Lead-free Green

# SWITCH FOR VBUS LINE WITH OVERVOLTAGE, SURGE, AND ESD PROTECTION

## Description

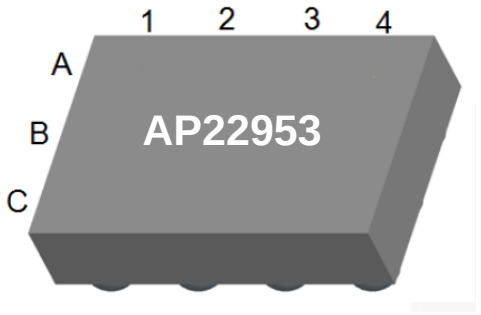
The AP22953 device is a single-chip solution for USB 2.0/3.0/Type-C connector VBUS line protection. The bidirectional MOSFET switch ensures normal current flow in both charging and host mode while protecting the internal circuits from overvoltage conditions at the $V_{BUS\_CON}$ pin. On the $V_{BUS\_CON}$ pin, the device has overvoltage protection up to 30V. After the #EN pin is pulled low, the AP22953 counts 20ms before turning on the MOSFET via soft-start delay. The #ACK pin indicates the MOSFET is fully turned ON.

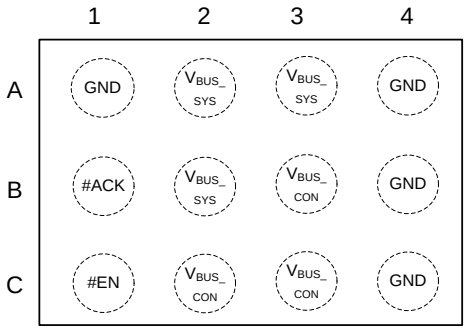
The typical application interface for the AP22953 is the $V_{BUS}$ line in USB connectors. Typical end equipment for the AP22953 include smartphones, tablet PCs, wearables, and electronic-point-of-sale (EPOS) systems. The AP22953 can also be used with other devices that use a 5V power rail interface.

Overtemperature protection turns off the switch at 145°C (typical).

The AP22953 is available in the wafer level chip scale W-WLB2013-12 1.988mm x 1.288mm x 0.64mm package with backside laminate.

## Pin Assignments




WL-CSP (Top View)

## Features

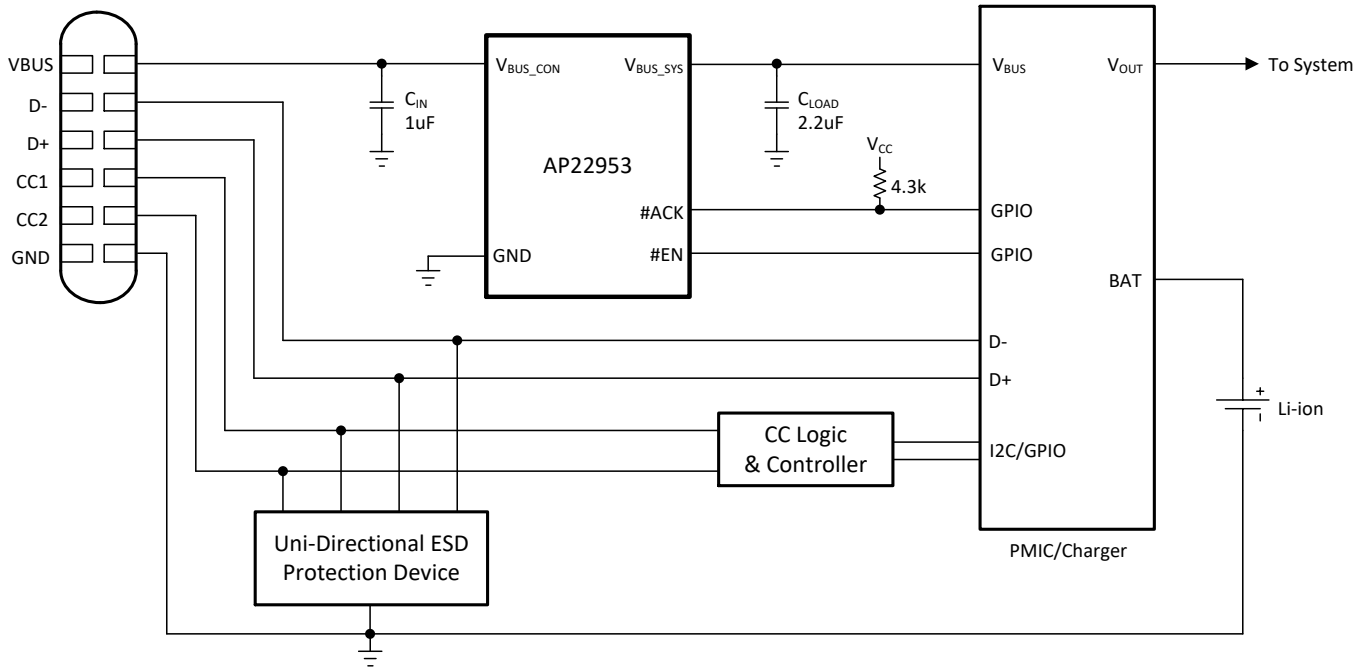
- Surge protection
  - IEC61000-4-5 >100V
- Integrated 39mΩ (typ) N-Channel MOSFET Switch
- Overvoltage Protection (OVP) at $V_{BUS\_CON}$ Up to 30VDC
- Integrated Input Enable and Status Output Signal
- Overtemperature Protection (OTP)
- ESD Protection
  - Human Body Model >4kV
  - Charged Device Model >1kV
  - IEC61000-4-2 Air Discharge >15kV
  - IEC61000-4-2 Contact Discharge >15kV
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**
- **For automotive applications requiring specific change control (i.e. parts qualified to AEC-Q100/101/200, PPAP capable, and manufactured in IATF 16949 certified facilities), please contact us or your local Diodes representative.**
  **https://www.diodes.com/quality/product-definitions/**

## Applications

- Smartphones
- Tablet PCs
- Wearables
- Electronic-Point-of-Sale (EPOS) Systems

Notes:
1. No purposely added lead. Fully EU Directive 2002/95/EC (RoHS), 2011/65/EU (RoHS 2) & 2015/863/EU (RoHS 3) compliant.
2. See https://www.diodes.com/quality/lead-free/ for more information about Diodes Incorporated's definitions of Halogen- and Antimony-free, "Green" and Lead-free.
3. Halogen- and Antimony-free "Green" products are defined as those which contain <900ppm bromine, <900ppm chlorine (<1500ppm total Br + Cl) and <1000ppm antimony compounds.

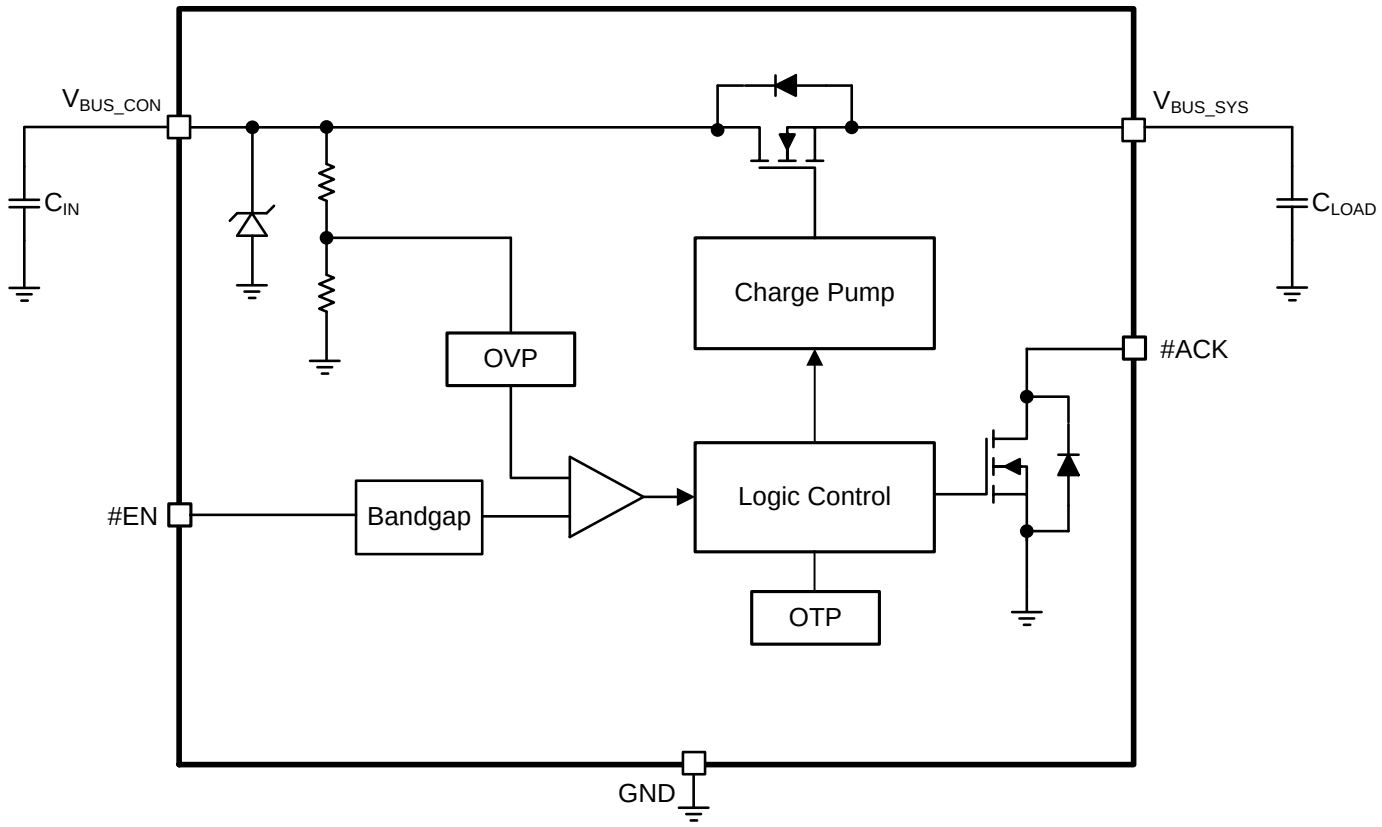
## Typical Applications Circuit




## Pin Descriptions

| Pin Name | Pin Number | I/O | Function |
|---|---|---|---|
| $V_{BUS\_CON}$ | B3, C2, C3 | I/O | Supply voltage from USB connector $V_{BUS}$ pin. Bypass $V_{BUS\_CON}$ with a 1μF ceramic capacitor as close as possible to the device. |
| $V_{BUS\_SYS}$ | A2, A3, B2 | I/O | Internal supply voltage rail to PMIC $V_{BUS}$ plane. Bypass $V_{BUS\_SYS}$ with a 2.2μF ceramic capacitor as close as possible to the device. |
| #ACK | B1 | O | Open-Drain Acknowledge pin. |
| #EN | C1 | I | Enable Active-Low Input. Drive #EN low to enable the switch. Drive #EN high to disable the switch. |
| GND | A1, A4, B4, C4 | Ground | Device ground. Connect to PCB ground plane |

## Functional Block Diagram



## Absolute Maximum Ratings (@ $T_A$ = +25°C, unless otherwise specified.)

| Symbol | | Parameter | Ratings | Unit |
|---|---|---|---|---|
| ESD | HBM | Human Body Model ESD Protection | 4 | kV |
| | CDM | Charged Device Model ESD Protection | 1 | kV |
| | IEC system level | IEC 61000-4-2. Contact Discharge, $V_{BUS\_CON}$ (Note 4) | 15 | kV |
| | IEC system level | IEC 61000-4-2. Air Gap Discharge, $V_{BUS\_CON}$ (Note 4) | 15 | kV |
| Surge | | IEC 61000-4-5 Surge Protection, $V_{BUS\_CON}$ (Note 4) | 100 | V |
| $V_{BUS\_CON}$ | | Supply voltage from USB connector | -0.3 to +30 | V |
| $V_{BUS\_SYS}$ | | Internal supply DC voltage rail on the PCB | -0.3 to +7 | V |
| #ACK, #EN | | $V_{\#ACK}$, $V_{\#EN}$ Voltages | -0.3 to +7 | V |
| $I_{CON}$, $I_{SYS}$ | | Switch I/O Current (Continuous) | 3.5 | A |
| $T_A$ | | Operating Ambient Temperature | -40 to +85 | °C |
| $T_{ST}$ | | Storage Temperature Range | -40 to +150 | °C |
| $P_D$ | | Power Dissipation | 670 | mW |
| $R_{\theta JA}$ | | Thermal Resistance, Junction to Ambient | 89 | °C/W |
| $R_{\theta JC}$ | | Thermal Resistance, Junction to Case | 0.6 | °C/W |

Notes: 4. The JEDEC high-K (2s2p) board used to derive this data was a 3in x 3in, multilayer board with 1oz internal power and ground planes with 2oz copper traces on top and bottom of the board.

5. EVM has been tested per typical circuit with capacitors connected to the $V_{BUS\_CON}$ and $V_{BUS\_SYS}$.

Caution: Stresses greater than the 'Absolute Maximum Ratings' specified above, may cause permanent damage to the device. These are stress ratings only; functional operation of the device at these or any other conditions exceeding those indicated in this specification is not implied. Device reliability may be affected by exposure to absolute maximum rating conditions for extended periods of time.

## Recommended Operating Conditions (@ $T_A$ = +25°C, unless otherwise specified.)

| Symbol | Parameter | Min | Nom | Max | Unit |
|---|---|---|---|---|---|
| $V_{BUS\_CON}$ | Supply voltage from USB connector | — | — | 5.9 | V |
| $V_{BUS\_SYS}$ | Internal supply DC voltage rail on the PCB | — | — | 5.9 | V |
| $C_{LOAD}$ | Output load capacitance, $V_{BUS\_SYS}$ pin | — | 2.2 | — | µF |
| $C_{IN}$ | Input capacitance, $V_{BUS\_CON}$ pin | — | 1 | — | µF |
| $R_{PULL-UP}$ | Pull-up resistor, #ACK | — | 4.3 | 100 | kΩ |
| $I_{VBUS}$ | Continuous current on $V_{BUS\_CON}$ and $V_{BUS\_SYS}$ pins | — | — | 3.5 | A |
| $I_{DIODE}$ | Continuous current through the MOSFET body diode | — | — | 1 | A |

## Electrical Characteristics (@ $T_A$ = +25°C, unless otherwise specified. $C_{IN}$ = 1µF, $C_{OUT}$ = 2.2µF. Typical values are at $V_{BUS}$ = +5.0V, $I_{VBUS}$ ≤ 3.5A) (Note 6)

| Symbol | Parameter | Test Conditions (Note 7) | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **Supply** | | | | | | |
| $I_{VBUS\_SLEEP}$ | $V_{BUS\_CON}$ operating current consumption | Measured at $V_{BUS\_CON}$ pin, $V_{BUS\_CON}$ = 5V, #EN = 5V | — | 30 | 70 | µA |
| $I_{VBUS}$ | | Measured at $V_{BUS\_CON}$ pin, $V_{BUS\_CON}$ = 5V, #EN = 0V and no load | — | 175 | 373 | µA |
| $I_{VBUS\_SYS}$ | $V_{BUS\_CON}$ operating current consumption | Measured at $V_{BUS\_SYS}$ pin, $V_{BUS\_SYS}$ = 5V, #EN = 0V and $V_{BUS\_CON}$ = Hi-Z | — | 175 | 373 | µA |
| $I_{HOST\_LEAK}$ | Host mode leakage current | Measured at $V_{BUS\_SYS}$ pin, $V_{BUS\_SYS}$ = 5V, #EN = 5V and $V_{BUS\_CON}$ = Hi-Z | — | 110 | — | µA |
| **I/O Voltage Protection** | | | | | | |
| $V_{OVP\_RISING}$ | Input overvoltage protection threshold, $V_{BUS\_CON}$ | $V_{BUS\_CON}$ increasing from 5V | 6 | 6.2 | 6.4 | V |
| $V_{HYS\_OVP}$ | Hysteresis on OVP, $V_{BUS\_CON}$ | $V_{BUS\_CON}$ decreasing from 7V to 5V | — | 50 | — | mV |
| $V_{OVP\_FALLING}$ | Input overvoltage protection threshold, $V_{BUS\_CON}$ | $V_{BUS\_CON}$ decreasing from 7V to 5V | 5.93 | — | 6.37 | V |
| $V_{UVLO}$ | Input undervoltage lockout, $V_{BUS\_CON}$ | $V_{BUS\_CON}$ voltage rising from 0V to 5V | 2.3 | 2.75 | 3.2 | V |
| $V_{HYS\_UVLO}$ | Hysteresis on UVLO, $V_{BUS\_CON}$ | Difference between rising and falling UVLO thresholds | — | 100 | — | mV |
| $V_{UVLO\_FALLING}$ | Input undervoltage lockout, $V_{BUS\_CON}$ | $V_{BUS\_CON}$ voltage rising from 5V to 0V | — | 2.65 | — | V |
| $V_{UVLO\_SYS}$ | $V_{BUS\_SYS}$ undervoltage lockout, $V_{BUS\_SYS}$ | $V_{BUS\_SYS}$ voltage rising from 0V to 5V | 2.9 | 3.35 | 3.8 | V |
| $V_{HYS\_UVLO\_SYS}$ | $V_{BUS\_SYS}$ UVLO Hysteresis, $V_{BUS\_SYS}$ | Difference between rising and falling UVLO thresholds on $V_{BUS\_SYS}$ | — | 700 | — | mV |
| $V_{UVLO\_SYS\_FALL}$ | $V_{BUS\_SYS}$ undervoltage lockout, $V_{BUS\_SYS}$ | $V_{BUS\_SYS}$ voltage falling from 7V to 5V | — | 2.65 | — | V |
| $t_{OVP\_RES}$ | OVP response time | Measured from OVP condition to MOSFET Turn Off. $V_{BUS\_CON}$ rises at 1V /100 ns (Notes 8) | — | — | 100 | ns |
| $t_{OVP\_RECOV}$ | Recovery time | Measured from OVP Clear to MOSFET Turn ON (Notes 9) | — | 15 | — | ms |
| **Switching Characteristics** | | | | | | |
| $R_{DS(on)}$ | Switch ON-resistance | $V_{BUS\_CON}$ = 5 V, $I_{OUT}$ = 1 A, $T_A$ = 25˚C | — | 39 | 50 | mΩ |
| **Digital Signals** | | | | | | |
| $V_{IH}$ | High-level input voltage, #EN | — | 1.2 | — | — | V |
| $V_{IL}$ | Low-level input voltage, #EN | — | — | — | 0.7 | V |
| $I_{IL}$ | Input leakage current, #EN | $V_I$ = 3.3V | — | — | 1 | µA |
| $V_{OL}$ | Low-level output voltage, #ACK | $I_{OL}$= 1 mA | — | — | 0.4 | V |
| **Timing Characteristics** | | | | | | |
| $t_{DELAY}$ | USB charging turn-on delay | Measured from #EN asserted Low to MOSFET Turn On, excluding soft-start time | — | 15 | — | ms |
| $t_{SS}$ | USB charging rise time (soft-start delay) | Measure from $V_{BUS\_SYS}$ rises above 25% until #ACK goes Low 10%, $R_{LOAD}$ = 1MΩ and $C_{LOAD}$ = NC | — | 18 | — | ms |
| $t_{OFF\_DELAY}$ | USB charging turn-off time | Measured from #EN asserted High to $V_{BUS\_SYS}$ falling to 10%, $R_{LOAD}$ = 10Ω and $C_{LOAD}$ =NC | — | 4 | — | ns |
| **Thermal Protection** | | | | | | |
| $T_{SHDN}$ | Thermal Shutdown | Junction temperature | — | 145 | — | °C |
| $T_{HYS}$ | Thermal Shutdown Hysteresis | Junction temperature | — | 35 | — | °C |

Notes: 6. Specifications are over -40ºC to +85ºC and are guaranteed by characterization and design.
7. Pulse-testing techniques maintain junction temperature close to ambient temperature; thermal effects must be taken into account separately.
8. Parameters provided for reference only, and do not constitute part of DIODES's published device specifications.
9. Excludes soft-start time.

## Timing Diagrams ($V_{BUS\_CON}$ = 5V, $C_{IN}$ = 1μF, $C_{LOAD}$ = 2.2μF, #EN = Enable, $T_A$=25°C.)

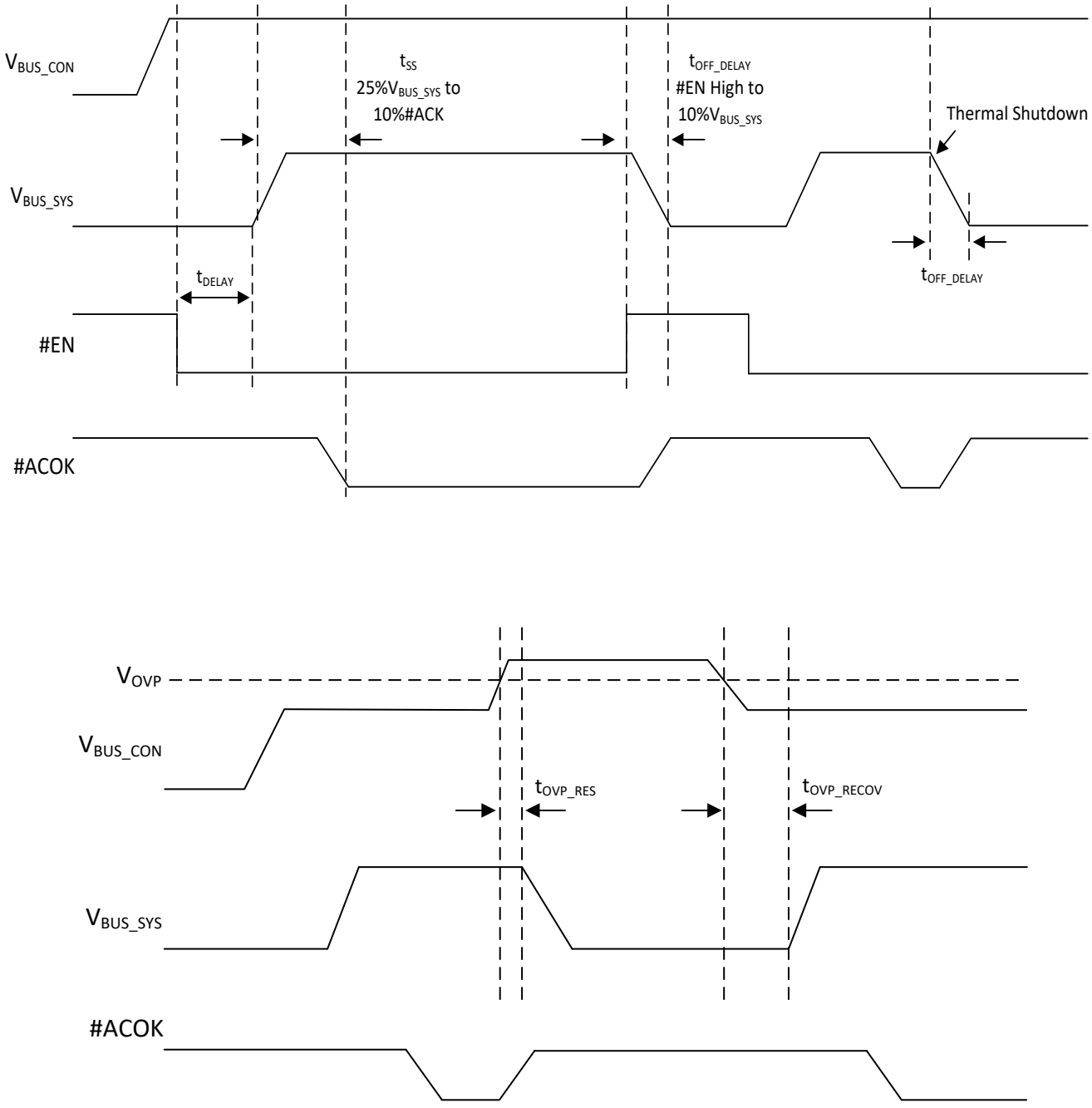
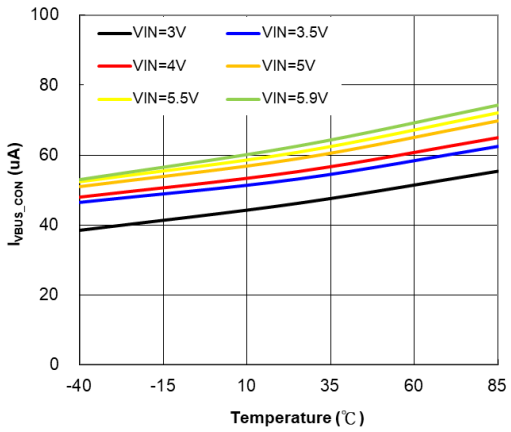


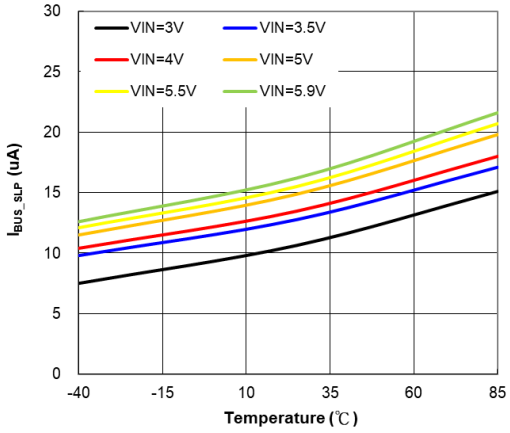

**Figure 1. Timing for Power up, Normal operation, OTP and OVP protection**

## Typical Performance Characteristics ($C_{IN}$ = 1µF, $C_{LOAD}$ = 2.2µF, unless otherwise specified.)

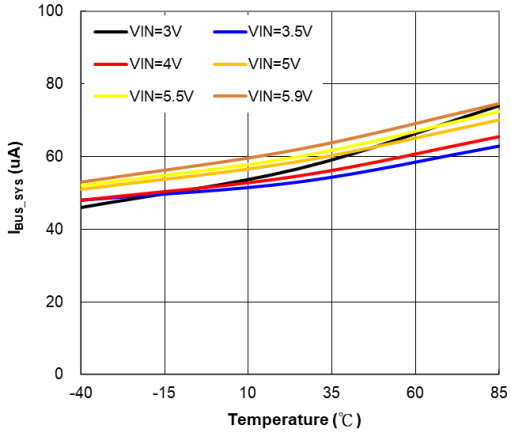
Input Operating Current vs. Temperature



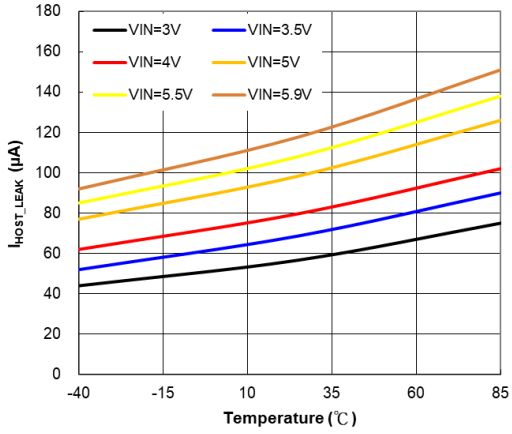

Input Sleeping Current vs. Temperature



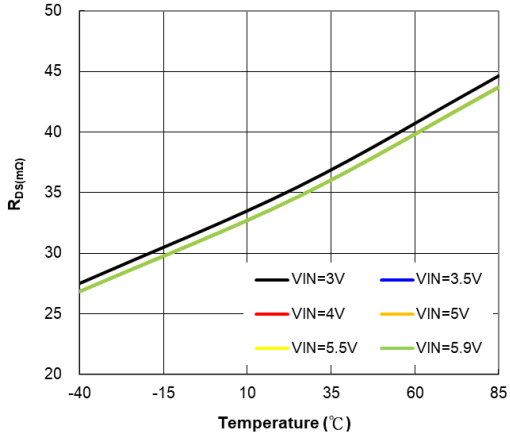

Output Operating Current vs. Temperature



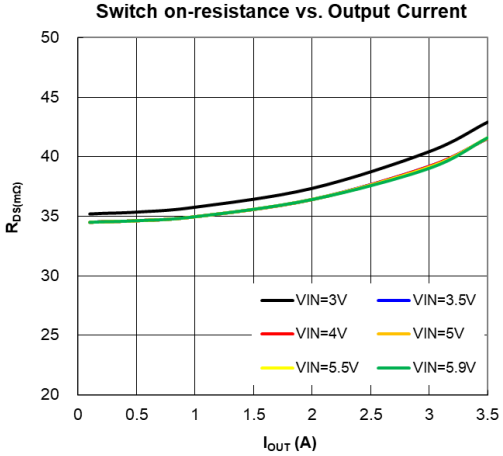

HOST Leakage Current vs. Temperature




Switch on-resistance vs. Temperature

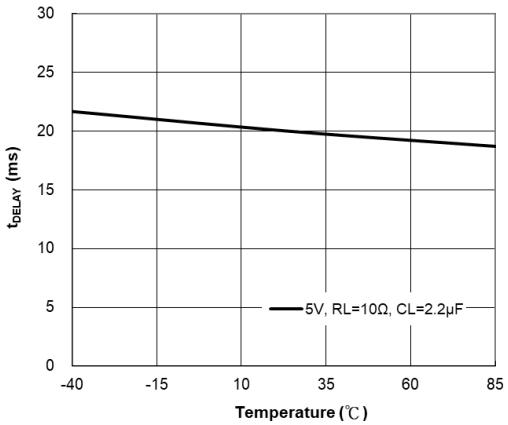



Switch on-resistance vs. Output Current

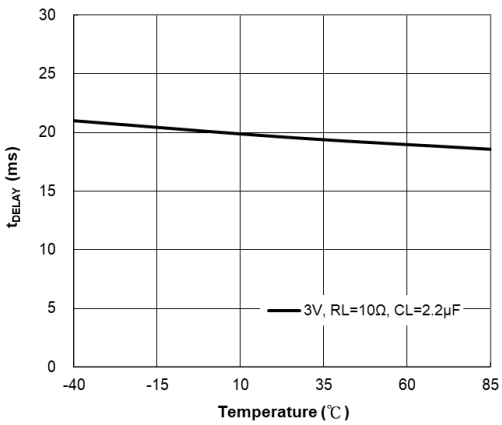


## Typical Performance Characteristics ($C_{IN}$ = 1µF, $C_{LOAD}$ = 2.2µF, unless otherwise specified.)

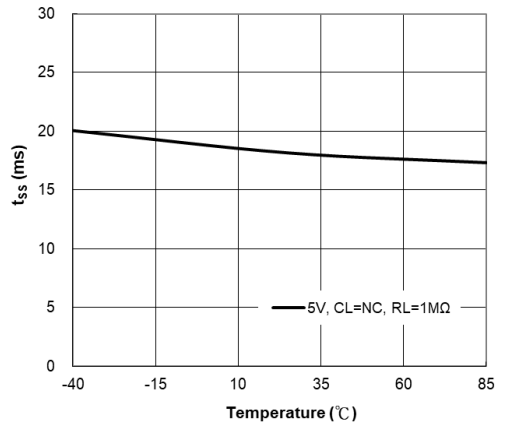
Turn On Delay Time vs. Temperature



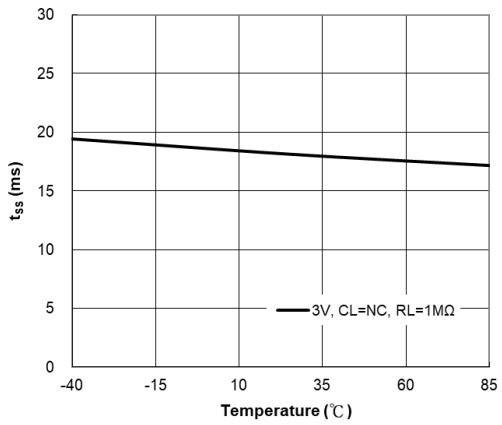

Turn On Delay Time vs. Temperature



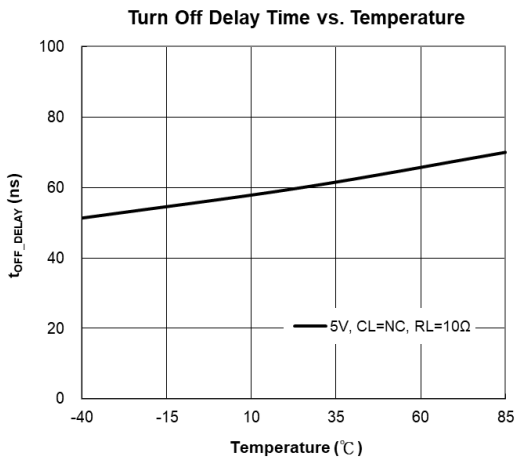

Soft-Start Delay Time vs. Temperature



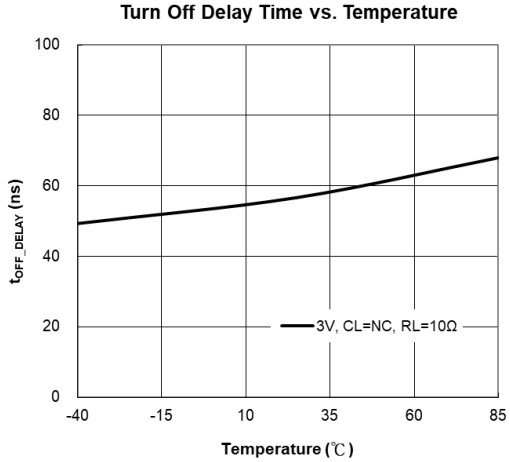

Soft-Start Delay Time vs. Temperature




Turn Off Delay Time vs. Temperature




Turn Off Delay Time vs. Temperature

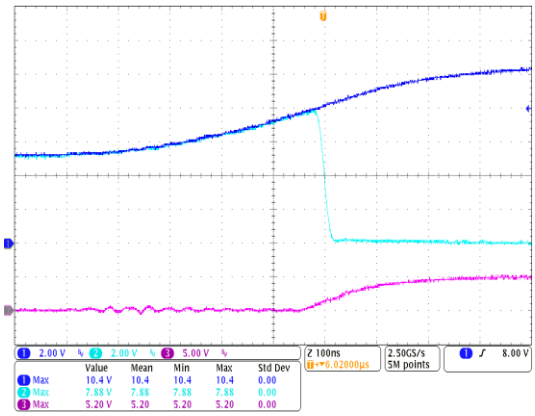


## Typical Performance Characteristics ($C_{IN}$ = 1µF, $C_{LOAD}$ = 2.2µF, unless otherwise specified.)

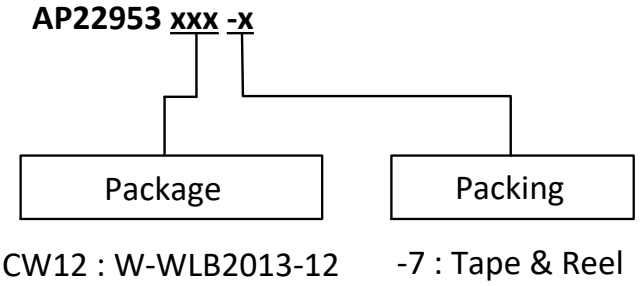
**OVP Response Time**

CH1 = $V_{BUS\_CON}$, CH2 = $V_{BUS\_SYS}$, CH3 = #ACK

$V_{BUS\ CON}$ ramp from 5V to 10V



## Ordering Information

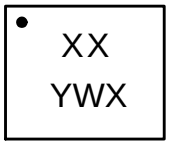



| Part Number | Package Code | Packaging | 7" Tape and Reel | |
|---|---|---|---|---|
| | | | Quantity | Part Number Suffix |
| AP22953CW12-7 | CW12 | W-WLB2013-12 | 3,000/Tape & Reel | -7 |

## Marking Information

**W-WLB1318-12**

**( Top View )**



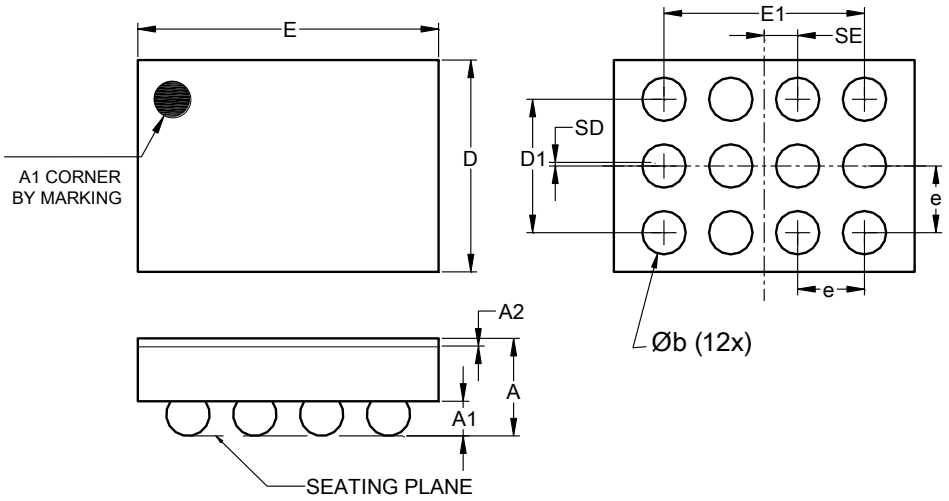

XX : Identification Code
Y : Year : 0~9
W : Week : A~Z : 1~26 week;
a~z : 27~52 week; z represents
52 and 53 week
X : Internal Code

| Part Number | Package | Identification Code |
|---|---|---|
| AP22953CW12-7 | W-WLB2013-12 | HW |

## Package Outline Dimensions

Please see https://www.diodes.com/design/support/packaging/ for the latest version.

**(1) Package Type: W-WLB2013-12**

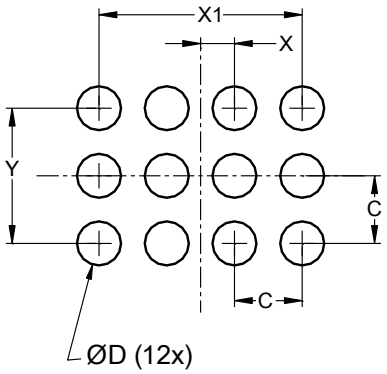



| W-WLB2013-12 | | | |
|---|---|---|---|
| **Dim** | **Min** | **Typ** | **Max** |
| **A** | 0.597 | 0.64 | 0.683 |
| **A1** | 0.182 | 0.202 | 0.222 |
| **A2** | 0.022 | 0.025 | 0.028 |
| **D** | 1.238 | 1.288 | 1.338 |
| **E** | 1.938 | 1.988 | 2.038 |
| **D1** | 0.750 | 0.800 | 0.850 |
| **E1** | 1.150 | 1.200 | 1.250 |
| **b** | 0.232 | 0.262 | 0.292 |
| **e** | 0.400 BSC | | |
| **SD** | 0.000 BSC | | |
| **SE** | 0.200 BSC | | |
| **All Dimensions in mm** | | | |

## Suggested Pad Layout

Please see https://www.diodes.com/design/support/packaging/ for the latest version.

**(1) Package Type: W-WLB1318-12**




| Dimensions | Value (in mm) |
|---|---|
| **C** | 0.400 |
| **D** | 0.230 |
| **X** | 0.200 |
| **X1** | 1.200 |
| **Y** | 0.800 |

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