

# Hex Half-Bridge Driver

## NCV7723B

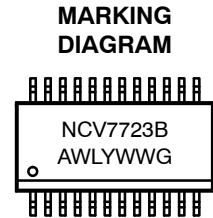
The NCV7723B is a six channel half-bridge driver with protection features designed specifically for automotive and industrial motion control applications. The product has independent controls and diagnostics, and the drivers can be operated in forward, reverse, brake, and high impedance states. The device is controlled via a 16 bit SPI interface and is daisy chain compatible. Outputs 1 and 2 can be controlled through an external PWM signal.

### Features

- Low Quiescent Current Sleep Mode
- High-Side and Low-Side Drivers  
Connected in Half-Bridge Configurations
- Integrated Freewheeling Protection (LS and HS)
- 500 mA Typical, 1.1 A Peak Current
- $R_{DS(on)} = 0.8 \Omega$  (Typ)
- OUT1 and OUT2 External PWM Control
- 5 MHz SPI Communication
- 16 Bit Frame Error Detection
- Daisy Chain Compatible with Multiple of 8 bit Devices
- Compliance with 3.3 V and 5 V Systems
- Undervoltage and Overvoltage Lockout
- Per Channel Fault Reporting
- Overcurrent Protection
- Overtemperature Protection
- Underload Detection (HS and LS)
- Exposed Pad Package
- NCV Prefix for Automotive and Other Applications Requiring Unique Site and Control Change Requirements; AEC-Q100 Qualified and PPAP Capable
- This is a Pb-Free Device

### Typical Applications

- Automotive
- Industrial
- DC Motor Management for HVAC Application



NCV7723B = Specific Device Code  
 A = Assembly Location  
 WL = Wafer Lot  
 Y = Year  
 WW = Work Week  
 G = Pb-Free Package

### ORDERING INFORMATION

See detailed ordering and shipping information on page 23 of this data sheet.

# NCV7723B

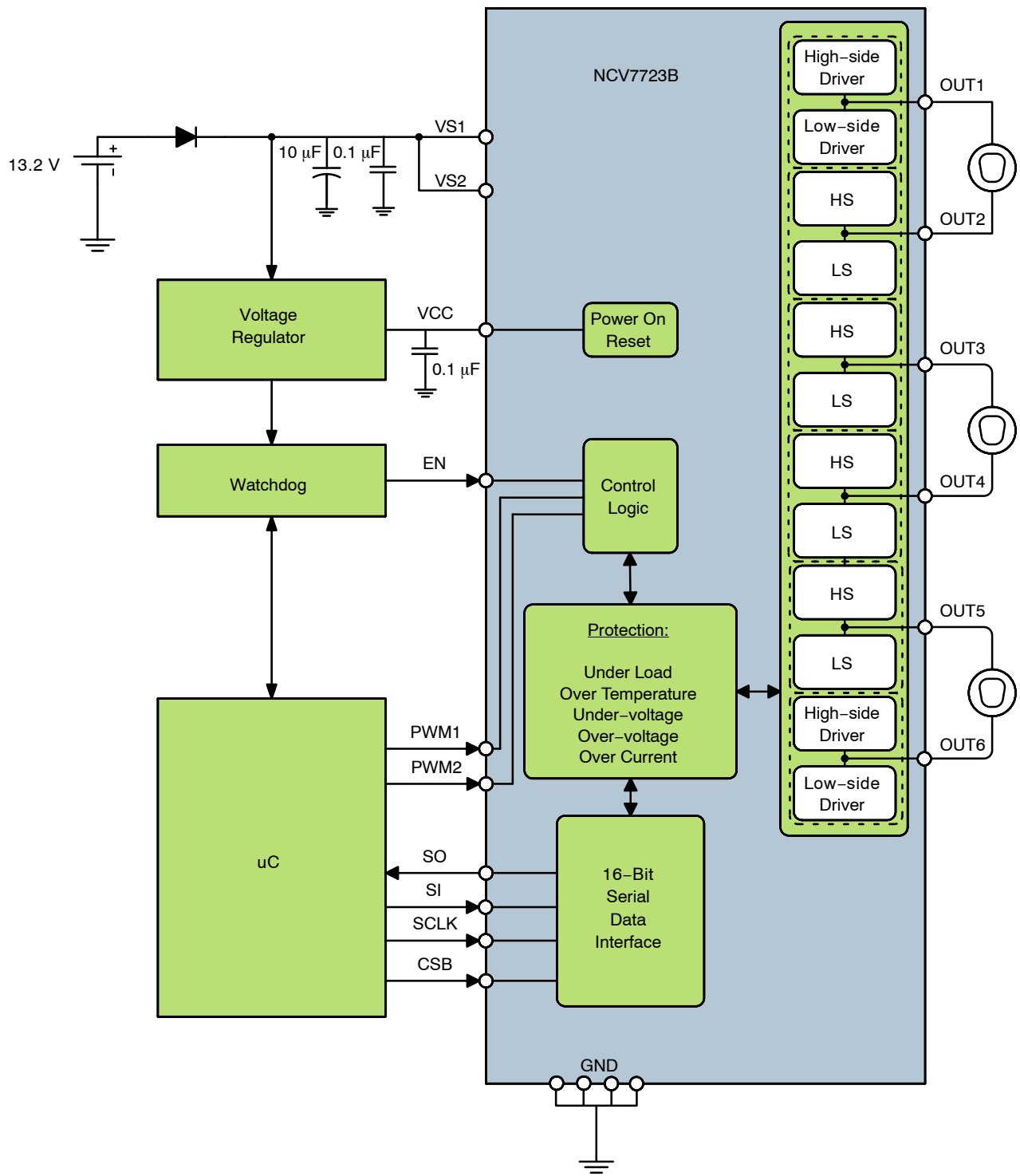


Figure 1. Typical Application



# NCV7723B

**PIN FUNCTION DESCRIPTION** The pin-out for the Half-Bridge Driver in SSOP24 NB EP package is shown in the table below.

| Pin#<br>SSOP24 | Symbol      | Description  |
|----------------|-------------|--|
| 1              | GND         | Ground. Must be connected to other GND pins externally.  |
| 2              | OUT1        | Half-bridge output 1   |
| 3              | OUT5        | Half-bridge output 5   |
| 4              | NC          | No Connection. This pin should be isolated from any traces or via on the PCB board.  |
| 5              | SI          | 16 bit serial communication input. 3.3 V / 5 V (TTL) Compatible – internally pulled down.  |
| 6              | VCC         | Power supply input for Logic.  |
| 7              | SO          | 16 bit serial communication output. 3.3 V / 5 V Compliant  |
| 8              | EN          | Enable – active high; wakes the device from sleep mode. 3.3 V / 5 V (TTL) Compatible – internally pulled down.                         |
| 9              | NC          | No Connection. This pin should be isolated from any traces or via on the PCB board.  |
| 10             | OUT6        | Half-bridge output 6   |
| 11             | OUT4        | Half-bridge output 4   |
| 12             | GND         | Ground. Must be connected to other GND pins externally.  |
| 13             | GND         | Ground. Must be connected to other GND pins externally.  |
| 14             | OUT3        | Half-bridge output 3   |
| 15             | NC          | No Connection. This pin should be isolated from any traces or via on the PCB board.  |
| 16             | VS2         | Power Supply input for outputs 3, 4, and 6. This pin must be connected to VS1 externally.  |
| 17             | PWM1        | External PWM input for output 1. 3.3 V / 5 V (TTL) Compatible – internally pulled down. Connect to ground or leave floating if unused. |
| 18             | PWM2        | External PWM input for output 2. 3.3 V / 5 V (TTL) Compatible – internally pulled down. Connect to ground or leave floating if unused. |
| 19             | CSB         | Chip select bar – active low; enables serial communication operation. 3.3 V / 5 V (TTL) Compatible – internally pulled up.             |
| 20             | SCLK        | Serial communication clock input. 3.3 V / 5 V (TTL) Compatible – internally pulled down.   |
| 21             | VS1         | Power Supply input for outputs 1, 2, and 5. This pin must be connected to VS2 externally.  |
| 22             | NC          | No Connection. This pin should be isolated from any traces or via on the PCB board.  |
| 23             | OUT2        | Half-bridge output 2   |
| 24             | GND         | Ground. Must be connected to other GND pins externally.  |
| EPAD           | Exposed Pad | Connect to GND or leave unconnected.   |

## MAXIMUM RATINGS (Voltages are with respect to GND)

| Rating  | Symbol             | Value                                   | Unit |
|---|--------------------|---|------|
| VSx Pin Voltage (VS1, VS2)<br>(DC)<br>(AC), $t < 500$ ms, $I_{vsx} > -2$ A  | VsxdcMax<br>VSxac  | -0.3 to 45<br>-1.0                      | V    |
| Pin Voltage (Vcc, SI, SCLK, CSB, SO, EN, PWM1, PWM2)  | VioMax             | -0.3 to 5.5                             | V    |
| OUTx Pin Voltage<br>(DC)<br>(AC)<br>(AC), $t < 500$ ms, $I_{OUTx} > -1.1$ A<br>(AC), $t < 500$ ms, $I_{OUTx} < 1$ A | VoutxDc<br>VoutxAc | -0.3 to 45<br>-0.3 to 45<br>-1.0<br>1.0 | V    |
| OUTx Pin Current (OUT1, ..., OUT6)  | IoutxImax          | -2.0 to 2.0                             | A    |
| Junction Temperature Range  | T <sub>J</sub>     | -40 to 150                              | °C   |
| Storage Temperature Range   | T <sub>str</sub>   | -55 to 150                              | °C   |
| Peak Reflow Soldering Temperature: Pb-free 60 to 150 seconds at 217°C   | (Note 1)           | 260                                     | °C   |

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

1. See or download **onsemi's** Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

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## ATTRIBUTES

| Characteristic   | Symbol   | Value                       | Unit   |
|--|--|-----------------------------|--|
| Short Circuit Reliability Characterization   | AECQ10x  | Grade A                     |  |
| ESD Capability<br>Human Body Model per AEC-Q100-002<br>Charged Device Model per AEC-Q100-011 | VSx, OUTx<br>All Other Pins                                      | Vesd4k<br>Vesd2k<br>Vesd750 | $\geq \pm 4.0$ kV<br>$\geq \pm 2.0$ kV<br>$\geq \pm 750$ V |
| Moisture Sensitivity Level   | MSL  | MSL2                        |  |
| Package Thermal Resistance – Still-air<br>Junction-to-Ambient<br>Junction-to-Board           | (Note 2)<br>R <sub>θJA</sub><br>(Note 2)<br>R <sub>ψJBOARD</sub> | 32.1<br>21.8                | °C/W<br>°C/W   |

2. Based on JE5D51-7, 1.6 mm thick FR4, 2S2P PCB with 600 mm<sup>2</sup> 2 oz. copper and 18 thermal vias to 80x80 mm 1 oz. internal spreader planes. Simulated with each channel dissipating 0.2 W.

## RECOMMENDED OPERATING CONDITIONS

| Parameter                                | Symbol | Min  | Max  | Unit |
|--|--------|------|------|------|
| Digital Supply Input Voltage             | VCCOp  | 3.15 | 5.25 | V    |
| Battery Supply Input Voltage (VS1 = VS2) | VSxOp  | 5.5  | 32   | V    |
| DC Output Current                        | IxOp   | -    | 0.5  | A    |
| Junction Temperature                     | TjOp   | -40  | 125  | °C   |

Functional operation above the stresses listed in the Recommended Operating Ranges is not implied. Extended exposure to stresses beyond the Recommended Operating Ranges limits may affect device reliability.

## ELECTRICAL CHARACTERISTICS

(-40°C ≤ T<sub>J</sub> ≤ 150°C, 5.5 V ≤ VSx ≤ 40 V, 3.15 V ≤ V<sub>CC</sub> ≤ 5.25 V, EN = V<sub>CC</sub>, unless otherwise specified.)

| Characteristic                                       | Symbol  | Conditions   | Min        | Typ        | Max        | Unit |
|--|---------|--|------------|------------|------------|------|
| <b>POWER SUPPLIES</b>                                |         |  |            |            |            |      |
| Supply Current (VS1 + VS2)<br>Sleep Mode             | IqVSx85 | VS1 = VS2 = 13.2 V, V <sub>CC</sub> = 0 V<br>-40°C to 85°C               | -          | 1.0        | 2.5        | μA   |
| Supply Current (VS1 + VS2)<br>Active Mode            | IvsOp   | EN = V <sub>CC</sub> , 5.5V < VSx < 32 V<br>No Load, All Outputs Off     | -          | 0.5        | 1.0        | mA   |
| Supply Current (Vcc)<br>Sleep Mode                   | IqVCC   | CSB = V <sub>CC</sub> , EN = SI = SCLK = 0 V<br>-40°C to 85°C            | -          | 1.0        | 2.5        | μA   |
| Active Mode  | IVCCOp  | EN = CSB = V <sub>CC</sub> , SI = SCLK = 0 V<br>No Load, All Outputs Off | -          | 1.5        | 3.0        | mA   |
| Total Sleep Mode Current<br>I(VS1) + I(VS2) + I(VCC) | IqTot   | Sleep Mode, -40°C to 85°C<br>VS1 = VS2 = 13.2 V, No Load                 | -          | 2.0        | 5.0        | μA   |
| VCC Power-on Reset Threshold                         | VCCpor  | V <sub>CC</sub> increasing   | -          | 2.70       | 2.90       | V    |
| VSx Undervoltage Detection Threshold                 | VSxuv   | VSx decreasing<br>VSx increasing   | 3.5<br>3.7 | 4.1<br>4.3 | 4.5<br>4.7 | V    |
| VSx Undervoltage Detection Hysteresis                | VSxuHys |  | 100        | -          | 450        | mV   |
| VSx Overvoltage Detection Threshold                  | VsXov   | VSx increasing<br>VSx decreasing   | 32<br>29.5 | 36<br>33.5 | 40<br>37.5 | V    |
| VSx Overvoltage Detection Hysteresis                 | VSxoHys |  | -          | 2.5        | -          | V    |

## DRIVER OUTPUT CHARACTERISTICS

|  |                          |  |              |     |     |          |
|--|--------------------------|--|--------------|-----|-----|----------|
| Output High R <sub>DS(on)</sub> (source) | RDSonHS                  | I <sub>out</sub> = -500 mA, Vs = 13.2 V<br>V <sub>CC</sub> = 3.15 V              | -            | 0.8 | 1.8 | Ω        |
| Output Low R <sub>DS(on)</sub> (sink)    | RDSonLS                  | I <sub>out</sub> = 500 mA, Vs = 13.2 V<br>V <sub>CC</sub> = 3.15 V               | -            | 0.8 | 1.8 | Ω        |
| Source Leakage Current                   | IsrcLkg13.2<br>IsrcLkg28 | V <sub>CC</sub> = 5 V, OUT (1-6) = 0 V, EN = 0/5 V<br>VSx = 13.2 V<br>VSx = 28 V | -1.0<br>-2.0 | -   | -   | μA<br>μA |

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## ELECTRICAL CHARACTERISTICS

( $-40^{\circ}\text{C} \leq T_J \leq 150^{\circ}\text{C}$ ,  $5.5\text{ V} \leq V_{Sx} \leq 40\text{ V}$ ,  $3.15\text{ V} \leq V_{CC} \leq 5.25\text{ V}$ ,  $EN = V_{CC}$ , unless otherwise specified.) (continued)

| Characteristic                            | Symbol                   | Conditions  | Min  | Typ  | Max  | Unit          |
|---|--------------------------|---|------|------|------|---------------|
| <b>DRIVER OUTPUT CHARACTERISTICS</b>      |                          |   |      |      |      |               |
| Sink Leakage Current                      | IsnkLkg13.2<br>IsnkLkg28 | $V_{CC} = 5\text{ V}$ , $EN = 0/5\text{ V}$<br>OUT (1-6) = $V_{Sx} = 13.2\text{ V}$<br>OUT (1-6) = $V_{Sx} = 28\text{ V}$ | -    | -    | 1.0  | $\mu\text{A}$ |
|   |                          |   | -    | -    | 2.0  | $\mu\text{A}$ |
| Overcurrent Shutdown Threshold (Source)   | IsdSrc                   | $V_{CC} = 5\text{ V}$ , $V_{Sx} = 13.2\text{ V}$  | -2.0 | -1.5 | -1.1 | A             |
| Overcurrent Shutdown Threshold (Sink)     | IsdSnk                   | $V_{CC} = 5\text{ V}$ , $V_{Sx} = 13.2\text{ V}$  | 1.1  | 1.5  | 2.0  | A             |
| Over Current Delay Timer                  | TdOc                     |   | 10   | 25   | 50   | $\mu\text{s}$ |
| Underload Detection Threshold (Low Side)  | IuldLS                   | $V_{CC} = 5\text{ V}$ , $V_{Sx} = 13.2\text{ V}$  | -    | 2.5  | 7.5  | mA            |
| Underload Detection Threshold (High Side) | IuldHS                   | $V_{CC} = 5\text{ V}$ , $V_{Sx} = 13.2\text{ V}$  | -7.5 | -2.5 | -    | mA            |
| Underload Detection Delay Time            | TdUld                    | $V_{CC} = 5\text{ V}$ , $V_{Sx} = 13.2\text{ V}$  | 200  | 350  | 600  | $\mu\text{s}$ |
| Body Diode Forward Voltage                | IbdFwd                   | $I_f = 500\text{ mA}$   | -    | 0.9  | 1.3  | V             |

## DRIVER OUTPUT SWITCHING CHARACTERISTICS

|   |            |   |    |     |     |               |
|---|------------|---|----|-----|-----|---------------|
| High Side Turn On Time                        | ThsOn      | $V_s = 13.2\text{ V}$ , $R_{load} = 70\ \Omega$ | -  | 120 | 165 | $\mu\text{s}$ |
| High Side Turn Off Time                       | ThsOff     | $V_s = 13.2\text{ V}$ , $R_{load} = 70\ \Omega$ | -  | 20  | 45  | $\mu\text{s}$ |
| Low Side Turn On Time                         | TlsOn      | $V_s = 13.2\text{ V}$ , $R_{load} = 70\ \Omega$ | -  | 120 | 165 | $\mu\text{s}$ |
| Low Side Turn Off Time                        | TlsOff     | $V_s = 13.2\text{ V}$ , $R_{load} = 70\ \Omega$ | -  | 35  | 75  | $\mu\text{s}$ |
| High Side Rise Time                           | ThsTr      | $V_s = 13.2\text{ V}$ , $R_{load} = 70\ \Omega$ | 10 | 30  | 50  | $\mu\text{s}$ |
| High Side Fall Time                           | ThsTf      | $V_s = 13.2\text{ V}$ , $R_{load} = 70\ \Omega$ | 10 | 30  | 50  | $\mu\text{s}$ |
| Low Side Rise Time                            | TlsTr      | $V_s = 13.2\text{ V}$ , $R_{load} = 70\ \Omega$ | 10 | 30  | 50  | $\mu\text{s}$ |
| Low Side Fall Time                            | TlsTf      | $V_s = 13.2\text{ V}$ , $R_{load} = 70\ \Omega$ | 10 | 30  | 50  | $\mu\text{s}$ |
| High Side Off to Low Side On Non-Overlap Time | ThsOffLsOn | $V_s = 13.2\text{ V}$ , $R_{load} = 70\ \Omega$ | 5  | -   | -   | $\mu\text{s}$ |
| Low Side Off to High Side On Non-Overlap Time | TlsOffHsOn | $V_s = 13.2\text{ V}$ , $R_{load} = 70\ \Omega$ | 5  | -   | -   | $\mu\text{s}$ |
| PWM High to High Side On Time                 | ThsOnPWM   | $V_s = 13.2\text{ V}$ , $R_{load} = 70\ \Omega$ | -  | 120 | 165 | $\mu\text{s}$ |
| PWM Low to High Side Off Time                 | ThsOffPWM  | $V_s = 13.2\text{ V}$ , $R_{load} = 70\ \Omega$ | -  | 20  | 45  | $\mu\text{s}$ |
| PWM High to Low Side On Time                  | TlsOnPWM   | $V_s = 13.2\text{ V}$ , $R_{load} = 70\ \Omega$ | -  | 120 | 165 | $\mu\text{s}$ |
| PWM Low to Low Side Off Time                  | TlsOffPWM  | $V_s = 13.2\text{ V}$ , $R_{load} = 70\ \Omega$ | -  | 35  | 75  | $\mu\text{s}$ |

## THERMAL RESPONSE

|                             |       |          |     |     |     |                    |
|-----------------------------|-------|----------|-----|-----|-----|--------------------|
| Thermal Warning             | Twr   | (Note 3) | 120 | 140 | 170 | $^{\circ}\text{C}$ |
| Thermal Warning Hysteresis  | TwHy  | (Note 3) | -   | 20  | -   | $^{\circ}\text{C}$ |
| Thermal Shutdown            | Tsd   | (Note 3) | 150 | 175 | 200 | $^{\circ}\text{C}$ |
| Thermal Shutdown Hysteresis | TsdHy | (Note 3) | -   | 20  | -   | $^{\circ}\text{C}$ |

## LOGIC INPUTS - EN, SI, SCLK, CSB, PWM1, PWM2

|   |      |          |     |     |     |            |
|---|------|----------|-----|-----|-----|------------|
| Input Threshold                                 | High | VthInH   | 2.0 | -   | -   | V          |
|   | Low  | VthInL   | -   | -   | 0.6 | V          |
| Input Hysteresis - SI, SCLK, CSB, PWM1, PWM2    |      | VthInHys | 50  | 150 | 300 | mV         |
| Input Hysteresis - EN                           |      | VthENHys | 150 | 400 | 800 | mV         |
| Pull-down Resistance - EN, SI, SCLK, PWM1, PWM2 |      | Rpdx     | 50  | 125 | 200 | k $\Omega$ |
| Pull-up Resistance - CSB                        |      | RpuCSB   | 50  | 125 | 250 | k $\Omega$ |
| Input Capacitance                               |      | Cinx     | -   | -   | 15  | pF         |

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## ELECTRICAL CHARACTERISTICS

( $-40^{\circ}\text{C} \leq T_J \leq 150^{\circ}\text{C}$ ,  $5.5\text{ V} \leq V_{Sx} \leq 40\text{ V}$ ,  $3.15\text{ V} \leq V_{CC} \leq 5.25\text{ V}$ ,  $EN = V_{CC}$ , unless otherwise specified.) (continued)

| Characteristic               | Symbol     | Conditions  | Min            | Typ | Max | Unit          |
|------------------------------|------------|---|----------------|-----|-----|---------------|
| <b>LOGIC OUTPUT – SO</b>     |            |   |                |     |     |               |
| Output High                  | VsoH       | ISOURCE = -1 mA   | $V_{CC} - 0.6$ | -   | -   | V             |
| Output Low                   | VsoL       | ISINK = 1.6 mA  | -              | -   | 0.4 | V             |
| Tri-state Leakage            | ItriStLkg  | CSB = 5 V   | -5             | -   | 5   | $\mu\text{A}$ |
| Tri-state Output Capacitance | ItriStCout | CSB = $V_{CC}$ , $0\text{ V} < V_{CC} < 5.25\text{ V}$ (Note 3) | -              | -   | 15  | pF            |

## SERIAL PERIPHERAL INTERFACE

|                                      |          |   |      |            |    |     |               |
|--------------------------------------|----------|---|------|------------|----|-----|---------------|
| SCLK Frequency                       | Fclk     |   | -    | -          | -  | 5.0 | MHz           |
| SCLK Clock Period                    | TpClk    | $V_{CC} = 5\text{ V}$<br>$V_{CC} = 3.3\text{ V}$                            | -    | 200<br>500 | -  | -   | ns            |
| SCLK High Time                       | TclkH    |   | 1    | 85         | -  | -   | ns            |
| SCLK Low Time                        | TclkL    |   | 2    | 85         | -  | -   | ns            |
| SCLK Setup Time                      | TclkSup  |   | 3, 4 | 85         | -  | -   | ns            |
| SI Setup Time                        | TsiSup   |   | 11   | 50         | -  | -   | ns            |
| SI Hold Time                         | TsiH     |   | 12   | 50         | -  | -   | ns            |
| CSB Setup Time                       | TcsbSup  |   | 5, 6 | 100        | -  | -   | ns            |
| CSB High Time                        | TcsbH    | (Note 4)  | 7    | 5.0        | -  | -   | $\mu\text{s}$ |
| SO enable after CSB falling edge     | TenSo    |   | 8    | -          | -  | 200 | ns            |
| SO disable after CSB rising edge     | TdisSo   |   | 9    | -          | -  | 200 | ns            |
| SO Rise/Fall Time                    | TsoR/F   | Clload = 40 pF (Note 3)   | -    | -          | 10 | 25  | ns            |
| SO Valid Time                        | TsoV     | Clload = 40 pF (Note 3)<br>SCLK $\uparrow$ to SO 50%                        | 10   | -          | 50 | 100 | ns            |
| EN Low Valid Time                    | TenL     | $V_{CC} = 5\text{ V}$ ; EN H $\rightarrow$ L 50% to<br>OUTx turning off 50% | -    | 10         | -  | -   | $\mu\text{s}$ |
| EN High to SPI Valid                 | TenHspIV |   | -    | -          | -  | 100 | $\mu\text{s}$ |
| SRR Delay Between Consecutive Frames | Tsrr     | (Note 5)  | -    | 150        | -  | -   | $\mu\text{s}$ |

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

3. Not production tested.

4. This is the minimum time the user must wait between SPI commands.

5. This is the minimum time the user must wait between consecutive SRR requests.

CHARACTERISTIC TIMING DIAGRAMS

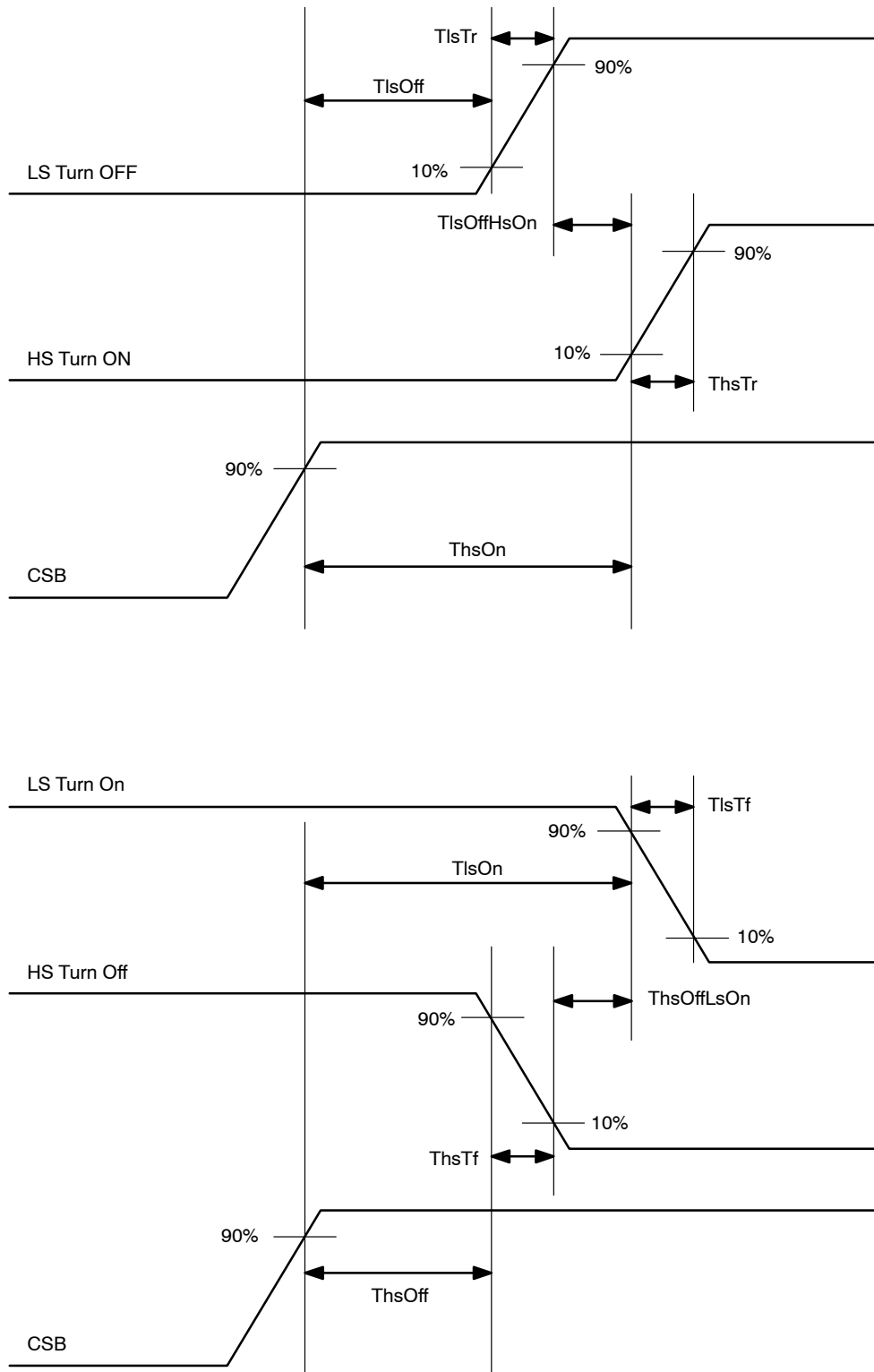


Figure 4. Detailed Driver Timing



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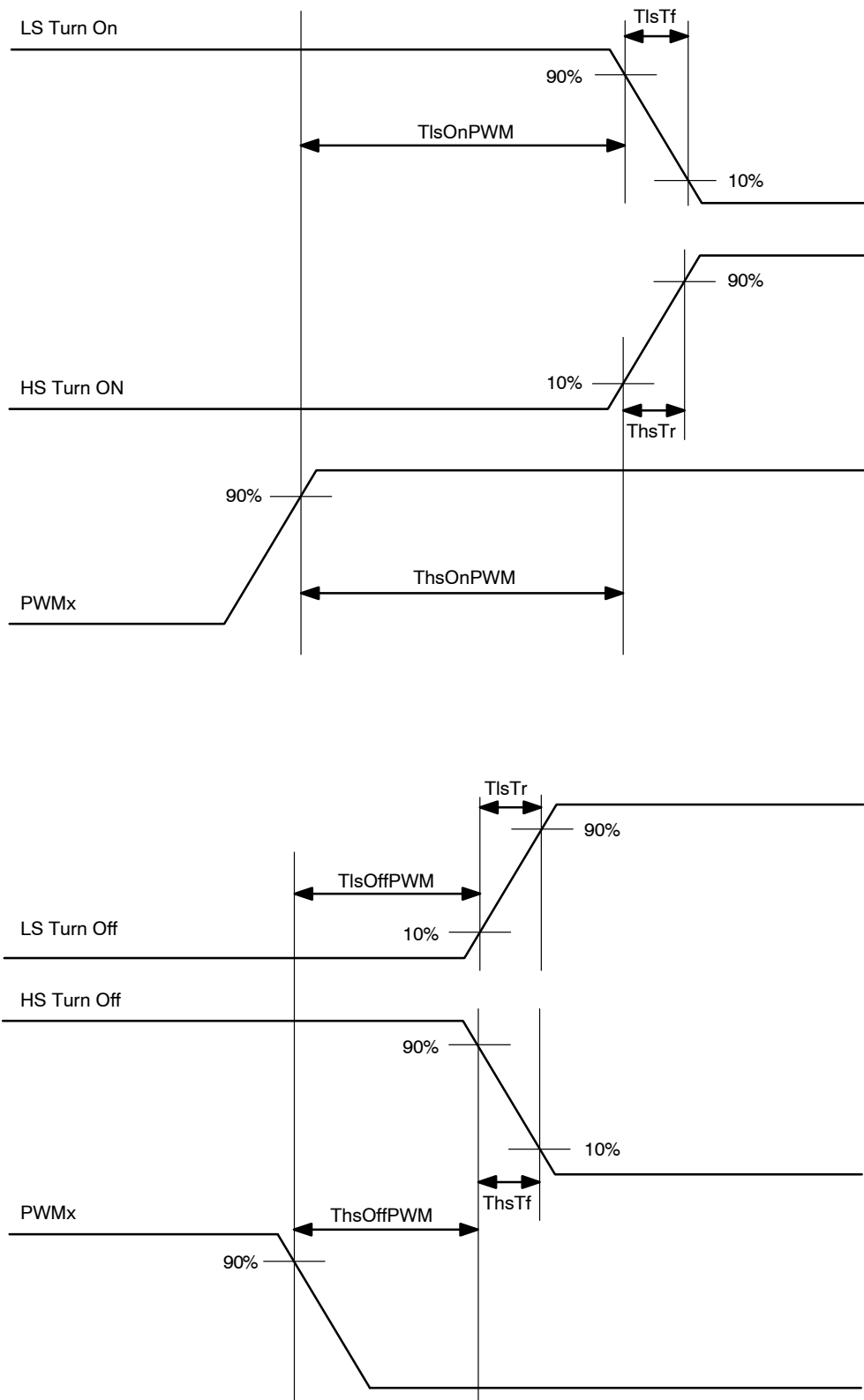


Figure 5. Detailed Driver Timing (OUT1 / OUT2 PWM)

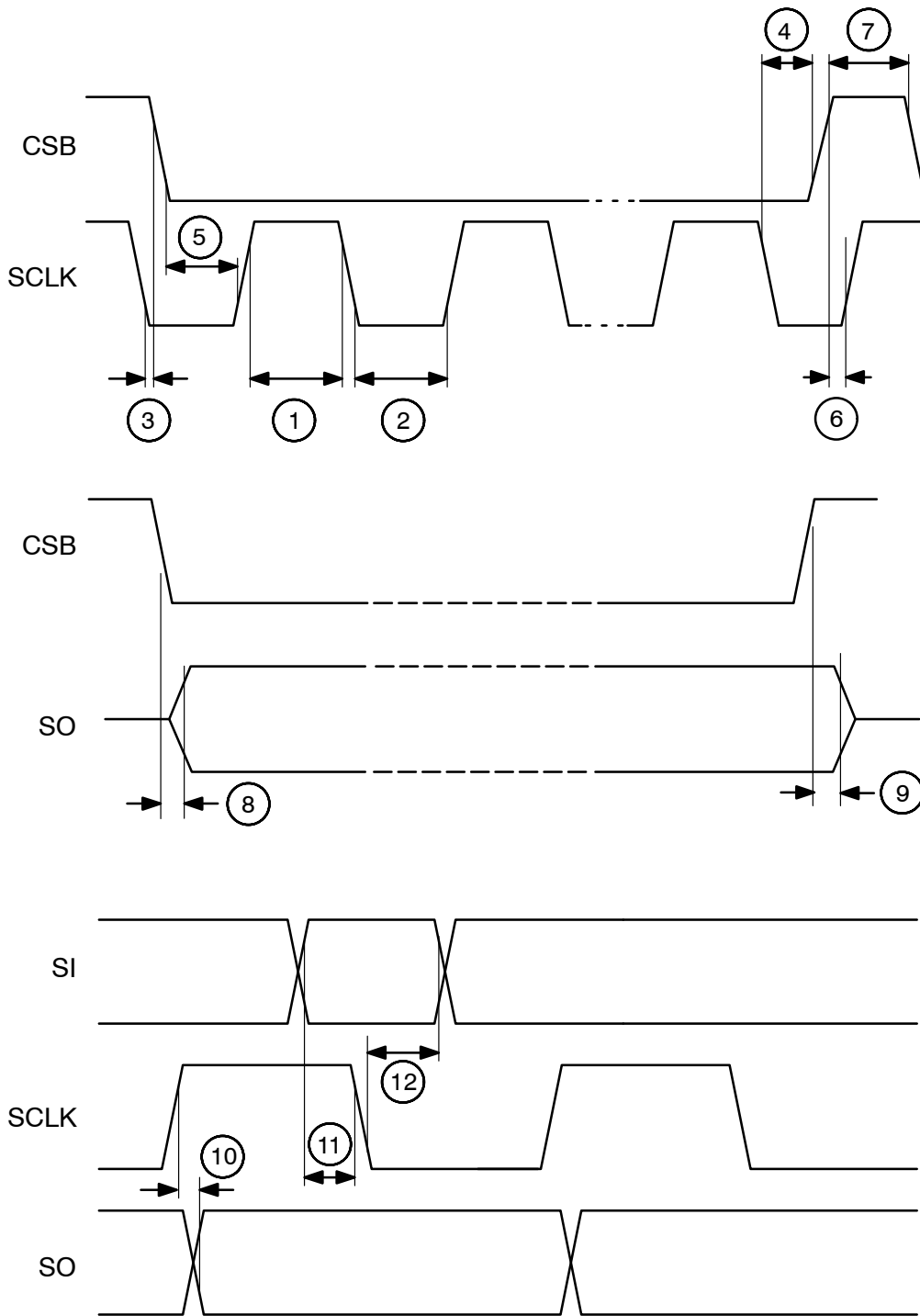


Figure 6. Detailed SPI Timing

TYPICAL PERFORMANCE GRAPHS

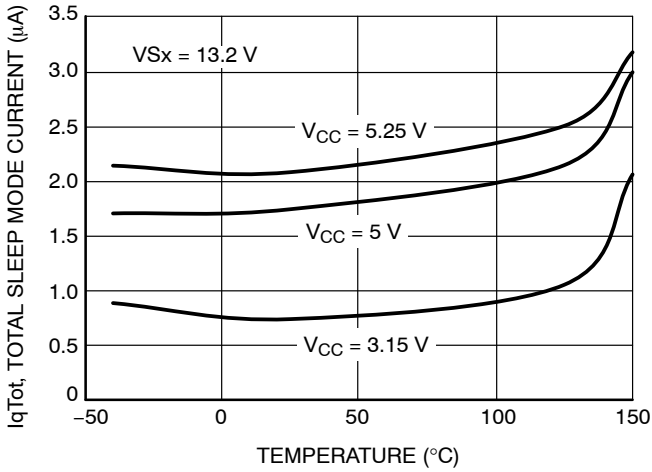


Figure 7.  $I_{qTot}$  vs. Temperature

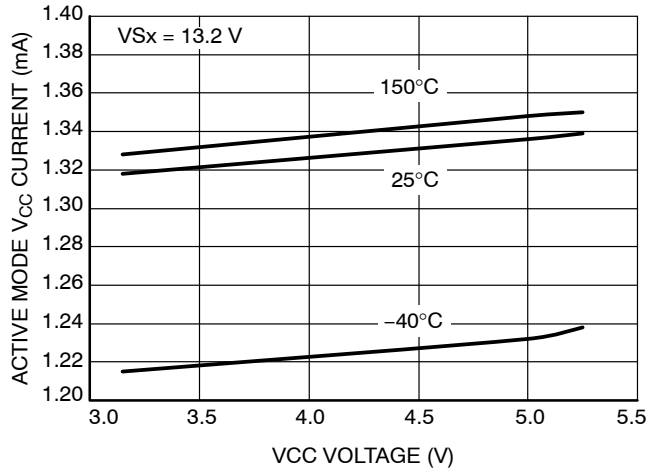


Figure 8.  $I(V_{CC})$  Active Mode vs.  $V(V_{CC})$

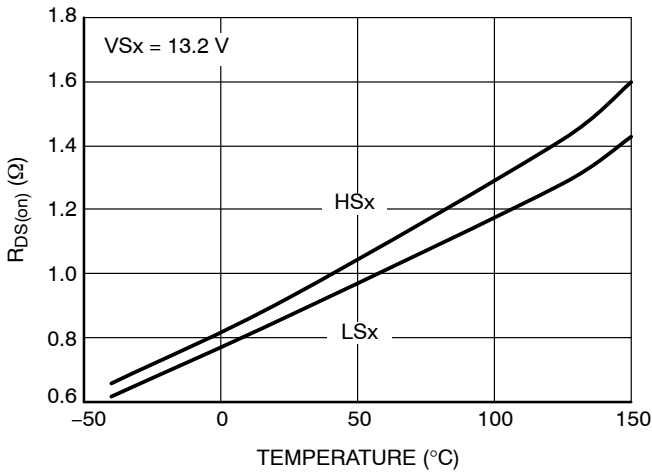


Figure 9.  $R_{DS(on)}$  vs. Temperature

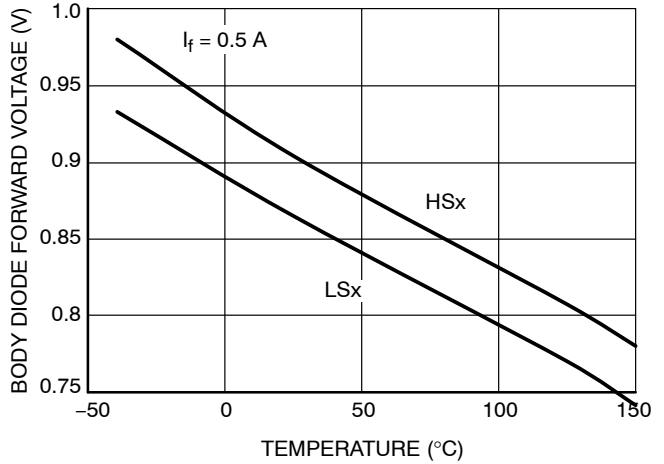


Figure 10. Body Diode vs. Temperature

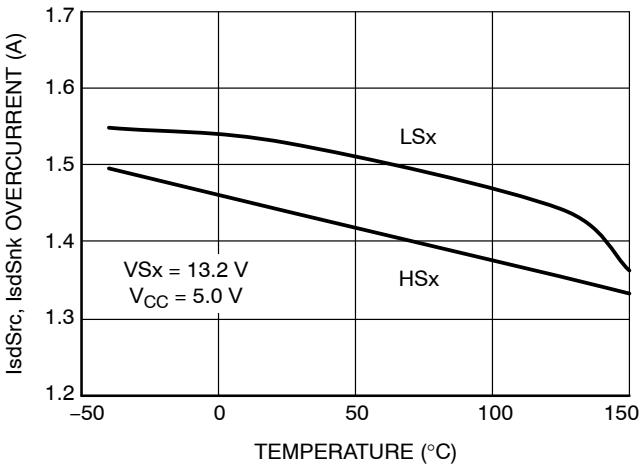


Figure 11. Overcurrent vs. Temperature

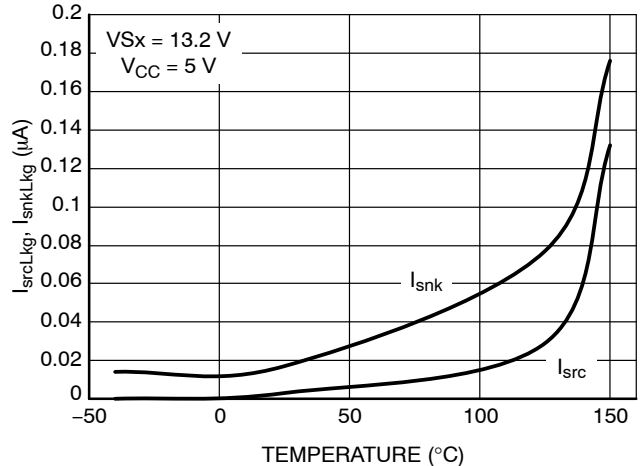


Figure 12. Leakage vs. Temperature

DETAILED OPERATING DESCRIPTION

General Overview

The NCV7723B is comprised of twelve NMOS power drivers. The drivers are arranged as six half-bridge output channels, allowing for three independent full-bridge configured loads. Output control and status reporting is handled via the SPI (Serial Peripheral Interface) communications port. OUT1 and OUT2 can be controlled with an external PWM signal.

Each output is characterized for a typical 0.5 A DC load and has a maximum 2.0 A surge capability (at  $V_{Sx} = 13.2\text{ V}$ ). Maximum allowable junction temperature is  $150^{\circ}\text{C}$  and may constrain the maximum load current and/or limit the number of drivers active at once.

An active-high enable function (EN) allows global control of the outputs and provides a low quiescent current sleep mode when the device is not being utilized. An internal pull-down resistor is provided on the input to ensure the device enters sleep mode if the input signal is lost.

After EN transitions from low to high, the  $V_{CC}$  POR cycle will proceed and bring the device into normal operation. The device configuration registers can then be programmed via SPI. Bringing EN low clears all registers (no configuration or status data is stored), disables the drivers, and enters sleep mode.

SPI Communication

16-bit full duplex SPI communication has been implemented for device configuration, driver control, and reading the status data. In addition to the 16-bit status data, a pseudo-bit (PRE\_15) can also be retrieved from the SO output.

The device must be enabled ( $EN = H$ ) for SPI communication. The SPI inputs are TTL compatible and the SO output high level is defined by the applied  $V_{CC}$ . The active-low CSB input has a pull-up resistor and the remaining inputs have pull-down resistors to bias them to known states when SPI communication is inactive.

The latched thermal shutdown (TSD) status bit PRE\_15 is available on SO until the first rising SCLK edge after CSB goes low. The following conditions must be met for a valid TSD read to be captured:

1. SCLK and SI are low before the CSB cycle;
2. CSB transitions from high to low;
3. CSB setup time ( $T_{csbSup}$ : Figure 6, #5) is satisfied.

Figure 13 shows the SPI communication frame format, and Tables 1 and 2 define the command input and diagnostic status output bits.

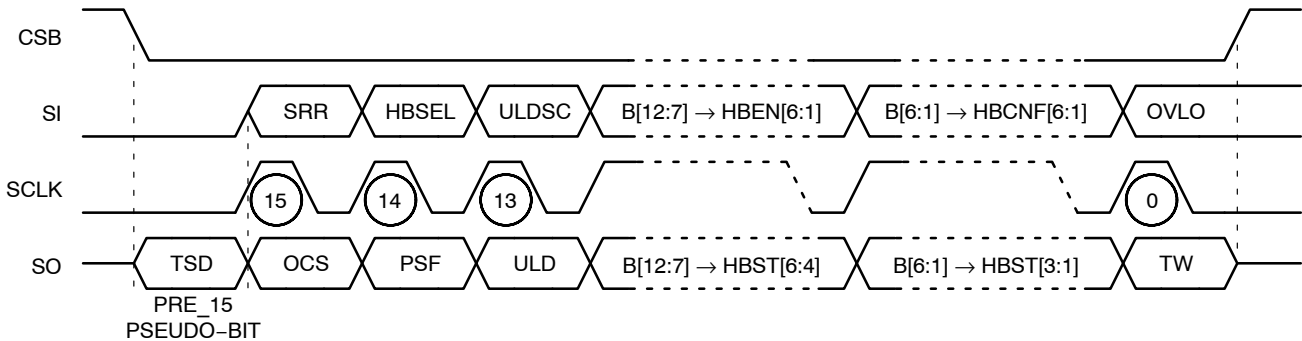


Figure 13. SPI Communication Frame Format

Communication is implemented as follows and is also illustrated in Figures 13 and 15:

1. SI and SCLK are set low before the CSB cycle.
2. CSB goes low to begin a serial data frame; pseudo-bit PRE\_15 is immediately available at SO.
3. SI data is shifted in on every rising edge of SCLK, starting with the most significant bit (MSB), SRR.
4. SI data is recognized on every falling edge of the SCLK.
5. Current SO data is simultaneously shifted out on every rising edge of SCLK, starting with the MSB (OCS).
6. CSB goes high to end the frame and SO becomes tri-state.
7. The last 16 bits clocked into SI are transferred to the device's data register if no frame error is detected, otherwise the entire frame is ignored and the previous input data is preserved.

# NCV7723B

**Table 1. SPI COMMAND INPUT DEFINITIONS**

| Channels 6 – 1 |          |                            |  |                           |
|----------------|----------|----------------------------|--|---------------------------|
| Bit#           | Name     | Function                   | Status*                                | Scope                     |
| 15             | SRR      | Status Register Reset**    | 1 = Reset                              | Global Status Reset       |
| 14             | HBSEL*** | Half Bridge Selection      | Reserved                               | –                         |
| 13             | ULDSC    | Underload Shutdown Control | 1 = Enabled                            | Per Half-Bridge Operation |
| 12             | HBEN6    | Enable Half-Bridge 6       | 0 = Hi-Z<br>1 = Enabled                | Per Half-Bridge           |
| 11             | HBEN5    | Enable Half-Bridge 5       |  |                           |
| 10             | HBEN4    | Enable Half-Bridge 4       |  |                           |
| 9              | HBEN3    | Enable Half-Bridge 3       |  |                           |
| 8              | HBEN2    | Enable Half-Bridge 2       |  |                           |
| 7              | HBEN1    | Enable Half-Bridge 1       |  |                           |
| 6              | HBCNF6   | Configure Half-Bridge 6    | 0 = LS On, HS Off<br>1 = LS Off, HS On | Per Half-Bridge           |
| 5              | HBCNF5   | Configure Half-Bridge 5    |  |                           |
| 4              | HBCNF4   | Configure Half-Bridge 4    |  |                           |
| 3              | HBCNF3   | Configure Half-Bridge 3    |  |                           |
| 2              | HBCNF2   | Configure Half-Bridge 2    |  |                           |
| 1              | HBCNF1   | Configure Half-Bridge 1    |  |                           |
| 0              | OVLO     | VSx Overvoltage Lockout    | 1 = Enabled                            | Global Lockout            |

\*All command input bits are set to 0 at V<sub>CC</sub> power-on reset.

\*\*Latched faults are cleared and outputs can be re-programmed if no fault exists after SRR asserted.

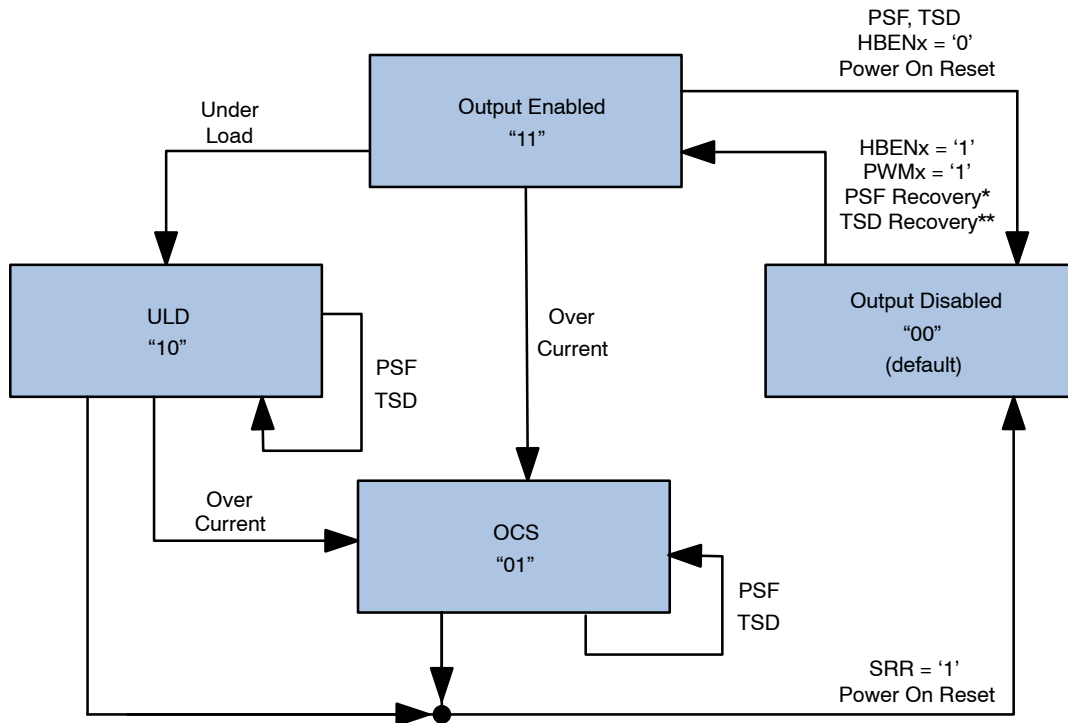
\*\*\*HBSEL enables channel group selection for family devices with more than 6 channels. In the NCV7723B it is recommended to set the HBSEL bit to 0.

Table 2. SPI STATUS OUTPUT DEFINITIONS

| Channels 6 – 1 |            |  |   |  |
|----------------|------------|--|---|--|
| Bit#           | Name       | Function                                   | Status*   | Scope  |
| PRE_15         | TSD        | Latched Thermal Shutdown                   | 1 = Fault   | Global Notification; Per Half-Bridge Operation |
| 15             | OCS        | Latched Overcurrent Shutdown               | 1 = Fault   | Global Notification; Per Half-Bridge Operation |
| 14             | PSF        | VS1 and/or VS2 Undervoltage or Overvoltage | 1 = Fault   | Global Notification; Global Operation          |
| 13             | ULD        | Underload Detect                           | 1 = Fault   | Global Notification; Per Half-Bridge Operation |
| 12             | HBST6[1:0] | Half Bridge 6 Output Status                | 0x00b – Output Disabled<br>0x01b – OCS<br>0x10b – ULD<br>0x11b – Output Enabled | Per Half-Bridge                                |
| 11             |            |  |   |  |
| 10             | HBST5[1:0] | Half Bridge 5 Output Status                |   |  |
| 9              |            |  |   |  |
| 8              | HBST4[1:0] | Half Bridge 4 Output Status                |   |  |
| 7              |            |  |   |  |
| 6              | HBST3[1:0] | Half Bridge 3 Output Status                |   |  |
| 5              |            |  |   |  |
| 4              | HBST2[1:0] | Half Bridge 2 Output Status                |   |  |
| 3              |            |  |   |  |
| 2              | HBST1[1:0] | Half Bridge 1 Output Status                |   |  |
| 1              |            |  |   |  |
| 0              | TW         | Thermal Warning                            | 1 = Fault   | Global Notification; Per Half-Bridge Operation |

\*All status output bits are set to 0 at Vcc power-on reset (POR).

HBSTx[1:0] bits are priority encoded to provide the status information of each of the half-bridge outputs. Figure 14 shows the priority encoding state diagram for the HBSTx[1:0] bits.



\*PSF Recovery: VSx rising above the undervoltage threshold or falling below the overvoltage threshold (OVLO = 1)

\*\*TSD Recovery: Sending SRR after junction temperature has fallen below the thermal shutdown threshold

Figure 14. SO HBSTx [1:0] Priority Encoding State Diagram

**Priority Encoding**

If an under load event precedes an over current event on the same half-bridge, the device will report HBSTx = ‘10’ and then HBSTx = ‘01’ as shown in Figure 14. An over current event preceding an under load event will report HBSTx = ‘01’ since there is no direct path from the OCS state to the ULD state. Thus an over current shutdown fault must be cleared before an underload fault is reported on the same half-bridge.

**Frame Error Detection**

The NCV7723B employs frame error detection to help ensure input data integrity. SCLK is compared to an  $n \times 8$  bit counter and a valid frame (CSB H-L-H cycle) has integer multiples of 8 SCLK cycles. For the first 16 bits shifted into SI, SCLK is compared to a modulo16 counter ( $n = 2$ ), and SCLK is compared to a modulo 8 counter ( $n = 1, 2, \dots, m$ ) thereafter. This variable modulus allows for daisy chain operation with devices using different word lengths.

The last 16 bits clocked into SI are transferred to the NCV7723B’s data register if no frame error is detected, otherwise the entire frame is ignored and the previous input data is preserved.

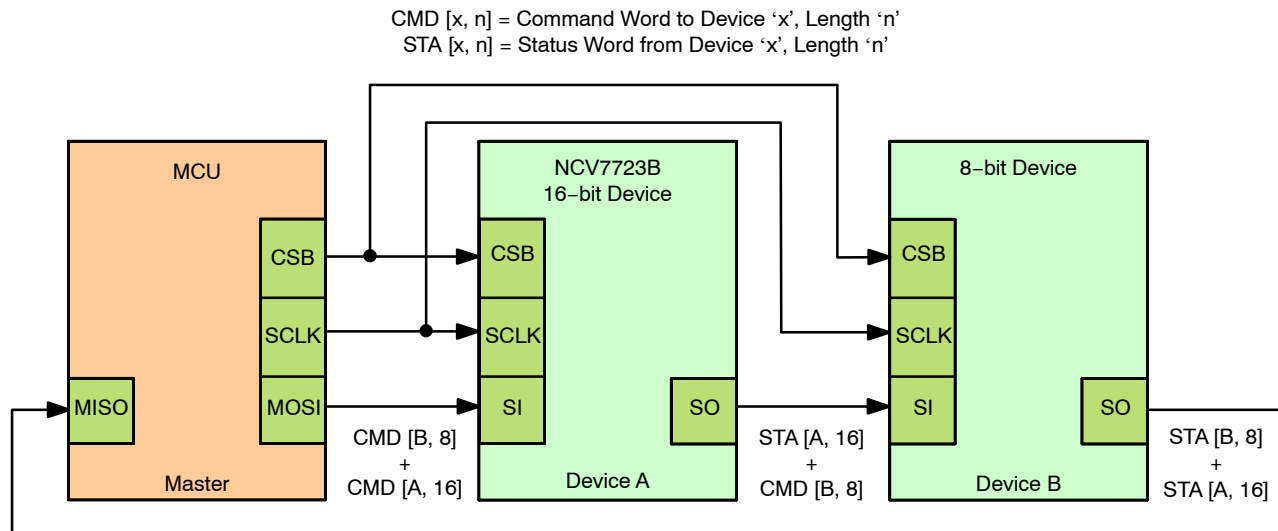
**Daisy Chain Operation**

Daisy chain operation is possible with multiple 16-bit and 8-bit devices that have a compatible SPI protocol. The clock phase and clock polarity with respect to the data for all the devices in the chain must be the same as the NCV7723B.

CSB and SCLK are parallel connected to every device in the chain while SO and SI are series connected between each device. The master’s MOSI is connected to the SI of the first device and the first device’s SO is connected to the next device’s SI. The SO of the final device in the chain is connected to the master’s MISO.

The hardware configuration for the NCV7723B daisy chained with an 8-bit SPI device is shown in Figure 15. A 24-bit frame made of 16-bit word ‘A’ and 8-bit word ‘B’ is sent from the master. Command word B is sent first followed by word A. The master simultaneously receives status word B first followed by word A. The progression of data from the MCU through the sequential devices is illustrated in Figure 15.

Compliance with the illustrated frame format is required for proper daisy chain operation. Situations should be avoided where an incorrect multiple of 8 bits is sent to the devices, but the frame length does not cause a frame error in the devices. For example, the word order could be inadvertently interleaved or reversed. Invalid data is accepted by the NCV7723B in such scenarios and possibly by other devices in the chain, depending on their frame error implementation. Data is received as a command by the device at the beginning of the chain, but the device at the end of the chain may receive status data from the preceding device as a command.



**Figure 15. Daisy Chain Configuration**





# NCV7723B

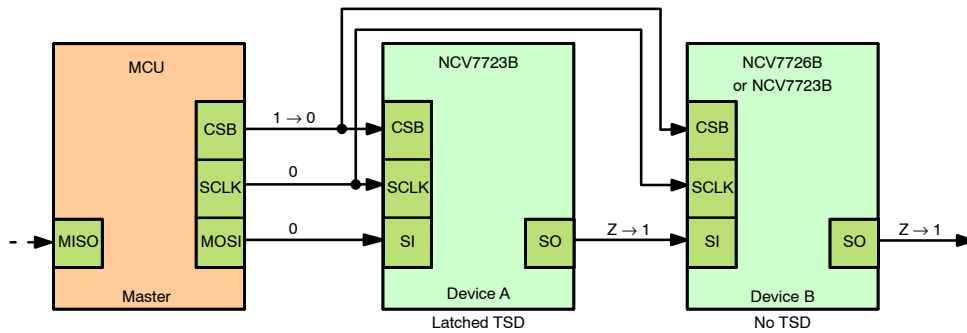


Figure 19. Daisy Chain With TSD Fault

## Power Up/Down Control

The  $V_{CC}$  supply input powers the device's logic core. A  $V_{CC}$  power-on reset (POR) function provides controlled power-up/down.  $V_{CC}$  POR initializes the command input and status output registers to their default states (0x00), and ensures that the bridge output and SO drivers maintain Hi-Z as power is applied. SPI communication and normal device operation can proceed once  $V_{CC}$  rises above the POR threshold and EN remains high.

The VS1 and VS2 supply inputs power their respective output drivers (refer to Figure 2 and the PIN FUNCTION DESCRIPTION). The VSx inputs are monitored to ensure that the supply stays within the recommended operating range. If the VSx supply moves into either of the VS undervoltage or overvoltage regions, the output drivers are switched to Hi-Z but command and status data is preserved. Output drivers will remain on if OVLO = 0 during an overvoltage condition.

## Driver Control

The NCV7723B has the flexibility to control each half-bridge driver channel via SPI. Actual driver output state is determined by the command input and the current fault status bits.

High-side (HSx) and low-side (LSx) drivers of the same channel cannot be active at the same time, and non-overlap delays are imposed when switching between HSx and LSx drivers in the same channel, preventing current shoot-through.

After the device has powered up and the drivers are allowed to turn on, the drivers remain on until commanded off via SPI or until a fault condition occurs.

## PWM Control

Outputs 1 and 2 can be controlled in two ways: through normal SPI control (see Table 1) or from an external PWM signal. OUT1 can be turned on/off using the HBEN1 bit or

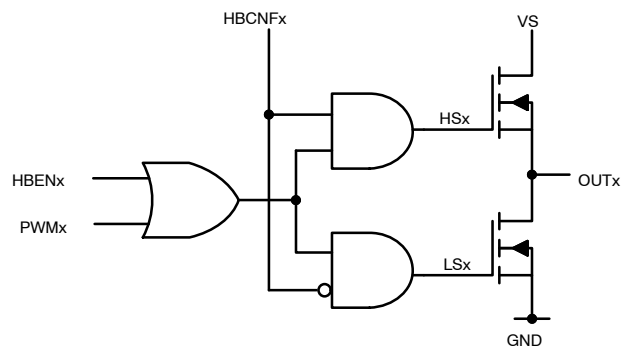
applying a logic level signal to pin 17 (PWM1). OUT2 can be turned on/off using the HBEN2 bit or applying a logic level signal to pin 18 (PWM2). Simplified logic functions are shown below in Figure 20.

### PWM Example: Turn on OUT1 High Side

To use OUT1 High Side with external PWM control, perform the following steps:

- Send command 0b0000000000000010 (0x0002)
  - Configures OUT1 to High Side (HBCNF1)
  - Disables OUT1 SPI Enable (HBEN1)
- Apply logic level PWM signal to PWM1

To use OUT1 Low Side with external PWM, set the HBCNF1 bit to 0 during step 1.



| PWMx | HBENx | HBCNFx | HSx | LSx | OUTx |
|------|-------|--------|-----|-----|------|
| 0    | 0     | x      | OFF | OFF | Z    |
| x    | 1     | 0      | OFF | ON  | Low  |
| x    | 1     | 1      | ON  | OFF | High |
| 1    | x     | 0      | OFF | ON  | Low  |
| 1    | x     | 1      | ON  | OFF | High |

Figure 20. PWM Control Logic

DIAGNOSTICS, PROTECTIONS, STATUS REPORTING AND RESET

Overview

The NCV7723B employs diagnostics designed to prevent destructive overstress during a fault condition. Diagnostics are classified as either supervisory or protection functions (Table 3). Supervisory functions provide status information about device conditions. Protection functions provide status information and activate fault management behaviors. Diagnostics resulting in output shutdown and latched status may depend on a qualifier and may require user intervention for output recovery and status memory clear. Diagnostics resulting in output lockout and non-latched status (VSOV or VSUV) may recover and clear automatically. Output configurations can be changed during output lockout. Outputs assume the new configurations or resume the previous configurations when an auto-recover fault is

resolved. Table 4 shows output states during faults and output recovery modes, and Table 5 shows the status memory and memory clear modes.

Table 3. DIAGNOSTIC CLASSES AND FUNCTIONS

| Name       | Class       | Function                             |
|------------|-------------|--------------------------------------|
| TSD        | Protection  | Thermal Shutdown                     |
| OCS        | Protection  | Overcurrent Shutdown                 |
| PSF        | Protection  | Under/overvoltage Lockout (OVLO = 1) |
| ULD        | Protection  | Underload Shutdown                   |
| HBSTx[1:0] | Supervisory | Half-Bridge X Output Status          |
| TW         | Supervisory | Thermal Warning                      |

Table 4. OUTPUT STATE VS. FAULT AND OUTPUT RECOVERY

| Fault      | Qualifier | OUTx State                              | OUTx Recovery | OUTx Recovery Scope |
|------------|-----------|---|---------------|---------------------|
| TSD        | -         | → Z                                     | Send SRR      | All Outputs         |
| OCS        | -         | → Z                                     | Send SRR      | All Outputs         |
| PSF – VSOV | OVLO = 1  | → Z → Y <sub>n</sub>   Y <sub>n+1</sub> | Auto*         | All Outputs         |
|            | OVLO = 0  | Unaffected                              | -             | -                   |
| PSF – VSUV | -         | → Z → Y <sub>n</sub>   Y <sub>n+1</sub> | Auto*         | All Outputs         |
| ULD        | ULDSC = 1 | → Z                                     | Send SRR      | All Outputs         |
|            | ULDSC = 0 | Unaffected                              | -             | -                   |
| TW         | -         | Unaffected                              | -             | -                   |

\*OUTx returns to its previous state (Y<sub>n</sub>) or new state (Y<sub>n+1</sub>) if fault is removed.

Table 5. STATUS MEMORY VS. FAULT AND MEMORY CLEAR

| Fault      | Qualifier | Status Memory | Memory Clear | Memory Clear Scope |
|------------|-----------|---------------|--------------|--------------------|
| TSD        | -         | Latched       | Send SRR     | Global             |
| OCS        | -         | Latched       | Send SRR     | Global             |
| PSF – VSOV | OVLO = X  | Non-Latched   | Auto*        | Global             |
| PSF – VSUV | -         | Non-Latched   | Auto*        | Global             |
| ULD        | ULDSC = X | Latched       | Send SRR     | Global             |
| TW         | -         | Non-Latched   | Auto*        | Global             |

\*Status memory returns to its no-fault state if fault is removed.

Status Information Retrieval

Current status information is retrieved during each SPI frame. To preserve device configuration and output states, the previous SI data pattern must be sent during the status retrieval frame.

Status information is prevented from being updated during a SPI frame but new status becomes available after CSB goes high at the end of the frame provided the frame did not contain an SRR request. Status information includes both global and per channel fault notification. To determine the channel(s) affected after detecting a global fault, examine driver output status and input configuration.

Status Register Reset – SRR

Sending SRR = 1 clears status memory and re-activates faulted outputs for all channels. The previous SI data pattern must be sent with SRR to preserve device configuration and output states.

At the rising edge of CSB, the SRR function is activated and an internal timer (T<sub>srr</sub>) is started. T<sub>srr</sub> is the minimum time the user must wait between consecutive SRR requests. If a fault is still present when SRR is sent, protection will be re-engaged and shutdown will recur. The status registers can also be reset by toggling the EN pin or by VCC power-on reset.

**Diagnostics Details**

The following sections describe individual diagnostics and behaviors. In each description and illustration, a SPI frame is assumed to always be valid and the SI data pattern sent for HBCNFx and HBENx is the same as the previous frame. Actual results can depend on asynchronous fault events and SPI clock frequency and frame rate.

**Undervoltage Lockout**

*Global Notification, Global Operation*

Undervoltage detection and lockout control is provided by monitoring the VS1, VS2 and VCC supply inputs. Undervoltage hysteresis is provided to ensure clean

detection transitions. Undervoltage timing is shown in Figure 21.

Undervoltage at either VSx input turns off all outputs and sets the power supply fail (PSF) status bit. The outputs return to their previously programmed state and the PSF status bit is cleared when VSx rises above the hysteresis voltage level. SPI communication is available and programmed output enable and configuration states are maintained if proper VCC is present during VSx undervoltage. Output enable and configuration states can also be programmed during VSx undervoltage if proper VCC is present, and state changes will take effect as VSx rises above the undervoltage threshold level.

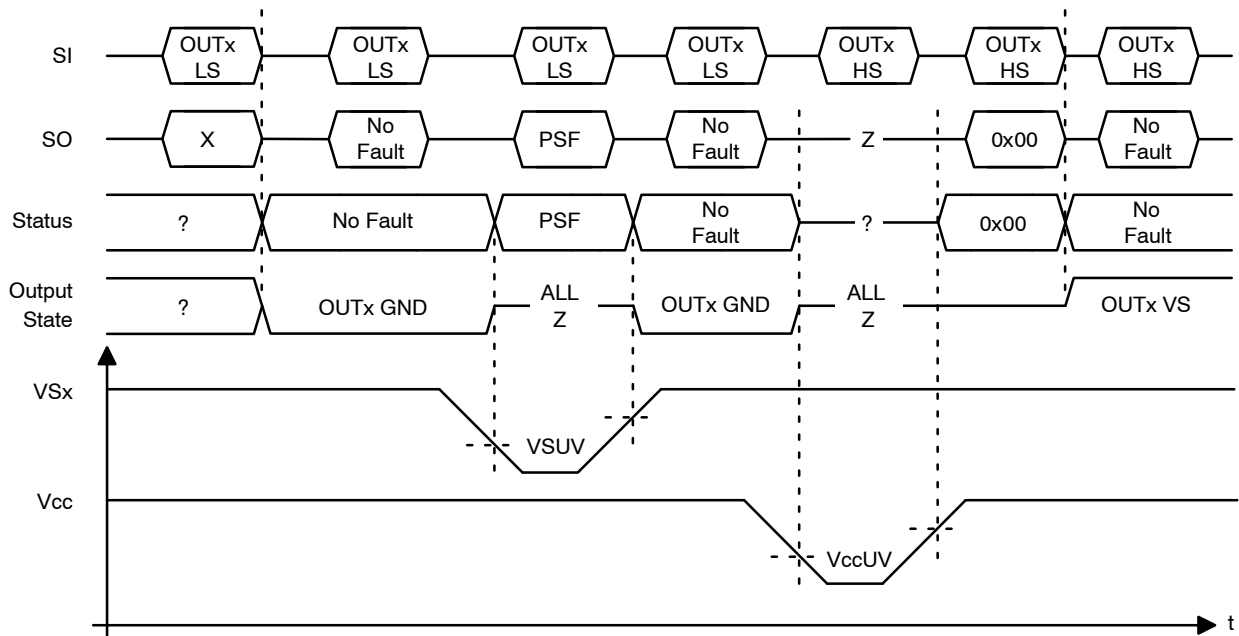


Figure 21. Undervoltage Timing

**Overvoltage Lockout**

*Global Notification, Global Operation*

Overvoltage detection and lockout control is provided by monitoring the VS1 and VS2 supply inputs. Hysteresis is provided to ensure clean detection transitions. Overvoltage timing is shown in Figure 22. Overvoltage at either VSx input turns off all outputs if the overvoltage lockout input bit is set (OVLO = 1) and sets the power supply fail (PSF) status bit (see Tables 4 and 5). The outputs return to their previously programmed state and the PSF status bit is cleared when VSx falls below the hysteresis voltage level.

Output enable and configuration states can also be programmed during an overvoltage lockout event but will not change state until VSx falls below the overvoltage threshold level.

NOTE: to reduce stress, it is recommended to operate the device with OVLO bit asserted to ensure that the drivers turn off during a load dump scenario. If OVLO = 0 during an overvoltage condition, outputs will remain on and the PSF status bit will be set.

# NCV7723B

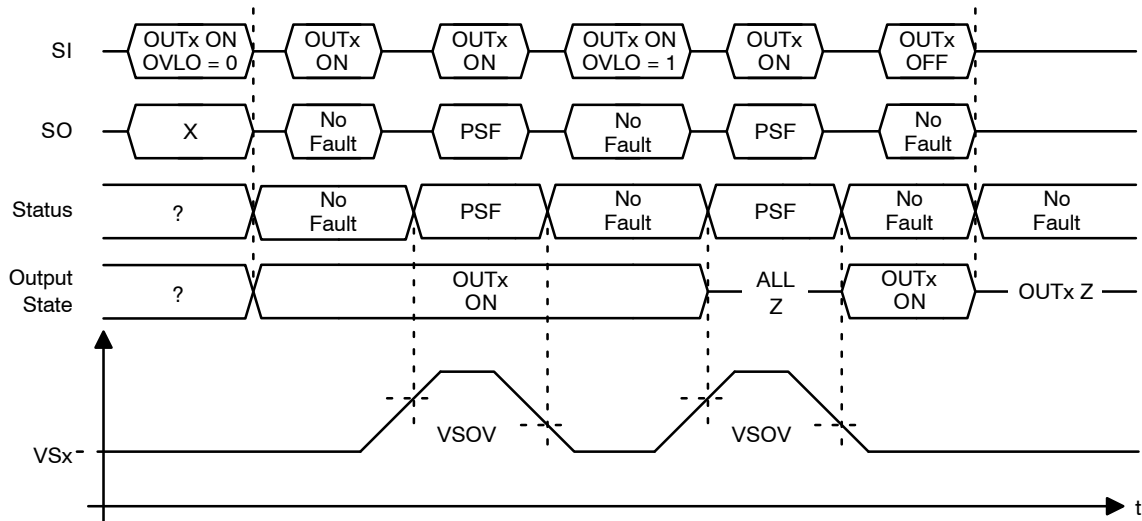


Figure 22. Overvoltage Timing

## Overcurrent Shutdown

### Global and per Channel Notification

#### Per Half-Bridge Operation

Overcurrent detection and shutdown control is provided by monitoring each HS and LS driver. Overcurrent timing is shown in Figure 23. Overcurrent in either driver starts a channel's overcurrent delay timer ( $T_{dOc}$ ). If overcurrent exists after the delay, both drivers are latched off and the

global overcurrent (OCS) status bit is set. The channel's corresponding  $HBSTx[1:0]$  bits are also set to "01" to indicate an OCS fault. Note that OCS fault reporting has priority over other faults as shown in Figure 14. The global OCS bit and individual channel bits are cleared and channels are re-activated by sending  $SRR = 1$ .

A persistent overcurrent cause should be resolved prior to re-activation to avoid repetitive stress on the drivers.

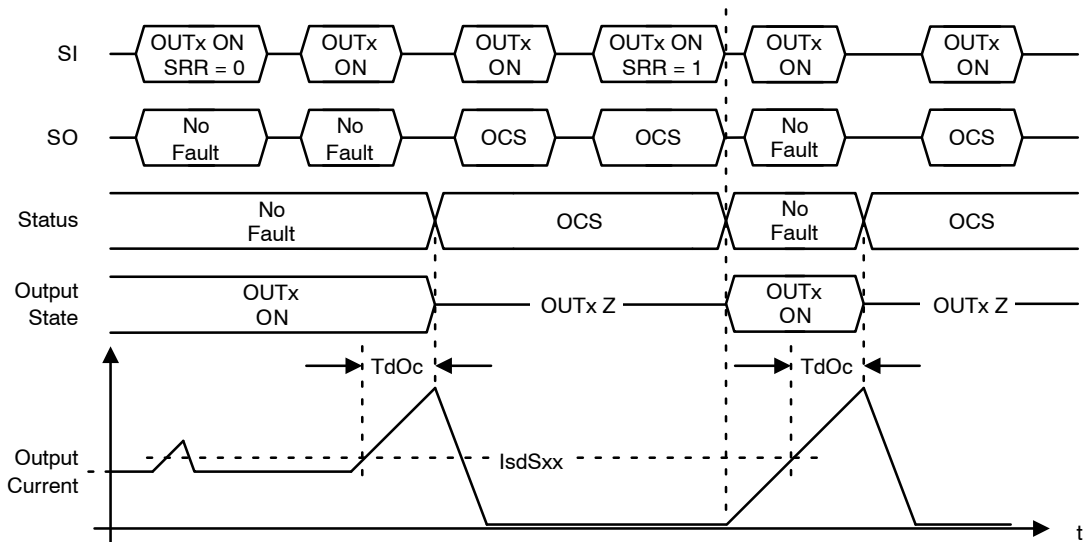


Figure 23. Overcurrent Timing

**Underload Shutdown**

*Global and per Channel Notification*

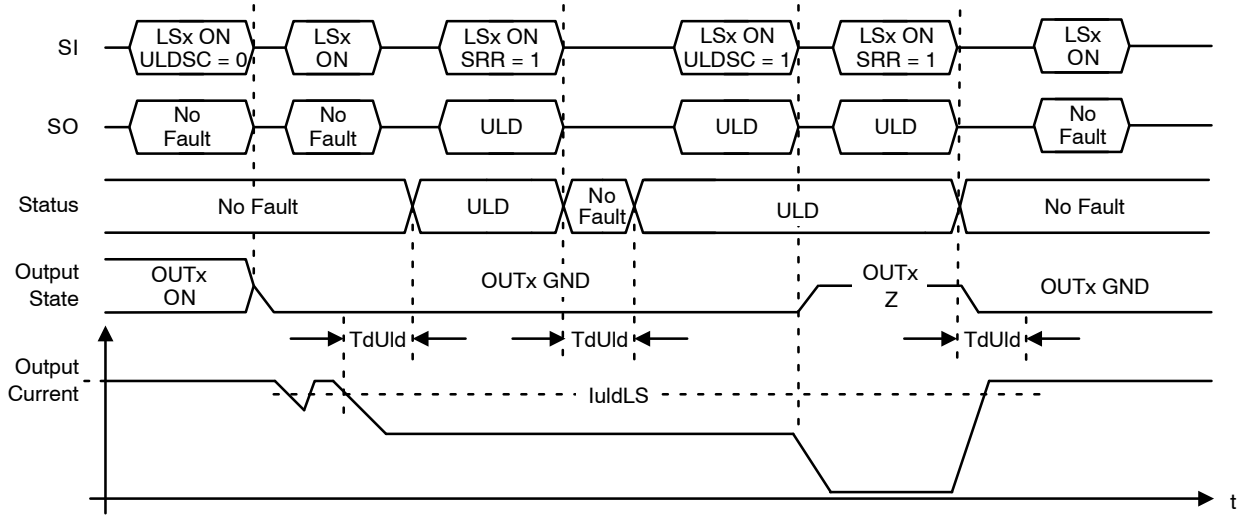
*Global Shutdown Control, Per Half-Bridge Operation*

Underload detection and shutdown control is provided by monitoring each half bridge driver. Underload timing is shown in Figure 24. Underload at any driver starts the global underload delay timer. If underload occurs in another channel after the global timer has been started, the delay for any subsequent underload will be the remainder of the timer.

If underload exists after the global delay timer and if the underload shutdown (ULDSC) command bit is set, both HS and LS drivers are latched off and the global underload

(ULD) status bit is set along with the corresponding per channel status bits HBSTx[1:0] set to “10”. Drivers will remain on if the ULDSC input bit is 0 (see Table 4 and 5). The global ULD bit and per channel HBSTx bits are cleared and channels are re-activated by sending SRR = 1.

NOTE: underload may result from a fault (e.g. open-load) condition or normal circuit behavior (e.g. L/R tau). In motor applications it is often desirable to actively brake the motor by turning on both HS or LS drivers in two half-bridge channels which may result in an underload condition as current decays.



**Figure 24. Underload Timing**

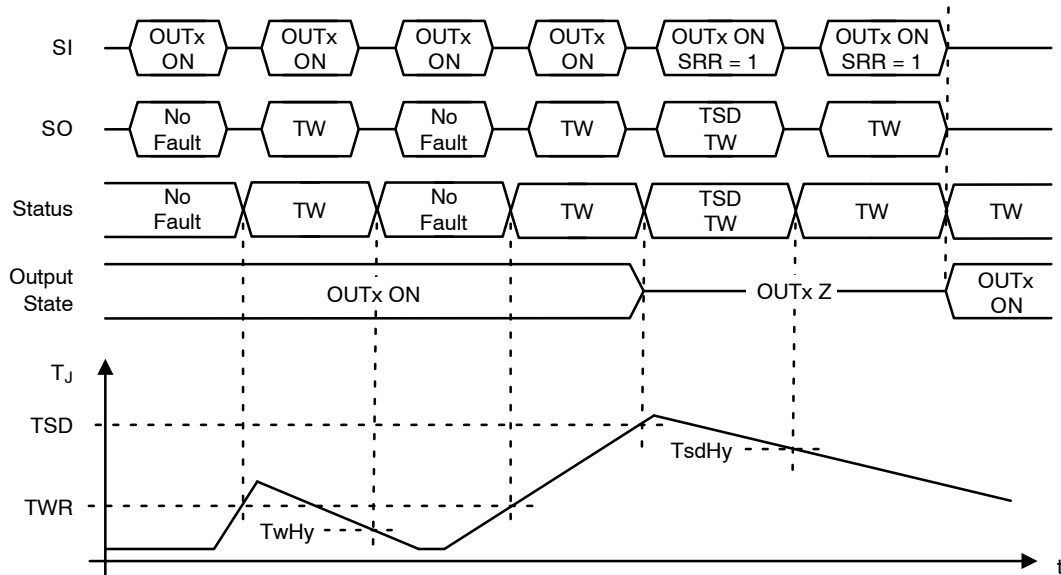
**Thermal Warning and Thermal Shutdown**

*Global Notification, Per Half-Bridge Operation*

Thermal warning (TW) and thermal shutdown (TSD) detection and control are provided for each half-bridge by monitoring the driver pair’s thermal sensor. Thermal hysteresis is provided for each of the warning and shutdown functions to ensure clean detection transitions. Software polling of the TW bit allows for avoidance of thermal shutdown since TW notification precedes TSD notification. Thermal warning and shutdown timing is shown in Figure 25.

The TW status bit is set when a half-bridge’s sensor temperature exceeds the warning level ( $T_J > T_{wr}$ ), and the bit is automatically cleared when sensor temperature falls below the warning hysteresis level ( $T_J < T_{wHy}$ ). A channel’s output state is unaffected by TW.

When sensor temperature exceeds the shutdown level ( $T_J > T_{sd}$ ), the channel’s HS and LS drivers are latched off, the TW bit is/remains set, and the TSD (PRE\_15) bit is set. The TSD bit is cleared and all affected channels are re-activated ( $T_J < T_{sdHy}$ ) by sending SRR = 1.



**Figure 25. Thermal Warning and Shutdown Timing**

The latched thermal shutdown (TSD) information is available on SO after CSB transitions from high to low and before the first rising SCLK edge. The following procedures must be met for a true TSD reading:

1. SCLK and SI are low before the CSB cycle. Violating these conditions will result in an

undetermined SPI behavior or/and an incorrect TSD reading.

2. CSB transitioning from high to low.
3. CSB setup time ( $T_{csbSup}$ ) is satisfied and the data is captured before the first SCLK rising edge.

# NCV7723B

## THERMAL PERFORMANCE ESTIMATES

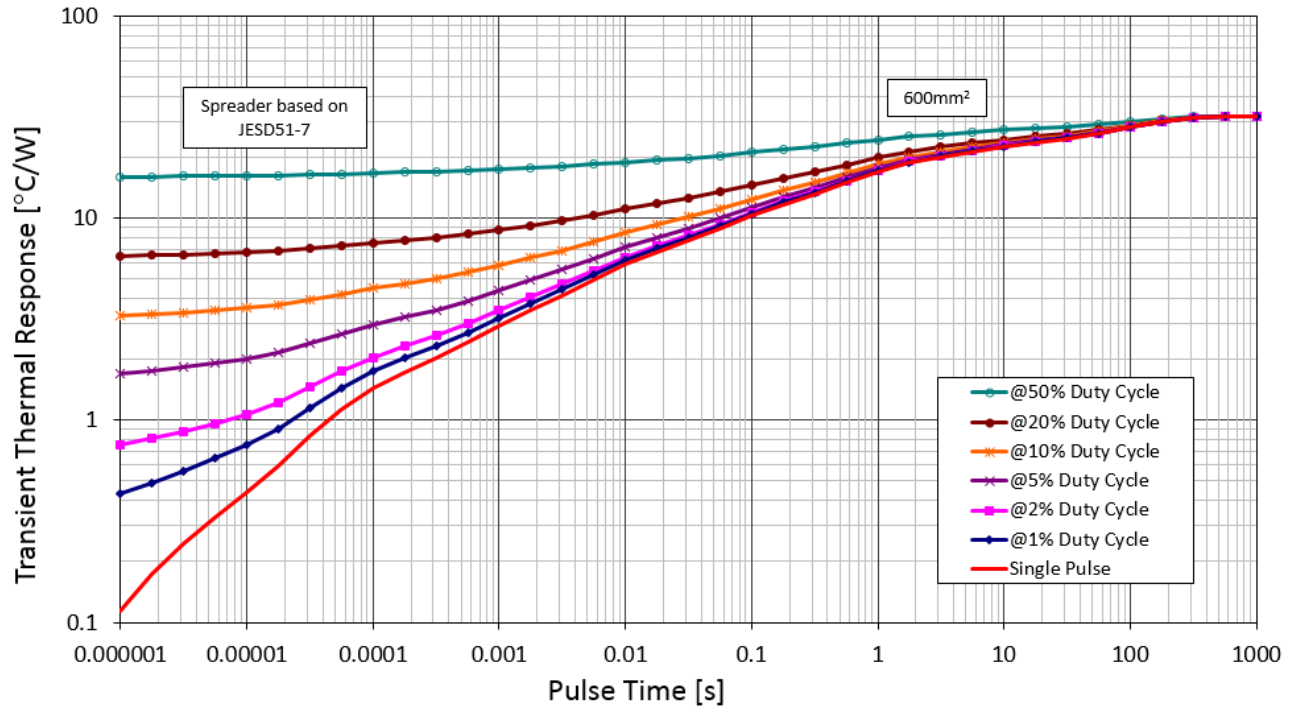


Figure 26. Transient R(t) vs. Pulse Time for 2 oz Spreader

### ORDERING INFORMATION

| Device        | Package                   | Shipping <sup>†</sup> |
|---------------|---------------------------|-----------------------|
| NCV7723DQBR2G | SSOP24 NB EP<br>(Pb-Free) | 2500 / Tape & Reel    |

<sup>†</sup>For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.

# MECHANICAL CASE OUTLINE PACKAGE DIMENSIONS

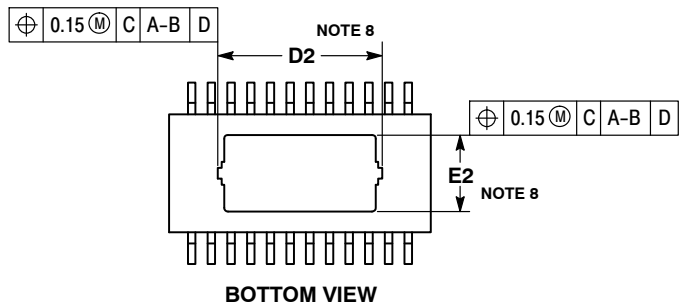
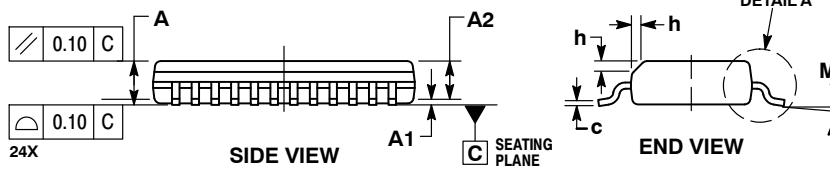
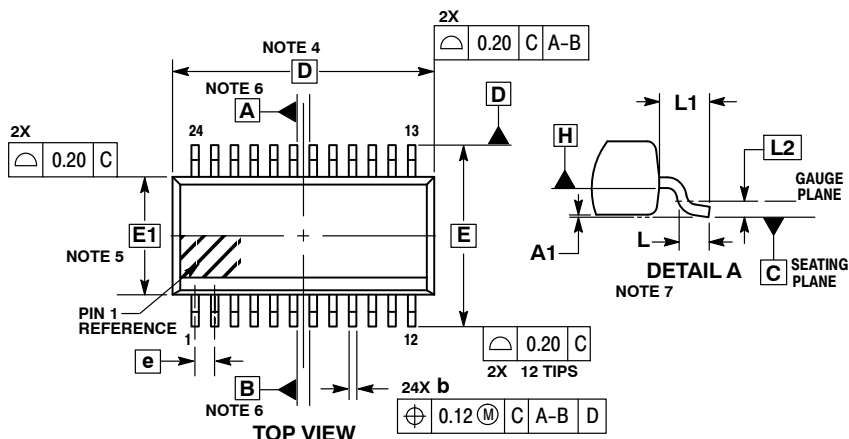
ON Semiconductor®



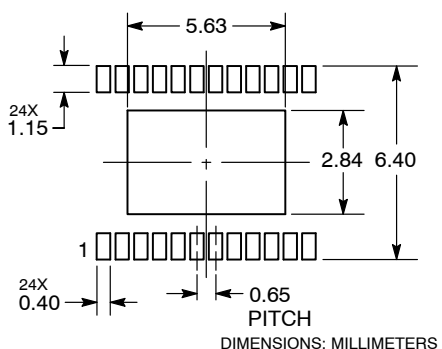
SCALE 1:1

SSOP24 NB EP  
CASE 940AK  
ISSUE O

DATE 24 APR 2012



### RECOMMENDED SOLDERING FOOTPRINT



- NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
  2. CONTROLLING DIMENSION: MILLIMETERS.
  3. DIMENSION b DOES NOT INCLUDE DAMBAR PROTRUSION. DAMBAR PROTRUSION SHALL BE 0.10 MAX. AT MMC. DAMBAR CANNOT BE LOCATED ON THE LOWER RADIUS OF THE FOOT. DIMENSION b APPLIES TO THE FLAT SECTION OF THE LEAD BETWEEN 0.10 TO 0.25 FROM THE LEAD TIP.
  4. DIMENSION D DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS. MOLD FLASH, PROTRUSIONS OR GATE BURRS SHALL NOT EXCEED 0.15 PER SIDE. DIMENSION D IS DETERMINED AT DATUM PLANE H.
  5. DIMENSION E1 DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSION. INTERLEAD FLASH OR PROTRUSION SHALL NOT EXCEED 0.25 PER SIDE. DIMENSION E1 IS DETERMINED AT DATUM PLANE H.
  6. DATUMS A AND B ARE DETERMINED AT DATUM PLANE H.
  7. A1 IS DEFINED AS THE VERTICAL DISTANCE FROM THE SEATING PLANE TO THE LOWEST POINT ON THE PACKAGE BODY.
  8. CONTOURS OF THE THERMAL PAD ARE UNCONTROLLED WITHIN THE REGION DEFINED BY DIMENSIONS D2 AND E2.

| MILLIMETERS |          |      |
|-------------|----------|------|
| DIM         | MIN      | MAX  |
| A           | ---      | 1.70 |
| A1          | 0.00     | 0.10 |
| A2          | 1.10     | 1.65 |
| b           | 0.19     | 0.30 |
| c           | 0.09     | 0.20 |
| D           | 8.64 BSC |      |
| D2          | 5.28     | 5.58 |
| E           | 6.00 BSC |      |
| E1          | 3.90 BSC |      |
| E2          | 2.44     | 2.64 |
| e           | 0.65 BSC |      |
| h           | 0.25     | 0.50 |
| L           | 0.40     | 0.85 |
| L1          | 1.00 REF |      |
| L2          | 0.25 BSC |      |
| M           | 0°       | 8°   |

### GENERIC MARKING DIAGRAM\*



- XXXX = Specific Device Code
  - A = Assembly Location
  - WL = Wafer Lot
  - YY = Year
  - WW = Work Week
  - G = Pb-Free Package
- (Note: Microdot may be in either location)

\*This information is generic. Please refer to device data sheet for actual part marking. Pb-Free indicator, "G" or microdot "•", may or may not be present. Some products may not follow the Generic Marking.

|                  |              |  |
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| DESCRIPTION:     | SSOP24 NB EP | PAGE 1 OF 1  |

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