

Application Note

Using the XTR200 for M-CRPS Current Monitor Outputs



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ABSTRACT

High performance power supplies for server, cloud, or AI applications incorporate an output current monitoring pin which provides a scaled down representation of the output current. This current monitoring function provides valuable information about the real-time output current on different voltage buses. Current transmitter products, such as the XTR200, are useful building blocks for performing the current monitor function. These devices convert an input voltage to an output current with a transfer function specified by a single external resistor. The XTR200 also integrates the output transistor, protection circuitry, and diagnostic capabilities in an extremely small 2mm x 3mm WSON package. This application note gives an example circuit for a current monitor output designed to meet the requirements outlined in the OCP M-CRPS Base Specification and progresses through the relevant design steps for engineers to adapt this design to other applications.

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1 Introduction

High performance power supplies for server applications incorporate an output current monitoring pin which provides a scaled down representation of the output current. This current monitoring function provides valuable information about the real-time output current on different voltage buses. The current monitor pins from multiple power supplies can also be joined together to measure the total output current on multiple buses.

Current transmitter products, such as the XTR200, are useful building blocks for performing the current monitor function. These devices convert an input voltage to an output current with a transfer function specified by a single external resistor. The XTR200 also integrates the output transistor, protection circuitry, and diagnostic capabilities in an extremely small 2mm × 3mm WSON package that is designed for space-constrained power supply and motherboard PCBs.

The Open Compute Project (OCP), which is a collaboration between multiple companies, has defined a standard for power supplies called the *Modular Hardware System – Common Redundant Power Supply (M-CRPS) Base Specification* [1]. The standards document clearly outlines several requirements for current monitoring outputs which allows interoperability across hardware from multiple manufacturers. The requirements for M-CRPS current monitoring outputs are outlined in [Table 1-1](#):

Table 1-1. Summary of Current Monitor Output Requirements from the M-CRPS Base Specification

Specification	Value	Comments
Sensitivity	0mA to 2mA (0% to 200% rated current) or 10μA/A (range of 0% to 200% rated current)	User selectable
Minimum bandwidth	40kHz	
Compliance voltage	3.3V	I _{mon} signal cannot exceed 3.3V under normal or abnormal operating conditions
Signal delay	≤20μs	5% to 105% load step, 8A/μs edge rate without external capacitance on power supply
Input leakage	<500nA	Verified at 85°C and 12V. Power supply not energized, in standby, or in cold redundant mode
Tolerance	15% at 10% rated current 2% at 140% rated current	

2 Detailed Description

An example current monitoring circuit is shown in [Figure 2-1](#). The circuit consists of three parts: current measurement, current transmission, and additional output circuitry for clamping and backwards compatibility. The design process in this document uses a hypothetical 12V power supply with a 50A rated output current capacity, but the concepts are applicable to all power supplies.

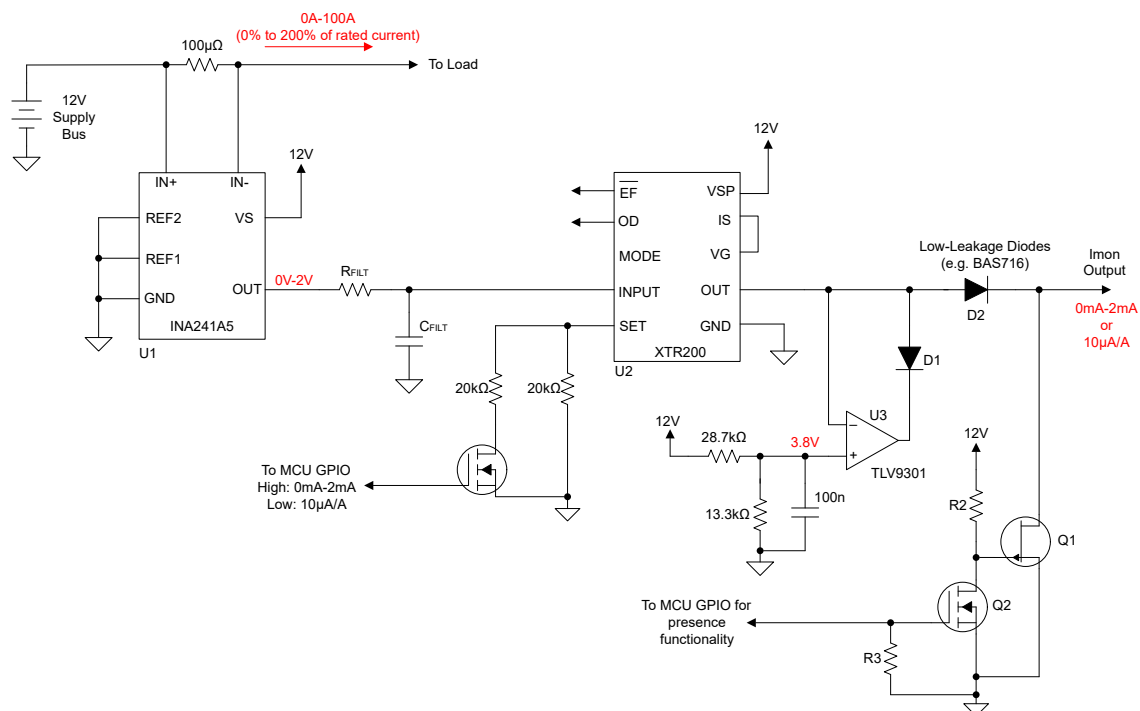


Figure 2-1. Simplified Schematic of a Current Monitor Output for a 50A Rated, 12V Power Supply

2.1 Current Measurement

[Figure 2-2](#) highlights the current measurement portion of the circuit. This function is based on the INA241 high-precision current measurement amplifier [2]. The device's extremely low (8µV, max) input offset voltage and (100nV/°C, max) drift enable very low value shunt resistors. The 100µΩ shunt resistor shown in the example schematic produces a voltage drop of 5mV at 50A of output current and 10mV at 100A (200% rated capacity). The "A5" variant of the INA241 has a fixed voltage gain of 200V/V. Therefore, at 200% rated output current (100A) the INA241A5 produces an output voltage of 2V.

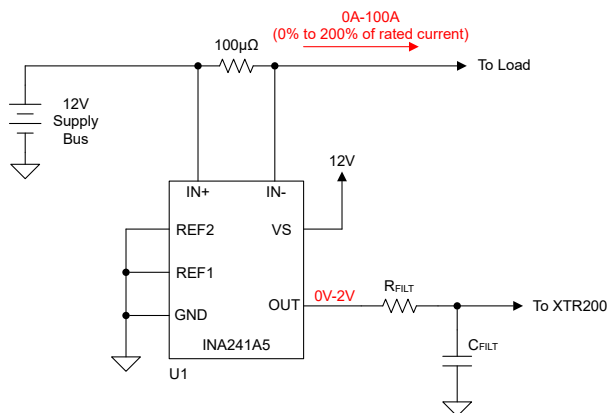


Figure 2-2. Current Measurement Portion Based on the INA241A5

Both reference pins on the INA241A5 are shown tied to ground such that at 0A output current, the INA241A5 output tries to reach 0V. However, the minimum output voltage of the INA241A5 is specified at 20mV max which translates to a minimum measurable current of 1A for a 100μΩ shunt. Above the minimum output voltage, error in the measurement comes predominantly from the INA241A5's maximum input offset voltage, 8μV. This offset voltage equates to 80mA of error in the current measurement, or 1.6% error at 10% rated output, which is well within the tolerance guidelines of the M-CRPS specification. An optional low-pass filter circuit consisting of R_{FILT} and C_{FILT} is shown in the schematic if bandwidth limiting is desired. The unfiltered -3dB bandwidth of the INA241A5 is 1.1MHz which is more than capable of achieving the <20μs signal delay requirement.

2.2 Current Transmission

In the current transmission portion, illustrated in Figure 2-3, the XTR200 converts the 0V to 2V output signal from the INA241A5 into a current output with a transfer function defined by the resistance between the SET pin and ground, called R_{SET}. The XTR200 is an extremely convenient building block for this function because the device integrates two op amps, precision resistors, an output transistor, and diagnostic and protection features in an extremely small 2mm x 3mm WSON package [3].

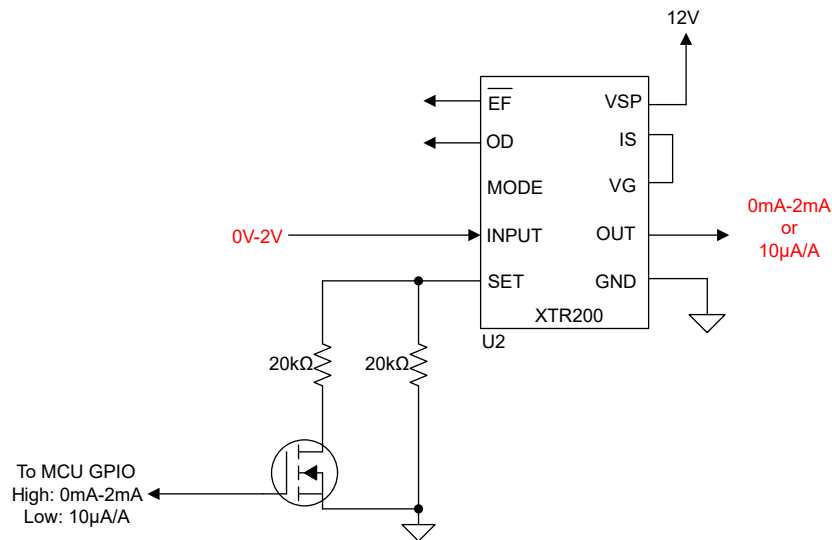


Figure 2-3. An XTR200 Converts the Output Voltage of the INA241A5 into the Monitor Current

The M-CRPS standard requires the current monitor to have a user-selectable transfer function of either 10μA per Amp of output current or 0mA to 2mA representing 0% to 200% of rated output current. Therefore, at 100A of output current, the XTR200 delivers either 1mA (10μA/A) or 2mA indicating 200% of rated output current for a 2V input signal from the INA241A5. The R_{SET} values for both cases can be calculated using Equation 1 and Equation 2.

$$R_{SET} = \frac{10 \cdot V_{IN}}{I_{OUT}} = \frac{10 \cdot 2V}{1mA} = 20k\Omega \quad (1)$$

$$R_{SET} = \frac{10 \cdot V_{IN}}{I_{OUT}} = \frac{10 \cdot 2V}{2mA} = 10k\Omega \quad (2)$$

Because two R_{SET} values are required, an NMOS transistor is shown to switch in a second resistor in parallel with the first. Two, 20kΩ resistors can be used to produce either a 20kΩ or 10kΩ R_{SET} value.

The output disable (OD) pin of the XTR200 can be used to place the output into a high-impedance state. The error flag (EF) pin exerts low in the event of a fault condition such as a short or open at the SET pin, or an over-temperature condition. It's important to note that while the XTR200 error flag normally indicates an open circuit load fault, the clamping circuitry placed after the XTR200 in this example schematic prevents detection of an open circuit fault. The IS and VG pins of the XTR200 are shorted together in Figure 3. These pins are for the use of an external transistor which is not necessary in this application. Shorting the pins together allows the internal output transistor of the XTR200 to deliver the current monitor signal.

Although the input offset voltage of the XTR200 (800µV, max) is larger than the INA241A5, this does not meaningfully degrade the precision of the circuit. The total input offset voltage of the signal path can be calculated by referring the XTR200 offset to the input of the INA241 and combining the two uncorrelated offsets as a root-sum-of-squares as shown in Equation 3:

$$V_{OS(Total)} = \sqrt{V_{os(INA241)}^2 + \left(\frac{V_{OS(XTR200)}}{A_V(INA241)}\right)^2} = \sqrt{(8\mu V)^2 + \left(\frac{800\mu V}{200V/V}\right)^2} = 8.94\mu V \quad (3)$$

This brings the total error in the current measurement to 89.4mA, or 1.8% at 10% rated output. This does not include the tolerance of the 100µΩ shunt resistor or the drift of the circuit over temperature.

2.3 Additional Output Circuitry

Additional circuitry, shown in Figure 2-4, is needed at the output of the XTR200 for compatibility with the M-CRPS standard. Diode D1 and op amp U3 form a clamp circuit which prevents the output voltage (after diode D2) from exceeding 3.3V. If the output voltage from the XTR200 is less than the clamp voltage at the non-inverting input of U3 (3.8V in the schematic), then the output of U3 saturates at the positive supply, reverse-biasing diode D1. However, if the output of the XTR200 exceeds the clamp voltage then the output of U3 goes low and sinks current through D1 to make the voltage at both the op amp's inputs equal. If using a Zener diode for the clamping function, select a low leakage type to avoid impacting the accuracy of the monitor current.

Diode D2 prevents reverse current flow back into the current monitoring circuitry if the circuit is unpowered. The M-CRPS standard defines a strict requirement of less than 500nA of leakage current into the Imon pin at 85°C and 12V. For this reason, both diode D1 and D2 are low-leakage types such as the BAS716. Diode leakage roughly doubles for every 10°C increase in temperature. Therefore, for the circuit to have <500nA of leakage at 85°C, there must be <7.8nA of leakage at 25°C.

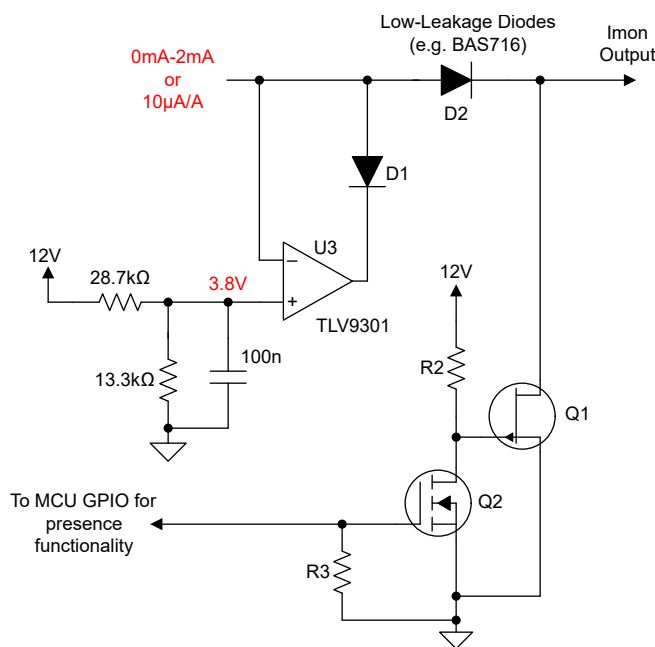


Figure 2-4. Output Clamping and Presence Functionality Circuitry

Transistor Q1 is PJFET which can be used to pull the Imon pin low to implement "presence" functionality. The M-CRPS standard recommends this additional circuitry on the output of the Imon pin to enable backwards compatibility with older systems. Because the leakage through Q1 directly contributes to the output leakage of the pin, a low-leakage PJFET, such as the MMBFJ177 must be used for this functionality. The off-state leakage of a typical NMOS transistor is too high to meet the standard requirements.

2.4 Simulations

The graphs in this section show the simulated performance of the circuit in various operating conditions. [Figure 2-5](#) shows the current monitor output for increasing power supply output current with both sensitivities. The circuit simulates with excellent linearity across a wide range of currents.

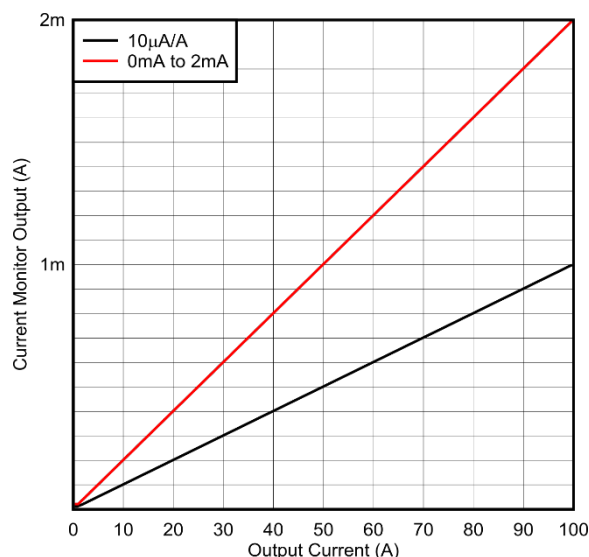


Figure 2-5. DC Transfer Characteristic of Current Monitor Output

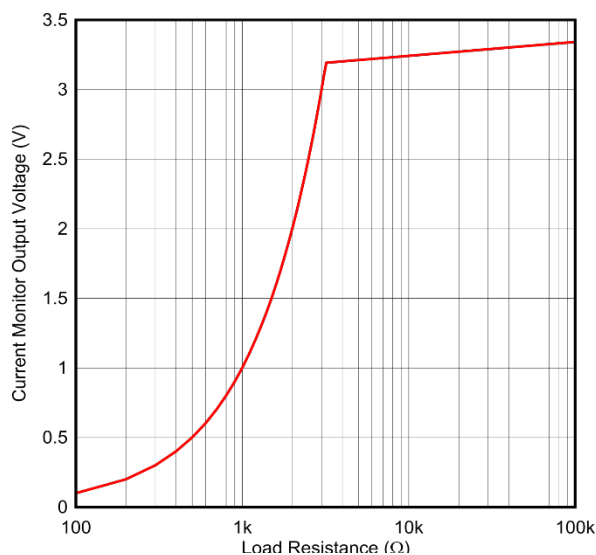


Figure 2-6. Output Voltage for 1mA Monitor Current and Increasing Load Resistance

[Figure 2-6](#) illustrates the clamping functionality of the circuit. The plot shows the output voltage at the current monitor pin for a 1mA monitor current. The load resistance at the monitor pin is swept from 100Ω to 100kΩ. At 3.3kΩ of load resistance, the output voltage reaches 3.3V and the monitor circuit begins to clamp the output voltage. As the load resistance continues to increase, the output voltage remains relatively flat at 3.3V as the M-CRPS standard requires.

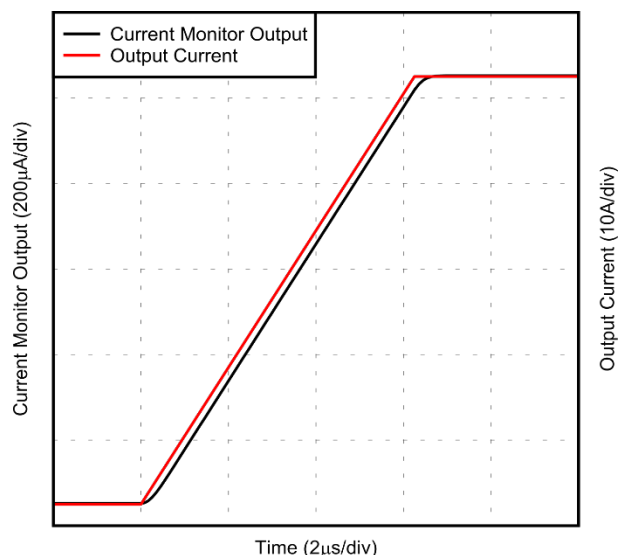


Figure 2-7. Rising Edge Transient Response of Current Monitor Output for 5% to 105% Load Step

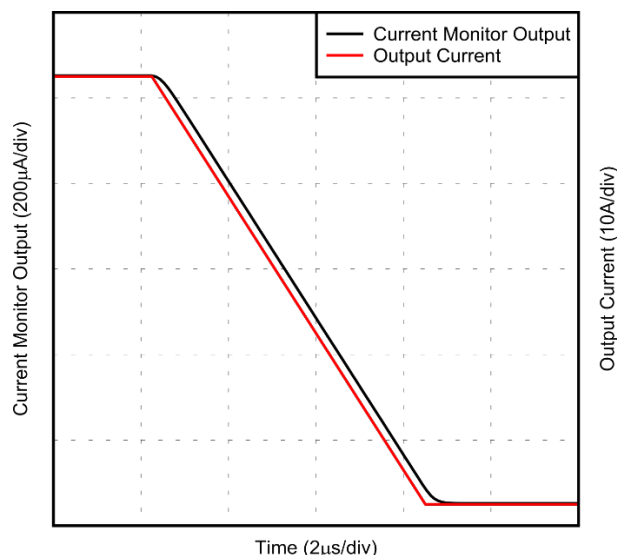


Figure 2-8. Falling Edge Transient Response of Current Monitor Output for 105% to 5% Load Step

Figure 2-7 and Figure 2-8 show the rising and falling transient response of the monitor circuit for a 5% to 105% (2.5A to 52.5A) load step, returning to 5%, with 8A/ μ s edge rates. The wide bandwidth of the XTR200 and the INA241A5 allows the monitor current to track the power supply output current with minimal delay or overshoot. The signal delay is far below the 20 μ s requirement of the standard.

3 Summary

This document outlines the key considerations when designing current monitor circuitry that complies with the OCP M-CRPS specification. The example circuit shown here makes use of a high-precision current shunt amplifier as well as the XTR200 current transmitter to produce a scaled down representation of the output current on a 12V bus. The use of the XTR200 allows for the sensitivity of the circuit to be user-configurable to meet the required transfer functions in the M-CRPS standard. The circuit additionally includes output clamping to limit the output voltage to approximately 3.3V as well as presence detection functionality for backwards compatibility. Simulations of the circuit's performance show excellent precision, transient response, and clamping functionality. The high performance, small size, and integration make the XTR200 an excellent choice for current monitor outputs in power supplies for enterprise computing applications.

4 References

1. Open Compute Project, [Server/MHS/DC-MHS-Specs-and-Designs](#), webpage.
2. Texas Instruments, [INA241](#), product folder.
3. Texas Instruments, [XTR200](#), product folder.

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