# NX5P2190

## Logic controlled high-side power switch

Rev. 1.1 — 15 January 2015 Product data sheet

## 1. General description

The NX5P2190 is an advanced power switch with adjustable current limit. It includes under-voltage and over-voltage lockout, over-current, over-temperature, reverse bias and in-rush current protection circuits. These circuits are designed to isolate a voltage source from a VBUS interface pin automatically when a fault occurs. The device features two power switch terminals, one input (VINT) and one output (VBUS). A current limit input (ILIM) defines the over-current and in-rush current limit, and a voltage detect output (VDET) monitors the voltage level on VBUS. An open-drain fault output ($\overline{\text{FAULT}}$) indicates when a fault condition occurs. An enable input (EN) controls the state of the switch. When EN is set LOW the device enters a low-power mode, disabling all protection circuits except the under-voltage lockout. The low-power mode can be entered at anytime unless the over temperature protection circuit has been triggered.

Designed for operation from 3 V to 5.5 V, the NX5P2190 is a complete solution for power domain isolation and protection applications. The enable input includes integrated logic level translation making the device compatible with lower voltage processors and controllers.

## 2. Features and benefits

- Wide supply voltage range from 3 V to 5.5 V
- 30 V tolerant on VBUS
- $I_{SW}$ maximum 2 A continuous current
- Very low ON resistance: 100 mΩ (maximum) at a supply voltage of 4.0 V
- Low-power mode (ground current 20 μA typical)
- 1.8 V control logic
- Soft start turn-on slew rate
- Protection circuitry
  - Over-temperature protection
  - Over-current protection with low current output mode
  - Reverse bias current/Back drive protection
  - Over-voltage lockout
  - Under-voltage lockout
  - Analog voltage limited VBUS monitor path
- ESD protection:
  - HBM JDS-001 Class 2 exceeds 2 kV
  - IEC61000-4-2 contact discharge exceeds 8 kV for pins VBUS
- Specified from −40 °C to +85 °C

## 3. Applications

- USB OTG applications

## 4. Ordering information

**Table 1. Ordering information**

| Type number | Package | | | |
|---|---|---|---|---|
| | Temperature range | Name | Description | Version |
| NX5P2190UK | –40 °C to +85 °C | WLCSP9 | wafer level chip-scale package; 9 bumps; body 1.36 x 1.36 x 0.51 mm. (Backside coating included) | NX5P2190UK |

## 5. Marking

**Table 2. Marking codes**

| Type number | Marking code |
|---|---|
| NX5P2190UK | NX5PC |

## 6. Functional diagram

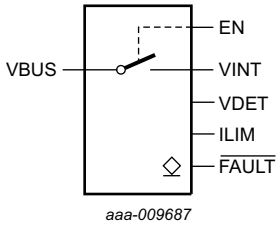



**Fig 1. Logic symbol**


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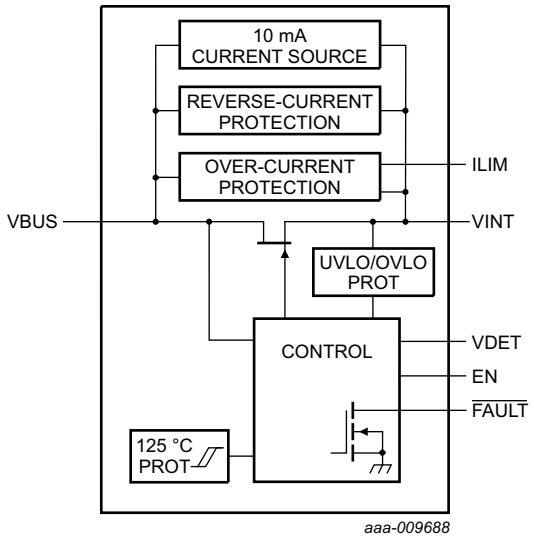



**Fig 2. Logic diagram (simplified schematic)**

# 7. Pinning information

## 7.1 Pinning

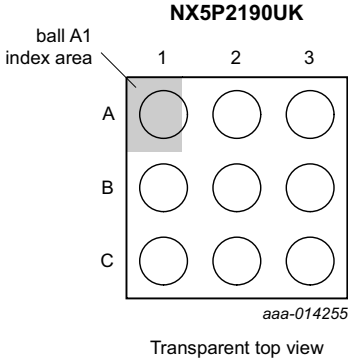



**Fig 3. Pin configuration WLCSP9 package**

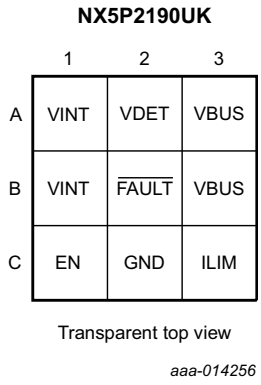



**Fig 4. Ball mapping for WLCSP9**


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### 7.2 Pin description

**Table 3. Pin description**

| Symbol | Pin | Description |
|---|---|---|
| VINT | A1, B1 | internal circuitry voltage I |
| VBUS | A3, B3 | external connector voltage O |
| EN | C1 | enable input (active HIGH) I |
| ILIM | C3 | current limiter I/O |
| VDET | A2 | VBUS voltage level indicator O |
| $\overline{\text{FAULT}}$ | B2 | fault condition indicator (open-drain; active LOW) |
| GND | C2 | ground (0 V) |

## 8. Functional description

**Table 4. Function table[1]**

| EN | VINT | VBUS | $\overline{\text{FAULT}}$ | Operation mode |
|---|---|---|---|---|
| X | 0 V | Z | L | No supply |
| X | 0 V | < 30 V | Z | Disabled; switch open |
| X | < 3.2 V | Z | L | Under-voltage lockout; switch open |
| H | > 5.5 V | Z | L | Over-voltage lockout; switch open |
| H | 3.2 V to 5.5 V | Z | L | Over-temperature; switch open |
| L | 3.2 V to 5.5 V | Z | Z | Disabled; switch open |
| H | 3.2 V to 5.5 V | VBUS = VINT | Z | Enabled; switch closed; active |
| H | 3.2 V to 5.5 V | 0 V to VINT | L | Over-current; Switch open; constant current on VBUS |
| H | 3.2 V to 5.5 V | 0 V to VINT | L | When ILIM is connected to GND, VBUS is default supplied with 10 mA current source |
| H | 3.2 V to 5.5 V | VINT + 30 mV < VBUS < VINT + 0.45 V (> 4 ms) | L | Reverse bias current/back drive; switch open |
| H | 3.2 V to 5.5 V | VBUS > VINT + 0.45 V | L | Reverse bias current/back drive; switch open |

[1] H = HIGH voltage level; L = LOW voltage level, Z = high-impedance OFF-state, X = Don't care.

**Table 5. Function table VDET versus VBUS[1]**

| VBUS | VDET | Operation mode |
|---|---|---|
| 3 V < VBUS < 30 V | 1.5 < VDET < 5.5 V | VDET detects VBUS voltage |

[1] See Figure 22.


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## 8.1 EN input

If EN is set LOW, the N-channel MOSFET is disabled, the $\overline{\text{FAULT}}$ output is set HIGH-impedance and the device enters low-power mode. In low-power mode, all protection circuits are disabled except the under-voltage lockout circuit. If EN is set HIGH, all protection circuits are reactivated. If no fault conditions exist and an $R_{ILIM}$ current limit resistor is detected, the N-channel MOSFET is enabled.

## 8.2 Under-voltage lockout (UVLO)

The UVLO circuit is active until VINT > 3.2 V. It disables the N-channel MOSFET, sets the $\overline{\text{FAULT}}$ output LOW and returns the device to low-power mode. The EN pin does not affect the UVLO circuit. Once VINT > 3.2 V, the EN pin controls the N-channel MOSFET state. The UVLO circuit remains active in low-power mode.

## 8.3 Over-voltage lockout (OVLO)

If EN is set HIGH and VINT > 5.9 V, the OVLO circuit is active. It disables the N-channel MOSFET and sets the $\overline{\text{FAULT}}$ output LOW. In low-power mode, the OVLO circuit is disabled and does not change the $\overline{\text{FAULT}}$ output state. If the OVLO circuit is active, setting the EN pin LOW returns the device to low-power mode.

## 8.4 ILIM

The over-current protection circuit's (OCP) trigger value $I_{ocp}$, is set using an external resistor connected to the ILIM pin (see Figure 6). If EN is set HIGH and the ILIM pin is grounded, the device is in over-current. The N-channel MOSFET is disabled, the $\overline{\text{FAULT}}$ output is set LOW and VBUS supplied by the 10 mA current source.

## 8.5 Over-current protection (OCP)

When the current through the N-channel MOSFET exceeds $I_{ocp}$ for 20 μs or VBUS < VINT − 200 mV, the device is in over-current. The OCP circuit disables the N-channel MOSFET within 2 μs, sets the $\overline{\text{FAULT}}$ output LOW and supplies VBUS from the 10 mA current source. The OCP circuit is automatically reset when VINT > VBUS > VINT − 200 mV for 20 μs. The N-channel MOSFET assumes the state defined by EN, the 10 mA current source is disconnected and the $\overline{\text{FAULT}}$ output is set HIGH-impedance. If the OCP circuit is active, setting the EN pin LOW returns the device to low-power mode.

## 8.6 Over-temperature protection (OTP)

If EN is set HIGH and the device temperature exceeds 125 °C, the device is in over temperature. The OTP circuit disables the N-channel MOSFET and sets the $\overline{\text{FAULT}}$ output LOW. Transitions on the EN pin have no effect. Once its temperature decreases to below 115 °C the device returns to the defined state. The OTP circuit is disabled in low-power mode.


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## 8.7 Reverse bias current/back drive protection (RCP)

The reverse bias current protection circuit can only be triggered when EN is set HIGH. If VBUS > (VINT + 30 mV) for longer than 4 ms; or VBUS > (VINT + 0.45 V) the device is in reverse bias. The RCP circuit disables the N-channel MOSFET and sets the $\overline{\text{FAULT}}$ output LOW. Once VBUS < VINT for longer than 4 ms the device returns to the defined state. If the RCP circuit is active, setting the EN pin LOW returns the device to low-power mode.

## 8.8 $\overline{\text{FAULT}}$ output

The $\overline{\text{FAULT}}$ output is an open-drain output that requires an external pull-up resistor. If any of the UVLO, OVLO, RCP, OCP or OTP circuits is activated, the $\overline{\text{FAULT}}$ output is set LOW to indicate that a fault has occurred. The $\overline{\text{FAULT}}$ output returns to the high impedance state automatically once the fault condition is removed.

## 8.9 VDET output

VDET is an analog output that allows a controller to monitor the voltage level on VBUS.

## 8.10 In-rush current protection

When the N-channel MOSFET is enabled, the in-rush current protection circuit clamps the switch current until VBUS = VINT − 200 mV. The resistor connected to ILIM sets the clamp current. The in-rush current protection circuit is disabled in low-power mode.


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## 9. Application diagram

The NX5P2190 typically connects a voltage source on VINT to the VBUS of a battery operated device. The external resistor $R_{ILIM}$ sets the maximum current limit threshold. The $\overline{FAULT}$ output is open-drain. It requires an external pull-up resistor.

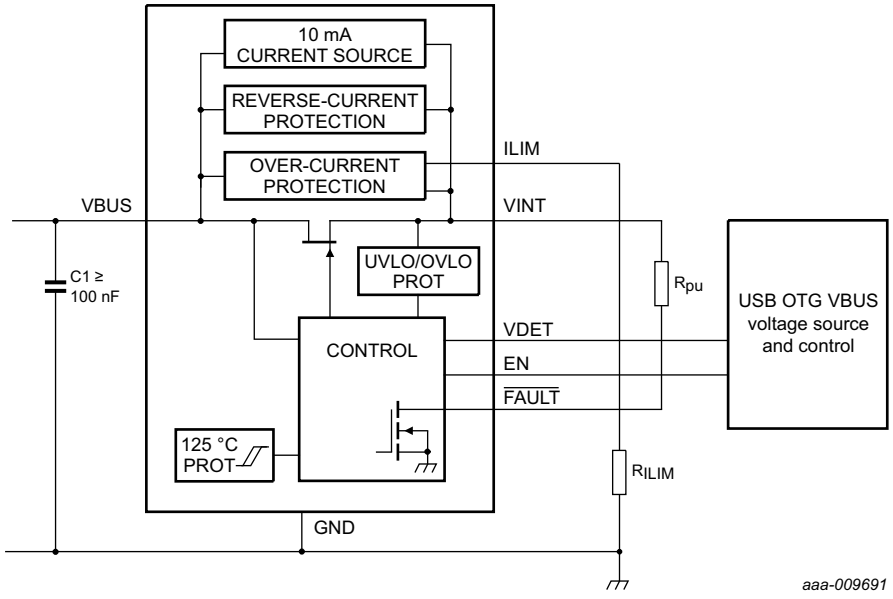



**Fig 5. NX5P2190 application diagram**


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## 10. Limiting values

**Table 6. Limiting values**

*In accordance with the Absolute Maximum Rating System (IEC 60134). Voltages are referenced to GND (ground = 0 V).*

| Symbol | Parameter | Conditions | Min | Max | Unit |
|---|---|---|---|---|---|
| $V_I$ | input voltage | VBUS [1] | −0.5 | +32 | V |
| | | VINT [1] | −0.5 | +6.5 | V |
| | | EN, ILIM [2][3] | −0.5 | VINT + 0.5 | V |
| $V_O$ | output voltage | $\overline{FAULT}$ | −0.5 | +6.0 | V |
| $I_{IK}$ | input clamping current | EN: $V_I$ < −0.5 V | −50 | - | mA |
| $I_{SK}$ | switch clamping current | VBUS; VINT; $V_I$ < −0.5 V | −50 | - | mA |
| $I_{SW}$ | switch current | $T_{amb}$ = 85 °C | - | ±2000 | mA |
| $T_{j(max)}$ | maximum junction temperature | | −40 | +125 | °C |
| $T_{stg}$ | storage temperature | | −65 | +150 | °C |
| $P_{tot}$ | total power dissipation | [4] | - | 400 | mW |

[1] The minimum and maximum switch voltage ratings may be exceeded if the switch clamping current rating is observed.

[2] The minimum input voltage rating may be exceeded if the input current rating is observed.

[3] The maximum input voltage should not exceed +6.5 V.

[4] The (absolute) maximum power dissipation depends on the junction temperature $T_j$. Higher power dissipation is allowed at lower ambient temperatures. The conditions to determine the specified values are $T_{amb}$ = 85 °C and the use of a two layer PCB.

## 11. Recommended operating conditions

**Table 7. Recommended operating conditions**

| Symbol | Parameter | Conditions | Min | Max | Unit |
|---|---|---|---|---|---|
| $V_I$ | input voltage | VINT | 3.0 | 5.5 | V |
| | | EN, ILIM | 0 | VINT | V |
| $V_O$ | output voltage | VBUS; EN = LOW | 0 | 30 | V |
| $T_{amb}$ | ambient temperature | | −40 | +85 | °C |

## 12. Thermal characteristics

**Table 8. Thermal characteristics**

| Symbol | Parameter | Conditions | Typ | Unit |
|---|---|---|---|---|
| $R_{th(j-a)}$ | thermal resistance from junction to ambient | [1] | 82 | K/W |

[1] $R_{th(j-a)}$ is dependent upon board layout. To minimize $R_{th(j-a)}$, ensure that all pins have a solid connection to larger copper layer areas. In multi-layer PCBs, the second layer should be used to create a large heat spreader area below the device. Avoid using solder-stop varnish under the device.


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## 13. Static characteristics

**Table 9. Static characteristics**

*$V_{I(VINT)}$ = 4.0 V to 5.5 V; unless otherwise specified; Voltages are referenced to GND (ground = 0 V).*

| Symbol | Parameter | Conditions | $T_{amb}$ = 25 °C | | | $T_{amb}$ = −40 °C to +85 °C | | Unit |
|---|---|---|---|---|---|---|---|---|
| | | | Min | Typ[1] | Max | Min | Max | |
| $V_{IH}$ | HIGH-level input voltage | EN input | 1.2 | - | - | 1.2 | - | V |
| $V_{IL}$ | LOW-level input voltage | EN input | - | - | 0.4 | - | 0.4 | V |
| $V_O$ | output voltage | VDET; $I_{VDET}$ = −2 mA; 3 V < VBUS < 30 V | 1.5 | - | 5.5 | 1.5 | 5.5 | V |
| $V_{OL}$ | LOW-level output voltage | $\overline{FAULT}$, $I_O$ = 8 mA | - | - | 0.5 | - | 0.5 | V |
| $I_O$ | output current | Current source | - | 10 | - | 8 | 15 | mA |
| | | EN = HIGH; $\overline{FAULT}$ = Hi-Z | - | - | $I_{ocp}$ | - | $I_{ocp}$ | mA |
| $I_{ocp}$ | overcurrent protection current | EN = HIGH; see Figure 6 | 200 | - | 2000 | - | - | mA |
| $R_{pu}$ | pull-up resistance | $\overline{FAULT}$ | 20 | - | 200 | - | - | kΩ |
| $V_{pu}$ | pull-up voltage | $\overline{FAULT}$ | - | - | VINT | - | VINT | V |
| $R_{ILIM}$ | current limit resistance | ILIM | 20 | - | 300 | 20 | 300 | kΩ |
| $I_{GND}$ | ground current | VBUS open; EN = LOW; see Figure 7 and Figure 8 | - | 20 | - | - | 40 | µA |
| | | VBUS open; EN = HIGH; see Figure 7 and Figure 8 | - | 220 | - | - | 360 | µA |
| $I_{OFF}$ | power-off leakage current | VBUS = 0 V to 30 V; VINT = 0 V; see Figure 9 [2] | - | 2 | - | - | 20 | µA |
| $I_{S(OFF)}$ | OFF-state leakage current | VBUS = 0 V to 30 V; see Figure 10 and Figure 11 [2] | - | 2 | - | - | 20 | µA |
| $V_{UVLO}$ | undervoltage lockout voltage | | 3.0 | 3.2 | 3.4 | 3.0 | 3.4 | V |
| $V_{OVLO}$ | overvoltage lockout voltage | | 5.5 | 5.9 | 6.25 | 5.5 | 6.25 | V |
| $V_{hys(OVLO)}$ | overvoltage lockout hysteresis voltage | | - | 150 | - | - | - | mV |
| $C_I$ | input capacitance | EN | - | 2 | - | - | - | pF |
| $C_{S(ON)}$ | ON-state capacitance | | - | - | 1 | - | 1 | nF |

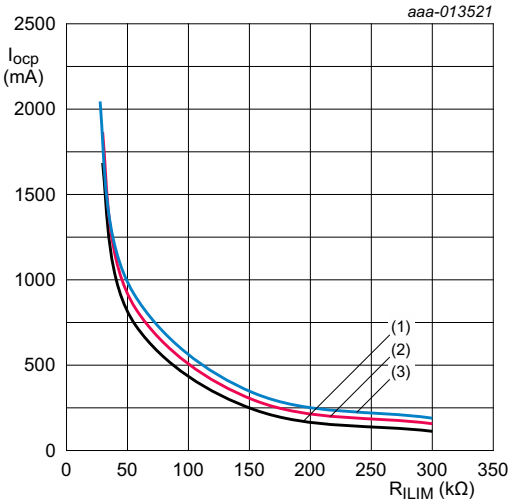
[1] Typical values are measured at $T_{amb}$ = 25 °C and $V_{I(VINT)}$ = 5.0 V.

[2] Typical value is measured at $T_{amb}$ = 25 °C and $V_{I(VBUS)}$ = 5.0 V.


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## 13.1 Graphs



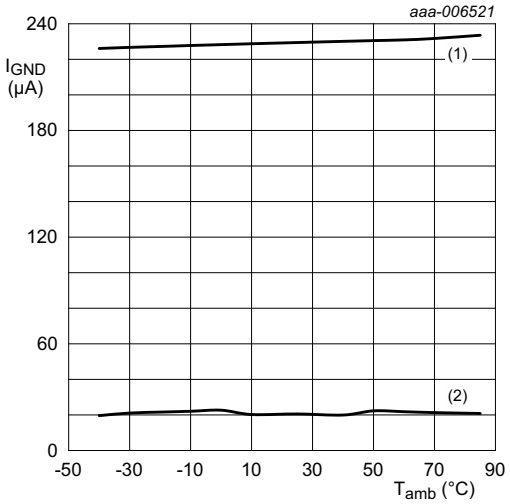

$T_{amb}$ = 25 °C.

(1) Minimum

(2) Typical

(3) Maximum

**Fig 6. Typical overcurrent protection current versus the external resistor value**




(1) Enabled

(2) Disabled

**Fig 7. Typical ground current versus temperature**

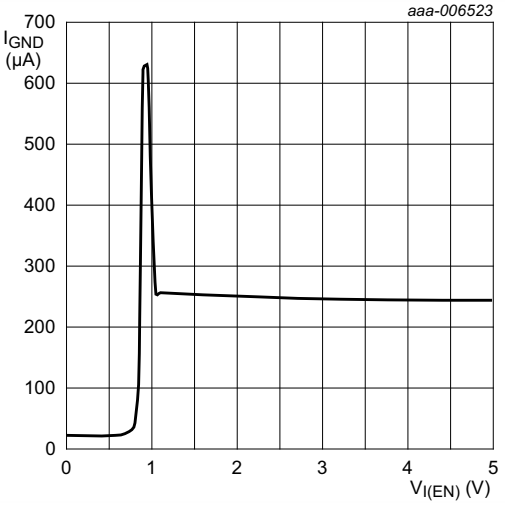
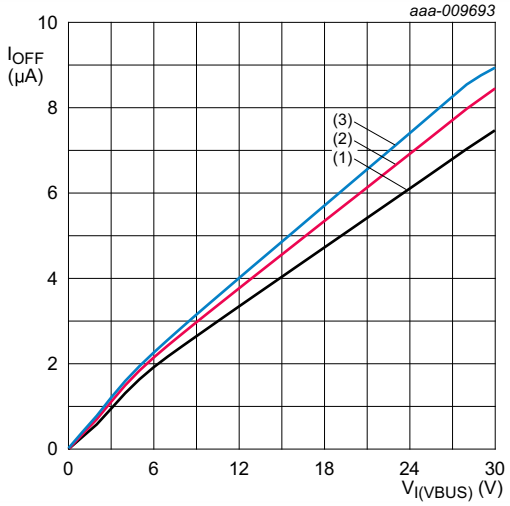



**Fig 8. Typical ground current versus input voltage**




(1) $T_{amb}$ = 85 °C

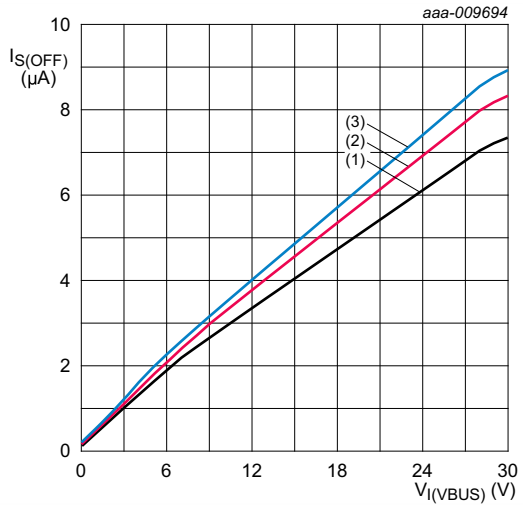
(2) $T_{amb}$ = 25 °C

(3) $T_{amb}$ = −40 °C

**Fig 9. Typical power-off leakage current versus input voltage on pin VBUS**

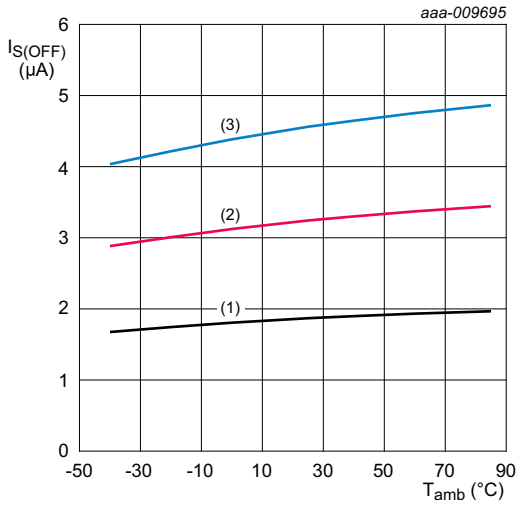

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(1) $T_{amb}$ = 85 °C
(2) $T_{amb}$ = 25 °C
(3) $T_{amb}$ = −40 °C

**Fig 10. Typical OFF-state leakage current versus input voltage on pin VBUS**




(1) $V_{I(VBUS)}$ = 5.0 V
(2) $V_{I(VBUS)}$ = 10.0 V
(3) $V_{I(VBUS)}$ = 15.0 V

**Fig 11. Typical OFF-state leakage current versus temperature**

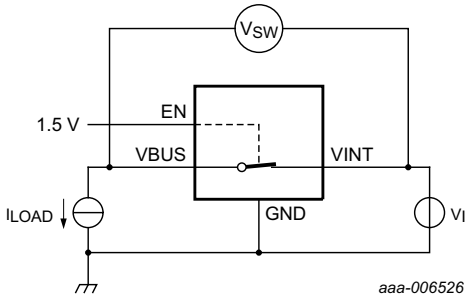
## 13.2 ON resistance

**Table 10. ON resistance**

*At recommended operating conditions; voltages are referenced to GND (ground = 0 V)*

| Symbol | Parameter | Conditions | $T_{amb}$ = 25 °C | | | $T_{amb}$ = −40 °C to +85 °C | | Unit |
|---|---|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | Min | Max | |
| $R_{ON}$ | ON resistance | switch enabled; $I_{LOAD}$ = 200 mA; see Figure 12, Figure 13 and Figure 14 | | | | | | |
| | | $V_{I(VINT)}$ = 4.0 V to 5.5 V | - | 60 | - | - | 100 | mΩ |

## 13.3 ON resistance test circuit and waveforms

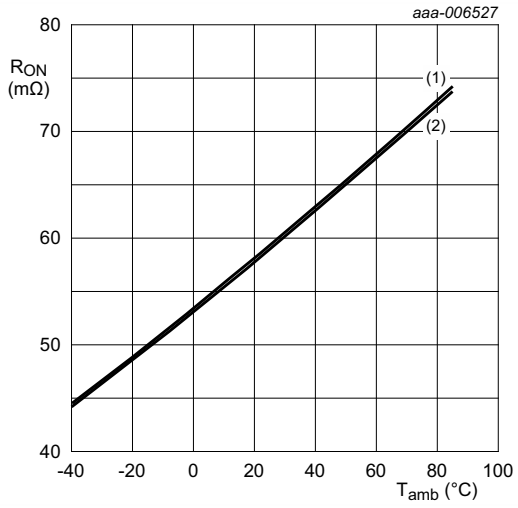



$R_{ON} = V_{SW} / I_{LOAD}$.

**Fig 12. Test circuit for measuring ON resistance**


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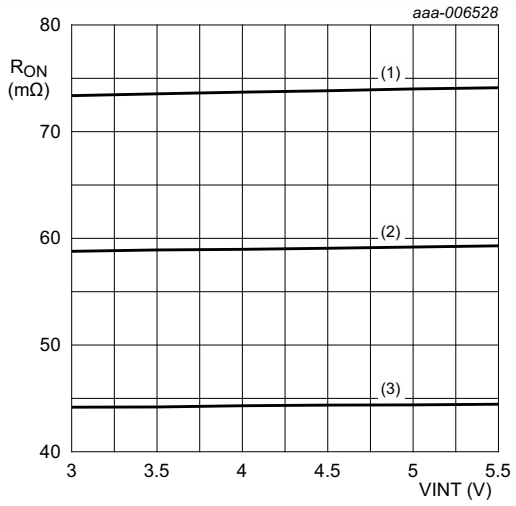
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(1) $V_{I(VINT)}$ = 5.5 V

(2) $V_{I(VINT)}$ = 4.0 V

**Fig 13. Typical ON resistance versus temperature**




(1) $T_{amb}$ = 85 °C

(2) $T_{amb}$ = 25 °C

(3) $T_{amb}$ = −40 °C

**Fig 14. Typical ON resistance versus input voltage**

# 14. Dynamic characteristics

**Table 11. Dynamic characteristics**

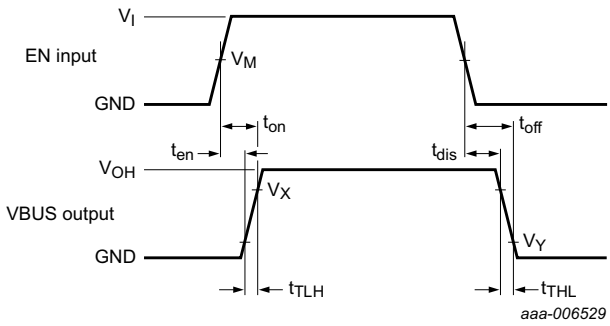
*At recommended operating conditions; voltages are referenced to GND (ground = 0 V); for test circuit, see Figure 16.*
*$V_{I(VINT)}$ = 4.0 V to 5.5 V.*

| Symbol | Parameter | Conditions | $T_{amb}$ = 25 °C | | | $T_{amb}$ = −40 °C to +85 °C | | Unit |
|---|---|---|---|---|---|---|---|---|
| | | | Min | Typ | Max | Min | Max | |
| $t_{en}$ | enable time | EN to VBUS; see Figure 15 | - | 0.24 | - | 0.16 | - | ms |
| $t_{dis}$ | disable time | EN to VBUS; see Figure 15 | - | 1.5 | - | - | - | ms |
| $t_{on}$ | turn-on time | EN to VBUS; see Figure 15 | - | 0.63 | - | 0.52 | - | ms |
| $t_{off}$ | turn-off time | EN to VBUS; see Figure 15 | - | 34.5 | - | - | - | ms |
| $t_{TLH}$ | LOW to HIGH output transition time | VBUS; see Figure 15 | - | 0.39 | - | 0.16 | - | ms |
| $t_{THL}$ | HIGH to LOW output transition time | VBUS; see Figure 15 | - | 33 | - | - | - | ms |


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## 14.1 Waveform and test circuits



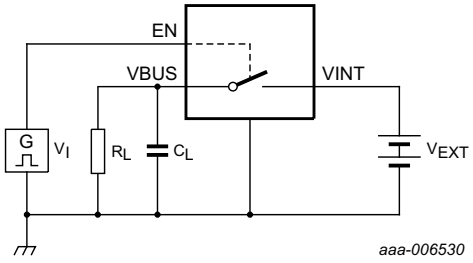

Measurement points are given in Table 12.

Logic level: $V_{OH}$ is the typical output voltage that occurs with the output load.

**Fig 15. Switching times**

**Table 12. Measurement points**

| Supply voltage | EN Input | Output | |
|---|---|---|---|
| $V_{I(VINT)}$ | $V_M$ | $V_X$ | $V_Y$ |
| 4.0 V to 5.5 V | 0.5 × $V_I$ | 0.9 × $V_{OH}$ | 0.1 × $V_{OH}$ |




Test data is given in Table 13.

Definitions test circuit:

$R_L$ = Load resistance.

$C_L$ = Load capacitance including jig and probe capacitance.

$V_{EXT}$ = External voltage for measuring switching times.

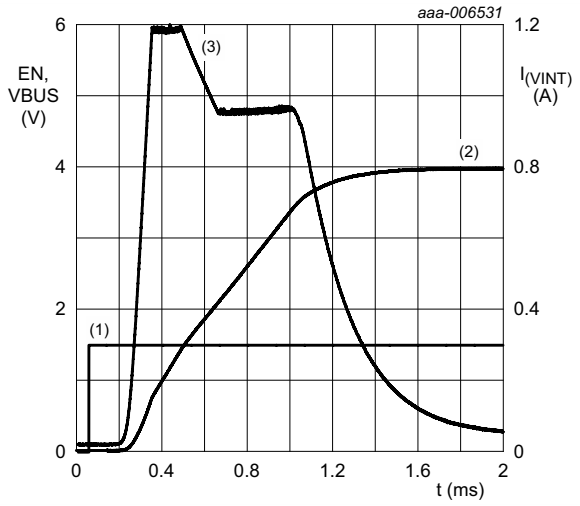
**Fig 16. Test circuit for measuring switching times**

**Table 13. Test data**

| Supply voltage | Input | Load | |
|---|---|---|---|
| $V_{EXT}$ | $V_I$ | $C_L$ | $R_L$ |
| 4.0 V to 5.5 V | 1.5 V | 100 µF | 150 Ω |


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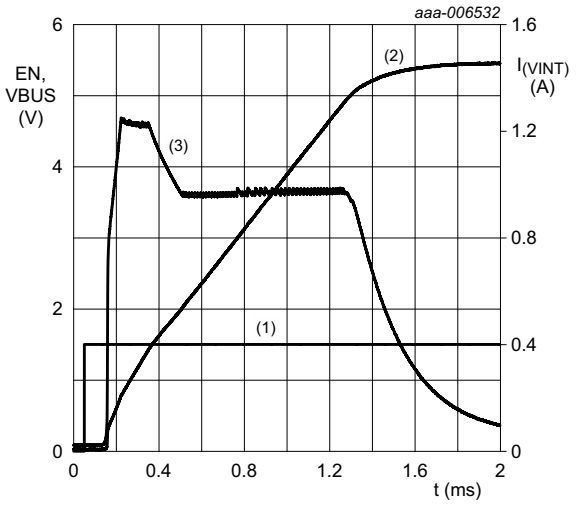

EN = 1.5 V; VINT = 4 V; $R_L$ = 150 Ω; $C_L$ = 220 µF; $R_{ILIM}$ = 50 kΩ; $T_{amb}$ = 25 °C.

(1) EN

(2) VBUS

(3) $I_{I(VINT)}$

**Fig 17. Typical enable time and in-rush current**



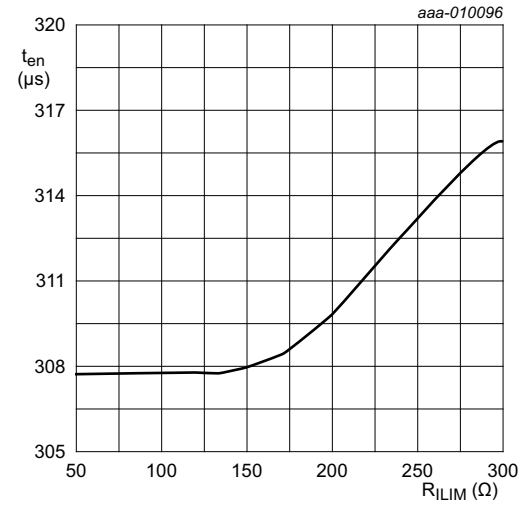

EN = 1.5 V; VINT = 5.5 V; $R_L$ = 150 Ω; $C_L$ = 220 µF; $R_{ILIM}$ = 50 kΩ; $T_{amb}$ = 25 °C.

(1) EN

(2) VBUS

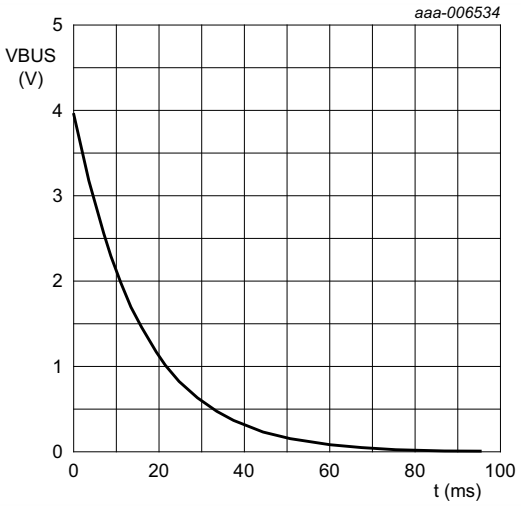
(3) $I_{I(VINT)}$

**Fig 18. Typical enable time and in-rush current**




EN = 1.5 V; VINT = 4 V; $R_L$ = 150 Ω; $C_L$ = 100 µF; $T_{amb}$ = 25 °C.

**Fig 19. Typical enable time versus current limit resistance ($R_{ILIM}$)**

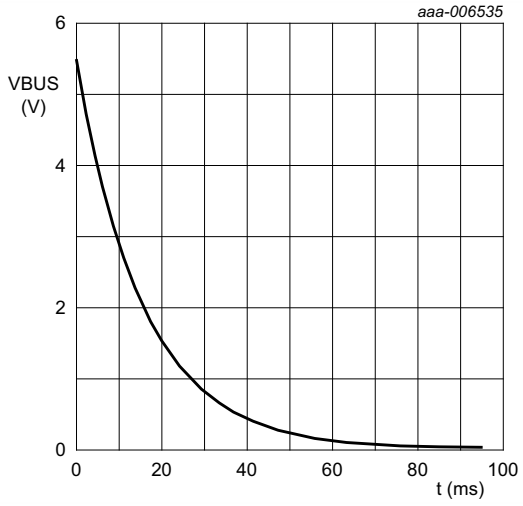



EN = 1.5 V; VINT = 4 V; $R_L$ = 150 Ω; $C_L$ = 100 µF; $R_{ILIM}$ = 50 kΩ; $T_{amb}$ = 25 °C.

**Fig 20. Typical disable time**


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EN = 1.5 V; VINT = 5.5 V; $R_L$ = 150 Ω; $C_L$ = 100 μF; $R_{ILIM}$ = 50 kΩ; $T_{amb}$ = 25 °C.

**Fig 21. Typical disable time**

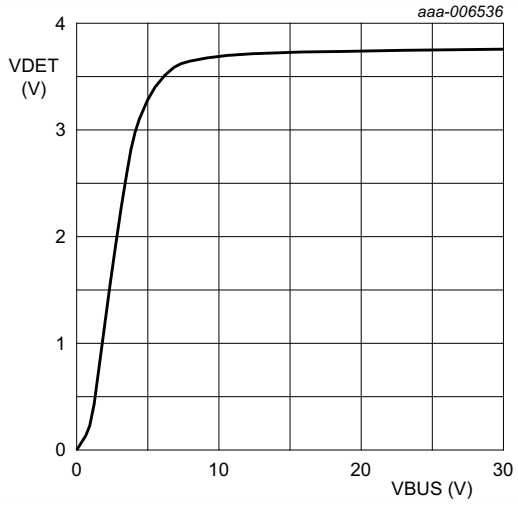


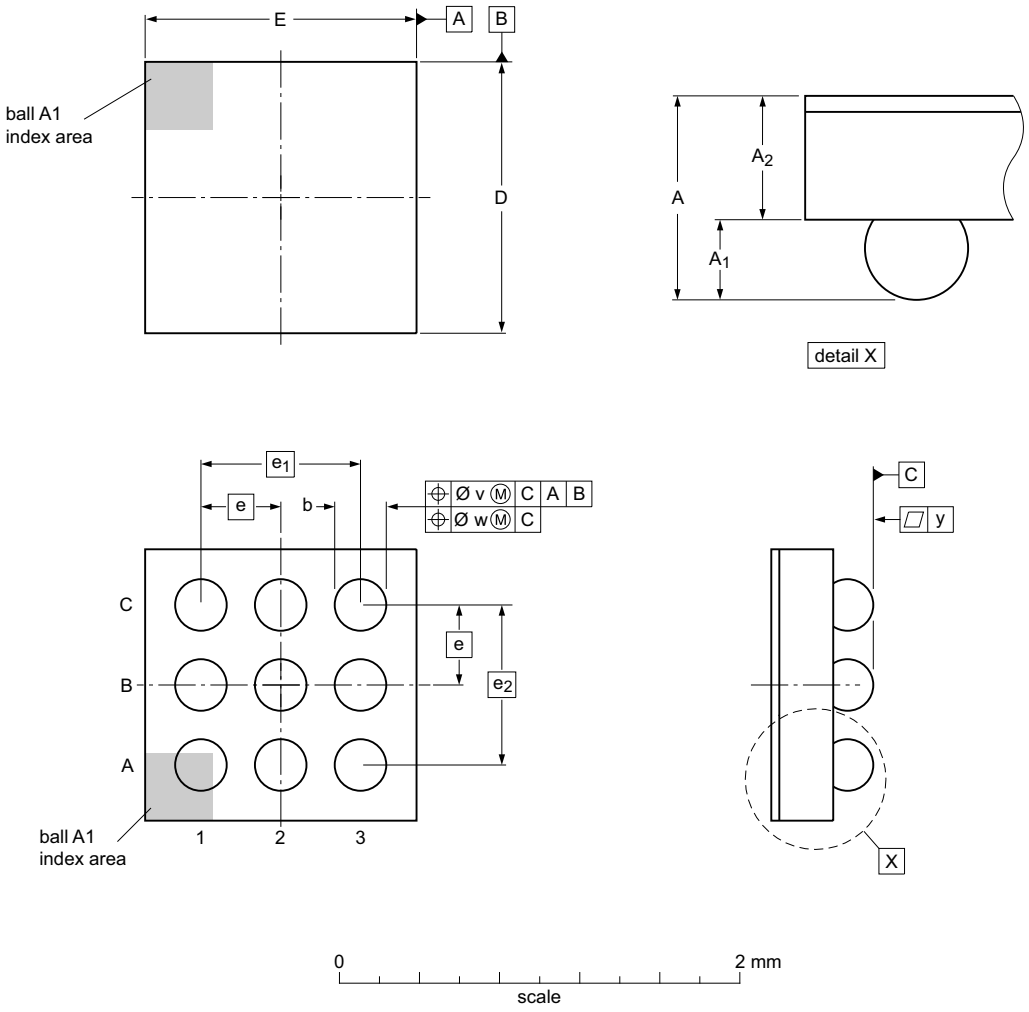

**Fig 22. Typical VDET versus VBUS**


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## 15. Package outline

**WLCSP9: wafer level chip-scale package;**
**9 bumps; body 1.36 x 1.36 x 0.51 mm (Backside coating included)** **NX5P2190UK**




Dimensions (mm are the original dimensions)

| Unit | | A | $A_1$ | $A_2$ | b | D | E | e | $e_1$ | $e_2$ | v | w | y |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| mm | max | 0.55 | 0.23 | 0.34 | 0.29 | 1.39 | 1.39 | | | | | | |
| | nom | 0.51 | 0.20 | 0.31 | 0.26 | 1.36 | 1.36 | 0.4 | 0.8 | 0.8 | 0.05 | 0.015 | 0.03 |
| | min | 0.47 | 0.17 | 0.29 | 0.23 | 1.33 | 1.33 | | | | | | |

*nx5p2190uk_po*

| Outline version | References | | | | European projection | Issue date |
|---|---|---|---|---|---|---|
| | IEC | JEDEC | JEITA | | | |
| NX5P2190UK | | | | | | ~~14-02-12~~ 14-02-14 |

**Fig 23. Package outline WLCSP9 package**


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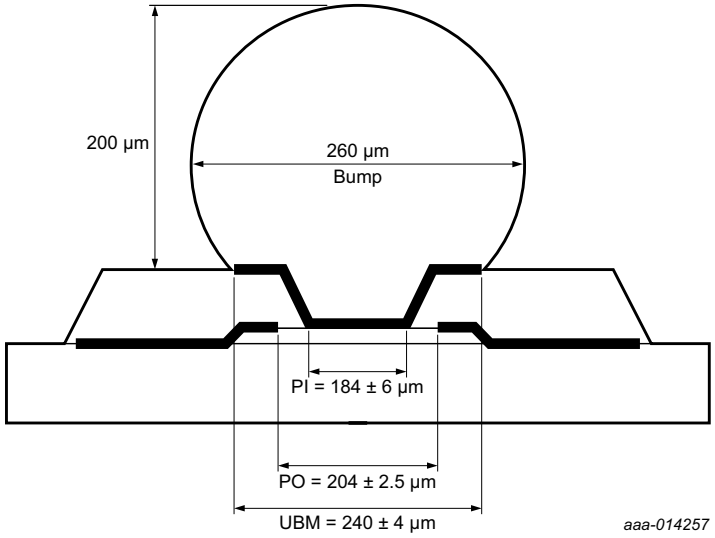



**Fig 24. Ball dimensions WLCSP9 package**

# 16. Abbreviations

**Table 14. Abbreviations**

| Acronym | Description |
|---|---|
| CDM | Charged Device Model |
| DUT | Device Under Test |
| ESD | ElectroStatic Discharge |
| HBM | Human Body Model |
| MOSFET | Metal-Oxide Semiconductor Field Effect Transistor |
| OCP | OverCurrent Protection |
| OTP | OverTemperature Protection |
| RCP | Reverse Current Protection |
| USB OTG | Universal Serial Bus On-The-Go |
| UVLO | Under-voltage lockout |
| VBUS | USB Power Supply |
| OVLO | Over-voltage lockout |

# 17. Revision history

**Table 15. Revision history**

| Document ID | Release date | Data sheet status | Change notice | Supersedes |
|---|---|---|---|---|
| NX5P2190 v.1.1 | 20150115 | Product data sheet | - | NX5P2190 v.1 |
| Modifications: | • A text correction to the first paragraph on page 1. | | | |
| NX5P2190 v.1 | 20150113 | Product data sheet | - | - |


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| Document status[1][2] | Product status[3] | Definition |
|---|---|---|
| Objective [short] data sheet | Development | This document contains data from the objective specification for product development. |
| Preliminary [short] data sheet | Qualification | This document contains data from the preliminary specification. |
| Product [short] data sheet | Production | This document contains the product specification. |

[1] Please consult the most recently issued document before initiating or completing a design.

[2] The term 'short data sheet' is explained in section "Definitions".

[3] The product status of device(s) described in this document may have changed since this document was published and may differ in case of multiple devices. The latest product status information is available on the Internet at URL http://www.nxp.com.

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