Application Report

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UCC24630 and UCC24636 Synchronous Rectifier Controller Configurations Guide

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ABSTRACT

The UCC24630/636 synchronous rectifier controllers are high-performance controllers and drivers for N-channel MOSFET power devices used for secondary-side synchronous rectification. The data sheets of the UCC24630 and UCC24636 devices show them in ground-referenced configurations only, apparently limiting the use cases of the devices. However, these devices can also be configured to be used in non-ground-referenced situations and where the output voltage is higher than the $V_{CC(MAX)}$ limit of the device. This guide will demonstrate implementations for high-side and low-side synchronous rectifiers different from those in the data sheets.

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Trademarks

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1 Purpose of the Synchronous Rectifier

The synchronous rectifier (SR) MOSFET replaces the diode as the output rectifier, thereby drastically reducing the conduction losses. The UCC23630/636 use Volt-second balancing rather than V_{DS}-sensing to control the SR MOSFET in CCM and DCM Flyback converters, respectively. This control method allows the use of MOSFETs with very low $R_{DS(on)}$ which minimizes conduction loses.

2 When to Use Which Controller

Use the UCC24630 for Continuous Conduction Mode (CCM) Flyback SR applications that operate at a fixed or slowly-varying frequency. The UCC24630 can also work in Discontinuous Conduction Mode (DCM), but the CCM-specific features may prove to be an unnecessary burden on DCM-only operation. The UCC24636 is an SR device for DCM and Quasi-Resonant (QR) Flyback converters, and is not suitable for use in CCM applications.

While the CCM-specific features have been removed, the UCC24636 accommodates for the need of widely-varying switching frequency. Both devices can be used in either high-side or low-side applications.

Typically low-side SR is simplest and easiest to design, whereas high-side SR requires some design adjustments and extra circuitry. Despite the complexity, high-side SR is often preferred due to its better EMI performance.

NOTE: This configuration guide should not be used in place of the data sheet, but in conjunction with it for SR design.

3 Comparison Table

Table 1. Configuration Comparison Table

CONFIGURATION	PROS	CONS
Low-Side SR	• GND-referenced MOSFET drive and direct power from V_{OUT} , for $V_{OUT} < V_{CC(max)}$ • Fewest amount of parts • No need for bias winding on transformer	• Capacitance of drain node may increase possibility of higher EMI • "Quiet" side of transformer winding is V_{OUT}, with (small) ripple voltage
High-Side with Bias Winding	• Allows heatsinking of MOSFET drain to "quiet" V_{OUT} or GND nodes • "Quiet" side of transformer winding is GND • Non-ultrafast diode D_B helps V_{BIAS} track V_{OUT} better	• Needs bias winding on transformer • VSC is indirect reflection of V_{OUT}, changes slowed by C_{VDD} • Entire SR control rides on switched voltage at high dv/dt
High Side without Bias Winding	• Allows heatsinking of MOSFET drain to "quiet" V_{OUT} or GND nodes • "Quiet" side of transformer is GND • No need for bias winding on transformer	• VSC is fixed to maximum expected V_{OUT}, no changes in V_{OUT} are detected • SR on-time is shorter than desired when V_{OUT} is low • Entire SR control rides on switched voltage at high dv/dt • May need LDO at R_B • Large amount of parts

Figure 1, Figure 2, and Figure 3 show typical SR implantations using the UCC24630. The same configurations apply when using the UCC24636.

4 UCC24630/636 Used in Low-side SR

The simplest low-side implementation for both devices is under the condition that $V_{OUT(max)} < V_{DD\_ABS\_MAX}$.

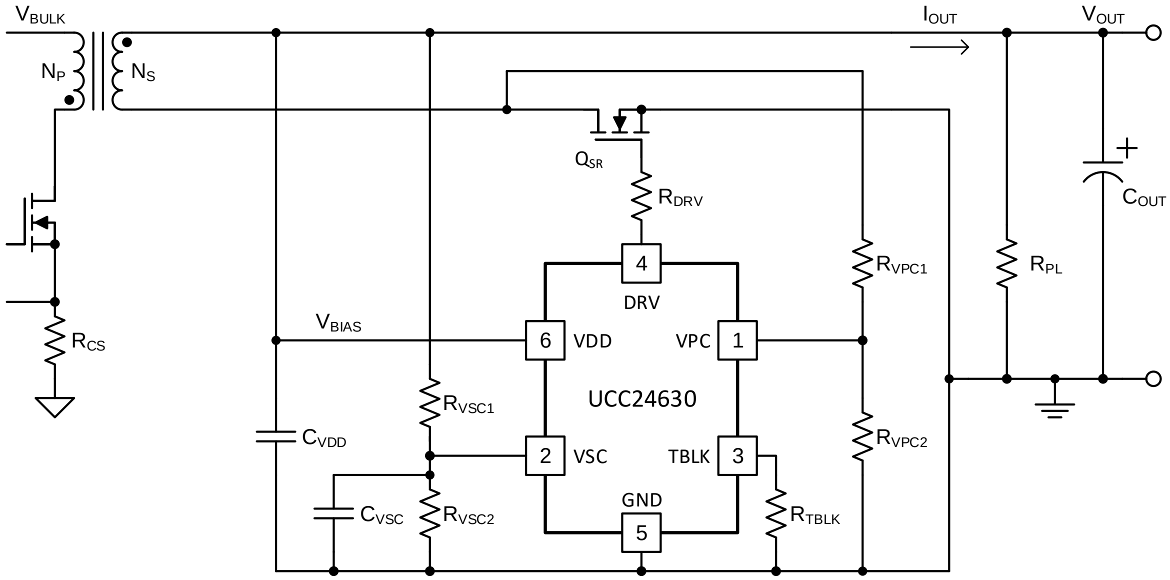

Figure 1. Low-Side SR Configuration

Setting R_{VPC1} and R_{VSC1} is done so using the following equations:

$$R_{VPC1} = \left[\frac{\left(\frac{V_{BULK\ (min)}}{N_{PS}} + V_{OUT\ (min)} \right)}{V_{VPCEN\ (max)} \times 1.1} - 1 \right] R_{VPC2} \tag{1}$$

where

- $V_{BULK(min)}$ is the converter minimum bulk capacitor voltage
- $V_{OUT(min)}$ is the minimum converter output operating voltage
- N_{PS} is the transformer primary to secondary turns ratio
- $V_{VPCEN(max)}$ = 0.45 V; synchronous rectifier enable voltage (1)

$$R_{VSC1} = \left[\frac{\left(\frac{R_{VPC1}}{R_{VPC2}} + 1 \right)}{Ratio_{VPC\_VSC} \times 1.1} - 1 \right] R_{VSC2} \tag{2}$$

where

- $Ratio_{VPC\_VSC}$ = 4.15; Current emulator gain K_{VPC} / K_{VSC} (2)

The values for R_{VPC2} and R_{VSC2} are suggested to be set as R_{VPC2} to 10 kΩ and R_{VSC2} to 47 kΩ to balance a trade-off between speed and stand-by power. Other values may be chosen at the designer's discretion.

A more in-depth guide to selecting R_{VPC2} and R_{VSC2} resistors can be found in section 8.3.2 in the UCC24636 datasheet.

5 UCC24630/636 Used in High-Side SR with Bias Winding

The following configurations sections show the UCC24630/636 used in configurations not shown in the datasheet and how to accommodate component values in design. The terms highlighted in **red** are modifications to the standard TI low-side SR equations.

In the configuration of Figure 2, the bias winding provides power to the device floating on the secondary switching node. Here, V_{BIAS} tracks V_{OUT} through N_{BS} and can be used as a source for the VSC-divider input.

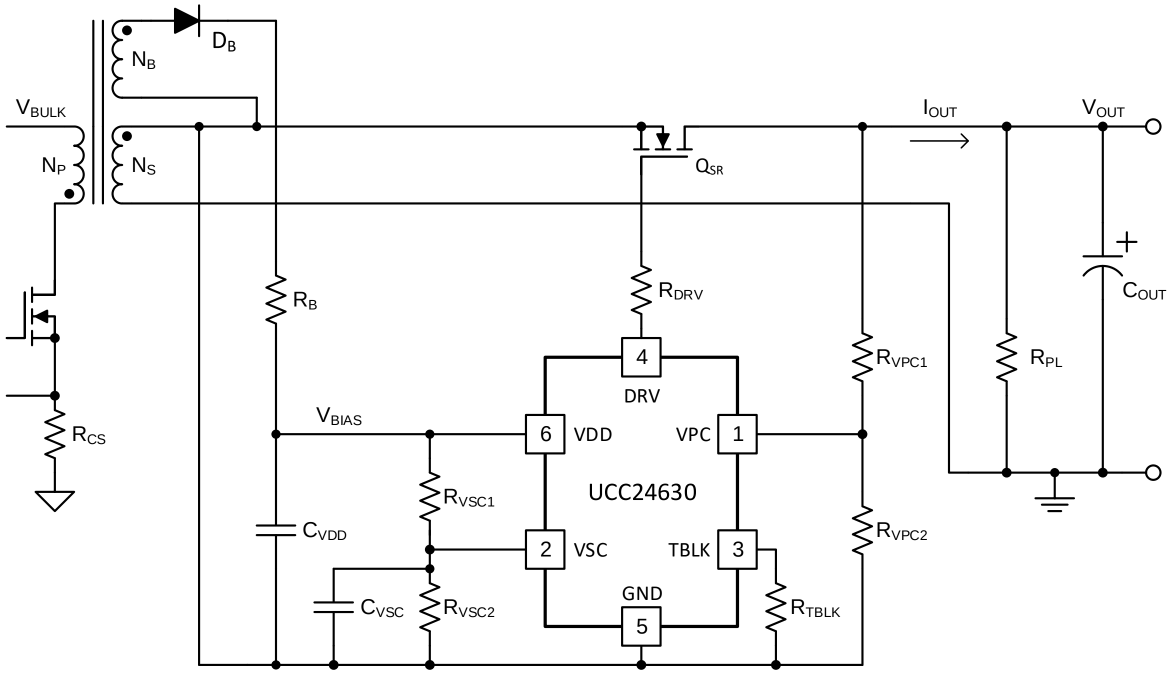

Figure 2. High-Side SR Configuration with Bias Winding

Setting R_{VPC1} and R_{VSC1} is done so using the following equations:

$$R_{VPC1} = \left[\frac{\left(\frac{V_{BULK\ (min)}}{N_{PS}} + V_{OUT\ (min)} \right)}{V_{VPCEN\ (max)} \times 1.1} - 1 \right] R_{VPC2} \tag{3}$$

$$R_{VSC1} = \left[\frac{N_{BS} \left(\frac{R_{VPC1}}{R_{VPC2}} + 1 \right)}{k_{VS}\ Ratio_{VPC\_VSC} \times 1.1} - 1 \right] R_{VSC2} \tag{4}$$

$$N_{BS} = \frac{N_B}{N_S}$$

where

- N_{BS} is the bias winding to secondary winding turns ratio (5)

$$N_{BS} < \frac{VDD_{ABS\_MAX}}{V_{OUT(max)}}$$

where

- $V_{OUT(max)}$ is the maximum converter output operating voltage (6)

$$k_{VS} = \frac{N_{BS} V_{OUT(min)}}{N_{BS} V_{OUT(min)} - V_{DB}}$$

where

- V_{DB} is the voltage drop of diode D_B (7)

Be aware that $V_{OUT(min)}$ and $V_{OUT(max)}$ are different values used in different places.

The values for R_{VPC2} and R_{VSC2} are suggested to be set as R_{VPC2} to 10 kΩ and R_{VSC2} to 47 kΩ to balance a trade-off between speed and stand-by power. Other values may be chosen at the designer's discretion.

A more in-depth guide to selecting R_{VPC2} and R_{VSC2} resistors can be found in section 8.3.2 in the UCC24636 datasheet.

6 UCC24630/636 Used in High-Side SR without Bias Winding

This configuration does not use a bias winding to power the controller. Here, V_{BIAS} is not able to track V_{OUT}, so D_Z must be used as a fixed source for the VSC-divider input. SR on-time is shorter than expected when V_{OUT} is low. A 5.1-V low current Zener diode such as the NXP PLVA6xxA series diodes is a good place to start with to avoid higher current losses as well as variations in operation due to temperature coefficients.

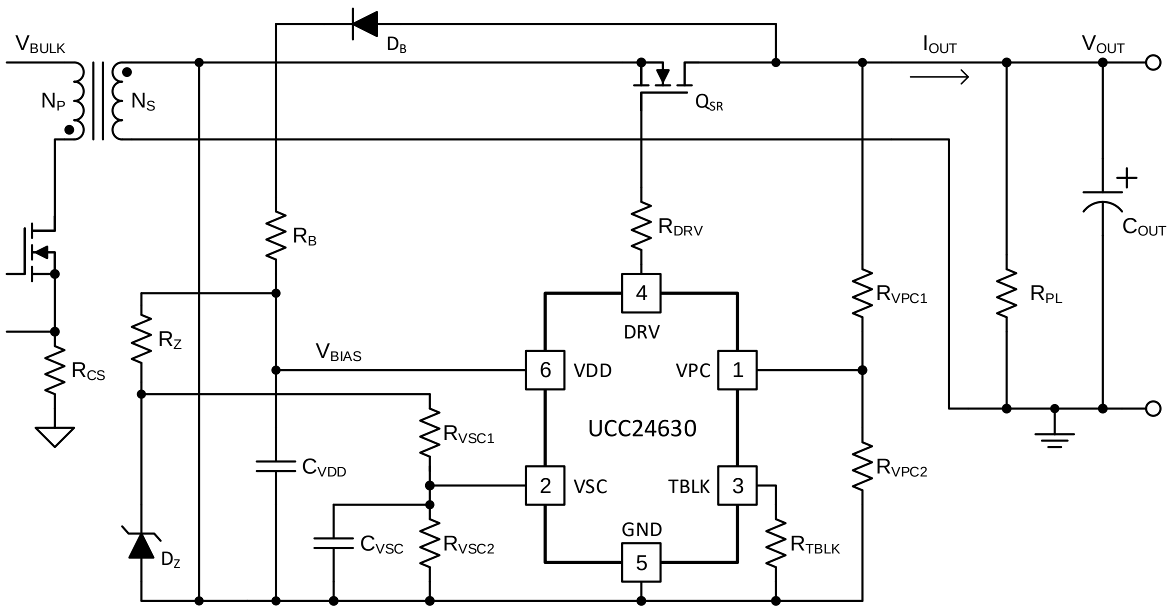

Figure 3. High-Side SR Configuration Without Bias Winding

Setting R_{VPC1} and R_{VSC1} is done so using the following equations:

$$R_{VPC1} = \left[\frac{\left(\frac{V_{BULK\ (min)}}{N_{PS}} + V_{OUT\ (min)} \right)}{V_{VPCEN\ (max)} \times 1.1} - 1 \right] R_{VPC2} \quad (8)$$

$$R_{VSC1} = \left[\frac{\left(\frac{R_{VPC1}}{R_{VPC2}} + 1 \right)}{k_{vZ}\ Ratio_{VPC\_VSC} \times 1.1} - 1 \right] R_{VSC2} \quad (9)$$

$$\frac{V_{BULK(max)}}{N_{PS}} + V_{OUT(max)} - V_{DB} < VDD_{ABS\_MAX} \quad (10)$$

where

- V_{DB} is the voltage drop of diode D_B
- $V_{BULK(max)}$ is the converter maximum primary bulk capacitor voltage

$$k_{vZ} = \frac{V_{DZ}}{V_{OUT(max)}} \quad (11)$$

where

- V_{DZ} is the voltage of Zener diode D_Z. Choose V_{DZ} to keep losses in R_Z and R_B low.

NOTE: An LDO may be required in place of R_B to keep VDD within its allowable range.

The values for R_{VPC2} and R_{VSC2} are suggested to be set to R_{VPC2} to 10 kΩ and R_{VSC2} to 47 kΩ to balance a trade-off between speed and stand-by power. Other values may be chosen at the designer's discretion.

A more in-depth guide to selecting R_{VPC2} and R_{VSC2} resistors can be found in section 8.3.2 in the UCC24636 datasheet.