

# **Optimizing HVAC Gateway Designs With Common Logic and Voltage Translation Use Cases**

Emrys Maier

## **ABSTRACT**

Heating, ventilation, and air conditioning (HVAC) gateways integrate numerous subsystems in a very small space. Though the HVAC gateways differ in style and functionality, they share similar digital interfacing challenges, such as communicating with different wireless modules. All of the use cases shown in the [Block Diagram](#) and [Logic and Translation Use Cases](#) sections of this document are commonly seen in HVAC gateway designs.

Logic gates, voltage translators, and other logic devices are utilized for many purposes throughout modern electronic systems. This document provides example solutions for common design challenges that can be solved using logic and translation. Not all of the solutions here appear in every system; however, all solutions shown are commonly used and effective.

There are dozens of logic families available from Texas Instruments, and it can be difficult to select the right one for the application. HVAC gateways vary in features, but the key design parameters remain the same making it easier to identify an appropriate family for this application. See [Section 4](#) for help finding the right logic family for the use case.

## **Contents**

1	Block Diagram.....	2
2	Optimizing Communication with Wireless Interfaces.....	3
3	Logic and Translation Use Cases .....	4
4	Recommended Logic and Translation Families for HVAC Gateways .....	7

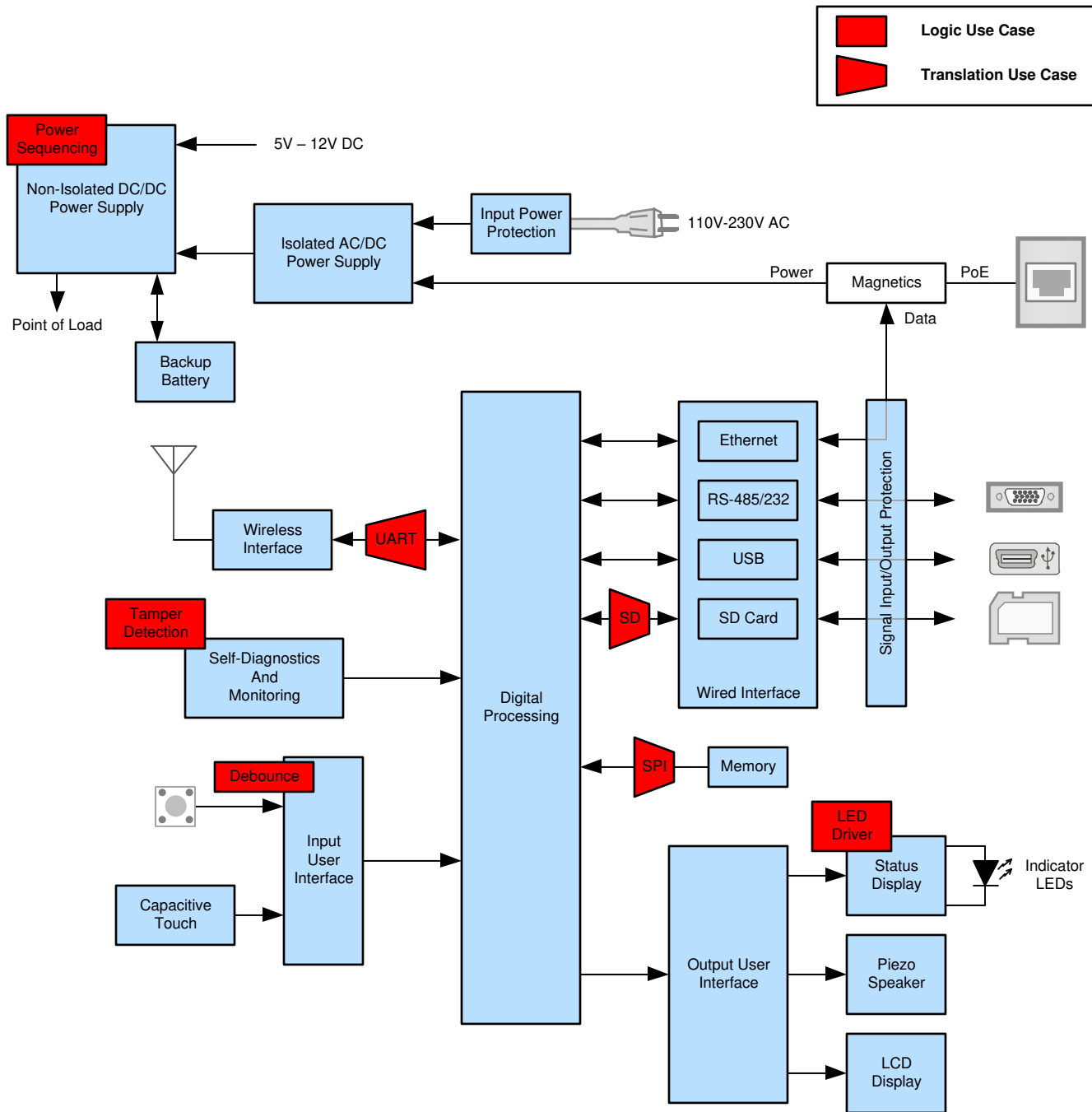
## **List of Figures**

1	Simplified Block Diagram for HVAC Gateways .....	2
2	Using Voltage Translation with an SD Card Communication Bus.....	3
3	Using Voltage Translation with an SPI-Communication Bus .....	3
4	Using Logic as Indicator LED Driver Application Examples .....	4
5	Using Logic to Combine Multiple Power-Good Signals.....	4
6	Using Logic to Prevent Multiple Triggers of a CMOS Input Due to Switch Bounce .....	5
7	Using Logic to Monitor a Normally Closed (NC) Tamper Switch.....	5
8	Using Logic to Monitor a Normally Open (NO) Tamper Switch .....	5
9	Using Voltage Translation with an SPI-Communication Bus .....	6
10	Using Voltage Translation with an SD Card Communication Bus.....	6

## **Trademarks**

Bluetooth is a registered trademark of Bluetooth SIG, Inc.  
 Wi-Fi is a registered trademark of Wi-Fi Alliance.  
 ZigBee is a registered trademark of ZigBee Alliance.  
 All other trademarks are the property of their respective owners.

# 1 Block Diagram



**Figure 1. Simplified Block Diagram for HVAC Gateways**

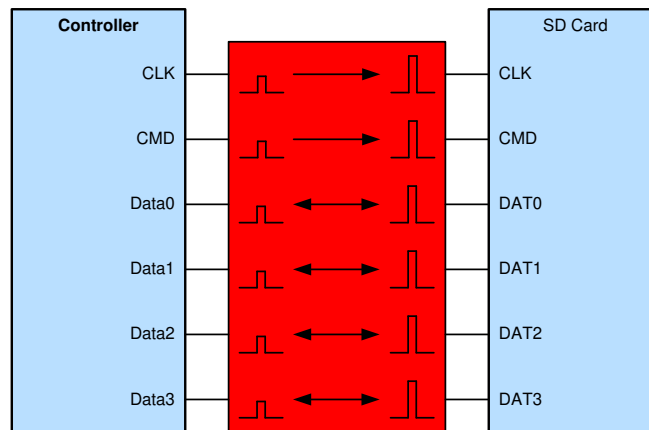
For the purpose of this report, a simplified HVAC gateway system block diagram is used to illustrate the logic and translation use cases, see [Figure 1](#). For a more complete view, see the interactive online end equipment reference diagram for [HVAC gateway](#).

## 2 Optimizing Communication with Wireless Interfaces

It is common for HVAC gateways to utilize wireless interfaces such as Wi-Fi®, ZigBee®, or Bluetooth® to connect to a local network. In many designs, the simplest method to achieve this is to utilize pre-built and pre-approved modules. These modules often have limited voltage operation ranges, and to support their usage, voltage-level shifters are typically required between the extremely low power processor, often operating as low as 1.2 V, and the wireless module, commonly operating at 3.3 V.

The most common communication protocols used between the processor and wireless interface are secure digital input output (SDIO) and universal asynchronous receiver/transmitter (UART). Each is addressed specifically in the following sections.

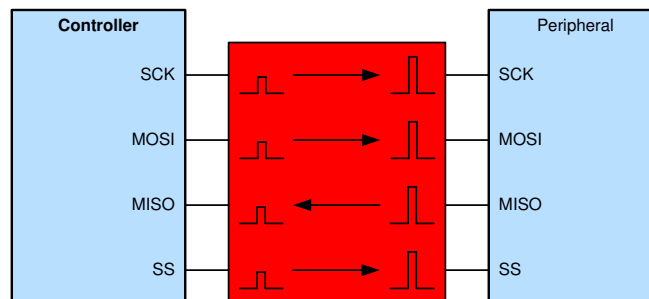
### 2.1 SDIO Voltage Translation



**Figure 2. Using Voltage Translation with an SD Card Communication Bus**

- Enable communication when devices have mismatched logic voltage levels
- Improve data rates over discrete translation solutions.
- Protect controller while SD Card is not connected.
- Find the right voltage level translator through the [online parametric search tool](#).

### 2.2 UART Voltage Translation



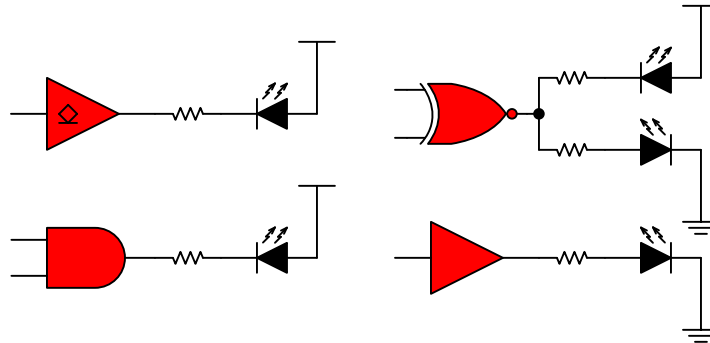
**Figure 3. Using Voltage Translation with an SPI-Communication Bus**

- Enable communication when devices have mismatched logic voltage levels.
- Prevent damage to devices that cannot support higher voltage inputs.
- Improve data rates over discrete translation solutions.
- Provide protection from disconnected peripherals.
- Find the right voltage level translator through the [online parametric search tool](#).

### 3 Logic and Translation Use Cases

#### 3.1 Logic Use Cases

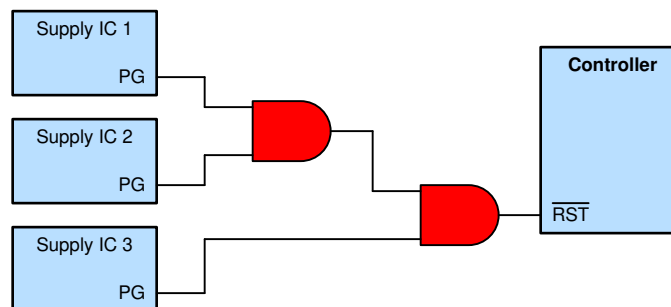
##### 3.1.1 Drive Indicator LEDs



**Figure 4. Using Logic as Indicator LED Driver Application Examples**

- Add system indicators without controller interaction required.
- Most logic gates can drive low-current indicator LEDs (1 to 25 mA).
- Logic functions add configurability.
- Disable indicator LEDs as desired.
- Find the right logic solutions through the [online parametric search tool](#).

##### 3.1.2 Power Sequencing: Combine Power Good Signals



**Figure 5. Using Logic to Combine Multiple Power-Good Signals**

- Combine power good signals to drive an active low reset.
- Add power indicator LEDs without software or system controller interaction.
- See more about this use case in the *Logic Minute* video [Combining Power Good Signals](#).
- Find the right AND gate through the [online parametric search tool](#).

### 3.1.3 Debounce Switches and Buttons

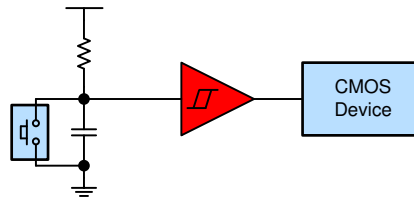


Figure 6. Using Logic to Prevent Multiple Triggers of a CMOS Input Due to Switch Bounce

- Prevents multiple triggers of CMOS inputs due to switch bounce.
- Works when the system controller is asleep.
- Works without a system controller.
- Reduces controller code complexity, no software debounce required.
- See more about this use case in the Logic Minute video [Debounce a Switch](#).
- Find the right Schmitt-trigger buffer through the [online parametric search tool](#).

### 3.1.4 Tamper Detection: Latching Alarm Circuit with Reset

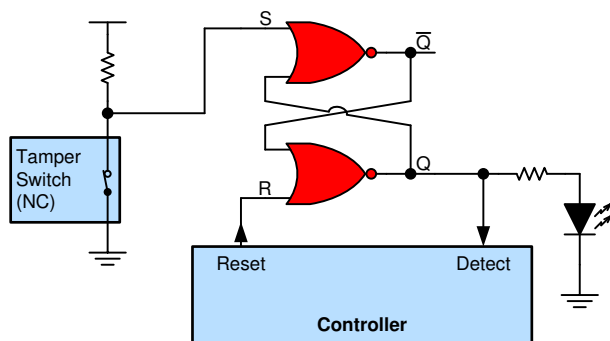


Figure 7. Using Logic to Monitor a Normally Closed (NC) Tamper Switch

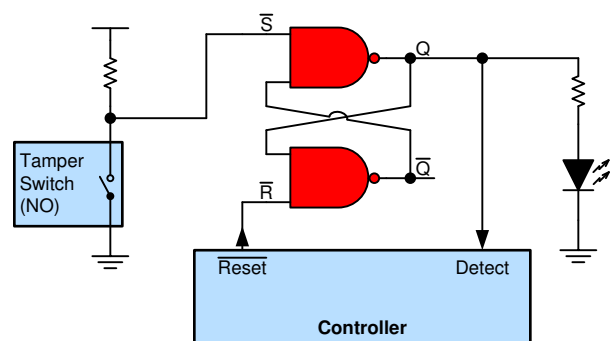
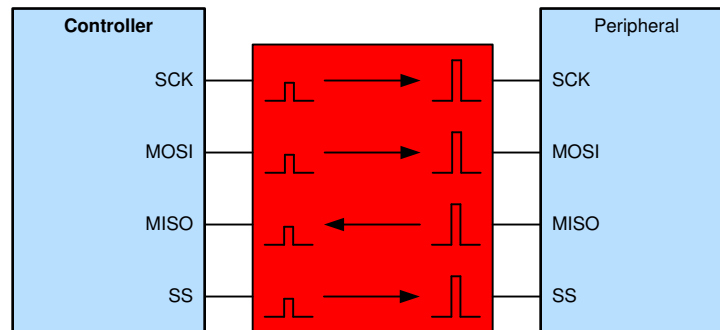


Figure 8. Using Logic to Monitor a Normally Open (NO) Tamper Switch

- Flags any tampering
- Extremely low power
- Works while the controller sleeps.
- Can be used without a controller.
- See more about this use case in the Logic Minute video [Using an S-R Latch in Alarm Circuitry](#).
- Find the right NOR or NAND gate through the [online parametric search tool](#).

## 3.2 Voltage Translation Use Cases

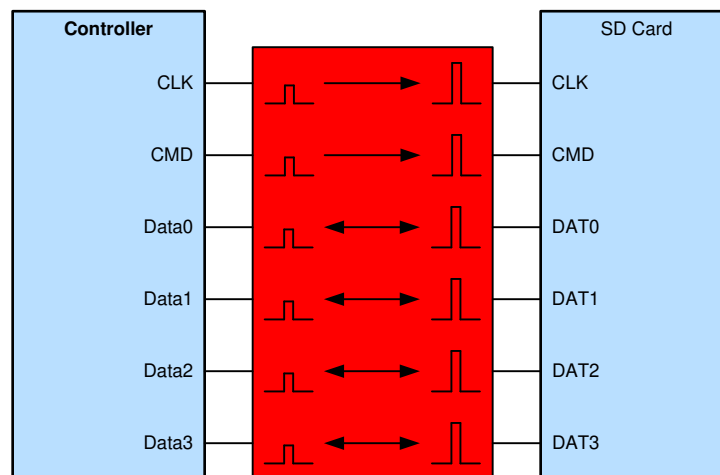
### 3.2.1 SPI Communication



**Figure 9. Using Voltage Translation with an SPI-Communication Bus**

- Enable communication when devices have mismatched logic voltage levels.
- Prevent damage to devices that cannot support higher voltage inputs.
- Improve data rates over discrete translation solutions.
- Provide protection from disconnected peripherals.
- Find the right voltage level translator through the [online parametric search tool](#).

### 3.2.2 SD Card Communication



**Figure 10. Using Voltage Translation with an SD Card Communication Bus**

- Enable communication when devices have mismatched logic voltage levels.
- Prevent damage to devices that cannot support higher voltage inputs.
- Improve data rates over discrete translation solutions.
- Protect controller while SD Card is not connected.
- Find the right voltage level translator through the [online parametric search tool](#).

## 4 Recommended Logic and Translation Families for HVAC Gateways

### 4.1 AUP: Advanced Ultra-low-Power CMOS Logic and Translation

Key Features: SN74AUPxGxxxx

- Low static- and dynamic-power consumption
- Wide  $V_{CC}$  operating range: 0.8 to 3.6 V
- Input hysteresis allows for slow input transition rate
- Best in class for speed-power optimization
- $I_{off}$  spec for partial power down support
- Packaging Options:
  - DSBGA
  - SC70
  - SM8
  - SON
  - SOT, SOT-23
  - UQFN
  - US8
  - X2SON

Key Features: SN74AUPxTxxxx

- Low static- and dynamic-power consumption
- 1.65-V to 3.6-V translation range
- Best in class for speed-power optimization
- $I_{off}$  spec for partial power down support

Find the right AUP family logic and voltage level translation devices through the [online parametric search tool](#).

### 4.2 AXC: Advanced eXtremely low-voltage CMOS Translation

Key Features

- Up and down translation across 0.65 V to 3.6 V
- Designed with glitch suppression circuitry to improve power sequencing performance
- Maximum quiescent current ( $I_{CCA} + I_{CCB}$ ) as low as 6  $\mu$ A (85°C maximum) and 14  $\mu$ A (125°C maximum)
- Up to 500-Mbps support when translating from 1.8 V to 3.3 V
- $V_{CC}$  isolation feature – If either  $V_{CC}$  input is below 100 mV, all I/Os outputs are disabled and become high impedance
- $I_{off}$  supports partial-power-down mode operation
- Operating temperature: –40°C to 125°C
- Packaging Options:
  - SC70
  - SM8
  - SON
  - SOT, SOT-23
  - UQFN
  - US8
  - X2SON

Find the right AXC family voltage level translation devices through the [online parametric search tool](#).

### 4.3 LVC: Low-Voltage CMOS Logic and Translation

Key Features: SN74LVCxxxx

- Huge portfolio of logic functions
- LVC: 4+ channels per package
- Overvoltage tolerant inputs allow unidirectional down-translation with any function
- High-drive outputs (up to 32 mA)
- Up to 250-Mbps operation
- $I_{off}$  supports partial-power-down mode operation.
- Packaging Options:
  - SOIC
  - TSSOP
  - VQFN
  - SOP
  - SSOP

Key Features: SN74LVCxGxxxx

- Put one, two, or three channels of any logic function right where they are needed
- Configurable gates available ('57, '58, '97, '98, '99 functions)
- Overvoltage tolerant inputs allow unidirectional down-translation with any gate or buffer
- High-drive outputs (up to 32 mA)
- Up to 250-Mbps operation
- $I_{off}$  supports partial-power-down mode operation
- Packaging Options:
  - SOT-23
  - SC70
  - X2SON
  - SOT-5X3
  - SON
  - DSBGA

Key Features: SN74LVCxTxxxx

- LVCxT: Up and down translation across 1.65 V to 5.5 V
- 1, 2, 8, or 16 channels per device
- High-drive outputs (up to 32 mA)
- Up to 250-Mbps operation
- $I_{off}$  supports partial-power-down mode operation

Find the right LVC family logic and voltage level translation devices through the [online parametric search tool](#).

### Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

Changes from Original (December 2019) to A Revision	Page
• Changed every occurrence of smart thermostat to HVAC gateway in <a href="#">Section 1</a> .....	2



## IMPORTANT NOTICE AND DISCLAIMER

TI PROVIDES TECHNICAL AND RELIABILITY DATA (INCLUDING DATASHEETS), DESIGN RESOURCES (INCLUDING REFERENCE DESIGNS), APPLICATION OR OTHER DESIGN ADVICE, WEB TOOLS, SAFETY INFORMATION, AND OTHER RESOURCES "AS IS" AND WITH ALL FAULTS, AND DISCLAIMS ALL WARRANTIES, EXPRESS AND IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE OR NON-INFRINGEMENT OF THIRD PARTY INTELLECTUAL PROPERTY RIGHTS.

These resources are intended for skilled developers designing with TI products. You are solely responsible for (1) selecting the appropriate TI products for your application, (2) designing, validating and testing your application, and (3) ensuring your application meets applicable standards, and any other safety, security, or other requirements. These resources are subject to change without notice. TI grants you permission to use these resources only for development of an application that uses the TI products described in the resource. Other reproduction and display of these resources is prohibited. No license is granted to any other TI intellectual property right or to any third party intellectual property right. TI disclaims responsibility for, and you will fully indemnify TI and its representatives against, any claims, damages, costs, losses, and liabilities arising out of your use of these resources.

TI's products are provided subject to TI's Terms of Sale ([www.ti.com/legal/termsofsale.html](http://www.ti.com/legal/termsofsale.html)) or other applicable terms available either on [ti.com](http://ti.com) or provided in conjunction with such TI products. TI's provision of these resources does not expand or otherwise alter TI's applicable warranties or warranty disclaimers for TI products.

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2020, Texas Instruments Incorporated