

TPS3700 Split Supply Positive and Negative Dual Voltage Monitoring Solution

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ABSTRACT

The TPS3700 is a 18-V undervoltage (UV) and overvoltage (OV) supervisor used for window voltage monitoring. The TI application note [SLVA600](#) shows how this device can be used to monitor negative rails. This application note describes using the TPS3700 for dual-voltage monitoring applications that require UV and OV monitoring on a positive and negative voltage rail, such as:

- The dual-rail on operational amplifiers
- Multiplexers
- Demultiplexers
- DACs
- ADCs
- Other high-precision analog circuitry that may need UV or OV protection

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⁽¹⁾ Both the positive VDD rail and negative VSS rail have independent overvoltage and undervoltage monitoring.

⁽²⁾ Overvoltage (OUTB) monitor circuit is configured the same way.

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1 Introduction

This application note describes how to configure the TPS3700 into a positive and negative voltage rail monitoring solution for undervoltage and overvoltage. This solution only requires two TPS3700 devices to accomplish dual-rail window voltage monitoring. This solution is useful in applications where positive and negative voltage rails are common. Several analog devices, such as operational amplifiers, data converters, and multiplexers require both positive and negative voltage rails. Any application that uses such analog devices, and needs both rails to be monitored, would benefit from this application note. Most applications that require specific voltage rails need solutions to monitor the voltage rails to make sure they are in the expected operating range for correct system operation. The TPS3700 devices have $V_{DD(max)} = 18\text{ V}$ and are available in automotive grade and the TPS3701 devices have $V_{DD(max)} = 36\text{ V}$. Both devices are available in a very small WSON package (1.5 mm x 1.5 mm).

2 TPS3700 Dual Rail OV and UV Monitoring Solution Overview

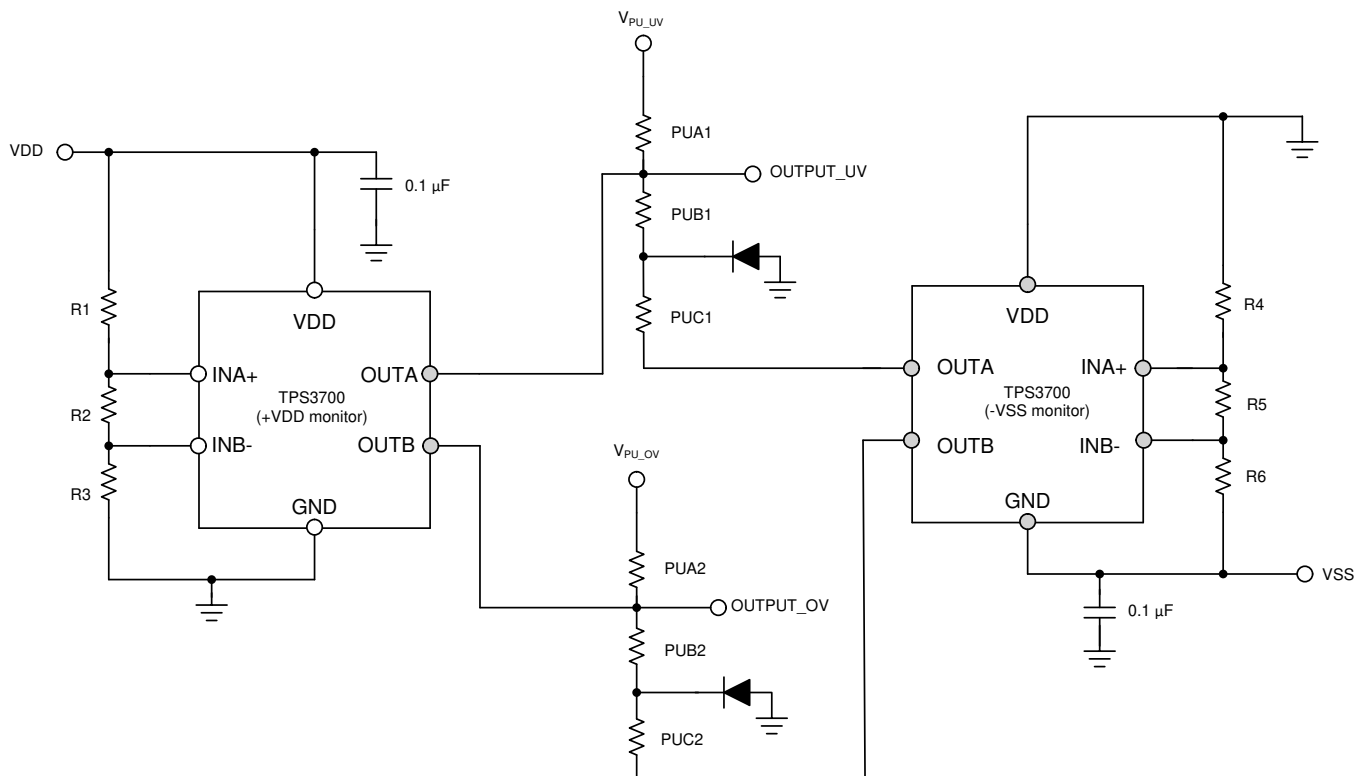


Figure 1. TPS3700 Dual Voltage Rail (+VDD and -VSS) OV and UV Monitor Circuit ⁽³⁾

3 Setting the Overvoltage and Undervoltage Threshold

For negative rail monitoring, VSS represents the negative potential with respect to GND, similar to VDD representing the positive voltage with respect to GND. The calculation of sense ladder resistor (R1, R2, R3, and R4, R5, R6) is the same for both +VDD and -VSS rail.

VDD: the positive (+VDD) supply voltage rail

VSS: the negative (-VSS) supply voltage rail

V_{OV} : Overvoltage threshold for OUTB to trigger low voltage

V_{UV} : Undervoltage threshold for OUTA to trigger low voltage

⁽³⁾ Both the positive VDD rail and negative VSS rail have independent overvoltage and undervoltage monitoring.

V_{IT+} : Positive going input threshold voltage in volts (0.4 V typical for TPS3700)

V_{IT-} : Negative going input threshold voltage in volts (0.395 V typical for TPS3700)

$R_{Ladder} [\Omega] = \text{Max Supply Voltage [V]} \div \text{Max Current in Resistor Ladder [A]}$ (1)

$R3 = R6 [\Omega] = V_{THP} \times R_{Ladder} \div V_{OV}$ (2)

$R2 = R5 [\Omega] = V_{THP} \times R_{Ladder} \div V_{UV}$ (3)

$R1 = R4 [\Omega] = R_{Ladder} - R2 - R3$ (4)

4 Designing the TPS3700 Output Circuit for Overvoltage and Undervoltage Monitoring

Figure 2 shows circuit to set the output voltage at proper V_{OL} and V_{OH} levels. The same resistor ladder configuration with diode is also used for the OUTB pins on the TPS3700 device for overvoltage monitoring.

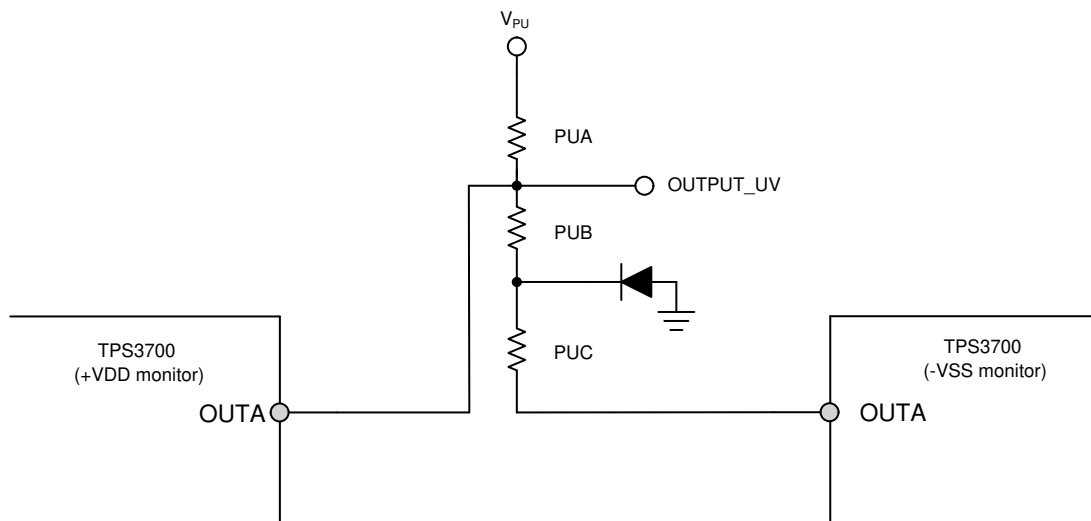


Figure 2. Undervoltage (OUTA) Monitor Circuit Configuration ⁽⁴⁾

NOTE: Section 4 describes how to configure undervoltage monitoring using the OUTA pin on two TPS3700 devices for both +VDD and -VSS supplies. To configure overvoltage monitoring use the OUTB pins.

Please note the terminology below:

V_{FB} : Forward bias of the diode

V_{OL} : The output voltage at OUTA or OUTB when asserted to logic low due to an undervoltage (OUTA) or overvoltage (OUTB) fault

I_{OL} : The current into the OUTA or OUTB pin when asserted to logic low due to an undervoltage (OUTA) or overvoltage (OUTB) fault

The following cases show the possible output configurations:

⁽⁴⁾ Overvoltage (OUTB) monitor circuit is configured the same way.

4.1 Case 1 - No Undervoltage Condition on +VDD or -VSS Supply

When there is no undervoltage condition on either supply, the OUTA pins on each TPS3700 device are high-impedance, so the Output_UV pulls up to V_{PU} through the resistor ladder. In the case of $-VSS$ supply monitor, GND is at $-VSS$ potential. The recommended maximum output voltage for OUTA and OUTB pins with respect to GND is 18 V for TP3700. Equation 5 notes the maximum pullup voltage (V_{PU}) allowed for TPS3700.

$$V_{OUT(max)} \geq |VSS| + V_{PU} \text{ for the maximum VSS value while no undervoltage or overvoltage fault} \quad (5)$$

4.2 Case 2- Undervoltage Condition on -VSS Supply

When an undervoltage condition occurs on the $-VSS$ supply, meaning the negative voltage drops towards 0 V from the negative threshold value, the OUTA of the TPS3700 monitoring the $-VSS$ supply asserts to V_{OL} level with respect to GND pin connected to $-VSS$ and the diode turns on. The diode is necessary because, when it turns on during an undervoltage condition on $-VSS$ supply, OUTPUT_UV depends on the forward bias voltage of the diode (V_{FB}) instead of the VSS supply voltage.

The minimum pullup resistor R_{PUC} when OUTA is logic low is calculated in Equation 6.

$$R_{PUC(min)} = (V_{FB} + |VSS|) \div I_{OL(max)} \quad (6)$$

To make sure that the diode turns on, the current through R_{PUB} must be much less than the current through R_{PUC} . R_{PUA} and R_{PUB} are generally in the range of 10 k Ω to 100 k Ω .

4.3 Case 3- Undervoltage Condition on +VDD Supply

When an undervoltage condition occurs on the $+VDD$ supply, the OUTA of the TPS3700 monitoring the $+VDD$ supply asserts to logic low of V_{OL} , thus OUTPUT_UV is logic low indicating an undervoltage fault. The OUTA pin on the TPS3700 monitoring the $-VSS$ rail is high-impedance, so there is no current flowing through R_{PUB} and R_{PUC} . The diode is off and has no effect in this case. Select R_{PUA} using Equation 7 such that the current into OUTA is within the recommended operating conditions given in the TPS3700 data sheet.

$$R_{PUA(min)} = V_{PU} \div I_{OUTA(max)} \quad (7)$$

4.4 Case 4- Undervoltage on Both +VDD and -VSS Supplies

Using similar reasoning for Case 3, when there is an undervoltage on both $+VDD$ and $-VSS$ supplies, the OUTPUT_UV asserts to logic low because the OUTA pin of the TPS3700 monitoring the $+VDD$ supply asserts to V_{OL} . The OUTA for the TPS3700 device monitoring the $-VSS$ supply is at $-VSS$ so the diode turns on and supplies I_{OL} to this OUTA pin.

5 Wired OR Configuration for Window Mode (Undervoltage + Overvoltage Monitoring)

The TPS3700 devices can also be used in wired OR configuration to monitor both undervoltage and overvoltage for dual rails since these devices have open-drain output topology. Figure 3 shows both of the open-drain outputs tied together with a single resistor network to monitor both UV and OV on both $+VDD$ and $-VSS$ supplies. Using similar reasoning to the cases above, OUTPUT_UV+OV asserts to logic low if either $+VDD$ or $-VSS$ is out of the voltage window configured by the resistor ladders on INA+ and INB- for both TPS3700 devices. When both of the supplies are within the voltage window, all OUTA and OUTB pins are high-impedance and OUTPUT_UV+OV pull up to logic high = $V_{PU_{UV+OV}}$.

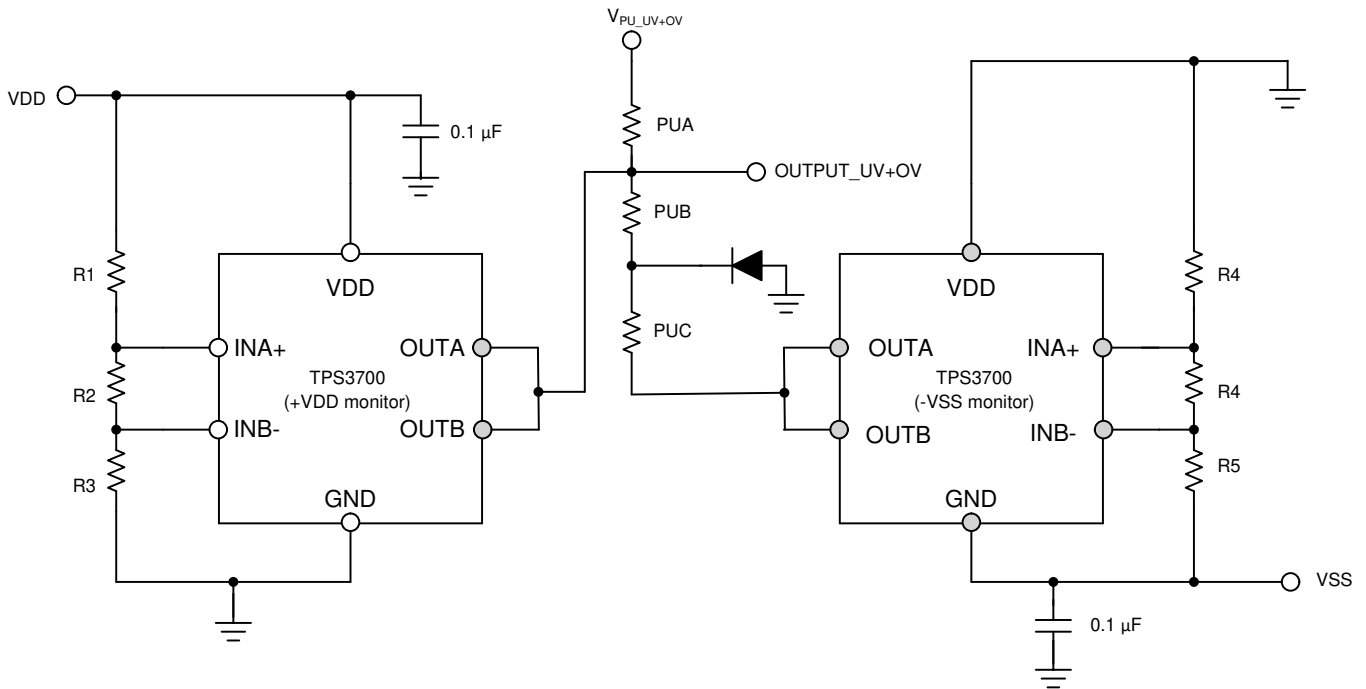


Figure 3. Window Supervisor for Dual-Rail Using TPS3700

6 Design Example

This section shows a window voltage monitor design example using two TPS3700 devices, as shown in Figure 4.

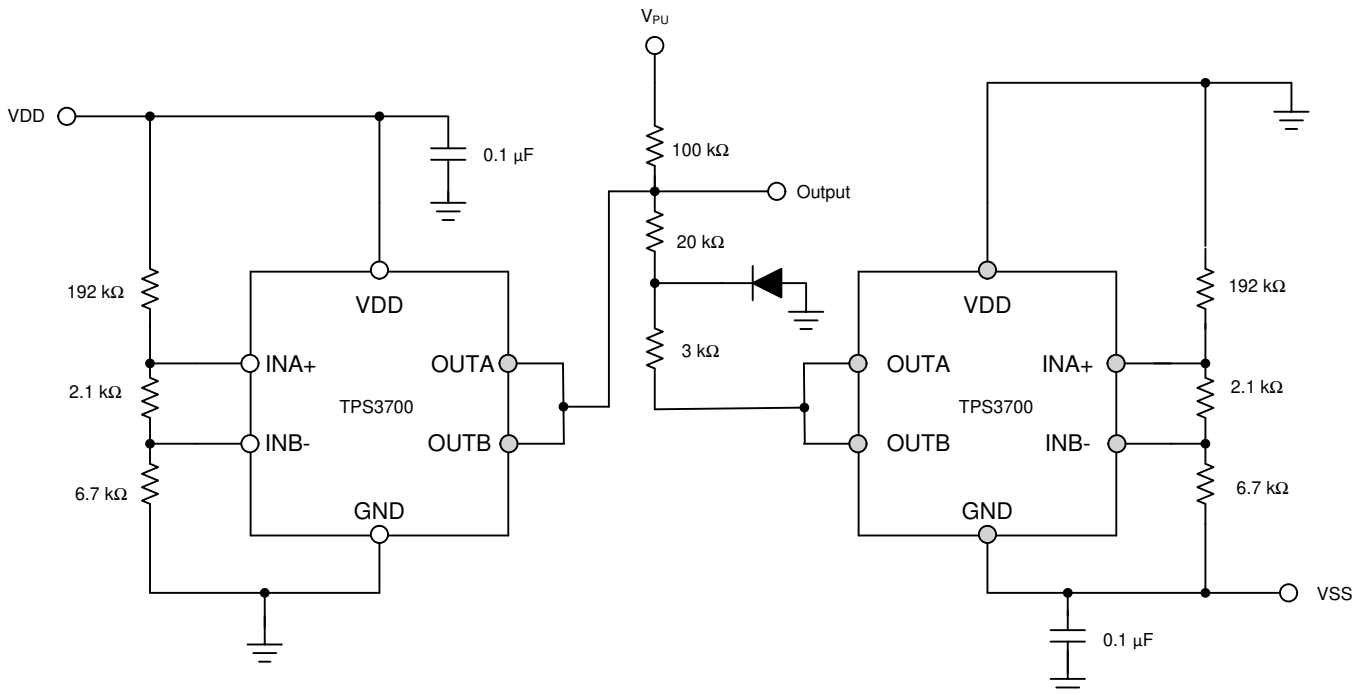


Figure 4. Window Voltage Monitor Design Example Circuit

6.1 Detailed Design Procedure

For this design example, the voltage threshold values and window voltage specifications for this design example is shown in [Table 1](#).

Table 1. Design Specifications

	POSITIVE RAIL (+VDD)	NEGATIVE RAIL (-VSS)
UV	9 V	-9 V
OV	12 V	-12 V
Inside the window	$9\text{ V} \leq \text{VSS} \leq 12\text{ V}$	$-12\text{ V} \leq \text{VSS} \leq -9\text{ V}$
Outside of the window	$\text{VDD} < 9\text{ V}$ or $\text{VDD} > 12\text{ V}$	$\text{VSS} > -9\text{ V}$, $\text{VSS} < -12\text{ V}$

6.2 Monitoring +VDD Positive Voltage Supply

[Figure 5](#) shows the results for the positive +VDD supply = [10 V, 12.5 V] only to show an overvoltage fault on the +VDD supply.

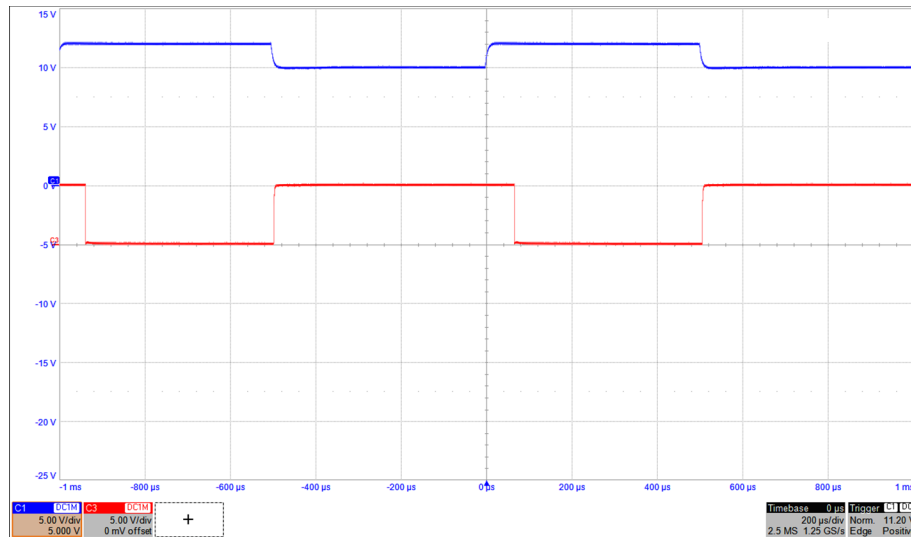


Figure 5. Overvoltage Fault on +VDD Supply (Blue Trace: VDD, Red Trace: Output)

6.3 Monitoring -VSS Negative Voltage Supply

Figure 6 shows the results for the negative -VSS supply = [-7 V, -10 V] only to show an undervoltage fault on the -VSS supply.

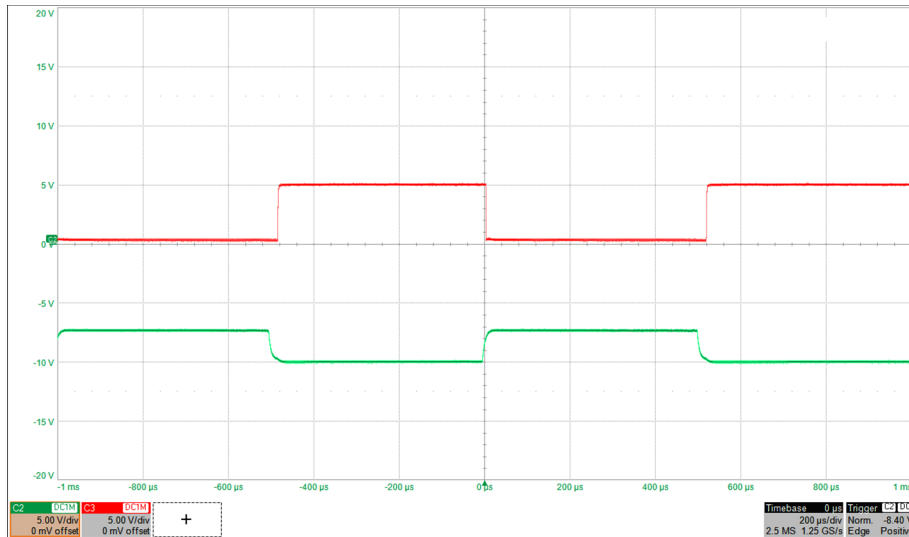


Figure 6. Undervoltage Fault on -VSS Supply (Green Trace: VSS, Red Trace: Output)

6.4 Monitoring Both +VDD and -VSS Supplies

Figure 7 shows the results for both +VDD = [10 V, 12.5 V] and -VSS = [-12 V, -15 V] supplies to show an overvoltage fault on the +VDD supply and an overvoltage fault on the -VSS supply.

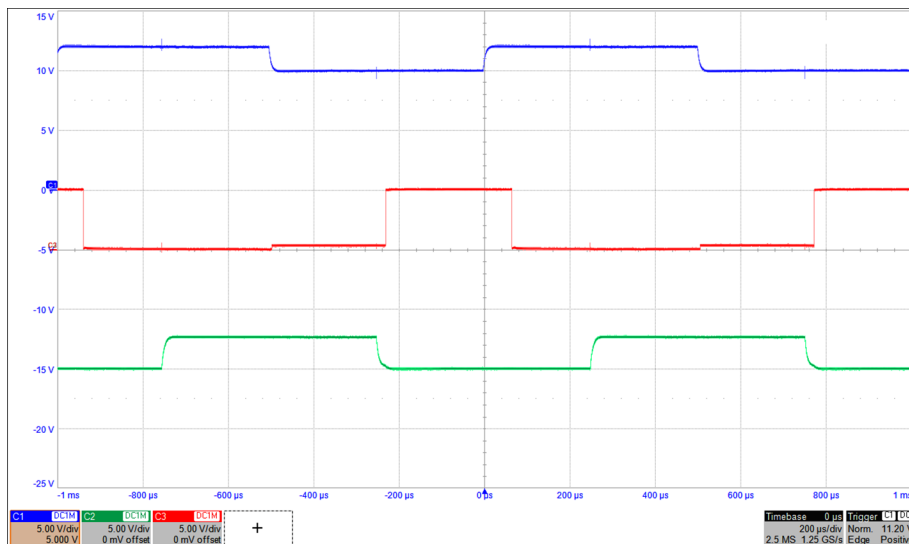


Figure 7. Window Voltage Monitoring with Overvoltage Faults on Both Supplies (Blue Trace: VDD, Green Trace: VSS, Red Trace: Output)

6.5 Design Simulation Results

Table 2 shows the output voltage values during each of the possible voltage monitoring scenarios.

Table 2. Results from Simulation

CASE	+VDD SUPPLY	-VSS SUPPLY	OUTPUT (mV)
1	Out of window	In the Window	10-15
2	Out of window	Out of window	10-15
3	In the window	Out of window	250
4	In the window	In the window	5000

7 Summary

This application report demonstrates a dual voltage rail (+VDD and -VSS) window voltage (UV and OV) monitoring solution using two TPS3700 devices. The voltage thresholds are adjustable through the resistor ladder values and the TPS3700 allows for wide V_{in} voltage monitoring with high accuracy (0.25% typical) not accounting for component tolerance.

8 References

The following references provide additional information and resources related to this application note.

- Texas Instruments, [Using the TPS3700 as a Negative Rail Over- and Undervoltage Detector](#) Application Report
- Texas Instruments, [TPS3700 High voltage \(18V\) window voltage detector with internal reference for over and undervoltage monitoring](#) Data Sheet
- Texas Instruments, [RAD-TOLERANT SPACE GRADE DIE, PRECISION PROGRAMMABLE REFERENCE](#) Data Sheet
- Texas Instruments, [TPS3701 High voltage \(36V\) window voltage detector with internal reference for over and undervoltage monitoring](#) Data Sheet

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