Voltage Level Translation Guide

Auto-Direction Sensing
Direction Controlled
Application-Specific
Translation Guide

Table of Contents

Introduction

In today's complex and high-performance system environment, higher levels of functional integration have led to lower power consumption CMOS process technologies operating at lower supply voltage levels. The ability to mix, match and support the simultaneous use of different operating supply voltage levels on the same circuit board has led to the need for voltage-level translation.

To remedy this problem of logic-threshold incompatibility between the driver output thresholds and receiver input thresholds, a voltage-level translator device from Texas Instruments should be used to accomplish this.

To assist circuit design and system engineers with their operating speed and lower-operating voltage level-translation needs, Texas Instruments (TI) offers a comprehensive voltage translation portfolio including dual-supply level translators; auto-direction sensing translators for both push-pull buffered and open-drain applications; and hybrid application-specific translators optimized for today's constantly emerging signal standards. Translation devices are needed in various markets such as consumer electronics, portable, computing, and networking applications—wherever the need exists for voltage-level translation.

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Translation Guide

Single-Supply Translators

Single-Supply Translation Logic

AUP technology is the industry’s lowest-power logic technology designed. The SN74AUP1Txx is designed for logic-level translation applications with input switching levels that accept 1.8-V LVCMOS signals, while operating from either a single 3.3-V or 2.5-V VCC supply.

The SN74AUP1Txx with configurable logic function (57, 58, 97, 98) can be easily configured to perform a required gate function by connecting A, B, and C inputs to VCC or ground (see datasheet). Up to nine commonly used logic gate functions can be performed.

Get more information: ti.com/product/SN74AUP1Txx

Single-Power Supply Translator

SN74LVxTxx

SN74LVxTxx is designed for wide voltage range allowing generations of desired output levels to connect to controllers or processors. The output level is referenced to the supply voltage and is able to support 1.8 V/2.5 V/3.3 V CMOS levels.

The input is designed with a lower threshold circuit to match 1.8 V input logic at \(V_{\text{CC}} = 3.3 \text{ V}\) and can be used in 1.8 V to 3.3 V level up translation. In addition, the 5 V tolerant input pins enable down translation (e.g. 3.3 V to 2.5 V output at \(V_{\text{CC}} = 2.5 \text{ V}\)).

The SN74LV1T00 is designed with current-drive capability of 8 mA to reduce line reflections, overshoot, and undershoot caused by high-drive outputs.

Get more information: ti.com/product/SN74LVxTxx

Key Features

- Single-supply voltage \(1.8-5.0 \text{ V} V_{\text{CC}}\)
- Operating range of 1.8 V to 5.5 V
- Up translation
  - 1.2 V to 1.8 V; 1.8 V to 2.5 V
  - 1.8 V to 3.3 V; 3.3 V to 5.0 V
- Down translation
  - 3.3/2.5 V to 1.8 V; 5.0/3.3 V to 2.5 V
- \(-40^\circ\text{C}\) to \(125^\circ\text{C}\) operating temperature range
- Packages available: SC-70 (DCK)
  + 2 mm × 1.25 mm (DCK)
  + 2.9 mm × 1.6 mm (DBV)
- Supports standard logic pinouts

Applications

- Industrial controllers
- Telecom
- Portable applications
- Servers
- PC and Notebooks
- Automotive
Dual-Supply Translators

Five Classes of Voltage Translators

Auto-direction sensing translators for open-drain applications

Bidirectional multi-voltage for open-drain & push-pull translators

Dual-supply configurable translators

Auto-direction sensing translators

Bidirectional Voltage Translators

LSFO10x

Key Features

• Provides bidirectional voltage translation
• Less than 1.5 ns max propagation delay
• High speed translation > 100 MHz
• Supports hot insertion
• 5 V Tolerance I/O port to support TTL
• LowRon provides less signal distortion
• Flow-through pinout for ease PCB trace routing
• –40°C to 125°C operating temperature range
• ESD performance tested per JESD 22

Applications

• GPIO, MDIO, PMBus, SMBus, SDIO, UART, I2C, and other interfaces in telecom infrastructure
• Industrial
• Personal computing
• Automotive

Get more information: ti.com/product/LSF010x

GTL2014 4-Bit LVTTL to GTL Bidirectional Transceiver

SN74GTL2014

Key Features

• Operates as a GTL−/GTL+/GTL+ to LVTTL or LV TTL to GTL−/GTL+/GTL+ translator
• The LVTTL input are tolerant up to 5.5 V allowing direct access to TTL or 5V CMOS
• The GTL input/output operate up to 3.6 V, allowing the device to be used in high voltage open-drain applications
• VREF goes down to 0.5 V for low voltage CPU usage
• Partial power-down permitted
• Latch-up protection exceed 500 mA per JESD70
• ESD protection on all terminals
  ■ 2k V HBM, JESD22-A114
  ■ 1k V CDM, IEC61000-4-2

Applications

• Server
• Base station
• Wireline communication

Get more information: ti.com/product/SN74GTL2014

Dual-Supply Translators

Bidirectional Voltage Translators

Bidirectional Multi-Voltage Translator

LSF010x

The LSF family are bidirectional voltage level translators operational from 1.0 V to 4.5 V (VREF_A) and 1.8 V to 5.5 V (VREF_B). This allows bidirectional voltage translations between 1.0 V and 5.0 V without the need for a direction terminal in open-drain or push-pull applications. LSF family supports level translation applications with transmission speeds greater than 100 Mbps for open-drain systems utilizing a 30 pF capacitance and 2500 pull-up resistor.

The low Ron of the switch allows connections to be made with minimal propagation delay and signal distortion. Assuming the higher voltage is on the Bn port.

Key Features

• Provides bidirectional voltage translation
• Less than 1.5 ns max propagation delay
• High speed translation > 100 MHz
• Supports hot insertion
• 5 V Tolerance I/O port to support TTL
• Low Ron provides less signal distortion
• Flow-through pinout for ease PCB trace routing
• –40°C to 125°C operating temperature range
• ESD performance tested per JESD 22

Applications

• GPIO, MDIO, PMBus, SMBus, SDIO, UART, I2C, and other interfaces in telecom infrastructure
• Industrial
• Personal computing
• Automotive

Get more information: ti.com/product/LSF010x

GTL2014 4-Bit LVTTL to GTL Bidirectional Transceiver

SN74GTL2014

The SN74GTL2014 is a 4-bits translator to interface between 3.3-V LVTTL chip set I/O and Xeon processor GTL−/GTL/GTL+ I/O. The SN74GTL2014 integrates ESD protection cells on all terminals and is available in a TSSOP package (5.0 mm × 4.4 mm). The device is characterized over the free air temperature range of –40°C to 85°C.

Key Features

• Operates as a GTL−/GTL+/GTL+ to LVTTL or LV TTL to GTL−/GTL+/GTL+ translator
• The LVTTL input are tolerant up to 5.5 V allowing direct access to TTL or 5V CMOS
• The GTL input/output operate up to 3.6 V, allowing the device to be used in high voltage open-drain applications
• VREF goes down to 0.5 V for low voltage CPU usage
• Partial power-down permitted
• Latch-up protection exceed 500 mA per JESD70
• ESD protection on all terminals
  ■ 2k V HBM, JESD22-A114
  ■ 1k V CDM, IEC61000-4-2

Applications

• Server
• Base station
• Wireline communication

Get more information: ti.com/product/SN74GTL2014
Dual-Supply Translators

Auto-Direction Sensing Translators Portfolio

TI's auto-direction sensing translation devices are ideal for point-to-point topologies when interfacing devices may be operating at different interface voltage levels. They improve connectivity between next-generation processors and peripheral devices by eliminating the requirement for direction-control signals used by traditional voltage-level translation devices. This decreases the control software complexity while saving valuable GPIO signals on core processors.

Bidirectional, Auto-Direction Sensing Translators with 0.9 V Support

TXB010x

These non-inverting translators use two separate configurable power-supply rails. As voltage signals levels continue to decrease, a new set of low-voltage-level translators are needed. This is the reason why the TXB010x family of low-voltage auto-direction sensing translators were made.

When the output-enable (OE) input is low, all outputs are placed in the high-impedance state. To ensure the high-impedance state during power up or power down, OE should be tied to GND through a pulldown resistor; the minimum value of the resistor is determined by the current-sourcing capability of the driver. The TXB010x family is designed so that the OE input circuit is supplied by V(0)C. The devices are fully specified for partial-power-down applications using I(O)P. The I(O)P circuitry disables the outputs, preventing damaging current backflow through the device when it is powered down.

To ensure the high-impedance state during power up or power down, OE should be tied to GND through a pulldown resistor; the minimum value of the resistor is determined by the current-sourcing capability of the driver.

Key Features
- Auto-direction sensing — no direction control signal needed
- Automatic reconfigurable I/O buffers — each I/O port is configured as both an input and an output
- Integrated pull-up resistors — provides modest DC-bias and current sourcing capabilities while saving BOM costs
- Output slew-rate control circuitry — edge-rate accelerator circuitry detects and speeds up AC-transitions to maintain fast data rate throughput
- VCC isolation feature — if either VCC input is at GND, all outputs are in the high-impedance state
- Highly integrated ESD protection — ±15-kV ESD protection on the B port

Applications
- Cell phones
- Tablets
- Portable GPS devices
- Bluetooth® headsets
- General portable consumer applications
- Computing
- Industrial
- Telecom

Get more information: ti.com/product/TXB010x

Bidirectional, Auto-Direction Sensing Translators for Open Drain Applications

TXS010x

These non-inverting translators use two separate configurable power-supply rails. The A port is designed to track VCCA. VCCA accepts any supply voltage from 1.2 V to 3.6 V. The B port is designed to track VCCB. VCCB accepts any supply voltage from 1.65 V to 5.5 V. This allows for universal low-voltage bidirectional translation between any of the 1.2-V, 1.5-V, 1.8-V, 2.5-V, 3.3-V, and 5-V voltage nodes. VCCA should not exceed VCCB.

When the output-enable (OE) input is low, all outputs are placed in the high-impedance state. This device is fully specified for partial-power-down applications using I(O)P. The I(O)P circuitry disables the outputs, preventing damaging current backflow through the device when it is powered down.

To ensure the high-impedance state during power up or power down, OE should be tied to GND through a pulldown resistor; the minimum value of the resistor is determined by the current-sourcing capability of the driver.

Key Features
- Optimized for push-pull drivers
- 100 Mbps max data rate transfer
- VCC isolation feature
- OE input circuit referenced to VCCA
- Low power consumption
- I(O)P supports operation in partial-power-down mode
- 1.2 V to 3.6 V on A-port and 1.65 V to 5.5 V on B-port (VCCA ≤ VCCB)

Applications
- Cell phones
- SPI and GPIO level translation
- Computing
- Industrial
- Automotive

Get more information: ti.com/product/TXS010x

Texas Instruments
Dual-Supply Bus Transceiver with Configurable Voltage Translation and 3-State Outputs

**SN74AVC2T244/SN74AVC4T234**

These devices are designed for asynchronous communication between data buses. The devices transmit data from the A bus to the B bus or from the B bus to the A bus, depending on the logic level at the direction-control (DIR) input.

**Key Features**
- 380 Mbps max data rate
- Control input levels, VIH/VIL, are referenced to VCCCA voltage
- Fully configurable dual-rail design allows each port to operate over full 1.2-V to 3.6-V power-supply range
- IOL supports operation in partial-power-down mode

**Applications**
- Handsets
- PDAs
- Computing
- Smartphones
- Industrial
- Telecom
- Automotive

Get more information: ti.com/product/SN74AVC2T244

Get more information: ti.com/product/SN74AVC4T234
Dual-Supply Translators

Application Specific Translators

SD Card, Memory Stick, and MMC Voltage-Translation Transceivers with ESD Protection and EMI Filtering

**TXS0206, TXS0206A, TXS0206-29**

Memory card standards recommend high-ESD protection for devices that connect directly to the external memory card. To meet this need, these devices incorporate ±8-kV Contact Discharge protection on the card side.

**Key Features**
- Voltage-translation transceiver for memory card interfaces (SD, Mini SD, MMC)
- Fully configurable dual-voltage supply architecture with both $V_{CCA}$ and $V_{CCB}$ operating range of 1.1 V to 3.6 V
- Six bidirectional channels capable of passing 60 Mbps data rates with 3 ns typical prop-delay
- No direction control needed on data/command paths
- Integrated pull-up resistors on card-side I/Os per SD specification
- SDIO-compliant integrated smart pull-up resistors — enables output drivers to maintain modest DC-bias current sourcing capabilities while maintaining low static power consumption
- Voltage-translation transceiver for SD/MMC card-side I/Os per SD specification

**Applications**
- Mobile phones
- PDAs
- Digital cameras
- Personal media players
- Camcorders
- Set-top boxes

Get more information: ti.com/product/TXS0206-29

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SDIO Port Expander with Voltage-Level Translation

**TXS02612**

The TXS02612 is designed to interface the cell phone baseband with external SDIO peripherals. The device includes a 6-channel SPDT switch with voltage-level translation capability. This allows a single SDIO port to be interfaced with two SDIO peripherals. The TXS02612 has three separate supply rails that operate over the full range of 1.1 V to 3.6 V. This allows the baseband and SDIO peripherals to operate at different supply voltages if required. The high-performance ESD protection is designed for external memory card interface.

**Key Features**
- 1.1-V to 3.6-V range
- 6-to-12 demultiplexer/multiplexer allows SDIO port expansion
- Built-in level translator eliminates voltage mismatch between baseband and SDIO peripheral
- ±8-kV contact discharge IEC 61000-4-2 ESD performance (B Port)

**Applications**
- Personal electronics
- Computing
- Server

Get more information: ti.com/product/TXS02612

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Dual-supply SIM Card Translator and 2:1 Multiplexer

**TXS02326**

The TXS02326 is a dual-supply SIM card solution for interfacing wireless baseband processors with two SIM cards. The 2:1 multiplexer function extends the single SIM card interface to support two SIM cards. The dual-supply voltage translation function supports 1.7 V to 3.3 V range on the processor side and either 1.8 V or 2.95 V on the SIM side. The two SIM card interface standards, Class-B (2.95 V) and Class-C (1.8 V) are supported by two integrated low-dropout (LDO) voltage regulators with selectable outputs. An integrated 400 kb/s I²C interface offers several configuration options, including safe power-down of the two SIM cards.

**Key Features**
- Dual-supply translator with voltage range of 1.7 V to 3.6 V
- 2:1 multiplexer function enables the use of a single SIM card interface to control two SIM cards
- Integrated dual-LDOs enable support of 1.8 V and 2.95 V SIM card standards

**Applications**
- Baseband processors
- Smart phones
- Netbooks

Get more information: ti.com/product/TXS02326
### Dual-Supply Translators

#### Translators by Application

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<thead>
<tr>
<th>Device</th>
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#### Dual-Supply Translators

#### Translators by Bit Count

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<th>Device</th>
<th>VCC Min. to Max. (V)</th>
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**Translation Guide 2014**  
Texas Instruments
Single and Dual Supply Translators
Translators by Bit Count

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**Additional Translators**

**FET Switches**

Devices from TI’s CBT, CBTD, CB3T and TVC families can be used in level-translation applications. The diagram shows a CB3T bus switch interfacing a 3-V bus with a 5-V (TTL) bus. The CB3T device down-translates the signals from the 5-V bus to 3-V levels.

No translation is necessary to transfer signals from the 3-V bus to the 5-V (TTL) bus, since the VCC level from the CB3T switch is greater than the required VIL of the 5-V (TTL) devices connected to the 5-V bus.

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**Overvoltage-Tolerant Devices and TTL-Compatible Inputs and Open-Drain Output Devices**

**Overvoltage-Tolerant Devices**

Devices with overvoltage-tolerant inputs can be used to perform down-translation as shown in the diagram. Logic families with overvoltage-tolerant inputs include:
- AHC
- LVC
- AUC
- AVC

**Advantages**
- Only one supply voltage needed
- Broader portfolio of HCT, AHCT, ACT and AUP families

**Devices with TTL-Compatible Inputs**

Up-translation from 3.3-V LVCMOS/ LVTTL to 5-V CMOS levels can be achieved with logic devices from TI’s HGT, AHCT, ACT and AUP families.

**Advantages**
- Only one supply voltage needed
- Broader portfolio of HCT, AHCT, ACT and AUP devices

**Devices with Open-Drain Outputs**

Devices with open-drain outputs can be used to perform both up-translation and down-translation. The output voltage is determined by VCCB. The output level can be higher than VCCB (up-translation) or lower than VILCCB (down-translation).

**Advantages**
- Flexibility in translating to/from a variety of voltage nodes

---

**Overvoltage-Tolerant Devices**

Advantages
- Broad portfolio of AHC, AUC, AVC, LV-A and LVC devices

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