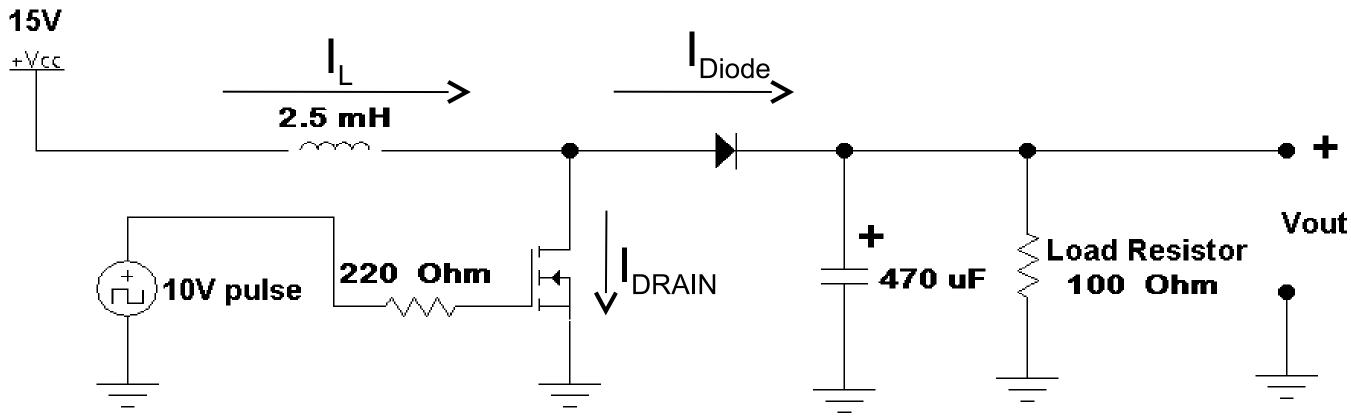
L. Sears

THE BOOST (STEP-UP) CONVERTER

V24.7



$V_{out} = V_{in} \times$ D.C.

This paper discusses the basic “Boost”, (“Step-Up”) inverter. This uses the **“flyback”** principle to provide an output voltage which is higher than the input voltage.

When the MOSFET is ON, a constant current flows through the inductor, storing energy. When the MOSFET turns OFF, the current in the inductor at that time tries to keep flowing. A path is provided by the diode, so the voltage at the drain will quickly rise (due to the action of the inductor) so the diode is forward- biased. The inductor current will now flow through the diode and into the filter capacitor and load. Since the diode is forward-biased, the voltage at the drain will rise to one diode- drop above V_{out}.

When the MOSFET turns ON again, the drain will be quickly pulled to ground, and the cycle will repeat. However, If diode current is still flowing (“continuous operation”), the fast fall-time at the drain may produce a large reverse-recovery current pulse in the drain and the diode. Note that the diode will be reversed- bias by a voltage approximately equal to the output voltage; this instantaneous reverse-bias voltage is what produces the large reverse-recovery current spike, I_{rr}.

In “continuous” mode, the MOSFET turns ON before the inductor current discharges to zero. In “discontinuous” mode, there is enough time between ON periods that the inductor has time to discharge to zero.

In this paper, continuous and discontinuous modes are shown, as well as the effect of diode recovery time.

Before we can go any further, we will review CURRENT THROUGH AN INDUCTOR

In Fig. A, a voltage source charges an inductor. The current will ramp linearly according to V = L(di/dt). The current through the inductor will be in the direction shown, and the top terminal would be **+** and the bottom terminal would be **-**. If at some point we could instantaneously remove the battery from the circuit and place a short circuit or resistor in its place (as in fig. B), the stored energy in the inductor would produce a current in the same direction as before (as shown). This discharge current would be in the same direction as the current was flowing during charging because *the current through an inductor cannot change instantly*.

Note that during the discharge phase the polarity of the inductor has reversed so that the current will continue to flow in the same direction as when it was charging. (Think of the inductor as a battery which is producing a current; the "battery" must have the top terminal positive and the bottom terminal negative).

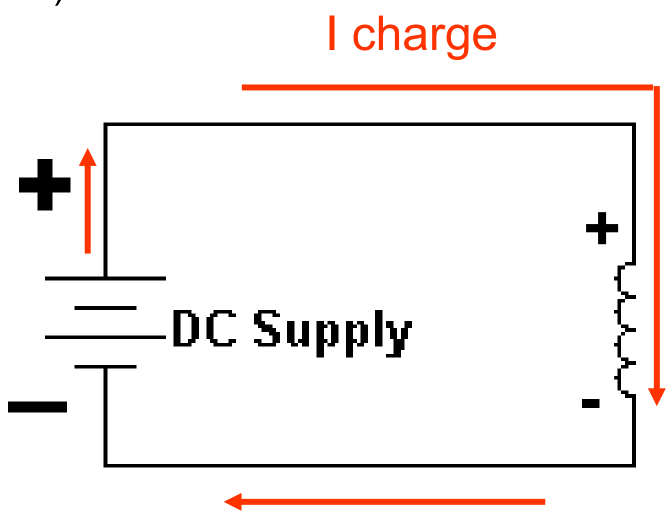


Fig A

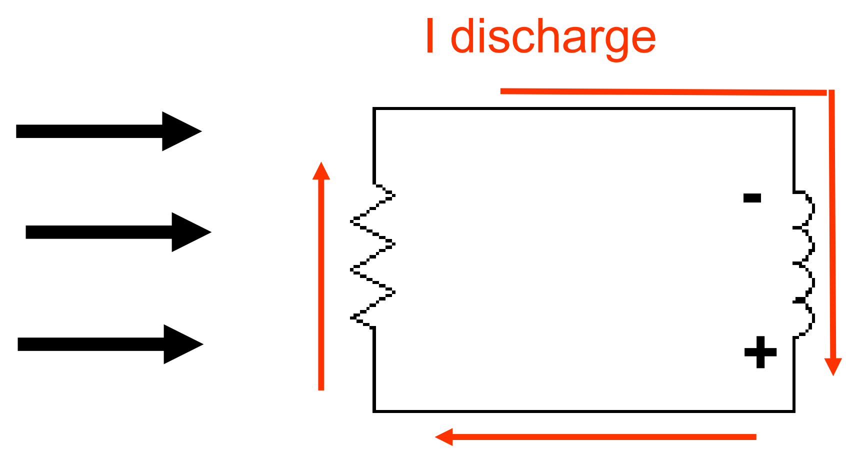
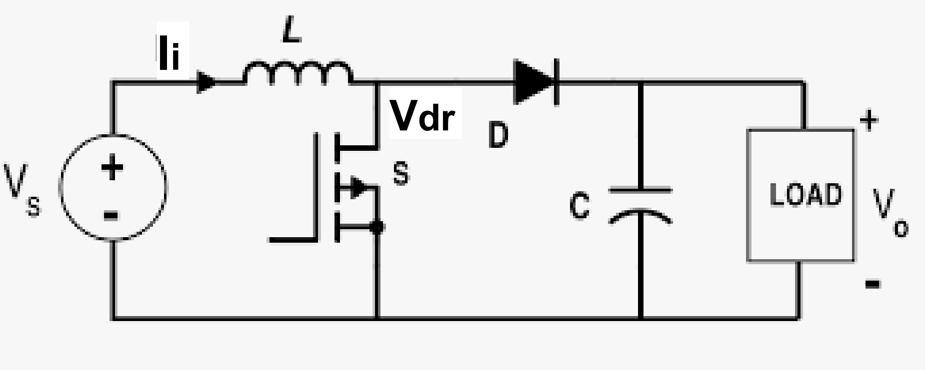


Fig B

BOOST CONVERTER WAVEFORMS



Vin ≈ 10 VDC.   Vout ≈ 20 VDC.   L = 470uH.

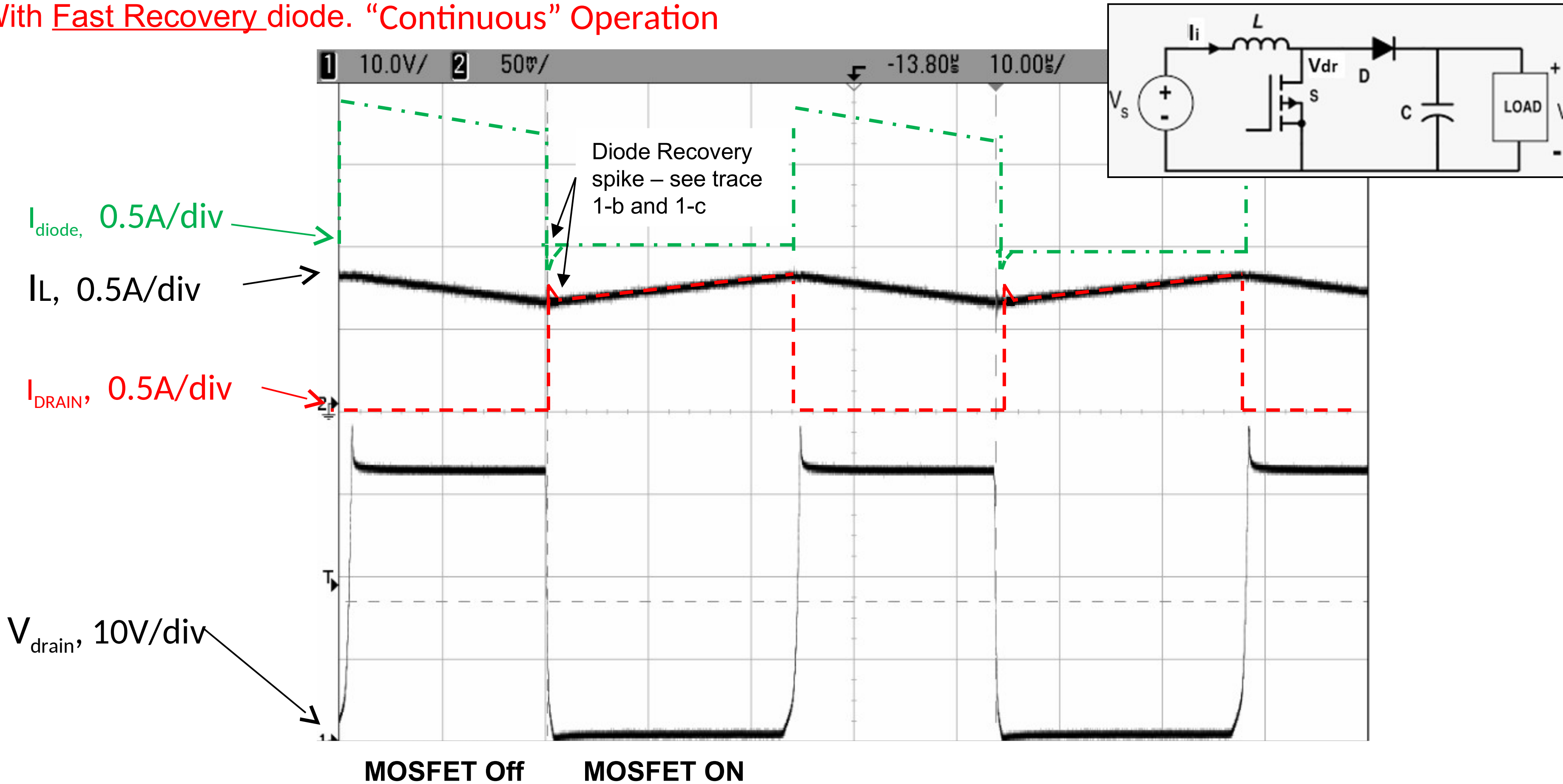
DIODE	Vin	Iin	Pin	Vout	Rload	Efficiency
Standard Recovery	10.2V	0.49A	4.49W	20.1	100Ω	81%
Fast Recovery	10.2V	0.44A	4.30W	20.7V	100Ω	95%

The following waveforms referred to the conditions in the table above.

TRACE 1-a

THE BOOST (STEP-UP) INVERTER

With Fast Recovery diode. “Continuous” Operation



Vin = 15VDC Iin = 0.67A f = 23KHz L = 2.5mH, 1.0Ω Rload = 100Ω Cout = 470uF

Diode = 1N49337 (Fast Recovery) Vout = 31.4VDC

All waveforms assume fast (< 100 ns) MOSFET rise and fall times

TRACE 1-b

THE BOOST (STEP-UP) INVERTER

With Fast Recovery diode. "Continuous" Operation

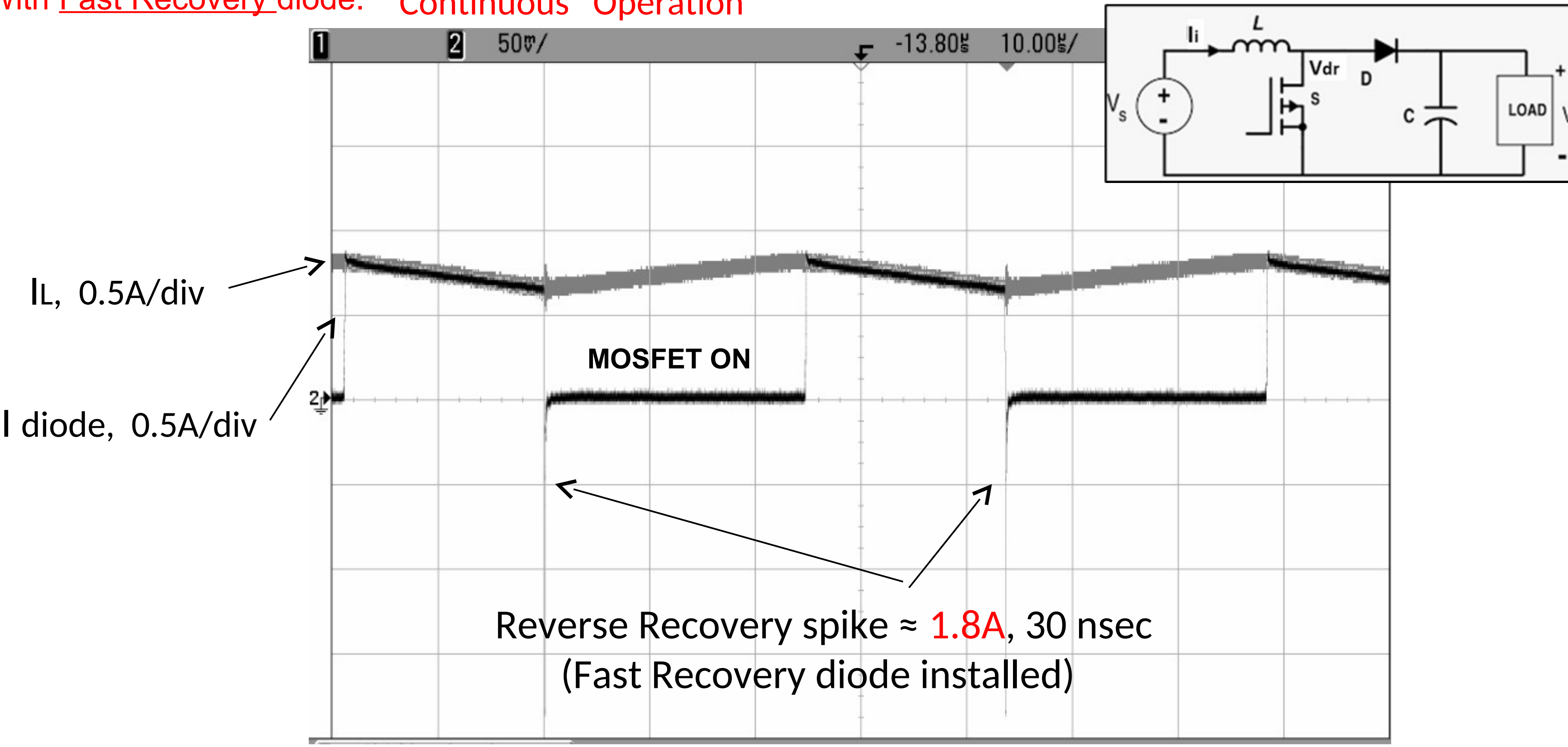


Figure 2

Showing inductor and diode current. Same conditions as Trace 1-a.

TRACE 1-c

THE BOOST (STEP-UP) INVERTER

With Std. Recovery diode

"Continuous" Operation

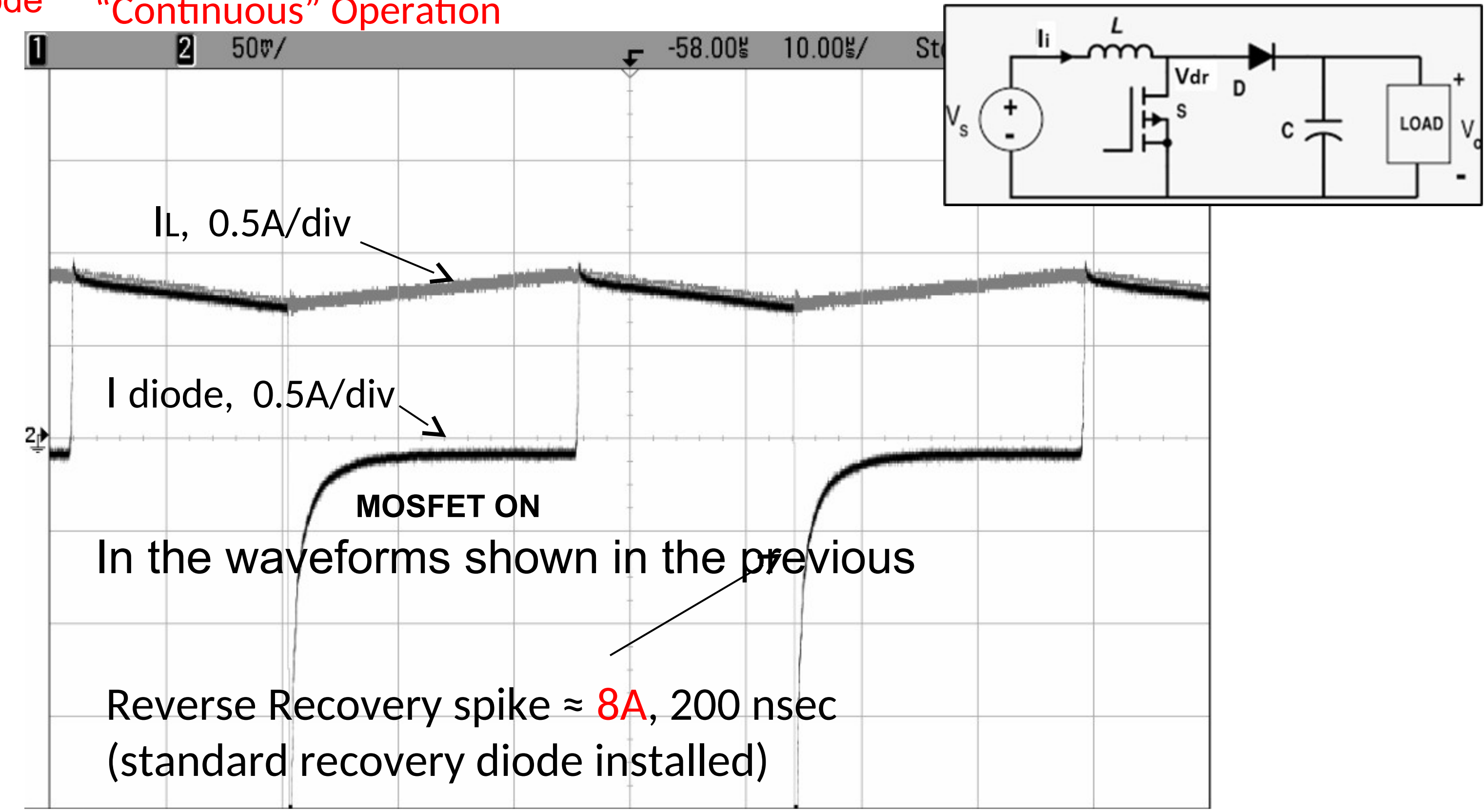


Figure 4

Showing inductor and diode current. Same conditions as 1-b, but with standard recovery diode (1N4004).

TRACE 2-a

THE BOOST (STEP-UP) INVERTER

With Fast Recovery diode OR Standard- Recovery diode

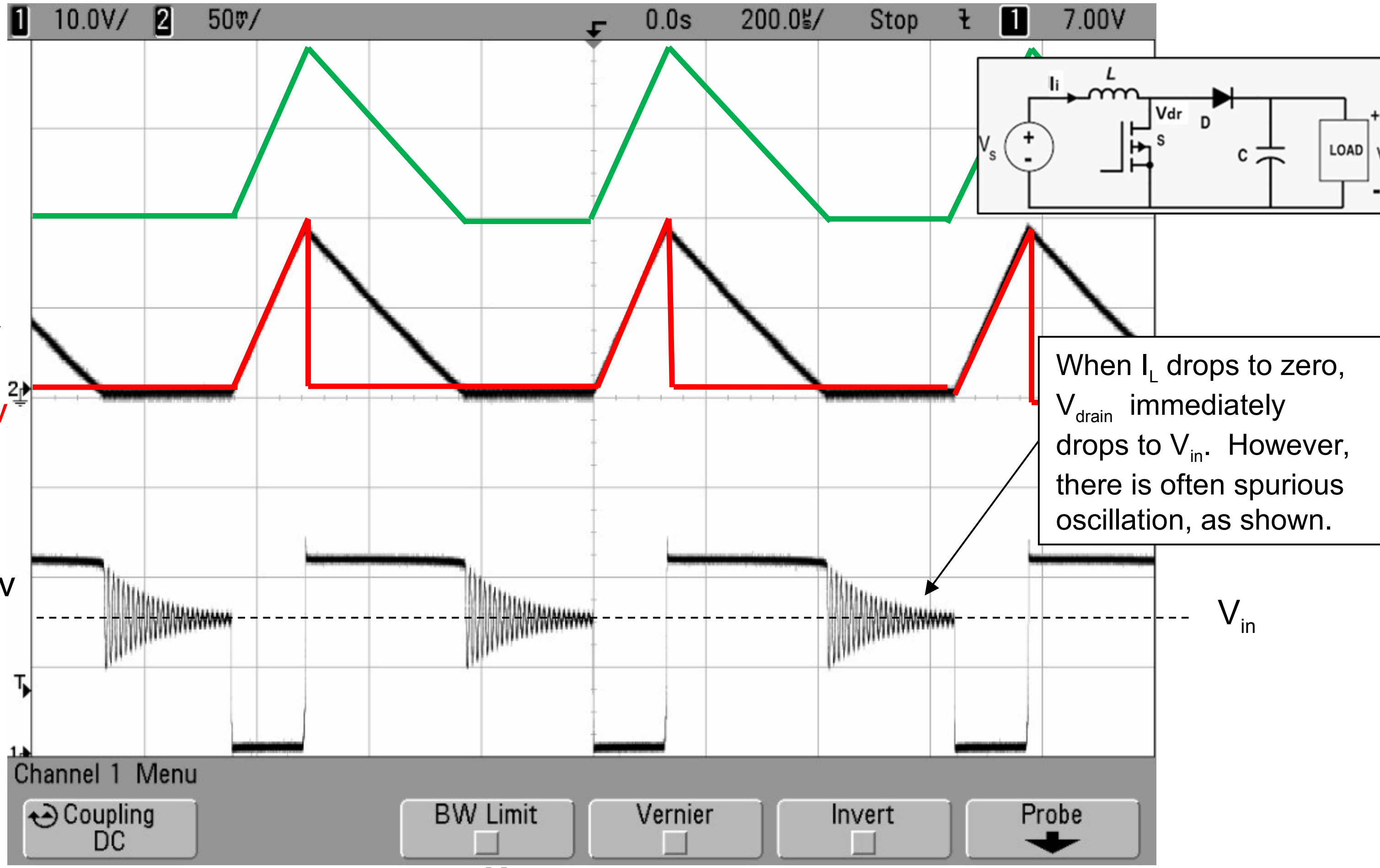
"Discontinuous Operation

Idiode, 0.5A/div

IL, 0.5A/div

Idrain, 0.5A/div

Vdrain, 10V/div



V_{in}

Vin = 15VDC   Iin = 0.28A   f = 1.56KHz   L = 2.5mH, 1.0Ω   Rload = 100Ω   Cout = 470uF

Diode = 1N49337 (Fast Recovery) OR 1N4004 (Std Recovery)   Vout = 20.8VDC

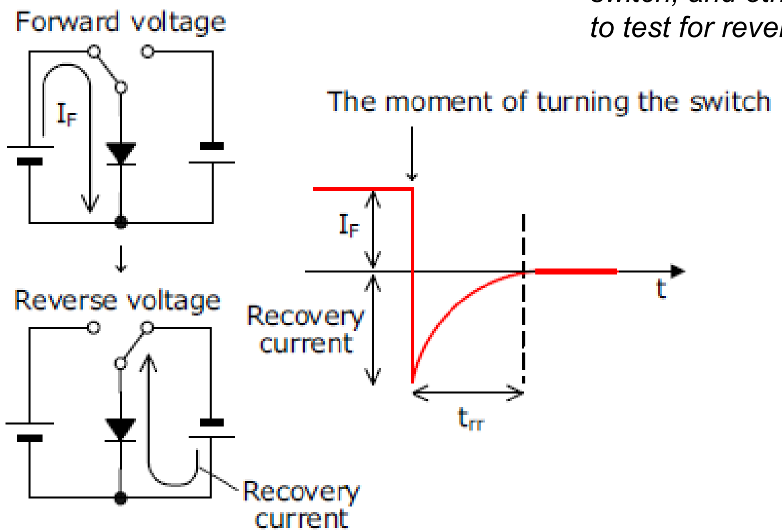
(Waveforms do not change because diode current drops to zero)

Diode Reverse-Recovery

The brief reverse-recovery current spike, Irr, produced during continuous operation, may result in diode failure due to high instantaneous power dissipation in the diode. A MOSFET will probably survive, but a BJT might be damaged by Irr.

As shown in the following figure, the recovery current flows when the reverse voltage is applied from the state where the forward voltage is applied by turning the switch. The time from when the recovery current flows until the recovery current decreases is called the Reverse Recovery Time, trr. The larger the forward current, I_F, the longer the trr. Since the recovery current causes noise and power loss, the shorter the trr, the better the characteristics.

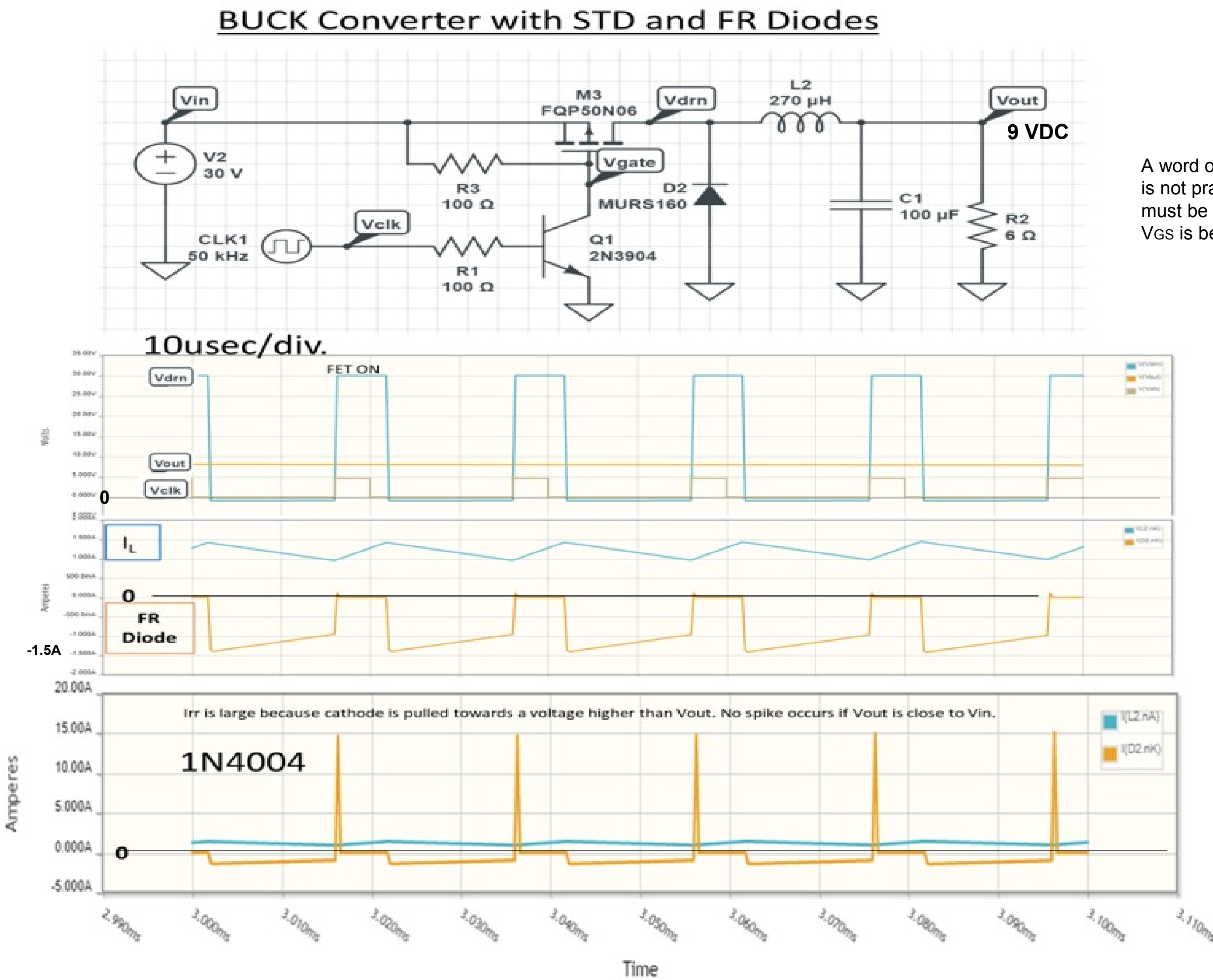
Note that the SPDT switch pictured in this diagram is shown for modeling purposes. You can't buy such a switch, and other, more complicated circuits are used to test for reverse- recovery characteristics.



With forward current flowing through diode, pulling the anode quickly to a negative voltage with a low-resistance MOSFET or BJT will result in a very large reverse-recovery current flowing through both the diode and the switch. In other words, the reverse- recovery spike occurs when a forward- conducting diode is quickly forced into the reversed-bias state.
The resulting reverse recovery current can be 10 or more times the diode forward current. At the same time, the voltage across the diode is very high; the resulting dissipation can be extreme. The use of a Schottky or fast-recovery diode is required, but the magnitude of the reverse recovery spike can also be reduced by slowing the turn on- time of the MOSFET or BJT.

REVERSE RECOVERY ISSUES WITH THE STEP- DOWN CONVERTER

A BOOST converter was described in the slides above. Note, however, that the step- down (BUCK) converter may also exhibit large diode reverse- recovery spikes in continuous operation. In the BUCK configuration, when the MOSFET turns ON, the cathode of the formerly forward-biased diode is abruptly pulled to a voltage that is <u>higher</u> than the output voltage. This reverse-biases the diode which produces the reverse- recovery current spike. The greater the input voltage compared to the output voltage, the greater the magnitude of the reverse- recovery pulse.



A word of caution: the circuit is not practical as shown; R3 must be a 9W resistor and V_{GS} is being exceeded!