Gate Driver Selection

1. Component Selection and Switching Performance

Using the IXGH24N60C4D1 as the switching element and TLP250 as gate driver is appropriate based on a thorough consideration of project requirements, especially regarding high-speed transitions and establishing effective electrical isolation. The choice of TLP250 as a gate driver is based on its capacity for providing a maximum current of 1.5 A, which is essential for charging the gate capacitance of an IGBT for fast transition time.

2. Mathematical Verification of Switching Speed

For compatibility between the driver and the switch, the mathematical estimation for the switching time can be deduced using the following relationship, considering the IGBT total gate charge Qg of 64 nC:

$$t_{switch} = \frac{Q_g}{I_{peak}} = \frac{64 \times 10^{-9}\ \mathrm{C}}{1.5\ \mathrm{A}} \approx 42.6\ \mathrm{ns}$$

This charging time is essentially instantaneous compared to our 2 kHz switching period of 500 µs (T = 1/fs), so the switching losses will be very small, and the signal fidelity will be very high.

3. Optimization of Gate Drive Voltage

The requirement for the 15V gate drive voltage is based on the IGBT characteristic curves. According to the specification for the device, the value of V_{CE}(sat) is significantly lowered to only a typical value of 2.28V when the value for V_{GE} is set to 15V. This is because for a lower value, the device is operating at a more resistant region of the curve; the conduction losses might go up to the maximum power dissipation level (Pc) of 190W. With the constant supply of 15V using the TLP250 device, the IGBT will be held in the fully saturated "ON" region, and this will reduce the losses.

4. Isolation Strategy and Grounding Conflict Resolution

An isolated DC–DC converter is required to power the gate driver in order to resolve the grounding conflict inherent in the Buck topology. The emitter of the high-side IGBT forms a floating switching node that rapidly transitions between the rectified high-voltage rail and the power-stage ground. Without isolation, directly referencing this node to the Arduino ground would introduce severe common-mode noise and likely destroy the microcontroller. The use of the isolated DC-DC helps in introducing a "floating" 15 V supply rail that synchronizes with the Emitter. Additionally, it also retains 2500 Vrms galvanic insulation to prevent destruction of control circuits.

5. Frequency Selection and Inductive Load Compatibility

At last, to meet the requirement for a higher frequency of the current ripple of 1 kHz in this project, the 2 kHz switching frequency was chosen. Switching time of only 42.6 ns makes the chosen IGBT (IXGH24N60C4D1) very efficient in handling this switching frequency.

Conclusion

The chosen IGBT (IXGH24N60C4D1) and gate driver (TLP250) offer high-speed and reliable switching performance while keeping losses low with the chosen operating frequency of 2 kHz. The constant supply voltage of 15 V facilitates full saturation of the IGBT. The use of the isolated DC-DC converter provides floating supply voltages referenced to the emitter of the IGBT and correspondingly solves the grounding conflict of high-side converters and high dv/dt of high-side converters.