Welcome to Infineon training!

Technical insights into the circuit design and operation of the 2EP open-loop transformer driver IC

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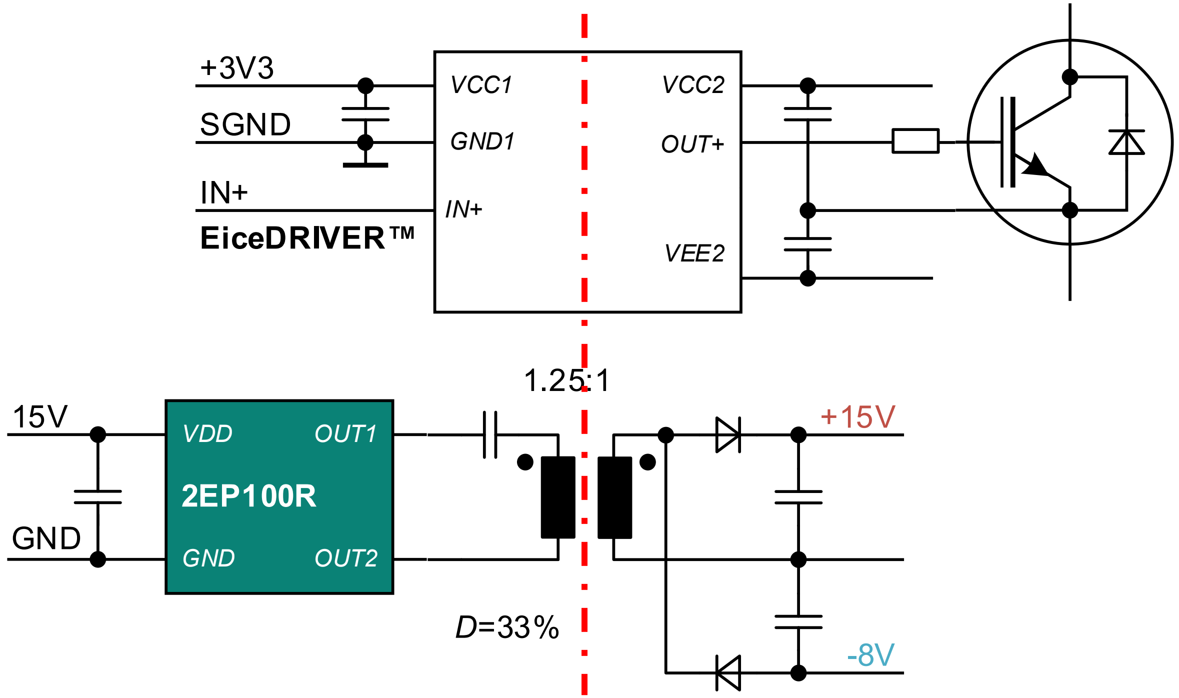
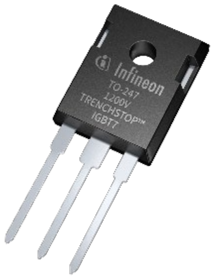
Agenda:

1. Key aspects - why 2EP?
2. Component selection
3. Supply topologies
4. Operational insights
5. Key takeaways + Q&A

Why 2EP?
Complementary function for gate driver and power switch





And every Driver needs a Supply

Every switch needs a Driver …

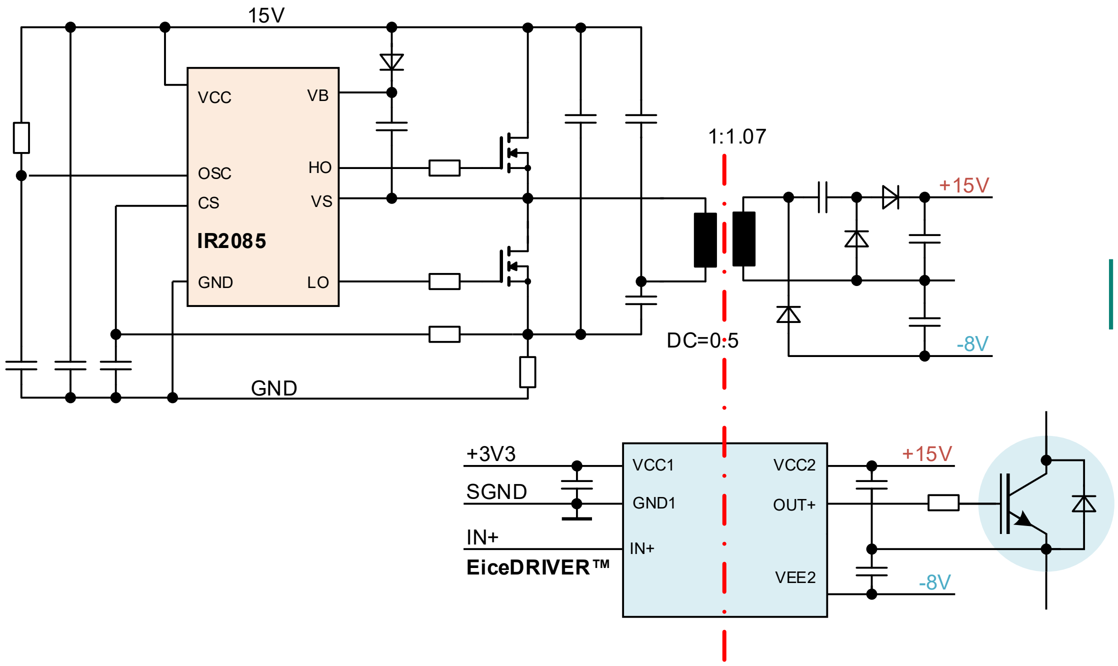
2EP takes supply from the primary side… and drives a transformer to generate isolated supply

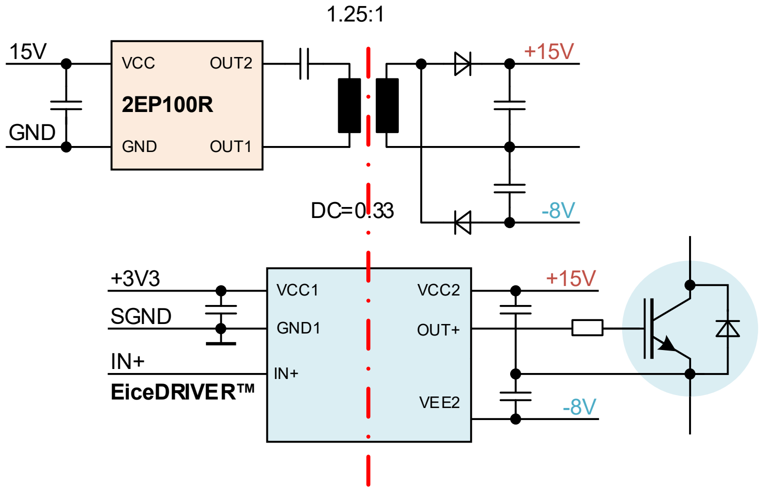
When customers use isolated gate driver ICs, an isolated supply is needed – 2EP provides it

Infineon offers the power switch, gate driver, and 2EP supply together as system solution

EiceDRIVER™ Power 2EP1xxR value proposition

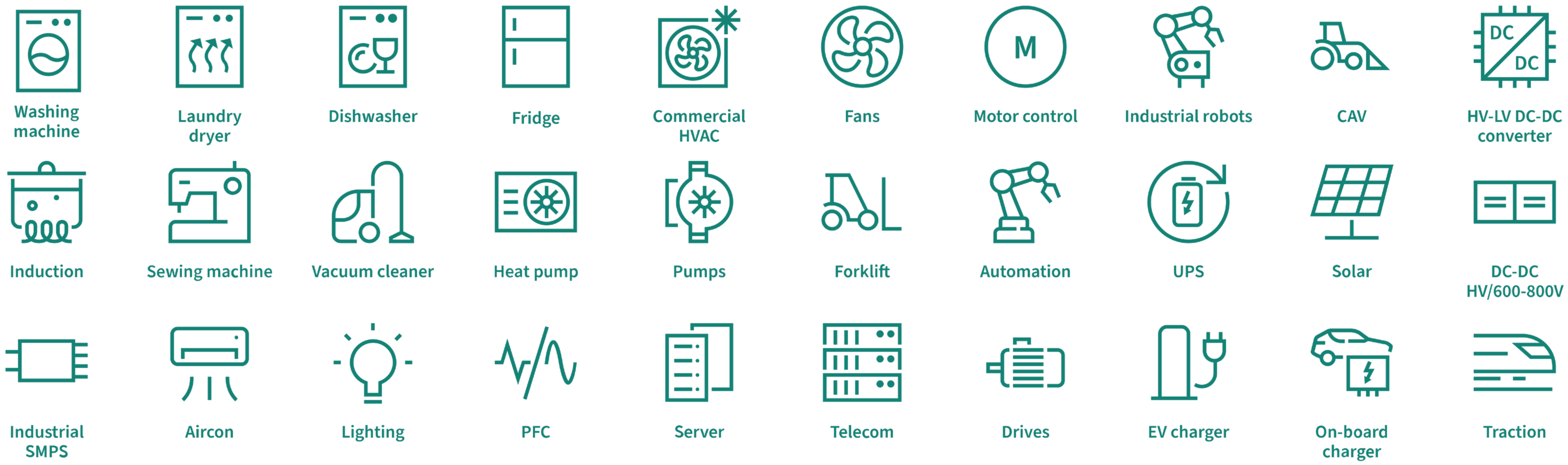
Discrete solution	2EP1xxR solution





- ✓ Significant bill-of-materials reduction
- ✓ Reduction in circuit complexity and area
- ✓ SiC readiness due to asymmetric output voltage
- ✓ Plug and play isolated power supply solution

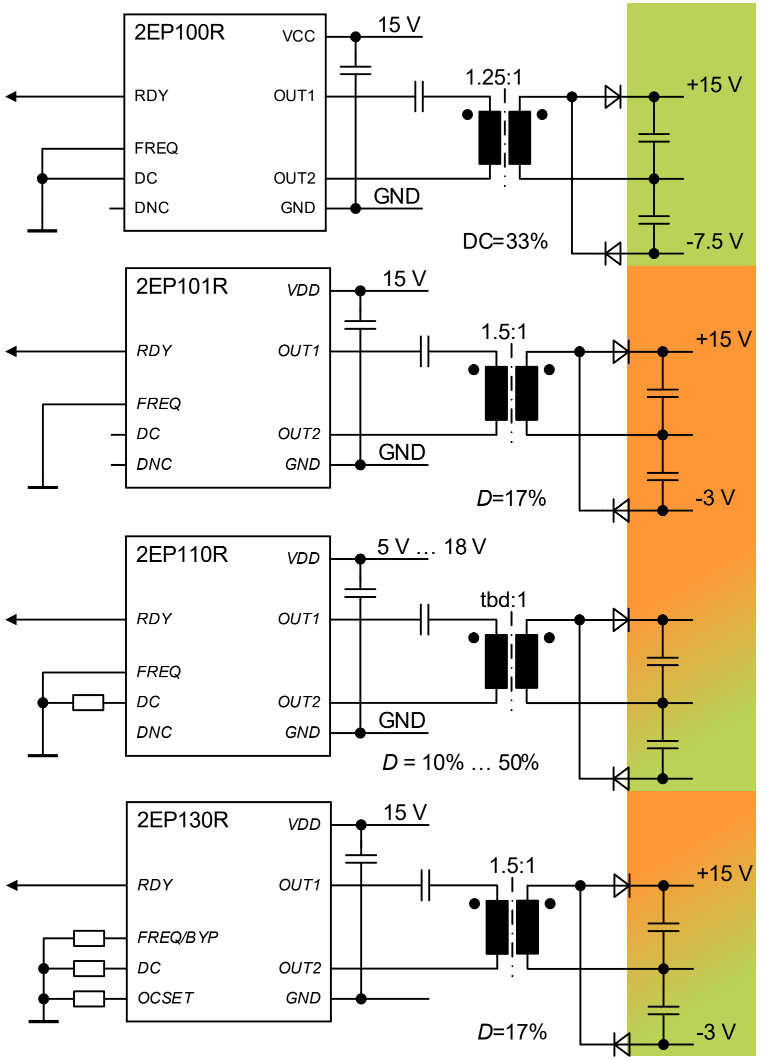
Why 2EP?
We love every application!



- If the application uses an isolated gate driver IC, the 2EP can provide its supply needs
- The questions we need to clarify with the customers are always the same:
  - Which gate voltages does your power switch need? – Impacts input voltage requirements and transfer ratio
  - How much gate driver power is required for the application conditions? – From switching frequency and gate charge in combination with the gate voltage
  - What isolation offset voltage is required? – Influences transformer selection which provides the isolation

Component selection – 2EP full-bridge transformer driver
Product variants vs. gate driver supply targets

PIN	FREQ		DC		OCSET	Application - gate driver supply
	Frequency		Duty cycle		Average OC limit	Examples
connection	GND	floating	GND	floating		
2EP100R	65 kHz	103 kHz	33%	50%	fixed	IGBT +15 V / -7,5 V
2EP101R	50 kHz	65 kHz	12%	17%		SiC MOS +15 V / -2 or -3 V
2EP110R			R adjustable, 41 steps 332R … 63400R 10% … 50%			SiC MOS +15 V / -2 … -5 V
2EP130R Resistive mode	R adjustable, 41 steps 332R … 63400R 50 kHz … 695 kHz				R adjustable, 5 steps 332R … 63400R 10% … 50%	SiC MOS All IGBT
2EP130R Bypass mode	External PWM signal 50 kHz … 695 kHz 10% … 50%		connect to GND			

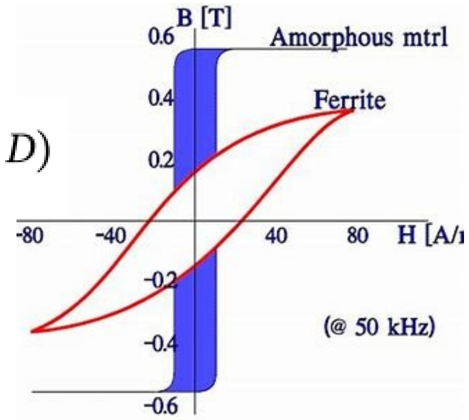


All variants of the 2EP1xxR family are pin compatible, designs for 2EP130R can be used for 2EP110R and 2EP100R by removing resistors or placing zero Ohm jumpers.

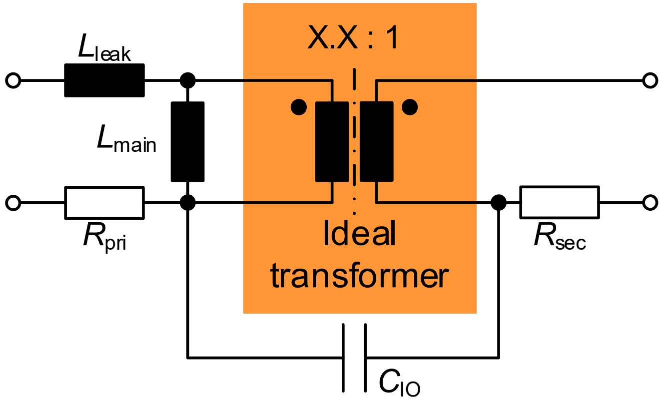
Component selection – Transformer
Key parameters to consider

- All losses have an impact on the open-loop output voltage!
- Voltage-time-product (V^*t): start of core material saturation
  → defines the minimal switching frequency
- Leak inductance (L_{leak}): Impacts losses; $f_{SW} \sim P_{leak}$; $L_{leak} \sim P_{leak}$
  influenced by winding configuration
- Main inductance (L_{main}): Impacts ripple current: $I \sim 1/L_{main}$
  influenced by core material and number of windings; bigger is better
- Winding resistance (R_{pri}, R_{sec}): Impacts losses; $R \sim P_{res}$
  influenced by number of windings and wire diameter; lower is better
- Capacitive coupling (C_{IO}): important for common mode immunity
  influenced by mechanical construction
- Isolation working voltage (V_{IOWM}): important for overall operational usability
  influenced by wire isolation

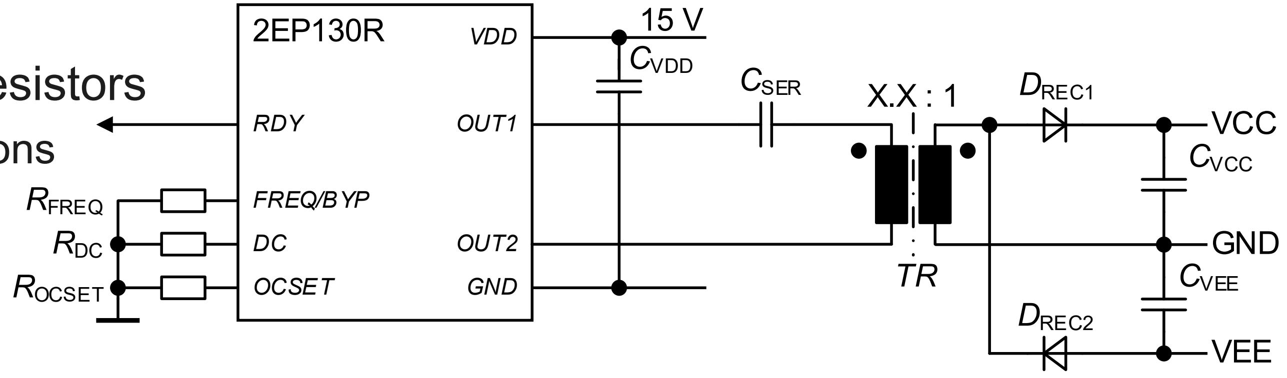
$$(V \cdot t)_{bipolar} = \frac{2 \cdot V_{VDD} \cdot D}{f_{SW}} \cdot (1 - D)$$



https://passive-components.eu/inductors-core-materials-and-their-losses/



Component selection – passives and rectifier diodes
Resistor configuration, voltage ripple



- Resistors: 2EP130R requires up to 3 configuration resistors
  - 41 specific resistor values for discrete configuration options
  - Options for frequency, duty cycle, and overcurrent limits
- Capacitors: low ESR capacitors preferred
  - Series capacitor C_{SER} between *OUT1* and transformer
    offset generator for duty cycle adjust and asymmetric load compensation
    to avoid transformer saturation; limit to 20 µF to ensure proper pre-charge at start-up

$$C_{SER} \geq \frac{I_{OUT}}{TTR \cdot V_{CSER,pp} \cdot f_{SW}}$$

  - Output supply capacitors C_{VCC}, C_{VEE}
    smoothing capacitors for output voltage stabilization

$$C_{Vxx} \geq \frac{I_{OUT} \cdot (1 - D)}{V_{OUT,pp} \cdot f_{SW}}$$

  - Input supply capacitor C_{VDD}
    smoothing capacitor for input voltage stabilization
- Rectifier diodes: low forward voltage drop and low reverse current preferred
  - Also important: reverse voltage rating and peak forward current rating
  - For loss reduction: reverse recovery charge

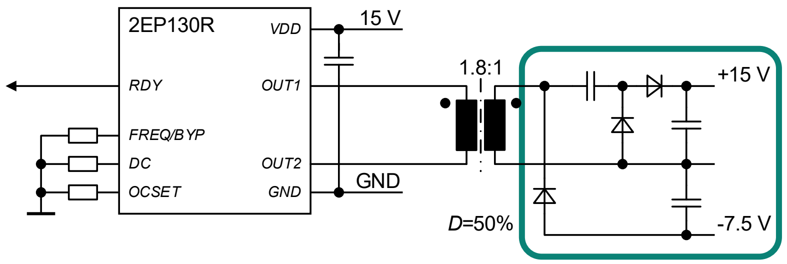
Topology consideration – How to rectify the transformer voltage? Voltage doubler, full bridge or peak rectification

Voltage doubler

- 50% duty cycle
- Low BOM, low area

- Transformer winding ratio gives the output voltage

- Two output voltages with fixed ratio between positive and negative output of 2:1
- Single rail output drives transformer in saturation (asymmetric current)

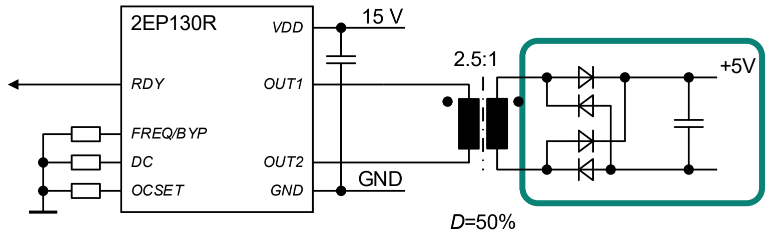


Full bridge rectification

- 50% duty cycle
- Low BOM, low area

- Transformer winding ratio gives the output voltage

- Single output voltage
- Low output ripple



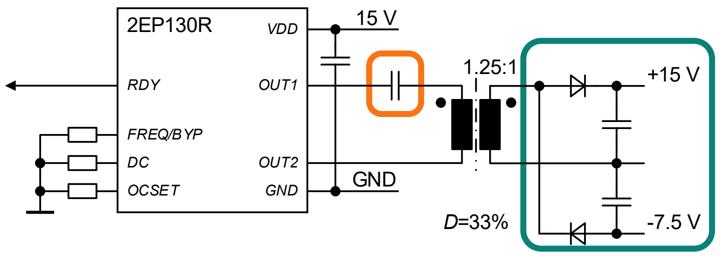
Peak rectification

- Duty cycle adjustable 10%-50%
- Lowest BOM, lowest area

- Transformer winding ratio gives the output voltage

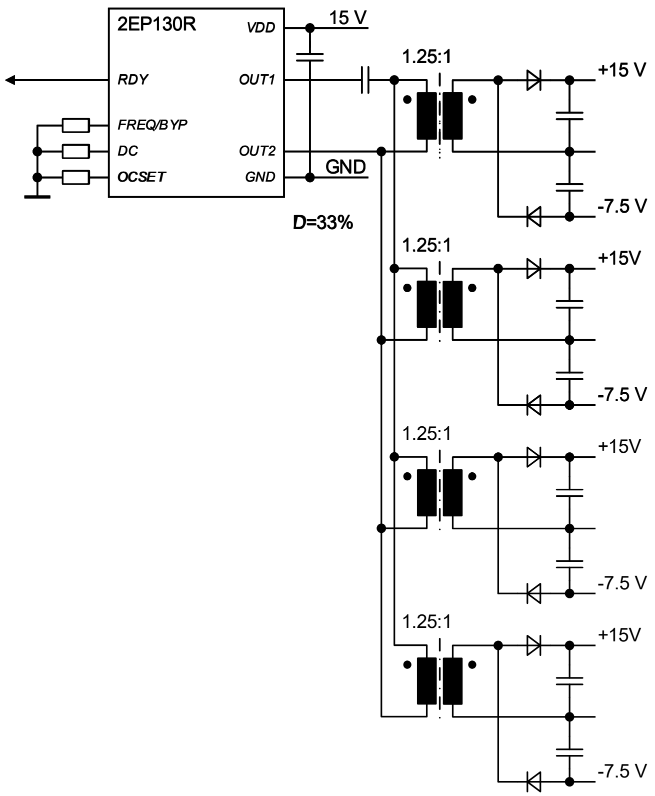
- Two output voltages with ratio between positive and negative output of 1:1 … 9:1
  - Ready for SiC MOS

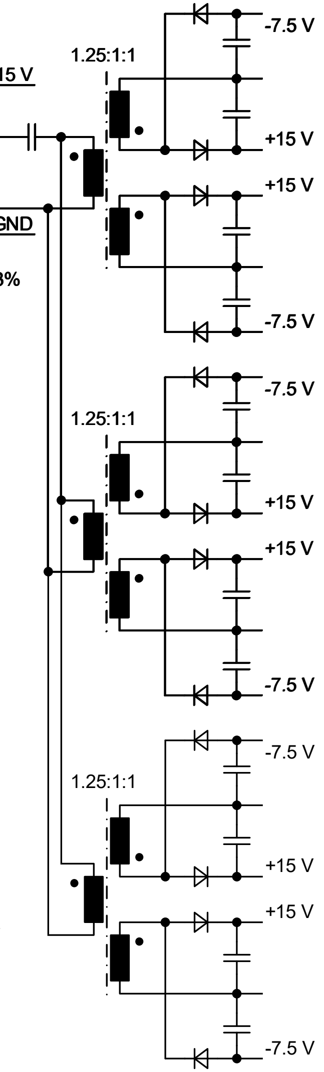
Suggested solution

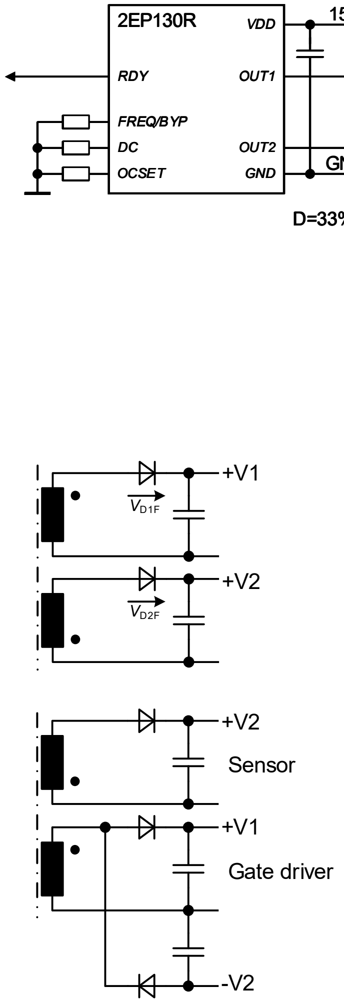


Topology consideration – One 2EP many output voltages? Keeping the overall power requirements in mind

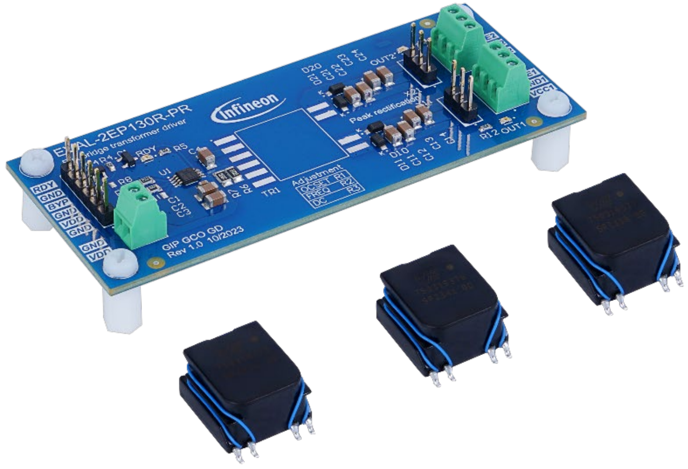
- IC output power up to 13 W (duty cycle and supply voltage dependent)
- Input supply voltage 4.5 … 20 V
- Output current limitation @ 50% of typical
  - 0.585 A (2EP110R)
  - 1.175 A 2EP130R)
- Within the operating range, the 2EP1xxR supports various transformer configuration:
  - Single switch driver supply
  - Supply for power half-bridge
  - Dual switch driver supply
  - Full bridge driver supply as single or dual output
  - B6 bridge driver supply
  - Special cases

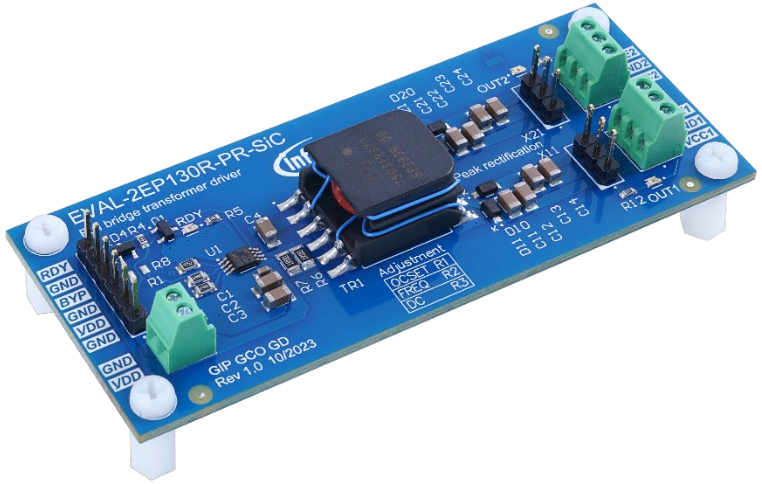


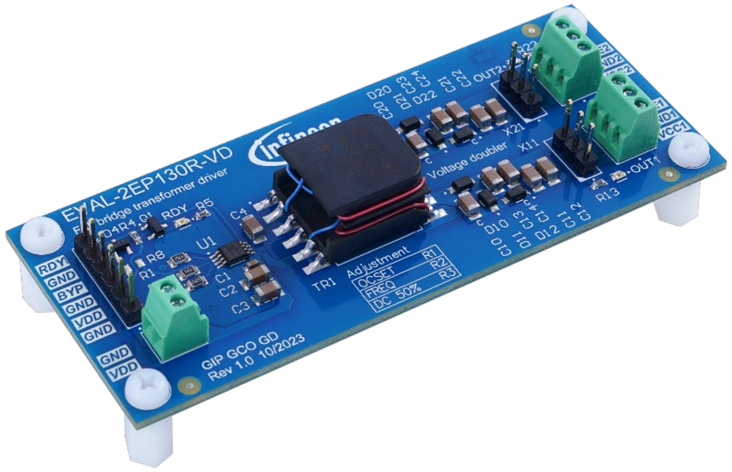




How to evaluate the open-loop transformer driver IC? EiceDRIVER™ 2EP1xxR evaluation boards







EVAL-2EP130R-PR
- Wide supply range
- Peak rectification topology
- Duty cycle e.g., 17%
- TTR 1.25, 1.4, 1.5
- 3 transformer options

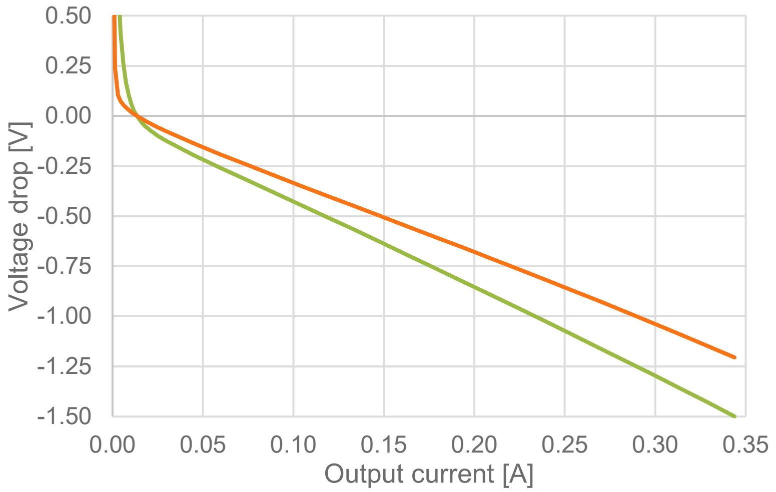
EVAL-2EP130R-PR-SiC
- Typ. SiC MOS supply +18 V / -2.5 V
- Peak rectification topology
- Duty cycle e.g. 17%
- TTR 1.4
- Pre-populated transformer

EVAL-2EP130R-VD
- Typ. IGBT supply +15 V / -7.5 V
- Voltage doubler topology
- Duty cycle 50%
- TTR 1.71
- Pre-populated transformer

Comparing parameter impact in open loop designs
Using a transformer with TTR = 1.25:1

Leakage inductance influence

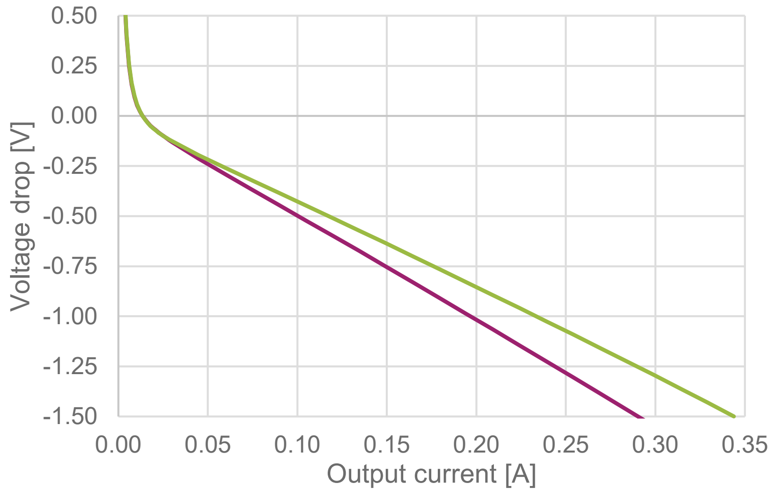
- Leakage inductance
  - 0.17 µH and 1.6 µH
- Switching frequency: 80 kHz
- Series resistance: 0.1 Ω



- lower is better, but keep an eye on startup behavior

Series resistance influence

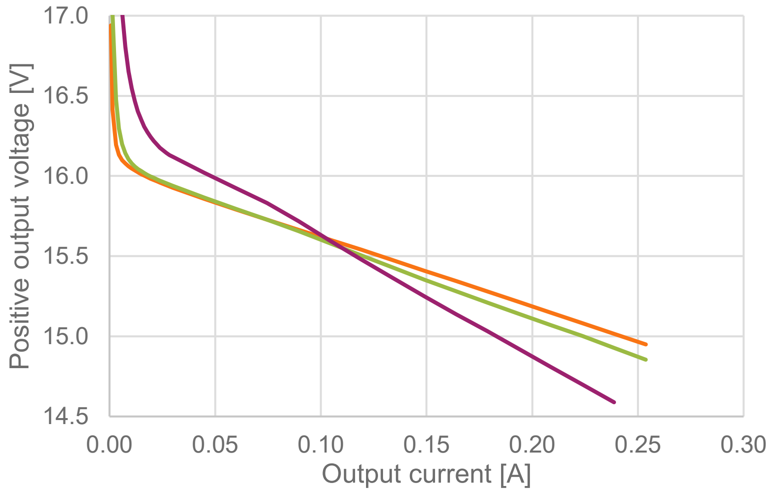
- Leakage inductance 1.6 µH
- Series resistance
  - 0.1 Ω and 0.57 Ω
- Switching frequency: 80 kHz



- lower is better, includes winding resistance

Switching frequency influence

- Leakage inductance 1.6 µH
- Switching frequency
  - 55 kHz, 99 kHz, and 207 kHz
- Series Resistance: 0.1 Ω



- lower is better, but consider (V*t)

BENEFITS OF A GATE DRIVE TRANSFORMER

Galvanic Isolation
Provide galvanic isolation to the gate drive circuit

Power Transfer
Transfer signal and power, removing the need for a bias supply

Negative Gate Bias
Enable easy negative gate bias

Short Propagation Delay
Can enable a short propagation delay

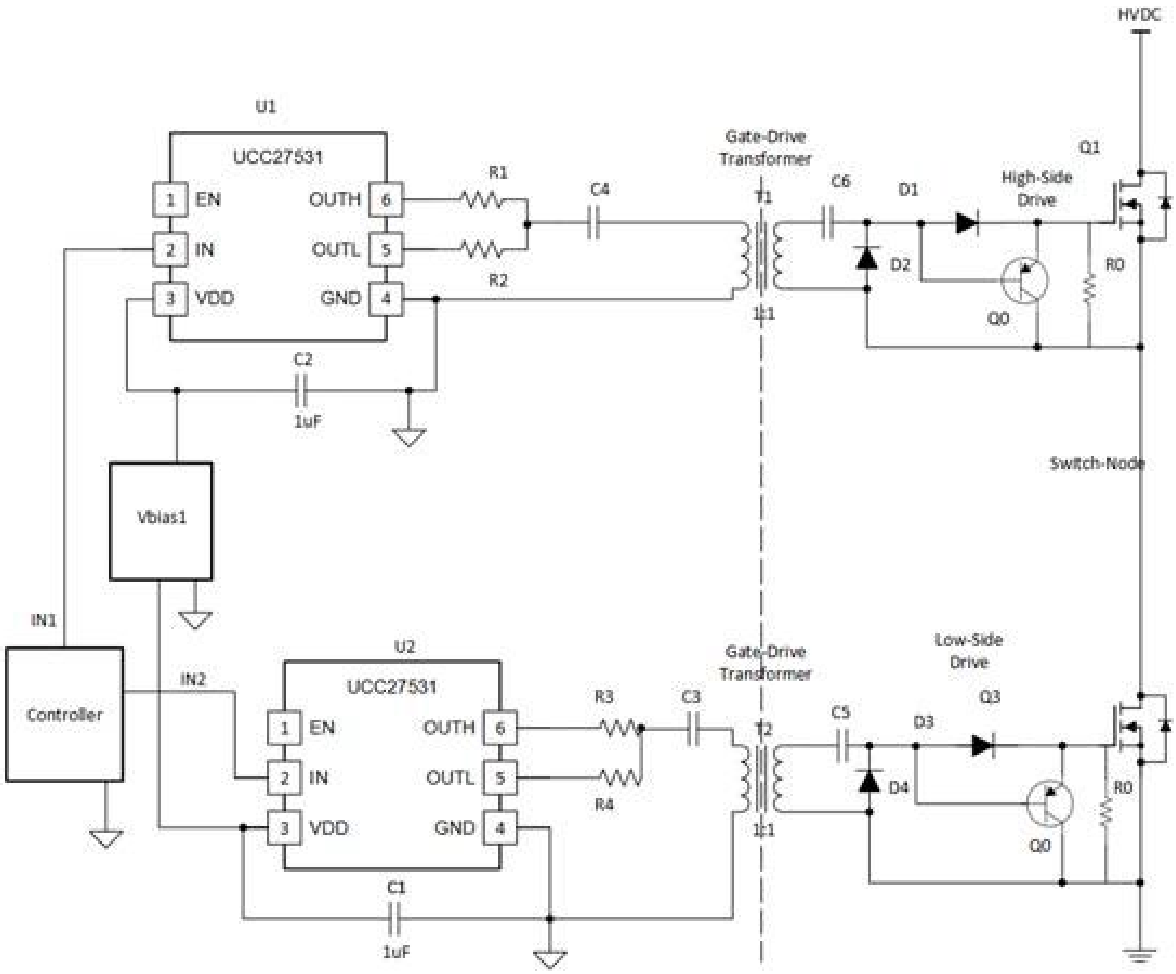
Voltage and Current Scaling
Scale voltage and current based on the turns ratio

SIGNAL VS. POWER GATE DRIVE TRANSFORMERS

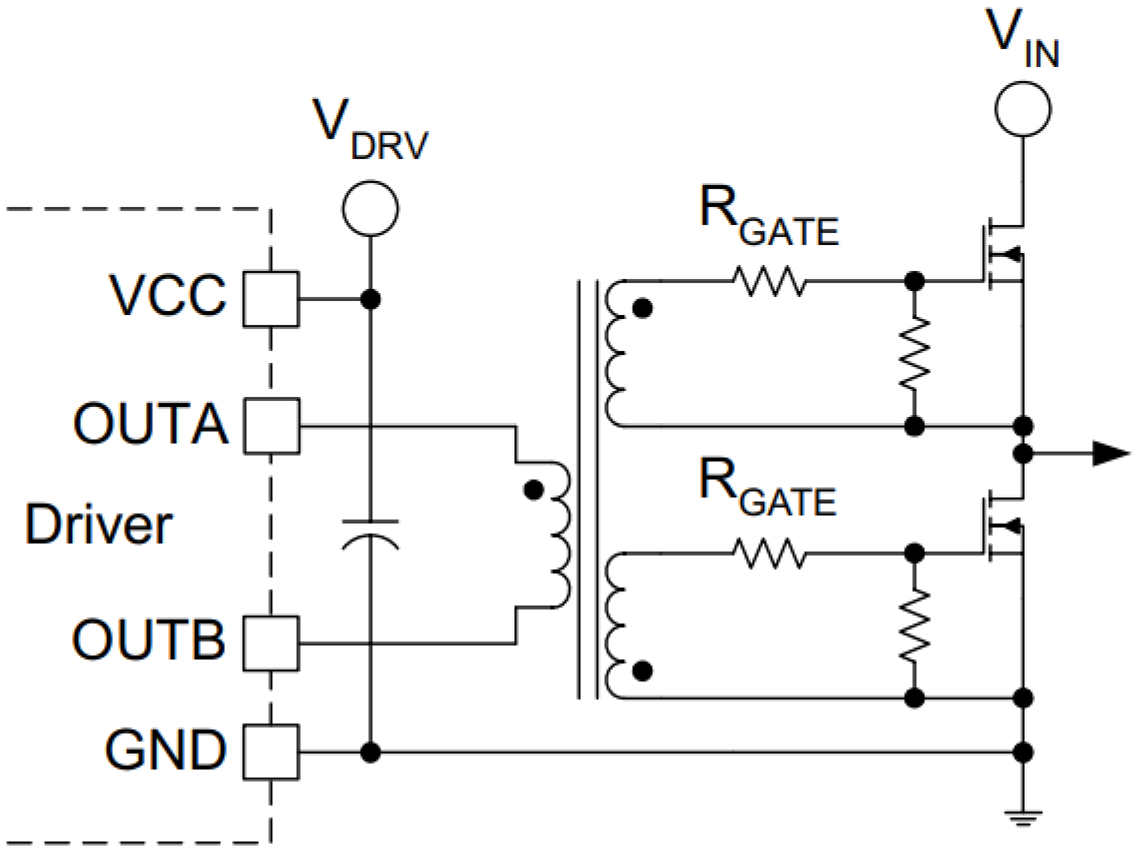
Feature	Signal Transformer	Power Gate Drive Transformer
Purpose	Small-signal transmission (data)	Deliver energy to drive power switches
Power Level	<100 mW	0.5 W – several W
Isolation Voltage	500 V – 3 kV	1 kV – 6 kV+
Core	Usually small ferrite core	Variety of cores depend on the application and targets
Parasitics	Minimized for wide bandwidth	Balanced to manage leakage & capacitance
Critical Parameter	Bandwidth & signal integrity	CMTI, fast gate charge delivery
Main Application	Communication interfaces, isolation	Gate drivers for MOSFETs, IGBTs, SiC, GaN
Typical Concern	Distortion, signal loss	EMI, sufficient energy transfer

TYPICAL GATE DRIVE TRANSFORMER SIGNAL

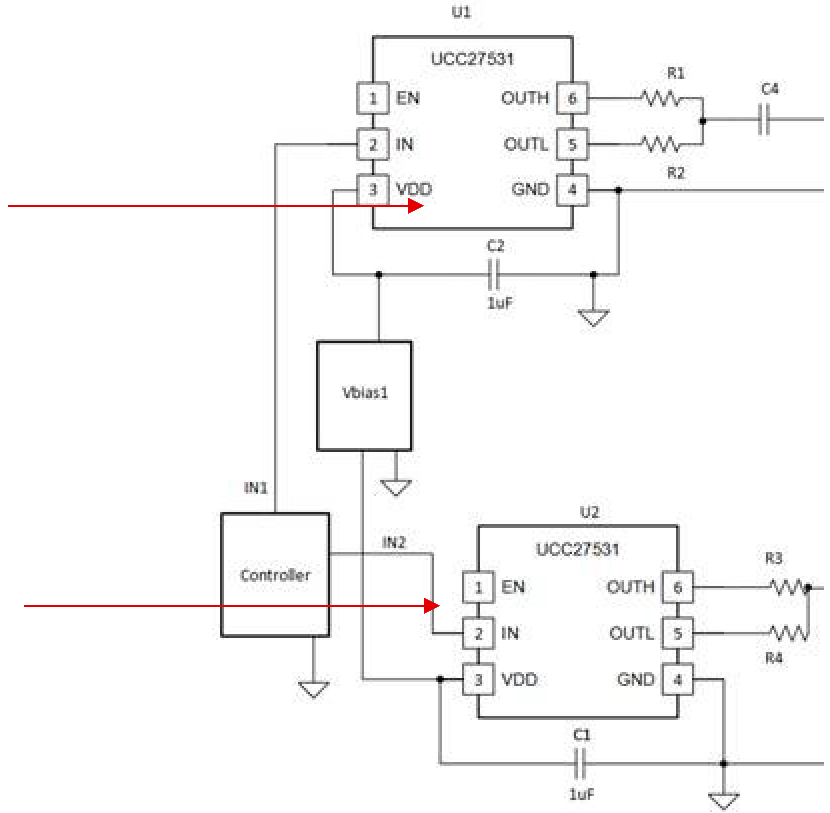
- Isolation requirements
- Volt-Second product
- Turns Ratio
- Leakage inductance
  - Bandwidth BW
- Magnetizing inductance
- Interwinding capacitance

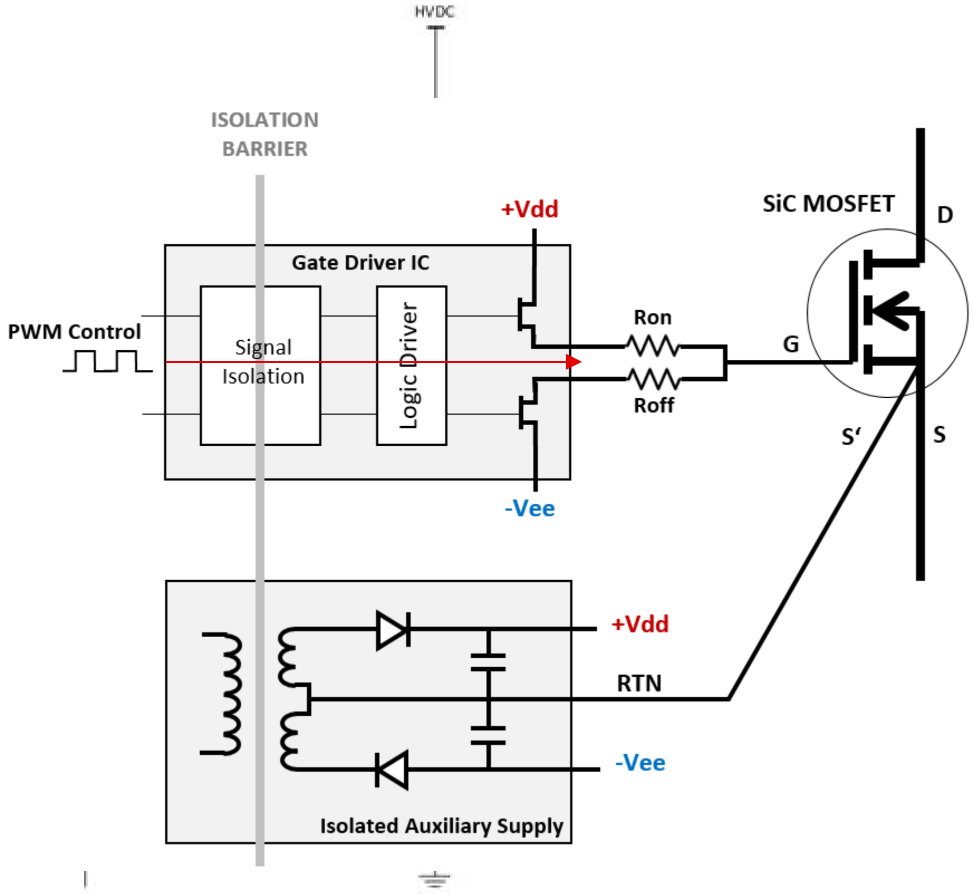


DOUBLE-ENDED TRANSFORMER-COUPLED GATE DRIVES SIGNAL



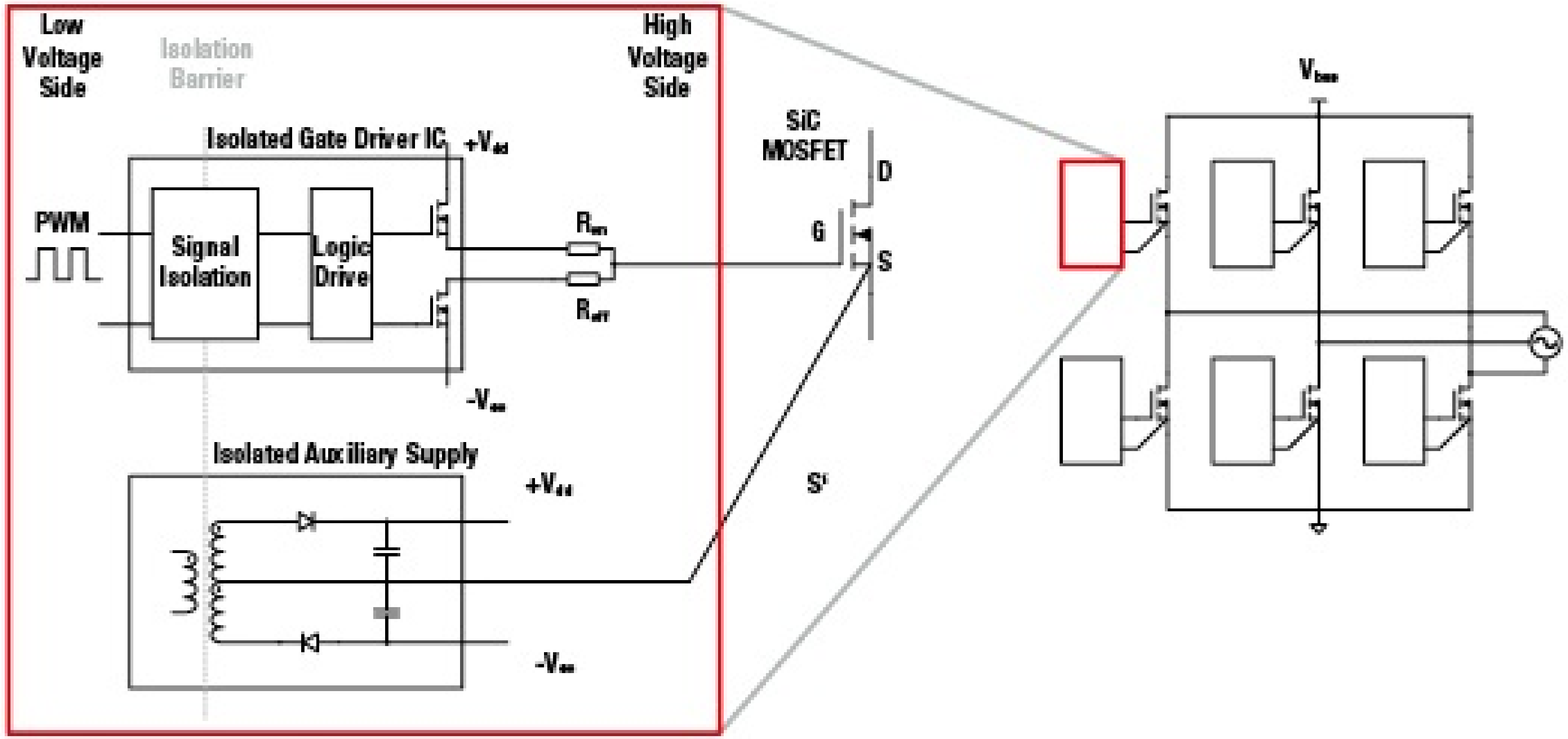
POWER GATE DRIVE TRANSFORMERS





WE-AGDT EXAMPLE OF APPLICATION

- 3-phase SiC Motor Driver



Gate Driver Power Stage

CONSIDERATION BEFORE DESIGNING A GATE DRIVE TRANSFORMER

Leakage Inductance: Minimize for fast switching and to avoid phase shift.

Interwinding Capacitance: Keep low to reduce common-mode noise.

Core Material: High permeability & low loss for high frequency.

Air Gap: Avoid to maintain strong magnetic coupling.

Core Size: Choose appropriate size for single-layer windings.

Winding Placement: Optimize coupling using interleaved techniques.

Core Saturation: Design to avoid flux walk and ensure reset.

Dielectric Isolation: Meet safety standards with suitable materials.

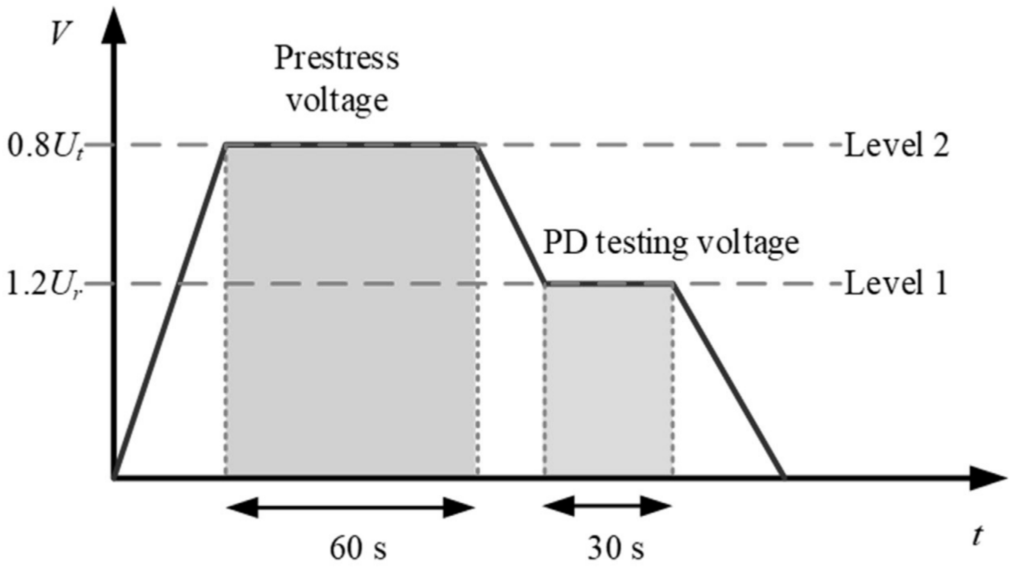
ISOLATION SYSTEM CONSIDERATIONS BEYOND NORMS

Not just creepage and clearance, but **partial discharge requirements** were the real driver.

Usage of high **insulated wires** on primary and secondaries.

Aimed to meet **reinforced insulation** and **long-term reliability**.

It is not just dielectric strength but **partial discharge free** operation under real working voltage.



HIGH-PERFORMANCE SIC GATE DRIVERS: MANAGING EFFICIENCY, SIZE & PARASITICS

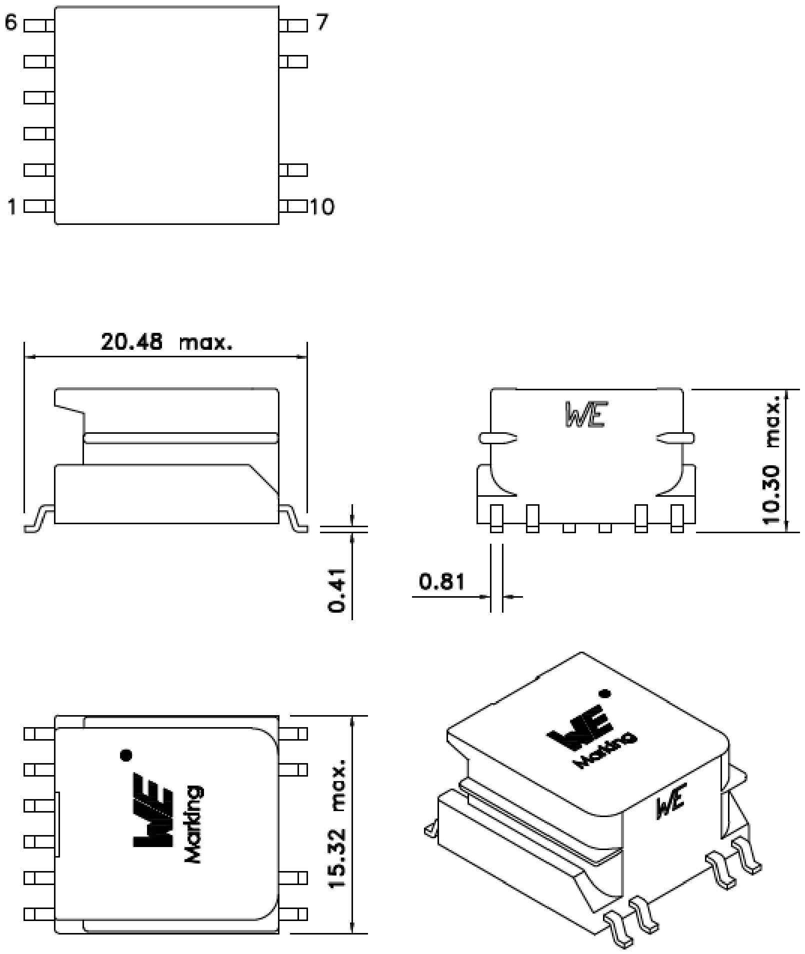
- **Challenges in High-Performance SiC Systems**
- Higher switching speeds → steep edges → capacitive coupling (CP) between HV and LV sides
- Parasitic capacitance causes displacement current:
  IP = CP × ΔU/Δt
- Example: ΔU/Δt = 80 kV/µs & CP = 12 pF ⇒ IP = 0.96 A ≈ 1 A
- Effects:
  - Dielectric stress and insulation degradation
  - Disturbed control signals
  - Common mode currents → EMI issues
  - Risk of unwanted MOSFET turn-on/off

- **Design Recommendations**
- Target CP < 10 pF in auxiliary DC/DC supply
- Compact layout + minimized ESL & ESR
- Output capacitors placed close to SiC Gate Driver
- Use of **Kelvin Source Connection** reduces interference

AGDT-NEW FAMILY SERIES

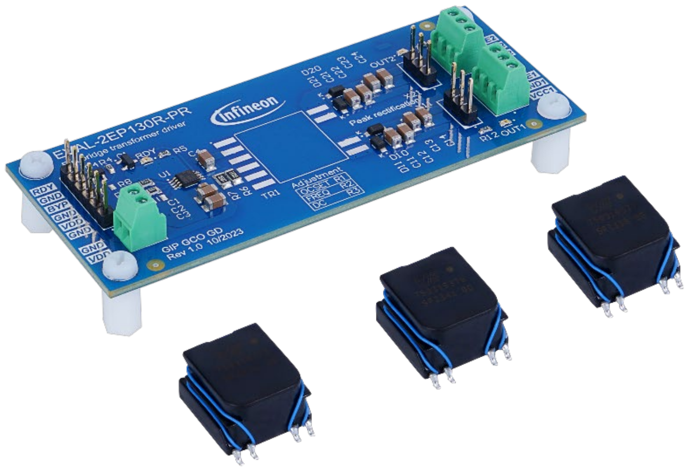
Part Number	Turns Ratio (Np : Ns : Ns)	Typical Primary Inductance (mH)	Typical Leakage Inductance (µH)	Unipolar Volt-Time Product (Vµsec)	Typical Interwinding Capacitance (pF)	IC
750317493	1 : 1.07 : 1.07	1.40	0.40	73	7	IR20855
750318016	1 : 1.07 : 1.07	1.40	0.35	78	6	IR20855
750319374	1. 71 : 1 : 1	1.00	2.28	63	4	2EP130R
750319375	1.25 : 1 : 1	1.10	1.75	52	3	2EP130R
750319376	1.5 : 1 : 1	1.10	1.50	47	2.7	2EP130R
750319377	1.4 : 1 : 1	0.675	1.00	37	1.6	2EP130R

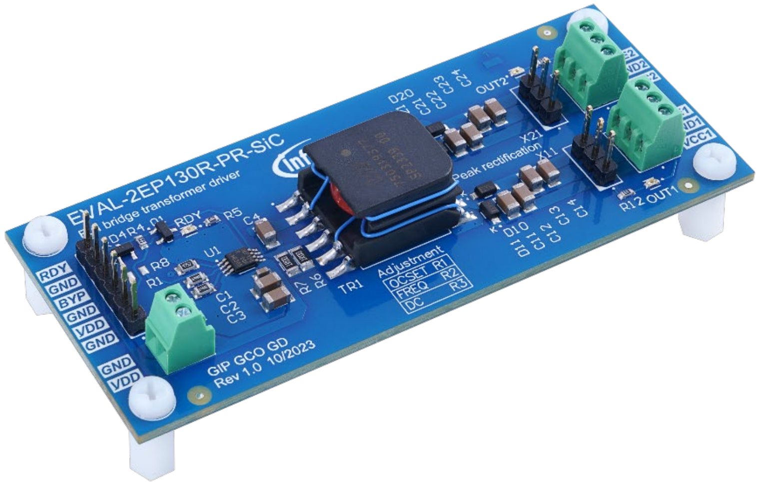
Dimensions: [mm]

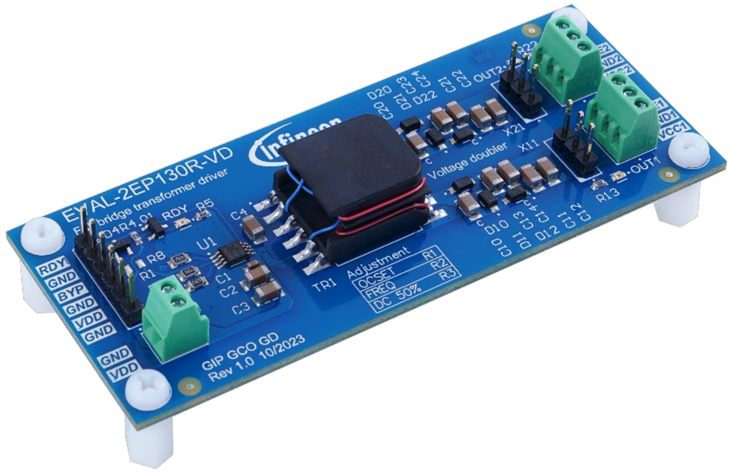


WE-AGDT REINFORCED HV DUAL

- Two isolated outputs with bipolar voltages for each output (example +15V/-7.5V)
- **Reinforced** Isolation per IEC 61800-5-1 and IEC 62368-1
- **15.4mm creepage and clearance** primary to secondary according to IEC 60664-1
- **5.75mm creepage and clearance** secondary to secondary according to IEC 60664-1
- 12kV surge PRI->SEC
- Partial Discharge 1987Vpeak Inception 1590Vpeak Extinction <10pC
- Topologies
  - **Half-Bridge open loop** with fix 50%-50% duty-cycle
    - Controller IC IR20855
    - Multiple reference designs online
  - **Full-Bridge open loop**
    - Controller IC 2EP1xxR
    - Multiple reference designs online







Key take-aways

1
– Isolated gate driver supplies are used in nearly all applications and design depends on power switch operating conditions

2
– Proper component selection is key for open loop gate driver supply designs

3
– 2EP is highly flexible, easy to configure, comes with many protection features, and the lowest BOM per channel

4
– Every Switch needs a Driver…
Every Driver needs a Power Supply!
➔ Infineon has you covered