EB206

Solving Noise Problems in High Power, High Frequency Control IC Driven Power Stages

Prepared by: Larry Baxter

INTRODUCTION

The MPIC2113 (high & low side driver) Control IC is one of a family of Motorola devices which provides a convenient and cost effective gate drive solution. The electrical design using the MPIC2113 is simple as it accepts ground–referenced logic level input signals and drives high & low side MOSFET or IGBT power transistors with an offset voltage of up to 500 V. All that is required is one MPIC2113 and a few external components.

However, switching high current at high speed is not without difficulties. This Design Tip was written to elaborate on some of the more subtle aspects which must be taken into account when designing such circuits. The design effort should be shifted from the circuit to the layout. Optimizing the layout requires minimizing stray inductances which most affect the operation of the circuit. Stray inductances in the main current path can store a significant amount of energy and at turn–off of the switching device, the following problems may occur:

- High voltage spikes
- Additional power dissipation in the switching devices due to absorbed inductive energy
- Noise generation resulting in erratic operation.

The noise can disturb the control circuit resulting in erratic operation or misfiring of the switching devices. An excessive negative voltage spike at the output reference (lead 5 labeled V_S) of the high side gate driver can damage the Control IC.

STRAY INDUCTANCES

A typical half–bridge circuit is shown in Figure 1. This circuit employs two MOSFETs, and an MPIC2113. The stray inductances are also shown in Figure 1.

The critical stray inductances which most affect the operation of the circuit are located in the high current path. L_{D1} and L_{S2} are due to the wiring inductance between the MOSFETs and the decoupling capacitors; L_{S1} and L_{D2} are due to the wiring inductance between the MOSFETs.

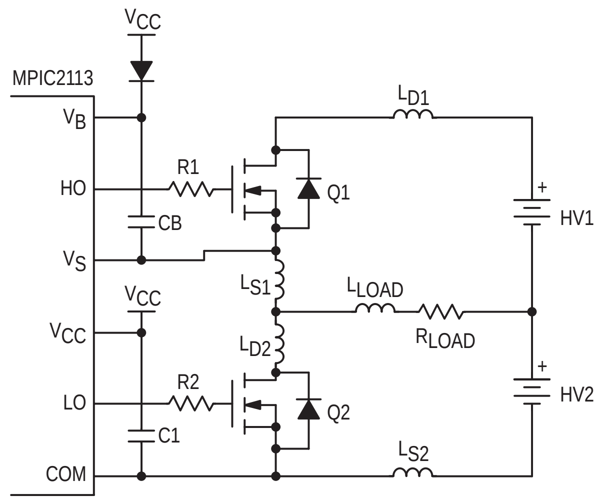

Figure 1. A Typical Half–Bridge Circuit with Stray Inductances

The following example illustrates the severity of the problem: assume that Q1 (see Figure 1) switches off a 10 A load current in 20 ns. If there is 10 nH of inductance in the current path, a 5 V spike can be measured across it during turn–off. A 3/4″ long straight piece of AWG24 round wire represents approximately 10 nH of inductance.

EXPERIMENTAL RESULTS

The test circuit is shown in Figure 2. The circuit uses the printed circuit demonstration board available for the MPIC2112 and MPIC2113 devices. The demo boards are available free for each of the Control IC devices. To eliminate the effects of the wiring between the power supply and the test circuit, a 100 μF, 250 V electrolytic capacitor was connected between the Q1D and Q2S terminals.

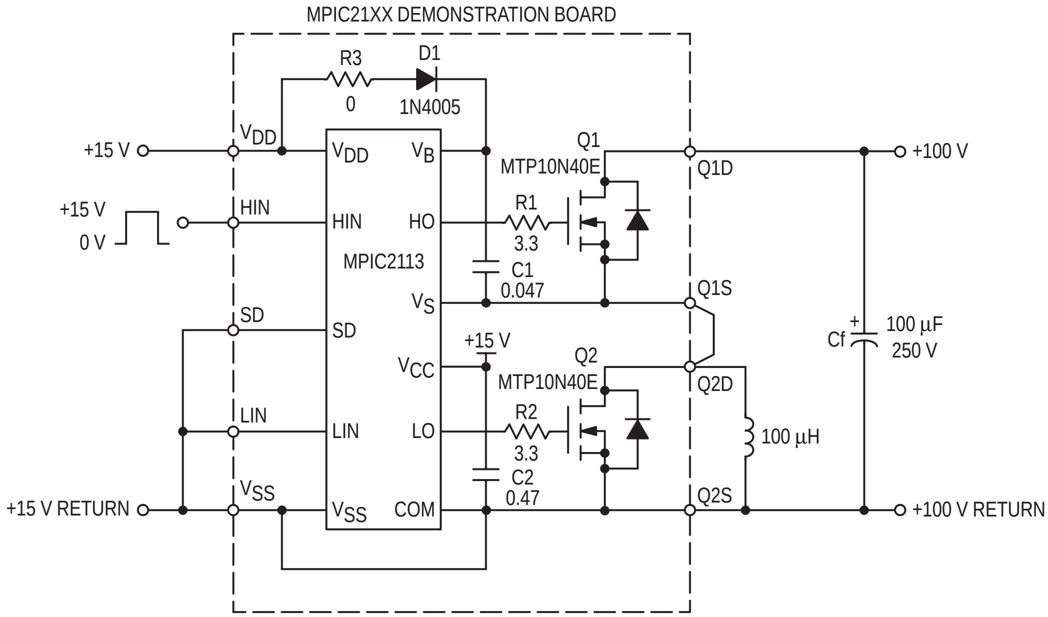

Figure 2. Test Circuit

The associated switching waveforms from the test circuit are shown in Figure 3. When Q1 turns off, the body diode of Q2 carries the freewheeling current. The voltage spike (transient) across the freewheeling diode is approximately 10 V, due to the turn on delay of the diode and the internal packaging inductances.

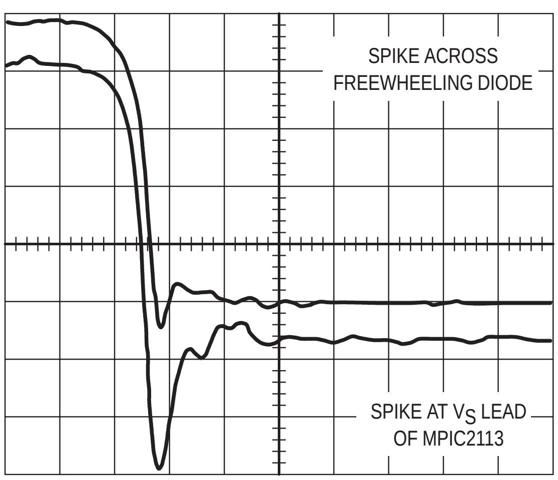

Figure 3. Waveforms while Q1 Turns Off a 20 A Inductive Load (20 ns/div and 20 V/div)

The resulting negative spike at lead 5 of MPIC2113 is 50 V, caused by the isolation of lead 5 from the freewheeling diode by the effects of L_{D2} and L_{S2}.

LIMITING THE SWITCHING SPEED

Driving MOS–gated power transistors directly from the MPIC2113 or similar Control IC can result in unnecessarily high switching speeds. The circuit shown in Figure 2 produced 4 ns turn–off time with 0 Ω series gate resistance and generated a negative spike of 90 V at lead 5 of the MPIC2113 under a given load and with our test layout.

A graph of the negative spike and the turn–off time versus series gate resistance is shown in Figure 4. Increasing the value of the series gate resistor, the amplitude of the negative spike decreases rapidly, while the turn–off time is a linear function of the series gate resistance.

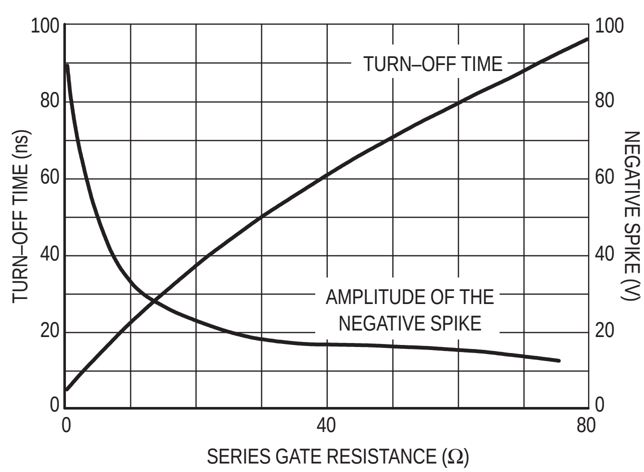

Figure 4. Series Gate Resistance versus the Amplitude of the Negative Voltage Spike and the Turn–Off Time

Selecting a resistor value just right from the "knee" (see Figure 4) provides a good trade–off between the spike amplitude and the turn–off speed. A 27 Ω gate resistor was selected for the test circuit which resulted in an 18 V spike amplitude and set the turn–off time to 48 ns.

ADDITIONAL SAFETY MARGIN

The current into lead 5 can be limited during the negative transient by inserting a resistor between lead 5 of the MPIC2113 and the source of the high–side MOSFET. The location of this resistor (R1A) is shown in Figure 5; the spike amplitude and the turn–off time versus the R1A value are shown in Figure 6. Comparing Figure 4 and Figure 6 shows that R1A suppresses the negative spike at lead 5 more effectively than R1 while having less effect on turn–off time.

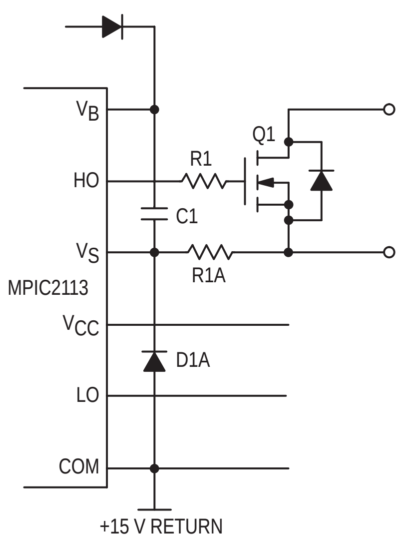

Figure 5. Adding R1A and D1A to the Circuit

Another method of suppressing the negative spike is to place a diode from lead 5 to ground. In Figure 5, this is D1A which is a fast, high voltage diode, while R1A limits the current through the diode. When selecting a diode for this application, the most important parameter is the turn–on time. The reverse recovery time is not critical, but if it is too long, then R1A dissipates significant power at high operating frequencies. It is generally true that if a diode has short reverse recovery time, then it has long turn–on time. A few different diodes have been tested in the circuit. Since the width of the negative spike was only 15 ns, none of them made a significant difference in the ampitude of the negative spike on lead 5.

However, if the stray inductances are higher, then the negative spike widens, which the diode can then effectively clamp.

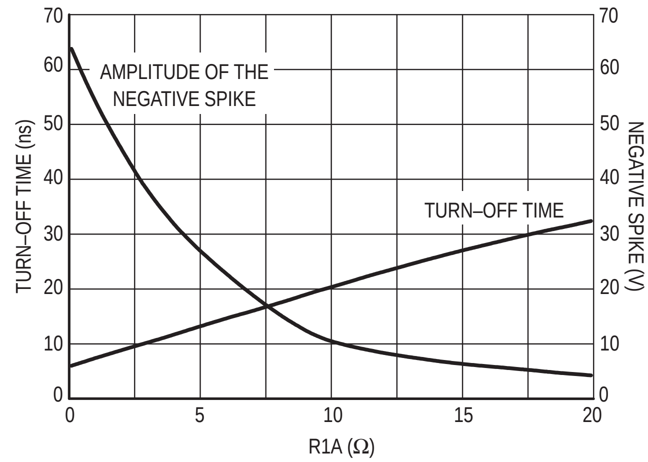

Figure 6. R1A versus the Amplitude of the Negative Spike at V_S Lead and the Turn–Off Time, R1 = 0 Ω

CONCLUSION

High speed switching in conjunction with stray inductances generates high voltage, high speed spikes. The energy of these spikes increases with stray inductance and the square of the current. Motorola guarantees the operation of Control IC drivers with a –5 V ground potential displacement. This assures proper operation of the circuit with moderate negative voltage spikes between the logic ground and power ground of the MOSFETs or IGBTs.

In order to ensure the reliable operation of the circuit the following actions should be taken:

- Minimize stray inductances along the main current loop through layout considerations
- Use proper high frequency decoupling physically close to the power stage
- Minimize the area of the high current loop
- Use twisted wires wherever possible
- Limit the switching speed of the switching devices, especially the turn–off speed of the high side switch, by at least sizing the series gate resistance
- Use R1A resistor and D1A diode to limit the current and voltage to lead 5

* This document was based on information in the International Rectifier Design Tip DT92–1A by Laszio Kiraly.

How to reach us:
USA / EUROPE / Locations Not Listed: Motorola Literature Distribution; P.O. Box 20912; Phoenix, Arizona 85036. 1–800–441–2447 or 602–303–5454

MFAX: RMFAX0@email.sps.mot.com – TOUCHTONE 602–244–6609
INTERNET: http://Design–NET.com

JAPAN: Nippon Motorola Ltd.; Tatsumi–SPD–JLDC, 6F Seibu–Butsuryu–Center, 3–14–2 Tatsumi Koto–Ku, Tokyo 135, Japan. 03–81–3521–8315

ASIA / PACIFIC: Motorola Semiconductors H.K. Ltd.; 8B Tai Ping Industrial Park, 51 Ting Kok Road, Tai Po, N.T., Hong Kong. 852–26629298

MOTOROLA

◊