

# TPS7H3xx4-SP Radiation-Hardened, 14V, 4-Channel Supervisor With Watchdog Timer

## 1 Features

- Radiation performance:
  - Radiation hardness assurance (RHA) up to a total ionizing dose (TID) of 100krad(Si)
  - Single-event latchup (SEL), single-event burnout (SEB), and single-event gate rupture (SEGR) immune up to linear energy transfer (LET) = 75MeV-cm<sup>2</sup>/mg
  - Single-event functional interrupt (SEFI) and single-event transient (SET) characterized up to LET = 75MeV-cm<sup>2</sup>/mg
- Wide supply IN voltage range (V<sub>IN</sub>): 3V to 14V
- Monitor up to 4 voltage rails with high accuracy:
  - TPS7H3024: 2 OV + 2 UV or 2 window with push-pull  $\overline{\text{RESET}}x$
  - TPS7H3134: 2 OV + 2 UV or 2 window with open-drain  $\overline{\text{RESET}}x$
  - TPS7H3034: 4 UV or 4 OV with push-pull  $\overline{\text{RESET}}x$
  - TPS7H3134: 4 UV or 4 OV with open-drain  $\overline{\text{RESET}}x$
- Monitor coherent processor execution using the watchdog timer
- Single resistor programmable global delay timer
- Programmable watchdog time-out
- Precision threshold voltage and hysteresis current:
  - V<sub>TH\_SENSEx</sub> of 599.7mV ± 1% across: voltage, temperature, and radiation (TID)
  - I<sub>HYS\_SENSEx</sub> of 24µA ± 3% across: voltage, temperature, and radiation (TID)
- Push-Pull outputs with programmable pull-up voltage from 1.6V to 7V
  - Global  $\overline{\text{RESET}}x$  pull-up domain (V<sub>PULL\_UP1</sub>)
  - Common PWRGD and  $\overline{\text{WDO}}$  pull-up domain (V<sub>PULL\_UP2</sub>)
- SR\_UVLO input to reset all outputs
  - Can also be used as configurable undervoltage lockout with an external resistor divider
- Available in military (–55°C to 125°C) temperature range

## 2 Applications

- Satellite electrical power system (EPS)
- Monitoring voltage rails for complex digital processors such as: FPGAs, SoCs, AFEs, and power systems for space applications
- Monitoring of coherent processor execution

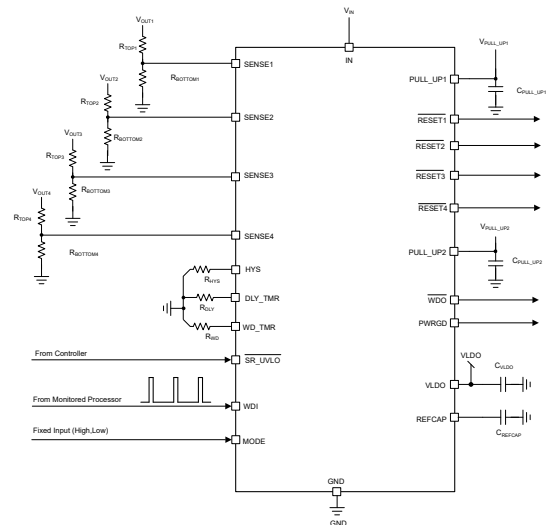
## 3 Description

The TPS7H3xx4-SP is an integrated, 3V to 14V, four-channel radiation-hardened power-supply supervisor with watchdog. An accurate 599.7mV ± 1% threshold voltage and a 24µA ± 3% hysteresis current provide programmable monitoring voltages. A global programmable delay timer is programmed via a single resistor. Additionally, a PWRGD output is provided to monitor the global power tree status. The device also incorporates a positive edge detection watchdog timer to monitor an external processor for coherent execution. Faults can be detected and mitigated by the external controller, using the SR\_UVLO input. The device is offered with push-pull and open-drain outputs types.

### Package Information

PART NUMBER <sup>(1)</sup>	GRADE	PACKAGE <sup>(2)</sup>
5962R2420601VXC	QMLV-RHA	22-pin ceramic (CFP) 6.21mm × 7.69mm Mass = 415.6mg
5962R2420602VXC <sup>(3)</sup>		
5962R2420603VXC <sup>(3)</sup>		
5962R2420604VXC <sup>(3)</sup>		
TPS7H3024HFT/EM	Engineering sample	
TPS7H3124HFT/EM <sup>(3)</sup>		
TPS7H3034HFT/EM <sup>(3)</sup>		
TPS7H3134HFT/EM <sup>(3)</sup>		

- For additional information, see [Section 4](#).
- The mass is a nominal value and the body size (length × width) is a nominal value and does not include pins.
- Advanced information.



Note: Outputs shown here are push-pull

### Typical Application



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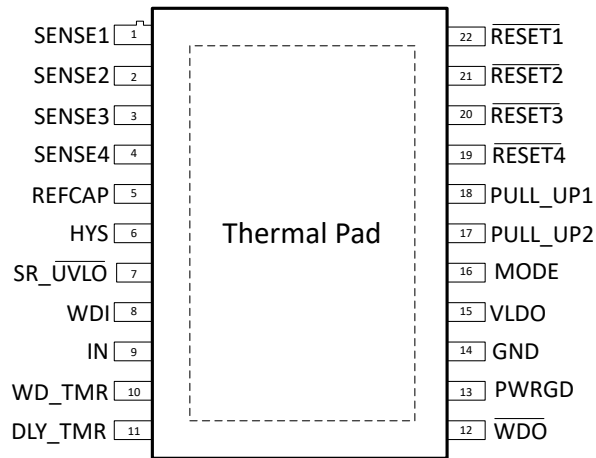
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## 4 Device Comparison Table

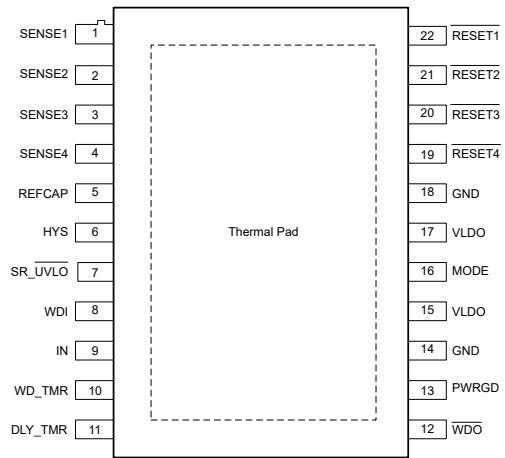
GENERIC PART NUMBER	OUTPUT TYPE	FUNCTION	RADIATION RATING <sup>(1)</sup>	GRADE <sup>(2)</sup>	PACKAGE	ORDERABLE PART NUMBER
TPS7H3024-SP	Push-pull	2 UV + 2 OV (or 2 window)	TID of 100krad(Si) RLAT, DSEE free to 75MeV-cm <sup>2</sup> /mg	QMLV-RHA	22-pin CFP HFT	5962R2420601VXC
			None	Engineering model <sup>(3)</sup>		TPS7H3024HFT/EM
TPS7H3124-SP	Open-drain		TID of 100krad(Si) RLAT, DSEE free to 75MeV-cm <sup>2</sup> /mg	QMLV-RHA		5962R2420602VXC <sup>(4)</sup>
			None	Engineering model <sup>(3)</sup>		TPS7H3124HFT/EM <sup>(4)</sup>
TPS7H3034-SP	Push-pull	4 UV or 4 OV	TID of 100krad(Si) RLAT, DSEE free to 75MeV-cm <sup>2</sup> /mg	QMLV-RHA		5962R2420603VXC <sup>(4)</sup>
			None	Engineering model <sup>(3)</sup>		TPS7H3034HFT/EM <sup>(4)</sup>
TPS7H3134-SP	Open-drain		TID of 100krad(Si) RLAT, DSEE free to 75MeV-cm <sup>2</sup> /mg	QMLV-RHA		5962R2420604VXC <sup>(4)</sup>
			None	Engineering model <sup>(3)</sup>		TPS7H3134HFT/EM <sup>(4)</sup>

- (1) TID is total ionizing dose and DSEE is destructive single event effects. Additional information is available in the associated TID reports and SEE reports for each product.
- (2) For additional information about part grade, view [TI Part Ratings](#).
- (3) These units are intended for engineering evaluation only. The units are processed to a non-compliant flow (such as no burn-in and only 25°C testing). These units are not designed for qualification, production, radiation testing, or flight use. Parts are not specified as to performance over temperature or operating life.
- (4) Advanced information.

## 5 Pin Configuration and Functions



**Figure 5-1. TPS7H30x4  
HFT Package  
22-Pin CFP  
(Top View)**



**Figure 5-2. TPS7H31x4  
HFT Package  
22-Pin CFP  
(Top View)**

**Table 5-1. Pin Functions**

NAME	PIN		TYPE <sup>(1)</sup>	DESCRIPTION
	TPS7H30x4	TPS7H31x4		
SENSE1	1	1	I	The non-inverting input of the comparator used to monitor a desired voltage rail. To set the $V_{ON1}$ and $V_{OFF1}$ voltages, connect an external resistive divider between the rail to be monitored and GND with the middle point tied to SENSE1 pin. A voltage greater than $V_{TH\_SENSEX}$ (599.7mV typical) on this pin is considered as a regulated voltage rail ( $V_{ON1}$ ). The $V_{OFF1}$ is a function of the $I_{HYS}$ current, the resistive divider, and $V_{TH\_SENSEX}$ . Refer to <a href="#">Top and Bottom Resistive Divider Design Equations</a> .
SENSE2	2	2	I	The non-inverting input of the comparator used to monitor a desired voltage rail. To set the $V_{ON2}$ and $V_{OFF2}$ voltages, connect an external resistive divider between the rail to be monitored and GND with the middle point tied to SENSE2 pin. A voltage greater than $V_{TH\_SENSEX}$ (599.7mV typical) on this pin is considered as a regulated voltage rail ( $V_{ON2}$ ). The $V_{OFF2}$ is a function of the $I_{HYS}$ current, the resistive divider, and $V_{TH\_SENSEX}$ . Refer to <a href="#">Top and Bottom Resistive Divider Design Equations</a> .
SENSE3	3	3	I	The non-inverting input of the comparator used to monitor a desired voltage rail. To set the $V_{ON3}$ and $V_{OFF3}$ voltages, connect an external resistive divider between the rail to be monitored and GND with the middle point tied to SENSE3 pin. A voltage greater than $V_{TH\_SENSEX}$ (599.7mV typical) on this pin is considered as a regulated voltage rail ( $V_{ON2}$ ). The $V_{OFF2}$ is a function of the $I_{HYS}$ current, the resistive divider, and $V_{TH\_SENSEX}$ . Refer to <a href="#">Top and Bottom Resistive Divider Design Equations</a> .
SENSE4	4	4	I	The non-inverting input of the comparator used to monitor a desired voltage rail. To set the $V_{ON4}$ and $V_{OFF4}$ voltages, connect an external resistive divider between the rail to be monitored and GND with the middle point tied to SENSE4 pin. A voltage greater than $V_{TH\_SENSEX}$ (599.7mV typical) on this pin is considered as a regulated voltage rail ( $V_{ON4}$ ). The $V_{OFF4}$ is a function of the $I_{HYS}$ current, the resistive divider, and $V_{TH\_SENSEX}$ . Refer to <a href="#">Top and Bottom Resistive Divider Design Equations</a> .
REFCAP	5	5	O	1.2V internal reference. This pin requires a 470nF external capacitor to GND. Do not load this pin with any additional external circuitry
HYS	6	6	O	Hysteresis. Connect a 49.9kΩ resistor between this pin and GND, to program the hysteresis current (typically 24μA) at SENSE1 to SENSE4. Users are recommended to use a resistor with a 0.1% or better tolerance.
SR_UVLO	7	7	O	System reset and UVLO input. Force this input low to assert all outputs low. A resistor divider from $V_{IN}$ to GND can be used to set the device turn-on level.

**Table 5-1. Pin Functions (continued)**

NAME	PIN		TYPE <sup>(1)</sup>	DESCRIPTION
	TPS7H30x4	TPS7H31x4		
WDI	8	8	I	Watchdog input. Toggle this signal from low to high to clear the watchdog timer. If this input is toggled low to high before the watchdog timer is expired, the $\overline{WDO}$ stays high, otherwise is asserted low.
IN	9	9	I	Input supply to the device. Input voltage range is from 3V to 14V. Connect at least a 0.1 $\mu$ F ceramic capacitor as close as possible to the pin.
WD_TMR	10	10	I/O	Watchdog timer. Connect a resistor to GND between 56.2k $\Omega$ and 174k $\Omega$ to set the watchdog timeout. The delay can be adjusted from 0.52s to 1.5s. Leave this pin floating to deactivate the watchdog timer.
DLY_TMR	11	11	I/O	Delay timer. Connect a resistor to GND between 10.5k $\Omega$ and 1.18M $\Omega$ to set the out-of-fault delay. The delay can be adjusted from 0.25ms to 25ms. Leave this pin floating for no delay.
$\overline{WDO}$	12	12	O	Watchdog output. Push-pull or open-drain output. For the push-pull output the $V_{OH}$ level is set by the PULL_UP2 input supply voltage. For the open-drain output an external pull-up to the desired logic level is needed. A 10k $\Omega$ pull-up resistor is recommended.
PWRGD	13	13	O	Power Good. This output indicates when all rails (SENSE1 to SENSE4) are in regulation. Push-pull or open-drain output. For the push-pull output the $V_{OH}$ level is set by the PULL_UP2 input supply voltage. For the open-drain output an external pull-up to the desired logic level is needed. A 10k $\Omega$ pull-up resistor is recommended.
GND	14	14, 18	—	Ground.
VLDO	15	15, 17	O	Output of internal regulator. This pin requires at least a 1 $\mu$ F external ceramic capacitor to GND. This voltage can be used to create positive offset when monitoring negative voltages. For the TPS7H31x4, connect pins 15 and 17 externally through a 10k $\Omega$ resistor. The maximum load for this LDO is 5mA. This pin is not protected for over-current events.
MODE	16	16	I	Logical input to control the behavior of the output stage (window or UV + OV). For more details refer to <a href="#">Section 8.3.4</a> . This input must not be dynamically changed. MODE=0 corresponds to 2 UV + 2 OV while MODE=1 corresponds to 2 window.
PULL_UP2	17	—	I	Input supply voltage to program the pull-up voltage for the push-pull outputs on PWRGD and $\overline{WDO}$ . Connect at least a 1 $\mu$ F ceramic capacitor as close as possible to the pin.
PULL_UP1	18	—	I	Input supply voltage to program the global pull-up voltage for the push-pull outputs on RESET1 to RESET4. Connect at least a 1 $\mu$ F ceramic capacitor as close as possible to the pin.
RESET4	19	19	O	Reset 4. $\overline{RESET4}$ is asserted low when SENSE4 is in a fault. Push-pull or open-drain output. For the push-pull output the $V_{OH}$ level is set by the PULL_UP1 input supply voltage. For the open-drain output an external pull-up to the desired logic level is needed. A 10k $\Omega$ pull-up resistor is recommended.
RESET3	20	20	O	Reset 3. $\overline{RESET3}$ is asserted low when SENSE3 is in a fault. Push-pull or open-drain output. For the push-pull output the $V_{OH}$ level is set by the PULL_UP1 input supply voltage. For the open-drain output an external pull-up to the desired logic level is needed. A 10k $\Omega$ pull-up resistor is recommended.
RESET2	21	21	O	Reset 2. $\overline{RESET2}$ is asserted low when SENSE2 is in a fault. Push-pull or open-drain output. For the push-pull output the $V_{OH}$ level is set by the PULL_UP1 input supply voltage. For the open-drain output an external pull-up to the desired logic level is needed. A 10k $\Omega$ pull-up resistor is recommended.
RESET1	22	22	O	Reset 1. $\overline{RESET1}$ is asserted low when SENSE1 is in a fault. Push-pull or open-drain output. For the push-pull output the $V_{OH}$ level is set by the PULL_UP1 input supply voltage. For the open-drain output an external pull-up to the desired logic level is needed. A 10k $\Omega$ pull-up resistor is recommended.
Thermal pad	—	—	—	Internally grounded. It is recommended to connect this metal thermal pad to a large ground plane for effective heat dissipation.

**Table 5-1. Pin Functions (continued)**

PIN			TYPE <sup>(1)</sup>	DESCRIPTION
NAME	TPS7H30x4	TPS7H31x4		
Metal lid	Lid	Lid	—	The lid is internally connected to the thermal pad and GND through the seal ring.

(1) I = Input, O = Output, I/O = Input or Output, — = Other

## 6 Specifications

### 6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted) <sup>(1)</sup> <sup>(2)</sup>

		MIN	MAX	UNIT
Input voltage	IN	-0.3	16	V
	WDI, MODE	-0.3	7.5	
	SENSE1, SENSE2, SENSE3, SENSE4	-0.3	3.6	
	PULL_UP1, PULL_UP2	-0.3	7.5	
	SR_UVLO	-0.3	7.5	
	DLY_TMR, WD_TMR	-0.3	3.6	
Output voltage	REFCAP	-0.3	2	V
	VLDO	-0.3	3.6	
	HYS	-0.3	3.6	
	RESET1, RESET2, RESET3, RESET4	-0.3	7.5	
	PWRGD, WDO	-0.3	7.5	
Output current	RESET1, RESET2, RESET3, RESET4	-20	20	mA
	PWRGD, WDO	-20	20	
Junction temperature	T <sub>J</sub>	-55	150	°C
Storage temperature	T <sub>stg</sub>	-65	150	°C

- (1) Operation outside the Absolute Maximum Ratings may cause permanent device damage. Absolute Maximum Ratings do not imply functional operation of the device at these or any other conditions beyond those listed under Recommended Operating Conditions. If used outside the Recommended Operating Conditions but within the Absolute Maximum Ratings, the device may not be fully functional, and this may affect device reliability, functionality, performance, and shorten the device lifetime.
- (2) All voltages values are with respect to GND.

### 6.2 ESD Ratings

			VALUE	UNIT
V <sub>ESD</sub>	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/ JEDEC JS-001, all pins <sup>(1)</sup>	±1000	V
		Charged-device model (CDM), per ANSI/ESDA/ JEDEC JS-002, all pins <sup>(2)</sup>	±250	

- (1) JEDEC document JEP155 states that 500V HBM allows safe manufacturing with a standard ESD control process.
- (2) JEDEC document JEP157 states that 250V CDM allows safe manufacturing with a standard ESD control process.

### 6.3 Recommended Operating Conditions

over operating temperature range (unless otherwise noted) <sup>(1)</sup>

		MIN	NOM	MAX	UNIT
Input voltage	IN	3		14	V
	WDI, MODE	0		7	
	SENSE1, SENSE2, SENSE3, SENSE4	0		3.5	
	PULL_UP1, PULL_UP2	1.6		7	
	SR_UVLO	0		7	
	Output voltage	RESET1, RESET2, RESET3, RESET4	0		
	PWRGD, WDO	0		7	
Output current	RESET1, RESET2, RESET3, RESET4	-10		10	mA
	PWRGD, WDO	-10		10	
Junction temperature	T <sub>J</sub>	-55		125	°C

over operating temperature range (unless otherwise noted) <sup>(1)</sup>

		MIN	NOM	MAX	UNIT
Input voltage slew rate	SR <sub>IN</sub>	0.001		10	V/μs

(1) All voltages values are with respect to GND.

## 6.4 Thermal Information

THERMAL METRIC <sup>(1)</sup>		TPS7H3xx4-SP		UNIT
		HFT (CFP)		
		22 pins		
R <sub>θJA</sub>	Junction-to-ambient thermal resistance	34.2		°C/W
R <sub>θJC(bot)</sub>	Junction-to-case (bottom) thermal resistance	7.7		°C/W
R <sub>θJB</sub>	Junction-to-board thermal resistance	17.2		°C/W
R <sub>θJC(top)</sub>	Junction-to-case (top) thermal resistance	16.9		°C/W
Ψ <sub>JT</sub>	Junction-to-top characterization parameter	8.6		°C/W
Ψ <sub>JB</sub>	Junction-to-board characterization parameter	17		°C/W

(1) For more information about traditional and new thermal metrics, see the [Semiconductor and IC Package Thermal Metrics application note](#).

## 6.5 Electrical Characteristics

Over 3V ≤ V<sub>IN</sub> ≤ 14V, R<sub>DLY\_TMR</sub> = 10kΩ, R<sub>WD\_TMR</sub> = 56.2kΩ, V<sub>PULL\_UP1</sub> = 3.3V, V<sub>PULL\_UP2</sub> = 3.3V, over temperature range (T<sub>A</sub> = –55°C to 125°C), unless otherwise noted; includes group E radiation testing at T<sub>A</sub> = 25°C for QML RHA devices <sup>(1)</sup> <sup>(2)</sup>

PARAMETER	TEST CONDITIONS	SUB-GROUP <sup>(3)</sup>	MIN	TYP	MAX	UNIT
<b>SUPPLY VOLTAGES AND CURRENTS</b>						
I <sub>Q_IN</sub>	V <sub>IN</sub> quiescent current	V <sub>SR_UVLO</sub> > V <sub>TH_SR_UVLO_RISING</sub> (MAX)	1, 2, 3	1.5	2.5	mA
I <sub>SD_IN</sub>	V <sub>IN</sub> shutdown current	V <sub>SR_UVLO</sub> = 0V	1, 2, 3	1.5	2.1	
UVLO <sub>RISE</sub>	V <sub>IN</sub> rising undervoltage lockout		1, 2, 3	2.73	2.80 2.88	V
UVLO <sub>FALL</sub>	V <sub>IN</sub> falling undervoltage lockout		1, 2, 3	2.58	2.65 2.72	
V <sub>LDO</sub>	Internal linear regulator output voltage	4V ≤ V <sub>IN</sub> ≤ 14V	1, 2, 3	3.23	3.29 3.37	V
		V <sub>IN</sub> = 3V	1, 2, 3	98%	99%	× V <sub>IN</sub>
VLDO <sub>I_MAX</sub>	VLDO maximum current	3.65V ≤ V <sub>IN</sub> ≤ 14V, VLDO = 98.5% × VLDO <sub>(NOM)</sub>	1, 2, 3		5	mA
REFCAP	Internal bandgap voltage		1, 2, 3	1.188	1.2 1.212	V
V <sub>POR_IN</sub>	IN power on reset voltage <sup>(4)</sup>	1.6V ≤ V <sub>PULL_UPx</sub> ≤ 7V, V <sub>OL</sub> ≤ 320mV with I <sub>RESETx</sub> = –1mA	1, 2, 3	1.42	2	
V <sub>POR_PULL_UPx</sub>	PULL_UPx power on reset voltage <sup>(5)</sup>	V <sub>IN</sub> = 0V, V <sub>OL</sub> ≤ 320mV, I <sub>RESETx</sub> = –100μA	1, 2, 3	0.85	1.1	
V <sub>HYS</sub>	HYS pin internal voltage	R <sub>HYS</sub> = 49.9kΩ	1, 2, 3	1.164	1.2 1.236	
<b>SENSE1 TO SENSE4, SR_UVLO, WDI AND MODE COMPARATOR INPUTS</b>						
V <sub>TH_SENSEx</sub>	Threshold voltage at SENSEx		1, 2, 3	593.1	599.7 604.9	mV
I <sub>HYS_SENSEx</sub>	SENSEx hysteresis current	V <sub>SENSEx</sub> = 700mV	1, 2, 3	23.28	24 24.72	μA
I <sub>LKG_SENSEx</sub>	Input leakage current at SENSEx	V <sub>SENSEx</sub> = 500mV	1, 2, 3		1 100	nA

## 6.5 Electrical Characteristics (continued)

Over  $3V \leq V_{IN} \leq 14V$ ,  $R_{DLY\_TMR} = 10k\Omega$ ,  $R_{WD\_TMR} = 56.2k\Omega$ ,  $V_{PULL\_UP1} = 3.3V$ ,  $V_{PULL\_UP2} = 3.3V$ , over temperature range ( $T_A = -55^\circ C$  to  $125^\circ C$ ), unless otherwise noted; includes group E radiation testing at  $T_A = 25^\circ C$  for QML RHA devices (1) (2)

PARAMETER		TEST CONDITIONS	SUB-GROUP (3)	MIN	TYP	MAX	UNIT
$V_{TH\_SR\_UVLO\_RISING}$	Rising threshold voltage at SR_UVLO		1, 2, 3	580	602	618	mV
$V_{TH\_SR\_UVLO\_FALLING}$	Falling threshold voltage at SR_UVLO		1, 2, 3	475	499	517	
$I_{LKG\_SR\_UVLO}$	Input leakage current at SR_UVLO	$V_{SR\_UVLO} = 7V$	1, 2, 3		2	100	nA
$V_{TH\_WDI\_RISING}$	Rising threshold voltage at WDI		1, 2, 3	578	602	624	mV
$V_{TH\_WDI\_FALLING}$	Falling threshold voltage at WDI		1, 2, 3	473	498	521	mV
$I_{LKG\_WDI}$	Input leakage current at WDI	$V_{WDI} = 7V$	1, 2, 3		1.4	100	nA
$V_{TH\_MODE\_RISING}$	Rising threshold voltage at MODE		1, 2, 3 7, 8	576	600	623	mV
$V_{TH\_MODE\_FALLING}$	Falling threshold voltage at MODE		1, 2, 3 7, 8	475	498	520	mV
$I_{LKG\_MODE}$	Input leakage current at MODE	$V_{MODE} = 7V$	1, 2, 3		1	100	nA
<b>RESET1 TO RESET4, PWRGD AND WDO PUSH PULL OUTPUTS (TPS7H3024 AND TPS7H3034)</b>							
$PULL\_UPxLKG$	PULL_UPx leakage current	$V_{PULL\_UPx} = 7V$ , $\overline{RESETx} = LOW$	1, 2, 3		48	100	$\mu A$
$V_{OL\_RESETx}$	Low-level $\overline{RESETx}$ output voltage	$1.6V \leq V_{PULL\_UP1} \leq 7V$	$I_{LOAD} = -2mA$	1, 2, 3		5%	x $V_{PULL\_UP1}$
			$I_{LOAD} = -10mA$	1, 2, 3		23%	
$V_{OH\_RESETx}$	High-level $\overline{RESETx}$ output voltage	$1.6V \leq V_{PULL\_UP1} \leq 7V$	$I_{LOAD} = 2mA$	1, 2, 3	95%		
			$I_{LOAD} = 10mA$	1, 2, 3	75%		
$V_{OL\_PWRGD}$	Low-level PWRGD output voltage	$1.6V \leq V_{PULL\_UP2} \leq 7V$	$I_{LOAD} = -2mA$	1, 2, 3		5%	x $V_{PULL\_UP2}$
			$I_{LOAD} = -10mA$	1, 2, 3		23%	
$V_{OH\_PWRGD}$	High-level PWRGD output voltage	$1.6V \leq V_{PULL\_UP2} \leq 7V$	$I_{LOAD} = 2mA$	1, 2, 3	95%		
			$I_{LOAD} = 10mA$	1, 2, 3	75%		
$V_{OL\_WDO}$	Low-level $\overline{WDO}$ output voltage	$1.6V \leq V_{PULL\_UP2} \leq 7V$	$I_{LOAD} = -2mA$	1, 2, 3		5%	x $V_{PULL\_UP2}$
			$I_{LOAD} = -10mA$	1, 2, 3		23%	
$V_{OH\_WDO}$	High-level $\overline{WDO}$ output voltage	$1.6V \leq V_{PULL\_UP2} \leq 7V$	$I_{LOAD} = 2mA$	1, 2, 3	95%		
			$I_{LOAD} = 10mA$	1, 2, 3	75%		
$SR_{\overline{RESETx}}\_RISE$	$\overline{RESETx}$ rising output voltage slew rate	10% to 90% of $V_{PULL\_UP1}$	$1.6V \leq V_{PULL\_UP1} \leq 7V$	7, 8 9, 10, 11	17	298	V/ $\mu s$
$SR_{PWRGD\_RISE}$	PWRGD rising output voltage slew rate	$R_{LOAD} = 50k\Omega$ , $C_{LOAD} = 100pF$		7, 8 9, 10, 11	17	298	
$SR_{\overline{WDO}}\_RISE$	$\overline{WDO}$ rising output voltage slew rate		7, 8 9, 10, 11	17	298		
$SR_{\overline{RESETx}}\_FALL$	$\overline{RESETx}$ falling output voltage slew rate	90% to 10% of $V_{PULL\_UP1}$	$1.6V \leq V_{PULL\_UP1} \leq 7V$	7, 8 9, 10, 11	44	186	
$SR_{PWRGD\_FALL}$	PWRGD falling output voltage slew rate	$R_{LOAD} = 50k\Omega$ , $C_{LOAD} = 100pF$		7, 8 9, 10, 11	44	186	
$SR_{\overline{WDO}}\_FALL$	$\overline{WDO}$ falling output voltage slew rate			7, 8 9, 10, 11	44	186	

## 6.5 Electrical Characteristics (continued)

Over  $3V \leq V_{IN} \leq 14V$ ,  $R_{DLY\_TMR} = 10k\Omega$ ,  $R_{WD\_TMR} = 56.2k\Omega$ ,  $V_{PULL\_UP1} = 3.3V$ ,  $V_{PULL\_UP2} = 3.3V$ , over temperature range ( $T_A = -55^\circ\text{C}$  to  $125^\circ\text{C}$ ), unless otherwise noted; includes group E radiation testing at  $T_A = 25^\circ\text{C}$  for QML RHA devices (1) (2)

PARAMETER		TEST CONDITIONS		SUB-GROUP (3)	MIN	TYP	MAX	UNIT
$R_{\overline{\text{RESET}}\_PULL\_UP}$	$\overline{\text{RESET}}$ PMOS source output resistance	$I_{LOAD} = 2\text{mA}$	$1.6V \leq V_{PULL\_UP1} < 3.3V$	1, 2, 3		20	40	$\Omega$
			$3.3V \leq V_{PULL\_UP1} \leq 7V$	1, 2, 3		9	20	
$R_{PWRGD\_PULL\_UP}$	PWRGD PMOS source output resistance	$I_{LOAD} = 2\text{mA}$	$1.6V \leq V_{PULL\_UP2} < 3.3V$	1, 2, 3		20	40	
			$3.3V \leq V_{PULL\_UP2} \leq 7V$	1, 2, 3		9	20	
$R_{\overline{\text{WDO}}\_PULL\_UP}$	$\overline{\text{WDO}}$ PMOS source output resistance	$I_{LOAD} = 2\text{mA}$	$1.6V \leq V_{PULL\_UP2} < 3.3V$	1, 2, 3		20	40	
			$3.3V \leq V_{PULL\_UP2} \leq 7V$	1, 2, 3		9	20	
$R_{\overline{\text{RESET}}\_PULL\_DOWN}$	$\overline{\text{RESET}}$ NMOS sink output resistance	$I_{LOAD} = -2\text{mA}$ , $1.6V \leq V_{PULL\_UP1} \leq 7V$		1, 2, 3		16	36	
$R_{PWRGD\_PULL\_DOWN}$	PWRGD NMOS sink output resistance	$I_{LOAD} = -2\text{mA}$ , $1.6V \leq V_{PULL\_UP1} \leq 7V$		1, 2, 3		16	36	
$R_{\overline{\text{WDO}}\_PULL\_DOWN}$	$\overline{\text{WDO}}$ NMOS sink output resistance	$I_{LOAD} = -2\text{mA}$ , $1.6V \leq V_{PULL\_UP1} \leq 7V$		1, 2, 3		16	36	
<b>RESET1 TO RESET4, PWRGD AND WDO OPEN DRAIN (TPS7H3124 AND TPS7H3134)</b>								
$\overline{\text{RESET}}_{LKG}$	$\overline{\text{RESET}}$ leakage current	$V_{\overline{\text{RESET}}} = 7V$		1, 2, 3		23	600	nA
$PWRGD_{LKG}$	PWRGD leakage current	$V_{PWRGD} = 7V$		1, 2, 3		23	600	
$\overline{\text{WDO}}_{LKG}$	$\overline{\text{WDO}}$ leakage current	$V_{\overline{\text{WDO}}} = 7V$		1, 2, 3		23	600	
$R_{\overline{\text{RESET}}\_PULL\_DOWN}$	$\overline{\text{RESET}}$ NMOS sink output resistance	$I_{LOAD} = -2\text{mA}$ , $1.6V \leq V_{PULL\_UP} \leq 7V$		1, 2, 3		131	200	$\Omega$
$R_{PWRGD\_PULL\_DOWN}$	PWRGD NMOS sink output resistance		1, 2, 3		131	200		
$R_{\overline{\text{WDO}}\_PULL\_DOWN}$	$\overline{\text{WDO}}$ NMOS sink output resistance		1, 2, 3		131	200		
$V_{OL\_RESET}$	Low level $\overline{\text{RESET}}$ output voltage	$1.6V \leq V_{PULL\_UP} \leq 7V$	$I_{LOAD} = -2\text{mA}$	1, 2, 3		0.262	0.4	V
			$I_{LOAD} = -10\text{mA}$	1, 2, 3		1.31	2	
$V_{OL\_PWRGD}$	Low level PWRGD output voltage	$1.6V \leq V_{PULL\_UP} \leq 7V$	$I_{LOAD} = -2\text{mA}$	1, 2, 3		0.262	0.4	
			$I_{LOAD} = -10\text{mA}$	1, 2, 3		1.31	2	
$V_{OL\_WDO}$	Low level $\overline{\text{WDO}}$ output voltage	$1.6V \leq V_{PULL\_UP} \leq 7V$	$I_{LOAD} = -2\text{mA}$	1, 2, 3		0.262	0.4	
			$I_{LOAD} = -10\text{mA}$	1, 2, 3		1.31	2	
<b>THERMAL PROTECTION</b>								
$T_{SD\_ENTER}$	Thermal shutdown enter temperature					185		$^\circ\text{C}$
$T_{SD\_EXIT}$	Thermal shutdown exit temperature					171		
<b>DELAY AND WATCHDOG TIMERS</b>								
$t_{DLY\_TMR}$	Delay time	$R_{DLY\_TMR} = 10.5k\Omega$		1, 2, 3	0.22	0.26	0.33	ms
		$R_{DLY\_TMR} = 619k\Omega$		1, 2, 3	11.3	12.5	13.7	
		$R_{DLY\_TMR} = 1.18M\Omega$		1, 2, 3	21.3	23.7	26.2	

## 6.5 Electrical Characteristics (continued)

Over  $3V \leq V_{IN} \leq 14V$ ,  $R_{DLY\_TMR} = 10k\Omega$ ,  $R_{WD\_TMR} = 56.2k\Omega$ ,  $V_{PULL\_UP1} = 3.3V$ ,  $V_{PULL\_UP2} = 3.3V$ , over temperature range ( $T_A = -55^\circ\text{C}$  to  $125^\circ\text{C}$ ), unless otherwise noted; includes group E radiation testing at  $T_A = 25^\circ\text{C}$  for QML RHA devices (1) (2)

PARAMETER		TEST CONDITIONS	SUB-GROUP (3)	MIN	TYP	MAX	UNIT
$t_{WD\_TMR}$	Watchdog time-out	$R_{WD\_TMR} = 56.2k\Omega$	1, 2, 3	0.43	0.52	0.57	s
		$R_{WD\_TMR} = 118k\Omega$	1, 2, 3	0.8	1	1.2	
		$R_{WD\_TMR} = 174k\Omega$	1, 2, 3	1.34	1.5	1.7	

- (1) See the 5962R24206 SMD (standard microcircuit drawing) for additional information on the RHA devices.
- (2) All voltage values are with respect to GND.
- (3) For subgroup definitions, see [Quality Conformance Inspection](#) table.
- (4)  $V_{POR\_IN}$  is the minimum  $V_{IN}$  voltage for a controlled output state, when  $1.6V \leq V_{PULL\_UPx} \leq 7V$ . Below  $V_{POR\_IN}$ , the output state cannot be determined.
- (5)  $V_{POR\_PULL\_UPx}$  is the minimum  $V_{PULL\_UPx}$  voltage for a controlled output state, when  $V_{IN} \leq 3V$ . Below  $V_{POR\_PULL\_UPx}$  the output state cannot be determined.

## 6.6 Timing Requirements

Over  $3V \leq V_{IN} \leq 14V$ ,  $R_{DLY\_TMR} = 10k\Omega$ ,  $R_{REG\_TMR} = 10k\Omega$ ,  $V_{PULL\_UP1} = 3.3V$ ,  $V_{PULL\_UP2} = 3.3V$ , over temperature range ( $T_A = -55^\circ\text{C}$  to  $125^\circ\text{C}$ ) unless otherwise noted; includes group E radiation testing at  $T_A = 25^\circ\text{C}$  for RHA devices (1)

PARAMETER		TEST CONDITIONS	SUB-GROUP (2)	MIN	TYP	MAX	UNIT	
$t_{START\_UP\_DLY}$	Start-up delay time (3)	$V_{REFCAP} \geq 1.1V$ , See <a href="#">Figure 7-1</a>	1, 2, 3		0.3	2.8	ms	
$t_{pd\_RESET\bar{x}}$	$\overline{RESET}$ propagation delay	DLY_TMR = Open, See <a href="#">Figure 7-2</a> and <a href="#">Figure 7-3</a>	1, 2, 3		0.62	4.3	$\mu\text{s}$	
$t_{pd\_PWRGD}$	PWRGD propagation delay	DLY_TMR = Open, See <a href="#">Figure 7-4</a>			0.51	4.3		
$t_{pd\_RESET\bar{x}}$	$\overline{RESET}$ propagation delay	DLY_TMR = Open, See <a href="#">Figure 7-5</a> and <a href="#">Figure 7-6</a>	1, 2, 3		2.6	4.9	$\mu\text{s}$	
$t_{pd\_PWRGD}$	PWRGD propagation delay	DLY_TMR = Open, See <a href="#">Figure 7-7</a>			2.6	4.9		
$t_{pd\_SR\_UVLO}$	SR_UVLO propagation delay	See <a href="#">Figure 7-8</a>	1, 2, 3		0.92	2	$\mu\text{s}$	
$t_{pd\_WDI}$	WDI propagation delay	See <a href="#">Figure 7-9</a> TPS7H3024 and TPS7H3034 (push-pull)	1, 2, 3		23	40	$\mu\text{s}$	
				$t_{WD\_TMR} = 0.52\text{s}$		47		80
				$t_{WD\_TMR} = 1.5\text{s}$		68		116
$t_{pd\_WDI}$	WDI propagation delay	See <a href="#">Figure 7-10</a> TPS7H3124 and TPS7H3134 (open-drain) $R_{PULL\_UP} = 10k\Omega$ and $C_{LOAD} = 100\text{pF}$	1, 2, 3		30	48	$\mu\text{s}$	
				$t_{WD\_TMR} = 0.52\text{s}$		54	94	$\mu\text{s}$
				$t_{WD\_TMR} = 1.5\text{s}$		76	131	$\mu\text{s}$
$t_{PW\_WDI}$	WDI minimum pulse width	See <a href="#">Figure 7-11</a>	4, 5, 6	2			$\times t_{WD\_OSC}$	
$t_{PW\_SR\_UVLO}$	SR_UVLO minimum pulse width for valid reset	See <a href="#">Figure 7-12</a>	4, 5, 6		0.61	1.1	$\mu\text{s}$	
$t_{h\_VENSEX\_FAULT}$	VSENSEx hold time for valid fault detection	$C_{LOAD} = 100\text{pF}$ , See <a href="#">Figure 7-13</a> and <a href="#">Figure 7-14</a>	4, 5, 6		0.56	2.2	$\mu\text{s}$	
$t_{h\_VENSEX\_RISE}$	Rising threshold on VSENSEx hold time	See <a href="#">Figure 7-15</a> and <a href="#">Figure 7-16</a>	4, 5, 6			3.7	$\mu\text{s}$	

- (1) See the 5962R24206 SMD (standard microcircuit drawing) for additional information on the RHA device.
- (2) For subgroup definitions, see [Quality Conformance Inspection](#) table.
- (3) During the power-on,  $V_{IN}$  must be at or above  $UVLO_{RISE(MAX)}$  for at least  $t_{Start\_up\_delay}$  for all internal references to be within specification.

## 6.7 Quality Conformance Inspection

MIL-STD-883, Method 5005 - Group A

SUBGROUP	DESCRIPTION	TEMP (°C)
1	Static tests at	25
2	Static tests at	125
3	Static tests at	-55
4	Dynamic tests at	25
5	Dynamic tests at	125
6	Dynamic tests at	-55
7	Functional tests at	25
8A	Functional tests at	125
8B	Functional tests at	-55
9	Switching tests at	25
10	Switching tests at	125
11	Switching tests at	-55

### 6.8 Typical Characteristics

$R_{DLY\_TMR} = 10.5k\Omega$ ,  $R_{WD\_TMR} = 56.2k\Omega$ ,  $V_{PULL\_UP1} = 3.3V$ ,  $V_{PULL\_UP2} = 3.3V$ ,  $R_{HYS} = 49.9k\Omega$ , MODE = Logic Low, for the TPS7H3024, unless otherwise noted.

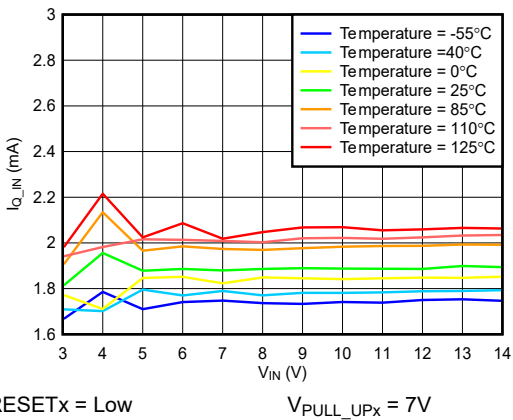


Figure 6-1.  $I_{Q\_IN}$  vs  $V_{IN}$  Across Temperature with RESETx = Low

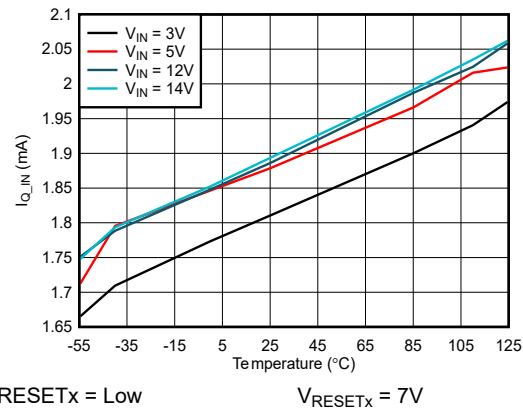


Figure 6-2.  $I_{Q\_IN}$  vs Temperature Across  $V_{IN}$  with RESETx = Low

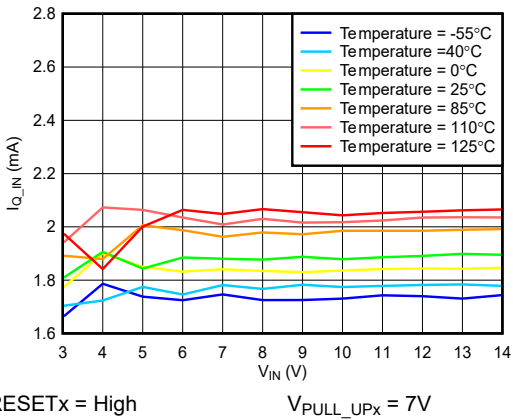


Figure 6-3.  $I_{Q\_IN}$  vs  $V_{IN}$  Across Temperature with RESETx = High

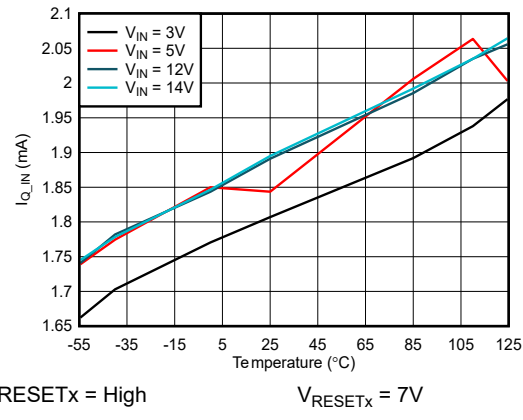


Figure 6-4.  $I_{Q\_IN}$  vs Temperature Across  $V_{IN}$  with RESETx = High

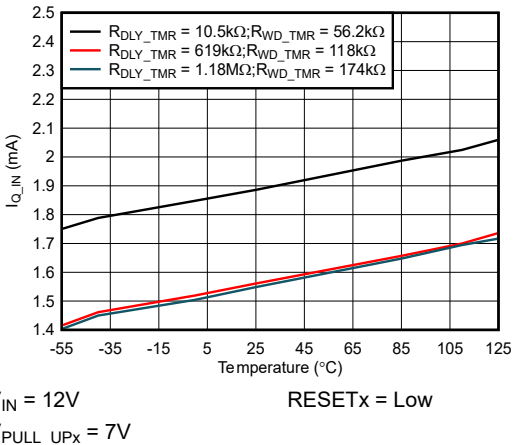


Figure 6-5.  $I_{Q\_IN}$  vs Temperature Across DLY\_TMR and WD\_TMR Resistance

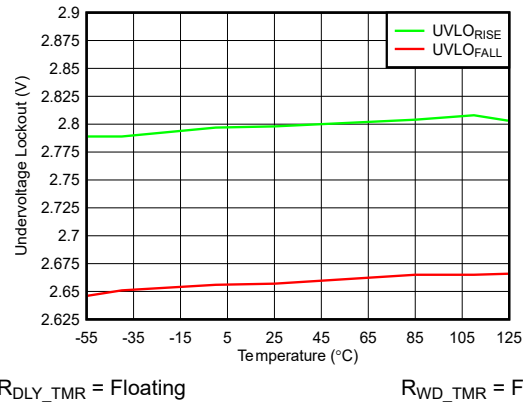


Figure 6-6. Undervoltage Lockout vs Temperature

### 6.8 Typical Characteristics (continued)

$R_{DLY\_TMR} = 10.5k\Omega$ ,  $R_{WD\_TMR} = 56.2k\Omega$ ,  $V_{PULL\_UP1} = 3.3V$ ,  $V_{PULL\_UP2} = 3.3V$ ,  $R_{HYS} = 49.9k\Omega$ , MODE = Logic Low, for the TPS7H3024, unless otherwise noted.

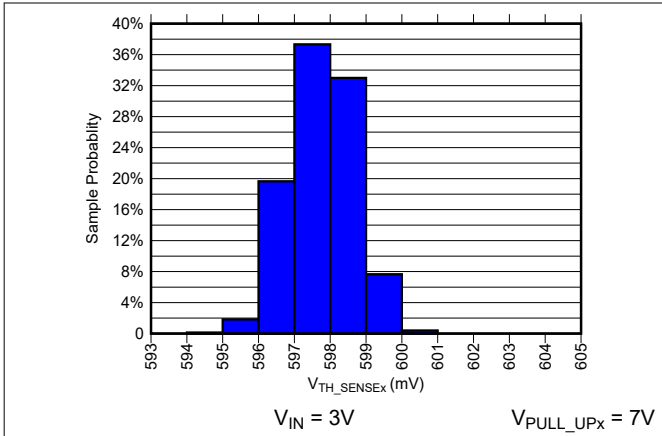


Figure 6-7.  $V_{TH\_SENSEx}$  Voltage Distribution at Temperature of  $-55^{\circ}C$

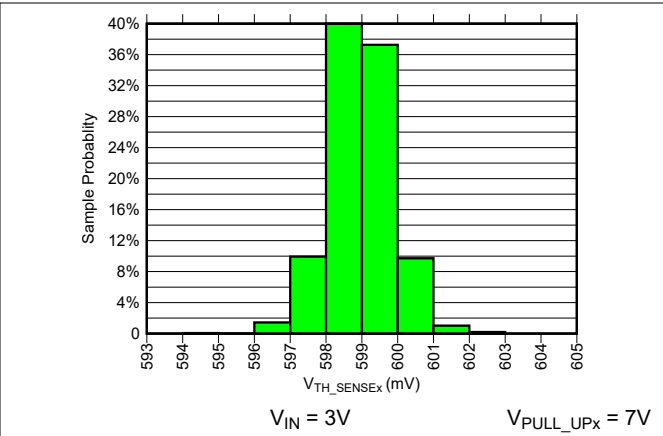


Figure 6-8.  $V_{TH\_SENSEx}$  Voltage Distribution at Temperature of  $+25^{\circ}C$

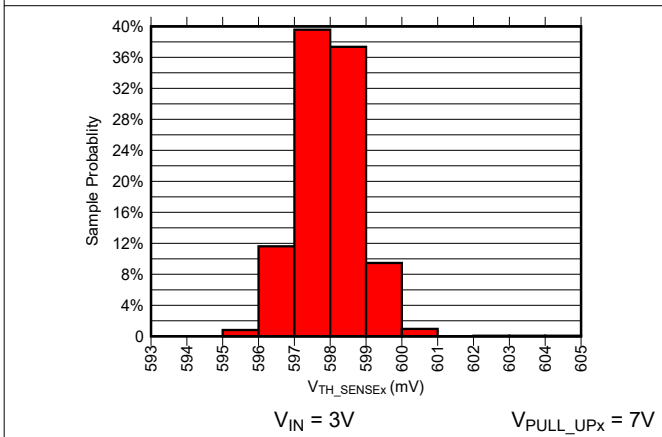


Figure 6-9.  $V_{TH\_SENSEx}$  Voltage Distribution at Temperature of  $125^{\circ}C$

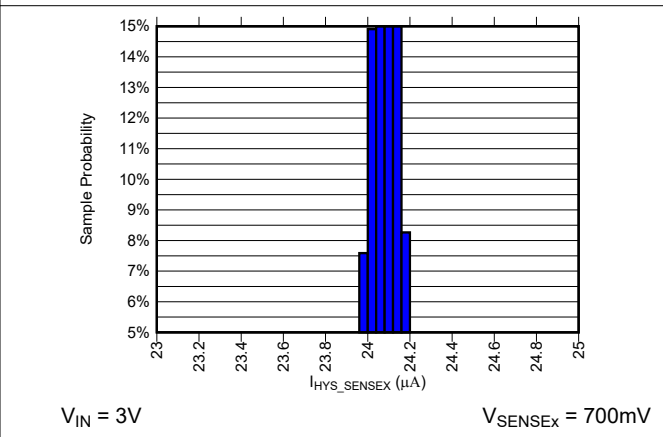


Figure 6-10.  $I_{HYS\_SENSEx}$  Current Distribution at Temperature of  $-55^{\circ}C$

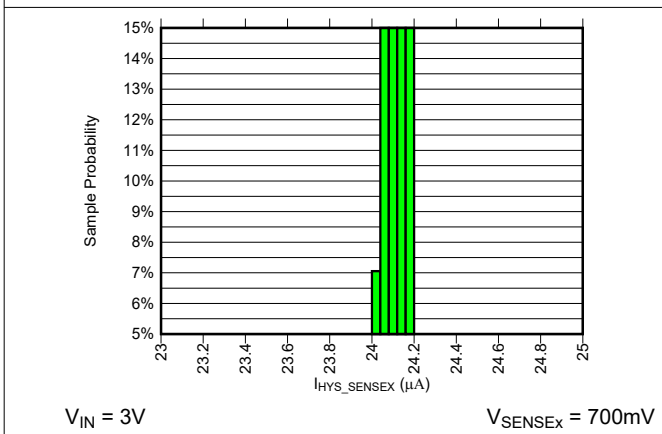


Figure 6-11.  $I_{HYS\_SENSEx}$  Current Distribution at Temperature of  $25^{\circ}C$

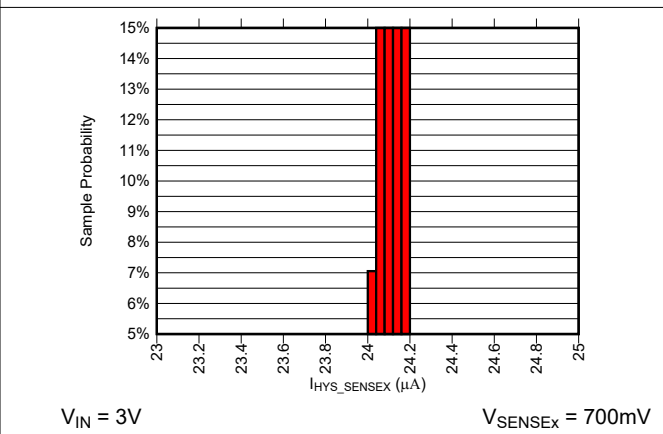


Figure 6-12.  $I_{HYS\_SENSEx}$  Current Distribution at Temperature of  $125^{\circ}C$

### 6.8 Typical Characteristics (continued)

$R_{DLY\_TMR} = 10.5k\Omega$ ,  $R_{WD\_TMR} = 56.2k\Omega$ ,  $V_{PULL\_UP1} = 3.3V$ ,  $V_{PULL\_UP2} = 3.3V$ ,  $R_{HYS} = 49.9k\Omega$ , MODE = Logic Low, for the TPS7H3024, unless otherwise noted.

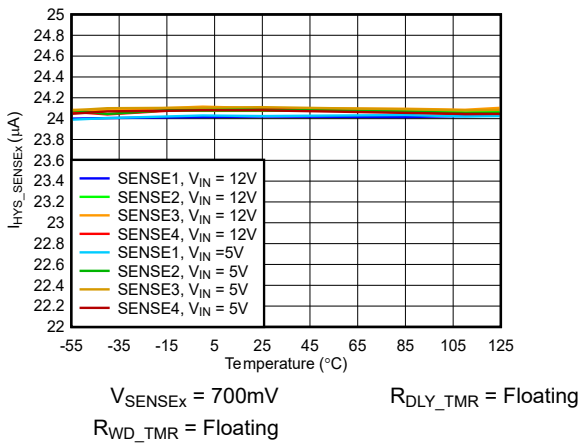


Figure 6-13.  $I_{HYS\_SENSEx}$  vs Temperature Across  $V_{IN}$  and  $SENSEx$  Channel

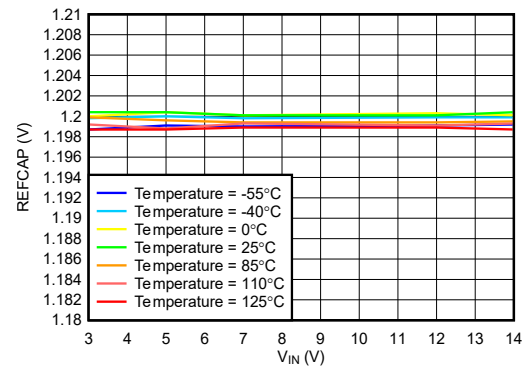


Figure 6-14. REFCAP vs  $V_{IN}$  Across Temperature

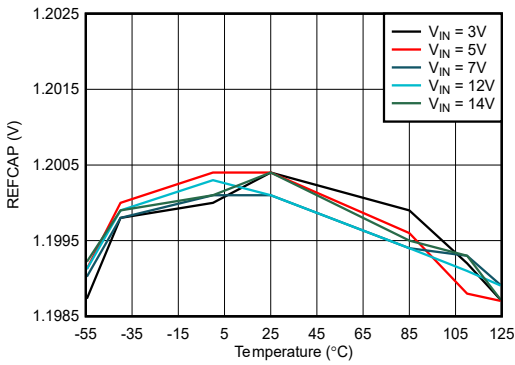


Figure 6-15. REFCAP vs Temperature Across  $V_{IN}$

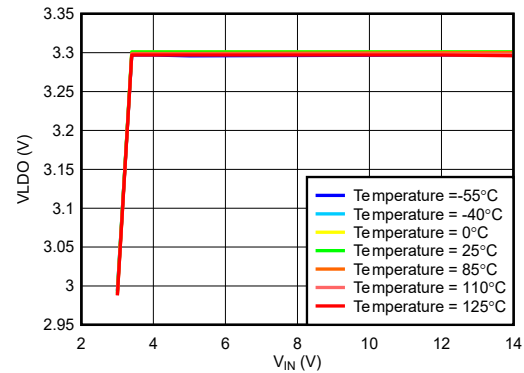


Figure 6-16. VLDO vs  $V_{IN}$  Across Temperature

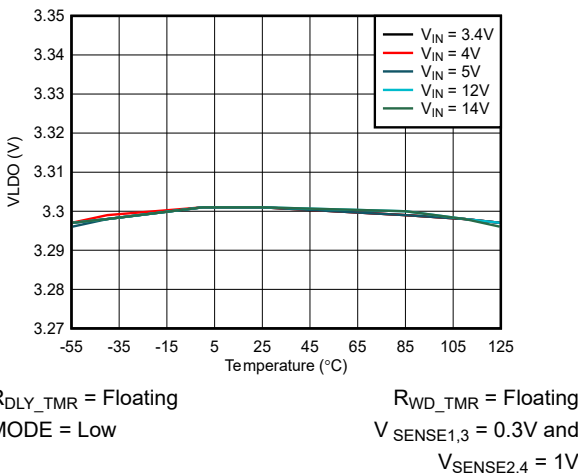


Figure 6-17. VLDO vs Temperature Across  $V_{IN}$

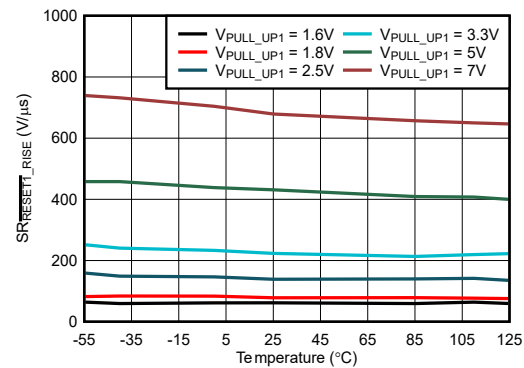


Figure 6-18.  $SR_{RESET1\_RISE}$  vs Temperature Across  $V_{PULL\_UP1}$

## 6.8 Typical Characteristics (continued)

$R_{DLY\_TMR} = 10.5k\Omega$ ,  $R_{WD\_TMR} = 56.2k\Omega$ ,  $V_{PULL\_UP1} = 3.3V$ ,  $V_{PULL\_UP2} = 3.3V$ ,  $R_{HYS} = 49.9k\Omega$ ,  $MODE = Logic\ Low$ , for the TPS7H3024, unless otherwise noted.

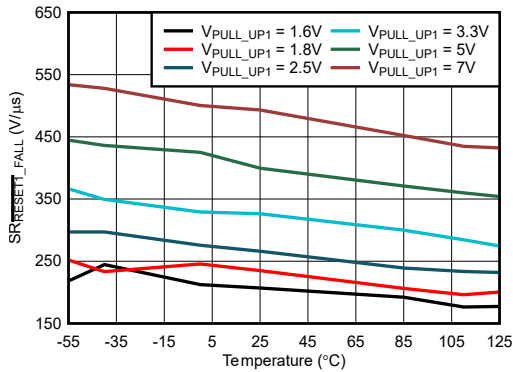


Figure 6-19.  $SR_{RESET1\_FALL}$  vs Temperature Across  $V_{PULL\_UP1}$

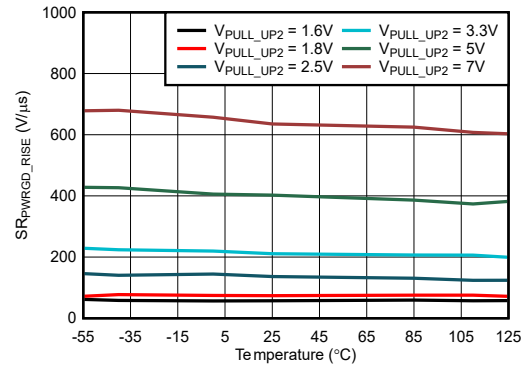


Figure 6-20.  $SR_{PWRGD\_RISE}$  vs Temperature Across  $V_{PULL\_UP2}$

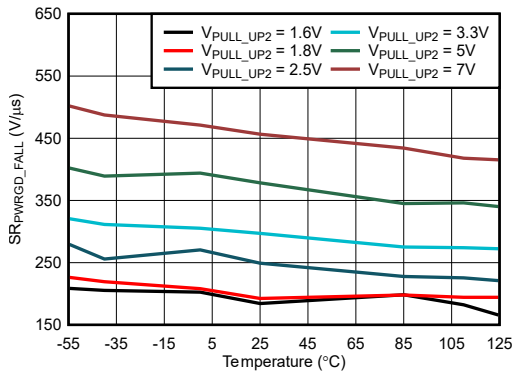


Figure 6-21.  $SR_{PWRGD\_FALL}$  vs Temperature Across  $V_{PULL\_UP2}$

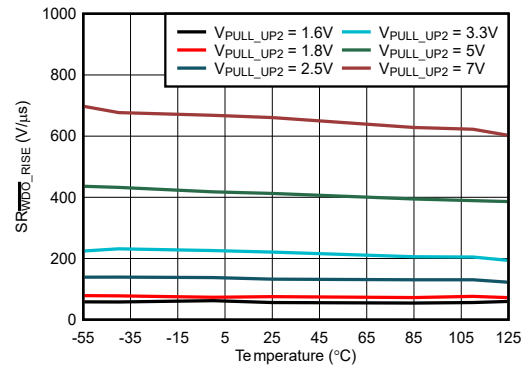


Figure 6-22.  $SR_{WD0\_RISE}$  vs Temperature Across  $V_{PULL\_UP2}$

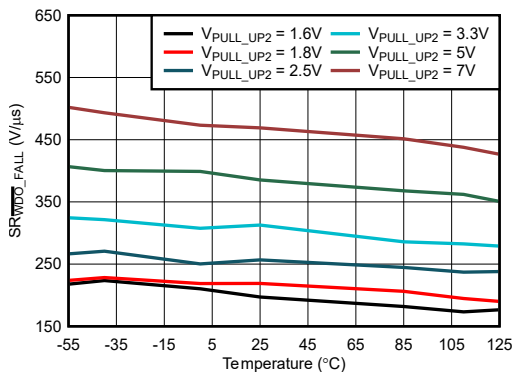


Figure 6-23.  $SR_{WD0\_FALL}$  vs Temperature Across  $V_{PULL\_UP2}$

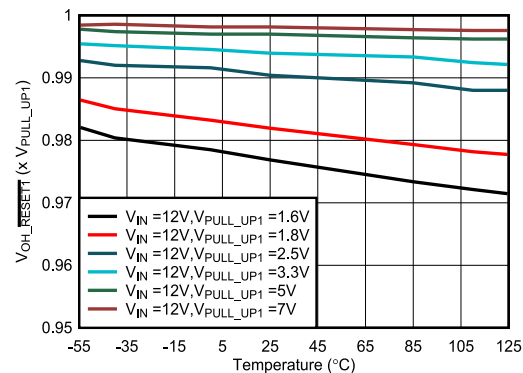


Figure 6-24.  $\overline{RESET1}$   $V_{OH}$  Voltage as Percentage of  $V_{PULL\_UP1}$  vs Temperature Across  $V_{PULL\_UP1}$  at  $I_{LOAD} = 2mA$

### 6.8 Typical Characteristics (continued)

$R_{DLY\_TMR} = 10.5k\Omega$ ,  $R_{WD\_TMR} = 56.2k\Omega$ ,  $V_{PULL\_UP1} = 3.3V$ ,  $V_{PULL\_UP2} = 3.3V$ ,  $R_{HYS} = 49.9k\Omega$ , MODE = Logic Low, for the TPS7H3024, unless otherwise noted.

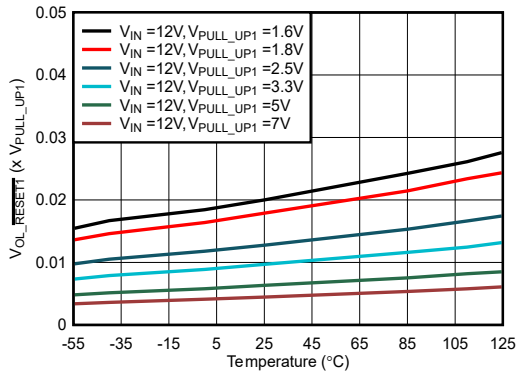


Figure 6-25. RESET1 VOL Voltage as Percentage of  $V_{PULL\_UP1}$  vs Temperature Across  $V_{PULL\_UP1}$  at  $I_{LOAD} = 2mA$

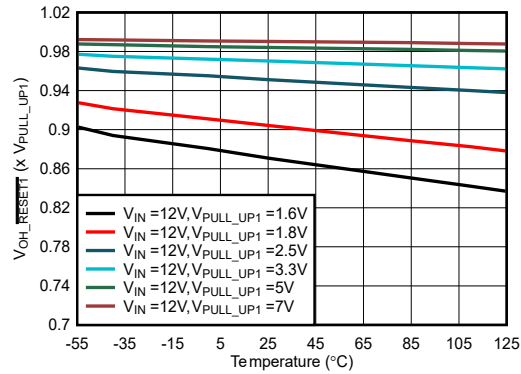


Figure 6-26. RESET1 VOH Voltage as Percentage of  $V_{PULL\_UP1}$  vs Temperature Across  $V_{PULL\_UP1}$  at  $I_{LOAD} = 10mA$



Figure 6-27. RESET1 VOL Voltage as Percentage of  $V_{PULL\_UP1}$  vs Temperature Across  $V_{PULL\_UP1}$  at  $I_{LOAD} = 10mA$

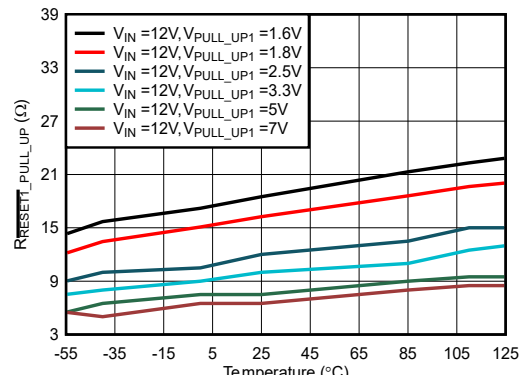


Figure 6-28. RESET1 Pull-Up Resistance vs Temperature Across  $V_{PULL\_UP1}$  at  $I_{LOAD} = 2mA$

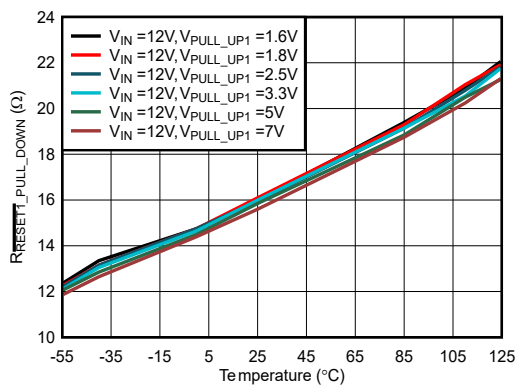


Figure 6-29. RESET1 Pull-Down Resistance vs Temperature Across  $V_{PULL\_UP1}$  at  $I_{LOAD} = 2mA$

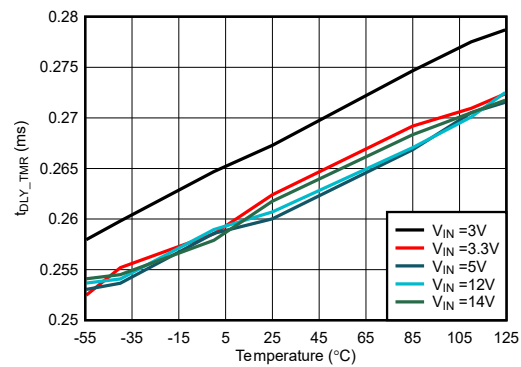
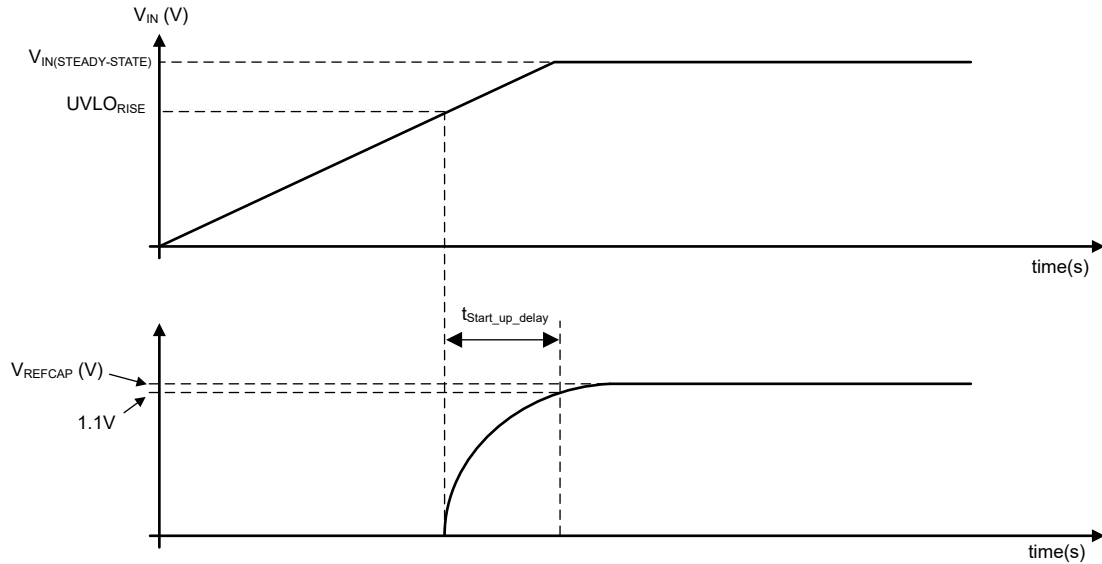


Figure 6-30. Delay Time vs Temperature Across  $V_{IN}$  with  $R_{DLY\_TMR} = 10.5k\Omega$



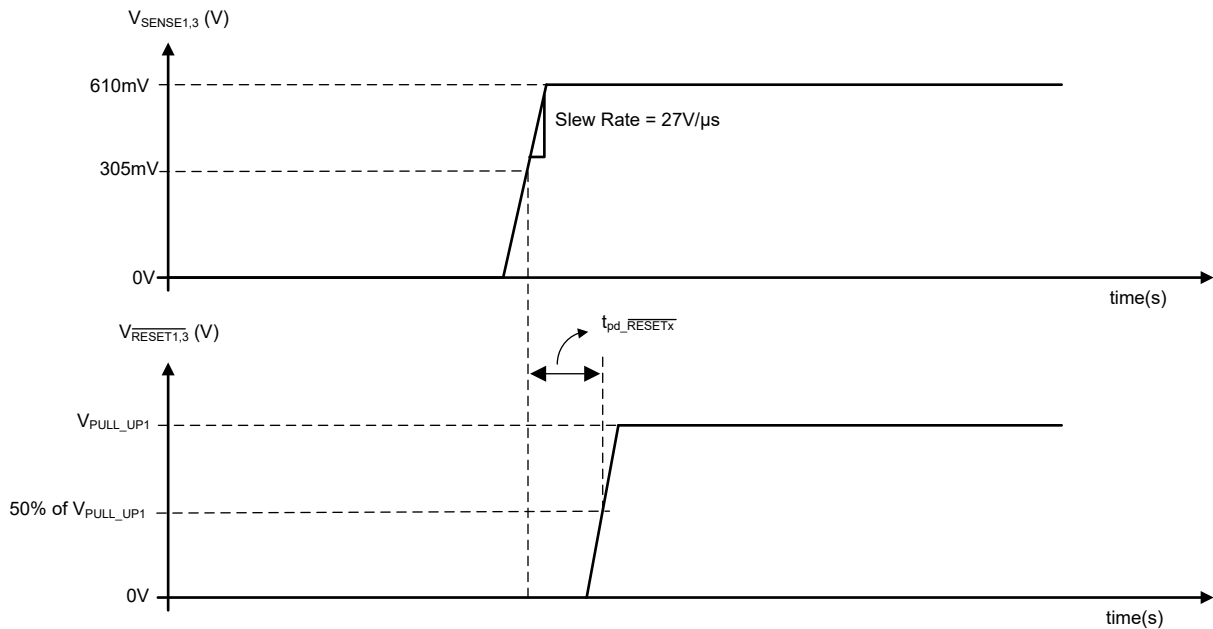
## 7 Parameter Measurement Information

With MODE=0, for all measurements referenced to the PWRGD voltage, the SENSEx voltage is forced in a non-fault state, unless otherwise specified.

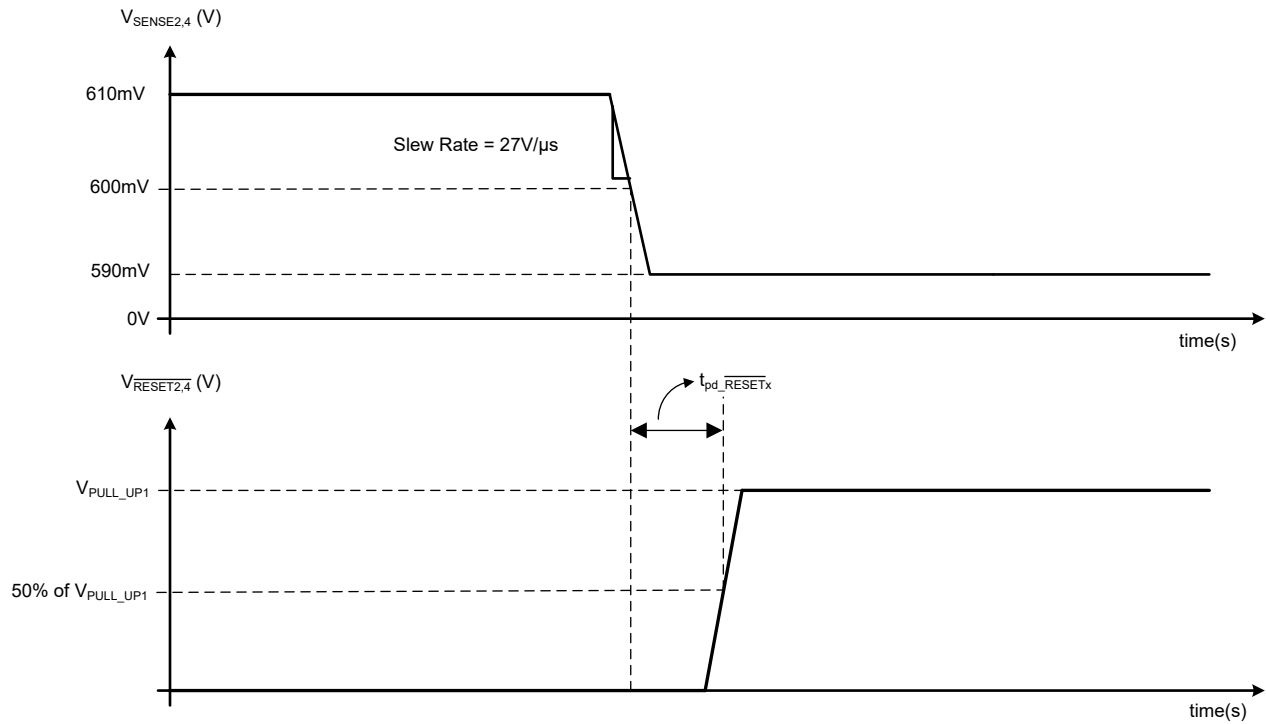


A.  $V_{IN(STEADY-STATE)}$  is a valid operating voltage from 3V to 14V

**Figure 7-1.  $t_{start\_up\_delay}$  Time Measurement**

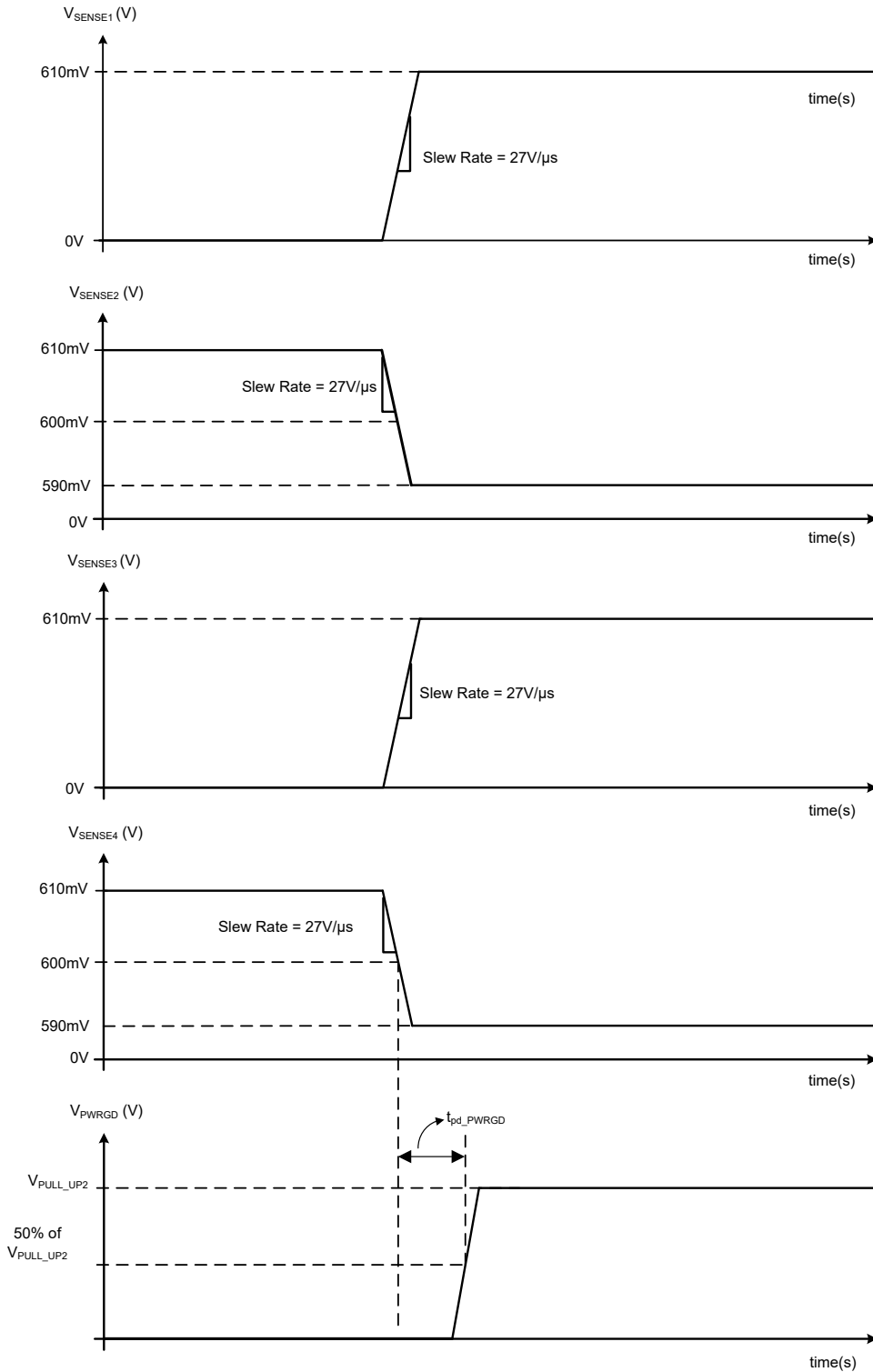


**Figure 7-2.  $\overline{RESET1}$  and  $\overline{RESET3}$  Propagation Delay ( $t_{pd\_RESETx}$ ) Time Measurement for TPS7H30x4 (Push-Pull)**



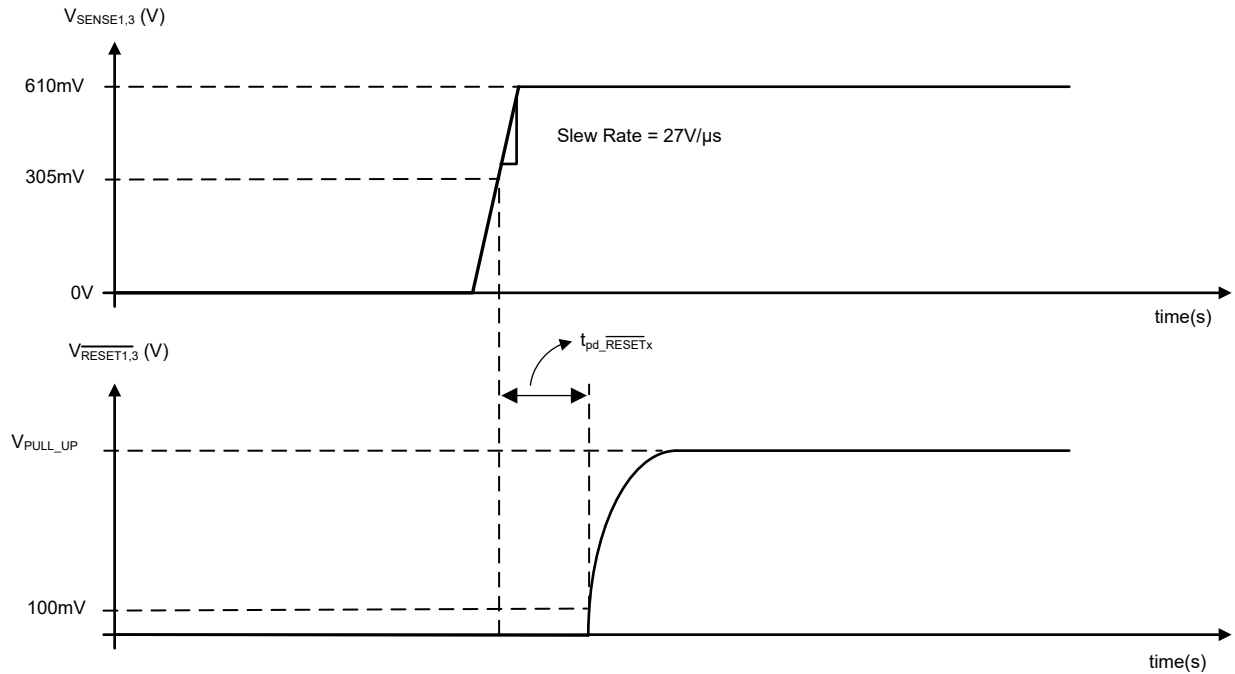
A. For  $t_{pd\_RESETx}$ , each SENSE<sub>x</sub> propagation delay is measured independently.

**Figure 7-3.  $\overline{RESET2}$  and  $\overline{RESET4}$  Propagation Delay ( $t_{pd\_RESETx}$ ) Time Measurement for TPS7H30x4 (Push-Pull)**

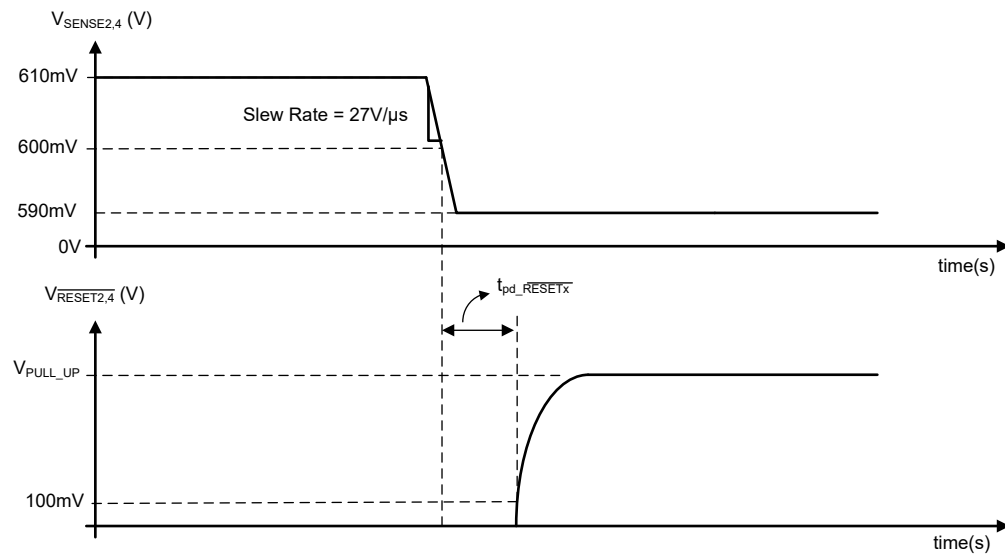


A. In the TPS7H3034 with MODE=0, all V<sub>SENSEX</sub> are ramped up as per V<sub>SENSE1,3</sub> in this diagram.

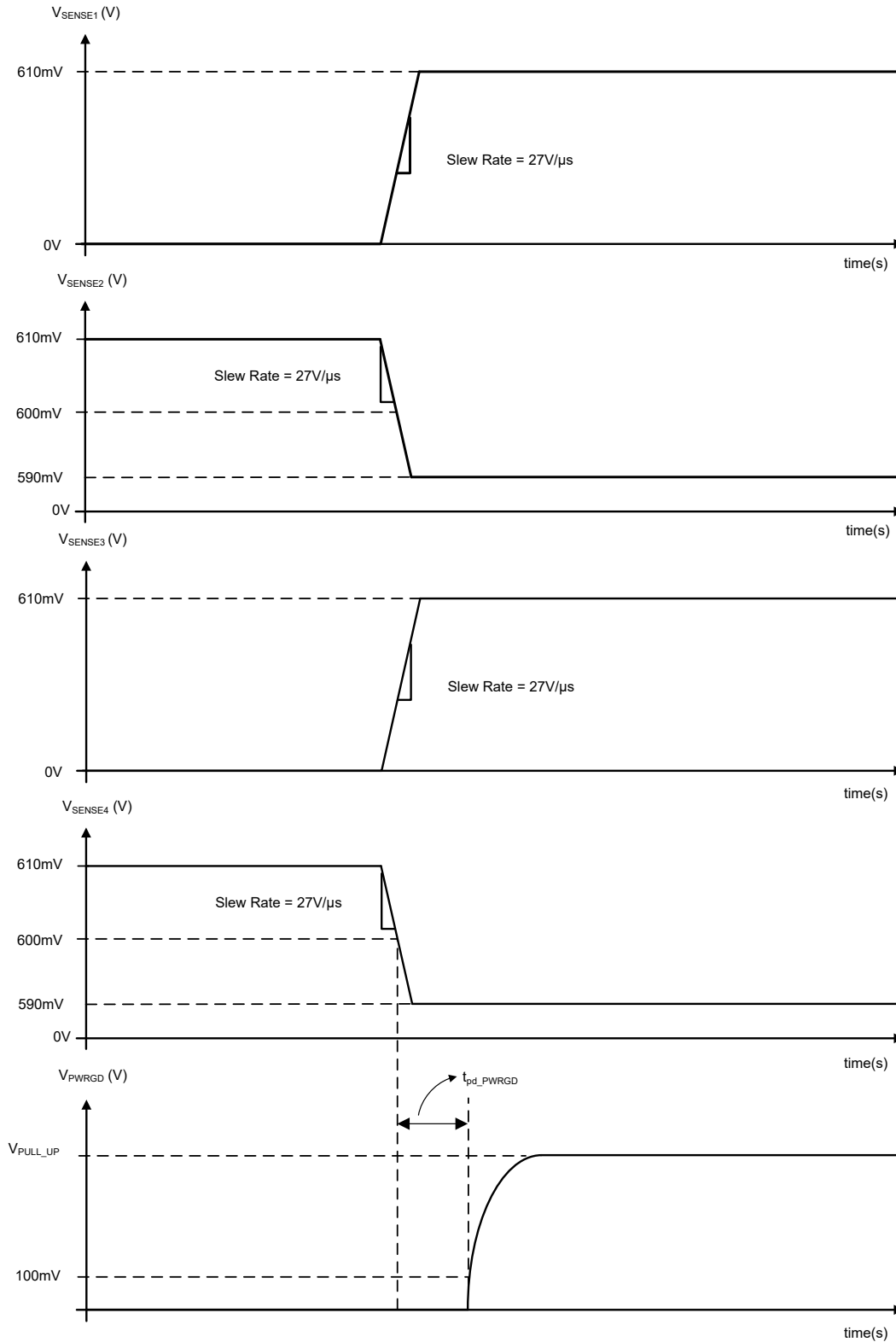
**Figure 7-4. PWRGD Propagation Delay ( $t_{pd\_PWRGD}$ ) for TPS7H3024 (Push-Pull)**



**Figure 7-5.  $\overline{RESET1}$  and  $\overline{RESET3}$  Propagation Delay ( $t_{pd\_RESETx}$ ) Time Measurement for TPS7H31x4 (Open-Drain)**

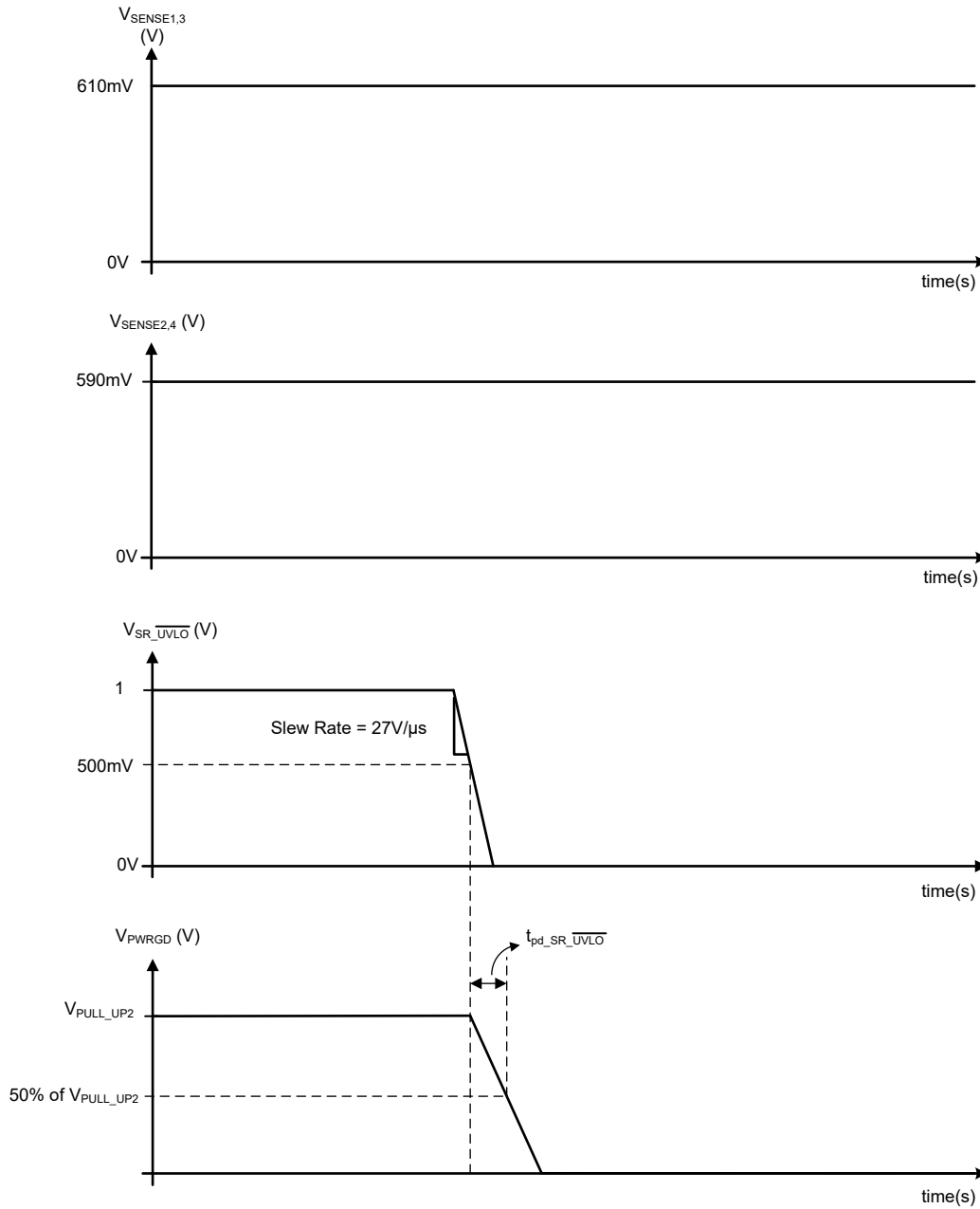


**Figure 7-6.  $\overline{RESET2}$  and  $\overline{RESET4}$  Propagation Delay ( $t_{pd\_RESETx}$ ) Time Measurement for TPS7H31x4 (Open-Drain)**

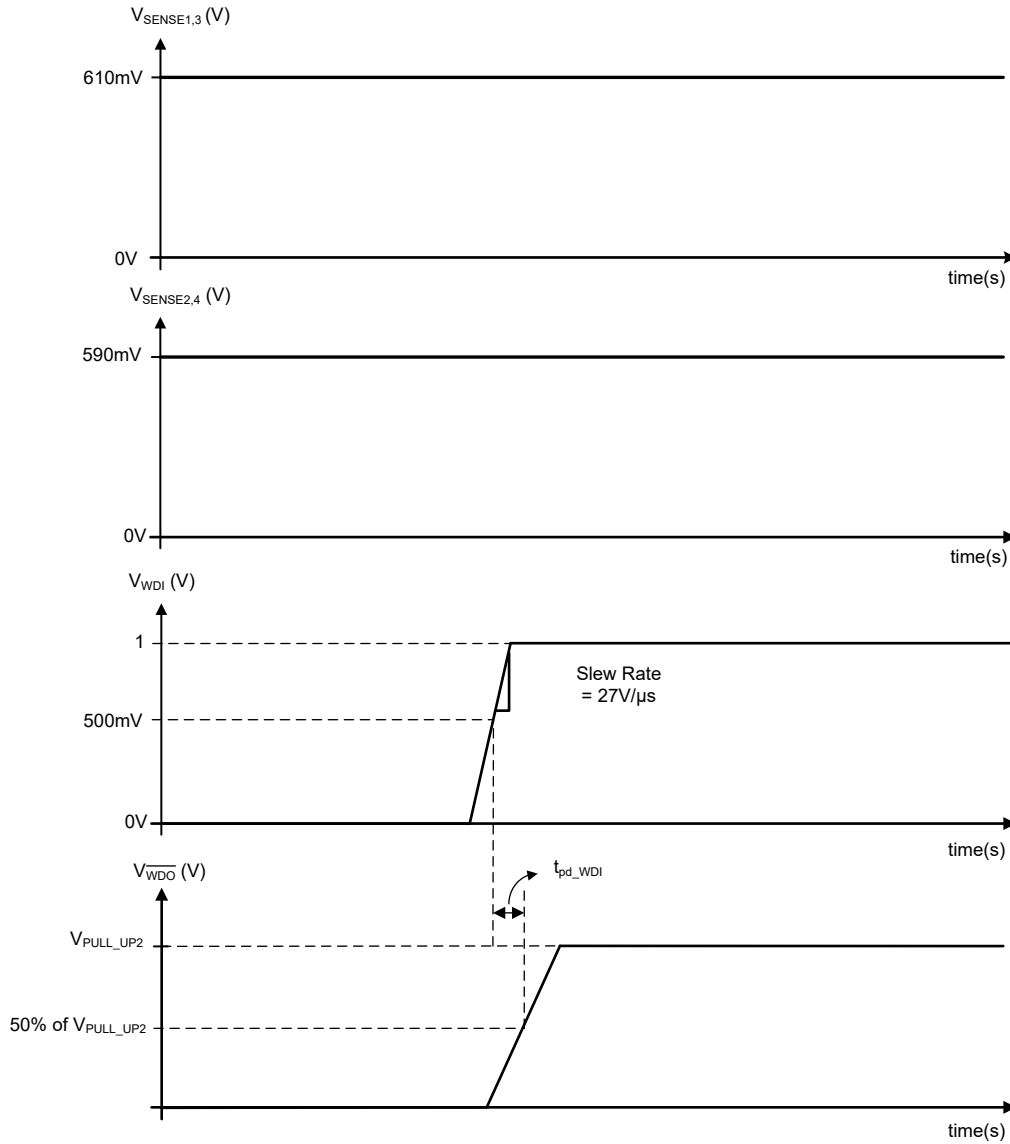


A. In the TPS7H3134 with MODE=0, all  $V_{SENSEx}$  are ramped up as per  $V_{SENSE1,3}$  in this diagram.

**Figure 7-7. PWRGD Propagation Delay ( $t_{pd\_PWRGD}$ ) for TPS7H3124 (Open-Drain)**

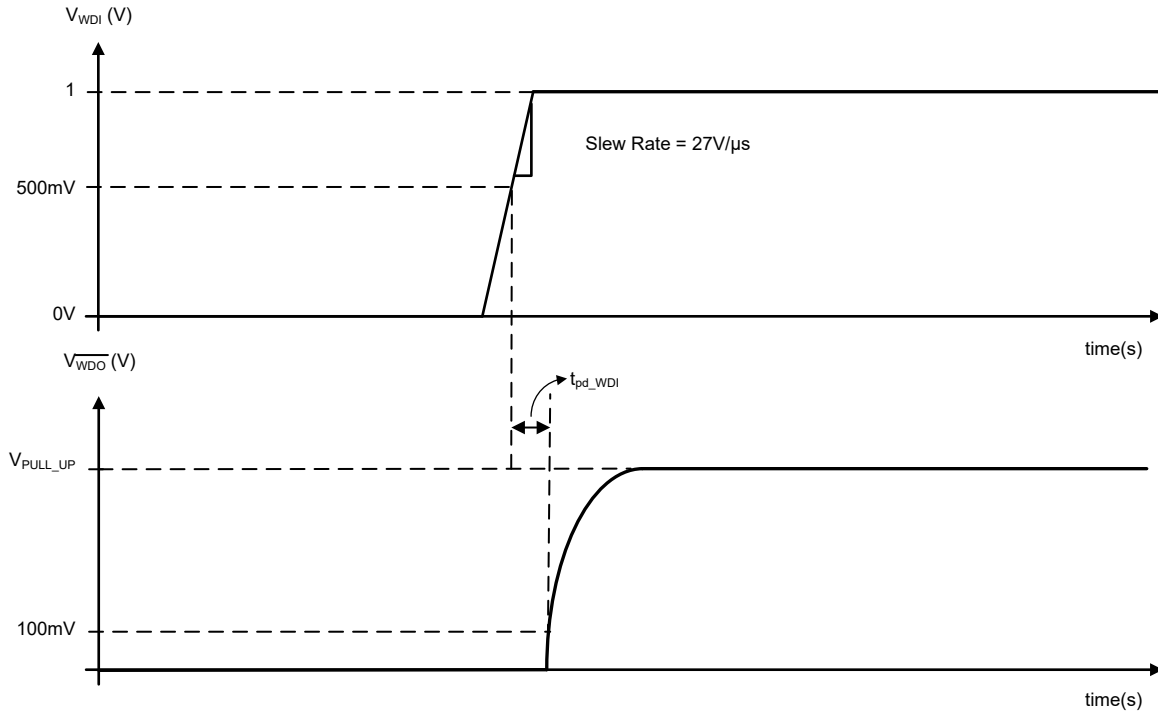


**Figure 7-8.  $\overline{SR\_UVLO}$  Propagation Delay ( $t_{pd\_SR\_UVLO}$ )**



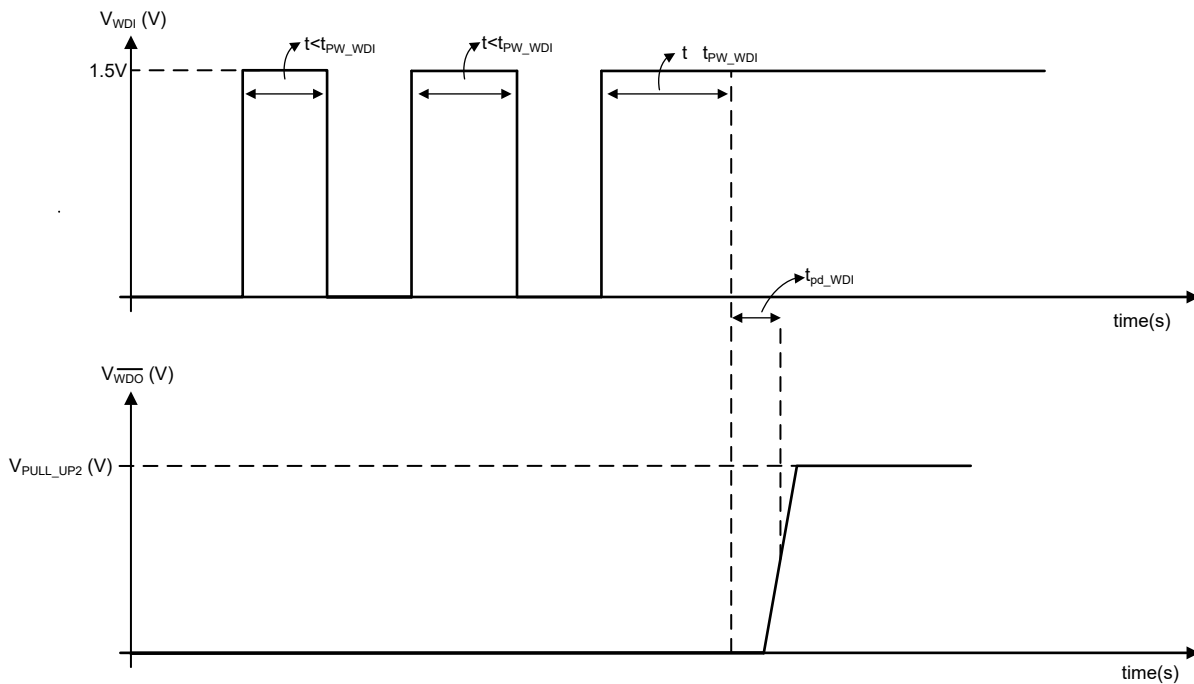
A. With MODE=0 for TPS7H3024. In the TPS7H3034 with MODE=0, all  $V_{SENSEx}$  are forced high as per  $V_{SENSE1,3}$  in this diagram.

**Figure 7-9. WDI Propagation Delay ( $t_{pd\_WDI}$ ) for TPS7H3024 (Push-Pull)**



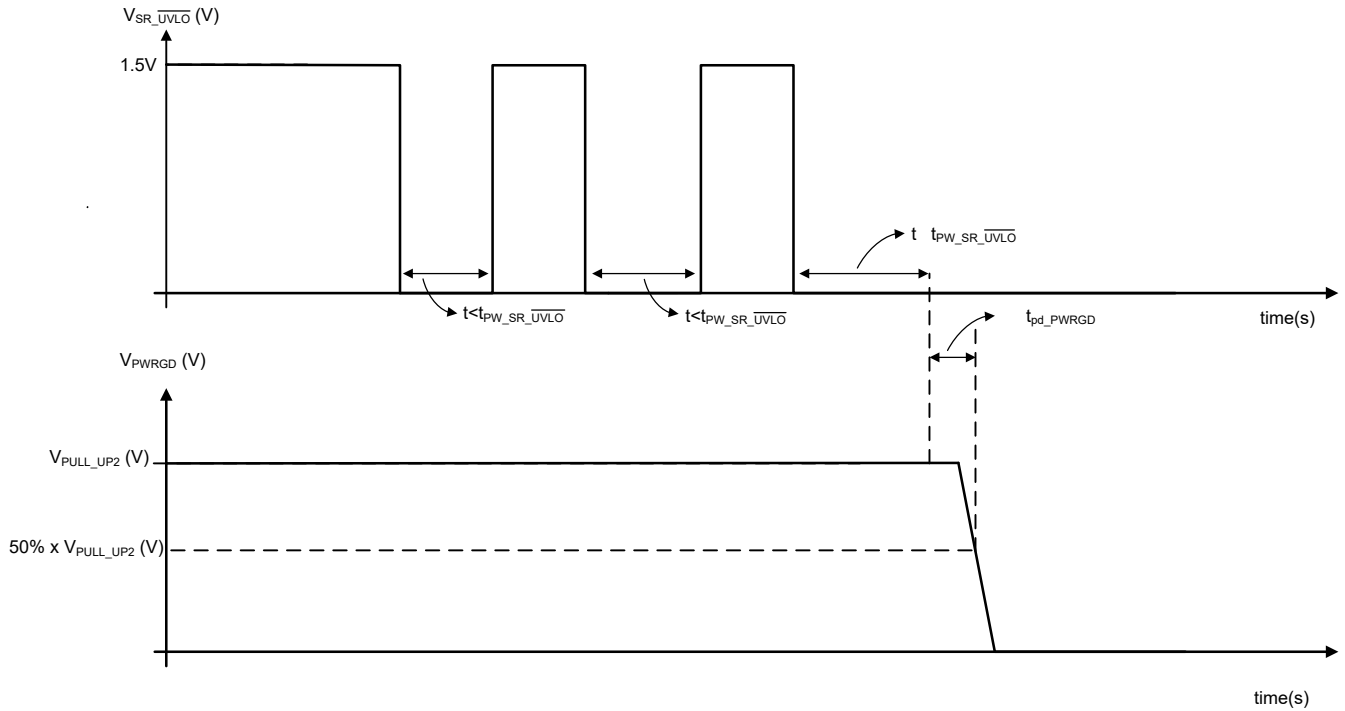
A. In the TPS7H31x4 (open-drain) the WDO is not masked with PWRGD.

**Figure 7-10. WDI Propagation Delay ( $t_{pd\_WDI}$ ) for TPS7H31x4 (Open-Drain)**

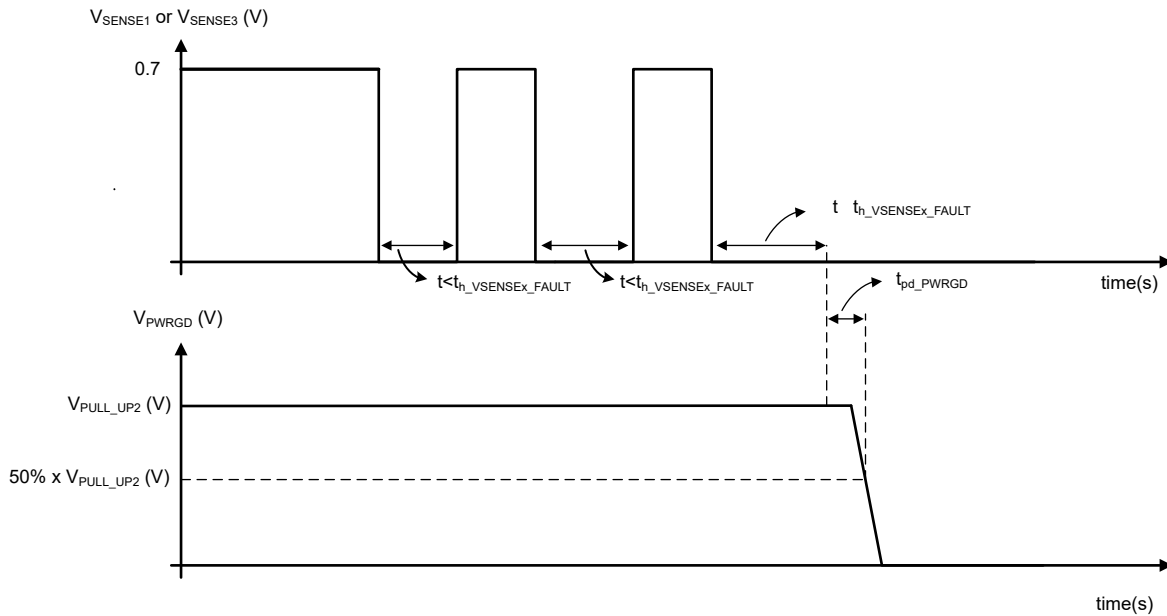


A. With  $V_{SENSE1,3} = 1.5V$ ;  $V_{SENSE2,4} = 0V$  for the TPS7H30x4 (push-pull). In the TPS7H31x4, WDO is not masked by PWRDG.

**Figure 7-11. WDI Pulse Width ( $t_{pW\_WDI}$ )**

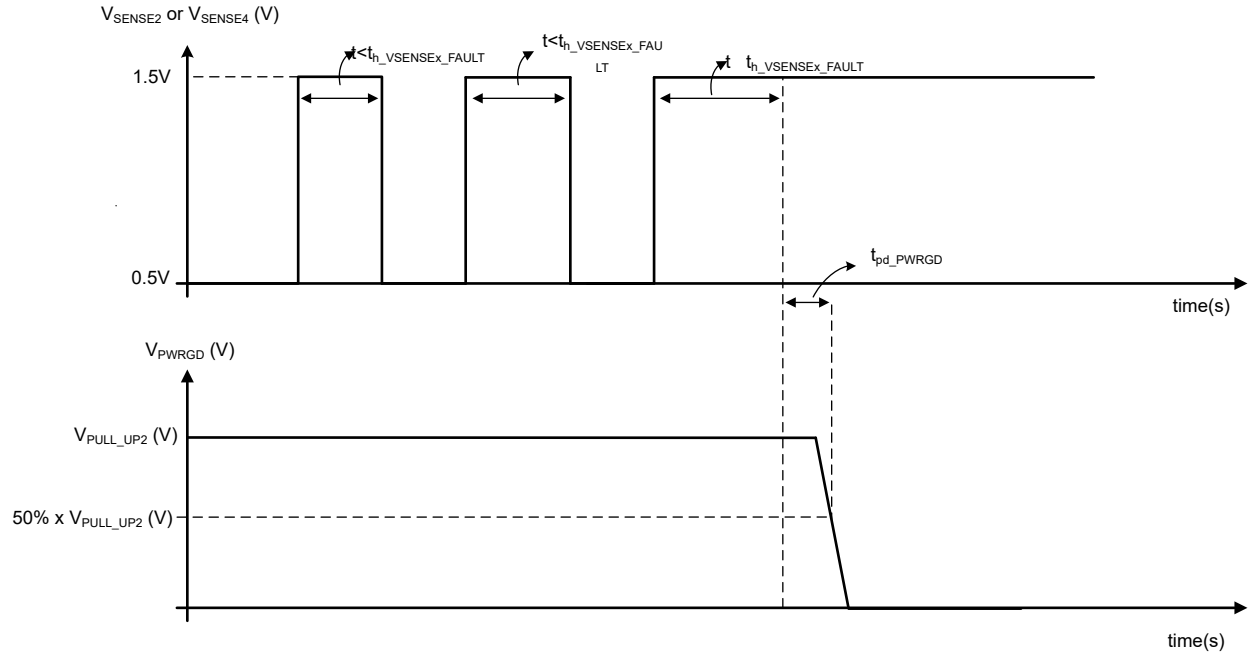


**Figure 7-12. SR\_UVLO Pulse Width ( $t_{pw\_SR\_UVLO}$ )**



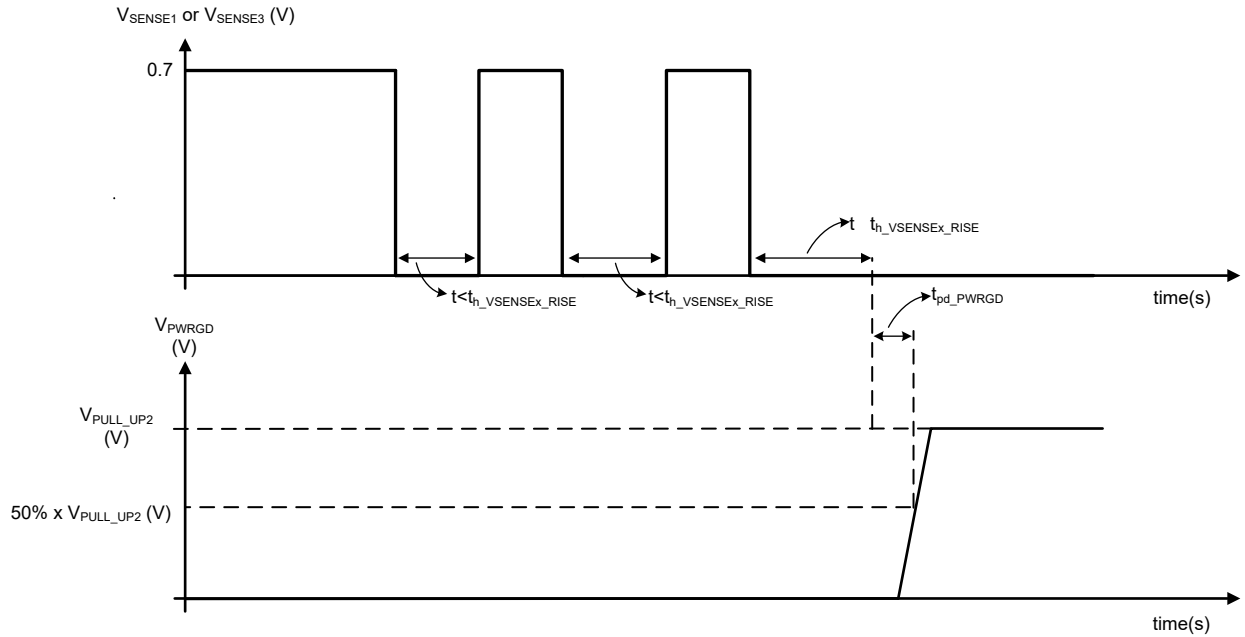
A. For  $t_{th\_VSENSEx\_FAULT}$  each SENSEx is measured independently.

**Figure 7-13. VSENSE1 and VSENSE3 Hold Time for Valid Fault Detection ( $t_{th\_VSENSEx\_FAULT}$ )**



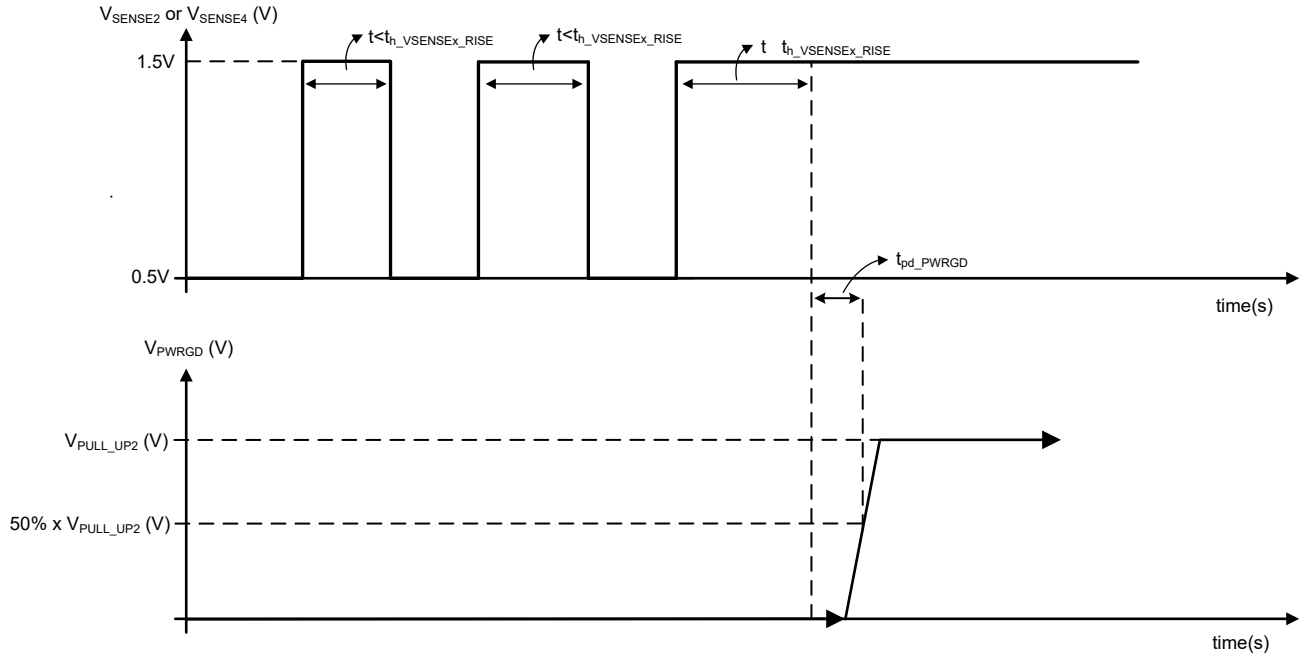
A. For  $t_{h\_VSENSEx\_FAULT}$  each SENSEx is measured independently.

**Figure 7-14. VSENSE2 and VSENSE4 Hold Time for Valid Fault Detection ( $t_{h\_VSENSEx\_FAULT}$ )**



A. For  $t_{h\_VSENSEx\_FAULT}$  each SENSEx is measured independently.

**Figure 7-15. VSENSE1 and VSENSE3 Rising Threshold Hold Time ( $t_{h\_VSENSEx\_RISE}$ )**



A. For  $t_{h\_VSENSEx\_FAULT}$  each SENSEx is measured independently.

**Figure 7-16. VSENSE2 and VSENSE4 Rising Threshold Hold Time ( $t_{h\_VSENSEx\_RISE}$ )**

## 8 Detailed Description

### 8.1 Overview

The TPS7H3xx4 are four-channel, 3V to 14V, voltage supervisors with an integrated watchdog timer for space applications. The active low  $\overline{\text{RESETx}}$  outputs readily supports monitoring of devices with disable low inputs. [Table 8-1](#) describe the monitoring capabilities (undervoltage, overvoltage or window) and output types (push-pull or open-drain) for the offered GPNs. The behavior of the front-end is controlled by the logical value of the MODE pin.

**Table 8-1. TPS7H3xx4 Functional Modes**

GPN	Output Topology	Function	Mode <sup>(1) (2) (3)</sup>
TPS7H3024	Push-pull	2 UV + 2 OV	0
		2 window	1
TPS7H3124	Open-drain	2 UV + 2 OV	0
		2 window	1
TPS7H3034	Push-pull	4 UV	0
		4 OV	1
TPS7H3134	Open-drain	4 UV	0
		4 OV	1

(1) Mode is a static input, the user must not change the logical value dynamically. Once the device is power-up, the value must not change.

(2)  $0 = V_{\text{MODE}} < V_{\text{TH\_MODE\_FALLING(min)}}$

(3)  $1 = V_{\text{MODE}} > V_{\text{TH\_MODE\_RISING(max)}}$

The logic high for the  $\overline{\text{RESETx}}$ , PWRGD, and  $\overline{\text{WDO}}$  is externally controlled using the PULL\_UPx input voltage supply. Users are required to connect at least a 1 $\mu$ F capacitor as close to the PULL\_UPx pins as possible. The logic high of all the  $\overline{\text{RESETx}}$  outputs is programmed via the PULL\_UP1 input, while the PWRGD and  $\overline{\text{WDO}}$  is programmed via PULL\_UP2. The voltage range of the PULL\_UPx inputs is from 1.6V to 7V.

For open-drain outputs, the user must pull up the output through a resistor (typically 10k $\Omega$ ) to the required logic voltage. The maximum pull-up voltage is 7V.

The SENSEx inputs are connected to the non-inverting input of a comparator which is used to classify the monitored voltages as:

1. In regulation.
2. Not in regulation.

For more details on the behavior of the undervoltage and overvoltage comparators refer to [Section 8.3.3.3](#). Each of these inputs feature a threshold level of 599.7mV (typical) with an accuracy of  $\pm 1\%$  across voltage, temperature, and radiation (TID). The hysteresis voltage threshold level can be adjusted by the user and determined by the R<sub>TOPx</sub> resistance and the hysteresis current (I<sub>HYS\_SENSEx</sub>). The I<sub>HYS\_SENSEx</sub> becomes active once the rising voltage at SENSEx exceeds the V<sub>TH\_SENSEx</sub> threshold (typically 599.7mV). I<sub>HYS</sub> is 24 $\mu$ A with an accuracy of  $\pm 3\%$  across voltage, temperature, and radiation (TID). In addition the device offers an output called PWRGD to monitor the status of the power tree (complete system).

#### Note

For the overvoltage comparators, the  $\overline{\text{RESETx}}$  output is logically inverted from the front-end comparator output. Refer to [Figure 8-16](#) and [Figure 8-18](#) for details.

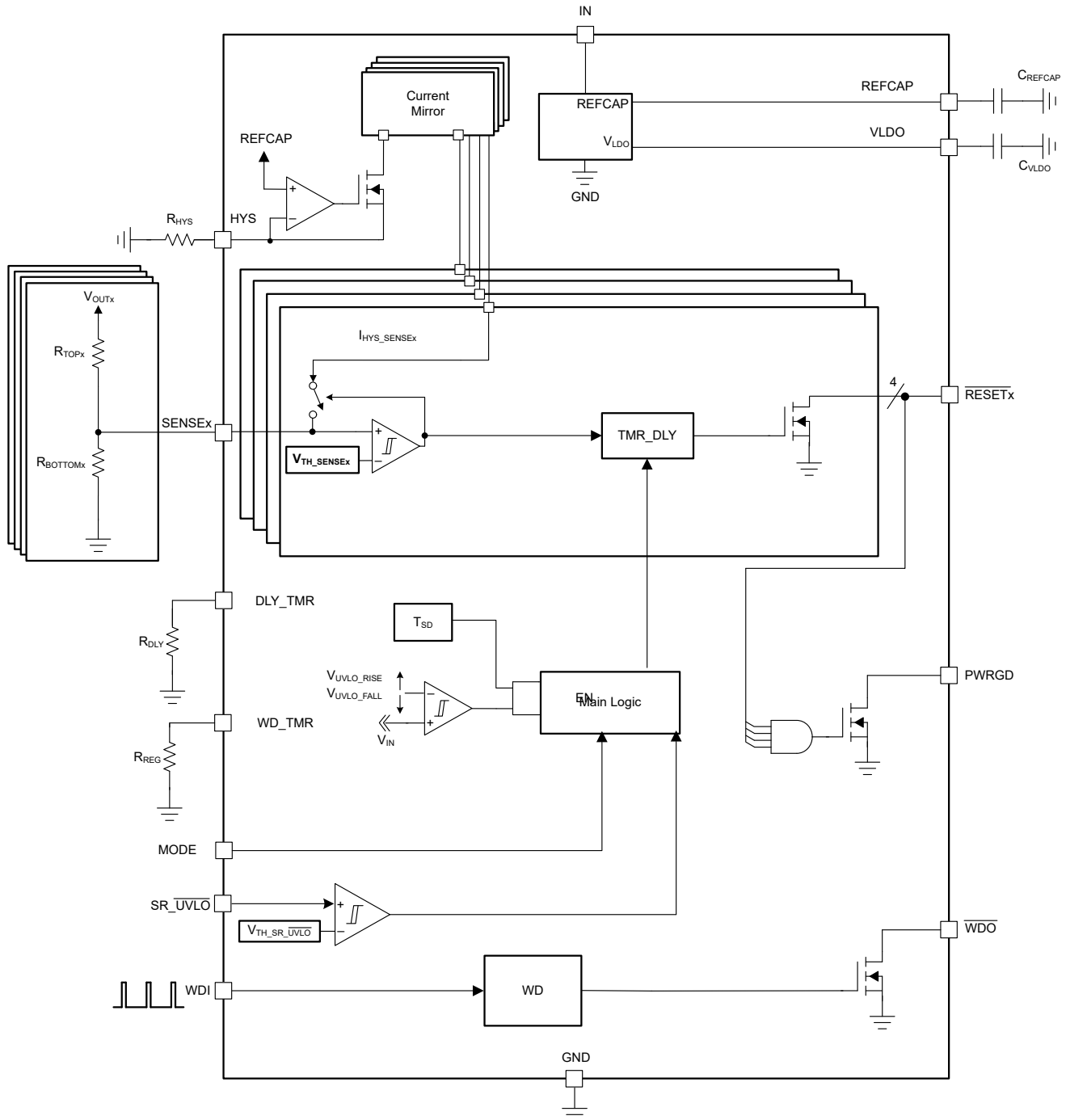
In addition to the voltage supervision, the TPS7H3xx4 incorporates a rising-edge watchdog timer. The watchdog input (WDI) detects rising-edge voltage changes. When the watchdog timer logic detects a rising voltage on the WDI pin, the timer is cleared if the watchdog timer is already active, or starts counting if the pulse is the first detected pulse. With the detection of a rising pulse on the WDI pin, the system has until the programmed time-out (0.5ms to 1.5ms nominally) to clear the timer again. If the timer is cleared before the time-out, the

watchdog output ( $\overline{WDO}$ ) remains high, otherwise WDO is asserted low. Usually the watchdog timer is used to monitor coherent processor execution. Typically a processor induces a rising-edge voltage on the WDI using an output channel and the  $\overline{WDO}$  is connected to a non-maskable interrupt. If the processor is stuck, the WDI pin is not toggled, and, consequently the  $\overline{WDO}$  goes low to reset the processor to a known state.

The device incorporates two programmable timers:

1. **DLY\_TMR**: Sets the out-of-fault delay. Once the monitored voltage changes state, from not in regulation to in regulation, the  $\overline{RESETx}$  is asserted high once the delay programmed by the user (using the DLY\_TMR) is expired. This timer can be programmed from 0.25ms to 25ms, by using a 10.5k $\Omega$  to a 1.18M $\Omega$  resistor, respectively. This delay is not valid when the input ("monitored voltage") changes state from in regulation to not in regulation to propagate the fault as soon as possible.
2. **WD\_TMR**: Sets the time-out for the watchdog timer. When the watchdog input detects a rising voltage on the input (WDI), the monitored process has until the programmed time-out to provide another rising voltage for the output ( $\overline{WDO}$ ) to stay high, otherwise the output goes low.





- In the TPS7H3124, the RESET2 and RESET4 output stages are driven logically inverted from the output of the input comparator to detect overvoltage events. This behavior also applies to the TPS7H3134 when MODE=1. For more details refer to [Figure 8-18](#)
- In the TPS7H3024, when MODE=1, the RESET1 and RESET3 outputs are of the window comparator type. For more details refer to [Figure 8-12](#). RESET2 and RESET4 are the overvoltage comparator flags.

**Figure 8-2. Block Diagram for the TPS7H31x4 (Open-Drain Outputs)**

## 8.3 Feature Description

### 8.3.1 Input Voltage (IN), VLDO, and REFCAP

During steady state operation, the input voltage of the TPS7H3024 must be from 3V to 14V. A minimum bypass capacitance of 0.1 $\mu$ F is required between  $V_{IN}$  and GND. The input bypass capacitors is recommended to be placed as close to the device as possible. The  $V_{IN}$  slew rate must be controlled between 10V/ $\mu$ s to 1mV/ $\mu$ s for proper IC operation.

The voltage applied at  $V_{IN}$  serves as the input for the internal regulator that generates the VLDO voltage, typically 3.29V. At input voltages less than 3.65, the VLDO regulator can be on dropout. The recommended capacitance for VLDO is 1 $\mu$ F of ceramic type. The VLDO can be loaded up to a maximum of 5mA.

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#### Note

The VLDO output is not protected against short circuit conditions.

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During power up, the user is recommended to wait at least 2.8ms ( $t_{Start\_up\_delay}$ ) after  $V_{IN} > UVLO_{RISE}$ . This is to make sure all internal time constants are surpassed, otherwise the reference can be out of the  $\pm 1\%$  accuracy.

Each device generates an internal 1.2V bandgap reference that is used throughout the various internal control logic blocks. This is the voltage present on the REFCAP pin during steady state operation. This voltage is divided down to produce the reference for the comparator inputs at:

1.  $SENSE_x = 599.7\text{mV}$  (typical)
2.  $SR\_UVLO = 602\text{mV}$  (typical) during a rising voltage and 489mV during a falling voltage.
3.  $WDI = 602\text{mV}$  (typical) during a rising voltage and 498mV during a falling voltage.
4.  $MODE = 600\text{mV}$  (typical) during a rising voltage and 498mV during a falling voltage.

The  $V_{TH\_SENSE_x}$  reference is measured at the  $\overline{RESET_x}$  outputs to account for offsets in the error amplifier and maintain regulation within  $\pm 1\%$  across voltage, temperature, and radiation TID (up to 100krad in silicon). This tight reference tolerance allows the user to monitor voltage rails with high accuracy.

A 470nF capacitor to GND is required at the REFCAP pin for proper electrical operation as well as to provide robust SET performance of the device.

#### 8.3.1.1 Undervoltage Lockout ( $V_{POR\_IN} < V_{IN} < UVLO$ )

When the voltage on  $V_{IN}$  is less than the UVLO (2.79V typical) voltage, but greater than the power-on reset voltage ( $V_{POR\_IN}$ , 1.42V typical), the output pins ( $\overline{RESET_x}$ , PWRGD and  $\overline{WDO}$ ) are in a logic low state, regardless of the voltage at the following device input pins:

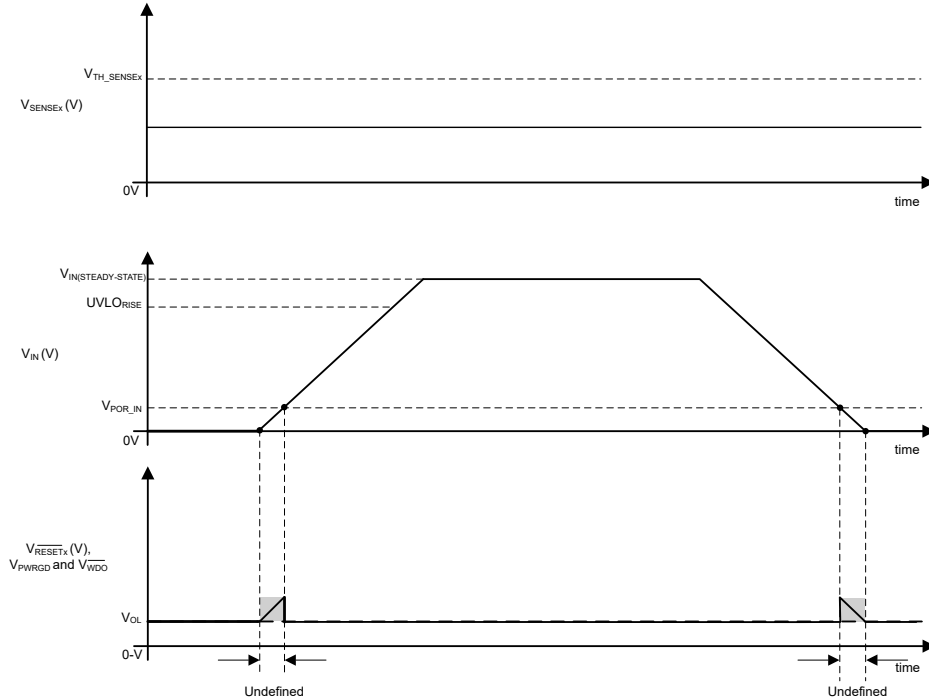
- $SENSE_x$
- $SR\_UVLO$
- $WDI$
- $MODE$

#### 8.3.1.2 Power-On Reset ( $V_{IN} < V_{POR\_IN}$ )

When the voltage on  $V_{IN}$  is lower than the power on reset voltage ( $V_{POR\_IN}$ ), the output signal is undefined and is not to be relied for setting external devices to the correct logic level.

Figure 8-3 shows the  $\overline{RESET_x}$  outputs relationship to a rising input voltage ( $V_{IN}$ ). As can be observed, the  $\overline{RESET_x}$  are undefined when  $V_{IN}$  is lower than  $V_{POR\_IN}$  (typically 1.42V). During this time the outputs can be any value from 0V to  $V_{IN}$ .

In this example, the input voltages to all input comparators ( $SENSE_x$ ) are below the  $V_{TH\_SENSE_x}$  (typically 599.7mV). For this reason the  $\overline{RESET_x}$ , PWRGD and  $\overline{WDO}$  stays low after  $V_{IN}$  rises above  $UVLO_{RISE}$  (typically 2.79V).



**Figure 8-3. Outputs in a Valid Low State After  $V_{IN} > V_{POR\_IN}$**

A. This figure assumes:

1. A valid external pull-up voltage is connected to the PULL\_UPx inputs ( $1.6V \leq V_{PULL\_UPx} \leq 7V$ ).
2.  $V_{IN(STEADY-STATE)}$  is a valid  $V_{IN}$  voltage from 3V to 14V.
3. All inputs are assumed to be of undervoltage (UV) type for this graph.
4.  $V_{OL}$  represents:  $V_{OL\_RESETx}$ ,  $V_{OL\_PWRGD}$  and  $V_{OL\_WDO}$  or the low logic output voltage for all outputs.

### 8.3.2 SR\_UVLO

The SR\_UVLO (system reset and undervoltage lockout) input pin allows for an external controller to propagate an external fault by asserting (or force low) all outputs at once. When SR\_UVLO is low ( $< V_{TH\_SR\_UVLO\_FALLING}$ ) the device enters in shutdown mode and all outputs are forced logical low. As the SR\_UVLO is the input to an accurate ( $\pm 3.17\%$ ) comparator with a rising threshold voltage of  $V_{TH\_SR\_UVLO\_RISING} = 602mV$ , the designer can use the pin to set an external undervoltage lock-out if desired (refer to Figure 8-4). A fixed hysteresis of 103mV is incorporated in the comparator.

Usually the designer knows the voltage at which desired to enable the TPS7H3024. With that information, the resistive divider values can be calculated using Equation 1. Usually the top resistor is fixed to a 10k $\Omega$  value, but other values can be used. Using a larger value resistor minimizes power dissipation but can allow noise to couple into the outputs signal due a "weaker" pull-up.

$$R_{BOTTOM\_SR\_UVLO} = R_{TOP\_SR\_UVLO} \times \frac{V_{TH\_SR\_UVLO\_RISING}}{V_{IN\_UVLO\_DESIRED} - V_{TH\_SR\_UVLO\_RISING}} \quad (1)$$

where:

- $V_{TH\_SR\_UVLO\_RISING}$  is the internal reference during a rising voltage on SR\_UVLO (602mV typically).
  - Rather than use the typical value the designer can use the centered to minimize the error across voltage, temperature and radiation as shown below:

$$\frac{V_{TH\_SR\_UVLO\_RISING(MIN)} + V_{TH\_SR\_UVLO\_RISING(MAX)}}{2} = \frac{0.580V + 0.618V}{2} = 0.599V \quad (2)$$

- $V_{IN\_UVLO\_DESIRED}$  is the desired external voltage to enable the device during a rising voltage on  $V_{IN}$ .

- $R_{TOP\_SR\_UVLO}$  is the selected top resistor for the divider.

Once the designer knows the actual (real) resistive divider values, [Equation 3](#) and [Equation 4](#) can be used to calculate the nominal rising and falling external undervoltage lockout as:

$$V_{IN\_UVLO\_RISING\_NOMINAL}(V) = \left(1 + \frac{R_{TOP\_SR\_UVLO}}{R_{BOTTOM\_SR\_UVLO}}\right) \times V_{TH\_SR\_UVLO\_RISING} \quad (3)$$

$$V_{IN\_UVLO\_FALLING\_NOMINAL}(V) = \left(1 + \frac{R_{TOP\_SR\_UVLO}}{R_{BOTTOM\_SR\_UVLO}}\right) \times V_{TH\_SR\_UVLO\_FALLING} \quad (4)$$

In [Equation 4](#) the designer can use the centered across temperature, voltage and radiation (TID) as:

$$\frac{V_{TH\_SR\_UVLO\_FALLING(MIN)} + V_{TH\_SR\_UVLO\_FALLING(MAX)}}{2} = \frac{0.475V + 0.517V}{2} = 0.496V \quad (5)$$

During startup the device needs to have a stable input voltage ( $UVLO_{RISE} \leq V_{IN} \leq 14$ ) for at least 2.8ms ( $t_{START\_UP\_DELAY}$ ). This is to make sure all internal time constants have been passed. This also makes sure that the  $V_{TH\_SENSEX}$  reference is settled and the accuracy is within specification (1%). When  $V_{IN}$  is a fast rising voltage, an external delay capacitance can be added to the resistive divider to enable the device after the  $t_{START\_UP\_DELAY}$  have been exceeded as shown in [Figure 8-4](#). To select the capacitance ( $C_{DELAY}$ ) for the  $SR\_UVLO$  pin we can use [Equation 6](#).

$$C_{DELAY} (F) > \frac{t_{DELAY}(s)}{R_{TH}(\Omega) \times \ln\left(-\frac{V_{TH}(V)}{V(t) - V_{TH}(V)}\right)} \quad (6)$$

where:

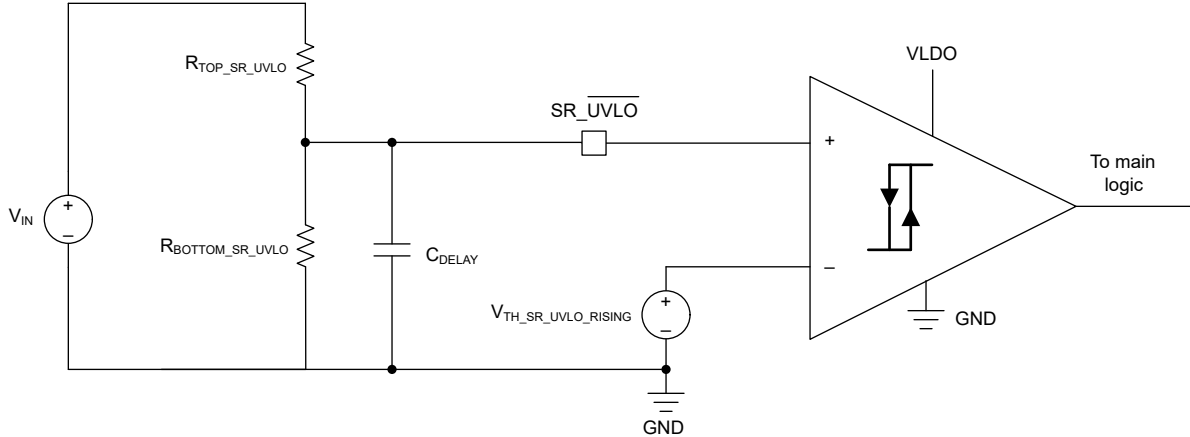
- $t_{DELAY}$  (s) is the desired delay time in seconds (at least 2.8ms after  $V_{IN} > UVLO_{RISE}$ ).
- $R_{TH}$  is the Thévenin equivalent resistance, which is the parallel between  $R_{TOP\_SR\_UVLO}$  and  $R_{BOTTOM\_SR\_UVLO}$  in ohms.

$$R_{TH}(\Omega) = \frac{R_{TOP\_SR\_UVLO}(\Omega) \times R_{BOTTOM\_SR\_UVLO}(\Omega)}{R_{TOP\_SR\_UVLO}(\Omega) + R_{BOTTOM\_SR\_UVLO}(\Omega)} \quad (7)$$

- $V_{TH}$  is the Thévenin equivalent voltage, which is the voltage at  $V_{SR\_UVLO}$  during steady state operation in volts.

$$V_{TH}(V) = \left(\frac{R_{BOTTOM\_SR\_UVLO}(\Omega)}{R_{TOP\_SR\_UVLO}(\Omega) + R_{BOTTOM\_SR\_UVLO}(\Omega)}\right) \times V_{IN}(V) \quad (8)$$

- $V(t)$  is the voltage at  $SR\_UVLO$  ( $V_{SR\_UVLO}$ ) which starts the sequence up. In this case 0.602V.
  - We can use the centered value across temperature and voltage as specified on [Equation 2](#).

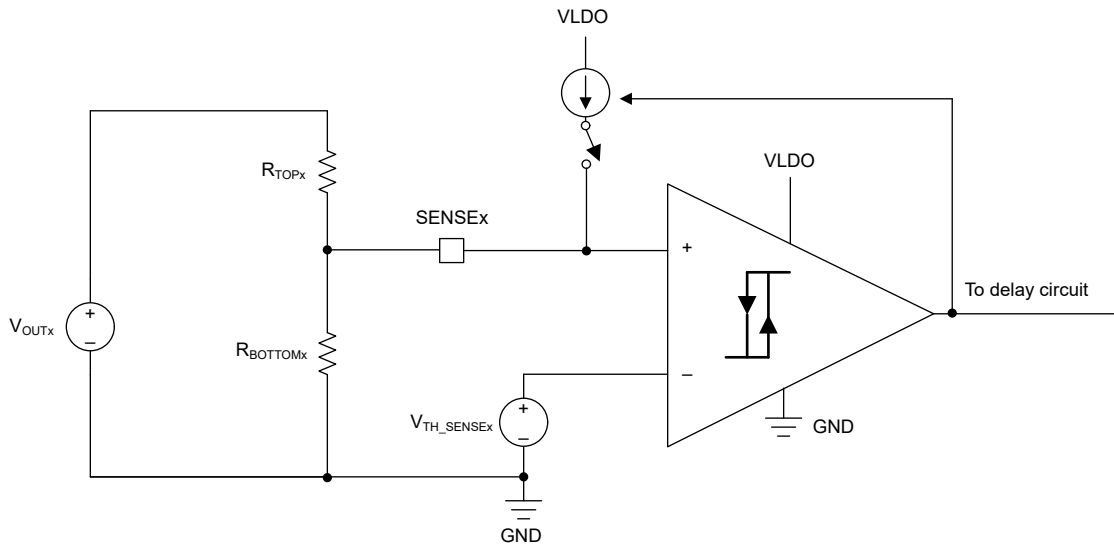


**Figure 8-4. Monitor a Main Rail to Automatically Start the Sequence UP and  $\overline{\text{DOWN}}$**

### 8.3.3 SENSE<sub>x</sub> Inputs

#### 8.3.3.1 $V_{\text{TH\_SENSEX}}$ and $V_{\text{OUTX\_RISE}}$

The TPS7H3024 voltage supervisor integrates four input comparators, with an accurate ( $\pm 1\%$ ) threshold voltage of 599.7mV ( $V_{\text{TH\_SENSEX}}$ ) typical.  $V_{\text{TH\_SENSEX}}$  is measured at the  $\overline{\text{RESETx}}$  outputs to account for comparator offsets in the threshold. Maximum flexibility is provided as external resistive dividers can be adjusted to sense a desired voltage rail ( $V_{\text{OUTX}}$ ). Figure 8-5 shows a conceptual diagram of the comparators connected to the SENSE<sub>x</sub> inputs. As can be observed, the sensed voltage rail ( $V_{\text{OUTX}}$ ) is attenuated (using an external resistive divider,  $R_{\text{TOPx}}$  and  $R_{\text{BOTTOMx}}$ ) and compared against the  $V_{\text{TH\_SENSEX}}$  voltage. It is recommended to maintain the steady-state SENSE<sub>x</sub> voltage below 1.6V, to maintain good threshold ( $V_{\text{TH\_SENSEX}}$ ) accuracy over lifetime.



#### Note

The comparator by itself does not have a built-in voltage hysteresis. The hysteresis is controlled externally using the hysteresis current ( $I_{\text{HYS\_SENSEX}}$ ) and the top resistor ( $R_{\text{TOPx}}$ ). For more details, refer to Section 8.3.3.4. The input comparator does not change for the undervoltage or overvoltage type. The overvoltage is implemented by inverting the signal that drives the output stage.

**Figure 8-5. SENSE<sub>x</sub> Comparators Inputs**

When the voltage at the monitored rail ( $V_{\text{OUTX}}$ ) is rising, the hysteresis current ( $I_{\text{HYS\_SENSEX}}$ ) is not connected to the SENSE<sub>x</sub> input. The SENSE<sub>x</sub> (attenuated  $V_{\text{OUTX}}$ ) voltage is compared to the internal reference ( $V_{\text{TH\_SENSEX}}$ ). When  $V_{\text{SENSEX}} > V_{\text{TH\_SENSEX}}$  the voltage is considered as:

1. In regulation: for an undervoltage channel (UV).
2. Not in regulation: for an overvoltage channel (OV)

Calculate the rising voltage threshold voltage on  $V_{OUTx}$  by doing a simple voltage divider as:

$$V_{OUTx\_RISE\_NOMINAL}(V) = \left(1 + \frac{R_{TOPx}}{R_{BOTTOMx}}\right) \times V_{TH\_SENSEx} \quad (9)$$

Where:

- $V_{TH\_SENSEx}$  is the typical sense threshold voltage of 599.7mV.
  - If it is desired to minimize the error on the monitored voltage across temperature, the centered value can be used instead of the typical as:

$$V_{TH\_SENSEx} = \frac{V_{TH\_SENSEx(MIN)} + V_{TH\_SENSEx(MAX)}}{2} = 599mV \quad (10)$$

- $R_{TOPx}$  is the top resistor in  $\Omega$ .
- $R_{BOTTOMx}$  is the bottom resistor in  $\Omega$ .

As with any system, there is some variation (or errors) of the design variables, in this case the top resistor, bottom resistors and the SENSEx threshold voltage ( $V_{TH\_SENSEx}$ ). Using the derivative method to calculate the total error (with the assumption that all variables are uncorrelated and both resistors have the same tolerance value), the  $V_{TH\_RISEx\_NOMINAL}$  error can be calculated as:

$$V_{OUTx\_RISE\_ERROR}(V) = \pm \sqrt{\frac{V_{TH\_SENSEx}^2 \times \left[ (2 \times R_{TOL}^2 \times R_{TOPx}^2) + (V_{TH\_SENSEx\_ACC}^2 \times (R_{TOPx} + R_{BOTTOMx})^2) \right]}{R_{BOTTOMx}^2}} \quad (11)$$

Where:

- $R_{TOL}$  is the resistors tolerance (same for top and bottom resistors) as numeric value. For example, for 0.1% tolerance resistors, we use 0.001.
- $V_{TH\_SENSEx\_ACC}$  is the SENSEx threshold accuracy as numeric value (in this case 0.01).
- $R_{TOPx}$  and  $R_{BOTTOMx}$  are in  $\Omega$ .
- $V_{TH\_SENSEx}$  is 0.599 Volts (center across temperature).

Using [Equation 9](#) and [Equation 11](#), calculate the rising voltage threshold range as:

$$V_{OUTx\_RISE} = V_{OUTx\_RISE\_NOMINAL} \pm V_{OUTx\_RISE\_ERROR} \quad (12)$$

#### Note

Remember  $V_{TH\_SENSEx}$  is the reference voltage when accounting for the comparator offsets  
 $V_{TH\_SENSEx} = V_{REF} + V_{IOx}$ .

Although it is not required, in noisy applications it is good analog design practice to place a small bypass capacitor at the SENSEx inputs to reduce sensitivity to transient voltages on the monitored signal.

#### 8.3.3.2 $I_{HYS\_SENSEx}$ and $V_{OUTx\_FALL}$

The TPS7H3024 has a built-in hysteresis current of 24 $\mu$ A with an accuracy of  $\pm 3\%$  (with  $R_{HYS} = 49.9k\Omega$ ). The hysteresis current is approximately equivalent to  $V_{HYS}/R_{HYS}$ . A tolerance of 0.1% for the  $R_{HYS}$  resistor is recommended as the tolerance ultimately affects the accuracy of the hysteresis current. This current is mirrored internally across all SENSEx inputs. This hysteresis current becomes active when the SENSEx voltage is greater than the threshold voltage ( $599.7mV \pm 1\%$ , refer to [Equation 12](#) and [Figure 8-5](#)). This current ( $I_{HYS\_SENSEx}$ ) multiplied by the  $R_{TOPx}$  resistance induces a voltage ( $V_{HYS\_SENSEx}$ ) that is added to the SENSEx node. This effectively boost (or increments) the node voltage (in this case  $V_{SENSEx}$ ).

When the  $V_{OUTx}$  voltage is falling and becomes lower than  $V_{OUT\_FALLx}$ , the voltage is considered as:

1. Not in regulation: for an undervoltage channel (UV).
2. In regulation: for an overvoltage channel (OV).

The hysteresis voltage is defined as:

$$V_{\text{HYS\_SENSE}_x\text{\_NOMINAL}}(V) = I_{\text{HYS\_SENSE}_x} \times R_{\text{TOP}_x} \quad (13)$$

Where:

- $I_{\text{HYS\_SENSE}_x} = 24 \times 10^{-6}$  Amps (or 24 $\mu$ A)
- $R_{\text{TOP}_x}$  units are in Ohms ( $\Omega$ )

The falling voltage threshold can be calculated as:

$$V_{\text{OUT}_x\text{\_FALL\_NOMINAL}}(V) = V_{\text{OUT}_x\text{\_RISE\_NOMINAL}} - V_{\text{HYS\_SENSE}_x\text{\_NOMINAL}} \quad (14)$$

Using [Equation 9](#) and [Equation 14](#)

$$V_{\text{OUT}_x\text{\_FALL\_NOMINAL}}(V) = \left[ \left( 1 + \frac{R_{\text{TOP}_x}}{R_{\text{BOTTOM}_x}} \right) \times V_{\text{TH\_SENSE}_x} \right] - (I_{\text{HYS\_SENSE}_x} \times R_{\text{TOP}_x}) \quad (15)$$

Where:

- $V_{\text{TH\_SENSE}_x}$  is the nominal sense threshold voltage of 0.599V
- $I_{\text{HYS\_SENSE}_x} = 24 \times 10^{-6}$  Amps (or 24 $\mu$ A)
- $R_{\text{TOP}_x}$  and  $R_{\text{BOTTOM}_x}$  units are in Ohms ( $\Omega$ )

The  $V_{\text{OUT}_x\text{\_FALL}}$  error can be calculated as:

$$V_{\text{TH\_FALL}_x\text{\_ERROR}}(V) = \pm \sqrt{\frac{A + B + C + D}{R_{\text{BOTTOM}_x}^2}} \quad (16)$$

[Equation 16](#) is obtained using the derivative method and under the assumptions that all variables are uncorrelated and both resistors have the same tolerance

Where the equation terms are:

$$A = I_{\text{HYS\_SENSE}_x}^2 \times I_{\text{HYS\_SENSE}_x\text{\_ACC}}^2 \times R_{\text{TOP}_x}^2 \times R_{\text{BOTTOM}_x}^2 \quad (17)$$

$$B = R_{\text{TOL}}^2 \times R_{\text{TOP}_x}^2 \times V_{\text{TH\_SENSE}_x}^2 \quad (18)$$

$$C = R_{\text{TOL}}^2 \times R_{\text{TOP}_x}^2 \times [(I_{\text{HYS\_SENSE}_x} \times R_{\text{BOTTOM}_x}) - V_{\text{TH\_SENSE}_x}]^2 \quad (19)$$

$$D = V_{\text{TH\_SENSE}_x}^2 \times V_{\text{TH\_SENSE}_x\text{\_ACC}}^2 \times (R_{\text{TOP}_x} + R_{\text{BOTTOM}_x})^2 \quad (20)$$

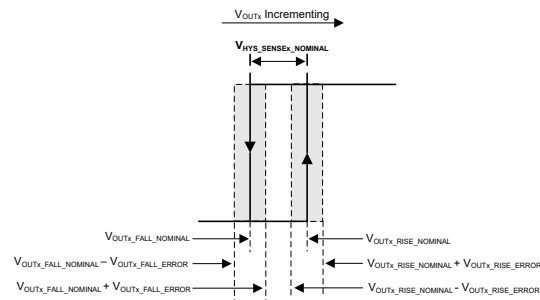
Where:

- $R_{\text{TOL}}$  is the resistors tolerance (same for top and bottom resistors) as numeric value. For example, for 0.1% tolerance resistors, we use 0.001.
- $V_{\text{TH\_SENSE}_x\text{\_ACC}}$  is the SENSE $_x$  threshold accuracy as numeric value (in this case 0.01).
- $I_{\text{HYS\_SENSE}_x\text{\_ACC}}$  is the hysteresis current accuracy as numeric value (in this case 0.03).
- $V_{\text{TH\_SENSE}_x}$  is the nominal sense threshold voltage of 0.599V.
- $I_{\text{HYS\_SENSE}_x} = 24 \times 10^{-6}$  Amps (or 24 $\mu$ A).
- $R_{\text{TOP}_x}$  and  $R_{\text{BOTTOM}_x}$  units are in Ohms ( $\Omega$ ).

Using [Equation 15](#) and [Equation 16](#) we can calculate the falling voltage range as:

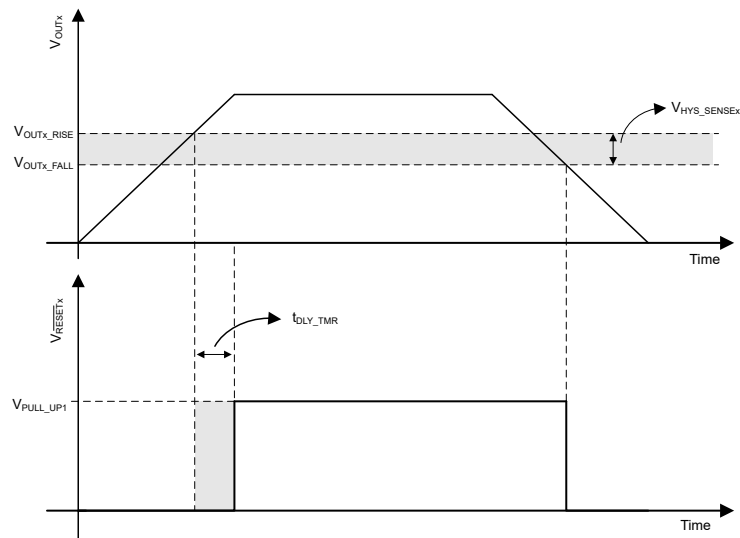
$$V_{\text{OUT}_x\text{\_FALL}} = V_{\text{OUT}_x\text{\_FALL\_NOMINAL}} \pm V_{\text{OUT}_x\text{\_FALL\_ERROR}} \quad (21)$$

Figure 8-6, shows a conceptual diagram of the rising and falling voltage, the diagram also shows the errors on this voltage due to  $V_{TH}$  accuracy,  $I_{HYS}$  accuracy, and the resistive divider tolerances. At the system level, take into account errors for a robust design.



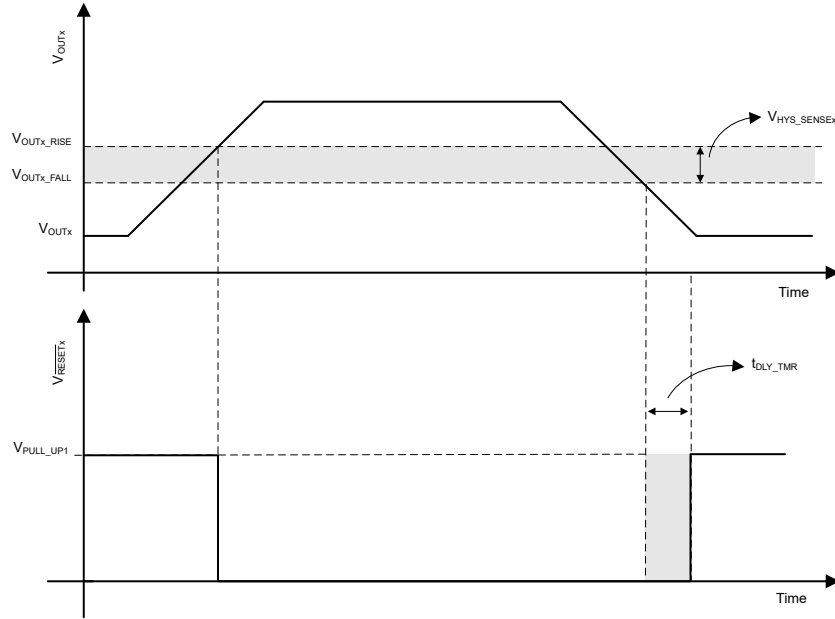
**Figure 8-6. Rising and Falling Threshold Voltages for the SENSE<sub>x</sub> Comparators**

### 8.3.3.3 Input to Output Time Diagrams



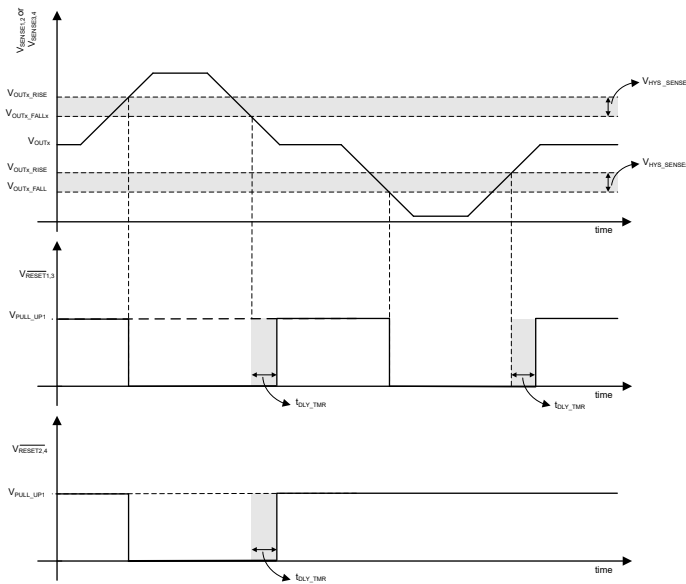
- A. In the TPS7H3024 and TPS7H3124 the Channel # 1 (pin # 1) and channel # 3 (pin # 3) are of undervoltage type, when MODE=0.

**Figure 8-7. Undervoltage channel (UV) time diagram**



A. Channel # 2 (pin # 2) and channel # 4 (pin # 4) are of overvoltage type, when MODE=1.

**Figure 8-8. Overvoltage channel (OV) time diagram**



A. Channel # 1 (pin # 1) and channel # 2 (pin # 2) are internally or'ed to create a window channel while the channel # 3 (pin # 3) and channel # 4 (pin # 4) are or'ed to create a second window channel, when MODE=1

B.  $V_{OUTx\_RISE}$ ,  $V_{OUTx\_FALL}$  and  $V_{HYS\_SENSEx}$  for the undervoltage and overvoltage can be different values.

**Figure 8-9. Window channel time diagram**

### 8.3.3.4 Top and Bottom Resistive Divider Design Equations

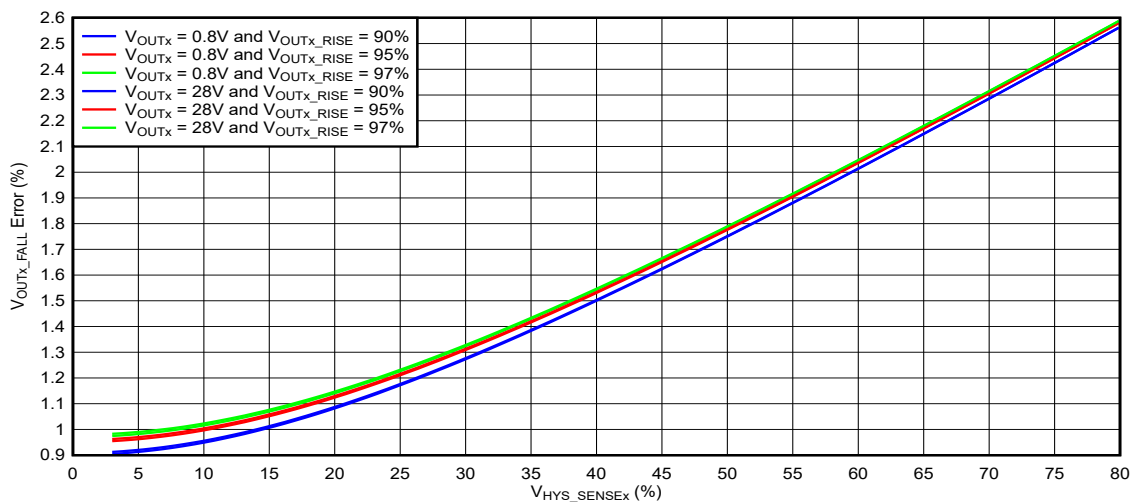
At the system level the designer knows (or selects) the  $V_{OUTx\_RISE}$  and  $V_{OUTx\_FALL}$  levels. Usually these voltages are selected as percentages of the nominal rail voltage ( $V_{OUTx}$ ) being monitored. Knowing this information, we can calculate the nominal resistive divider components values ( $R_{TOPx}$  and  $R_{BOTTOMx}$ ) for the desired target levels. Using [Equation 13](#) and [Equation 14](#) we can calculate the top resistor as:

$$R_{TOPx} = \frac{V_{OUTx\_RISE} - V_{OUTx\_FALL}}{I_{HYS\_SENSEx}} \quad (22)$$

From [Equation 9](#) we can calculate the bottom resistor as:

$$R_{BOTTOMx} = \frac{R_{TOPx} \times V_{TH\_SENSEx}}{V_{OUTx\_RISE} - V_{TH\_SENSEx}} \quad (23)$$

It's important to notice that the larger the separation between  $V_{OUTx\_RISE}$  and  $V_{OUTx\_FALL}$  (referred to as  $V_{HYS\_SENSEx}$ ), the bigger the error in the falling voltage. [Figure 8-10](#) shows a plot of the error in the  $V_{OUTx\_FALL}$  for different sense hysteresis voltages ( $V_{HYS\_SENSEx} = V_{OUTx\_RISE} - V_{OUTx\_FALL}$ ). The plot is created for three different  $V_{OUTx\_RISE}$  voltages (or percentages of the nominal output voltage as 90, 95, and 97% ) and two different output voltages (0.8V and 28V). As can be observed, the output voltage has very little impact on the falling voltage error (differences cannot be easily viewed on the plot). The error (in percent) can go from approximately 1% (at  $V_{HYS\_SENSEx} = 3\%$ ) to around 2.6% (at  $V_{HYS\_SENSEx} = 80\%$ ).



**Figure 8-10.  $V_{OUTx\_FALL}$  Absolute Error vs  $V_{HYS\_SENSEx}$**

- This plot does not include the error on the  $V_{OUTx\_FALL}$  due to the difference between the calculated top and bottom resistors using [Equation 22](#) and [Equation 23](#) and the actual resistance values that a designer can procure.
- The resistor tolerance used for the calculation is 0.1%,  $V_{TH\_SENSEx}$  accuracy is 1%, and the  $I_{HYS\_SENSEx}$  accuracy is 3%.
- In this plot the  $V_{HYS\_SENSEx}$  (%) represents the separation as percentages of the nominal output voltage ( $V_{OUTx}$ ).
- In this plot, the  $V_{OUTx\_FALL}$  error in % is normalized with respect to the full-scale voltage (or  $V_{OUTx}$ ).

### 8.3.4 MODE

The mode pin is an input that change the behavior of the output stage to detect for:

- Undervoltage (UV)
- Overvoltage (OV)
- Window

For more details refer to [Table 8-1](#) and [Section 8.3.5](#).

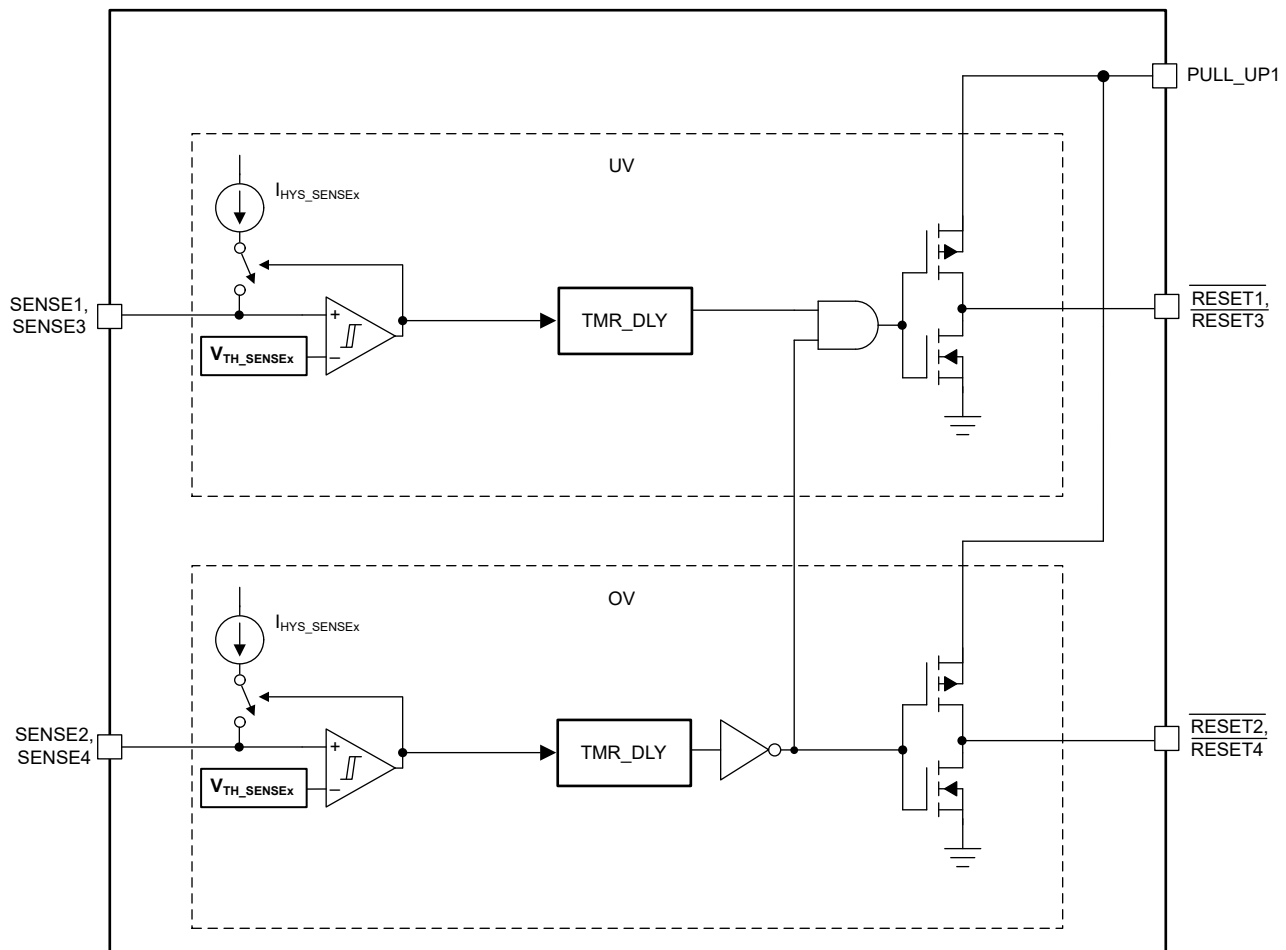
**Note**

MODE can be connected to the VLDO for a logic high. Use a series resistor for protection.

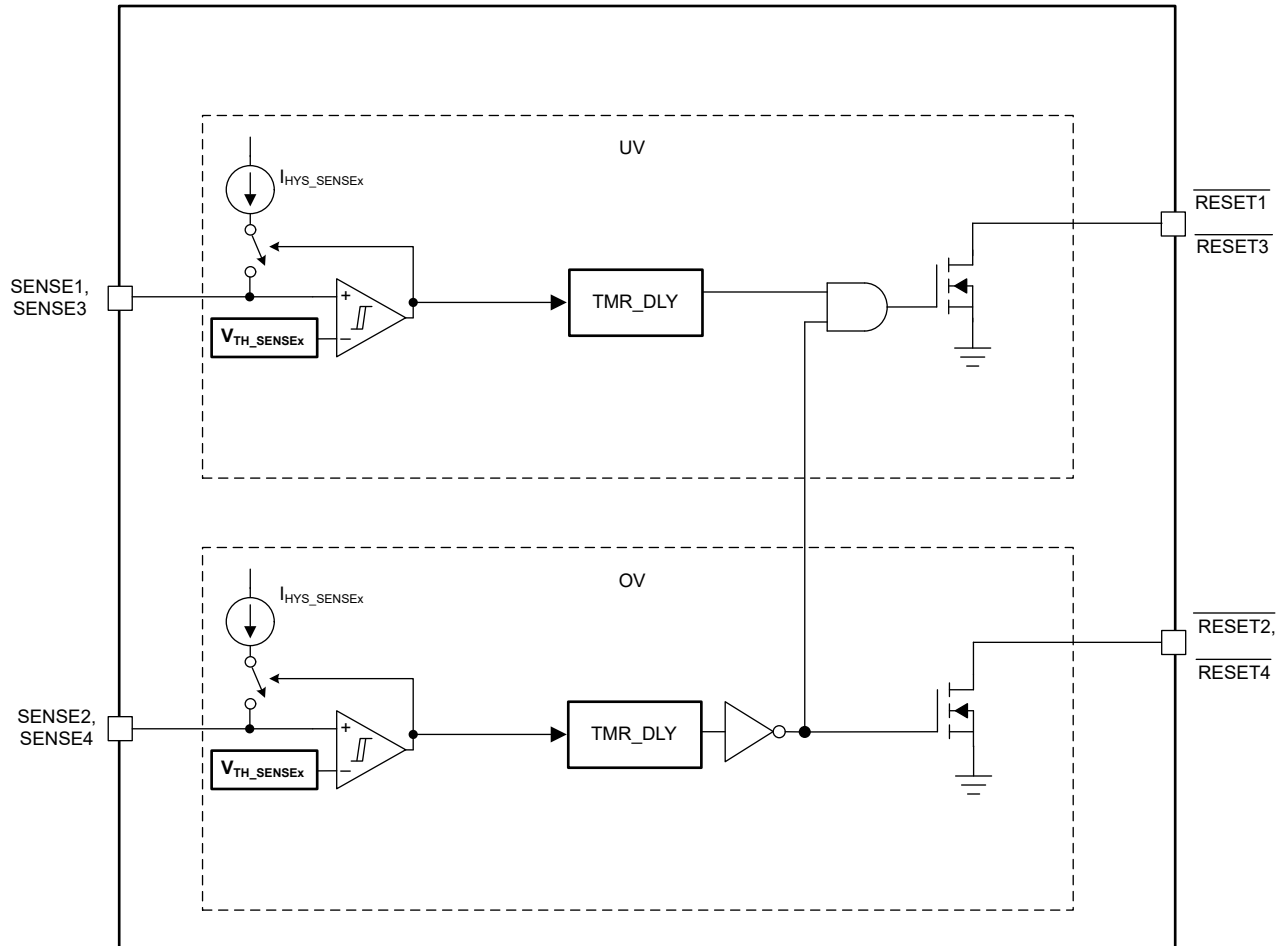
**8.3.5 Output Stages ( $\overline{\text{RESET}}_x$ , PWRGD,  $\overline{\text{WDO}}$ , PULL\_UP1, and PULL\_UP2)**

The output stage's ( $\overline{\text{RESET}}_1$  to  $\overline{\text{RESET}}_4$ ), PWRGD and  $\overline{\text{WDO}}$  are offered in push-pull and open-drain type. For more details on the output type by the GPN refer to [Table 8-1](#). When the output are of overvoltage type, the  $\overline{\text{RESET}}_x$  is driven logically inverted from the output of the SENSE $_x$  comparators as shown in [Figure 8-11](#) (also refer to [Figure 8-16](#) and [Figure 8-18](#) ).

In the case of the TPS7H3024 (push-pull outputs) and TPS7H3124 (open-drain outputs) with MODE=1, the SENSE1 (UV) and SENSE2 (OV) are internally AND'ed, the output is used to drive the  $\overline{\text{RESET}}_1$  output. In this case  $\overline{\text{RESET}}_1$  is the output of a window comparator.  $\overline{\text{RESET}}_2$  is left unchanged and is the OV flag of SENSE2. As both the window and the OV flag are available, the system can read the outputs to know which type of fault occurred in the system (UV or OV). The same is true for SENSE3 and SENSE4, which form the second window comparator.



**Figure 8-11. Window Comparator for TPS7H3024 when MODE=1**



**Figure 8-12. Window Comparator for TPS7H3124 when MODE=1**

SENSE1 and SENSE2 are one window comparator channel while SENSE3 and SENSE4 create the second window comparator channel.

### 8.3.5.1 Push-Pull Outputs

The pull-up voltage for the push-pull outputs is externally provided by the user. PULL\_UP1 (input) is the pull-up voltage domain for all  $\overline{\text{RESET}}_x$  outputs ( $\overline{\text{RESET}}_1$  to  $\overline{\text{RESET}}_4$ ), while PULL\_UP2 (input) is the pull-up voltage domain for the PWRGD and  $\overline{\text{WDO}}$  outputs. Refer to [Figure 8-13](#) to [Figure 8-16](#).

#### Note

There are no sequencing requirements for IN, PULL\_UP1, and PULL\_UP2.

Each output stage consists of a high side PMOS and low side NMOS (CMOS) pair. The PMOS resistance is typically 9Ω (max of 20Ω) while the NMOS is 16Ω typically (max of 36Ω), when  $V_{\text{PULL\_UPx}} \geq 3.3\text{V}$ . PULL\_UP1 and PULL\_UP2, have a voltage range of 1.6V to 7V, and can be independently biased or tied to the same voltage rail, however both must be biased. The output resistance of the PMOS leg has a PULL\_UPx voltage dependency. The lower the PULL\_UPx voltage, the higher the PMOS resistance.

When  $V_{IN} < V_{POR\_IN}$  (2V maximum) or  $V_{PULL\_UPx} > V_{POR\_PULL\_UPx}$  (1.1V maximum) the outputs are in a known pull-down state. At this condition the outputs have reduced sinking capabilities with  $V_{OL} \leq 320mV$  when the device is sinking 100 $\mu A$  of current into the outputs:

- $\overline{RESETx}$
- PWRGD
- $\overline{WDO}$

Once the input voltage range is within the recommended input voltage range of 3V to 14V, the outputs have the full strength capabilities of  $\pm 10mA$ , per output.

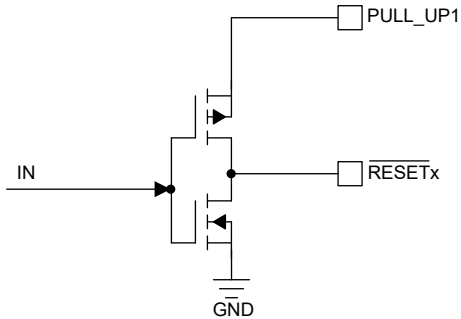


Figure 8-13.  $\overline{RESETx}$  Push-Pull Output Stages for UV Channel Type

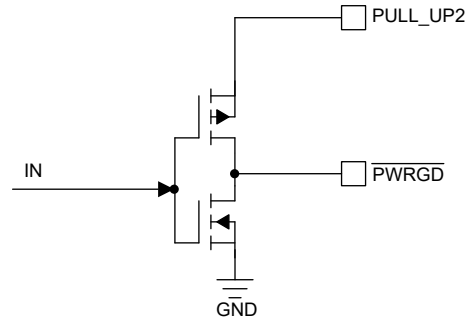


Figure 8-14. PWRGD Push-Pull Output Stage for UV Channel Type

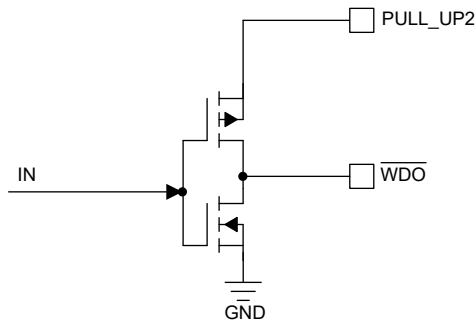
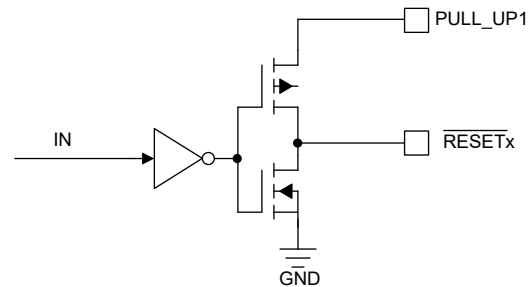


Figure 8-15.  $\overline{WDO}$  Push-Pull Output Stage for UV Channel Type



- A. Only the  $\overline{RESETx}$  are dependent on the type of channel as: UV or OV. This is dependent in the logical value of the MODE input pin.

Figure 8-16.  $\overline{RESETx}$  Push-Pull Output Stages for OV Channel Type

### 8.3.5.2 Open-Drain Outputs (TPS7H3124 and TPS7H3134)

In the open-drain variants (TPS7H31x4) the pins are externally pulled-up through a resistor to a voltage source with the desired logic level. The maximum pull-up voltage for the outputs ( $\overline{RESETx}$ , PWRGD and  $\overline{WDO}$ ) is 7V. Select the pull-up resistor value to keep the maximum current sunk by the outputs below the recommended operating condition maximum of 2mA. Generally a pull up resistor of 10k $\Omega$  is sufficient. Using a larger value resistor will minimize power dissipation but can allow noise to couple into the outputs signal due a "weaker" pull-up. Refer to [Figure 8-17](#) and [Figure 8-18](#).

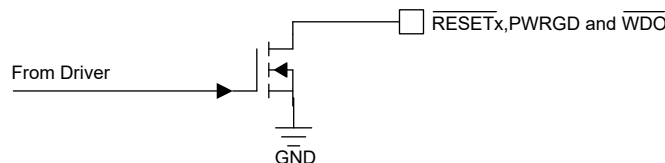
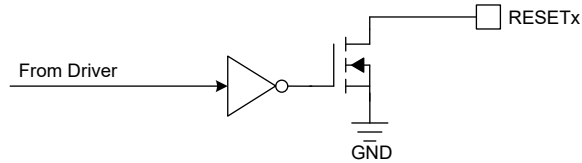


Figure 8-17.  $\overline{RESETx}$ , PWRGD and  $\overline{WDO}$  Outputs in Open-Drain



A. Only the  $\overline{\text{RESETx}}$  are dependent on the type of channel as: UV or OV. This is dependent in the logical value of the MODE input pin.

**Figure 8-18.  $\overline{\text{RESETx}}$  overvoltage (OV) Outputs in Open-Drain**

### 8.3.6 WDI

The watchdog input (WDI) pin is the input of the non-inverting input of a comparator with a 602mV voltage reference ( $V_{\text{TH\_WDI\_RISING}}$ ). The comparator has a built-in 104mV (fixed) hysteresis voltage to aid in noise immunity. The watchdog state machine clears (or resets the watchdog counter) every time a rising voltage is detected on the WDI pin. To account for the variation of the watchdog time-out, it is recommended to use the minimum value of the WD\_TMR when determining how often the processor sends the WDI signal. For example, if the WD\_TMR is programmed to 1s, the actual timeout is from 0.8s to 1.2s. Therefore, it is recommended the WDI signal be sent by the processor at least every 0.8s to account for the worst case variation. The WD\_TMR (or timeout) is programmed by the user, by using the WD\_TMR input. The timer have a programmable range from 520ms to 1.5s. For more details refer to [Section 8.3.7.2](#).

### 8.3.7 User-Programmable TIMERS

The TPS7H3024 has two adjustable timers:

1. DLY\_TMR with a typical range from 260 $\mu$ s to 23.37ms.
2. WD\_TMR with a typical range from 520ms to 1.5s.

Both timers are programmed via a single resistor from the DLY\_TMR and WD\_TMR pins to GND. The resistors are used to program the internal oscillator frequency of the timers. Leaving the DLY\_TMR or the WD\_TMR pin floating disables the respective timer. Disabling a timer reduces the quiescent ( $I_{\text{Q\_IN}}$ ) current of the device. Refer to [Figure 6-5](#) for more details.

#### Note

The resistor configuration of the timer pins must be valid at power up and must not be dynamically changed.

#### 8.3.7.1 DLY\_TMR

The TPS7H3024 includes an adjustable time delay. A single resistor connected between the DLY\_TMR pin and GND programs the delay. Possible resistor ( $R_{\text{DLY}}$ ) values are from 10.5k $\Omega$  to 1.18M $\Omega$  for a delay from 260 $\mu$ s to 23.7ms, respectively. This delay is valid only during the out-of-fault conditions as follow:

1. UV: in the undervoltage channel (UV) the delay is valid when  $V_{\text{OUTx}}$  voltage is rising and crosses the  $V_{\text{OUTx\_RISE}}$ .
2. OV: in the overvoltage channel (OV) the delay is valid when the  $V_{\text{OUTx}}$  voltage is falling and crosses the  $V_{\text{OUTx\_FALL}}$ .

For more details refer to [Figure 8-7](#) and [Figure 8-8](#).

If no delay is preferred for the system, the pin (DLY\_TMR) can be left floating. Disabling the timer results in a reduced current consumption on the device ( $I_{\text{Q\_IN}}$ ). When no delay is preferred, an inherent propagation delay of 4.3 $\mu$ s (maximum) is observed, between  $V_{\text{OUTx}}$  crossing the  $V_{\text{OUTx\_RISE}}$  and  $V_{\text{OUTx\_FALL}}$ .

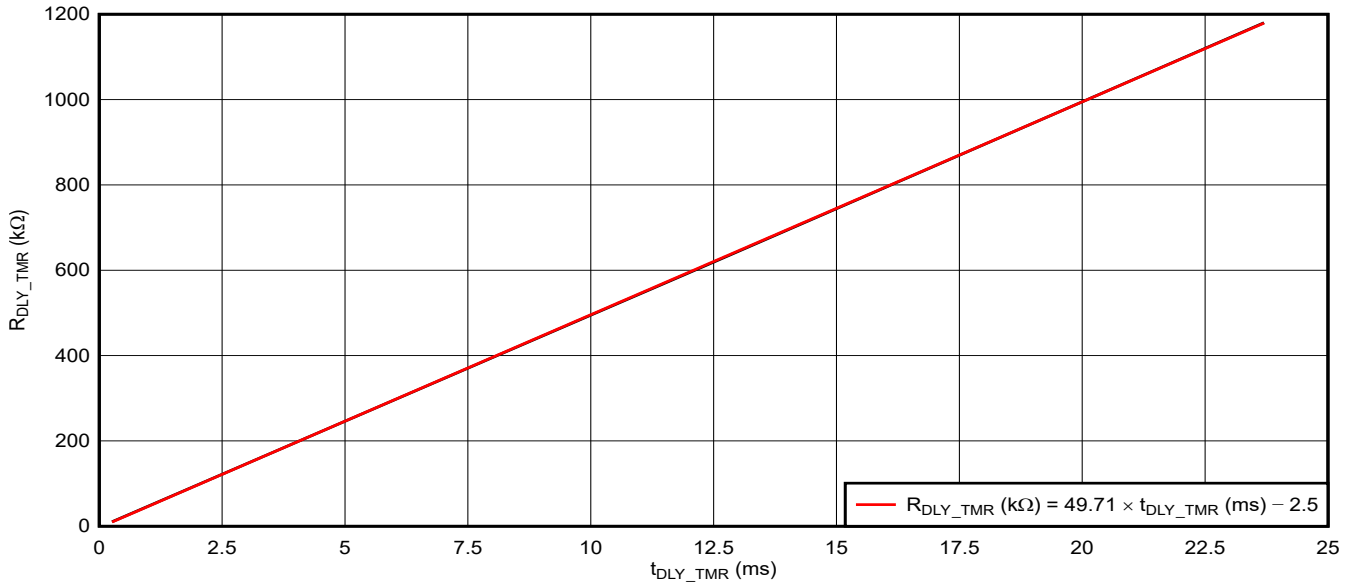
The DLY\_TMR resistor can be selected using [Equation 24](#). [Figure 8-19](#) shows the linear trend between the DLY\_TMR resistor and the delay time.

$$R_{\text{DLY\_TMR}}(\text{k}\Omega) = [49.71 \times t_{\text{DLY\_TMR}}(\text{ms})] - 2.5 \quad (24)$$

Table 8-2 shows nominal resistors value for different delay times.

**Table 8-2. Typical DLY\_TMR Resistors**

DELAY (ms)	R <sub>DLY_TMR</sub> (kΩ)
0.260	10.5
12.5	619
23.7	1180



**Figure 8-19. R<sub>DLY\_TMR</sub> vs t<sub>DLY\_TMR</sub> Across Full Oscillator Range**

### 8.3.7.2 WD\_TMR

The WD\_TMR is an adjustable timer that programs the time-out of the internal watchdog timer. The watchdog timer is commonly used to monitor coherent processor execution. If the monitored processor is halted due to a fault, the WDI pin does not detect a rising edge resulting in asserting the  $\overline{WDO}$  low, hence resetting the processor to a known state. A typical connection between the monitored processor and the TPS7H3024 is shown in Figure 8-20. Figure 8-21 shows the correct and incorrect (late pulse) handshake between the processor and the watchdog in the TPS7H3024.

The user can program the WD\_TMR using a single resistor between the WD\_TMR pin and GND. The range of the resistor (R<sub>WD</sub>) is from 56.2kΩ to 174kΩ, for a time from 520ms to 1.5s, respectively. If the user does not want to use the watchdog timer, the pin can be left floating. Disabling the watchdog timer reduces the quiescent (I<sub>Q\_IN</sub>) current of the device.

#### Note

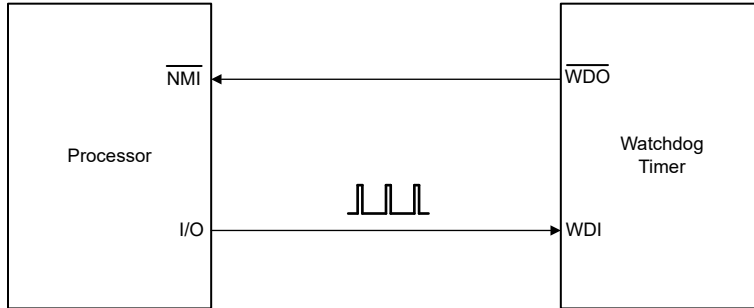
When the watchdog timer is disabled (by floating the WD\_TMR pin),  $\overline{WDO}$  is equal to PWRGD.

The REG\_TMR resistor can be selected using Equation 25. Figure 8-22 shows the linear trend between the WD\_TMR resistor and the allowed time to clear the watchdog timer (or time-out).

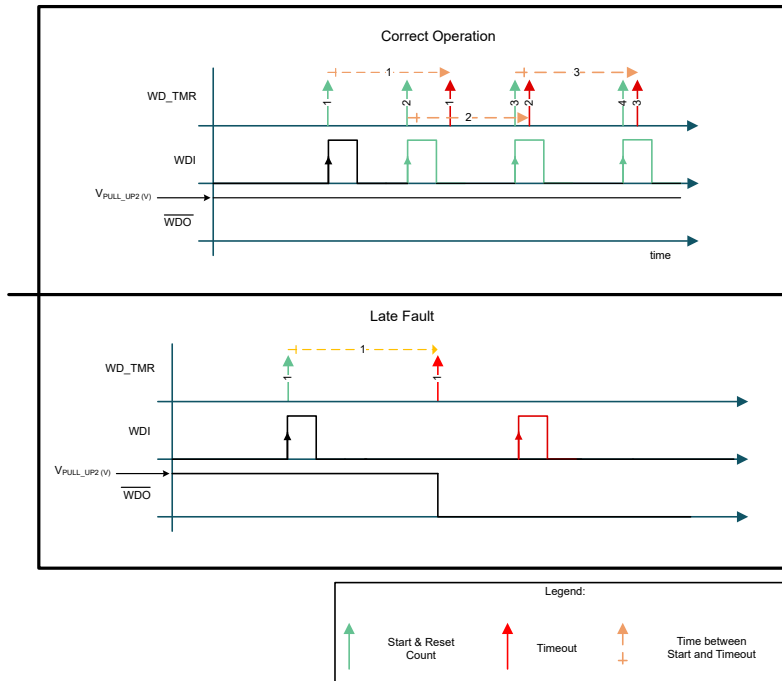
$$R_{WD\_TMR}(k\Omega) = [114.5 \times t_{WD\_TMR}(s)] - 3.5 \quad (25)$$

Table 8-3 shows typical resistor values for different allowed regulation times. The WDI pin minimum pulse width is specified as twice the watchdog oscillator period. The oscillator period can be calculated using Equation 26.

$$t_{WD\_OSC}(s) = \frac{t_{WD\_TMR}(s)}{57,344} \quad (26)$$



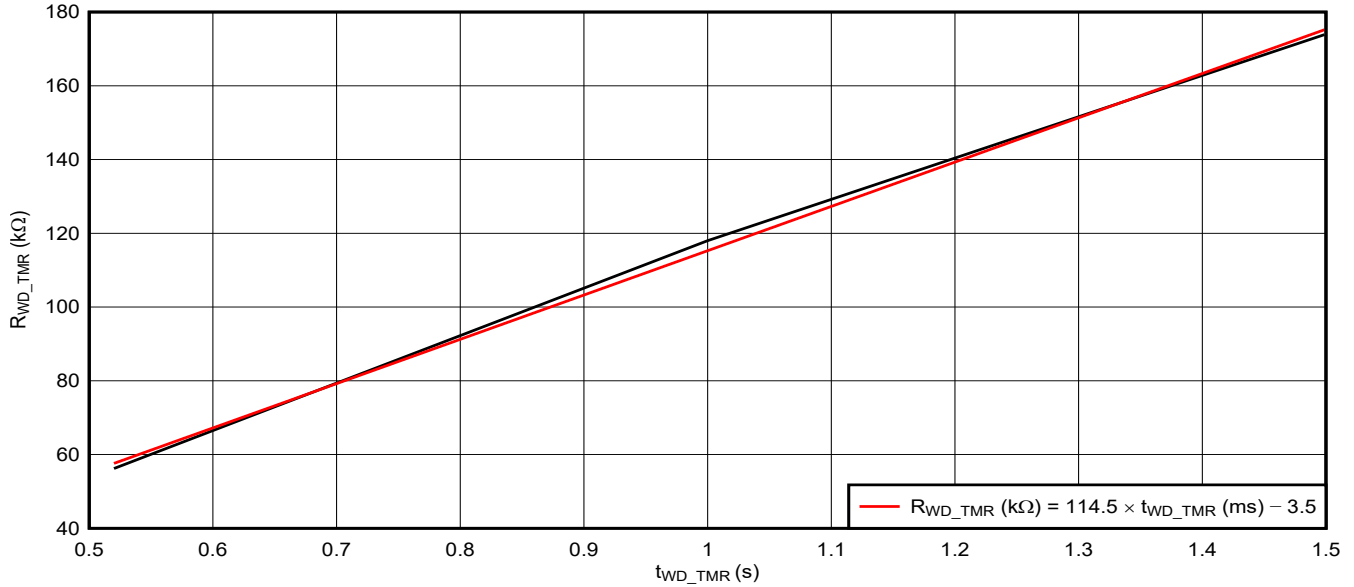
**Figure 8-20. Watchdog Timer Typical Handshake Between TPS7H3024 and Monitored Processor**



**Figure 8-21. Watchdog Timing Diagram**

**Table 8-3. Typical REG\_TMR Resistors**

ALLOWED REGULATION TIME (s)	R <sub>REG_TMR</sub> (kΩ)
0.52	56.2
1	118
1.5	174



**Figure 8-22.  $R_{WD\_TMR}$  vs  $t_{WD\_TMR}$  Across Full Oscillator Range**

### 8.4 Device Functional Modes

**Table 8-4.  $\overline{RESETx}$ ,  $\overline{PWRGD}$  and  $\overline{WDO}$  Truth Table when  $V_{IN}$  and  $V_{PULL\_UPx}$  is Lower than the Recommended Minimum Voltage for TPS7H3xx4.**

$\overline{SR\_UVLO}$ (1) (2)	$\overline{SENSEx}$ (3) (4)	$\overline{RESETx}$	$\overline{PWRGD}$	$\overline{WDO}$	IN	PULL_UPx
0 or 1	0 or 1	Undetermined	Undetermined	Undetermined	$V_{IN} < V_{POR\_IN}$	$V_{PULL\_UPx} < V_{POR\_PULL\_UPx}$
		L	L	L	$V_{IN} < V_{POR\_IN}$	$V_{POR\_PULL\_UPx} < V_{PULL\_UPx} < 1.6V$
		L	L	L	$V_{POR\_IN} < V_{IN} < 3V$	$V_{PULL\_UPx} < V_{POR\_PULL\_UPx}$
		L	L	L	$V_{POR\_IN} < V_{IN} < 3V$	$1.6V < V_{PULL\_UPx} < 7V$

**Table 8-5. RESETx, PWRGD and WDO Truth Table when  $V_{IN}$  and  $V_{PULL\_UPx}$  is Within Recommended Operating Voltages for the TPS7H3024 and TPS7H3124**

SR_ÜVLO (1) (2)	MODE (5) (6)	SENSE1 (3) (4)	SENSE2 (3) (4)	SENSE3 (3) (4)	SENSE4 (3) (4)	RESET1	RESET2	RESET3	RESET4	PWRGD	WDO (7) (8)
0	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1	L	L	L	L	L	L
1	0	0	0	0	0	L	H	L	H	L	L
		0	0	0	1	L	H	L	L	L	L
		0	0	1	0	L	H	H	H	L	L
		0	0	1	1	L	H	H	L	L	L
		0	1	0	0	L	L	L	H	L	L
		0	1	0	1	L	L	L	L	L	L
		0	1	1	0	L	L	H	H	L	L
		0	1	1	1	L	L	H	L	L	L
		1	0	0	0	H	H	L	H	L	L
		1	0	0	1	H	H	L	L	L	L
		1	0	1	0	H	H	H	H	H	H
		1	0	1	1	H	H	H	L	L	L
		1	1	0	0	H	L	L	H	L	L
		1	1	0	1	H	L	L	L	L	L
	1	1	1	0	H	L	H	H	L	L	
	1	1	1	1	H	L	H	L	L	L	
	1	0	0	0	0	L	H	L	H	L	L
		0	0	0	1	L	H	L	L	L	L
		0	0	1	0	L	H	H	H	L	L
		0	0	1	1	L	H	L	L	L	L
		0	1	0	0	L	L	L	H	L	L
		0	1	0	1	L	L	L	L	L	L
		0	1	1	0	L	L	H	H	L	L
		0	1	1	1	L	L	L	L	L	L
		1	0	0	0	H	H	L	H	L	L
		1	0	0	1	H	H	L	L	L	L
		1	0	1	0	H	H	H	H	H	H
		1	0	1	1	H	H	L	L	L	L
1		1	0	0	L	L	L	H	L	L	
1		1	0	1	L	L	L	L	L	L	
1	1	1	0	L	L	H	H	L	L		
1	1	1	1	L	L	L	L	L	L		

**Table 8-6. RESETx, PWRGD and WDO Truth Table When VIN and VPULL\_UPx is Within Recommended Operating Voltages for the TPS7H3034 and TPS7H3134**

SR_ÜVLO (1) (2)	MODE (5) (6)	SENSE1 (3) (4)	SENSE2 (3) (4)	SENSE3 (3) (4)	SENSE4 (3) (4)	RESET1	RESET2	RESET3	RESET4	PWRGD	WDO (7) (8)	
0	0 or 1	0 or 1	0 or 1	0 or 1	0 or 1	L	L	L	L	L	L	
1	0	0	0	0	0	L	L	L	L	L	L	
		0	0	0	1	L	L	L	H	L	L	
		0	0	1	0	L	L	H	L	L	L	
		0	0	1	1	L	L	H	H	L	L	
		0	1	0	0	L	H	L	L	L	L	
		0	1	0	1	L	H	L	H	L	L	
		0	1	1	0	L	H	H	L	L	L	
		0	1	1	1	L	H	H	H	L	L	
		1	0	0	0	H	L	L	L	L	L	
		1	0	0	1	H	L	L	H	L	L	
		1	0	1	0	H	L	H	L	L	L	
		1	0	1	1	H	L	H	H	L	L	
		1	1	0	0	H	H	L	L	L	L	
		1	1	0	1	H	H	L	H	L	L	
	1	1	1	0	H	H	H	L	L	L		
	1	1	1	1	H	H	H	H	H	H		
	1	0	0	0	0	H	H	H	H	H	H	H
		0	0	0	1	H	H	H	L	L	L	
		0	0	1	0	H	H	L	H	L	L	
		0	0	1	1	H	H	L	L	L	L	
		0	1	0	0	H	L	H	H	L	L	
		0	1	0	1	H	L	H	L	L	L	
		0	1	1	0	H	L	L	H	L	L	
		0	1	1	1	H	L	L	L	L	L	
		1	0	0	0	L	H	H	H	L	L	
		1	0	0	1	L	H	H	L	L	L	
		1	0	1	0	L	H	L	L	L	L	
		1	0	1	1	L	H	L	L	L	L	
1		1	0	0	L	L	H	H	L	L		
1		1	0	1	L	L	H	L	L	L		
1	1	1	0	L	L	L	H	L	L			
1	1	1	1	L	L	L	L	L	L			

(1)  $0 = V_{SR\_ÜVLO} < V_{TH\_SR\_ÜVLO\_FALLING}$

(2)  $1 = V_{SR\_ÜVLO} > V_{TH\_SR\_ÜVLO\_RISING}$

(3)  $0 = V_{SENSEx} < V_{TH\_SENSEx}$

(4)  $1 = V_{SENSEx} > V_{TH\_SENSEx}$

(5)  $0 = V_{MODE} < V_{TH\_MODE\_FALLING}$

(6)  $1 = V_{MODE} > V_{TH\_MODE\_RISING}$

(7) Assuming a valid rising edge pulse in WDI before the Watchdog timer is expired.

(8) In the TPS7H3124, the WDO is not masked by PWRGD, WDO remains high as long as a valid pulse is provided in WDI; otherwise, it goes low.

## 9 Application and Implementation

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### Note

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation to confirm system functionality.

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### 9.1 Application Information

The TPS7H3024 is a radiation hardened 4-channel voltage supervisor with a watchdog timer. It can be used to supervise FPGAs, ASICs, AFEs, and various power system voltage rails and processor coherent execution.

### 9.2 Typical Application

#### 9.2.1 Window Voltage Monitoring

In many modern systems (or sub-systems), multiple voltage rails are often needed (we refer to this as the power tree). Often these power trees have tight voltage specification for reliable operation. If these specifications are not satisfied, unreliable operation or permanent malfunction can happen. To help enable reliable operation, voltage rails are supervised in real time and corrective action (such as power-down, disabling local regulators, and so forth.) is propagated through the system.

In this example, two voltage rails are monitored using a window trigger to make sure the rails are operating within specification. Detailed design procedure and component selection is provided below. The design is summarized in [Figure 9-1](#).

### Note

All calculated numbers shown in this example are rounded to two decimal places with the exception of the bottom resistor for the sense divider which is rounded to 3 decimal places.

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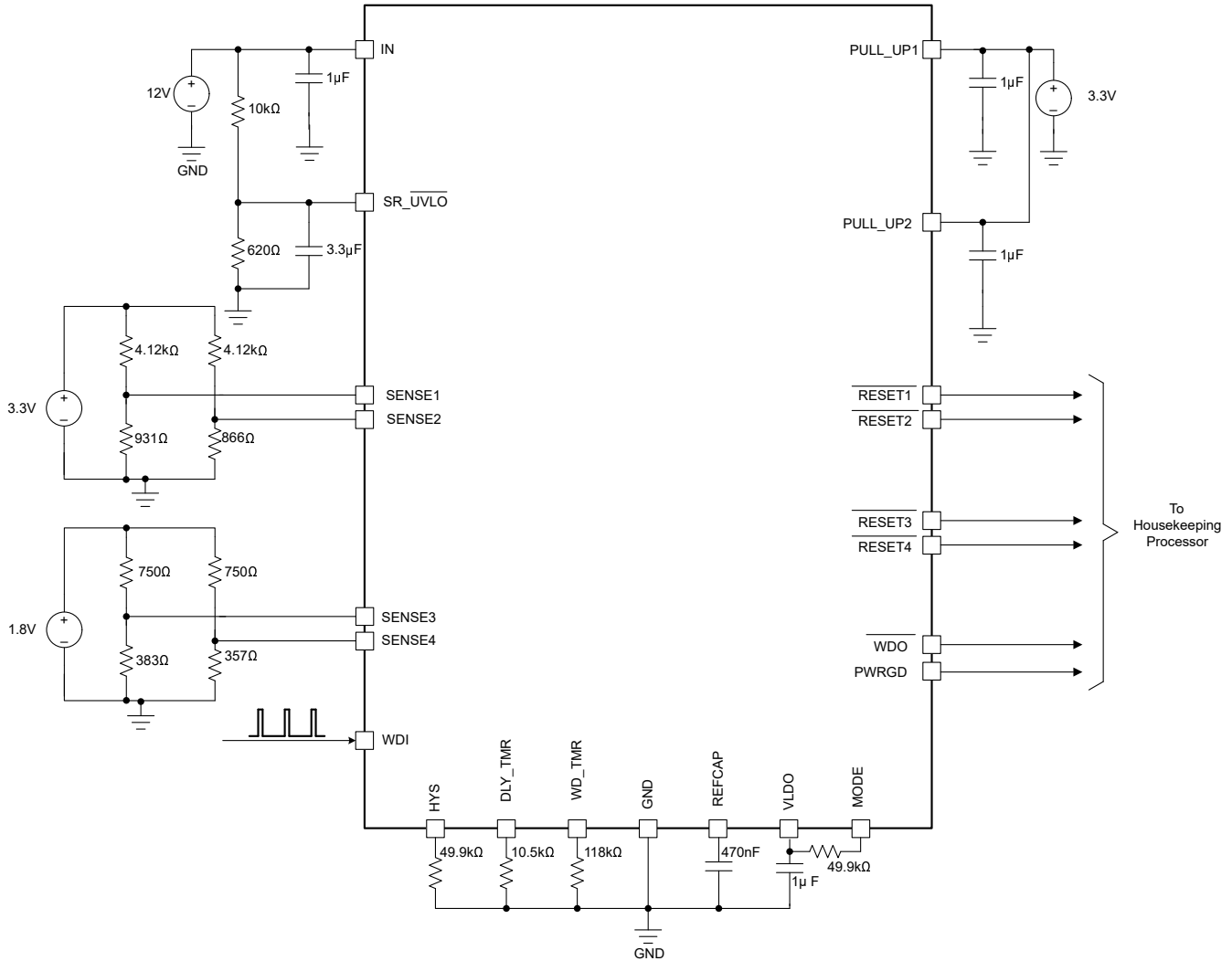


Figure 9-1. Window Voltage Monitoring with Watchdog

### 9.2.1.1 Design Requirements

This design requires monitoring two voltage rails using window comparators to make sure of reliable operation. As window supervision is used, the upper and lower system specification bounds are monitored. Additionally, coherent processor execution is monitored using the watchdog. The supervisor IC is set to start around 86% (or 10.31V) of the nominal 12V rail, using an external resistive divider driving the  $\overline{\text{SR\_UVLO}}$  pin.

All flags are assumed to be monitored by a house-keeping processor, and the  $\overline{\text{WDO}}$  is used to drive the non-maskable interrupt of the processor. All design conditions are defined in [Table 9-1](#).

Table 9-1. Design Conditions

PARAMETER	DESIGN REQUIREMENT	DESIGN RESULT
System nominal voltage	Monitor the 12V input voltage to the supervisor and enable the IC when the voltage is greater than 10.3V (86%) for at least 2.8ms. When the voltage decrements below 8.5V (or 71%) the system is disabled.	The TPS7H3024 can be externally enabled accurately by using the $\overline{\text{SR\_UVLO}}$ . The internal reference is accurate to 3.1% across temperature, voltage and TID. For minimal error, users are recommended to use 0.1% tolerance resistors.

**Table 9-1. Design Conditions (continued)**

PARAMETER	DESIGN REQUIREMENT	DESIGN RESULT
V <sub>OUT1</sub> = 3.3V (nominal)	Undervoltage with: V <sub>OUT1_RISE_UV</sub> = 98% and V <sub>OUT1_FALL_UV</sub> = 95%	V <sub>OUT1_RISE_UV</sub> = 3.25V V <sub>OUT1_FALL_UV</sub> = 3.15V
	Overvoltage with: V <sub>OUT1_RISE_OV</sub> = 105% and V <sub>OUT1_FALL_OV</sub> = 102%	V <sub>OUT1_RISE_OV</sub> = 3.45V V <sub>OUT1_FALL_OV</sub> = 3.35V
V <sub>OUT2</sub> = 1.8V (nominal)	Undervoltage with: V <sub>OUT2_RISE_UV</sub> = 98% and V <sub>OUT2_FALL_UV</sub> = 97%	V <sub>OUT2_RISE_UV</sub> = 1.77V V <sub>OUT2_FALL_UV</sub> = 1.75V
	Overvoltage with: V <sub>OUT2_RISE_OV</sub> = 103% and V <sub>OUTx_FALL_OV</sub> = 102%	V <sub>OUT2_RISE_OV</sub> = 1.86V V <sub>OUT2_FALL_OV</sub> = 1.84V
RESETx delay during the out-of-fault state	Delay of 260µs nominal	R <sub>DLY_TMR</sub> = 10.5kΩ
Watchdog timeout	1 second nominal	R <sub>WD_TMR</sub> = 118kΩ

### 9.2.1.2 Detailed Design Procedure

#### 9.2.1.2.1 Input Power Supplies and Decoupling Capacitors

The TPS7H3024 has three input power supplies:

1. IN, the input supply to provide power to the TPS7H3024 IC. This power supply must be decoupled with at least 1µF or greater as close to the pin as possible. In this application, V<sub>IN</sub> = 12V.
2. PULL\_UP1, which is the input supply to program the RESETx output voltage high (V<sub>OH</sub>). These outputs are connected to the house-keeping processor. This power supply must be decoupled with at least 1µF or greater as close to the pin as possible. In this application, the V<sub>PULL\_UP1</sub> = 3.3V.
3. PULL\_UP2, which is the input supply to program the output voltage high (V<sub>OH</sub>) of PWRGD and WDO outputs. These outputs are connected to the house-keeping processor, in particular WDO is usually connected to the non maskable (NMO) input of the processor that is generating the WDI pulse. This power supply must be decoupled with at least 1µF or greater as close to the pin as possible. In this application, the V<sub>PULL\_UP1</sub> = 3.3V.

The TPS7H3024 also has two regulated voltage outputs that need to be decoupled for good electrical and radiation performance. These are:

1. REFCAP, the 1.2V reference, used internally in the device to generate all radiometric voltage reference such as:
  - V<sub>TH\_SENSEx</sub>
  - I<sub>HYS\_SENSEx</sub>
  - V<sub>TH\_SR\_UVLO</sub>
  - V<sub>TH\_WDI</sub>
  - V<sub>TH\_MODE</sub>

Decouple this reference with a 470nF ceramic capacitor as close to the pin as possible. Do not load this pin externally.
2. VLDO, this is the output of the internal regulator used to provide power to the internal circuits on the TPS7H3024. Decouple this regulator with at least 1µF as close to the pin as possible. This LDO can be loaded up to 5mA. Is important to understand that this LDO is not protected for short circuits.

#### 9.2.1.2.2 SR\_UVLO Threshold

In this application the SR\_UVLO pin is used to monitored the input voltage supply of 12V and enables the device when the desired voltage is reached.

The IC is enabled when the rail voltage is greater than 10.26V (or 85.5% of the nominal voltage, typically). The falling voltage is not controlled as the hysteresis voltage on the SR\_UVLO is internally controlled. However is calculated to be 8.55V (or 71.2% of the nominal voltage, typically). As the TPS7H3024 has an internal time constant ( $t_{\text{Start\_up\_delay}}$ ) of 2.8ms (maximum), a delay capacitor of 3.3μF is added to SR\_UVLO pin. This capacitor is added to introduce a delay in the SR\_UVLO pin when  $V_{\text{IN}}$  is rising. This capacitor adds a second condition to start the sequence up, if  $V_{\text{IN}} \geq 10.26\text{V}$  (typical) for at least 2.8ms then the IC is enabled.

Fixing the upper resistor for the resistive divider in SR\_UVLO, we can calculate the bottom resistor per our design requirements. The upper resistor is fixed to 10kΩ. Using the equation in Equation 1 the bottom resistor is calculated as:

$$V_{\text{BOTTOM\_SR\_UVLO}} = 10\text{k}\Omega \times \frac{0.599\text{V}}{10.26\text{V} - 0.599\text{V}} = 620\Omega \quad (27)$$

Now that the reference resistor is calculated, we can select the actual (or real) resistor. In this case a 0.1% tolerance resistor is used to select the closest value (in this specific case the reference and real resistor is the same)

- $R_{\text{BOTTOM\_SR\_UVLO}} = 620\Omega$

With the actual resistor values, we can back-calculate the rising and falling voltages that enables and disables the supervisor, respectively. Using Equation 3 and Equation 4 as:

$$V_{\text{IN\_UVLO\_RISING\_NOMINAL}}(\text{V}) = \left(1 + \frac{10\text{k}\Omega}{620\Omega}\right) \times 0.599\text{V} \cong 10.26\text{V} \quad (28)$$

$$V_{\text{IN\_UVLO\_FALLING\_NOMINAL}}(\text{V}) = \left(1 + \frac{10\text{k}\Omega}{620\Omega}\right) \times 0.496\text{V} \cong 8.50\text{V} \quad (29)$$

The delay capacitor is calculated using Equation 7, Equation 8, and Equation 6 as:

$$R_{\text{TH}}(\Omega) = \frac{10\text{k}\Omega \times 620\Omega}{10\text{k}\Omega + 620\Omega} = 583.80\Omega \quad (30)$$

$$V_{\text{TH}}(\Omega) = \left(\frac{620\Omega}{10\text{k}\Omega + 620\Omega}\right) \times 12\text{V} = 0.70\text{V} \quad (31)$$

$$C_{\text{DELAY}}(\text{F}) \geq \frac{0.0028\text{s}}{583.8\Omega \times \ln\left(\frac{0.7\text{V}}{0.599\text{V} - 0.7\text{V}}\right)} = 2.48\mu\text{F} \quad (32)$$

The delay capacitor is selected as 3.3μF.

### 9.2.1.2.3 SENSEx Thresholds

The SENSEx inputs are used to monitor the voltage rails against system level bounds (or limits). For this design the output voltages to be monitored are:

1.  $V_{\text{OUT1}} = 3.3\text{V}$
2.  $V_{\text{OUT2}} = 1.8\text{V}$

The design  $V_{\text{OUTx\_RISE}}$  and  $V_{\text{OUTx\_FALL}}$  for each rail is specified in Table 9-2

**Table 9-2. Rise and Fall Design Requirement by Channel**

Channel #	Channel Type	$V_{\text{OUTx\_NOM}}$ (V)	$V_{\text{ONx\_RISE}}$ (%)	$V_{\text{ONx\_RISE}}$ (V)	$V_{\text{ONx\_FALL}}$ (%)	$V_{\text{ONx\_FALL}}$ (V)
1	UV	3.3	98	3.23	95	3.14
2	OV		105	3.47	102	3.37
3	UV	1.8	98	1.76	97	1.75
4	OV		103	1.85	102	1.84

Using Equation 22 and Equation 23 we can calculate the top and bottom reference resistors and select the closest resistor values using 0.1% resistor values. Table 9-3 shows the reference (or calculated) top and bottom resistors. Table 9-4 shows the selected resistors for the application.

**Table 9-3. SENSEx Reference Nominal Resistors**

Channel #	R <sub>TOP</sub> (kΩ)	R <sub>BOTTOM</sub> (kΩ)
1	4.13	0.94
2		0.86
3	0.75	0.39
4		0.36

An calculation example for channel 1 (or SENSE1) top and bottom resistor is shown below:

$$\frac{3.23 \text{ V} - 3.14 \text{ V}}{24 \mu\text{A}} = 4.13\text{k}\Omega \quad (33)$$

$$\frac{4.13 \text{ k}\Omega \times 0.60 \text{ V}}{3.23 \text{ V} - 0.60 \text{ V}} = 0.94\text{k}\Omega \quad (34)$$

**Table 9-4. SENSEx Selected Resistors Using 0.1% Tolerance Resistors**

Channel #	R <sub>TOP</sub> (kΩ)	R <sub>BOTTOM</sub> (kΩ)
1	4.12	0.931
2		0.866
3	0.75	0.383
4		0.357

Now that the actual resistors are known, we can calculate the actual on and off nominal voltages and the error voltages by using Equation 9, Equation 11, Equation 12, Equation 15, Equation 16, and Equation 21. Using the errors, we can calculate the upper and lower voltages and normalize the values with respect to the nominal output voltage.

**Table 9-5. V<sub>OUTX\_RISE</sub> Nominal Values With Statistics in Volts and Percentage**

Channel #	V <sub>OUTX_RISE_NOMINAL</sub> (V)	V <sub>OUTX_RISE_NOMINAL</sub> <sup>(1)</sup> (%)
1	3.25	98.48
2	3.45	104.51
3	1.77	98.44
4	1.86	103.19

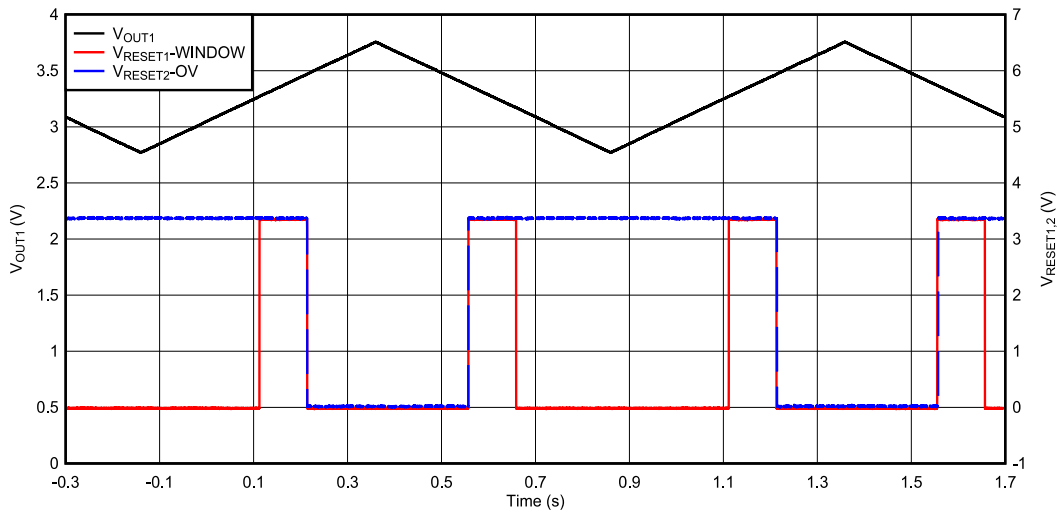
(1) Values are normalized to the nominal output voltage for that rail.

**Table 9-6. V<sub>OUTX\_FALL</sub> Nominal Values with Statistics in Volts and Percentage**

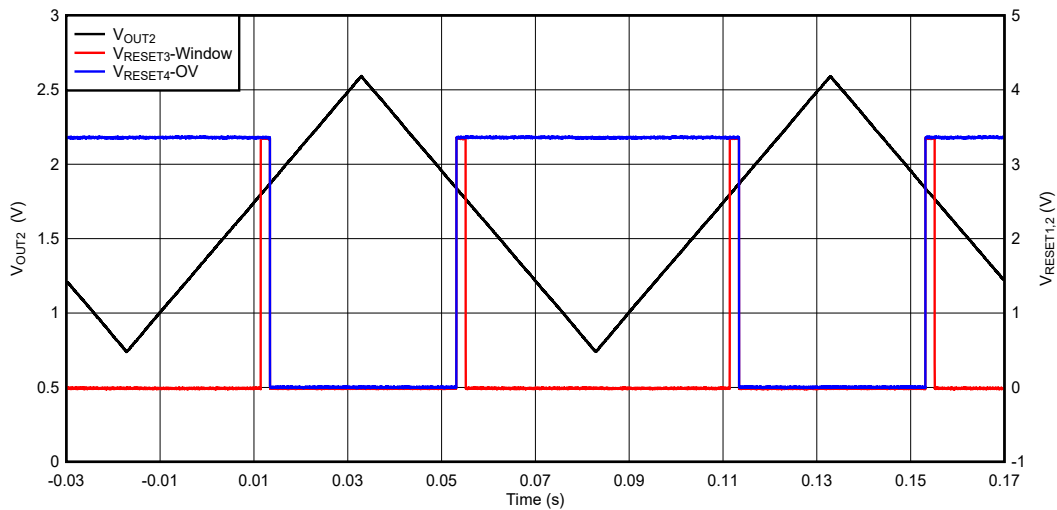
Channel #	V <sub>OUTX_FALL_NOMINAL</sub> (V)	V <sub>OUTX_FALL_NOMINAL</sub> (%) <sup>(1)</sup>
1	3.15	95.48
2	3.35	104.51
3	1.75	98.88
4	1.84	103.19

(1) Values are normalized to the nominal output voltage for that rail.

### 9.2.1.3 Application Curves



**Figure 9-2.  $V_{OUT1}$ ,  $V_{RESET1}$ , and  $V_{RESET2}$  vs Time**



**Figure 9-3.  $V_{OUT2}$ ,  $V_{RESET3}$ , and  $V_{RESET4}$  vs Time**

## 9.3 Power Supply Recommendations

The TPS7H3024 is designed to operate from an input supply ( $V_{IN}$ ) with a voltage range from 3V to 14V.  $V_{IN}$  needs to be decoupled with at least one 0.1 $\mu$ F ceramic capacitor from  $V_{IN}$  to GND, as close to the pin as possible

In the TPS7H3024 the PULL\_UP1 and PULL\_UP2 are also considered power inputs, in this case for the push-pull outputs. The voltage range on these inputs is from 1.6V to 7V. Connect at least one 1 $\mu$ F ceramic capacitor from PULL\_UP1 to GND and from PULL\_UP2 to GND. These capacitors must be placed as close to the pins as possible.

## 9.4 Layout

### 9.4.1 Layout Guidelines

- Connect a high quality ceramic capacitor (such as X7R) as close to the pins as possible. The signals and capacitor values are:
  - $V_{IN} \geq 0.1\mu\text{F}$

- REFCAP = 470nF
- VLDO = 1 $\mu$ F
- PULL\_UPx  $\geq$  1 $\mu$ F
- Avoid passing noisy traces near the VLDO and REFCAP pins as the pins are internal references to the device.
- If needed, place a small capacitor between the SENSEx pins and GND to reduce the sensitivity to transient voltages on the monitored signal.
- As users typically use the supervisor in conjunction with switch mode power supplies, users must keep the SENSEx trace away from noisy sources as much as possible. Avoid routing this trace directly under the noise-source. If not possible, make sure that the trace is routed on another layer with a ground layer separating the trace and noise-source.

### 9.4.2 Layout Example

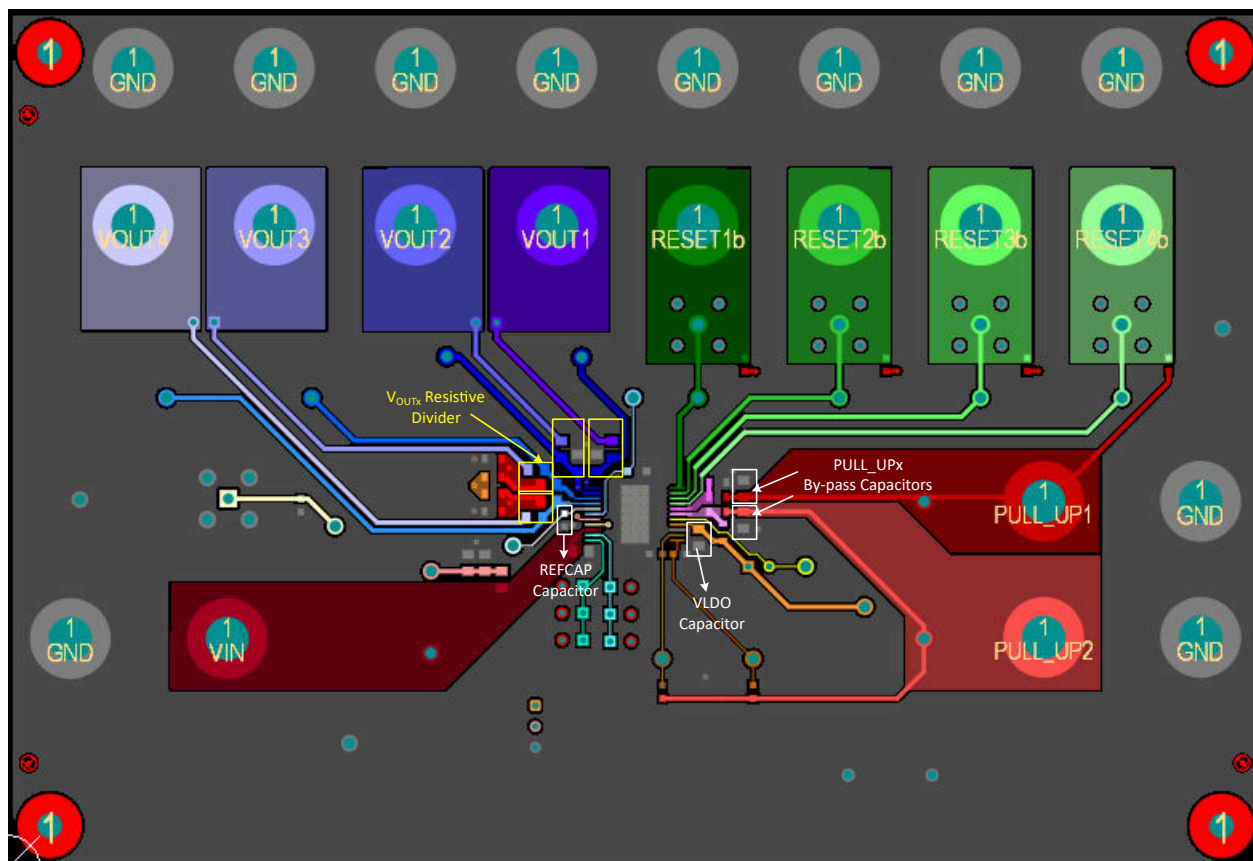
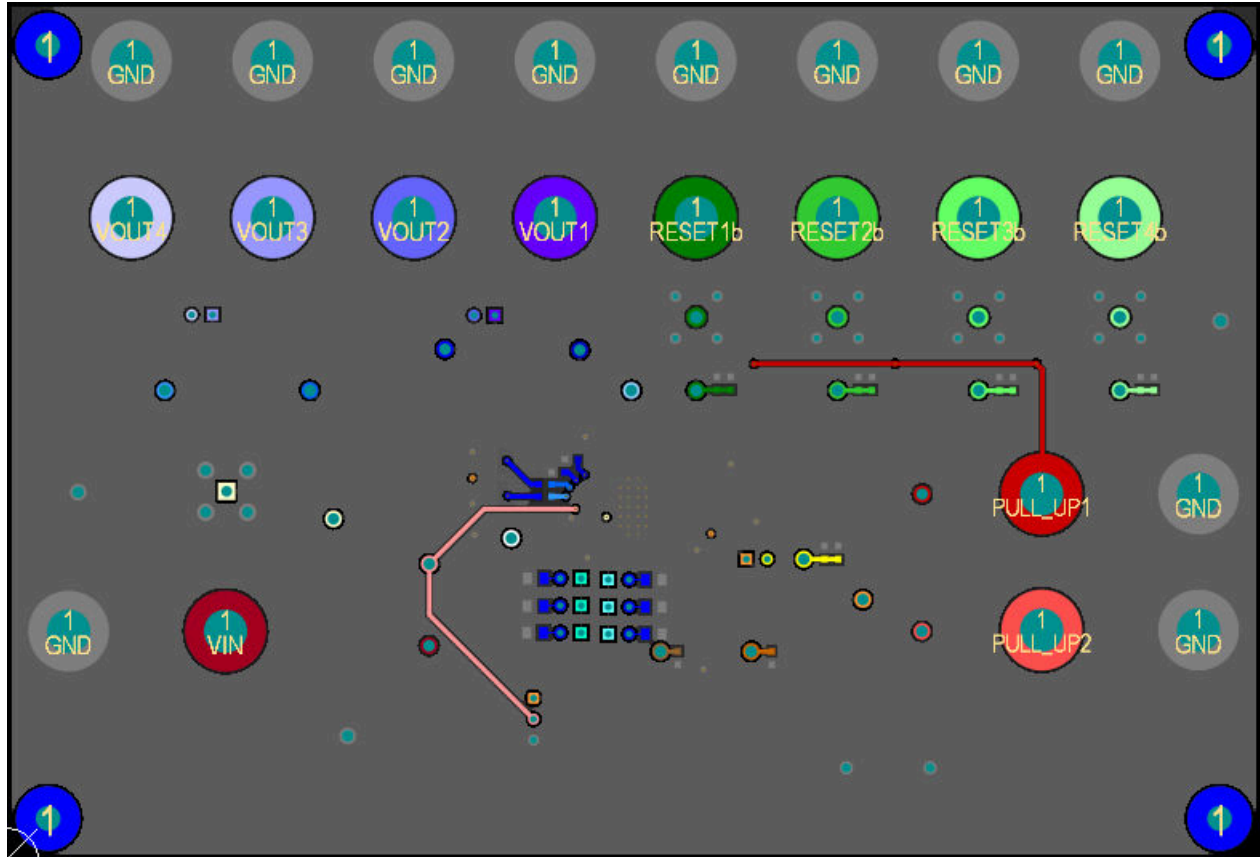


Figure 9-4. Printed Circuit Board Layout Example: Top Layer



**Figure 9-5. Printed Circuit Board Layout Example: Bottom Layer**

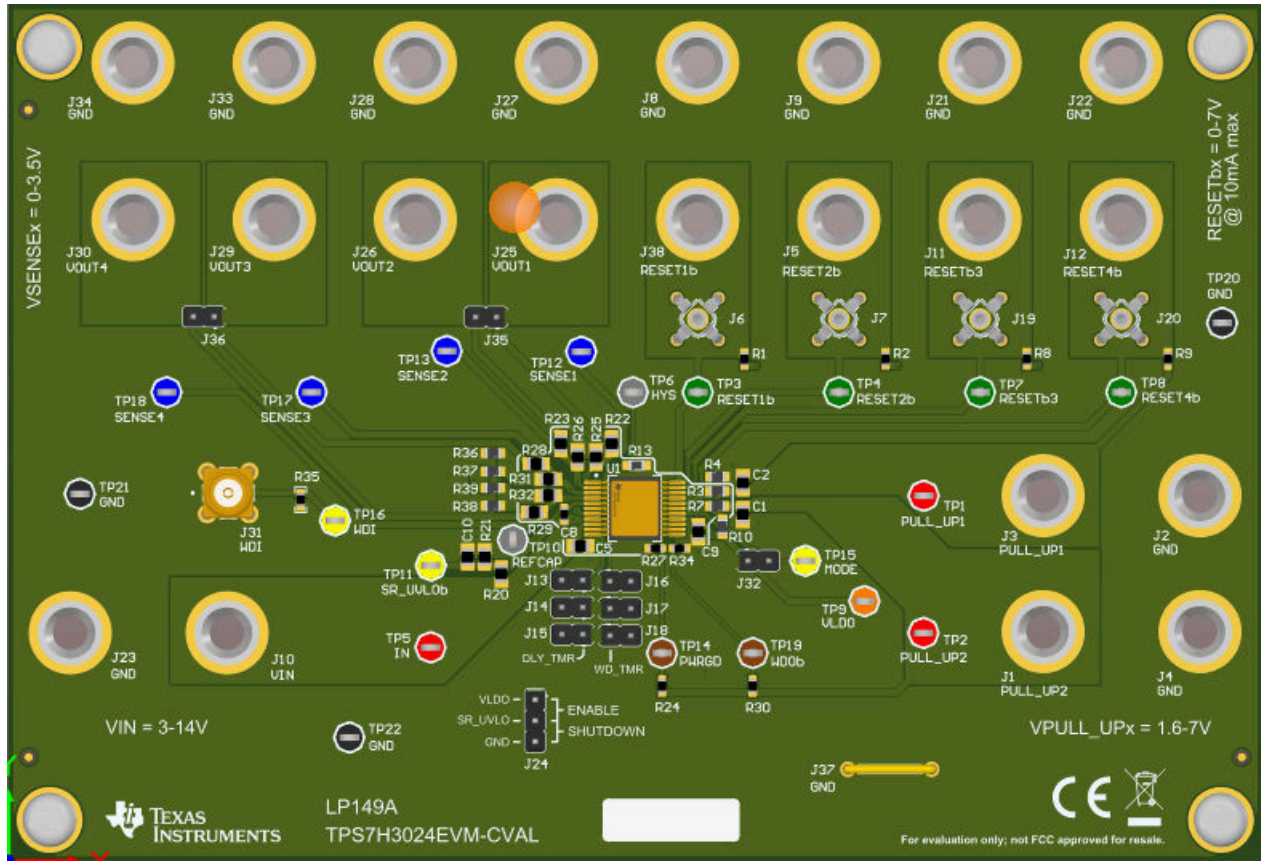
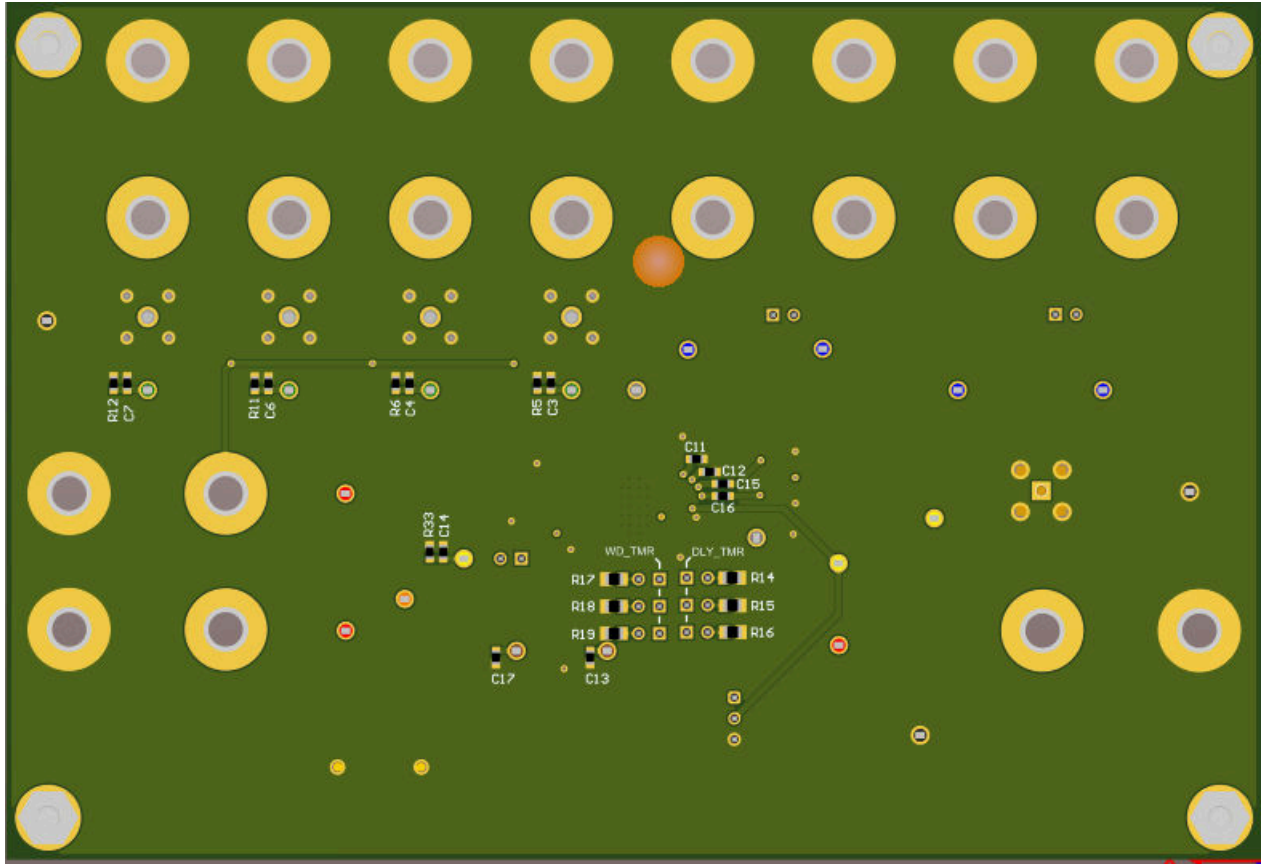


Figure 9-6. Printed Circuit Board Layout Example: Top Layer 3D View



**Figure 9-7. Printed Circuit Board Layout Example: Bottom Layer 3D View**

## 10 Device and Documentation Support

### 10.1 Documentation Support

#### 10.1.1 Related Documentation

The following related documents are available for download at [www.ti.com](http://www.ti.com):

- Texas Instruments, [Optimizing Resistor Dividers at a Comparator application note](#)
- Texas Instruments, [TPS7H3024EVM-CVAL Evaluation Module user's guide](#)
- Texas Instruments, [TPS7H3024-SP Neutron Displacement Damage \(NDD\) Characterization radiation report](#)
- Texas Instruments, [TPS7H3024-SP Single-Event Effects \(SEE\) radiation report](#)
- Texas Instruments, [TPS7H3024-SP Total Ionizing Dose \(TID\) radiation report](#)
- DLA Land and Marine, [standard microcircuit drawing](#)

### 10.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on [ti.com](http://ti.com). Click on *Notifications* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

### 10.3 Support Resources

[TI E2E™ support forums](#) are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

Linked content is provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's [Terms of Use](#).

### 10.4 Trademarks

TI E2E™ is a trademark of Texas Instruments.

All trademarks are the property of their respective owners.

### 10.5 Electrostatic Discharge Caution



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

### 10.6 Glossary

[TI Glossary](#) This glossary lists and explains terms, acronyms, and definitions.

## 11 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

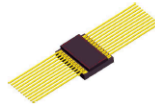
Changes from Revision A (August 2025) to Revision B (May 2026)	Page
• Added TPS7H3034-SP, TPS7H3124-SP, and TPS7H3134-SP QMLV as <i>Advanced Information</i> throughout...	1
• Updated document to separate TPS7H30x4 and TPS7H31x4 throughout.....	1
• Added SENSE1, RESET1, and $\overline{\text{RESET}}1$ typical characteristics graphs.....	13
• Updated TPS7H3xx4 Functional Modes.....	30

Changes from Revision * (April 2025) to Revision A (August 2025)	Page
• Changed TPS7H3024-SP QMLV from <i>Advanced Information</i> to <i>Production Data</i> .....	1

## 12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this datasheet, refer to the left-hand navigation.

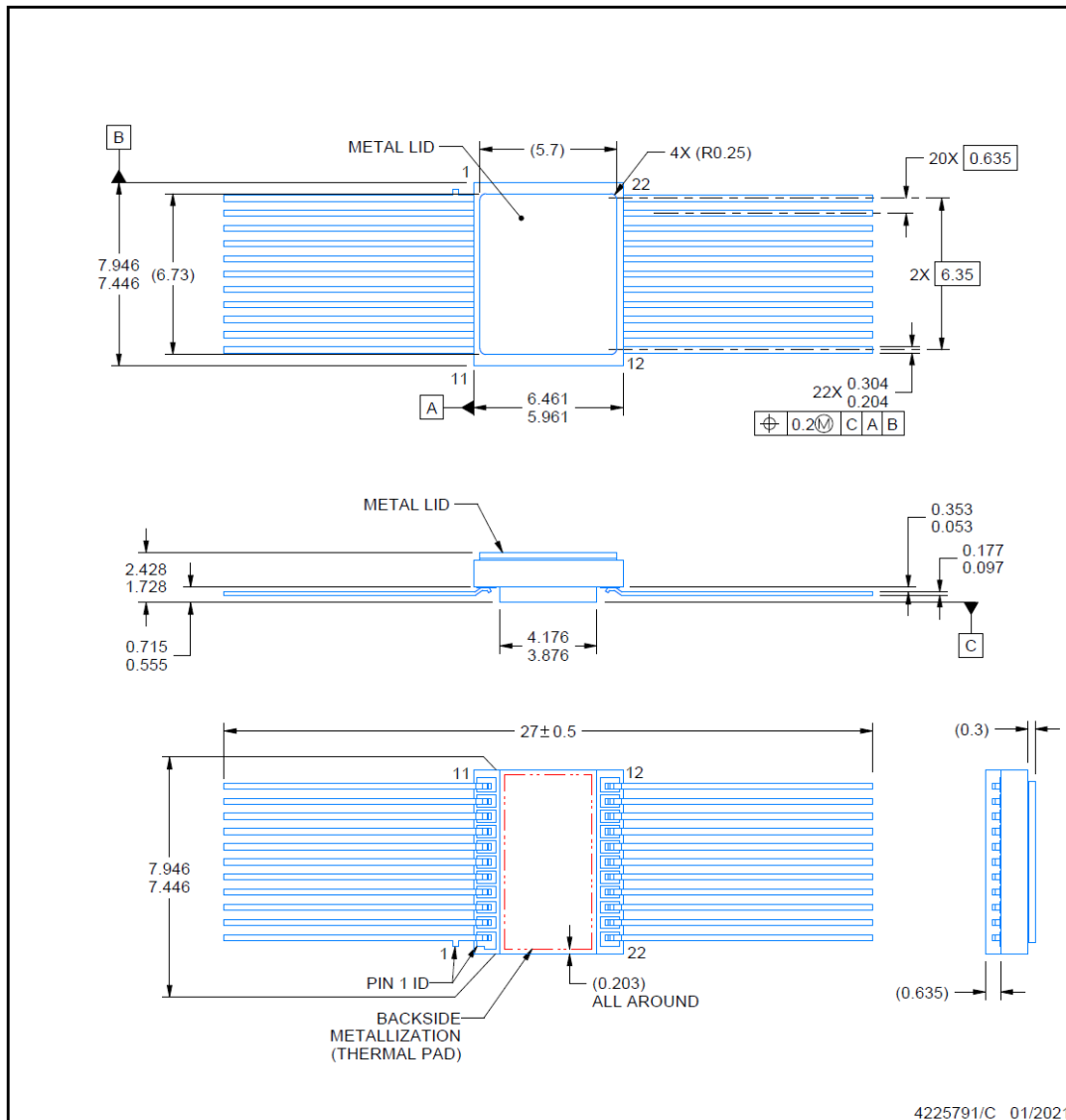
## 12.1 Mechanical Data



**HFT0022A**

**PACKAGE OUTLINE**  
**CFP - 2.428mm max height**

CERAMIC FLATPACK



**NOTES:**

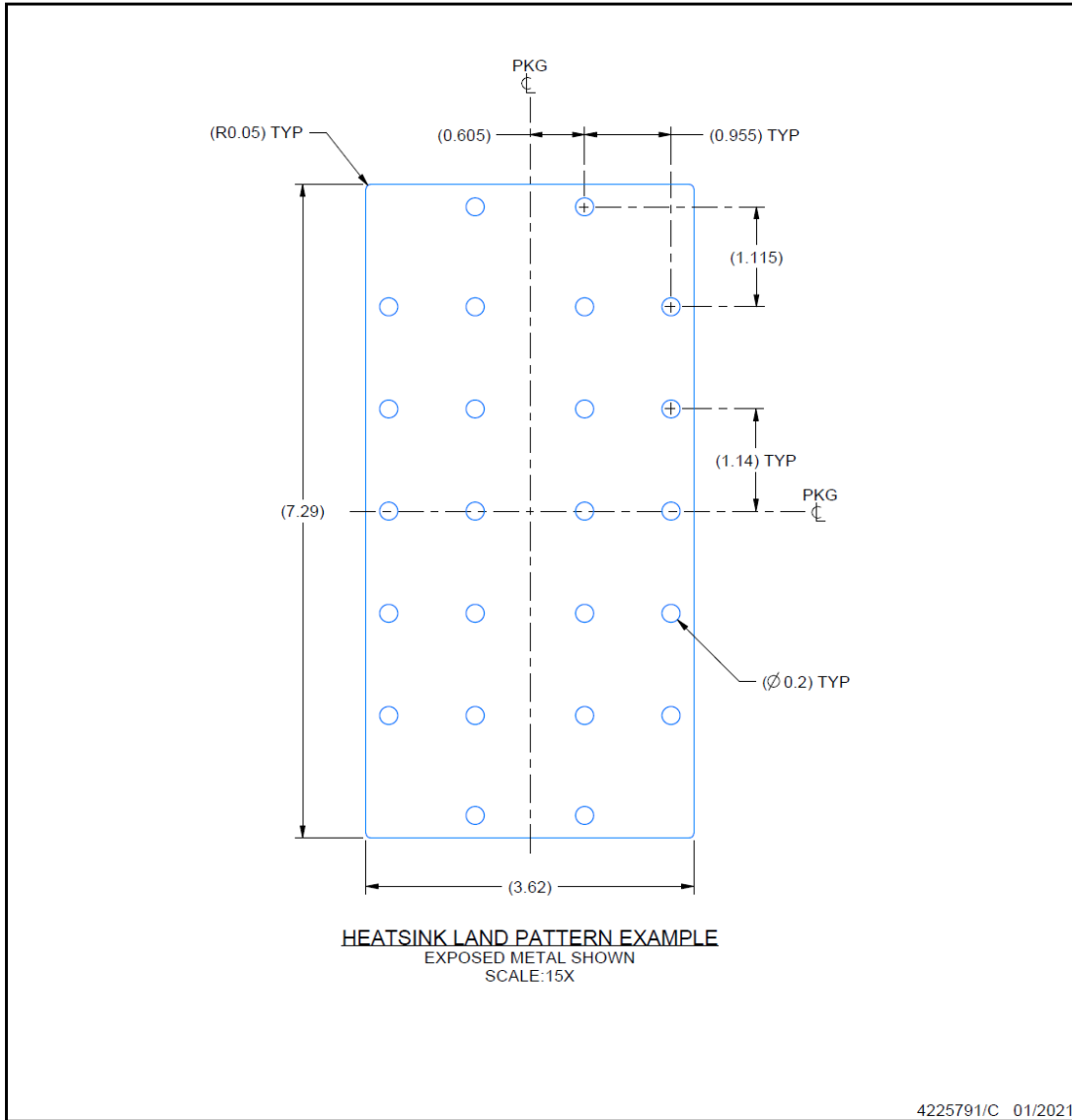
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This package is hermetically sealed with a metal lid. The lid is not connected to any lead.
4. The leads are gold plated.
5. Metal lid is connected to backside metalization

**EXAMPLE BOARD LAYOUT**

**HFT0022A**

**CFP - 2.428mm max height**

CERAMIC FLATPACK



**PACKAGING INFORMATION**

Orderable part number	Status (1)	Material type (2)	Package   Pins	Package qty   Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
<a href="#">5962R2420601VXC</a>	Active	Production	CFP (HFT)   22	15   TUBE	Yes	NIAU	N/A for Pkg Type	-55 to 125	5962R2420601VXC TPS7H3024MHFTV
<a href="#">PTPS7H3034HFT/EM</a>	Active	Preproduction	CFP (HFT)   22	15   TUBE	-	Call TI	Call TI	-55 to 125	
<a href="#">PTPS7H3124HFT/EM</a>	Active	Preproduction	CFP (HFT)   22	15   TUBE	-	Call TI	Call TI	-55 to 125	
<a href="#">PTPS7H3134HFT/EM</a>	Active	Preproduction	CFP (HFT)   22	15   TUBE	-	Call TI	Call TI	-55 to 125	
<a href="#">TPS7H3024HFT/EM</a>	Active	Production	CFP (HFT)   22	15   TUBE	Yes	NIAU	N/A for Pkg Type	25 to 25	TPS7H3024HFTEM EVAL ONLY

(1) **Status:** For more details on status, see our [product life cycle](#).

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the [TI RoHS Statement](#) for additional information and value definition.

(4) **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

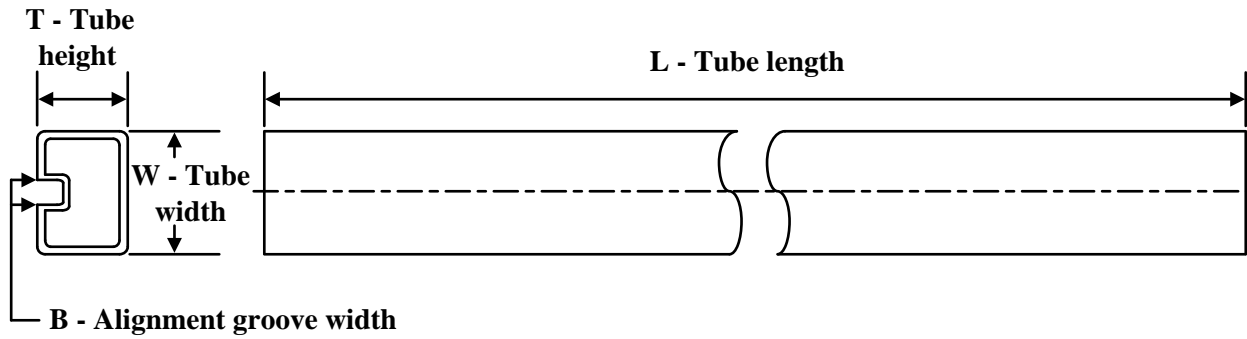
(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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**TUBE**


\*All dimensions are nominal

Device	Package Name	Package Type	Pins	SPQ	L (mm)	W (mm)	T (μm)	B (mm)
5962R2420601VXC	HFT	CFP	22	15	506.98	32.77	9910	NA
TPS7H3024HFT/EM	HFT	CFP	22	15	506.98	32.77	9910	NA

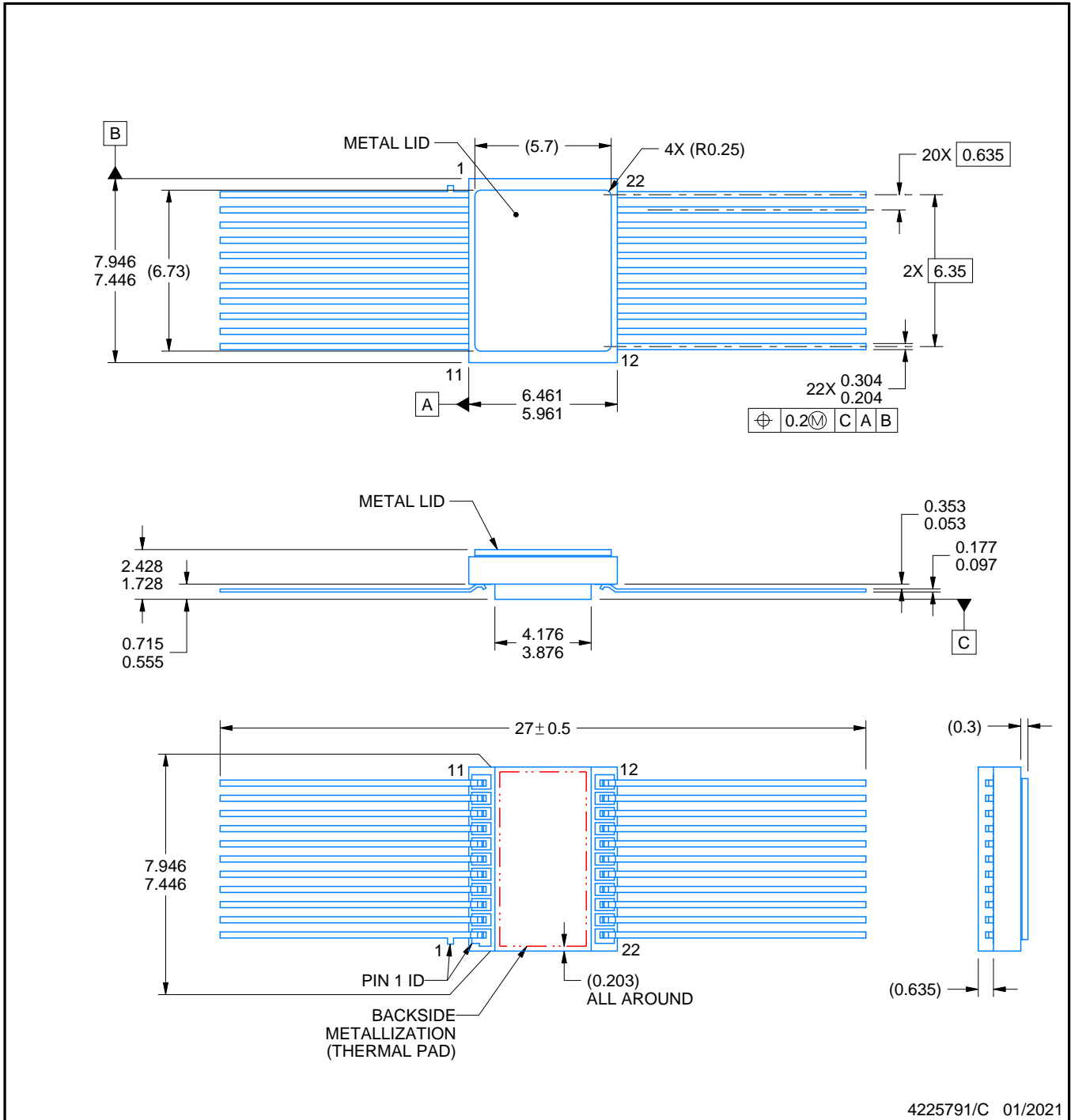
# HFT0022A



## PACKAGE OUTLINE

CFP - 2.428mm max height

CERAMIC FLATPACK



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**NOTES:**

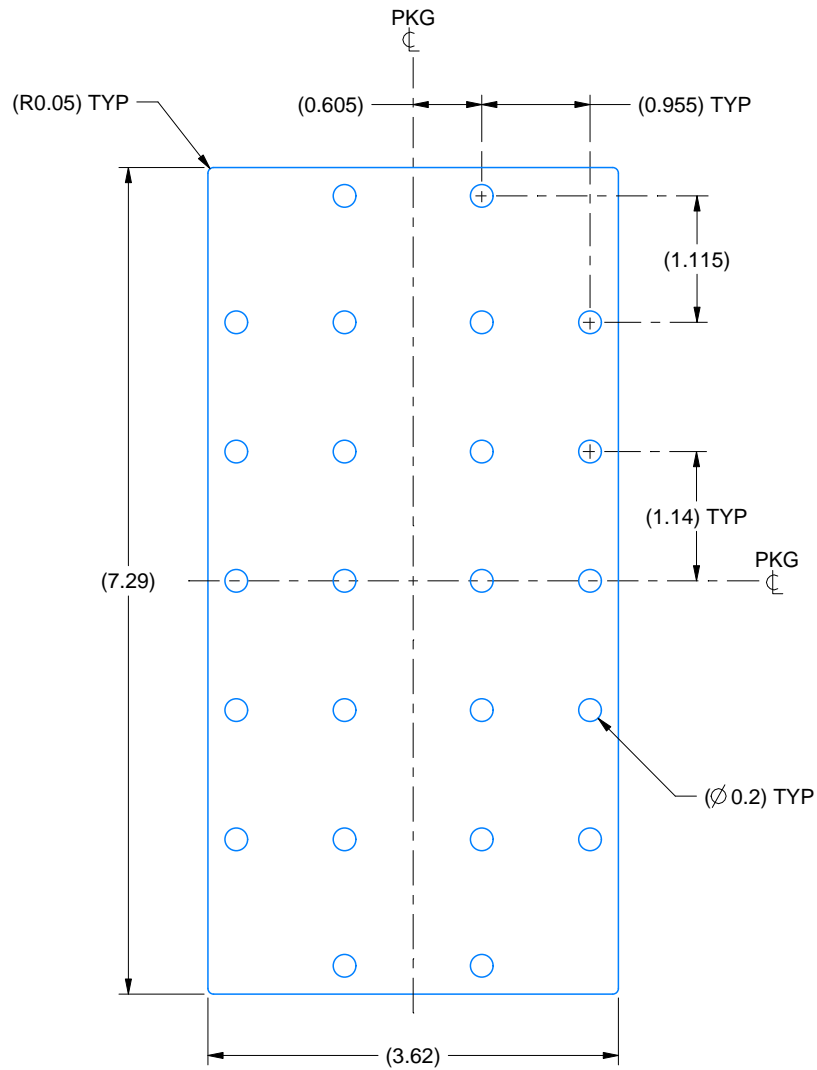
1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This package is hermetically sealed with a metal lid. The lid is not connected to any lead.
4. The leads are gold plated.
5. Metal lid is connected to backside metallization

# EXAMPLE BOARD LAYOUT

HFT0022A

CFP - 2.428mm max height

CERAMIC FLATPACK



HEATSINK LAND PATTERN EXAMPLE  
EXPOSED METAL SHOWN  
SCALE:15X

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# REVISIONS

REV	DESCRIPTION	ECR	DATE	ENGINEER / DRAFTER
A	RELEASE NEW DRAWING	2186323	03/13/2020	R. RAZAK / ANIS FAUZI
B	ADD LAND PATTERN VIEW / SHEET	2190485	10/22/2020	R. RAZAK / ANIS FAUZI
C	UPDATE TOTAL LEAD LENGTH TO $27 \pm 0.5$	2192775	01/28/2021	R. RAZAK / ANIS FAUZI

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