

SIZING THE UCC3919 CHARGE-PUMP CAPACITOR

Edward Jung

PMP Systems Powers

ABSTRACT

The UCC3919 works in most hot-swap designs with the charge-pump capacitance recommended in the UCC3919 data sheet. However, this capacitance may be inadequate in high-current designs. This application report describes a method to size the charge-pump capacitance to ensure proper UCC3919 operation in any hot-swap design.

1 Introduction

An internal charge pump boosts the supply voltage to the UCC3919 linear current amplifier (LCA). This allows the LCA to drive a high-side, low-cost N-channel FET instead of a more expensive P-channel FET. Because of its high source impedance (i.e., 100 k Ω), the charge-pump output voltage droops when the LCA turns on the hot-swap FET. The amount of droop increases with the gate voltage slew rate and capacitance. If the droop is large enough to trip the charge-pump UVLO comparator, then the LCA shuts off, and it is not possible to turn on the FET. The UCC3919 data sheet recommends a 0.01- μ F to 0.1- μ F external charge-pump capacitor to provide adequate charge. This capacitance range is satisfactory for low-to-moderate current hot-swap designs. High-current hot-swap designs that use a larger FET require more capacitance. Instead of a *one size fits all* approach to selecting the charge-pump capacitance, an equation that customizes the charge-pump capacitance to the application is desirable. This application report presents a practical model of the UCC3919 and derives such an equation. This equation also applies to the UCC2919, an industrial-grade version of the UCC3919.

2 Turnon

Figure 1 is a simplified circuit model of the UCC3919 that shows only the LCA, charge pump, and charge-pump comparator. The turnon voltages are shown in Figure 2.

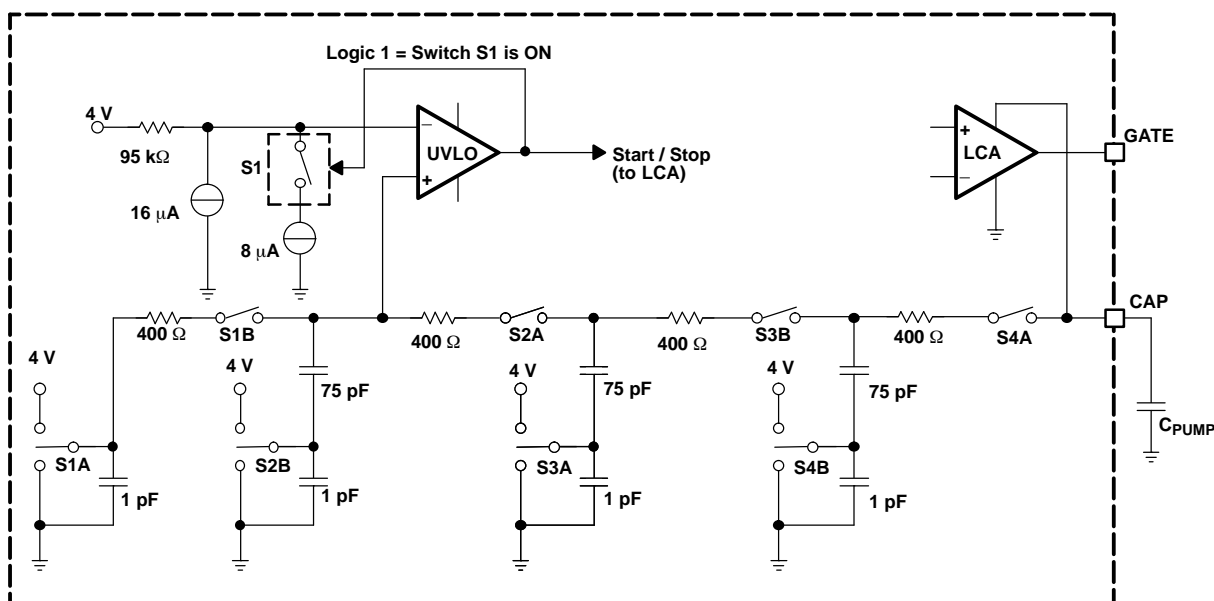


Figure 1. A Simplified UCC3919 Circuit Model

The UCC3919 charges capacitor C_{PUMP} when the \overline{SD} input de-asserts. The UVLO comparator enables the LCA when the capacitor voltage rises to V_{START} , the charge-pump UVLO minimum voltage to start. For the UCC3919 example in Figure 2, V_{START} is approximately 9 V. Figure 2 shows the UCC3919 turning on with different C_{PUMP} capacitors. Note that the hot-swap FET turnon delay is proportional to C_{PUMP} .

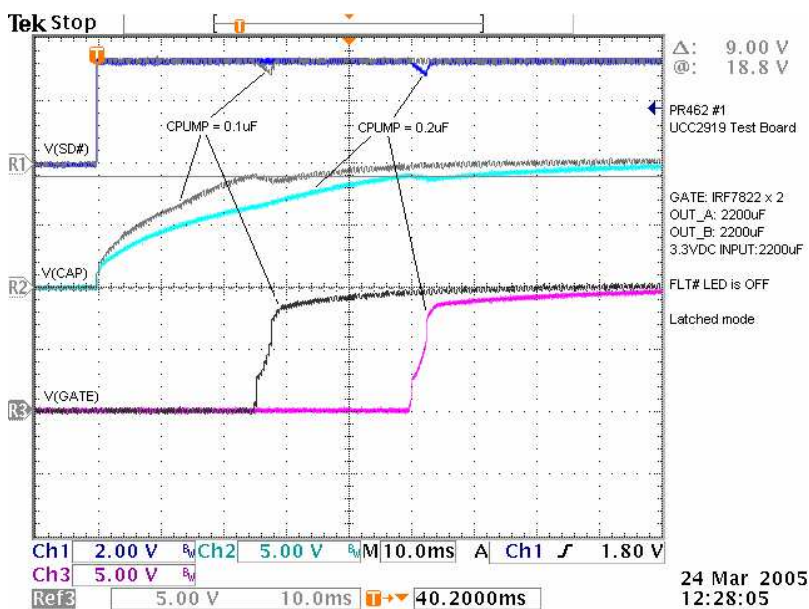


Figure 2. Typical UCC3919 Voltages at Turnon

3 SIZING C_{PUMP} FOR A PARTICULAR APPLICATION

Figure 3 shows a gate-drive circuit model that can be used to calculate the charge-pump capacitance.

The R_O represents the equivalent LCA output resistance, V_{CAP} represents the charge-pump output voltage, and C_g models the FET gate capacitance. The charge-pump voltage V_{CAP} rises to V_{START} just before switch SW1 closes. The closing of switch SW1 models the LCA turning on. The voltage source V_{OUT} represents the load voltage when the hot-swap FET is on.

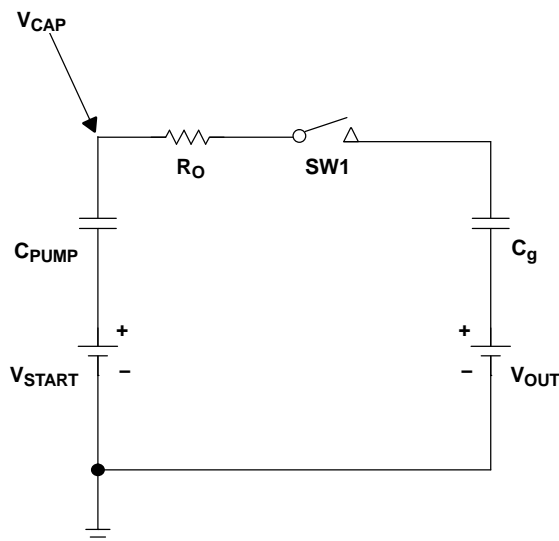


Figure 3. UCC3919 Gate-Drive Circuit Model.

When switch SW1 closes, charge from capacitor C_{PUMP} transfers to capacitor C_g causing the charge-pump voltage to drop by ΔV_{CAP} . Equation 1 describes this relationship.

$$C_{PUMP} = \frac{\Delta Q_{PUMP}}{\Delta V_{CAP}} \quad (1)$$

The charge lost by capacitor C_{PUMP} is gained by capacitor C_g .

$$\Delta Q_{PUMP} = \Delta Q_G \Big|_{V_{GS} = (V_{START} - V_{OUT} - V_{HYST})} \quad (2)$$

To ensure proper turnon, the charge-pump voltage droop must be less than the UVLO comparator hysteresis.

$$\Delta V_{CAP} \leq V_{HYST} \quad (3)$$

Combine equations (1), (2), and (3) to get Equation 4.

$$C_{PUMP} \geq \frac{\Delta Q_G}{V_{HYST}} \Big|_{V_{GS} = (V_{START} - V_{OUT} - V_{HYST})} \quad (4)$$

For a worst-case calculation, use the maximum value for V_{START} and the minimum value for V_{HYST} in Equation 5.

UCC3919 production data over temperature and the V_{DD} supply voltage show that:

$$V_{START} (\text{max}) = 11 \text{ V}$$

$$V_{HYST} (\text{min}) = 0.7 \text{ V}$$

Therefore:

SUMMARY

$$C_{\text{PUMP}} \geq \frac{\Delta Q_G}{0.7 \text{ V}} \bigg|_{V_{\text{GS}} = (10.3 \text{ V} - V_{\text{OUT}})} \quad (5)$$

As an example, consider a 3.3-V output hot-swap design that drives three IRF7822 FETs. The curve in [Figure 4](#) shows 58.75 nC of gate charge for a gate-to-source voltage of 7 V. Thus, the required charge-pump capacitance is

$$C_{\text{PUMP}} \geq \frac{58.75 \text{ nC} \times 3}{0.7 \text{ V}} = 0.252 \text{ } \mu\text{F} \quad (6)$$

A standard $0.33\text{-}\mu\text{F} \pm 10\%$ X7R dielectric capacitor works for this design. Note that 10% is the capacitor's initial tolerance. This tolerance is measured at room temperature and zero-bias voltage. The actual tolerance is higher when the capacitor's operating temperature and operating voltage are considered.

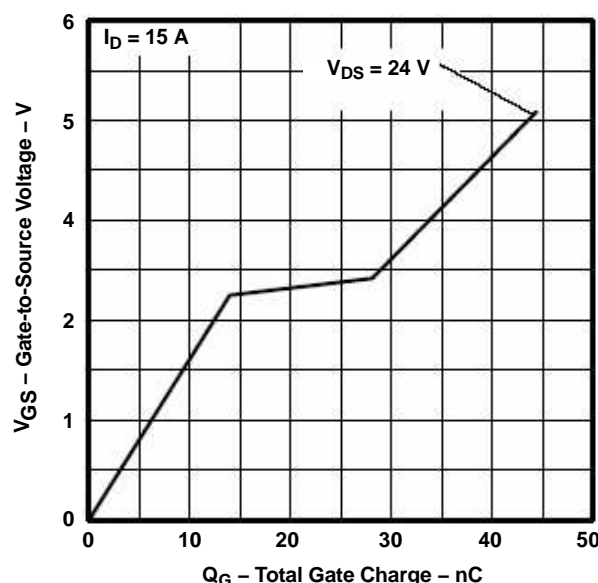


Figure 4. IRF7822 Gate Charge vs Gate-to-Source Voltage ⁽¹⁾

⁽¹⁾ Reprinted with permission from International Rectifier; Fig 2, page 3, International Rectifier IRF7822 datasheet.

4 SUMMARY

The UCC3919 works in a low-to-moderate current, hot-swap design with a 0.01- μF to 0.1- μF capacitance at the CAP pin as recommended in the data sheet ([SLUS374](#)). A high-current, hot-swap design that uses a larger FET requires more capacitance. This capacitance can be determined using the simple approach presented in this application report. The larger capacitance increases the hot-swap FET turnon delay but has no other effect on the UCC3919.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		Applications	
Amplifiers	amplifier.ti.com	Audio	www.ti.com/audio
Data Converters	dataconverter.ti.com	Automotive	www.ti.com/automotive
DSP	dsp.ti.com	Broadband	www.ti.com/broadband
Interface	interface.ti.com	Digital Control	www.ti.com/digitalcontrol
Logic	logic.ti.com	Military	www.ti.com/military
Power Mgmt	power.ti.com	Optical Networking	www.ti.com/opticalnetwork
Microcontrollers	microcontroller.ti.com	Security	www.ti.com/security
		Telephony	www.ti.com/telephony
		Video & Imaging	www.ti.com/video
		Wireless	www.ti.com/wireless

Mailing Address: Texas Instruments
Post Office Box 655303 Dallas, Texas 75265

Copyright © 2005, Texas Instruments Incorporated