Bootstrap Gate Driver Design for High-Side MOSFETs

Nithishwaran S
Dept of Electronics and Communication Engineering
Sri Eshwar College of Engineering

ABSTRACT

The bootstrap gate driver circuit is a widely used technique to drive high-side N-channel MOSFETs in half-bridge and full-bridge power conversion topologies. By employing a bootstrap capacitor, diode, and complementary low-side switch, this circuit efficiently generates the higher gate drive voltage needed for the high-side transistor, which references a floating switch node rather than ground. The bootstrap capacitor charges when the low-side MOSFET is ON and supplies energy to the high-side MOSFET gate during its ON state, enabling proper switching at high frequencies without requiring an isolated gate driver power supply. Optimal component selection, including the bootstrap capacitor sizing and deadtime control in PWM signals, is critical to ensuring robust operation and minimizing switching losses. The circuit provides a cost-effective, compact, and reliable solution for high-side MOSFET control in power electronics applications.

Keywords : Bootstrap gate driver, Bootstrap capacitor, Half-bridge Topology,Bootstrap gate driver, eSim

INTRODUCTION:

The bootstrap gate driver circuit is used to drive high-side N-channel MOSFETs that require gate voltages higher than the supply voltage. It employs a bootstrap capacitor and diode to generate the necessary gate drive voltage referenced to the switch node. This method enables efficient and cost-effective high-side switching in half-bridge and full-bridge power converters. Proper component selection and timing control are critical to ensuring reliable circuit operation.

PURPOSE:

The purpose of the circuit is to drive a high-side N-channel MOSFET by providing a gate voltage higher than the source voltage using a bootstrap technique. It uses a bootstrap capacitor and diode to charge and store energy during low-side switching, enabling proper turn-on of the high-side MOSFET. This allows efficient switching in half-bridge configurations by ensuring the high-side device receives the necessary gate voltage for full enhancement. The circuit also incorporates timing control to prevent shoot-through and ensure reliable operation.

WORKING PRINCIPLE:

The working principle of the bootstrap gate driver circuit is based on creating a floating gate drive voltage for a high-side N-channel MOSFET. When the low-side MOSFET is turned on, the switching node is pulled to ground, allowing the bootstrap capacitor to charge through the bootstrap diode from the supply voltage. This stored charge on the capacitor then provides a voltage higher than the source voltage of the high-side MOSFET during its turn-on period. By applying this boosted voltage to the gate relative to the MOSFET source, the high-side MOSFET is fully enhanced and switched on. When the high-side MOSFET turns off and the low-side MOSFET turns on, the capacitor recharges, repeating the cycle continuously. This mechanism enables efficient high-side switching in half-bridge or full-bridge topological.

CIRCUIT DIAGRAM:

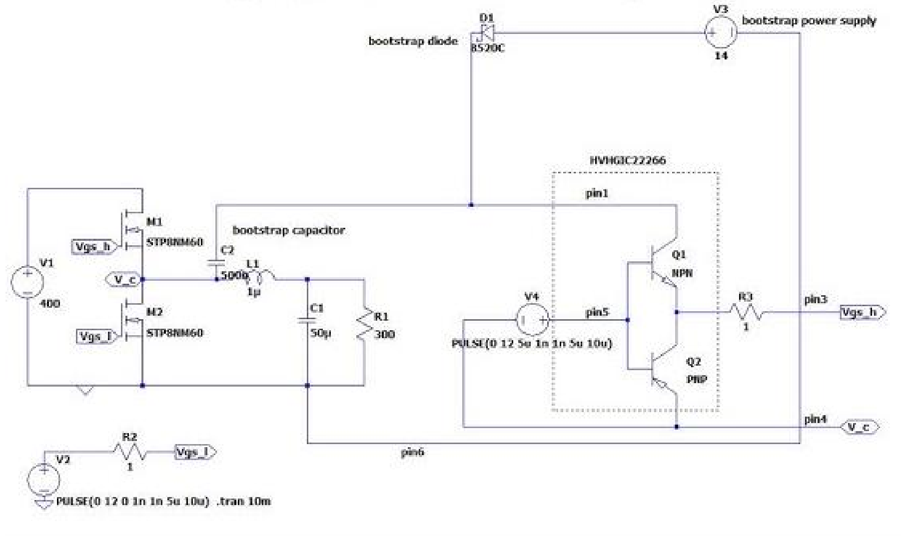

Fig 1: Circuit Diagram

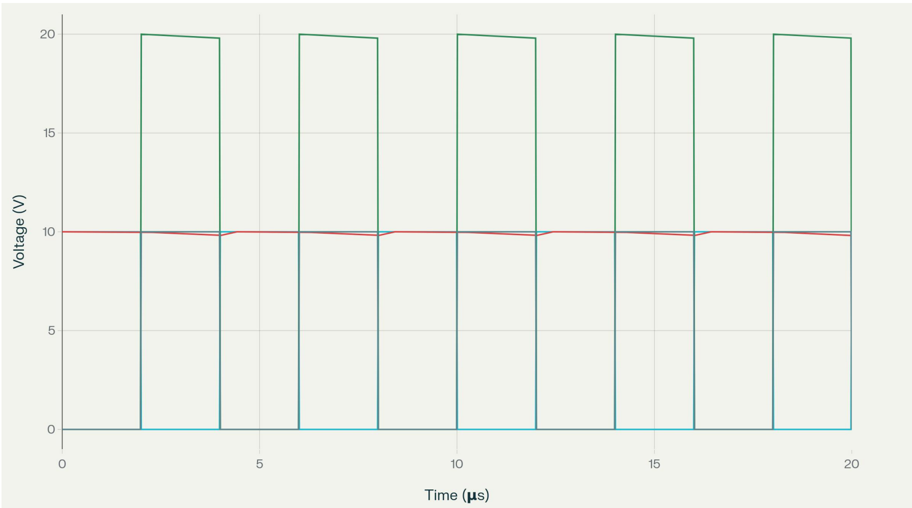

Fig 2: Expected Output

This circuit is a bootstrap gate driver setup designed to control a high-side N-channel MOSFET in switching applications. The bootstrap diode and capacitor store energy from the supply, which is used to raise the gate voltage of the high-side MOSFET above the source potential for proper operation. Complementary PWM signals ensure the switching sequence, while this section acts as the gate driver, delivering the appropriate voltage pulses. This topology allows efficient high-side switching using low-cost, non-isolated components

PROPOSED SYSTEM:

The proposed system is a ‘bootstrap-based high-side MOSFET gate driver’ designed for efficient and reliable switching in power electronics applications. It uses a bootstrap capacitor and diode to generate the elevated gate drive voltage required by the high-side N-channel MOSFET, referencing the floating switch node instead of ground. Complementary PWM signals control the switching of low-side and high-side MOSFETs, ensuring proper energy transfer and preventing shoot-through. This system offers a cost-effective, simple, and compact solution for driving high-side MOSFETs in circuits like half-bridge converters, motor drives, and DC-DC converters, enabling high-frequency operation with minimal component count and complexity.

eSim Circuit:

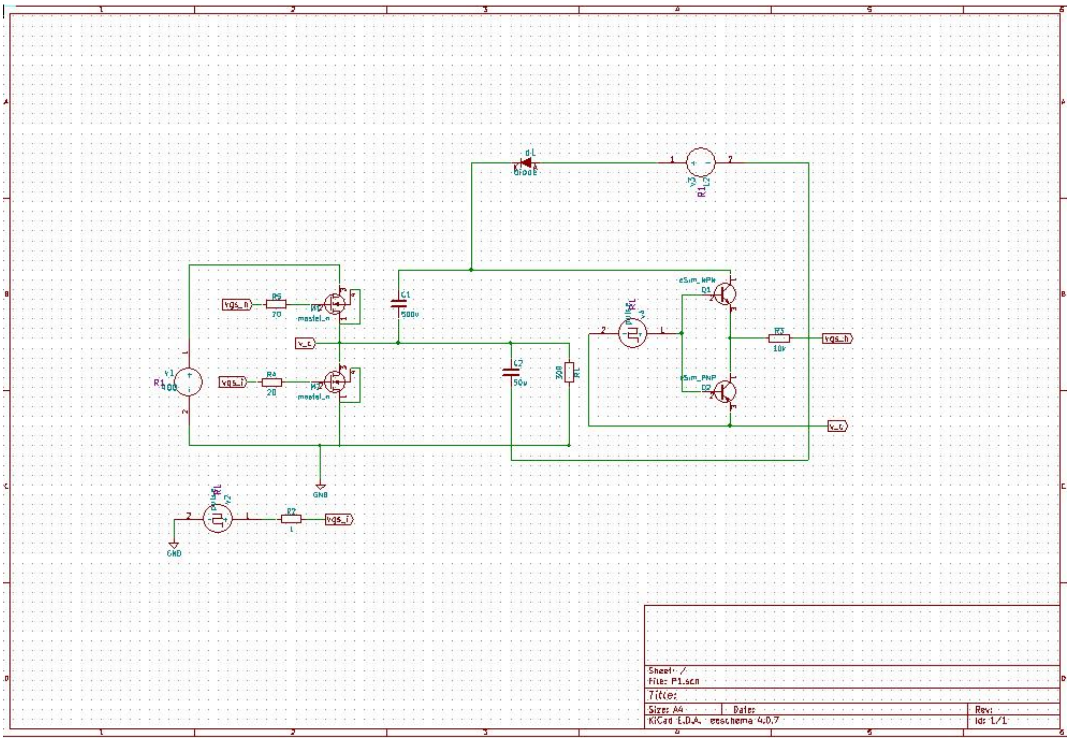

Fig 3: Booststrap Driver in eSim Software

OUTPUT WAVEFORM:

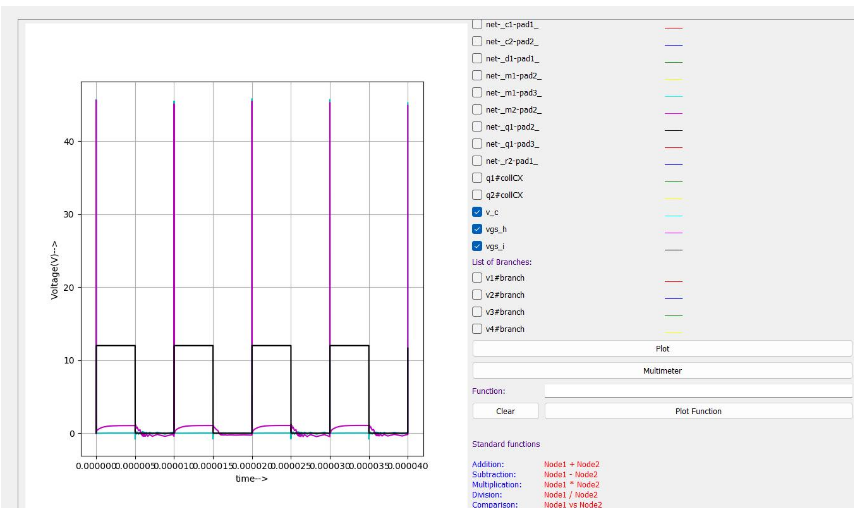

Fig 4 : Output waveform (Python plot)

The bootstrap gate driver circuit operates by using a bootstrap capacitor and diode to generate the elevated gate voltage required for the high-side N-channel MOSFET. When the low-side MOSFET is turned on, the switch node is pulled to ground, allowing the bootstrap capacitor to charge through the bootstrap diode from the supply voltage. Once the low-side MOSFET turns off and the high-side MOSFET is switched on, the bootstrap capacitor provides the necessary gate drive voltage referenced to the switch node, which can be higher than the supply voltage itself. This technique enables efficient high-side switching in half-bridge and full-bridge circuits without requiring an isolated power supply, making it a cost-effective and widely used solution in power electronics.

CONCLUSION :

The proposed bootstrap gate driver circuit offers a simple, efficient, and cost-effective solution for driving high-side N-channel MOSFETs used in power electronic applications. By utilizing a bootstrap capacitor and diode, the circuit generates the elevated gate voltage needed for proper MOSFET operation referenced to the floating switch node. This design supports high-frequency switching while minimizing component count and eliminating the need for isolated power supplies. Overall, it enhances switching performance, reduces losses, and enables compact system implementation in half-bridge and full-bridge converters.

REFERNCES :

1. IEEE Transactions on Power Electronics, "High-Side Bootstrap Circuit Design and Application," 2018
2. Kumar, A., & Ghosh, R. S. (2020). A review of bootstrap gate drivers for MOSFETs. International Journal of Electronics and Communication Engineering
3. Singh, M., & Verma, S. (2021). Optimization of Bootstrap Circuit Parameters for Efficient High-Side MOSFET Driving. IEEE Access, 9, 127845-127854.