# REVERSE-BIAS EFFECTS ON POWER CONVERTER OUTPUTS IN SERIES

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## ABSTRACT

*Series connection of outputs of power converters can lead to confusing or even damaging effects. This article explains how this can happen and how the effects can be mitigated.*

## ARTICLE

Isolated power converter outputs are commonly connected in series, either to generate positive and negative rails by grounding the mid-point or simply to obtain a higher voltage. The outputs may be from the same or separate converters.

There is a risk however that during start-up, one of the outputs could see a reverse voltage bias on its terminals. Figure 1 shows a typical application where a low power DC-DC converter provides +/- 12 V for analog circuitry from a system 5 V. Before the DC-DC converter is powered through the switch, there is a 'sneak' current path shown in bold which includes the lower leg of the transformer center-tapped secondary (assuming D2 has slightly lower forward voltage than D1). The current flow raises the negative output of the converter to a positive voltage of about one diode drop above ground. Even if there is not a physical switch on the input to the DC-DC converter, its internal soft start or start delay may transiently cause the same effect as the converter powers up.

Another application shown in Figure 2 uses two converters to generate a non-standard voltage, perhaps 18 V from two 9 V converters. If DC-DC 2 starts up before DC-DC 1 and C1 value is substantially larger than the converter output capacitors, the positive output of DC-DC 1 is reversed biased while C1 charges and until the converter generates its own output. Even before either converter starts, there is again a potential sneak system impedance to the mid-point of the series connection forcing DC-DC 1 positive output to a diode voltage drop negative by the current flowing to system ground through DC-DC 1 transformer, output diode and the external load.

In both cases, the reverse voltage is clamped to the value of an internal diode drop. Although this voltage is unlikely to cause damaging component stress, it could cause substrate diode conduction in ICs connected to the output and anomalous start-up. If the converters include solid tantalum output capacitors however, real problems could occur especially at high temperatures. In a survey of manufacturers' data, it has been reported that for solid tantalum capacitors, a common guideline is a maximum safe reverse voltage of 0.1V at 125 Celsius [1].

The effect of the current flow through the secondary of the converter transformer before it starts up is more insidious. This current can occur in all topologies with the exception of those with a series capacitor such as Cuk or SEPIC. How much can flow depends on the topology and resistance/ diode voltage drops as well as the sneak system impedance. For example in a simple boost or flyback converter as in Figure 2, all of the current flows through the secondary of the transformer whereas in versions of the buck or forward converter, it depends on the relative volt drops of the forward and 'freewheel' diodes and winding resistances. Bi-phase or center-tapped push-pull circuits as in Figure 1 divide the current between the two output windings in some ratio. If D1 and D2 in Figure 1 actually had identical forward voltage drops and the winding and connection resistances were identical, the current would divide equally between the two secondary windings which, being in anti-phase, would produce no net magnetisation and no ill effects. In reality, unequal currents can be expected.

The practical effect of the current again depends on the topology. A transformer is not normally intended to sustain continuous DC so the core is pre-magnetised by the sneak current before the converter starts and perhaps even magnetically saturated. The example of Figure 1 has a push-pull topology with a small, high permeability core with perhaps 0.005 square inch cross sectional area and a center-tapped eight-turn secondary. The transformer will saturate with only about 150 mA DC through one leg of this winding. As the converter starts into a saturated core, depending on which phase energises first, one primary switch of the converter could immediately see a damaging current. In this application, a sneak current of this magnitude could easily flow.

Larger cores in higher power buck or forward converters have much higher DC saturation levels for similar inductances and turns and at higher power there is likely to be more comprehensive protection for the primary switches.

Isolated boost or flyback converters, while conducting the full sneak current through their transformer secondaries before they start, are also more immune to saturation as the gapped or low permeability cores allow higher DC bias through the windings. However, the simplest self-oscillating circuits can be affected. These circuits typically rely on a feedback winding to initiate oscillation. If the core is pre-magnetised, feedback on the very first switching cycle is attenuated and the circuit can lock into a high dissipation and damaging state depending on the rise time of the DC-DC input voltage. The effect has been seen at Murata Power Solutions with as little as 30mA initial bias current through the output of a 2 watt self-oscillating flyback converter.

Fortunately there is a simple solution to the problems described. Diodes fitted across the converter outputs such that they are reverse biased in normal operation can divert offending currents away from the converters. They should have a lower forward voltage drop than the total of the internal diode and resistance drops, typically being Schottky types. Beware of their leakage current at high temperature though as it can cause substantial dissipation with a continuous high reverse voltage. If the converters use solid tantalum output capacitors the parallel diode clamp voltage may still be too high so another solution may be necessary such as including an extra series output diode as well as the parallel diode. This series diode should have a forward volt drop similar to or lower than the parallel diode to ensure the net voltage across the tantalum capacitor is always positive. Of course this diode does reduce overall efficiency and output voltage accuracy if remote sensing is not available.

In AC-DC converters, there is normally no path for the sneak current to flow back to the supply but the effect of transient reverse bias of DC-DC 1 in Figure 2 as C1 charges is still possible. This can be mitigated by splitting the high value capacitor into two, one across each converter output as well as fitting the parallel diode.

REFERENCE

[1] “Reverse voltage behaviour of solid tantalum capacitors”, I. Bishop and J. Gill, AVX

Figure 1. Series connection internally to the converter for bi-polarity outputs

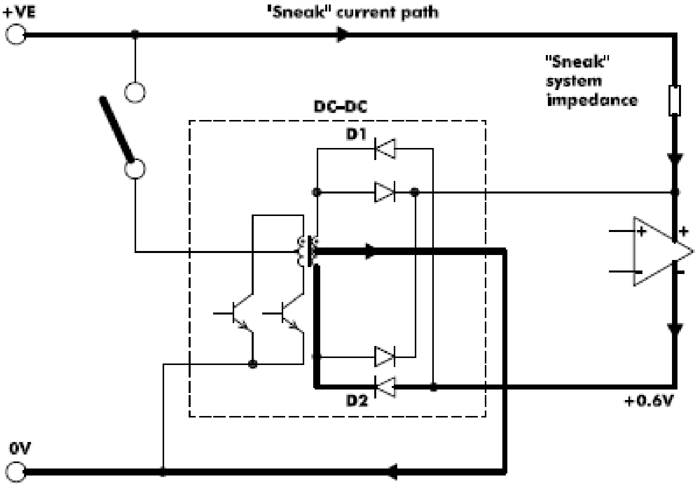

Figure 2. Series connection for higher output voltages