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Design Note

Inductorless Bias Supply Design for Synchronous Rectification and High Side Drive Applications

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Developing a bias supply which is higher than a power supply's input voltage is usually required in high side switch applications. Two such examples are Buck regulators and Synchronous Switch converters using N-channel MOSFETs as the switching device. Independent of the specific application, there are numerous requirements for cost effective bias supplies without the added complexity of inductors, switches, transformer windings or even an independent power supply. The circuit shown in Figure 1 exemplifies the need in a transformer coupled, Synchronous Switch application in a Forward converter.

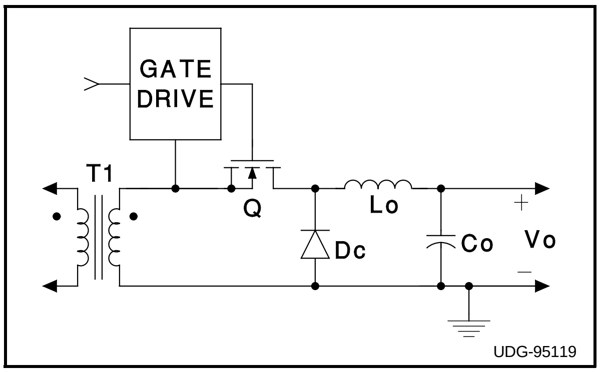

Figure 1. Synchronous Switch

A number of more demanding applications than the conventional Synchronous Switch examples exist, all with similar high side bias supply needs. For example, adding an overcurrent limit or circuit breaker function to the output will require a more sophisticated detection and gate drive circuit than the previous examples. A further extension would be the need to completely regulate the output voltage by pulse width modulating the switch. Note, however, that each of these will require the MOSFET switch to be "reversed" from that found in the Synchronous Switch example. This is necessary so that the MOSFET body diode does not always conduct while the input is greater than the output voltage. With this adaptation, its "channel" can be switched "on" to perform rectification only when required. Furthermore, this allows for the gate drive to be pulse width modulated to regulate the output voltage or to control output current. A diode, placed in series with the switch is required to prevent the MOSFET body diode from conducting when the transformer secondary voltage reverses. The basic circuit is shown in Figure 2.

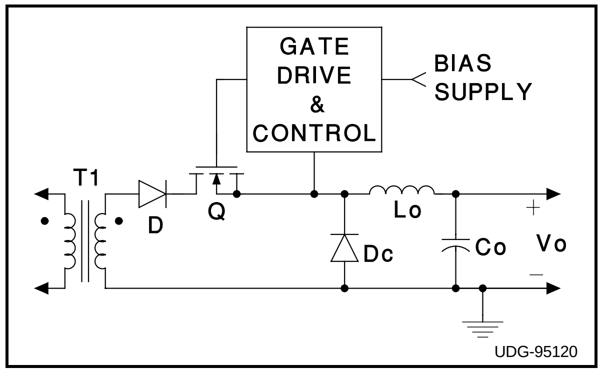

Figure 2. Controlled Switch with Series Diode

One problem with the configuration shown in Figure 2 is that the control circuit is "floating" and all control signals will require isolation which adds unnecessary complexity. An improved arrangement, shown in Figure 3, references the control circuit and gate drive to the supply's positive output rail. Note that the output filter stage consisting of the commutating diode (Dc), output filter capacitor (Co) and output inductor (Lo) has been reconfigured yet performs the same task. For simplicity, the output inductor has been moved to the lower (return) rail for two reasons. First, it enables the gate drive and control circuitry to be solidly referenced to the positive output voltage. Secondly, it eliminates the need for a "floating" gate drive which would have been required if the inductor were left in the positive output rail. Additional noise immunity in the control logic is generally gained with this configuration since its

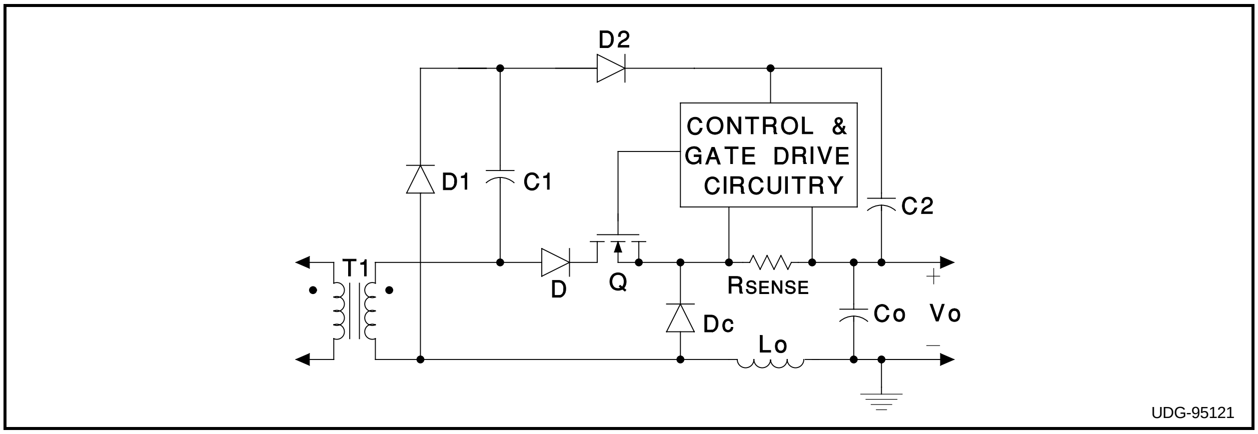

Figure 3. Improved Circuit Configuration

common mode range is reduced. Note that a direct measurement of output current is also available for overcurrent protection purposes or current mode control by using a sense resistor in series with the positive output.

Operation of the basic charge pump circuitry used to develop the high side bias is as follows. The sequence begins at turn-off of the main power supply switch on the transformer's primary side which causes the secondary voltage waveform to collapse. Power is transferred to the bias supply during the transformer's resetting or "backstroke". As the voltage across the secondary winding reverses, capacitor C1 is charged through diode D1 to the peak amplitude of the secondary reset voltage. Note that these components are "isolated" from the bias supply capacitor (C2) by diode D2 while C1 swings below the positive output rail and charges. During the normal transfer of power to the output stage the secondary transformer voltage is positive. As this occurs, Diode D1 is reversed biased and turns off while capacitor C1 is lifted along with the positive secondary transformer voltage. When the voltage across capacitor C1 exceeds that across the bias supply capacitor (C2), diode D2 conducts. Note that this takes place whether or not the power switch and diode are conducting. Charge stored in C1 is delivered to C2 beginning with the rise of secondary transformer voltage, replenishing C2. Eventually, diode D2 will discontinue conducting as C1's voltage drops below that of C2. The entire cycle is repeated beginning at the reset of T1 when the secondary voltage goes negative, starting the charge of C1 again. One noteworthy additional benefit of this circuit is that it may snub some of the parasitic energy across the transformer during its transient reset which can reduce the peak reverse voltage of the output (power) diode.

In center tapped transformer secondary applications, for example push-pull, half and full bridge topologies, the circuit can be replicated to accommodate the second high side switch and drive circuitry, as shown in Figure 4. This arrangement will provide power to the bias supply from both windings of the secondary. At first glance, the lower side circuitry may seem unnecessary, or even wrong. But when the time comes for it to transfer power to the output, this lower side becomes the upper side of the schematic and the need for it becomes apparent.

Many other arrangements of the basic diode and capacitor charge pump circuit are possible - without using inductors and/or additional switches for these low power applications. For more demanding ones, a linear or switchmode integrated circuit regulator can be considered to deliver a precisely regulated bias voltage.

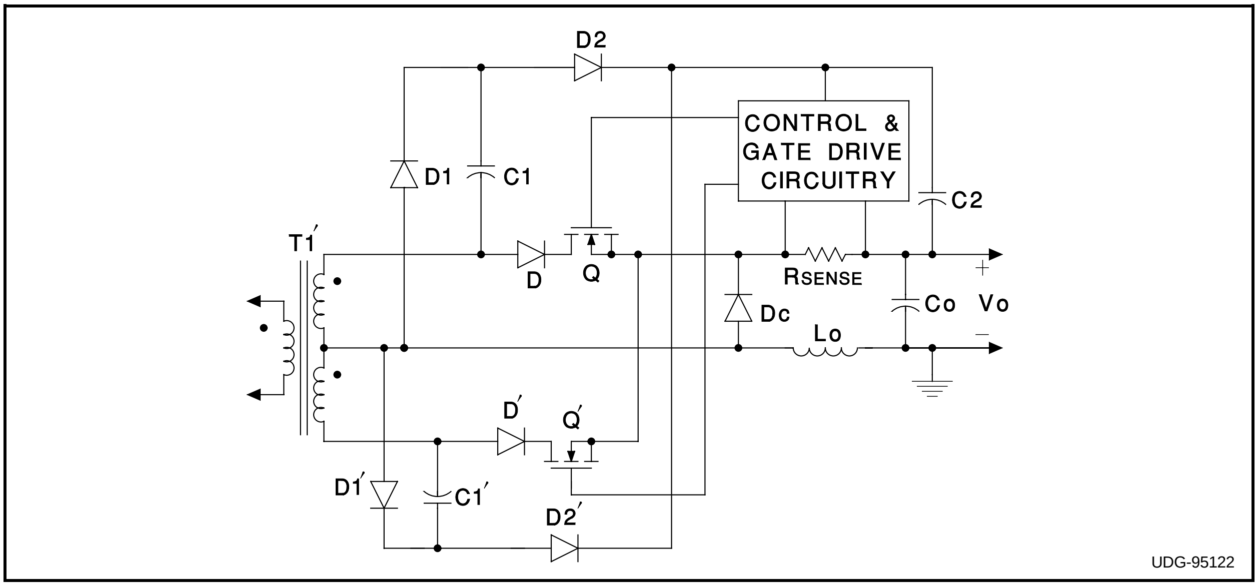

Figure 4. Center Tapped Application of Improved Circuitry

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