



Whitepaper

# Advantages of Wireless Human-Machine Interface (HMI) for Industrial Automation

How leveraging Bluetooth in industrial devices can transform the user experience and improve product lifetime value

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## Human-machine interfaces (HMI) are ubiquitous and have become the subject of a tremendous amount of development in recent years.

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While today's consumer products offer enhanced connectivity and a more immersive user experience through innovative HMI designs, industrial products continue to employ physical interfaces typically featuring HMIs that rely on small displays or simple LEDs and resort to electromechanical switches or pushbuttons as their primary means of interaction. If a device features local connectivity, it is typically implemented using cables and physical connectors. There is great potential to improve the user experience by transforming the way industrial products are interconnected, and this presents an opportunity for innovative vendors to differentiate their products in an increasingly crowded market.

Industrial device HMI presents significant challenges for designers. Product design specifications may be guided by standards; devices may have limitations on their physical size, and controls may need to be fitted to larger installations. Products used in industrial settings represent critical capital investments that are expected to reliably remain in service for many years, even as their local ruggedized interfaces are subjected to diverse stress factors. Safety is also an important consideration. Products must remain safe to operate when connected to other equipment, such as computers, which typically requires the use of galvanic isolation on all external ports.

Modern, standards-driven wireless technologies, such as Bluetooth, present designers with new tools that can help them transform the user experience for industrial devices. In addition, human-machine interfaces based on Bluetooth offer cost savings compared to conventional wired connectivity solutions.

### Contents:

- Creating a better, more efficient user experience with Bluetooth
- Increased cost savings and future proofing with wireless interfaces
- Embedded systems and mobile phone access

## Bluetooth Offers a Superior User Experience



Using Bluetooth with industrial devices eliminates the physical dependence on specific connector types by enabling end-users to connect to their devices wirelessly using any Bluetooth-enabled device. Nearly all devices, including smartphones, tablets, and laptops, support Bluetooth, which clearly illustrates the platform-independence of this technology. This can be extremely beneficial for end-customers as they are no longer limited to using custom devices that are physically and electrically compatible. Even competing operating systems and product brands become compatible by using Bluetooth.

With the increased flexibility of Bluetooth, developers are free to create more innovative and intuitive graphical user interfaces by leveraging mobile applications and are no longer restricted by device dimensions or the need to accommodate physical buttons. Easily understood user interfaces not only provide an aesthetically pleasing experience but can also reduce user-related errors. Intuitive screens can help in navigating features and provide users with clear instructions, as opposed to the complex sequences of button pushes used in conventional designs. Thus, the time required to train operators on new systems can be reduced, providing an additional benefit to end customers.

When access to devices and data is simplified, new data-driven use cases and features can be developed. These include reducing the time needed to reconfigure device settings or adding features like predictive maintenance by accessing and analyzing operational data. These operations can be accomplished over-the-air without impacting normal operations. And, by introducing cloud connectivity, operator errors can be addressed by distributing the new settings centrally from a hosted database instead of relying on them to be programmed locally by operators.

## Removing Physical Connections Can Deliver Cost Savings

Bluetooth offers significant cost savings compared to traditional human-machine interfaces. Galvanically isolated serial ports are one of the most common interface technologies in the industrial device market. The bill of materials cost for a system-in-a-package Bluetooth module can be up to 48% lower than that of an isolated serial port, and, if the device also has a local LCD display and electromechanical components, such as switches and pushbuttons, the cost difference becomes even greater.

Further savings can be derived from reduced maintenance costs. With Bluetooth, there are no mechanical parts accessible to the user; thus, there are no failures associated with those components, resulting in fewer product returns. For end customers, a wireless interface removes the possibility of experiencing mechanical failures caused by mishaps like broken connectors, thus avoiding costly repairs.



## Improving Future-Proofing and Security through Wireless Interfaces

Industrial devices are expected to have a working life of many years, which greatly exceeds the typical lifetime of most consumer products. Over this time, new features are inevitably developed to meet evolving market requirements. Adding new functionality to industrial devices can be a cumbersome process because they are often located in places with limited physical access or where access requires substantial effort and costs. By using over-the-air firmware updates, wireless technology provides a much simpler channel for upgrades. For end-customers, device upgrades provide new ways of leveraging their initial investment, and device manufacturers are empowered to implement new business models focused on selling optional software-enabled features, which can extend the lifetime revenue of their products.

Like all software, mobile applications require maintenance, and the underlying operating systems continue to evolve. When selecting a Bluetooth vendor, a device manufacturer should pay close attention to their vendor's commitment to maintaining both the Bluetooth stack as well as the mobile application libraries. A vendor that provides timely and tested updates to their libraries when new major versions of the operating systems are released is preferred.

Industrial systems are increasingly becoming the targets of cyberattacks. In addition, there is a growing number of regulations already in place or being planned. An example of one recent regulation is SB327 in California, which sets forth rules for internet-connected devices. While Bluetooth inherently includes security features, such as encryption, it is not enough to rely on the security provided by the standard itself. Device manufacturers should ensure that their Bluetooth vendors have a strong security posture and that wireless SoCs and modules include advanced features, such as [secure boot](#), to prevent unsigned firmware from being executed on their devices.

Cloud connectivity is becoming mainstream in the industrial IoT. By combining Bluetooth with modern mobile operating systems, secure cloud connectivity becomes much simpler than updating legacy desktop applications. Moreover, cloud applications make software update delivery more centralized. As the Industry 4.0 wave sweeps through different market verticals, the demand for cloud-based solutions is predicted to continue its growth trajectory.

## Reducing the Number of Electromechanical Devices will Improve Reliability

What is the mean time before failure for a push-button or display? How many mating cycles can a physical connector endure without fault? These, among many others, are questions designers must consider for devices with physical user interfaces. Conversely, wireless technologies are not subject to mechanical stresses, and removing a physical interface means that there is one less variable to consider when hardening a design for industrial environments.

Anything that physically connects to a device requires an opening in the enclosure. Because industrial devices are often deployed in variable and harsh environments, such openings must be protected against dust, water splashes, and other conditions that could damage the device or its parts. With Bluetooth, device enclosures can be completely sealed. If LED indicators are used, even they can be placed inside an enclosure and observed through a translucent barrier.

The reliability gains made possible through the use of Bluetooth can deliver real cost savings for device manufacturers and end customers. These include:

- Less time spent on designing the enclosure to withstand harsh environments, which results in faster time-to-market.
- Reduced number of electromechanical components, which are commonly very costly compared with semiconductor parts; so, removing these costly components from the design also improves gross margin.
- Lower Total Cost of Ownership (TCO) for end customers since a simplified human-machine interface using Bluetooth requires less maintenance.

Industrial environments in which large numbers of machines and equipment contribute to RF noise levels are known to be a challenge for radio technology. Because Bluetooth uses frequency hopping, it is better equipped to withstand RFI from various sources. This is an important consideration since the 2.4 GHz ISM band is used by many applications and technologies. An interferer blocking one or more channels will be unable to entirely disrupt communications. Therefore, Bluetooth is also suitable for industrial settings.



## Bluetooth Connectivity Design Considerations

There are a variety of ways to add Bluetooth connectivity to an application. In cases where a developer has a combination of in-house Bluetooth design expertise, embedded firmware and mobile development teams, and the resources necessary to take a design through the RF certification process, designing a Bluetooth-enabled SoC solution into an application can be cost-effective.

Pre-integrated and pre-certified wireless modules are an ideal solution for companies with limited wireless product design expertise. Choosing an integrated module with pre-certified RF and hardware enables companies to spend less time adding wireless technology to their designs.

The benefits of choosing a Bluetooth module include:

- Integrated antenna options, which minimizes the need for in-house RF expertise
- Pre-certification, which avoids lengthy and costly RF certification efforts
- Out-of-the-box performance that meets most needs

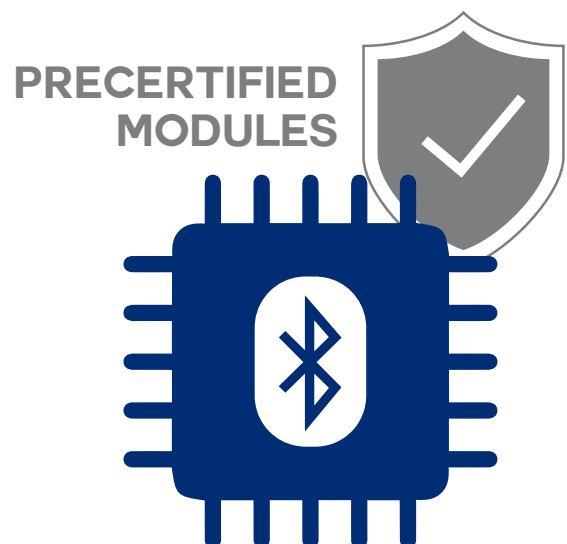
## Preprogrammed Modules Offer Benefits

Adding Bluetooth connectivity using modules still requires a degree of familiarity with Bluetooth protocols as well as an understanding of how to exercise a vendor's Bluetooth stack and associated APIs. In many Bluetooth-enabled applications, developers must also create an embedded host that interfaces with the Bluetooth-connected coprocessor (NCP). This host-to-NCP communication link usually exposes low-level control of the NCP, and the embedded host must devote significant on-chip resources to maintain buffers and monitor the status of the NCP's Bluetooth link. In order to meet these requirements, engineers may be tempted to select an embedded host that is over-specified and carries a higher cost than the application actually requires. The over-specified MCU may also consume more power than is necessary.

Evaluating the right solution presents its own challenges, however, as developers must explore all possible use-cases and evaluate how each one may affect functionality. It is also necessary to test as many of these scenarios as possible to see if the application functions as expected and then troubleshoot or fix bugs as they arise. This can potentially involve complex debugging across both the host and NCP development environment.

Fortunately, Bluetooth design can be further simplified by selecting a precertified module, preprogrammed with Bluetooth firmware, to deliver out-of-the-box connectivity. The benefits of preprogrammed modules include:

- Access to a Bluetooth stack and embedded application firmware that is preprogrammed, eliminating the need for firmware development
- Gaining a production-level testing infrastructure build-up for stack and firmware handled by the module vendor
- Built-in support for firmware updates and boot-loading, thus future-proofing for security updates, bug fixes, and improvements in robustness



## Expediting Connections Between Embedded Systems and Mobile Phones

As outlined earlier, the advantages of using Bluetooth include access to a wide range of potential user interface design resources and, particularly, the convenience of using a tablet or other form of mobile device as a controller. However, mobile app development is a specialized area, so it is often an element of product design for which manufacturers will need to engage outside development services. Developers who know how to properly write application code that can interface with low-level Bluetooth APIs in both iOS and Android platforms are relatively rare, and services offering this specialized skill can be costly. Companies might also need to engage separate experts for each platform, which adds up-front costs and introduces time-consuming project setup difficulties.

Starting mobile app development using a wireless interface library that has been developed and provided by the module vendor can significantly lower barriers to entry into mobile app development. A mobile library specifically designed to interface with a chosen preprogrammed module provides:

- An abstracted interface to core Bluetooth APIs across multiple mobile operating systems
- Specialized APIs designed for optimal control of the interfacing embedded module
- A cloud-to-module route for firmware updates

[Silicon Labs' Bluetooth Xpress](#) products combine these development optimizations to provide streamlined embedded-to-phone connectivity.

Bluetooth Xpress products combine firmware, hardware, and mobile development optimizations to deliver Bluetooth Low Energy 5 modules that can reduce the time required to take an application from concept to prototype to just one day. Bluetooth Xpress products include the Xpress framework for mobile application development, which greatly reduces the development time required to add Bluetooth connectivity to mobile apps.

The key features of [Silicon Labs Bluetooth Xpress modules \(BGX220P and BGX220S\)](#) are:

- An out-of-the-box, preprogrammed, precertified Bluetooth solution supporting Bluetooth 5 features including 2M and long-range PHY
- Onboard wireless stacks controlled through a high-level Gecko OS Xpress Command API for setup and control
- Baud rate, flow control, GPIO, and Bluetooth performance parameters that are all configurable for application-specific requirements
- An I2C master interface enables Bluetooth Low Energy wireless-to-I2C communication
- Input pin monitoring for automated digital logic transition response
- Requires only modest resources from a host processor, enabling developers to add wireless connectivity to any MCU
- Available in both PCB and SiP form factors
- One point of contact for design support
- Support for Security and Firmware updates



Bluetooth Xpress modules function in three use cases:

1. BGX220 to smartphone – In this use case, the BGX acts as a peripheral, which is discoverable and connectable by a smartphone.
2. BGX220 to BGX220 – In this use case, one BGX acts as a discoverable, connectable peripheral, and a second BGX acts as the control, which scans and connects. When connected, a BGX220 can function in either a streaming mode, where data bytes are transmitted between the two points in a no-overhead data stream, or in command mode, where Bluetooth Xpress commands can be executed remotely.
3. BGX with no embedded host – This use case is a variation of use cases #1 and #2. In this case, onboard Bluetooth Xpress functionality, such as input pin monitoring, event notifications, and the Bluetooth-to-I2C bridge, provide functionality that is sufficient to take on all responsibilities of the embedded host processor.

In these defined use cases, flow control signals from the BGX indicate buffer status and can be used to indicate whether the embedded host can transmit data.

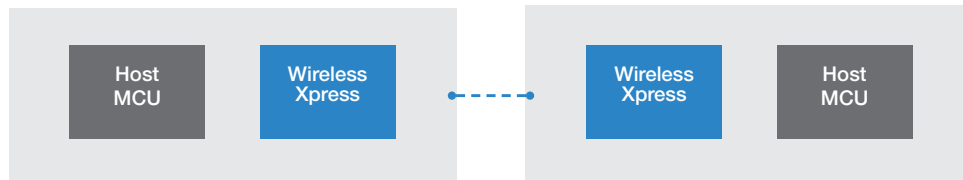


Figure 4.1. BGX to BGX Use Case

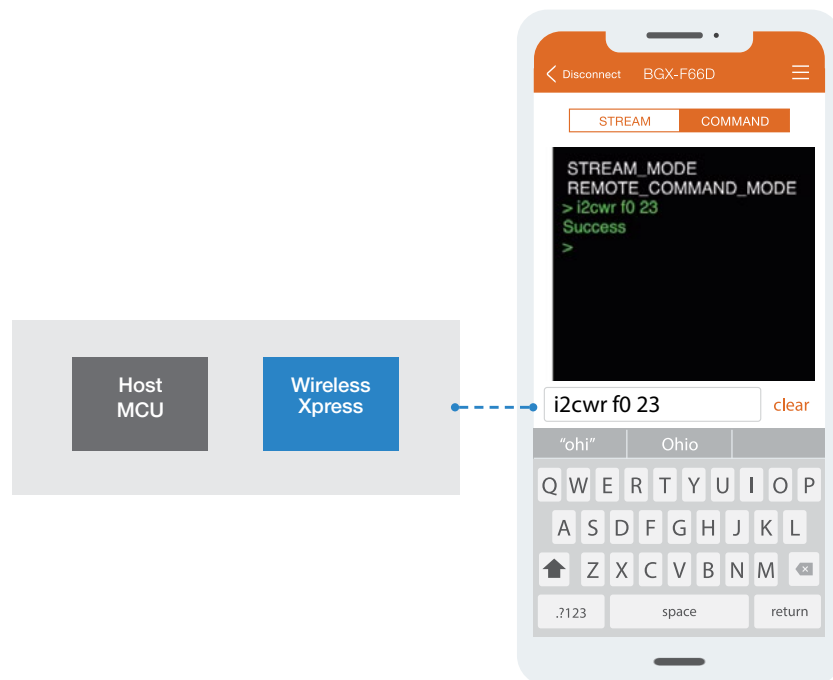


Figure 4.2. BGX to Phone Use Case

Figure A: Bluetooth modules can be deployed in many ways to meet application's specific needs



## Configuration and Communication with Bluetooth Xpress

A system controls Bluetooth Xpress's preprogrammed functionality through a command interface that is configurable at runtime, with default settings that are saved to non-volatile memory. This interface, which is available through serial interface pins and executable over-the-air through the Bluetooth Interface, functions as a high-level network coprocessor.

In most operational states, Bluetooth Xpress acts as a zero-overhead Bluetooth-to-serial data stream. For example, a Bluetooth Xpress module can signal to an embedded host that a connection has been established by changing the state of a port pin. At the point of connection, the RX and TX pins of the serial interface act as a bidirectional data interface, functioning identically to a wired serial link. Data can be written from the host to the Bluetooth Xpress module's RX pin, and Bluetooth Xpress then transmits that data byte-by-byte across the BLE link. On the other side of the BLE link, either a smartphone receives the data and delivers a buffer to a mobile app or another Bluetooth Xpress module receives the data. This receiving Bluetooth Xpress module then sends the data out through its TX pin to be received by the remote embedded host.



## Leveraging Bluetooth for Industrial Automation HMIs

Many industrial automation devices use serial protocols for local configuration and diagnostic ports. The technology is well-known and widely supported. While many of these physical serial ports have become a rare commodity in modern laptops, virtual COM-port drivers allow USB to be used instead. This legacy architecture is now fertile ground for Bluetooth-based human machine interface alternatives.

The picture shown in Figure B, (page 10) outlines a conventional industrial automation device that supports a local configuration and diagnostics port using a serial interface. The cable interface introduces challenges that also add to product cost while decreasing convenience and negatively impacting the overall user experience.

To ensure user safety, the cable interface is galvanically isolated from the rest of the industrial automation device's circuitry. In addition, the cable interface requires an IC to provide the RS-232 driver and the actual physical serial port. These, and the required passive components, add to the device bill of materials and increase the PCB space required.

The cable interface may also impose a physical access challenge. In cases where the device is installed in hard-to-reach locations, it may not be possible to connect the cable to the device. This means that the device is only capable of delivering part of its potential functionality and benefits.

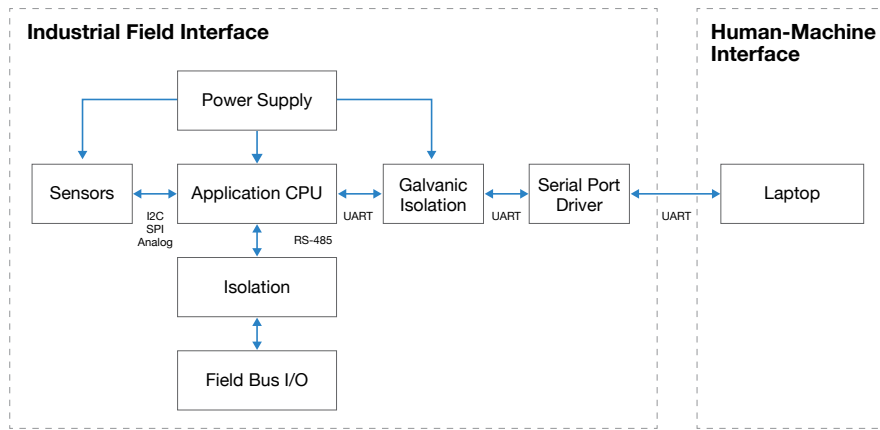


Figure B: A conventional approach to product design using a serial port with galvanic isolation

Now consider the example in Figure C, which illustrates the same industrial device enabled with a Silicon Labs BGX220 Bluetooth Xpress module, which is designed for easy cable replacement scenarios. The application CPU could continue using the existing UART interface because Bluetooth Xpress supports the transfer of serial data over the Bluetooth link. This greatly reduces the time and risk associated with the Bluetooth integration since the designer does not need to have any prior knowledge of Bluetooth. All intelligence is built into the stack and application firmware running on the module. Bluetooth Xpress also supports SPI interfacing, should that be more suitable for the application.

Bluetooth Xpress modules come in different form factors, with the smallest System-in-Package model being only 6 x 6 mm in size, making it ideal for space-constrained applications. Because the module also includes an antenna, the designer has more flexibility in the placement of the module on the circuit board.

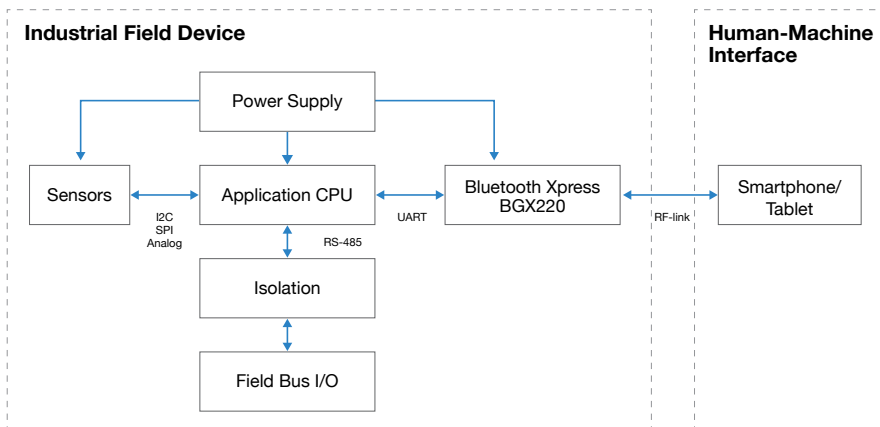


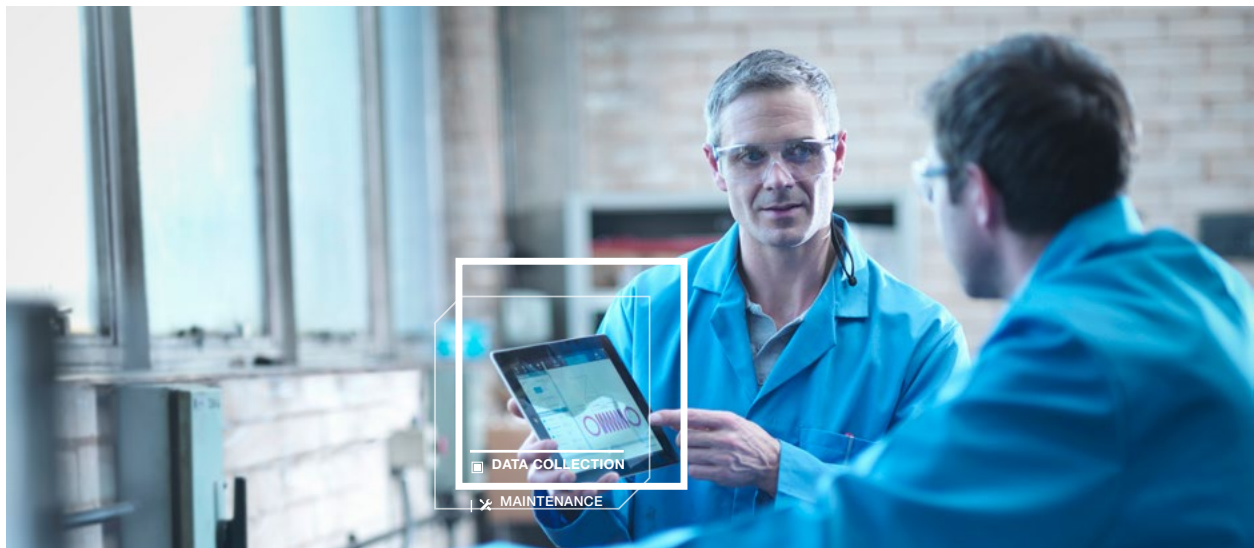
Figure C: An example application using Bluetooth for cable replacement

An important point is that using Bluetooth for the human-machine interface does not replace or impact the use of field bus communications. This maintains backwards compatibility with the previous generation of devices, something that is valued by many industrial automation device customers.

By removing the galvanic isolation, serial interface driver, and physical connector, the bill of materials can be simplified and product costs related to the cable interface reduced by up to 48%. Removing the physical connector also eliminates the need for enclosure openings to make the connector accessible to the user. Should the connector require extra protection against environmental conditions, such as dust or moisture, an even greater cost savings can be achieved, as those protectors are no longer needed with the Bluetooth-based solution.

This architecture allows users to wirelessly connect multiple devices from a single location without requiring physical access to the devices, which can also improve functional safety. This makes it possible to modify device configurations more flexibly and download diagnostic data stored in devices for analysis and troubleshooting. Bluetooth, by default, includes data encryption and hashing, which adds another layer of protection against cyber threats.

As outlined above, the mobile application framework that comes with Bluetooth Xpress products significantly simplifies Bluetooth integration. By abstracting low-level Bluetooth functionality to be accessed via an API, device manufacturers can achieve faster time-to-market as valuable development efforts are spent on adding functionality rather than learning Bluetooth's peculiarities for Android or iOS. And mobile applications also support cloud connection, which can be used to provide new cloud-based product offerings.



## Conclusion

By its nature, Bluetooth is hardware-agnostic. A growing number of devices now support Bluetooth connectivity, which means it is an effective abstraction layer between low-level functionality and high-level control and monitoring features.

The benefits of Bluetooth in industrial environments are numerous. As a cable-replacement technology, it is already a proven solution with applications in HMI design. Adding Bluetooth connectivity using a module like Silicon Labs Bluetooth Xpress can deliver significant and measurable savings. Costly components required for physical cable interfaces can be eliminated and significant cost reductions achieved. More user-friendly interfaces can be provided using mobile applications, and functionality can be further extended by connecting applications to the cloud.

With readily available APIs for easy integration at the board, link, and mobile application levels, the Bluetooth Xpress portfolio is an ideal solution for replacing existing cable interfaces with serial communications. Using pre-certified modules enables faster time-to-market as device manufacturers no longer have to worry about time-consuming certification processes and can instead focus on marketing efforts to make their devices successful. Kickstart your wireless HMI project by ordering the [Bluetooth Xpress evaluation kit here](#).

Watch the “Transforming HMI in Industrial Devices Using Bluetooth” on-demand webinar where the authors discussed and answered questions on HMI & [BGX220](#).

