_{sw} \Delta_{V_{gate}}{}^{2}\right)$$

$$P_{gate} = 0.5W + 0.4W + 0.1W = 1\text{W} \quad \text{(for 10kHz)}$$

Choosing the right DC/DC converter

SiC Gate Driver

Very little power is needed:



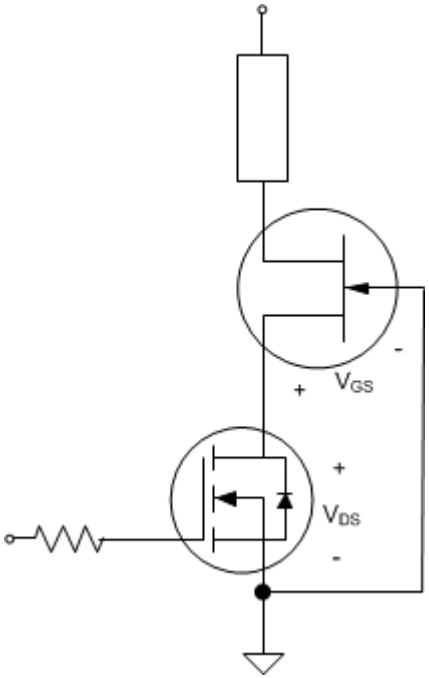
$$P_{gate} = P_{driver} + \left(Q_{gate} f_{sw} \Delta_{V_{gate}}\right) + \left(C_{ge} f_{sw} \Delta_{V_{gate}}{}^{2}\right)$$

$P_{gate} = 0.6 + 0.05 + 0.05 = 0.7\text{W}$ (for 10kHz) e.g. **RxxP2005D**, 1W)
$P_{gate} = 0.8 + 0.25 + 0.25 = 1.9\text{W}$ (for 50kHz) e.g. **RxxP22005D**, 2W)

Choosing the right DC/DC converter

Other Drivers-
SiC/IGBT Cascode

- 30V IGBT controls a 1.2kV SiC JFET
- Threshold voltage around 5V
- Vgs drive = +15V / 0V (single-sided driver)
- Add JFET gate resistor to control di/dt



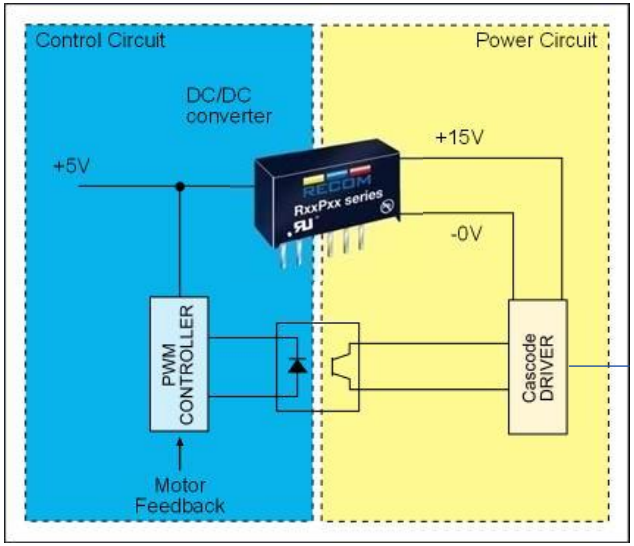
Choosing the right DC/DC converter

Other Drivers – SiC/IGBT Cascode

$$P_{gate} = P_{driver} + \left(Q_{gate} f_{sw} \Delta_{V_{gate}}\right)$$

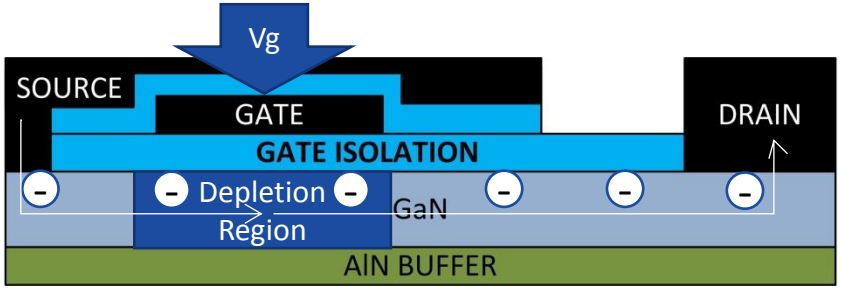
$$P_{gate} = 0.6W + 0.1W = 0.7\text{W} \quad (\text{for } 100\text{kHz})$$

- **Low Power**
- **High Isolation**
- e.g. **R05P15S,** 1W, 6.4kVDC Isolation



Choosing the right DC/DC converter

Other Drivers – Normally off GaN HEMT



- Significantly lower switching dissipation (electron injection)
- Low threshold voltage (typically 1.4V) – Absolute max allowed V_{gate}=6V
- Can be driven with single sided 5V driver

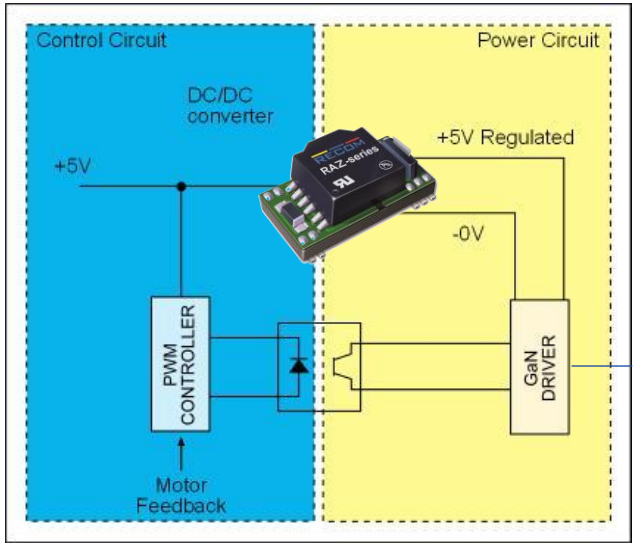
Choosing the right DC/DC converter

Other Drivers – Normally off GaN HEMT

$$P_{gate} = P_{driver} + \left(Q_{gate} f_{sw} \Delta V_{gate}\right)$$

$$P_{gate} = 0.05W + 0.05W = 0.1\text{W} \quad (\text{for } 1\text{MHz})$$

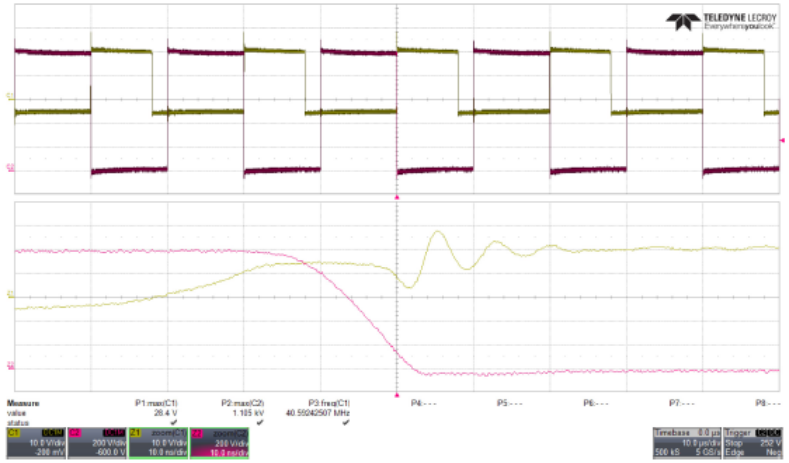
- **Low Power**
- **Regulated output**
- **High Isolation**
- e.g. **RAZ-0505S**, Regulated 1W, 2kVDC



Eval Board Example:
10kW: 100kV/µs slew rate, 50kHz

Lab Notebook Entry from LeCroy DSO
DSO S/N: LCRY2807N59346
User: LeCroyUser
Time: 3/20/2017 3:35:40 PM

sic

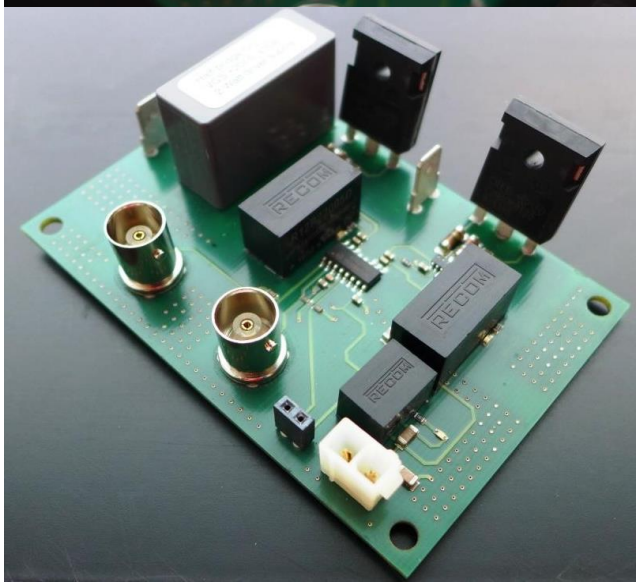


Channel Status

		C1	C2	C3	C4
Vertical	V / Div	10.0 V	200 V	10.0 V	500 mV
	Offset	-200 mV	-600.0 V	-30.00 V	0 mV
	Coupling	DC1MΩ	DC1MΩ	DC1MΩ	DC50Ω
	BW-Limit	1GHZ	1GHZ	1GHZ	1GHZ
	Probe	10	100	1.000000	1.000000
	Sweeps	1 #	1 #	1 #	1 #

Acquisition Status

Horizontal	Time / Div	10.0 µs	Sampling Rate	5.000000000 GS/s
	Time / Pt	200.000 ps	Sampling Mode	RealTime
	Pts / Div	50.0000 kS	Trigger Delay	0.0 µs
Trigger	Mode	Stop	Slope	Negative
	Type	Edge	Level	252 V
	Source	C2	Coupling	DC



Choosing the right DC/DC converter

Examples for IGBT / SiC / GaN converters

High Isolated DC/DC for Medical and Industrial:

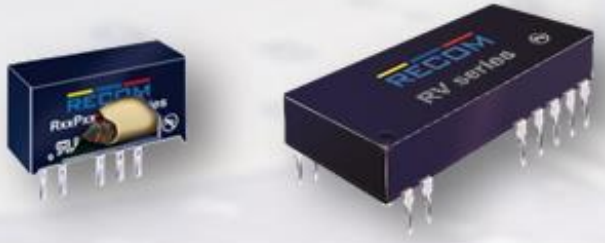
RxxPxx, RxxP2xx, RV, REC3.5, REC6, REM1, REM3, REM6, REM10

- 1W and 2W in SIP7 package / 3W-10W in DIP24
- Re³inforced Isolation construction up to 10kVDC
- REM: 2 MOPP for patient safety 250VACrms, 5kVAC/1min
- REM: Creepage and Clearance ≥ 8mm
- UL60601-1 3rd Ed. Medical approved

High Isolated DC/DC for IGBT/SiC/GaN:

RH, RP, RGZ, RKZ, RV, RxxPxx, RxxP2xx

- asymmetric dual output +15/-9V and +20/-5V and +15/-3V
- high isolation up to 6.4kVDC in SIP7, DIP14 & DIP24
- extremely low isolation capacitance
- efficiency up to 86%



Selection Guide Overview

DC/DC CONVERTERS

IGBT / SiC MOSFET

- Designed for IGBT/SiC driver circuits
- Up to 2 Watts
- Isolation voltages up to 6.4 kVDC
- Different pinout and package style
- Asymmetric output
- High efficiency
- High isolation
- Optional short circuit protection (/P)
- RoHS compliant
- REACH compliant
- EN60950-1 certified
- 3 year warranty

Series	Power (W)	Vin (VDC)	Vout (VDC)	Isolation	Case / Dimensions		Certifications	Other features
 RH-xx1509D	1	5, 12, 24	+15/-9	3 or 4 kVDC/1 sec.	SIP7	19.6 x 10.2 x 7.05 mm (0.8" x 0.4" x 0.3")	EN60950-1	Asymmetrical outputs, designed for isolated IGBT drivers, operating temperature range: -40°C to +90°C, continuous short circuit protection (/P)
 RP-xx1509D	1	5, 12, 24	+15/-9	5.2 kVDC / 1 sec.	SIP7	19.65 x 10.2 x 7.05 mm (0.8" x 0.4" x 0.3")	EN60950-1	Asymmetrical outputs, designed for isolated IGBT drivers, operating temperature range: -40°C to +85°C
 RxxP1509D	1	5, 12, 24	+15/-9	6.4 kVDC / 1 sec.	SIP7	19.5 x 12.5 x 9.8 mm (0.8" x 0.5" x 0.4")	EN60950-1	Asymmetrical outputs, designed for isolated IGBT drivers, operating temperature range: -40°C to +90°C, continuous short circuit protection (/P)
 RGZ-xx1509D	2	5, 12, 24	+15/-9	3 or 4 kVDC/1 sec.	DIP14	19.9 x 10.0 x 7.1 mm (0.8" x 0.4" x 0.3")	EN60950-1	Asymmetrical outputs, designed for isolated IGBT drivers, operating temperature range: -40°C to +90°C, continuous short circuit protection (/P)
 RKZ-xx1509D RKZ-xx2005D	2	5, 12, 24 5, 12, 15, 24	+15/-9 +20/-5	3 or 4 kVDC/1 sec.	SIP7	19.6 x 10.2 x 7.05 mm (0.8" x 0.4" x 0.3")	EN/IEC/UL60950-1 EN55022	Asymmetrical outputs, designed for isolated IGBT/SiC drivers, operating temperature range: -40°C to +100°C, continuous short circuit protection (/P)
new  R15P21503D	2	15	+15/-3	5.2 kVDC / 1 min.	SIP7	19.5 x 12.5 x 9.8 mm (0.8" x 0.5" x 0.4")	EN/IEC/UL60950-1 EN55022	Asymmetrical outputs, designed for isolated SiC drivers, operating temperature range: -40°C to +95°C
 RV-xx1509D	2	5, 12, 24	+15/-9	6 kVDC / 1 sec.	DIP24	32.4 x 14.7 x 11.1 mm (1.3" x 0.6" x 0.4")	EN60950-1	Asymmetrical outputs, designed for isolated IGBT drivers, operating temperature range: -40°C to +90°C
 RxxP21509D RxxP22005D	2	5, 12, 24 5, 12, 15, 24	+15/-9 +20/-5	6.4 kVDC / 1 sec. 5.2 kVDC / 1 min.	SIP7	19.5 x 12.5 x 9.8 mm (0.8" x 0.5" x 0.4")	EN/IEC/UL60950-1 EN55022	Asymmetrical outputs, designed for isolated IGBT/SiC drivers, operating temperature range: -40°C to +95°C, continuous short circuit protection (/P)

This Selection Guide only represents a variety of our most popular products. Please visit www.recom-power.com or contact your local sales rep in case you do not find what you are looking for. 21

DC/DC CONVERTERS

SUMMARY:

- Different switching technologies demand different gate driver voltages.
- The easiest way to power the gate driver is via isolated DC/DC converters.
- There are asymmetric output DC/DC converters that are specifically designed to power gate drivers.
- The DC/DC supply is usually very low power, 2W or less, even if the application is switching many kW.

RECOM

We Power Your Products

Application Support & Tools

- EMC Lab for customer application measurements, EMC Seminars
- Application Notes and 7 white paper documents on the website
  3 special documents about IGBT, SiC and GaN Gate Driver Techn.
- New Product Selection Guide from April 2017
- New 3 rd. Edition of RECOM‘s DC/DC-Book of Knowledge
  (now new with chapter 10 about magnetics and transformers)
- Lots of different sample kits with datasheets directly available
- Use the support of our Top Distributor RUTRONIK from Breda

Thanks a lot for your attention !!

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- Florian Boess, RECOM Electronic, F.Boess@recom-power.com