Application Note

Design Example to Implement Automatic Switchover for Backup Power Using TPS2121

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ABSTRACT

This application note introduces automatic switchover design not using GPIO(General Purpose Input Output) signal from MCU (Micro Controller Unit) for increasing battery run time. This is a requirement for applications using solar cell or variable source as main power and battery as backup power. The battery must be used as the power source of the system if main power source gets lower than target voltage to maintain minimum Vout. MCU can be used to monitor the power inputs and select the power source with GPIO between battery and main power source. However, this means MCU must be in active mode even using battery as a power source. This is very critical for the applications which require long battery run time. This report shows how to implement automatic switchover using TPS2121 for longer battery run time with MCU in sleep mode from required application.

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1 Introduction

This design example uses solar cell as a main power source which is a variable source. Main power needs to source the VOUT while it is above the backup power. However, main power can fall below backup power due to weather conditions. If the main power is low, then the system needs to switchover to a backup power source without interrupting normal operation. Without the switchover, this could cause the downstream load to reset or enter an undervoltage lockout condition. The battery is generally used as backup power to maintain minimum VOUT for the system.

Battery must last as long as possible to run the system without interrupting normal operation. To maximize the battery run time, leakage current from the battery needs to be minimized. TPS2121 supports I_{SBY} = 25 µA (max) for disabled input power. With VCOMP mode configuration, TPS2121 can support automatic switchover and minimizes leakage current. Therefore TPS2121 can minimize the leakage current from the battery when the main power is selected as VOUT to the system. See Section 2 for detail about this.

TPS2121 has additional features like over-voltage protection, fast reverse current blocking, active current limiting, and soft start control. Large input capacitors are recommended if switching between high current rails. The capacitors help to provide a temporary power source for stable switchover.

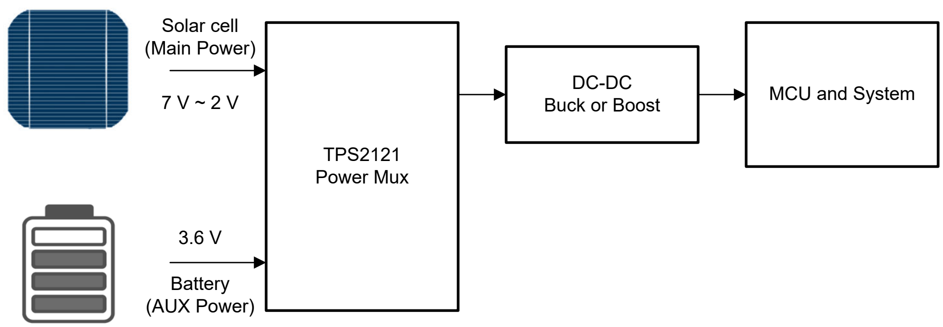


Figure 1-1. Simplified Block Diagram

1.1 Design Example Specification

Table 1-1. Design Example Specification

PARAMETER	SPECIFICATIONS	DETAILS
Main Power (IN1)	VIN1	2 V - 7 V (Solar cell)
Auxiliary Power (IN2)	VIN2	3.6 V (Battery)
Output Voltage	VOUT	Highest voltage between VIN1 and VIN2 (Minimum : VBAT, Maximum : 7V)
Output Capacitance	C_{OUT}	320 µF
Load Current	I_{OUT}	100 mA
Quiescent Current	I_{SBY} (Disabled input)	< 50 µA

2 Design Considerations

2.1 Highest Voltage Operation Scheme (VCOMP)

If both PR1 and CP2 are less than VREF (typ 1.06 V), the device uses an internal comparator between two inputs to determine the priority source. This mode can be easily implemented by pulling down PR1 and CP2 to ground. Figure 2-1 shows simplified application circuit for this configuration.

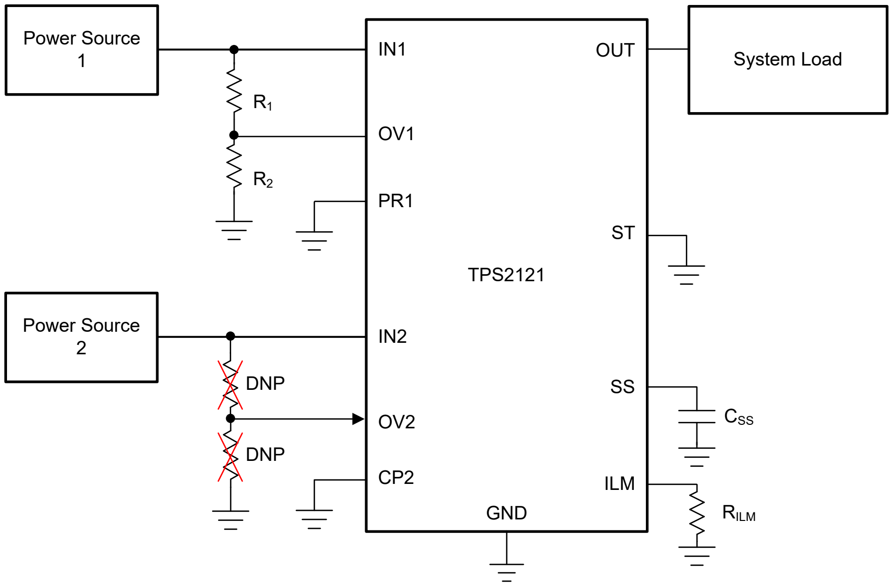


Figure 2-1. Simplified Design Example with VCOMP Configuration

Figure 2-2 shows how V_{COMP} priority source is selected with fixed V_{IN1}. If both of the input voltages are equal, V_{comp} and hysteresis ensures that IN2 takes priority. If IN2 falls below the V_{comp} and hysteresis, then IN1 will have priority. If IN2 gets reapplied, IN2 takes priority when it falls within V_{comp} of IN1. Figure 2-3 shows the case with fixed V_{IN2}. If IN1 rises above the V_{comp} and hysteresis from IN2, then IN1 takes priority. If IN1 falls below the V_{comp} from IN2, IN2 takes priority over IN1.

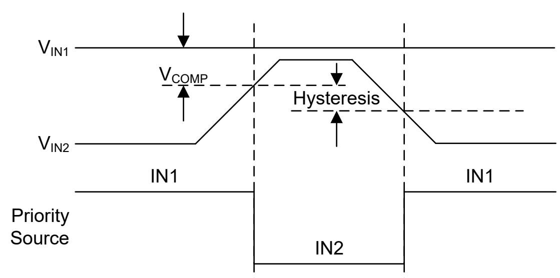


Figure 2-2. VCOMP Priority Source Selection (Fixed V_{IN1})

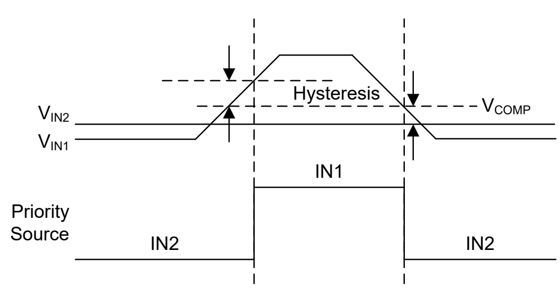


Figure 2-3. VCOMP Priority Source Selection (Fixed V_{IN2})

In this design example, IN2 is used as an auxiliary power source from battery to maintain minimum V_{OUT} as battery voltage. Figure 2-3 shows how V_{COMP} priority source is selected with fixed V_{IN2}. See Figure 2-4 to understand how power selection works by changing the main power and switchover timing. Minimum V_{OUT} is not affected by V_{comp} and hysteresis to maintain minimum V_{OUT}. Auxiliary power source takes priority before main power rises above V_{comp} and the hysteresis voltage.

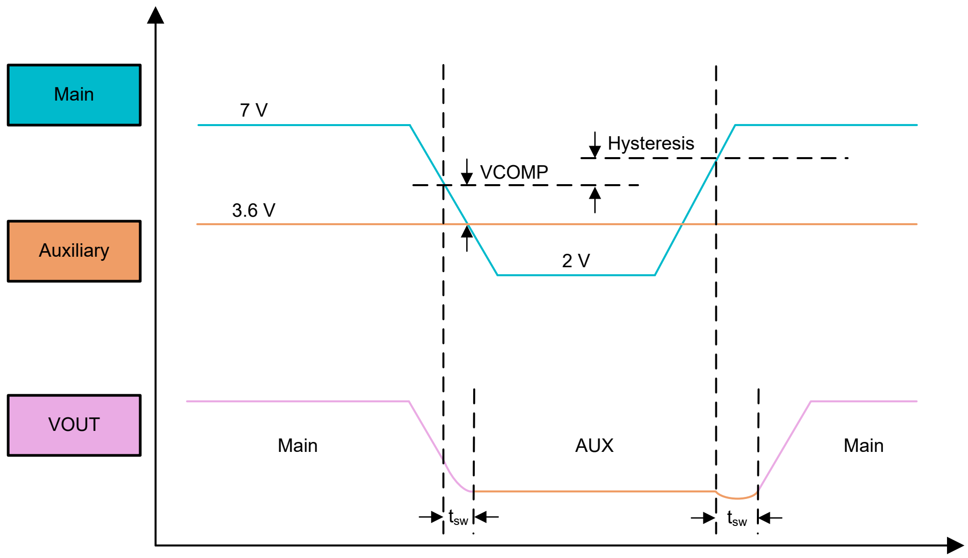


Figure 2-4. Seamless Switchover Timing Diagram

If there is no requirement for minimum V_{OUT}, user can select IN2 as main power and IN1 as auxiliary power. Then the system can maximize the main power range for V_{OUT} since switchover occurs when main power falls below auxiliary power due to V_{comp} and hysteresis. Therefore the system can minimize battery use to save the capacity.

By pulling CP2 down to ground, this process helps eliminate the leakage current. Also it is recommended not to populate resistors for OV2 setting in this design example to remove the additional leakage current from battery. Table 2-1 shows I_Q, I_{SBY} values user can estimate. I_Q is the current from enabled input under no load condition. I_{SBY} is the current from disabled input in no load condition. TPS2121 supports typ 15 µA for I_{SBY}. Therefore it can achieve required quiescent current (<50 µA) in this design example. For further details about specification, see the *TPS212x 2.8-V to 22-V Priority Power MUX with Seamless Switchover* data sheet.

Table 2-1. Specifications for I_Q, I_{SBY}

PARAMETER		TEST CONDITIONS	T_J	MIN	TYP	MAX	UNIT
INPUT SOURCE (IN1, IN2)							
$I_{Q, INx}$	Quiescent Current (INx Powering OUT)	OUT = Open	-40°C to 125°C		300	400	µA
$I_{SBY, INx}$	Standby Current (INx not powering OUT)	$V_{OUT} = V_{INx}$	25°C	0	15	25	µA
			-40°C to 125°C			25	µA

2.2 Output Voltage Dip and Switchover

Once input settles to steady state, TPS2121 utilizes a fast switchover to minimize output voltage dip. However, in VCOMP configuration, TPS2121 does not support fast switchover since CP2 > V_{REF} is the required condition. So normal switchover time is 100 µs. The amount of voltage drop on the output is dependent on the output load current (I_{OUT}), and the load capacitance (C_{OUT}). The minimum output voltage ($V_{OUT,MIN}$) during switchover can be found using the following equations:

$$V_{OUT,\,MIN} = V_{SW} - V_{DIP} \tag{1}$$

$$V_{DIP} = t_{SW} \times \frac{I_{OUT}}{C_{OUT}} \tag{2}$$

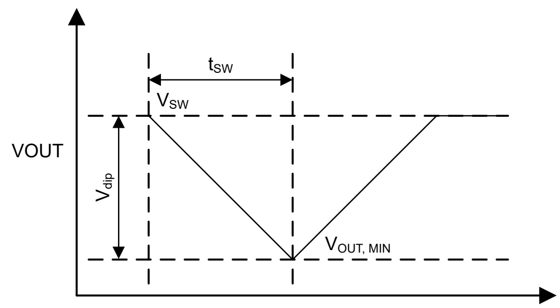


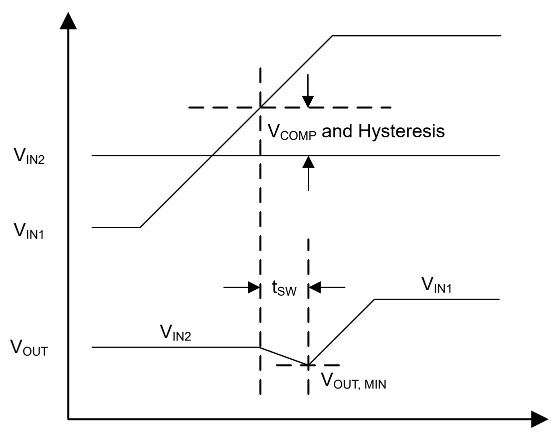
Figure 2-5. Graph of V_{DIP}

V_{DIP} occurs after the device recognizes the voltage on IN1 crosses the switchover thresholds described in Figure 2-5. The maximum output dip (V_{DIP}) and output load current(I_{OUT}) are dependent on system specifications, as shown below. These values can be predetermined and adjusted by varying the load capacitance of the system. For this design example, calculations are shown in Equation 3. Therefore, the output of this design example drops additional 31.25 mV during switching between two inputs.

Nominal V_{DIP} Calculation

$$V_{DIP} = 100\mu s \times \frac{100mA}{320\mu F} = 31.25mV \tag{3}$$

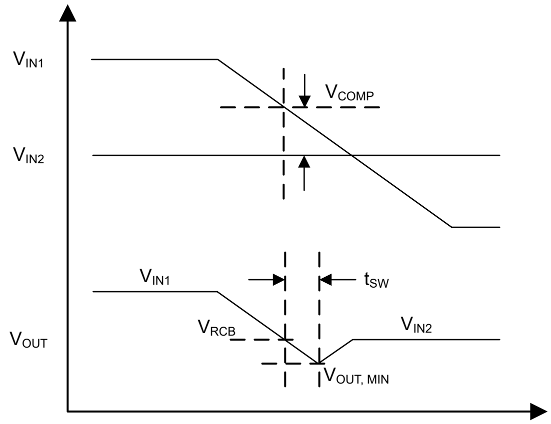
If switching from a lower to a higher voltage, the selected channel does not detect reverse voltage and shall turn on immediately using the current monitor to limit the output current to a safe level.



$V_{OUT,MIN}$ = V_{IN2} - (t_{SW} x SROUT) where SROUT = I_{OUT}/C_{OUT}
$V_{OUT,MIN}$ = 3.6 V - (100 µs x 100 mA / 320 µF) = 3.568 V
$V_{OUT,MIN}$ = 3.6 V - (100 µs x 300 mA / 320 µF) = 3.506 V

Figure 2-6. Switchover from Lower to Higher Voltage

If an input is selected while the output voltage is still a higher voltage, then that channel continues to block reverse current by waiting to turn on until the output drops below the V_{RCB} threshold.

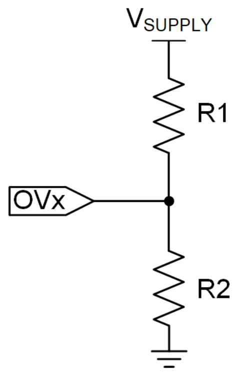


$V_{OUT,MIN} = V_{IN2} + V_{RCB}$ - (t_{SW} x SROUT) where SROUT = I_{OUT}/C_{OUT}
$V_{OUT,MIN}$ = 3.6 V + 25 mV - (100 µs x 100 mA / 320 µF) = 3.593 V
$V_{OUT,MIN}$ = 3.6 V + 25 mV - (100 µs x 300 mA / 320 µF) = 3.531 V

Figure 2-7. Switchover from Higher to Lower Voltage

2.3 Overvoltage Calculation

Output overvoltage protection is available for both IN1 and IN2 if either applied voltage is greater than the maximum supported load voltage. The VREF comparator on the OV1 and OV2 pins allows for the overvoltage protection threshold to be adjusted independently. When overvoltage is engaged, the corresponding channel turns off immediately if the pin reaches 1.1 V. Then TPS2121 will utilize the switchover to the other input if it is a valid voltage. However, OVP for IN2 is not used in this design example.



$$V_{OVx} = V_{INx} \times \frac{R2}{(R1 + R2)}$$

Figure 2-8. OV Resistors

In this design example, overvoltage on channel 1 is programmed to 7 V which is maximum voltage from IN1. The OV resistor calculations is shown in Equation 4.

$$1.1\ \text{V} = V_{IN1} \times \frac{5\text{k}}{5\text{k} + 26.8\text{k}} \rightarrow 7\ \text{V} \quad (4)$$

3 Test Results

3.1 Seamless Switchover from Main Power (IN1) to Backup Power (IN2)

The first scenario showcases when main power source (IN1) is decreased to backup power source (IN2), resulting in automatic switchover to IN2. This design example will start automatic switchover when the voltage on IN1 is approximately 3.89 V. Since IN2 is 3.6 V, once IN1 reaches (3.6 V + V_{COMP}), TPS2121 will switch over to IN2. Looking at the Figure 3-1, IN1 is blue line, IN2 is green line, VOUT is purple line.

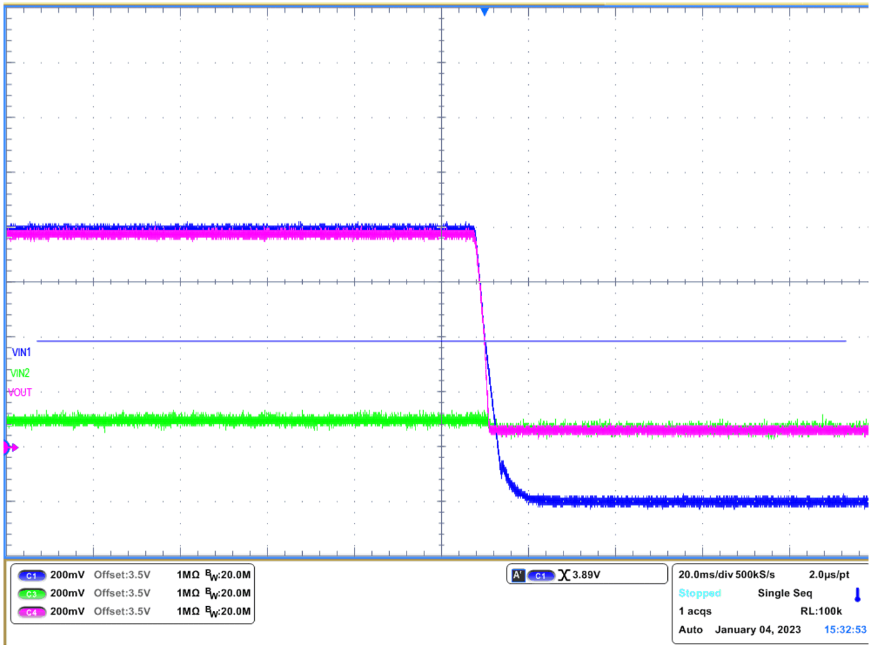


Figure 3-1. Seamless Switchover from IN1 to IN2

Zooming in on Figure 3-2 as IN1 decreases below 3.89 V, VOUT drops. Fast reverse current blocking will prevent the reverse current while VOUT is above VIN2. As the VOUT falls within V_{RCB} of VIN2 (25 mV + 3.6 V), VIN2 quickly turns back on to avoid unnecessary voltage drops during switchover. Since expected voltage drop is 31.25 mV during switchover, VOUT drops to approximately 3.596 V. Figure 2-7 shows this.

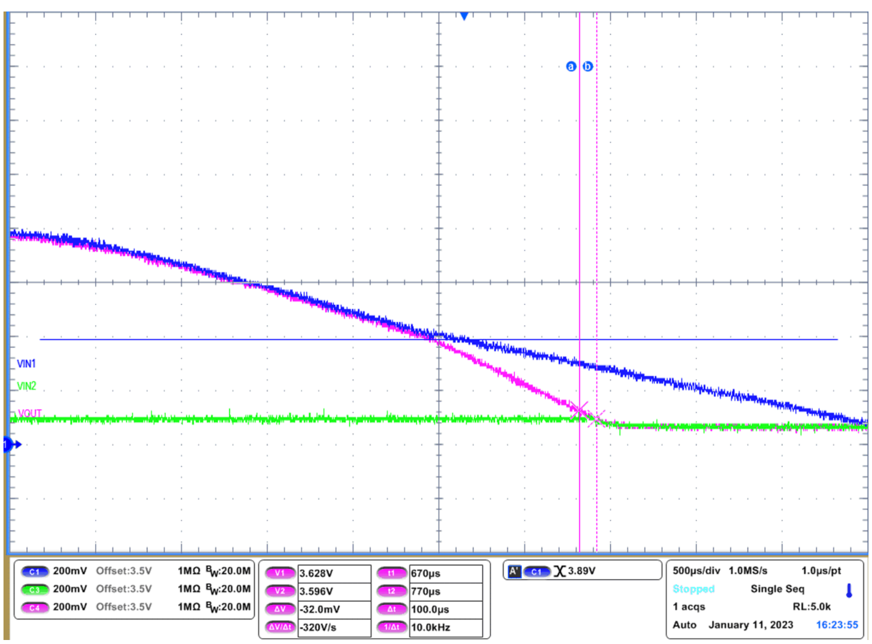


Figure 3-2. Seamless Switchover from IN1 to IN2

3.2 Seamless Switchover from Backup Power (IN2) to Main Power (IN1)

In this scenario, main power source (IN1) has increased above backup power source (IN2), while backup power is supplying downstream system. In this design example, switchover will start automatically when the voltage on IN1 reaches approximately 4.03 V. Figure 3-3 shows the switchover in this scenario. Since IN2 is 3.6 V, once IN1 reaches (3.6 V + V_{COMP} + Hysteresis), TPS2121 will switch over to IN1.

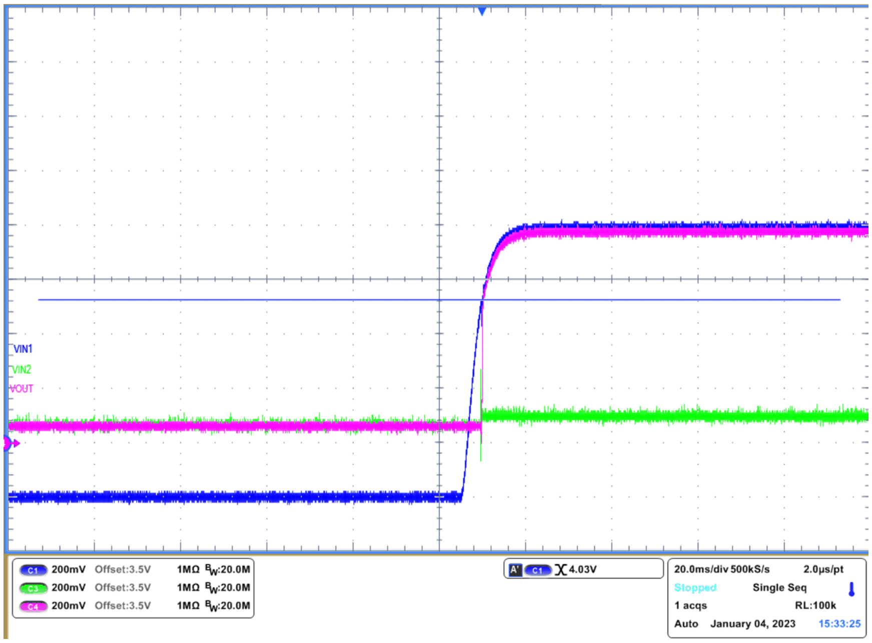


Figure 3-3. Seamless Switchover from IN2 to IN1

Zooming in on Figure 3-4, as IN1 increases above 4.03 V, switchover is occurred. It shows IN2 oscillating which causes a delay in choosing a stable supply. Once this oscillation is done, switchover is occurred. VOUT is dropped approximately 32 mV during switchover, Since expected voltage drop during switchover is 31.25 mV. Figure 2-6 shows this.

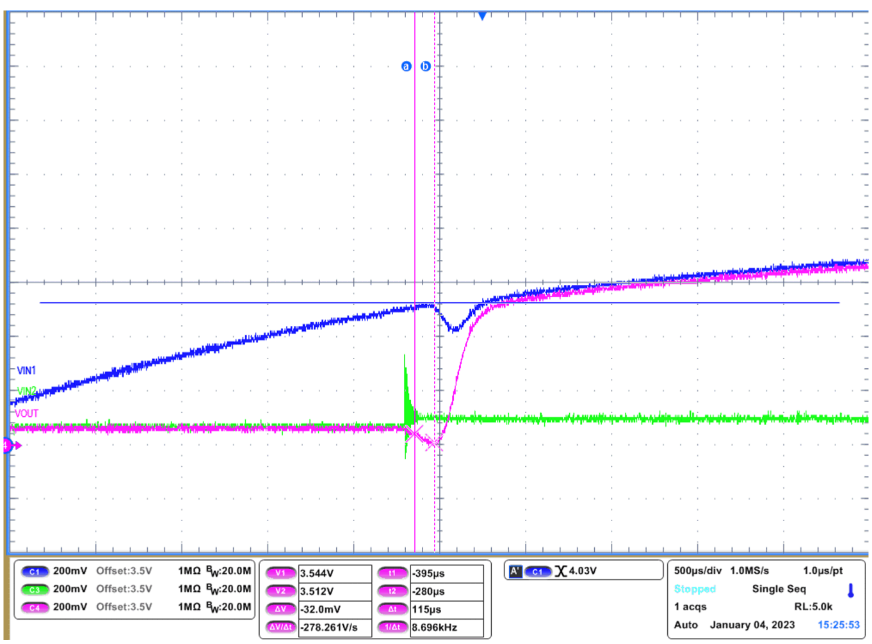


Figure 3-4. Seamless Switchover from IN2 to IN1

4 Summary

Automatic switchover design without using MCU GPIO is described in this application note. The described design allows MCU to go and stay in sleep mode to minimize battery power consumption in required application. TPS2121 supports Highest Voltage Operation mode (VCOMP) and seamless transition without interrupting normal operation. This application note described the design example and experimental results to achieve seamless switchover of the power sources as well as standby and leakage current of the design.

5 References

- Texas Instruments, *TPS212x 2.8-V to 22-V Priority Power MUX with Seamless Switchover*, data sheet.
- Texas Instruments, *TPS212X, Evaluation Module User's Guide*.
- Texas Instruments, *Seamless Switchover for Backup Power Reference Design*.

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