Voltage Level Translation Guide

Auto-Direction Sensing
Direction Controlled
Application-Specific
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 electronic, portable, computing, and networking applications—wherever the need exists to interface lower operating processors with higher operating legacy peripherals.

Portable Electronic Block Diagram
Dual-Supply Translators

Packaging

Packages
Dimensions are in inches (millimeters)

- 6-ball NanoStar™ pkg. (YEP/YZP)
- 8-Pin WCSP (YZP)
- 56-ball VFBGA (GQL)
- 8-ball NanoStar™ pkg. (YEP/YZP)
- 8-pin μQFN (DQM)
- 16-pin QFN (RSV)
- 16-pin QFN (RGY)
- 24-pin QFN (RHL)

- 83-ball LFBGA (GRG)
- 96-ball LFBGA (GKE)
- 114-ball LFBGA (GKF)
- 20-ball VFBGA (ZXY)
- 12-ball UFBGA (ZXU)

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**Dual-Supply Translators**

Four Classes of Voltage Translators

Auto-direction sensing translators

- **VccA**
- **VccB**

Processor  ➔  Peripheral

**TXB010x and TXB030x**

Auto-direction sensing translators for open-drain applications

- **VccA**
- **VccB**

Processor  ➔  Peripheral

**TXS010x/E and TXS030x**

Application-specific translators

- **VccA**
- **VccB**

Processor  ➔  SD/SDIO Card

**TXS02xxx and TXS45xx**

Dual-supply configurable translators

- **VccA**
- **VccB**

Processor  ➔  Peripheral

**SN74AVCxT45/245/234/244 and SN74LVCxT45/245**

*Auto-Direction Sensing Translators Portfolio*

**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
- **Devices ending in E suffix** include integrated IEC 61000-4-2 ESD protection.

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.
Dual-Supply Translators

Auto-Direction Sensing Translators

Bidirectional Auto Direction Sensing Translators with 0.9 V Support

TXB030x

Get samples, data sheets, EVMs and app reports at: www.ti.com/product/TXB030x

Key Features

• Optimized for push-pull applications
• Fully symmetric supply voltages: 0.9 V to 3.6 V on both A-port and B-port
• V_{CC} isolation feature – If either V_{CC} input is at GND, all outputs are in the high-impedance state
• OE input circuit referenced to V_{CCA}
• Low power consumption, 5-μA max I_{CC}
• 8-kV Human-Body Model (HBM)

Applications

• Cell phones
• Tablets
• Portable GPS devices
• Bluetooth® headsets
• General portable consumer applications

These non-inverting translators use two separate configurable power-supply rails. As voltage signal levels continue to decrease, a new set of low-voltage-level translators are needed. This is the reason why the TXB030x 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 TXB030x family is designed so that the OE input circuit is supplied by V_{CCA}. The 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.

Bidirectional Auto Direction Sensing Translators

TXB010x

Get samples, data sheets, EVMs and app reports at: www.ti.com/product/TXB010x

Key Features

• Optimized for push-pull drivers
• 100 Mbps max data rate transfer
• V_{CC} isolation feature
• OE input circuit referenced to V_{CCA}
• Low power consumption
• I_{off} 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 (V_{CCA} ≤ V_{CCB})

Applications

• Cell phones
• SD/SDIO level translation
• SPI and GPIO level translation

These non-inverting translators use two separate configurable power-supply rails. 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. 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. V_{CCA} should not exceed V_{CCB}.

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_{off}. The I_{off} 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.
**Dual-Supply Translators**

**Auto-Direction Sensing Translators for Open Drain Applications with 0.9 V Support**

**TXS030x**

Get samples, data sheets, EVMs and app reports at: [www.ti.com/product/TXS030x](http://www.ti.com/product/TXS030x)

**Key Features**
- Optimized for open-drain applications
- Fully symmetric supply voltages: 0.9 V to 3.6 V on both A-port and B-port
- $V_{CC}$ isolation feature – if either $V_{CC}$ input is at GND, all outputs are in the high-impedance state
- OE input circuit referenced to $V_{CCA}$
- Low power consumption, 5-μA max $I_{CC}$
- 8-kV Human-Body Model (HBM)

**Applications**
- Cell phones
- Tablets
- Portable GPS devices
- Bluetooth® headsets
- General portable consumer applications

These two-bit non-inverting translators use two separate configurable power-supply rails. The A port is designed to track $V_{CCA}$. $V_{CCA}$ accepts any supply voltage from 0.9 V to 3.6 V. The B port is designed to track $V_{CCB}$. $V_{CCB}$ accepts any supply voltage from 0.9 V to 3.6 V. This allows for low-voltage bidirectional translation between 1-V, 1.2-V, 1.5-V, 1.8-V, 2.5-V and 3.3-V voltage nodes.

For the TXS0302, 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 TXS0302 is designed so that the OE input circuit is supplied by $V_{CCA}$. This device is 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.

**TXS030x functional block diagram.**

**Bidirectional Auto Direction Sensing Translators for Open Drain Applications**

**TXS010x**

Get samples, data sheets, EVMs and app reports at: [www.ti.com/product/TXS010x](http://www.ti.com/product/TXS010x)

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

**Applications**
- Cell phones
- I²C level translation
- MMC and SIM card level translations

These non-inverting translators use two separate configurable power-supply rails. The A port is designed to track $V_{CCA}$. $V_{CCA}$ accepts any supply voltage from 1.65 V to 3.6 V. The B port is designed to track $V_{CCB}$. $V_{CCB}$ must be less than or equal to $V_{CCA}$. $V_{CCB}$ accepts any supply voltage from 2.3 V to 5.5 V. 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.

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.

**TXS010x functional block diagram.**

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Dual-Supply Translators

Configurable Translators with Direction Control Portfolio

Key Features
- Fully configurable rails — each \(V_{CC}\) rail is fully configurable from 1.2 V to 3.6 V (AVCxT devices) and from 1.65 V to 5.5 V (LVCxT devices)
- No power-up sequencing — either \(V_{CC}\) can be powered up first (AVCxT and LVCxT devices only)
- Standby mode — when one \(V_{CC}\) is switched off, all I/O ports are placed in the HiZ mode (AVCxT and LVCxT devices only).

TI translators with direction control are designed for asynchronous communication between two buses or devices operating at different supply voltages: \(V_{CCA}\) to interface with the A side and \(V_{CCB}\) to interface with the B side. These devices are available in a variety of bit widths and cover nearly every supply-voltage node in use today. They are flexible, easy to use and can translate bidirectionally (up-translate and down-translate), which makes them an ideal choice for most level-translation applications.

![Direction-control translators.](image)

Configurable Unidirectional Translators Portfolio

Key Features
- Unidirectional architecture eliminates the direction control pin saving precious GPIO pins on the processor
- Fully configurable rails from 0.9 V to 3.6 V enable support of 1.0 V nodes used by the most advanced processors
- \(I_{off}\) circuitry prevents damaging current backflow in power-down mode

TI unidirectional translators are designed for asynchronous communication between B-port inputs and A-port outputs operating at different supply voltages: \(V_{CCA}\) to interface with the A side and \(V_{CCB}\) to interface with the B side. These devices cover the most advanced (1.0V and 1.2V) supply-voltage nodes in use today and are fully configurable from 0.9V to 3.6V on both A-port and B-port sides. These devices are fully specified for partial power down applications and use Ioff circuitry that prevents damaging current backflow in power-down mode. These features make these translators an ideal choice for battery powered portable electronics applications.

![Unidirectional translators.](image)
Configurable Translators with Direction Control

Dual-Supply Bus Transceiver with Configurable Voltage Translation and 3-State Outputs
SN74AVCxT45/245

Get samples, data sheets, EVMs and app reports at: www.ti.com/product/SN74AVCxT45/245

Key Features

• 380 Mbps max data rate
• 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

Applications

• Handsets
• PDAs
• Computing
• Smartphones

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.

Dual-Supply Bus Transceiver with Configurable Voltage Translation and 3-State Outputs
SN74LVCxT45/245

Get samples, data sheets, EVMs and app reports at: www.ti.com/product/SN74LVCxT45/245

Key Features

• 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

Applications

• Portables
• Telecom
• Computing
• Translation from 3.3 V to 5 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.

The \( V_{CC} \) isolation feature ensures that if either \( V_{CC} \) input is at GND, then both ports are in the high-impedance state. To ensure the high-impedance state during power up or power down, OE should be tied to \( V_{CC} \) through a pullup resistor; the minimum value of the resistor is determined by the current-sinking capability of the driver.
### Dual-Supply Translators

#### Configurable Unidirectional Translators

**4-Bit, Dual-Supply, Non-Inverting Bus Translator**

**SN74AVC4T234**

Get samples, data sheets, EVMs and app reports at: [www.ti.com/product/SN74AVC4T234](http://www.ti.com/product/SN74AVC4T234)

**Key Features**

- 380 Mbps max data rate
- Wide operating V\text{CC} range of 1.2 V to 3.6 V
- 3.6-V I/O tolerant to support mixed-mode signal operation
- Input-disable feature allows floating input conditions
- Input hysteresis allows slow input transition and better switching noise immunity at input

**Applications**

- Handsets
- PDAs
- Computing
- Smartphones

This 4-bit non-inverting bus transceiver 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\text{CCA} while the B port is designed to track V\text{CCB}. Both V\text{CCA} and V\text{CCB} are configurable from 1.2 V to 3.6 V. The SN74AVC4T234 solution offers the industry’s low-power needs in battery-powered portable applications by ensuring both a very low static and dynamic power consumption across the entire V\text{CC} range of 1.2 V to 3.6 V, resulting in an increased battery life. This product also maintains excellent signal integrity. This device is fully specified for partial-power-down applications using I\text{off}. The I\text{off} circuitry disables the outputs, preventing damaging current backflow through the device when it is powered down. The V\text{CC} isolation feature ensures that if either V\text{CC} input is at GND, then A-side ports are in the high-impedance state.

### Logic Diagram (Positive Logic)

![Logic Diagram](image)

**2-Bit, Dual-Supply, Unidirectional Translator with Output Enable**

**SN74AVC2T244**

Get samples, data sheets, EVMs and app reports at: [www.ti.com/product/SN74AVC2T244](http://www.ti.com/product/SN74AVC2T244)

**Key Features**

- Wide operating V\text{CC} range of 0.9 V to 3.6 V
- Output enable pin allows user to disable outputs to reduce power consumption
- 380 Mbps max data rate
- Input hysteresis allows slow input transition and better switching noise immunity at input
- 4.5 V tolerant I/O to support mixed signal mode operation

**Applications**

- Handsets
- PDAs
- Computing
- Smartphones

This 2-bit unidirectional translator 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\text{CCA} while the B port is designed to track V\text{CCB}. Both V\text{CCA} and V\text{CCB} are configurable from 0.9 V to 3.6 V. The SN74AVC2T244 offers an output enable pin to disable outputs that reduces power consumption significantly in power down mode. It offers very low static and dynamic power consumption across the entire V\text{CC} range of 0.9 V to 3.6 V, making it the ideal translator for battery powered portable electronics applications.

**SN74AVC2T244 functional block diagram.**
Dual-Supply Translators

Application Specific Translators

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

**TXS0206 and TXS0206-29**


**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

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.

**Applications**

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

Interchip USB Voltage Level Translator

**TXS0202**

Get samples, data sheets, EVMs and app reports at: [www.ti.com/product/TXS0202](http://www.ti.com/product/TXS0202).

**Key Features**

- Auto-direction sensing translator
- Voltage range of 1.65-3.6 V
- I_{off} supports partial-power-down mode operation
- Actively detects the status of the host and peripheral and will determine which of the four various modes is desired
- No direction signal control needed
- Works with legacy to next-generation processors and peripherals
- This is done without any need for direction control, external FETs, or external pull up resistors

The TXS0202 is a two-bit voltage level translator optimized for use in Interchip USB (IC-USB) applications. V_{CCA} and V_{CCB} can each operate over the full range of 1.65 V to 3.6 V. The device has been designed to maintain cross-over skew to be less than 1 ns. The device has integrated pull-ups and pull-down resistors to aid in the protocol communication between a host and a peripheral. The translator is a buffered auto-direction sensing type translator. When the output-enable (OE) input is low, all outputs are placed in the high-impedance state.

**Applications**

- Handsets
  - Smartphone
  - Multimedia
  - Feature
- Tablet
- Portable gaming devices
**Dual-Supply Translators**

**Application Specific Translators**

Dual-supply SIM Card Translator and 2:1 Multiplexer

**TXS02326**

Get samples, data sheets, EVMs and app reports at: [www.ti.com/product/TXS02326](http://www.ti.com/product/TXS02326)

**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
- Available in popular 24-pin QFN package

**Applications**
- Cell phones

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 card 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.

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1.8 V and 3 V SIM Card Power Supply and Voltage Translator

**TXS4555**

Get samples, data sheets, EVMs and app reports at: [www.ti.com/product/TXS4555](http://www.ti.com/product/TXS4555)

**Key Features**
- Dual-supply translator with voltage range of 1.65 V to 3.3 V
- Integrated LDO accepts battery voltage from 2.3 V to 5.5 V and generates 1.8 V or 2.95 V output
- Proper shutdown sequence prevents data corruption in case of accidental phone shutdown
- Available in tiny 16-pin (9mm²) and 12-pin (3.5mm²) QFN packages

**Applications**
- Cell phones

The TXS4555 is a dual-supply SIM card solution for interfacing a wireless baseband processor with any Class-B (2.95 V) or Class-C (1.8 V) SIM card. The dual-supply voltage translation function supports 1.65 V to 3.3 V range on the processor side and accepts any battery voltage between 2.3 V and 5.5 V to generate a constant 1.8 V or 2.95 V output on the SIM card side. A dedicated low-dropout (LDO) voltage regulator with selectable output is used to generate the desired SIM card voltage. Proper shutdown sequence for the SIM card signals helps in prevention of corruption of data during accidental shutdown of the phone.
Translator Nomenclature

**Translator nomenclature**

<table>
<thead>
<tr>
<th>Prefix: TX = TI translator</th>
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<tbody>
<tr>
<td>Device type: S = Switch, B = Buffer</td>
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<tr>
<td>Grade</td>
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<tr>
<td>Bit width</td>
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<tr>
<td>ESD protection: E = IEC Level 4</td>
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<tr>
<td>TI package designator</td>
</tr>
<tr>
<td>Tape and reel: R or none = Standard reel, T = Small reel</td>
</tr>
</tbody>
</table>

**Translator nomenclature**

| TI prefix: |
| Technology family: AHC, AHCT, AVC, AUC, CBT, CBTD, CB3T, HCT, LVC, TVC |
| Bit width |
| Device type: T = Translation |
| Function identifier |
| TI package designator |
| Tape and reel: R or none = Standard reel, T = Small reel |

Selection Tables

<table>
<thead>
<tr>
<th>Device</th>
<th>$V_{CC}$ Min. to Max. (V)</th>
<th>$V_{CCA}$ (V)</th>
<th>$V_{CCB}$ (V)</th>
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1 Bus-hold option available

Preview products are listed in **bold blue.**
## Dual-Supply Translators

### Selection Tables (Continued)

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<thead>
<tr>
<th>Device</th>
<th>V&lt;sub&gt;CC&lt;/sub&gt; Min. to Max. (V)</th>
<th>V&lt;sub&gt;CCA&lt;/sub&gt; (V)</th>
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1 Bus-hold option available

Preview products are listed in bold blue.


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 \( V_{OH} \) level from the CB3T switch is greater than the required \( V_{IL} \) of the 5-V (TTL) devices connected to the 5-V bus.

**Advantage**
- Fast propagation delays

→ **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
- LV-A
- AUC
- AVC

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

**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 HCT, AHCT, ACT and AUP families.

**Advantages**
- Only one supply voltage needed
- Broad 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 \( V_{CCB} \). This output level can be higher than \( V_{CCA} \) (up-translation) or lower than \( V_{CCA} \) (down-translation).

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

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<td>OMAP Mobile Processors</td>
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