
Level Shifter Circuits - Design Basics and Applications

Author: Irena Zhuravchak, Technical Documentation Applications Engineer, A&C/CMSD

Abstract

This white paper highlights the crucial role of level shifters in the market of electronic components as well as the technical requirements and design challenges related to these devices. It will showcase the GreenPAK Dual Supply for level shifter solutions. Besides, there will be presented real examples of using the GreenPAK Dual Supply to create diverse level shifter designs. Moreover, in this paper, we introduce the new Dual Supply GreenPAK SLG47525/28 and its benefits.

Contents

| | |
|--|----------|
| Abstract | 1 |
| 1. Introduction | 2 |
| 2. Make a Level Shifter with GreenPAK | 3 |
| 3. Level Shifter with GreenPAK Applications | 5 |
| 3.1 Uni-directional Level Shifter | 5 |
| 3.2 Bi-directional with Dedicated Ports | 6 |
| 3.3 Bi-directional with External Direction Indicator | 7 |
| 3.4 Bi-directional, Autosensing | 8 |
| 4. Conclusion | 9 |
| 5. Revision History | 9 |

1. Introduction

A level shifter is an electronic device that changes the voltage level of signals between different logic circuits or microcontrollers. The main purpose of using a level shifter is to ensure compatibility between components that operate at different supply voltages.

Different logic families can operate at different logic levels, for example, one device at 3.3 V and another at 5 V. Without a level shifter, such devices may be incompatible or even damage each other. Another example is modern microcontrollers and peripherals: many modern microcontrollers operate at lower voltages (1.8V or 3.3V), while some peripherals such as LCDs, sensors, and others, can operate at higher voltages (5V or more). Different logic levels without proper conversion can damage components by exceeding allowable voltage levels. The level shifter can protect against component damage.

The market for level shifters is experiencing significant growth and is expected to continue expanding in the coming years. As of recent analyses, the global level shifter market size was valued at approximately \$1.66 billion in 2022. The level shifters market is expected to grow at a CAGR of 3.8% during the forecast period and the market is expected to reach US\$ 2.16 billion by 2029 ([MAXIMIZE MARKET RESEARCH](#)).

Despite such a considerable market increase, the development of level shifters can face many problems that can affect the performance, reliability, and compatibility of the final electronic systems. Here are some of the main challenges designers face:

Choosing the right type of level shifter

- Unidirectional vs. bidirectional: The choice between unidirectional and bidirectional level shifters depends on the specific signal transfer requirements. Bidirectional converters are usually more difficult to implement.

Compatibility with signal speed

- Signal delay: One of the main challenges is to ensure low signal delay during voltage level conversion, which is critical for high-speed applications.
- Bandwidth: Level converters must be able to operate at the required frequencies without signal degradation.

Power management

- Power consumption: Designing efficient level converters that consume minimum power is especially important for portable and low-power devices.
- Voltage stability: Ensuring stable operation at different supply voltages.

Physical limitations

- Size and placement: The minimum size of chips and their integration into small device form factors can be a challenge.

Compatibility with different logic levels

- Ensuring correct operation between logic families that have different logic signal levels.

Testing and validation

- Simulations and modeling: Using effective simulations to predict the performance of level shifters in various conditions.

Economic aspects

- Cost of production: Optimizing the cost of development and production of custom solutions with level shifter to ensure competitiveness.

The design of level-shift applications requires the consideration of many technical aspects and can be complex due to different performance, compatibility, and cost-effectiveness requirements. Solving these issues is key to ensuring the successful use of transducers in modern electronic systems. There's a lot to be gained from any GreenPAK Dual Supply part number for the level-shift solution.

2. Make a Level Shifter with GreenPAK

[GreenPAK](#) can often perform multiple functions within a single compact device, going beyond signal-level-only applications. Just a single GreenPAK device can implement glue logic, timing adjustment, reset, power sequencing, LED control, and more depending on design requirements and resource configuration. This versatility makes it possible to significantly reduce the number of components and simplify the development of electronic systems.

Dual Supply GreenPAKs provide flexibility in using different power sources, which is an obvious advantage for many applications. Below is a list of our Dual Supply GreenPAKs, along with the number of GPIOs dedicated to each voltage domain.

| Part Number | VDD1 GPIO | VDD2 GPIO |
|-------------|-----------|-----------|
| SLG46121V | 5 | 4 |
| SLG46535V | 7 | 4 |
| SLG46538V | 9 | 8 |
| SLG46621V | 9 | 8 |
| SLG47525 | 7 | 4 |
| SLG47528 | 9 | 8 |

Figure 1 shows the voltage domains of Dual Supply GreenPAKs. Pay special attention to the new SLG47525/28. These GreenPAKs interface 0.95 V to 1.98 V and 1.71 V to 5.5 V rails, closing the gap in GreenPAK voltage levels.

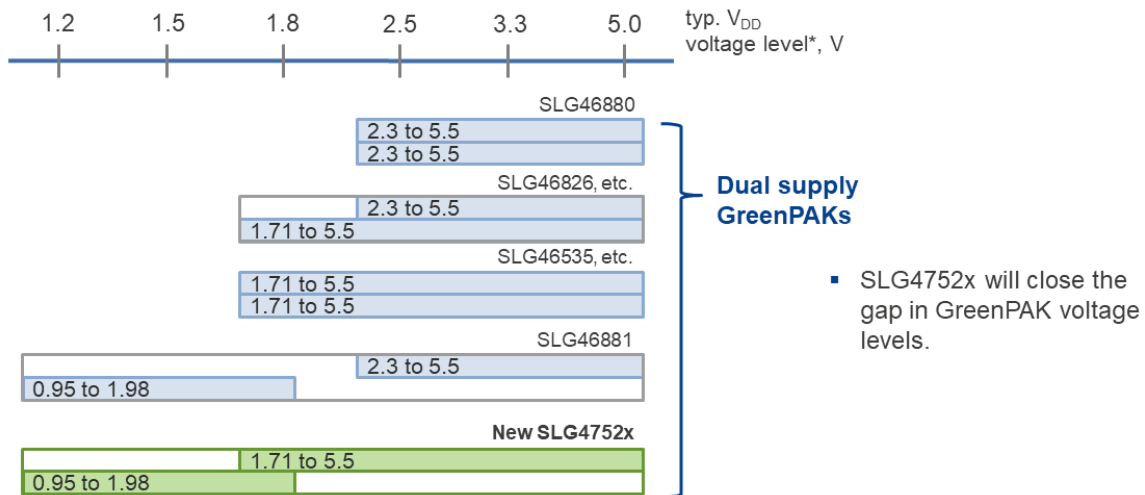


Figure 1. GreenPAK Voltage Levels

Let's discuss the most obvious benefits of using GreenPAK for a level shift.

The first thing is that GreenPAK enhances effectiveness with dual supply, as dual supply provides a wide range of high-efficiency level-shifter capabilities supporting 0.95 V to 1.98 V for VDD2 and 1.71 V to 5.5 V for VDD.

In addition, GreenPAK maximizes flexibility. It contains configurable GPIO where it's possible to set the pull-up/pull-down resistors, push-pull, open drain, and others. Some of the upsides include flexible GPIO routing ensuring the

Level Shifter Circuits - Design Basics and Applications

least complexity in PCB routing. GreenPAK lets integration of many components, generating custom timing and logic to further eliminate external components while bridging voltage domains and signal requirements.

Besides, GreenPAK ensures system stability by integrating many components leaving fewer points of failure and working on a simple logic level without any complicated core.

When it comes to power consumption, GreenPAK has flexible user-defined power-saving modes for all macrocells allowing continuous operation without ruining the power budget.

Last but not least, GreenPAK reduces board size and solution costs by being placed in a tiny package at a low price making it a perfect solution for mobile and wearable electronics.

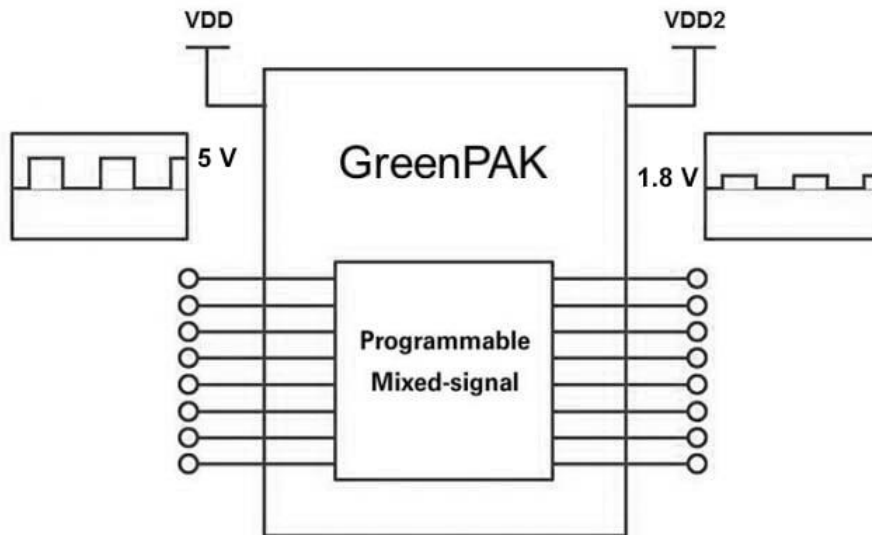


Figure 2. GreenPAK as a Level Shifter Basic Diagram

3. Level Shifter with GreenPAK Applications

Take a look at common level shifter designs, which can be created with any Dual Supply GreenPAK.

3.1 Uni-directional Level Shifter

The simplest form of level shift is uni-directional. They transmit signals in one direction only, from a source with one voltage to a receiver with another voltage.

Advantages:

- Ease of implementation and management.
- No need to determine the direction.

Disadvantages:

- Limitation in the direction of data transfer.
- Not suitable for applications where bidirectional data exchange is required.

Shifting a single direction, up or down, is easy in GreenPAK since all GPIO can be configured as inputs or outputs.

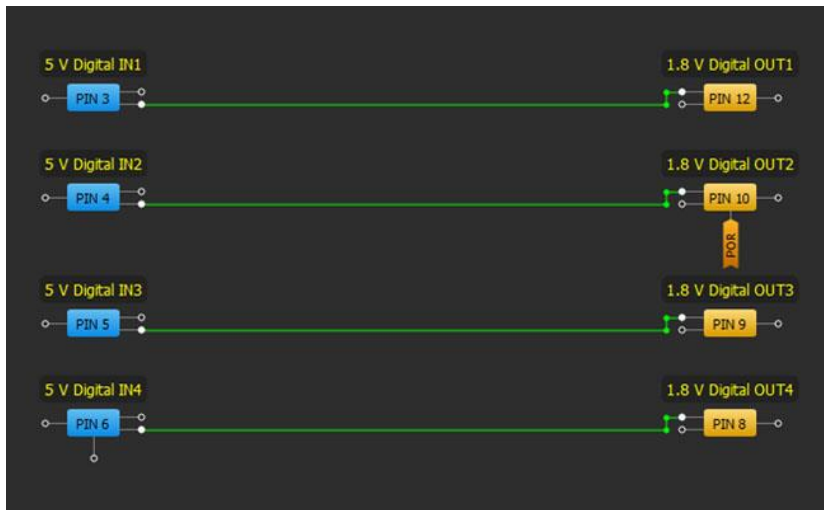


Figure 3. Uni-directional Level Shift Implemented in GreenPAK

Key Design Considerations

Number of signals: GreenPAK can support up to 9 inputs/8 outputs on a single voltage domain.

IO Configuration: Configurable pull-up/pull-down resistors on GreenPAK’s GPIO make communicating with any IC a snap.

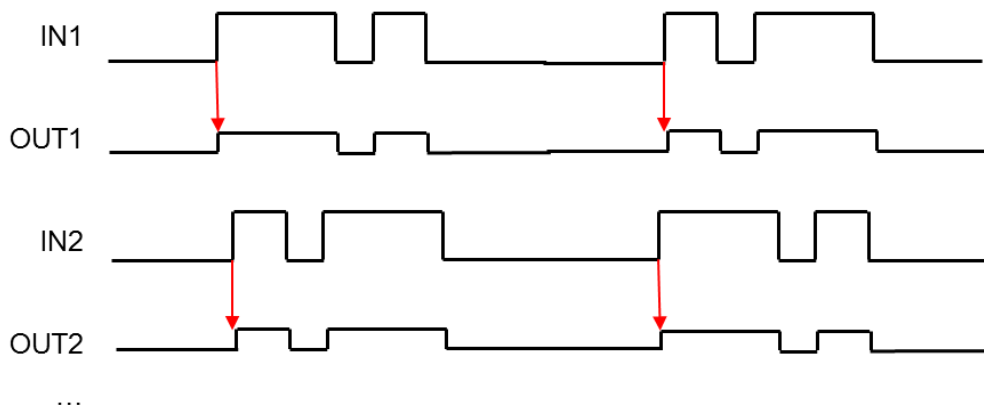


Figure 4. Timing Diagram

3.2 Bi-directional with Dedicated Ports

This type of level shifter is similar to uni-directional. They use an external signal to determine the direction of data transmission.

Advantages:

- Accurate control of data transfer direction.
- Ease of management for developers.

Disadvantages:

- The need for an additional control signal.
- Delays are possible when switching direction.

Using GreenPAK’s configurable GPIO to dedicate specific pins or groups of pins as input or output is easy. Each pin tied to a particular voltage domain can be configured independently allowing information to flow from lower to higher VDD or higher to lower VDD.

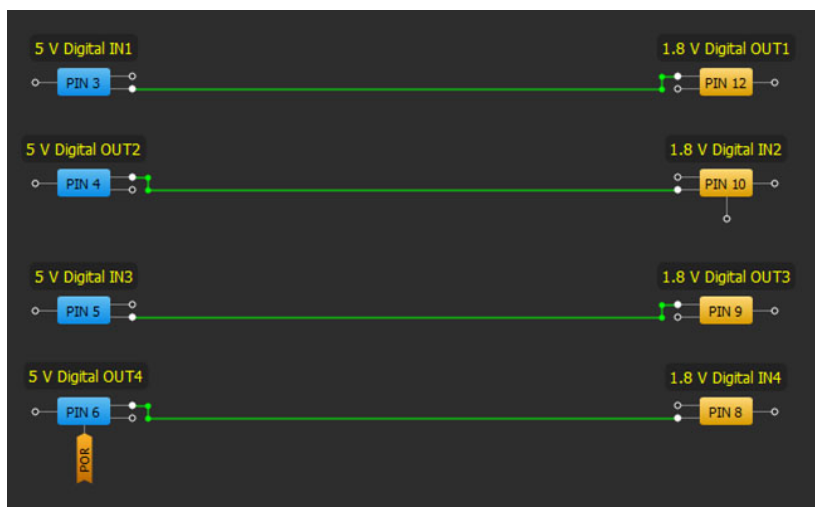


Figure 5. Bi-directional Level Shift with Dedicated Ports Implemented in GreenPAK

Key Design Considerations

Number of Signals: GreenPAK can support up to 9 inputs/8 outputs on a single voltage domain.

IO Configuration: Configurable pull-up/pull-down resistors on GreenPAK’s GPIO make communicating with any IC a snap.

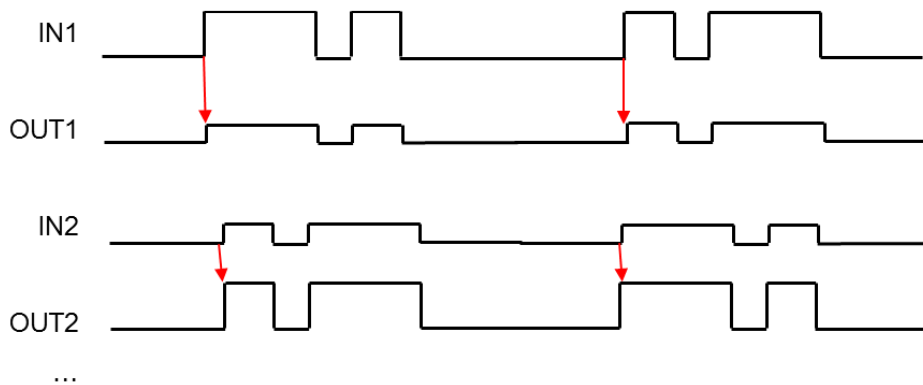


Figure 6. Timing Diagram

3.3 Bi-directional with External Direction Indicator

They use special ports to determine the direction of data transfer automatically.

Advantages:

- Automatic determination of direction without the need for external control.
- Smaller switching delays.

Disadvantages:

- More complex internal design.
- Less flexible in some specific applications.

With GreenPAK it is also possible to dual-purpose certain GPIO as digital input and output using the output enable pin to control the direction.

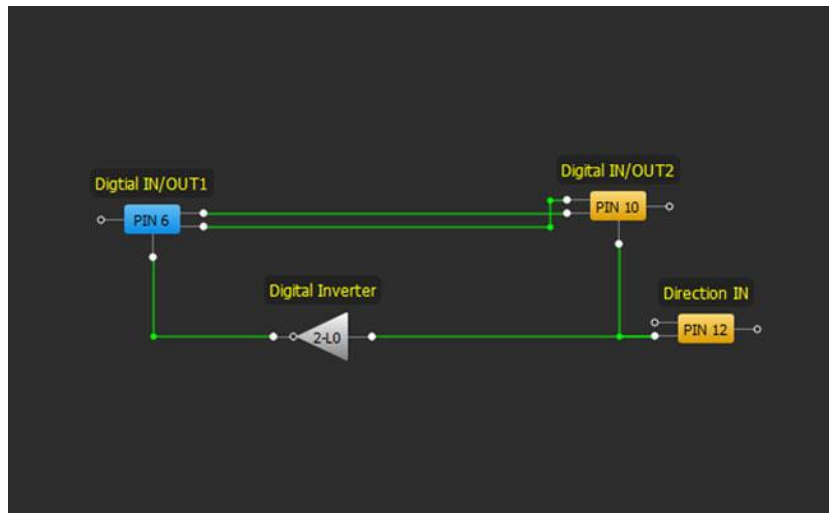


Figure 7. Bi-directional Level Shift with External Direction Signal Implemented in GreenPAK

Key Design Considerations

Direction Signal Polarity: Using GreenPAK’s integrated LUTs configured as an inverter can accommodate any signal polarity.

Direction Signal Origin: With GreenPAK, the direction signal input can be from either voltage domain.

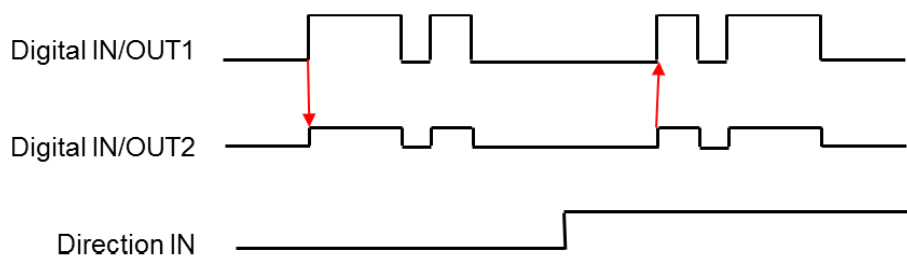


Figure 8. Timing Diagram

3.4 Bi-directional, Autosensing

They automatically determine the direction of data transmission based on signal activity on the transmission lines.

Advantages:

- Maximum flexibility and ease of use.
- Minimal signal delays.

Disadvantages:

- More complex internal design.
- Possible difficulties in predicting work in some specific cases.

Using GreenPAK’s configurable digital and timing resources, it is even possible to implement an auto-sensing, bi-directional, level-shift solution such as the I2C Level-shift shown in [AN-1104](#).

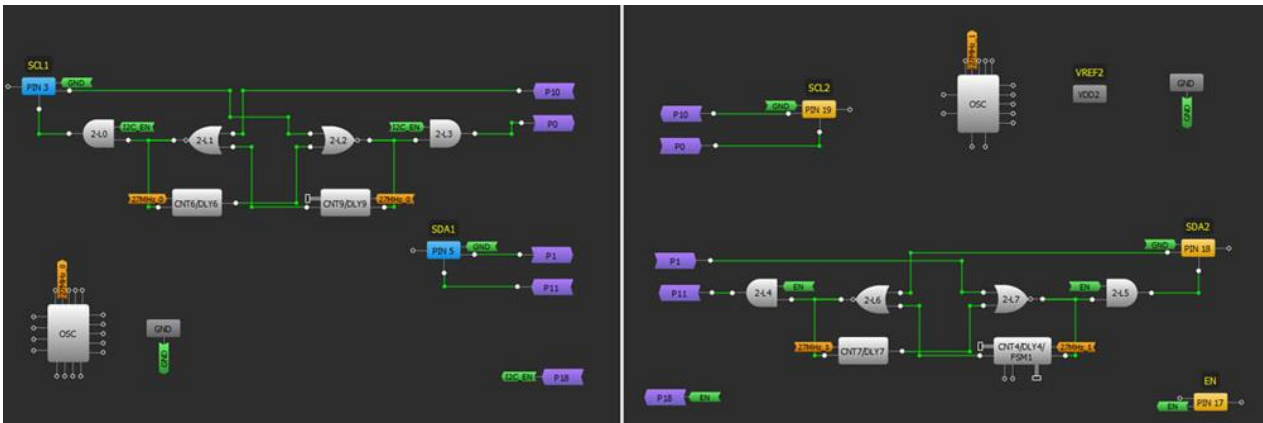


Figure 9. Auto-sensing Bi-directional I2C Level Shift

Key Design Considerations

Response Time: GreenPAK is capable of up to 1 MHz standard I2C.

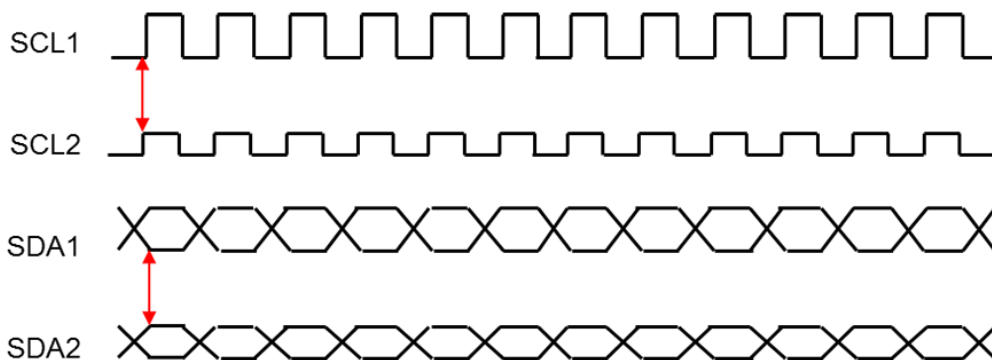


Figure 10. Timing Diagram

4. Conclusion

Level shifters are indispensable components in modern electronics, ensuring compatibility between devices operating at different voltages. Due to their ability to transmit signals between components with different voltage levels, they find wide applications in a variety of industries, including telecommunications, automotive, medical equipment, and consumer electronics.

There are several types of level converters – uni-directional and bi-directional – each with its own unique advantages and disadvantages.

With the development of technology and increasing requirements for the compatibility and efficiency of electronic systems, the market for level shifters is continuing to grow. This market is expected to expand in the coming years due to increasing demand for wearable devices, IoT, automotive electronics, and other application areas.

Designers need to choose the right type of level shifter, taking into consideration the specific requirements of their project, to ensure optimal performance of the electronic system. Considering these aspects, level shifters remain key elements for the successful design of modern electronic devices.

Dual Supply GreenPAKs provide additional flexibility in using different power sources, which is an obvious advantage for many applications. They increase efficiency by supporting a wide voltage range for VDD2 (0.95V to 1.98V) and VDD1 (1.71V to 5.5V). GreenPAK provides maximum flexibility with configurable GPIOs, simplifying routing on PCBs and allowing integration of many components to reduce system complexity. In addition, GreenPAK provides system stability and low power consumption, making it an ideal solution for mobile and wearable electronics. Thanks to its compact size and low cost, GreenPAK contributes to reducing the size of the board and the cost of the solution. Thus, level shifters on Dual Supply GreenPAK remain key elements for the successful design of modern electronic devices.

5. Revision History

| Revision | Date | Description |
|----------|-------------|------------------|
| 1.00 | Jul 2, 2024 | Initial release. |