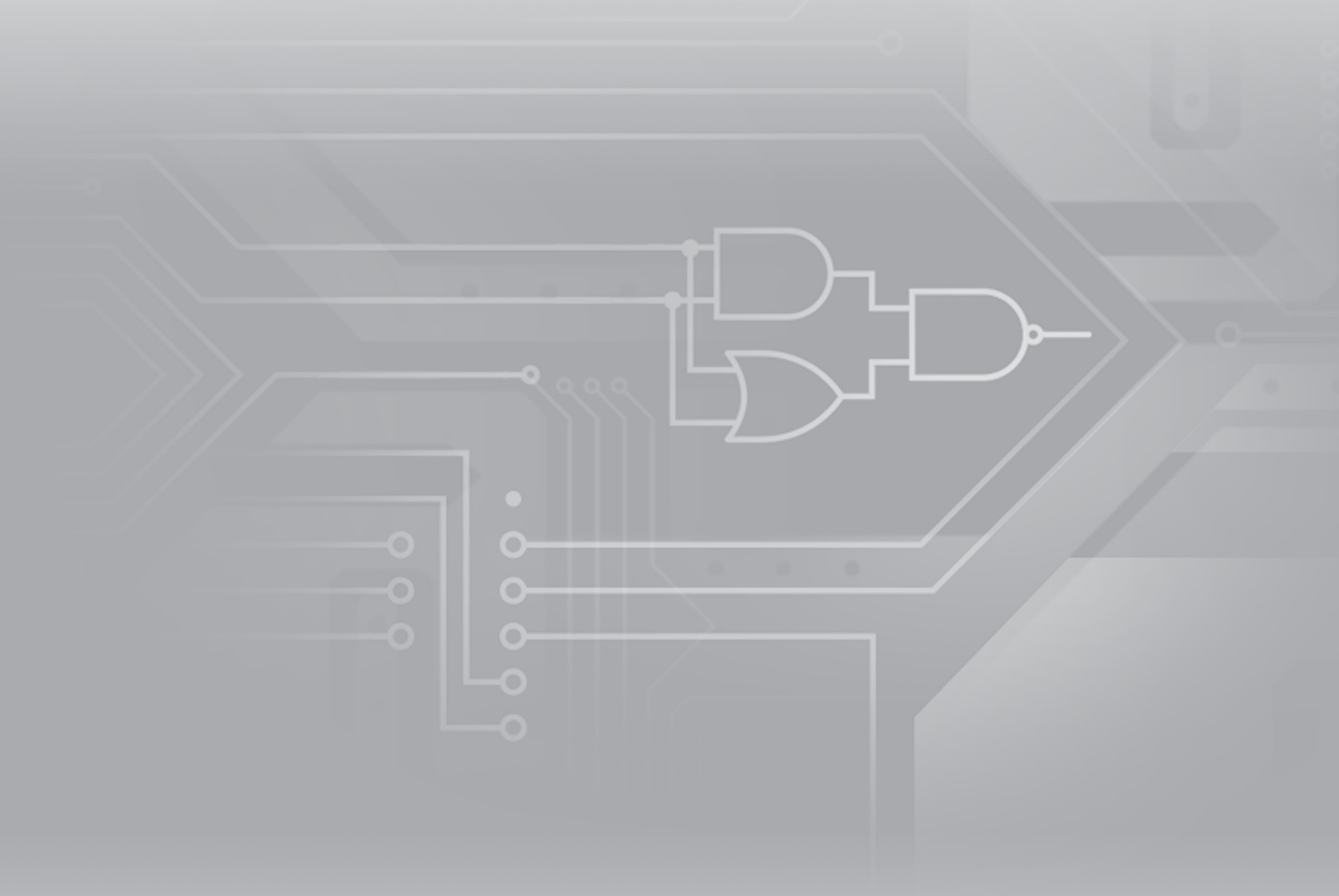
Voltage Translation Buying Guide

Auto-Direction Sensing • Direction Controlled • Application-Specific

Texas Instruments



ti.com/voltage-level-translation | Q3 2019

Table of Contents/Overview Voltage Translation Buying Guide

What class of voltage translator should I use!?

Know your interface? Jump to our quick selection table.

TI offers a wide range of voltage translators to fit the needs for a system's design. The portfolio is broken into three main classes: Direction Controlled, Auto Bi-Directional, and Uni-Directional.

When to use a direction-controlled translator?

Direction-controlled translators are the most flexible, easy-of-use, and offer the best signal integrity. They are best for one-to-one communication between devices such as RGMII, and with protocols featuring one master that determines when devices will transmit on the bus; such as in SPI and UART. Search direction controlled on ti.com | **Skip to the direction-controlled overview.**

When to use an auto bi-directional translator?

Some interfaces require that the I/O pins of each device be open-drain or open-collector so that any device can start to transmit on the bus. This is typically required for multi-master, multi-slave protocols; such as I^2C and SMBUS. Auto bi-directional voltage translators can 'auto-sense' the intended direction of communication and operate accordingly; however these translators are slower and have less drive strength compared to other classes of translators. Search auto bi-directional on ti.com | **Skip to the auto-directional overview.**

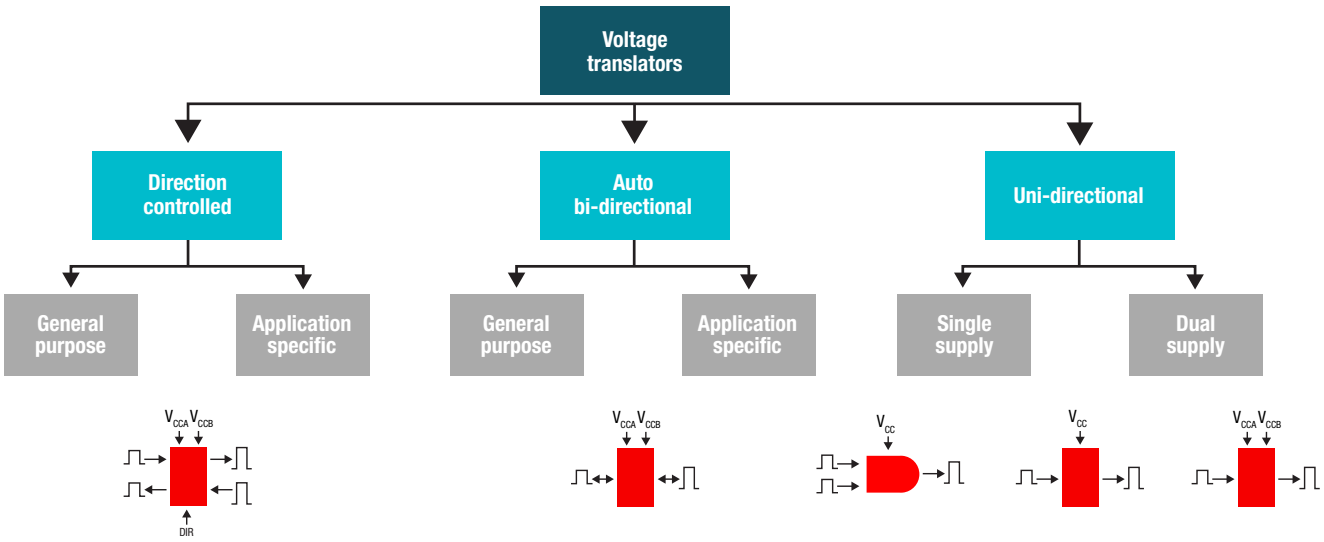
When to use a uni-directional translator?

As their name suggested, uni-directional translators are best when transmitted signals only need to go one direction. Typical examples are reset signals and clock synchronization signals. Search uni-directional on ti.com | **Skip to the uni-directional overview.**

Introduction

To help system designers interconnect devices operating on different voltage rails that have different IO voltage levels, 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 can be found in almost every market, including: consumer electronics, portable electronics, computing, automotive, industrial and networking applications. Wherever the need exists to interface lower operating processors with higher operating peripherals.



Direction Controlled Translators

Direction Controlled translators performs non-inverting up or down translation of a uni-directional signal. These translators have one or more direction control pins that allow the designer to configure which pins are inputs and outputs. This enables simultaneous up and down translation on one device and gives the user more flexibility.

Many devices within this class are available with Bus Hold, which allows the device to retain the last known state of the output when the inputs are floating or become high impedance. Bus Hold feature is indicated by "H" in the part number. More info about bus-hold circuits.

Benefits of Direction Controlled:

- Buffered output for high drive strength
- One or more direction control pins
- Devices available that have been optimized for common interfaces
- Bus Hold functionality available

Auto Bi-Directional Translators

Auto Bi-Directional translators are a class of voltage translators, which are available in dual supply configurations. Yet unlike the direction controlled translators they automatically sense the direction of the signal without the need for a direction control pin.

Across the three families within the class there are a number of trade-offs including drive-strength, data rate, and multi-voltage translation. The wide range of available functionalities gives the designer a number of parts to choose from TI's portfolio to suit their needs.

Benefits of Auto Bi-Directional:

- Works with bi-directional signals
- Devices available that have been optimized for common interfaces
- Works with both open-drain and push-pull interfaces
- Design flexibility with external pull-up resistors

Uni-Directional Translators

This class of translators performs a single direction, non-inverting up or down translation of an incoming signal at the input of a device to the output of the device.

Single supply translators only have one supply voltage, which provides the reference level for the output to track. Single supply translators include translating buffers, as well as translating logic gates. Translating logic gates have built-in logic functionality, and at the same time perform up or down voltage translation. Dual supply translators have two supply voltages, one at the V_{CC} level of the input signal, the other at the V_{CC} level of the output signal.

Benefits of Uni-Directional:

- Single supply translators provide simplicity in system design
- Dual supply translators provide dynamic operating range for voltage translation
- Voltage translating logic gates achieve two functions in one chip

Overview of device families

Family	AXC	AVC	LVC	LSF	TXB	TXS	AUP	LV1T
Class	Direction controlled			Auto directional			Uni-directional	
Interfaces supported	Push-Pull			Open-drain or push-pull	Push-pull	Open-drain	Push-pull	
V_{CC} (V)	0.65 – 3.6	1.2 – 3.6	1.65 – 5.5	0.9 – 5.5	1.2 – 5.5	1.2 – 5.5	0.9 – 3.6	1.65 – 5.5
Drive strength (mA)	12	12	32	—	0.02	0.02	4	8
Max data rate (Mbps)	380	340	300	200	140	100	380	100
Max bits	8	32	16	8	8	8	1	1

Select by interface					
Interface	2 Ch	4 Ch	6 Ch	8 Ch	16 Ch
SPI	—	SN74AXC4T774 TXB0104	—	SN74AXC8T245	SN74AVC16T245
UART	—	SN74AXC4T774 TXB0104	—	SN74AVC8T245 SN74AXC8T245	SN74AVC16T245
JTAG	—	SN74AXC4T774 TXB0104	—	SN74AXC8T245	SN74AVC16T245
I^2S	—	TXB0104 SN74AXC4T245	—	SN74AXC8T245	SN74AVC16T245
I^2C	TXS0102 LSF0102	TXS0104E LSF0204	—	TXS0108E LSF0108	—
MDIO	TXS0102 LSF0102	TXS0104E LSF0204	—	TXS0108E LSF0108	—
SMBus	TXS0102 LSF0102	TXS0104E LSF0204	—	TXS0108E LSF0108	—
RMII/RGMII	—	—	TXB0106	SN74AXC8T245	SN74AVC16T245
Quad-SPI	—	—	TXB0106	—	—
SDIO	—	LSF0204	—	LSF0108	—

Direction Controlled Translators .65 V—3.6 V

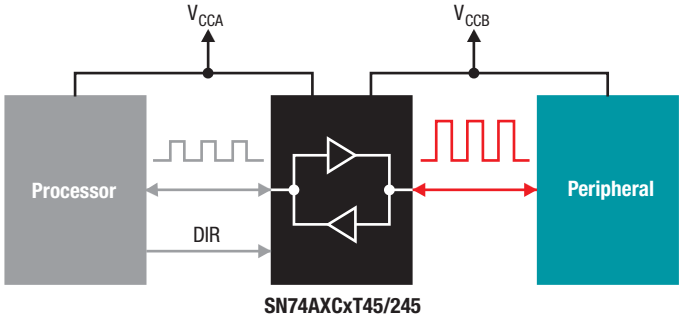
General Purpose

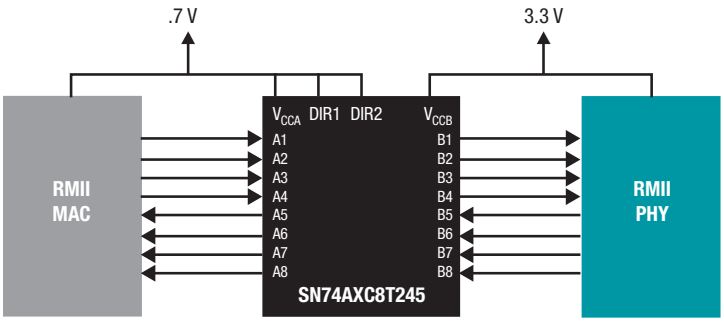
AXC Family I Search AXC on TI.com

The AXC direction controlled level translation family is the newest addition to TI's selection of direction controlled voltage translators. Designed for an ultra-low V_{CC} range between 0.65 V to 3.6 V, making it the lowest voltage level translator available in the industry. This allows the device to communicate with advance processors operating at low voltage nodes of 0.7 V, 0.8 V or 0.9 V. The wide V_{CC} range also accommodates the industry standard voltage nodes 1.2 V, 1.8 V, 2.5 V, and 3.3 V still commonly found in processors and peripherals.

The 4-bit and 8-bit device features a second direction control pin allowing two independent banks of buses, 2-bit and 4-bit respectively, on one device. This allows more control in how the device can be used through simultaneous up and down translation and, ideally, reduces the BOM count. Additionally these devices include an output enable pin, to put all outputs in a high impedance state which also reduces power consumption.

All devices in the family were rigorously designed to ensure glitch free power sequencing across hundreds of possible start up or shut down conditions. This allows either supply rail to be powered on or off, in any order without causing a glitch at the output. To learn more on independent power supply sequencing read our Application Report on Power Sequencing for AXC Family Devices.





Key features

- Fully configurable rails – each V_{CC} rail is fully configurable from 0.65 V to 3.6 V
- Up to 380 Mbps data rate support
- V_{CC} isolation – if either V_{CC} is at ground, all inputs and outputs enter a high impedance state
- I_{OFF} supports operation in partial-power-down mode
- Independent power supply sequencing

Benefits

- Wide V_{CC} range enables communication with most advance processors and FPGAs
- High data rate while supporting lower voltages
- Glitch free performance ensures system reliability on power-up and power-down

Package options

- X2SON
- SOT-5X3
- SOT-23
- TSSOP
- SC70
- VQFN

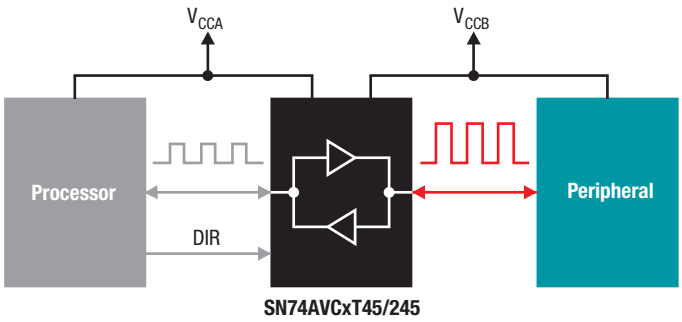
Applications

- Data center switches
- Baseband unit & remote radio unit
- Server motherboards
- IP camera
- Programmable logic controller
- Notebook PC's
- Enterprise SSD
- Infotainment & cluster
- ADAS

AVC Family I Search AVC on TI.com

The **AVC family** of voltage translators use two separate configurable power supply rails to enable asynchronous communications between A and B data ports, or vise-versa depending on the direction pin. The A port is designed to track V_{CCA} while the B port is designed to track V_{CCB}. Both V_{CCA} and V_{CCB} are configurable from 1.2 V to 3.6 V.

These devices are fully specified for partial-power-down applications using I_{OFF}. The I_{OFF} circuitry disables the outputs, preventing damaging current backflow through the device when it is powered down.



Popular devices	Bits	V_{CCA} range	V_{CCB} range	Data rate (Mbps)
SN74AVC1T45	1	1.2 – 3.6	1.2 – 3.6	500
SN74AVC8T245	8	1.2 – 3.6	1.2 – 3.6	320
SN74AVC32T245	32	1.2 – 3.6	1.2 – 3.6	320

Key features

- 500 Mbps max data rate on 1T/2T and 320 Mbps on 8T and higher
- Control input levels, V_{IH}/V_{IL}, are referenced to V_{CCA} voltage
- Fully configurable dual-rail design allows each port to operate over full 1.2 V to 3.6 V power-supply range
- I_{OFF} supports operation in partial-power-down mode
- V_{CC} isolation ensure that if either V_{CC} input is at ground both ports are in high impedance

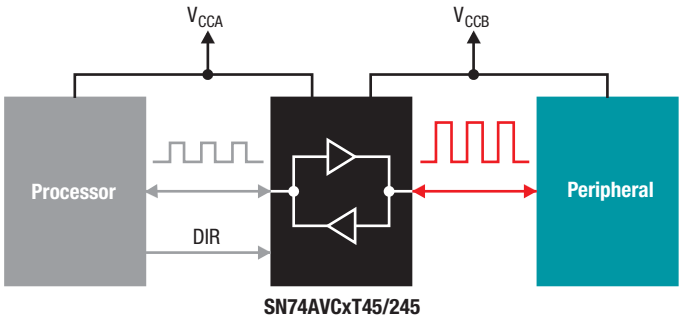
Package options

- DSBGA
- SC70
- SM8
- SOT-23
- SOT
- TSSOP
- TVSOP
- UQFN
- VQFN
- US8
- BGA MicroStar Junior™

LVC Family I Search LVC on TI.com

The LVC family of non-inverting voltage translators use two separate configurable power supply rails to enable asynchronous communications between A port inputs and B port outputs, or vise-versa depending on the direction pin. The A port is designed to track V_{CCA} while the B port is designed to track V_{CCB}. Both V_{CCA} and V_{CCB} are configurable from 1.65 V to 5.5 V.

These devices were designed to have high drive strength, of up to 32 mA, while maintaining low static and dynamic power consumption.



SN74AVCxT45/245

Popular devices	Bits	V_{CCA} range	V_{CCB} range	Data rate (Mbps)
SN74LVC1T45	1	1.65 – 5.5	1.65 – 5.5	420
SN74LVC8T245	8	1.65 – 5.5	1.65 – 5.5	320
SN74LVC16T245	16	1.65 – 5.5	1.65 – 5.5	320

Key features

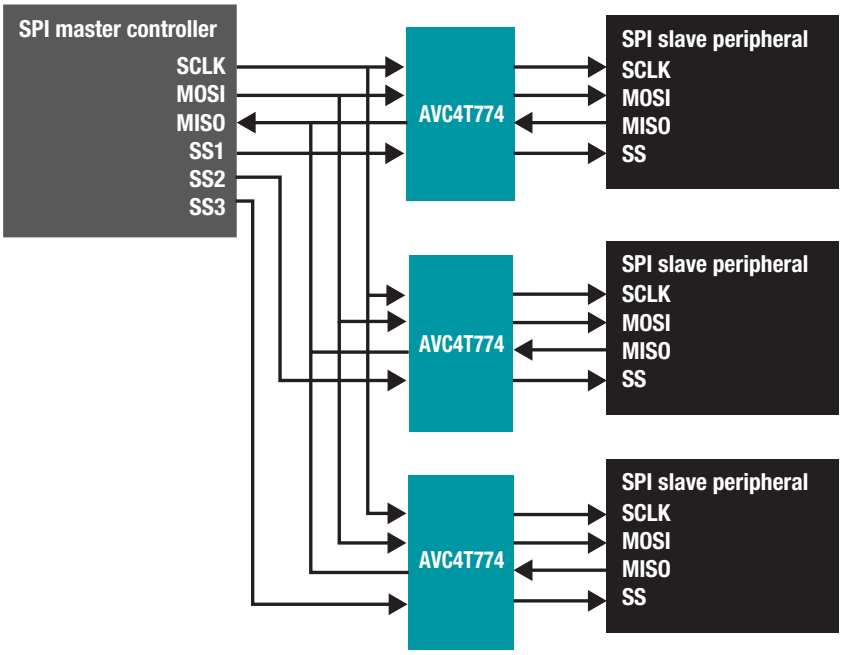
- High drive ability, up to 32 mA of current
- Up to 420 Mbps max data rate on 1T/2T
- Control input levels, V_{IH}/V_{IL}, are referenced to V_{CCA} voltage
- Fully configurable dual-rail design allows each port to operate over full 1.65 V to 5.5 V power-supply range
- I_{OFF} supports operation in partial-power-down mode
- V_{CC} isolation ensure that if either V_{CC} input is at ground both ports are in high impedance

Package options

- SO
- SOIC
- SSOP
- TSSOP
- TVSOP
- SC70
- VSSOP
- VQFN
- SM8
- DSBGA
- BGA MicroStar Junior™

Application Specific I Search Application Specific solutions on TI.com

TI's portfolio of direction controlled translators includes devices that have been optimized for use in common communication interfaces used by processors and peripherals. Direction controlled translators are best suited for interfaces where the direction of each data line is fixed, such as SPI or UART. If the data lines are bi-directional it is best to go with an auto bi-directional voltage translator such as TXS, TXB or LSF.



Popular devices	Interface	Bits	V_{CCA} range	V_{CCB} range
SN74AVC4T774	SPI	4	1.2 – 3.6	1.2 – 3.6
SN74AVCA406	SD & MMC	7	1.2 – 3.6	1.2 – 3.6
SN74AVC2T872	IC – USB	2	1.1 – 3.6	1.1 – 3.6

Interfaces supported

- SPI
- UART
- JTAG
- RMII/RGMII
- I^2S
- C-USB
- Audio
- SD/MMC

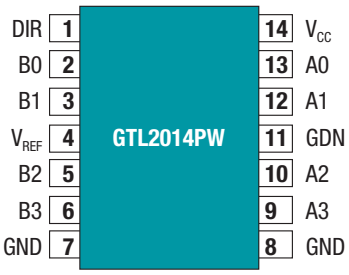
GTL/TTL Translators I Search GTL/TTL Translators on TI.com

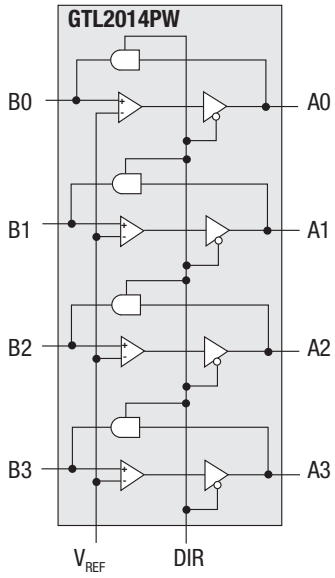
This class of voltage translators includes the GTL and GTLP families as well as the legacy FB and TTL families. These devices were designed to allow communication between Low Voltage Transistor Transistor Logic (LVTTL) and Gunning Transceiver Logic (GTL) interface levels. These devices have reduced voltage swing that allows them to have a fast data rate, high drive strength and low noise. GTL devices are best suited for backplane bus translation with most of the Intel® processors.

These devices come in both direction controlled and auto bi-directional configurations. Additionally a number of the parts within this class are specifically designed for common interfaces.

Package options

- TSSOP
- SC70
- HLQFP
- QFP
- SSOP
- SOIC
- TVSOP





Popular devices	Bits	V_{CC} range	V_{REF} range	Class
SN74GTL2014	4	3.0 – 3.6	0.5 – 1.65	Direction controlled
SN74GTL2003	8	0.95 – 5.5	0.95 – 5.5	Auto bi-directional
SN74GTL2007	12	3.0 – 3.6	0.5 – 1.8	Auto bi-directional

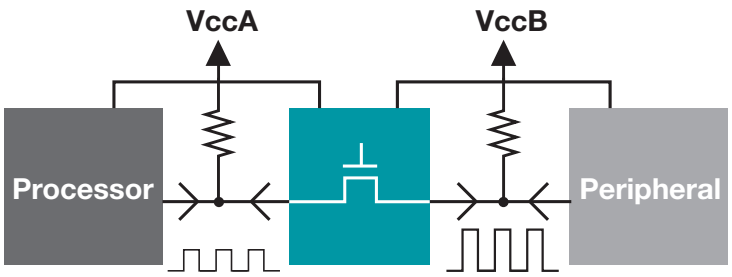
General Purpose

LSF Family I Search LSF on TI.com

The **LSF family** are bidirectional voltage level translators operational from 0.8 V to 4.5 V (V_{REF}_A) and 1.8 V to 5.5 V (V_{REF}_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 15 pF capacitance and 200 Ω pull-up resistor.

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

Voltage translation with the LSF family



Popular devices	Bits	V_{CCA} range	V_{CCB} range	Data rate (Mbps)
LSF0101	1	0.95 – 5.0	1.65 – 5.0	200
LSF0204	4	0.8 – 4.5	1.8 – 5.5	200
LSF0108	8	0.95 – 5.0	1.65 – 5.0	200

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 R_{ON} reduces signal distortion
- Flow-through pinout for easy PCB routing
- ESD performance tested per JESD 22

Package options

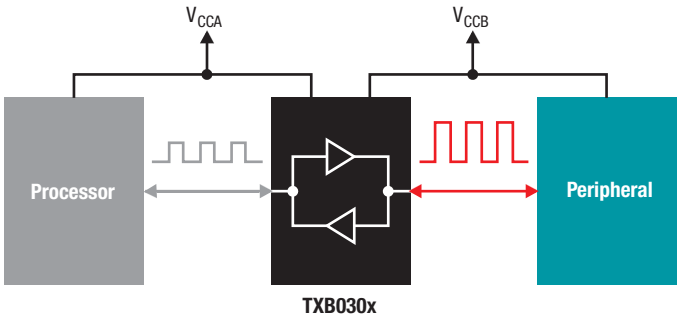
- VSSOP
- TSSOP
- DSBGA
- UQFN
- VQFN
- SM8
- X2SON
- SON

TXB Family I Search TXB on TI.com

The **TXB family** of non-inverting translators uses two separate configurable power-supply rails to enable bi-directional translation. In the TXB010x family, the A port is designed to track V_{CCA}. V_{CCA} accepts any supply voltage from 1.2 V to 3.6 V. The B port is designed to track V_{CCB}. V_{CCB} accepts any supply voltage from 1.65 V to 5.5 V.

The TXB030x family of devices functions similar to the TXB010x; however TXB030x has fully symmetrical supply voltages, accepting .9 V to 3.6 V on both supply ports.

A guide to voltage translation with TXB-type translators



Popular devices	Bits	V_{CCA} range	V_{CCB} range	Data rate (Mbps)
TXB0102	2	1.2 – 3.6	1.65 – 5.5	100
TXB0302	2	0.9 – 3.6	0.9 – 3.6	140
TXB0108	8	1.2 – 3.6	1.65 – 5.5	100

Key features

- Optimized for push-pull interfaces
- 140 Mbps max data rate
- Output Enable (OE) input circuit referenced to V_{CCA}
- Low power consumption
- TXB010x: 1.2 V to 3.6 V on A-port and 1.65 V to 5.5 V on B-port ($V_{CCA} \leq V_{CCB}$)
- TXB030x: 0.9 V to 3.6 V on both A-Port and B-Port

Package options

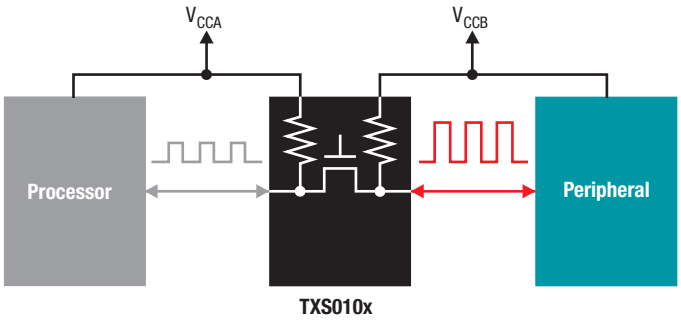
- X2SON
- UQFN
- TSSOP
- VQFN
- DSBGA
- SC70
- SOT-23
- SOT-5X3
- SOIC
- BGA MicroStar Junior™

TXS Family I Search TXS on TI.com

The **TXS family** of non-inverting auto bi-directional translators uses two separate configurable power-supply rails. The A port is designed to track V_{CCA}. The B port is designed to track V_{CCB}. V_{CCA} must be less than or equal to V_{CCB}. This allows for low-voltage bidirectional translation between any of the 1.8 V, 2.5 V, 3.3 V, and 5 V voltage nodes.

One-shot circuitry inside the device helps in rise and fall time edge acceleration.

A guide to voltage translation with TXS-type translators



Popular devices	Bits	V_{CCA} range	V_{CCB} range	Data rate (Mbps)
TXS0101	1	1.65 – 3.6	2.3 – 5.5	24
TXS0104E	4	1.65 – 3.6	2.3 – 5.5	24
TXS0108E	8	1.2 – 3.6	1.65 – 5.5	110

Key features

- Works with both open-drain and push-pull drivers
- Max data rates
  - 24 Mbps (push-pull)
  - 2 Mbps (open-drain)
  - 110 Mbps for TXS0108E
- 1.65 V to 3.6 V on A-port and 2.3 V to 5.5 V on B-port ($V_{CCA} \leq V_{CCB}$)
- TXS0108: 1.2 V to 3.6 V on A-port and 1.65 V to 5.5 V on B-port
- No power supply sequencing required
- IEC 61000-4-2 ESD protection on B-port for “E” suffix devices

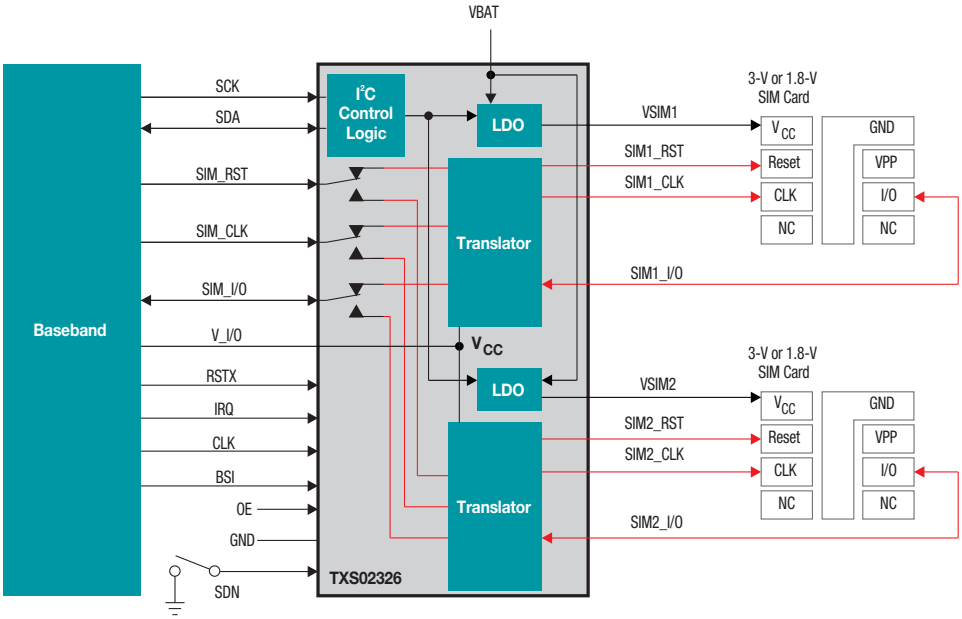
Package options

- VSSOP
- TSSOP
- DSBGA
- UQFN
- QFN
- SM8
- X2SON
- SON

Application Specific I Search Application Specific solutions on TI.com

TI's portfolio of auto bi-directional translators includes a number of devices that have been optimized for use in common communication interfaces used by processors and peripherals. Auto bi-directional translators are best suited in interfaces with truly bi-directional data lines such as I²C and SIM Cards.

A guide to voltage translation with TXS-type translators



Popular devices	Interface	Bits	V_{CCA} range	V_{CCB} range
TXS02612	SDIO	4	1.1 – 3.6	1.1 – 3.6
TXS02326A	SIM Card	6	1.7 – 3.3	2.3 – 5.5
TXS0202	I²C	2	1.65 – 3.6	1.65 – 3.6

Interfaces supported

- SPI, UART, and JTAG
- I²S
- Quad-SPI
- I²C, SMBus, and MDIO
- SD/MMC
- SIM card

1-Bit Dual-Supply Buffered Voltage Signal Level Shifter

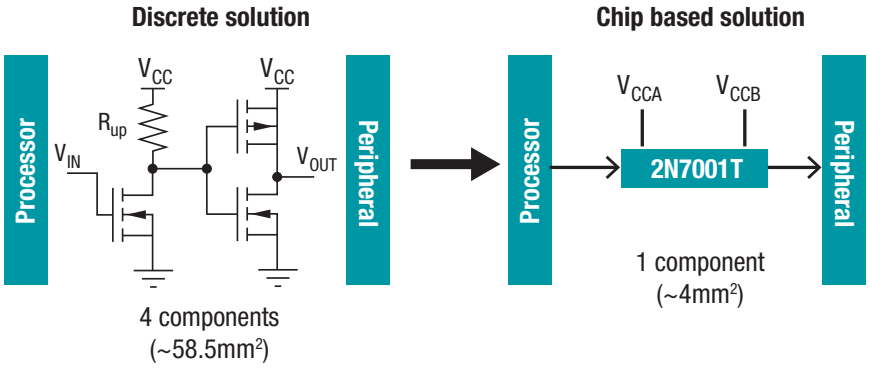
2N7001T I Search 2N on TI.com

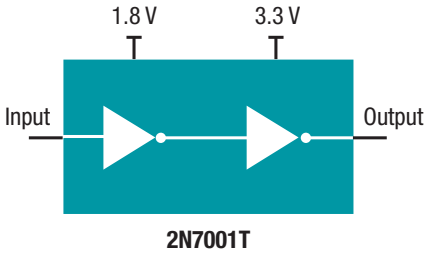
TI's newest addition to voltage translation is the **2N7001T**, a single-bit uni-directional buffered voltage level shifter that uses two separate power supply rails for up or down translation. Designed for simplicity, the 2N7001T is a single component that replaces the multiple components in traditional discrete level shifting implementations which helps in reducing design complexity, leakage and component count while improving signal performance. This allows for easier layout, as well as a great reduction in the space taken up by the level shifting circuit.

The device is capable of up to 100 Mbps data, and low leakage current reduces power consumption. Inherent V_{CC} isolation improves the robustness of the design, and removes the need for power sequencing. This allows the designer more flexibility in power supply design as discreet implementation may require power supply sequencing.

Other advantages over discrete implementation include improved signal performance through fast deterministic rise and fall times. The 2N7001T ensure system stability through glitch free performance.

Advantages of TI's integrated 2N7001T level shifter





Key features

- 1.65 V to 3.6 V on supply ports with independent sequencing.
- 12 mA of output drive current
- Up to 100 Mbps data rate
- V_{CC} isolation feature
- Partial power down– prevents excess current draw when either supply rail is powered down.
- ESD protection
  - 2000 V human body model
  - 1000 V charged-device model

Benefits

- Integrated solution saves space and makes for easier board layout than discrete implementation
- High data rate while supporting most industry standard voltage levels
- Glitch free performance ensures system reliability on power-up and power-down

Package options

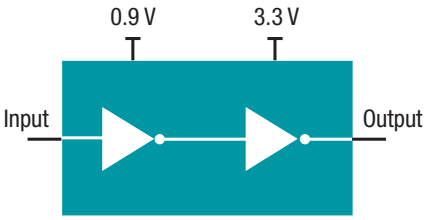
- X2SON
- SC70

Applications

- Notebook PCs
- LCD TV
- Grid communication
- Programmable logic controllers

AVC Family I Search AVC on TI.com

The uni-directional version of the AVC devices uses two separate configurable power-supply rails to enable asynchronous communication between B-port inputs and A-port outputs. The A port is designed to track V_{CCA} while the B port is designed to track V_{CCB}. Both V_{CCA} and V_{CCB} are configurable from 0.9 V to 3.6 V. The **SN74AVC2T244/SN74AVC4T234** offers Input hysteresis to allow slow input transition and better switching noise immunity at input. It offers very low static and dynamic power consumption across the entire V_{CC} range of 0.9 V to 3.6 V, making it the ideal translator for battery powered portable electronics applications.



SN74AVC2T244/4T234

Key features

- 380 Mbps max data rate
- Wide operating V_{CC} range of 0.9 V to 3.6 V
- 3.6-V I/O tolerant to support mixed-mode signal operation
- Input hysteresis allows slow input transition and better

Package options

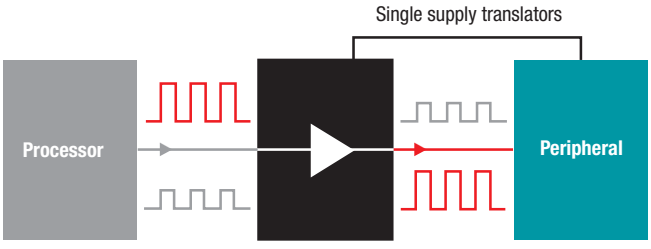
- X2SON
- µCSP

Popular devices	Bits	V_{CCA} range	V_{CCB} range	Data rate (Mbps)
SN74AVC2T244	2	0.9 – 3.6	0.9 – 3.6	380
SN74AVC4T234	4	0.9 – 3.6	0.9 – 3.6	380

AUP1T Family I Search AUP on TI.com

AUP technology is the Advanced Ultra low power logic technology, designed to suit low power systems. The **SN74AUP1Txx** devices are 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 V_{CC} supply. The AUP1T34 is a dual supply level translator that operates from 0.9 V to 3.6 V.

The SN74AUP1Txx with configurable logic function ('57,'58,'97,'98) can be easily configured to perform up to nine common gate functions.



SN74AUP1Txx

Key features

- Low power consumption: I_{CC} = 0.5 µA
- Schmitt-Trigger input: ΔV_T = 210 mV, reject input noise
- Nine configurable gate logic functions plus standard logic functions.
- ESD performance tested per JESD 22
  - 2000-V human-body model (A114-B, Class II)
  - 1000-V charged-device model (C101)

Package options

- DSBGA
- SON
- SC70
- SOT—23

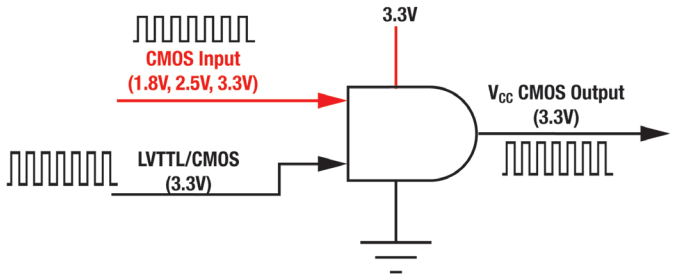
Popular devices	Description	V_{CCB} range	Data rate (Mbps)
SN74AUP1T00	NAND gate translator	2.3 – 3.6	380
SN74AUP1T34	Dual supply translator	0.9 – 3.6	380
SN74AUP1T97	Configurable gate translator	2.3 – 3.6	510

LV Family I Search LV on TI.com

SN74LV1T is a low voltage single supply CMOS logic gate that operates over a wide voltage range enabling the generation of a large number of desired output levels to connect to controllers or processors using TTL compatible input levels. The output level is referenced to the supply voltage and is able to support 1.8 V, 2.5 V, 3.3 V, and 5 V CMOS levels.

The input is designed with a lower threshold circuit to match 1.8 V input logic at V_{CC} = 3.3 V and can be used in 1.8 V to 3.3 V or 3.3 V to 5 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_{CC} = 2.5 V).

The SN74LV1T is designed with current-drive capability of 8 mA to reduce line reflections, overshoot, and undershoot caused by high-drive outputs.



Popular devices	Description	V_{CCB} range	Data rate (Mbps)
SN74LV4T125	Quadruple buffer translator	1.8 – 5.5	100
SN74LV1T00	NAND translator	1.8 – 5.5	100
SN74LV1T86	XOR translator	1.8 – 5.5	100

Key features

- Single-supply voltage 1.8 to 5.0 V V_{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
  - 5.0 V to 3.3 V
- Supports standard logic pinouts

Package options

- SC70
- SOT-23
- TSSOP
- VQFN

Voltage translation with overvoltage-tolerant and TTL-compatible inputs, and open drain output devices

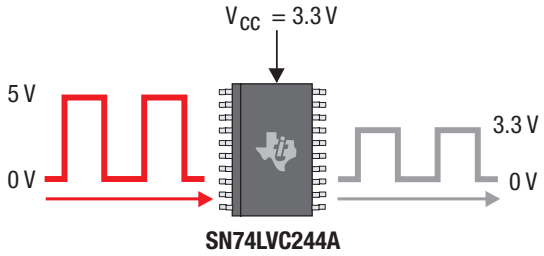
Down-translation with overvoltage-tolerant devices

Devices with overvoltage-tolerant inputs can be used to perform down-translation as shown in the diagram. The outputs voltage levels of most logic devices are determined by the supply voltage. Over-voltage inputs on a device allow higher voltage signals to be input without effecting the output voltage levels on the device; thus, the device acts as a down-translator. Popular logic families with overvoltage-tolerant inputs include:

- AHC, AUC, AVC, LV-A, LVC

Advantages

- Only one supply voltage needed
- Broad portfolio to choose from; wide range of functions and device specifications



Down-translation

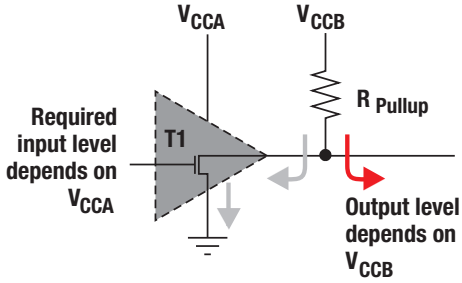
Up-translation with TTL-compatible devices

TTL-compatible inputs means the device is a BiCMOS or CMOS device with inputs designed to be compatible with LVTTL voltage levels, while the output of the device operate at 5V CMOS levels. That means the device can act as up-translation for 3.3 V LVCMOS / LVTTL to 5V CMOS levels. Popular logic families with TTL-compatible inputs include:

- HCT, AHCT, ACT, LV-AT

Advantages

- Only one supply voltage needed
- Broad portfolio to choose from; wide range of functions and device specifications



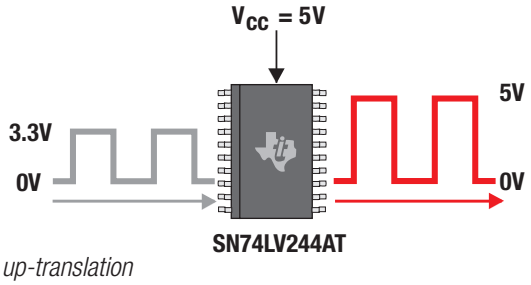
Translation with open-drain buffers

Devices with open-drain outputs

Devices with open-drain outputs can be used to perform both up translation and down-translation. Typically open-drain devices tie the same supply voltage for the logic device to a pull-up resistor to determine the output level and input level of the device. However this is not required, so the output voltage levels of an open-drain device can determined be tied to a V_{CCB}, as shown in the diagram.

Advantages

- Flexibility in translating to a variety of voltage nodes



TTL up-translation

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