Increasing the Efficiency of Low-Cost PoL DC DC Converters

The use of Point of Load DC to DC conversion to provide low-voltage rails locally is a trend that is only going to become more pervasive and more diverse as power needs increase in voltage, current and also required quality. The range of solutions available in the market is equally diverse, however some applications do not require digital control loops and multi-phase solutions and the associated cost, and a simple low cost flexible solution is often appropriate.

The variety of choices for a simple basic PWM controller ICs for this application is bewildering, but a somewhat standard pin out and functionality has been established with products such as the Intersil ISL8105.

Typical Application Diagram

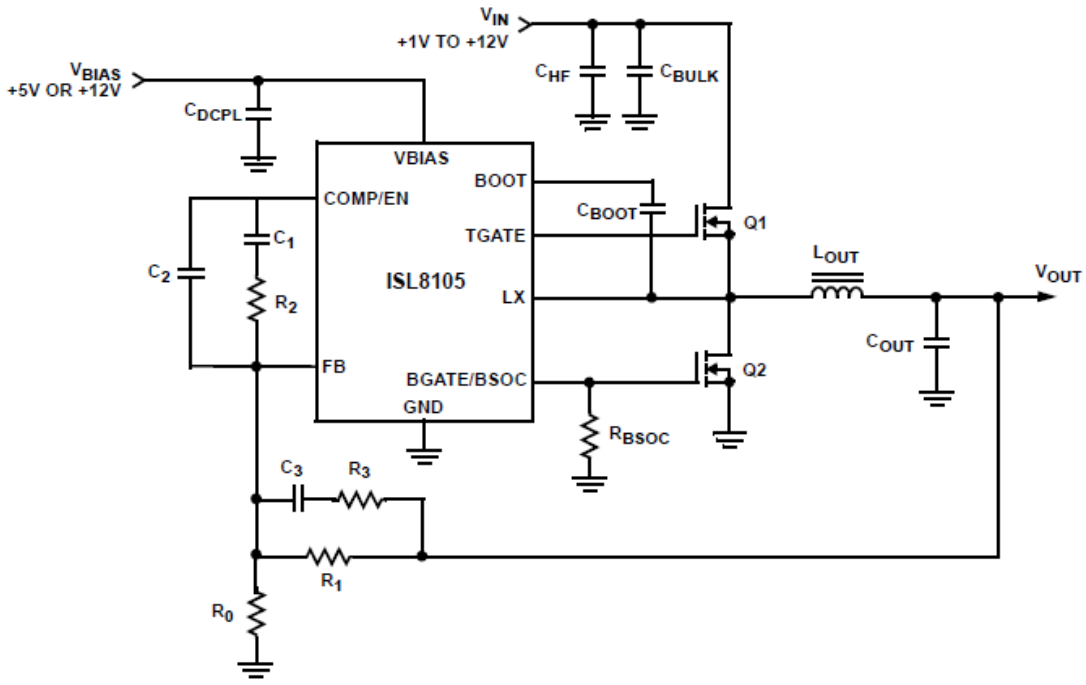

Figure 1. ISL8105 Typical Application Schematic taken from Intersil ISL8105 data sheet

Products with the same function and essentially the same pin out are available from vendors including Richtek, On semiconductor, Diodes Inc and other less well known manufacturers. Some vendors use a transconductance error amp, changing the compensation nodes slightly but the basic function and pin out is the same for many vendors for this function. The IC is fixed frequency and vendors typically offer frequency options, such as the 300KHz ISL8105IBZ and 600KHz ISL8105AIBZ. The main attraction of such a circuit is BOM cost: controllers such as the On Semiconductor NCP1587 have a published price of $0.28 at 2,500 units from an on-line distributor; the high volume price to an OEM should be about 1/3 of that price.

For improved step response, lower C_{OUT}, and smaller footprint, the higher frequency option of the ICs is the best choice, but since the ICs are budget ICs with only moderate strength drivers, and the appropriate MOSFETs would be multi-sourced (no point in using super-low Figure of Merit proprietary devices in a low cost BOM), the efficiency at 600KHz will be significantly lower than 300KHz, and the associated power dissipation may be a problem.

A simple way to increase efficiency is to add a NPN / PNP pair in Emitter follower configuration to increase the gate drive for the top FET, Q1 as shown in Figure 3. Switching losses are not an issue on the bottom FET as it is a synchronous rectifier with zero voltage switching.

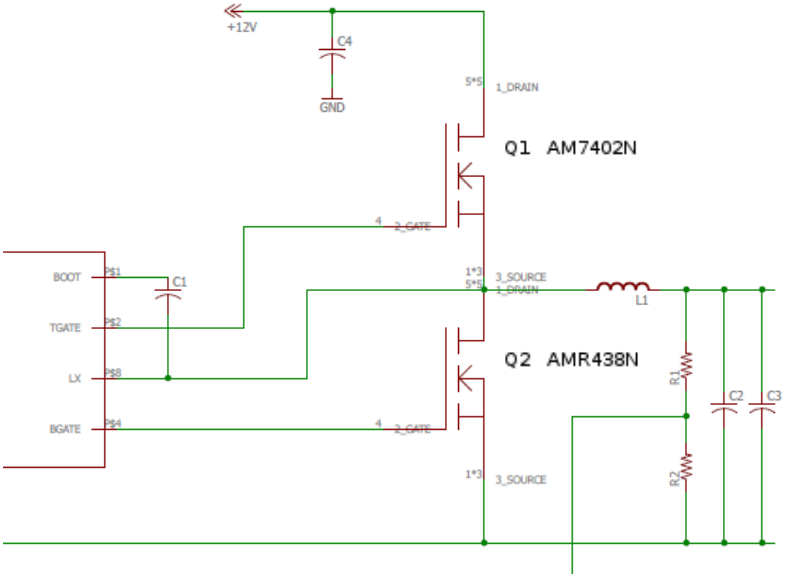

Figure 2. Standard drive circuit

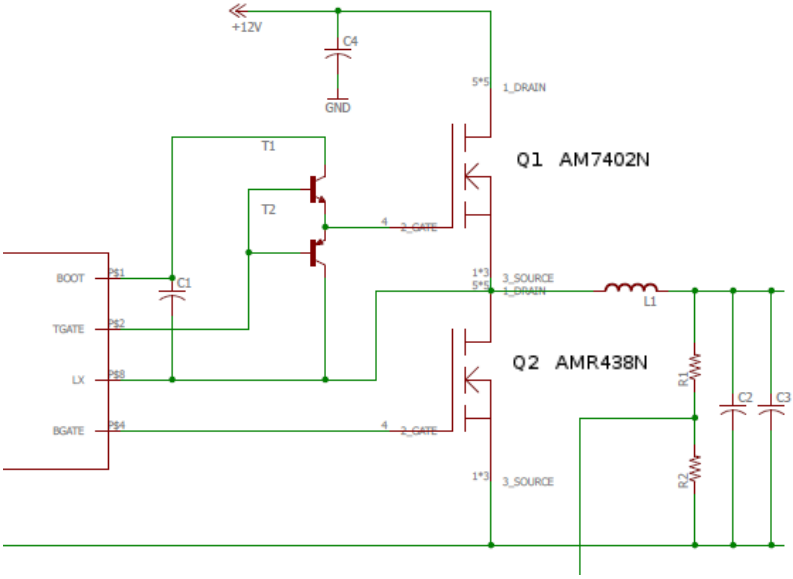

Figure 3 Addition of PNP/NPN Emitter followers. Resistors from Collector to Emitter may also improve efficiency slightly.

The PNP and NPN transistors can be a co-packaged pair such as the SOT-23 ZXTC2045E6. This package has approximately 3mm x 3mm footprint and a pin out that works very well for this application. Configured in a dual emitter follower unity voltage gain configuration, the bipolars provide higher current capability than the ICs can provide. Performance may be improved slightly by adding low value resistors from Collector to Emitter to reduce the voltage drop to zero for most of the on time of the transistor. A resistor can be added in series with the gate to reduce EMI, but the switching time and losses may increase.

In addition to providing higher current drive, the bipolar transistor buffer removes a lot of the board layout constraints for the IC and its path to the inductor node. The complementary transistors package has few other components connected and can easily be positioned close to the MOSFET,,and hence the inductor node, and the bootstrap capacitor. Having the SOT-23 buffer close to the power MOSFET reduces the parasitic inductance and also makes layout around the IC easier as traces to the IC (as opposed to the buffer) are less critical and this simplifies layout significantly. It is possible that a large part of the improvement in efficiency is actually due to reduction of the inductance in the source power leg and the gate series leg. The buffer concept also reduces the effects of variation in driver strength from IC vendor to vendor, allowing easier multi-sourcing.

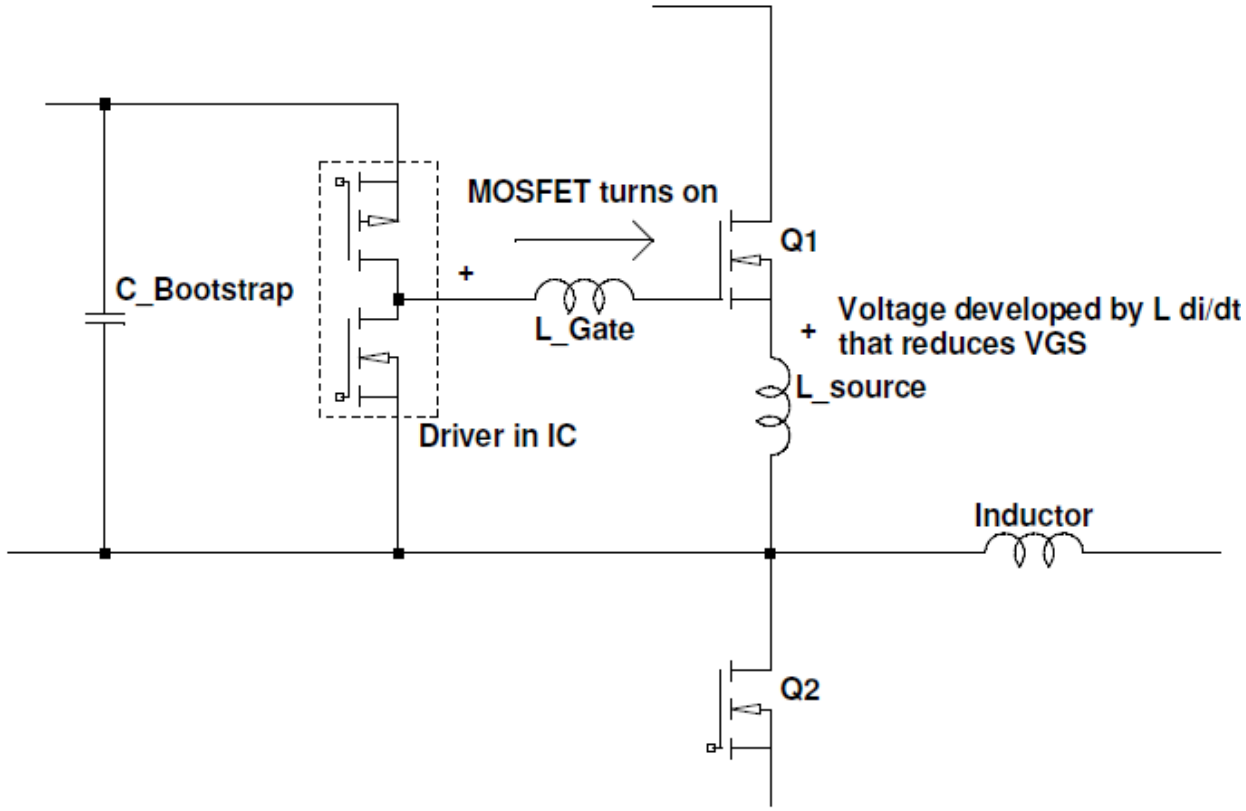

Figure 4. Effects of parasitic inductances on high side MOSFET turn on.

Test Data

A 600KHz 12V to 1.00 V DC DC converter was built with the option of stuffing the external bipolar buffer/driver. The efficiency was measured with the bipolar driver stuffed ("External driver") and then with it bypassed, ("No driver").

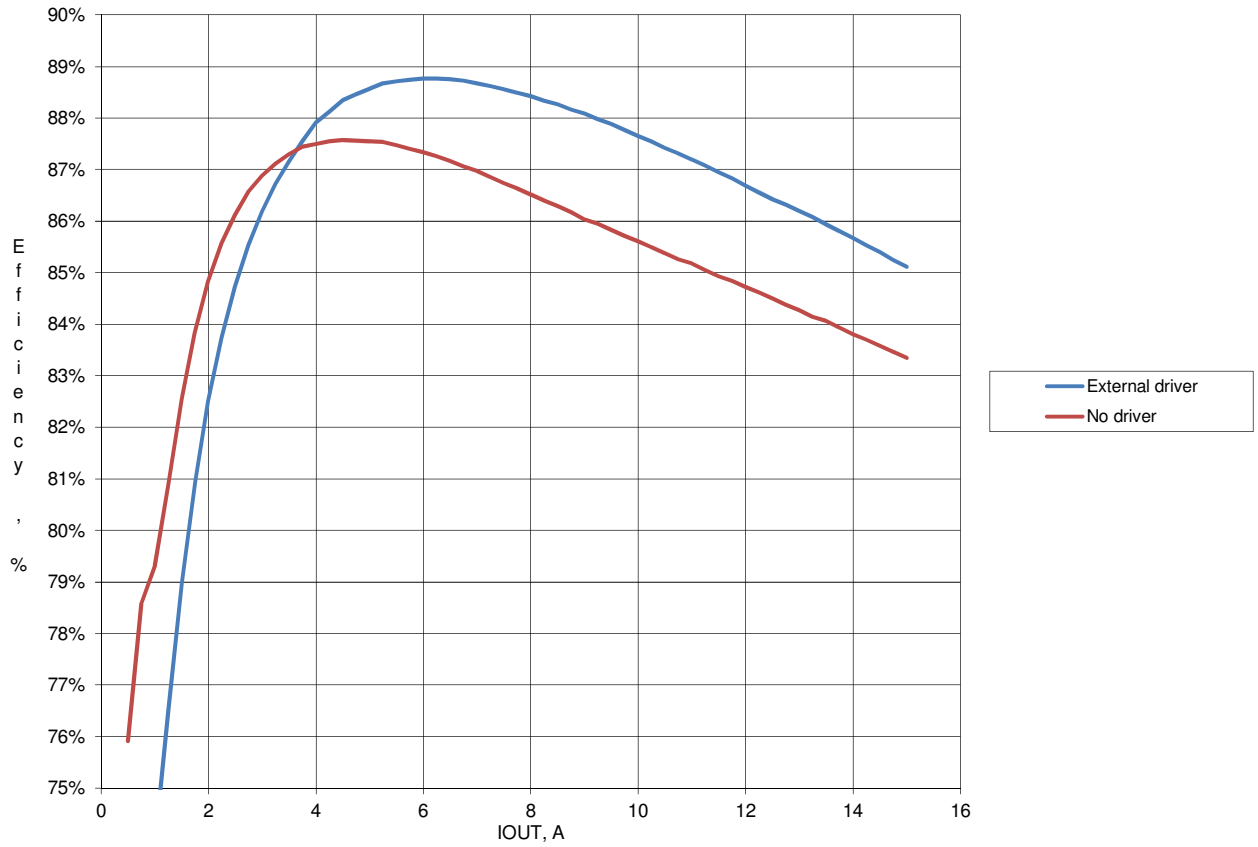

Figure 5. Improvement in Efficiency Due to External Driver, V_{IN} = 12V, V_{OUT} = 1.00V, IC: ISL8105A, FSW: 600KHZ, Q1: AM7402N, Q2: AMR438N, L: SER1408-681

As can be seen in Figure 5, the external driver gives the circuit about a 2% increase in efficiency and provides a reasonably efficient low cost PoL DC DC converter with a 89% peak efficiency and under 2W total losses at 14A output.

Conclusion

Cost-effective multi-sourced ICs and MOSFETs can be used to make an 89% efficient, 2W power dissipation 12V to 1.0V 600Khz DC DC converter. ICs such as Intersil ISL8105 and MOSFETs such as Analog Power AM7402N and AMR438N provide a low cost BOM. The addition of an external SOT-23 buffer/driver can increase efficiency by approximately 2% over designs with no such buffer by increasing gate drive current and reducing gate and source series inductance. Use of an external buffer/driver can also simplify layout, removing constraints of having a low inductance path from the IC's inductor pad to the power MOSFET source pins.

References

ISL8105, ISL8105A data sheet, Intersil, publication FN6306.5 April 15, 2010