



# Isolation in Digital Power Supply—Why and How

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## Introduction

With the aggressive growth of the internet and communication infrastructure, digital control techniques are becoming more and more popular in the power systems of telecom, networking, and computers because they can offer attractive advantages, including flexibility, component count reduction, advanced control algorithm, system communication, low sensitivity to external noises, and parameter variation. Digital power supplies are widely employed in high end server, storage, telecom brick module, etc. For these applications, isolation is often required.

The challenge of isolation in a digital power supply is in sending digital or analog signals across the isolation barrier with fast speed, accuracy, and compact size.<sup>1</sup> However, the traditional optocoupler solution has low bandwidth and current transfer ratio (CTR), which causes wide variation with temperature and degradation with time problems. The transformer solution also has bulk size, magnetic saturation problems, etc. These issues limit optocoupler or transformer use in some high reliability, compact size, and long life applications. This article discusses the digital isolation techniques to address these issues with Analog Devices' iCoupler® products in digital power supply design.

## Why You Need Isolation

When designing a power supply, complying with safety standards is essential to protect operators and other personnel from electric shock and hazardous energy. Isolation is an important method to meet safety standards. The isolation requirement specifies different levels of input and output voltage—both steady state and transient state—by many agencies throughout the world like VDE and IEC in Europe and UL in the United States. For instance, there are five categories of insulation introduced in UL60950:

- ▶ **Functional Insulation:** Insulation that is only necessary for the correct functioning of the equipment.
- ▶ **Basic Insulation:** Insulation to provide basic protection against electric shock.
- ▶ **Supplementary Insulation:** Independent insulation applied in addition to basic insulation, in order to reduce the risk of electric shock in the event of a failure of the basic insulation.
- ▶ **Double Insulation:** Insulation that comprises both basic insulation and supplementary insulation.

- ▶ **Reinforced Insulation:** A single insulation system that provides a degree of protection against electric shock and is equivalent to double insulation under the conditions specified in this standard.

## Primary Side Control and Secondary Side Control Comparison

According to the position of the controller, the isolated power control methods divide into two types: primary side control and secondary side control. Table 1 shows the function comparison between the primary side control and secondary side control. UVP and OVP stand for undervoltage protection and overvoltage protection, respectively, in the below table.

**Table 1. Function Comparison Between the Primary Side Control and Secondary Side Control**

Function	Primary Side Control	Secondary Side Control
Power up	Direct or simple dc regulated power supply is required to power the controller	Auxiliary isolated power is required to power the controller
Gate drive	A primary side switches' gate drivers do not need isolation; synchronous rectifier gate drivers need isolation	A synchronous rectifier's gate driver does not need isolation; primaryside switches' gate drivers need isolation
Input UVP/OVP	Isolation is not required	Isolation is required
Output UVP/OVP	Isolation is required	Isolation is not required
Control loop	Isolated control loop is required to regulate the output voltage	Isolated control loop is not required
System communication	Isolation is required	Isolation is not required
Remote on/off	Isolation is not required	Isolation is required

## Secondary Side Control

The ADP1051 is an Analog Devices' advanced digital power controller with a PMBus™ interface, which targets high power density and high efficiency applications like intermediate bus converters.<sup>2</sup> The ADP1051 is based on flexible state machine architecture and provides many attractive features such as reverse current protection, prebias startup,

constant current mode, adjustable output voltage slew rate, adaptive dead time control, and volt-second balance inside the chip, which reduces lots of external components compared with analog solution. Generally, the ADP1051 is used more often as secondary side control, as it is easy to have it communicate with the system. Therefore, signals such as PWM signals of synchronous rectifiers and  $V_{OUT}$  sensing do not need to cross the isolation boundary to communicate with the system. However, in this case, an auxiliary power supply is required to provide the initial power to the secondary side controller ADP1051 at the start up stage from the primary side. In addition, PWM signals, which are from ADP1051, need to cross the isolation boundary. Three approaches are discussed, which are gate drive transformer, digital isolator, and isolated gate driver.

### Gate Drive Transformer

Figure 1 shows the block diagram of a digital power supply with the gate drive transformer solution. In this approach, the secondary controller ADP1051 sends PWM signals to the ADP3654, which is a dual-channel, 4 A MOSFET driver. The ADP3654 then drives a gate drive transformer. The function of gate drive transformer is to transfer the drive signals from the secondary side to the primary side, and drive the primary side MOSFETs. An auxiliary isolated power supply provides the power to ADP1051 at start up stage.

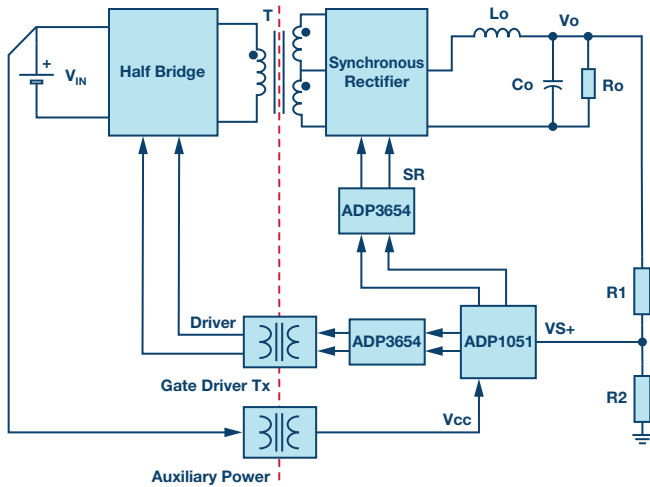


Figure 1. Gate drive transformer driven by ADP3654 solution.

The advantages of the gate drive transformer solution include minor time delay and lower cost. However, ADP3654 requires more careful design of the gate drive transformer, as the transformer needs to be reset after a period of on time—otherwise, it will saturate. In terms of gate drive transformer design for a half bridge topology, a double-ended transformer often is employed, which is shown in Figure 2.

Figure 2 shows the circuit of a gate drive transformer driven by the ADP3654. The ADP3654s  $V_{OA}$  and  $V_{OB}$  outputs connect to a gate drive transformer through a dc blocking capacitor  $C_{DC}$ . Considering the maximum volt seconds required under all operating conditions, a maximum 50% duty cycle is selected for half bridge. Once the core is selected, the number of primary winding  $N_p$  can be calculated by using Equation 1:

$$N_P = \frac{V_{dd} \times 0.5}{\Delta B \times A_e \times f_s} \tag{1}$$

Where  $V_{DD}$  is the voltage across the primary winding,  $f_s$  is the switching frequency,  $\Delta B$  is the peak-to-peak flux density change during half of the switching period, and  $A_e$  is the equivalent cross section area of the core. When  $V_{OA}$  drives high and  $V_{OB}$  drives low, Q1 is turned on and Q2 is turned off. When  $V_{OB}$  drives high and  $V_{OA}$  drives low, Q2 is turned on and Q1 is turned off. Note that this gate drive transformer is suitable for symmetrical half bridge, but not for asymmetrical half bridge or other active clamp topology.

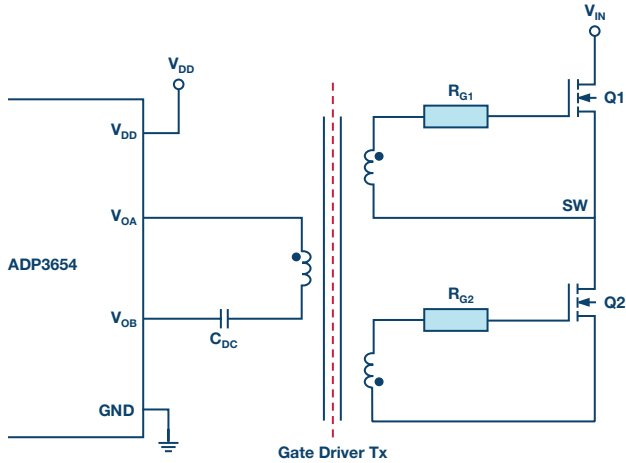


Figure 2. Double-ended gate drive transformer.

### Digital Isolator

Figure 3 shows a block diagram of a digital power supply, which implements a digital isolator solution. The dual-channel digital isolator ADuM3210 is used as digital isolation to transfer the PWM signals from the secondary side controller ADP1051 to the primary side half bridge driver.

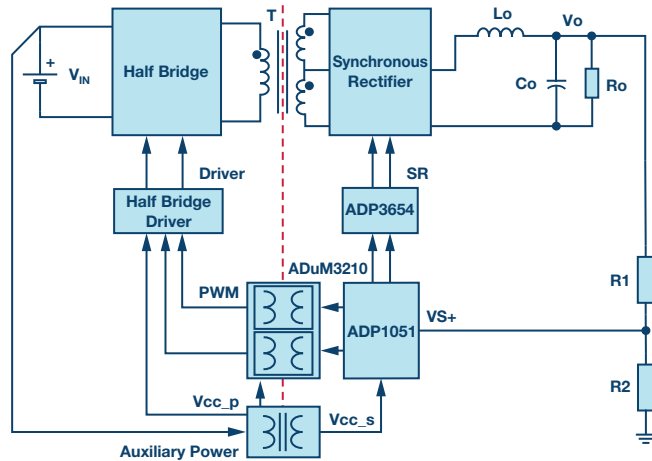


Figure 3. Digital isolator solution.

Compared to the complex gate drive transformer design, the digital isolator solution is smaller, more reliable, and simpler to use. There is no limitation to the duty cycle and this solution does not have the saturation issue. Because it saves over 50% PCB space, this solution can achieve a high power density design.

Figure 7. Linear optocoupler solution.

## General Optocoupler with Standard Amplifier

Another circuit can be applied to realize primary side control using a general optocoupler and a standard amplifier, which is shown in Figure 8. In this case, high output voltage accuracy is achieved without suffering from the wide CTR range of the optocoupler due to temperature changes. The measurement results show the output voltage variation is in the range of  $\pm 1\%$ , with the CTR range from 100% to 200%.

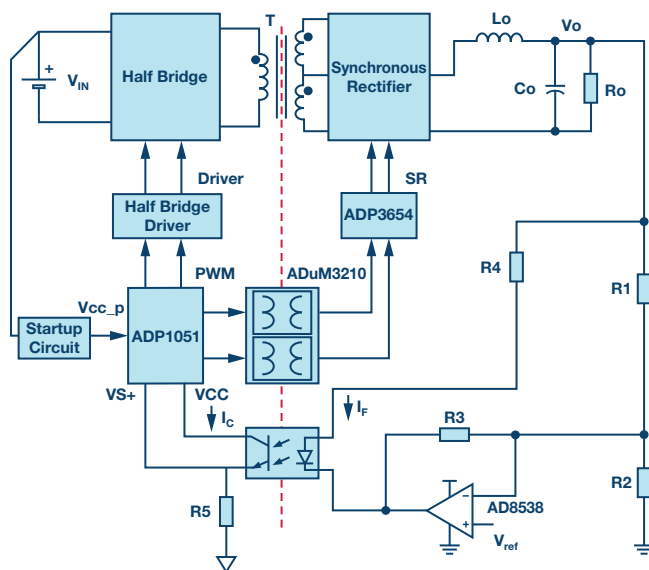


Figure 8. Optocoupler with amplifier solution.

The formula of CTR is

$$CTR = \frac{I_C}{I_F} \times 100\% \quad (2)$$

When CTR changes with temperature, the output of the amplifier will compensate the changes to maintain high accuracy on the output voltage. Note that the stable operation point and the swing range of the amplifier should be well designed to satisfy the CTR variation with the temperature requirement, in case the output of the amplifier saturates.

## Isolated Amplifier

The third method is the isolated amplifier, like the ADuM3190, which is shown in Figure 9. The ADuM3190 is an isolated amplifier that is ideal for linear feedback power supplies with primary side controllers, due to its high bandwidth and high accuracy compared to an optocoupler. This enables improvements in transient response, power density, and stability, as compared to commonly used optocoupler and shunt regulator solutions. With the proper design, the ADuM3190 can achieve  $\pm 1\%$  output voltage accuracy.

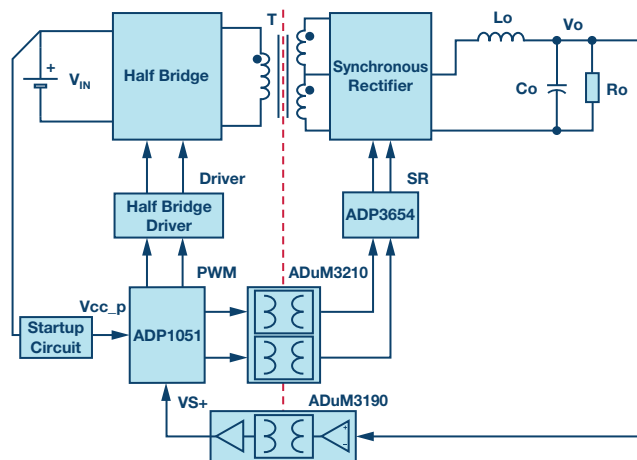


Figure 9. Isolated amplifier solution.

## Conclusion

Because of the increasing requirement for safety, high reliability, high power density, and intelligent management in today's power system in telecom, networking, and computer, isolation techniques will play more and more important role. Compared with traditional optocoupler and transformer solutions, Analog Devices' iCoupler ADuM3210, ADuM7223, and ADuM3190 with the digital power controller ADP1051 provide a high reliability, high bandwidth, and high power density solution.

## Reference

- 1 Baoxing Chen. "Microtransformer Isolation Benefits Digital Control." *Power Electronics Technology*, October, 2008.
- 2 ADP1051 Data Sheet. Analog Devices, Inc., 2014.

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Jason Duan received his B.S. and M.S. degrees in electrical engineering from Xi'an Jiaotong University in 2000 and 2003, respectively. He joined ADI Shanghai's Power Management Department in 2007. In 2013, he transferred from the Shanghai site to the San Jose site as a senior applications engineer. He currently focuses on the field of power electronics, including developing advanced digital power controller, ultralow noise linear regulator, and multiple channels PMU products. He can be reached at [jason.duan@analog.com](mailto:jason.duan@analog.com).

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