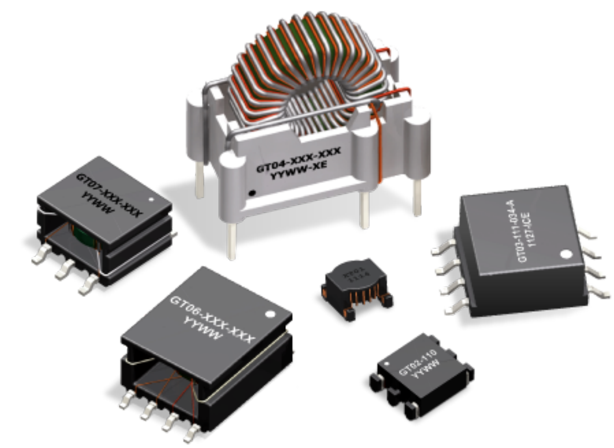
Applying Gate Drive Transformers in Push-Pull Topology as the High-Side and Low-Side Drivers

Application Information



1 Introduction

Gate Drive Transformers (GDTs) provide galvanic isolation, level shifting and common-mode noise immunity between low-voltage control electronics and power semiconductors (MOSFETs, IGBTs, SiC devices). In push-pull gate-drive topologies, a GDT replicates the drive waveform from the primary to one or more isolated secondaries, supporting both high-side (floating) and low-side (ground-referenced) gates.

Careful selection of transformer parameters – including turns ratio, volt-time (ET) rating, leakage inductance, interwinding capacitance, creepage and clearance distances, and insulation system – play a critical role in ensuring reliable switching performance, minimizing dynamic losses, and maintaining electromagnetic compatibility (EMC). ICE Components offers a versatile lineup of surface-mount (SMT) and through-hole (THT) gate drive transformers (GT02, GT03, GT04, GT06, GT07, GT17005, etc.) engineered for reinforced isolation, low leakage inductance, and automotive-grade durability.

2 Push-Pull Topology Overview

Operating Principle:

- A push-pull power topology operates by alternately switching two transistors (or switches) that drive current in opposite directions through a center-tapped transformer, efficiently transferring energy to the load while utilizing both halves of the transformer core.
- The GDT replicates the control IC signal from the primary to the secondary winding(s) while maintaining isolation.
- High-side drive delivers the gate signal to a floating reference; low-side drive delivers it to a ground-referenced device.

Key Advantages:

- Eliminates complex high-side driver ICs with bootstrap circuits.
- Provides excellent common-mode noise rejection.
- Enables high-speed signal transfer with low propagation delay.
- Can meet reinforced isolation requirements with appropriately rated windings and creepage.

3 High-Side vs Low-Side Drive Requirements

Similarities:

- Low leakage inductance is essential for fast gate transitions, reduced switching losses, and EMI control.
- Configurable turns ratios (e.g., 1:1, 1:1.5) support direct or level-shifted gate voltages for MOSFETs, IGBTs, and SiC devices.
- ET rating must meet gate timing demands
- Hi-Pot rating should exceed regulatory requirements.
- Maintain layout spacing to preserve isolation and minimize capacitive coupling.

High-Side Drive:

- May require extended creepage and clearance to meet reinforced isolation standards. The exact requirements depend on your safety system classification.

Low-Side Drive:

- Creepage and clearance may be less stringent. However, if both transformers share a common driver IC and safety isolation boundary (e.g., between control electronics and the power stage), then both may need similar creepage.

4 Design Considerations

Voltage-Time (ET) Product:

Avoid core saturation by selecting a GDT with a volt-second (ET) rating greater than the applied primary volt-seconds.

$$ET = \frac{E_P}{2f} \quad \textbf{or} \quad ET = E_P \cdot T_{ON}$$

Where: $\boldsymbol{E_P}$ = Drive voltage; $\boldsymbol{T_{ON}}$ = On-time per cycle; $\boldsymbol{f}$ = Operating frequency.

Turns Ratio:

Defines the relationship between primary and secondary voltages.

$$E_S = \frac{E_P \cdot N_S}{N_P}$$

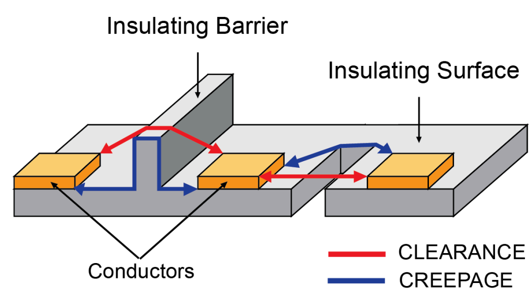
Where: $\boldsymbol{E_S}$ = Gate voltage; $\boldsymbol{E_P}$ = Drive voltage; $\boldsymbol{N_S}$ = Secondary Turns; $\boldsymbol{N_P}$ = Primary Turns.

Practical Guidelines:

- 1:1 is common for MOSFET gates (e.g., primary drive ±10–15 V → secondary ±10–15 V).
- Ratios >1:1 step the V_G up (e.g., 1:1.5 to raise a 15 V primary to ≈22.5 V secondary) when needed for particular devices.

Creepage and Clearance:

Creepage is the shortest path along an insulating surface between conductors, while clearance is the shortest distance through air between them.



Typical guideline ranges (system dependent):

- **Si MOSFET**s: ~3–6 mm creepage
- **IGBTs**: ~6–8 mm creepage
- **SiC MOSFETs**: ~8–12 mm creepage

Example: ICE's GT06 family with 12.5 mm creepage supports reinforced isolation in demanding environments.

5 GDT Suitability

Selecting an appropriate GDT requires consideration of the target switching device. The following guidelines outline GDT suitability across different device types.

- **Si MOSFETs**: $V_G \approx +10–12$ V; low gate charge (Q_G); high switching frequency – very suitable for GDTs.

- **IGBTs**: $V_G \approx +15$ V (on), −5 to −15 V (off); high gate charge; lower switching speed – possible with large ET and energy handling.

- **SiC MOSFETs**: $V_G \approx +18–20$ V (on), −3 to −5 V (off); moderate gate charge; very fast switching – feasible but demanding; leakage, overshoot and ET margin critical; isolated IC drivers are often preferred.

6 Example Application

Specifications:

- Input: 400 V_{DC}
- Output: ±15 V_{DC}
- Gate Drive Voltage: 12V
- Power Rating: 200 W
- Switching Frequency: 200 kHz
- Switches: N-channel (Si) MOSFETs

Implementation:

For a push-pull topology, each switch conducts for half the switching period.

$$t_{ON} = \frac{1}{2f} = \frac{1}{2(200{,}000)} = 2.5\mu s$$

So the required ET to fully enhance the MOSFET gate is ET = 12 V x 2.5 μs = **30.0 V·μs.**

Part Recommendations:

- **Gate Drive Transformer** – **GT06 Series** (High-Side and Low-Side)

  This GDT family is suitable for both high-side and low-side drive in systems requiring reinforced isolation and high dv/dt immunity. Select a variant with:

  - Turns ratio: 1:1 for direct ±12 V gate coupling
  - ET ≥ 49 V·μs (includes margin for tolerances and transients)
  - Creepage ≥ 12.5 mm
  - Hi-pot rating: 3750 VAC

- **Action Items and Selection Checklist**
  - Confirm primary driver amplitude E_P and compute required secondary E_S using $E_S = E_P \times (N_S/N_P)$.
  - Verify ET ≥ $E_P \times t_{ON}$ (example: 12 V × 2.5 μs = 30.0 V·μs) including margin for tolerances and transients.
  - Check leakage inductance, tested gate transition with chosen switching device and gate resistor, and EMI impact.
  - Confirm creepage, clearance, and hi-pot meet system isolation requirements (example: using GT06 for reinforced isolation).
  - If a standard part does not meet turns ratio or ET needs, you may **request a custom GDT** from ICE Components.

7 Conclusion

Selecting GDTs with the appropriate ET rating, turns ratio, leakage inductance, and creepage distance ensures reliable, efficient operation across a range of switching devices — including Si MOSFETs, IGBTs, and SiC MOSFETs. While GaN HEMTs typically require IC-based isolated drivers due to their low voltage tolerance and ultra-fast switching, transformer-based solutions remain highly effective for most silicon and wide-bandgap applications.

ICE Components' GT06 (reinforced isolation, higher ET, larger creepage) and GT02 (compact, low-profile) families are proven starting points for push-pull gate-drive implementations; please verify ET and turns ratio for your exact gate energy and switching frequency and **contact ICE Components** for custom windings if needed.

For more details about our GDTs, please visit:
https://www.icecomponents.com/product-category/transformers/gate-drive-transformers/

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