WQ
WIRELESS QUARTER

Issue 4, 2020

GREENER HOUSE GAS:
HYDROGEN SMART METERS HOLD THE KEY TO CLEANER ENERGY

MUSIC UNPLUGGED:
A PERFECT BLEND OF ART AND TECHNOLOGY

THE PATENT DEBATE:
WHY STANDARD ESSENTIAL PATENTS AREN'T WORKING

The IoT is the New Normal

To remain viable in a post COVID-19 world, business and industry are embracing the IoT on a massive scale

NORDIC ADDS Wi-Fi TO ITS PORTFOLIO

ACCELERATING THE SMART HOME VISION

INSIDE THE nRF CONNECT SDK

NORDIC SEMICONDUCTOR

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Welcome

Svenn-Tore Larsen
CEO

Nordic's staff are committed to a vision of the company becoming a billion-dollar firm in the next several years. But it's an ambitious target and we won't get there unless we maintain existing client loyalty and attract new business.

We regularly ask our customers how we can get better and it seems that while we've built a leading reputation in short range wireless and are making an impact with our low power cellular IoT solutions, our customers would like an end-to-end IoT solution from Nordic; one capable of connecting wireless sensors to the Cloud, for every application.

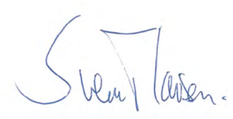
We've now taken a big step towards addressing this request by adding Wi-Fi expertise and Wi-Fi IP to Nordic through the acquisition of the Wi-Fi team from Imagination Technologies.

Imagination has a focus on graphics, vision and AI processing while Nordic concentrates on wireless tech. The transfer of Imagination's Ensigma Wi-Fi assets to Nordic makes a lot of sense for both firms as they each focus on their core competencies.

Originally developed as a consumer electronics technology, Wi-Fi is rapidly evolving into an industrial IoT protocol. That makes it a perfect complement to Nordic's existing product portfolio. And the competencies the new Wi-Fi team bring will perfectly complement Nordic's existing staff. These new employees will be warmly welcomed into the operations and culture of one of the best semiconductor companies in the world to work for.

It will take time to design and build Nordic Wi-Fi products but in the near future we will become one of a very select group of vendors who can globally supply all three key IoT technologies: Bluetooth LE, Wi-Fi and cellular IoT. That will be a proud milestone moment for the company.

> Wi-Fi is rapidly evolving into an industrial IoT protocol. That makes it a perfect complement to Nordic's existing product portfolio



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News

The latest developments from Nordic Semiconductor

Smart Home

Nordic and Amazon collaborate on Sidewalk project

Nordic Semiconductor and Amazon are cooperating on the development of Bluetooth LE solutions for Amazon Sidewalk, a neighborhood network designed to help customer devices work better at home and beyond the front door.

Amazon Sidewalk is based on a new protocol operating in the 900 MHz band which can extend the working range of many smart home applications by up to one kilometer. The capability allows consumers to position smart devices in places that the home wireless network previously failed to reach. Sidewalk can also help simplify new device setup and help devices stay online and up-to-date even if they are outside the range of home Wi-Fi.

Nordic is collaborating with Amazon to ensure it can offer customers development support for its Bluetooth LE solutions when used with Amazon Sidewalk technology and its associated ecosystem.

Support for Amazon Sidewalk follows on from Nordic's existing cooperation with Amazon Common Software (ACS), a platform to help accelerate the development of smart home and other wireless products. Nordic Semiconductor intends to provide and maintain a Device Porting Kit (DPK) for its wireless chips that allows them to be easily and natively integrated into ACS as one of its reference platforms.

"By cooperating with Amazon Sidewalk and ACS, we will be able to help our customers build smart home products that will bring even greater convenience, flexibility and safety to consumers," says Kjetil Holstad, Director of Product Management at Nordic Semiconductor.

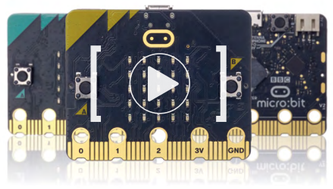
Elsewhere, Nordic announced that the latest version of its nRF Connect SDK includes example application software code for Alexa Gadgets. Alexa Gadgets are Bluetooth connected, interactive companion devices that work with Amazon Echo devices.

When a product is built with the Alexa Gadgets Toolkit technology, a customer can use Alexa, Amazon's Cloud-based voice service, to interact with that product.

By using the example code produced with the nRF Connect SDK, developers can accelerate time-to-market for Alexa Gadgets based on Nordic's nRF52 Series or nRF53 Series SoCs. (*See pg30.*)

Education

micro:bit to support AI, machine learning



The Micro:bit Educational Foundation has launched a new version of its pocket-sized educational computer, the first major update since the launch of the original BBC micro:bit in 2016.

The original micro:bit was powered by Nordic's nRF51822 SoC and, according to the Foundation, helped inspire more than 25 million children in over 60 countries to learn digital creativity and computing skills.

The new micro:bit is based on Nordic's nRF52833 SoC. The 64MHz, 32-bit Arm Cortex-M4 processor with floating point unit offers a powerful upgrade over its predecessor, in addition to twice the Flash memory and eight times the RAM allocation.

"Nordic Semiconductor was pivotal in the original development of the BBC micro:bit and remains pivotal to its success to this day," says Gareth Stockdale, CEO of the Micro:bit Educational Foundation and a joint lead on the original BBC project.

Additional enhancements include the integration of an on-board speaker, a MEMS microphone input with LED indicator, a capacitive touch sensor under the logo and built-in sleep/off mode. Together the upgrades enable the micro:bit to support new complex functionality such as AI and machine learning applications that respond to sound, voice, motion and light patterns.

"The purpose of the micro:bit is to help children unlock their creative potential and learn how to shape the world around them. Learning coding and computational thinking can enhance their life chances in the 21st century," says Stockdale.

Smart Health

COVID-19 tracker aims to get people back to work

A wearable Bluetooth LE tracker, that uses Direction Finding and Long Range technology to ensure accurate social distancing compliance, is helping staff at return to work during the COVID-19 pandemic.

The Nordic-powered Mimic S device launched by U.S.-based startup, Smart Mimic, uses Direction Finding to trigger an alarm whenever two employees come within two meters of one another, or spend longer than 30 seconds in close proximity.

Collected data is then sent to a smartphone-free, Cloud gateway and can be used to provide a workforce-wide 'heat map' of risky contacts on a dashboard as well as an employee head count.

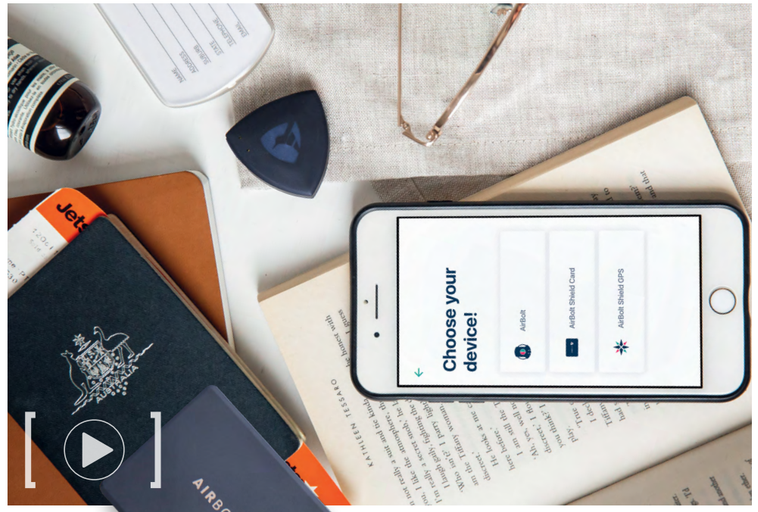
Dual cellular IoT, Bluetooth LE asset tracker delivers global coverage

Australian company, AirBolt, has combined low power cellular connectivity and assisted GPS alongside Bluetooth LE and Direction Finding technology in a tracking device. The lightweight and waterproof AirBolt GPS offers both precise localized and global asset tracking functionality.

AirBolt integrates Nordic's nRF9160 SiP and nRF52833 SoC, a three-axis MEMS accelerometer for free fall and motion detection and a temperature sensor for remote monitoring of the environment.

The solution also supports the company's ecosystem of secure access and remote asset management products. For example, the device can act as a gateway for the smart travel lock allowing users to remotely locate and monitor their luggage once it has left their possession. Alternatively, the solution can be used for enterprise level, large scale asset tracking, enabling companies to securely and remotely monitor critical equipment.

Nordic's nRF9160 SiP combines cellular network location data with GPS trilateration to provide precise position monitoring, while the nRF52833 enables 2D and 3D indoor location services as well as wireless connectivity between multiple AirBolt products and a smartphone app. The Li-Ion battery is said to provide best-in-class battery life of 12 months between recharges.



AirBolt uses Nordic's nRF9160 SiP and nRF52833 SoC, a three-axis MEMS accelerometer and a temperature sensor for remote monitoring of vital assets

"With user configurable options for data reporting the AirBolt GPS can operate for up to a year on a single charge which will be an absolute game changer for the industry," says Kabir Sidhu, CEO and Founder of AirBolt.

Tags offer precise location finding

A positioning system based on Bluetooth LE Angle-of-Arrival (AoA) technology can deliver sub-meter positioning accuracy, offer improved location finding and provide asset tracking in large facilities such as hospitals, supermarkets and warehouses.

Launched by Chinese positioning technology company, BlueIoT, the tags are powered by Nordic Semiconductor's nRF52833 SoC and can be placed in key locations throughout a facility. The tags can also be attached to assets in a warehouse, enabling customers, patients and staff to navigate their way to a specified location or item via a smartphone app.

"The nRF52833 is currently one of the few SoCs worldwide to offer ... all the requirements to implement a Bluetooth LE AoA positioning solution," says Rayson Zhao, CEO of BlueIoT Technology.

Industrial IoT

Wearable barcode scanner now integrates social distancing tool

German industrial technology firm, ProGlove, has added COVID-19 social distancing functionality to its ProGlove Connect app. Users of its wearable barcode scanners can now not only reduce the time it takes to scan items while keeping their hands free but also ensure they maintain appropriate distances from their coworkers at the same time.

The company's MARK scanners are already widely in use in factories and warehouses by customers such as BMW, Audi and Bosch, and while the app is currently in its beta phase it has been extensively tested on the company's own inhouse assembly lines. The company said the combination of optic, acoustic and haptic signals adds multiple warnings to ensure alerts are not overlooked in busy or noisy industrial environments.

"Humans are creatures of habit and can easily forget to maintain a safe distance apart," says Axel Schmidt, Senior Communications Manager at ProGlove. "Our solution ... can utilize a hardware device already widely in use. The extra COVID-19 social distance monitoring and alerting functionality has simply been added on top."

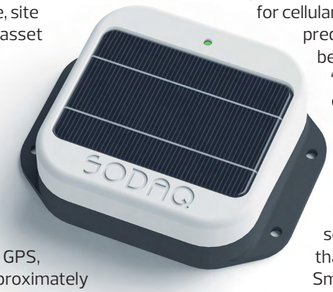
The ProGlove MARK wearable scanners are powered by Nordic Semiconductor's nRF52840 SoC, and are able to perform up to 10,000 scans between recharge.

Industrial IoT

Cellular asset tracker can operate on harvested solar energy alone

A Dutch engineering and design company has unveiled what it claims is the world's first solar-powered, perpetual operation cellular IoT asset tracker. SODAQ says in low duty cycle applications comprising up to eight 'pings' a day, its TRACK SOLAR device will operate continually on harvested solar energy alone, making it ideal for a wide range of logistics, offshore, site management and general asset tracking applications.

The tracker integrates Nordic's multi-mode NB-IoT/LTE-M nRF9160 SiP, as well as a light sensor, accelerometer, temperature sensor, and status LEDs. It offers positional accuracy of between five and 20 m for GPS, 10-50 m for Wi-Fi, and approximately 100 m for cellular.



TRACK SOLAR can, for example, be easily attached to the side of shipping containers and can monitor their location for up to five years. Operators are constantly informed of the container's location, preventing loss or theft.

"As the IoT moves into having hundreds of billions of devices installed worldwide, batteries suddenly become an important issue," says SODAQ CEO, Jan Willem Smeenk.

"First there is the cost issue of having to check and replace batteries which in large IoT installations quickly become the single biggest cost factor over an IoT product or sensor's lifetime. This cost factor will become even more significant as the data subscription costs for cellular continue to fall to what I predict will be around $1 a year before long.

"Second there is the environmental impact of having billions of batteries wasted a year. The future of IoT really does need to be batteryless and therefore self-powered whenever that's possible."

Smeenk says the tracker is able to operate without a battery by optimizing the available hardware and software, including the low power characteristics of the Nordic SiP, and obeying the three golden rules of low power IoT design: "Sleep as often as you can, work or go active for as short a period as possible, and communicate as briefly as possible when on-air."

By the Numbers

$119 million in revenue

Nordic Semiconductor has reported Q3 2020 revenue of $119 million, a notable increase of 45 percent from Q3 2019. Order backlog was a record high $288 million at the end of the quarter, offering support for continued year-on-year revenue growth. The company said the high revenue growth reflects accelerated technology adoption and broad-based demand increases across all end-user markets, with Bluetooth LE contributing 81.3 percent of total revenue during the quarter.

1 billion Arm chips shipped

In October 2020, Nordic Semiconductor shipped its one billionth Arm Cortex-M based ultra low power wireless SoC, a milestone reached in just eight years. Nordic's first Arm Cortex-M based SoC was launched in 2012 with the introduction of the nRF51 Series. Since then, each successive ultra-low power Nordic SoC has included an Arm Cortex-M processor, allowing Nordic chips to support every major low power wireless standard including Bluetooth, Thread, Zigbee, ANT and 2.4GHz proprietary, from a single chip. The latest SoC, the nRF5340, features two Arm Cortex-M33 cores.

In Brief

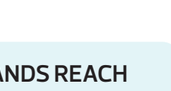
nRF9160 EXPANDS REACH

Nordic's nRF9160 cellular IoT SiP has expanded its global reach following recent certification and partnership announcements. The SiP has been certified for use on China Telecom's NB-IoT network that serves over 50 million customers through more than 400,000 NB-IoT base stations. In Japan the SiP has been certified by Marubeni Group for use on cellphone operator NTT DoCoMo's LTE-M network, that covers more than 99.8 percent of the country's 127 million population.

IoT BATTERY LIVES FOREVER

An emerging tech startup from California has created what it describes as a battery for the IoT "that never dies", providing a solution to one of the industry's biggest issues, battery life. According to Xidas, the VP3 solution employs vibration-based energy harvesting and overcomes the cost and maintenance required to replace wireless IoT sensor batteries. Continuously capturing the energy from small vibrations (less than 1 g of acceleration) in the environment—for example from industrial machinery—VP3 converts it into up to 10 mW of electrical power, capable of powering sensors for up to 20 years.

CELLULAR MODEM BUNDLE OFFERED



U.S. cellular modem specialist, Nimbelink, is offering its Skywire Nano Embedded Modem including 500 MB of data and 10 years service for $59. Cellular service is included for all major carriers in North America, as well as more than 100 countries worldwide. Based on Nordic's LTE-M/NB-IoT nRF9160 SiP, the embedded modem allows cellular IoT designs to be brought to market faster as it is end device certified for both LTE-M and NB-IoT cellular IoT networks.

IoT RECEIVES COVID BOOST

During the COVID-19 pandemic more than three quarters of businesses have increased the pace of their IoT projects to enable changes to their working practices, according to Vodafone Business' 2020 IoT Spotlight report. The survey, based on responses from more than 1600 businesses around the world, reported 84 percent of IoT adopters said the technology was key to maintaining business continuity during the pandemic, while 95 percent of businesses said they had received a return on investment. The report said IoT data was becoming "essential to business".

Smart Home

Smart home solutions gain HomeKit-over-Thread capability

The first smart home products to take advantage of Thread connectivity for Apple HomeKit devices have been launched by Eve Systems. The connected home solutions company has based its energy, lighting, security and outdoor products on Nordic's nRF52840 multiprotocol SoC, enabling these products to activate HomeKit-over-Thread functionality via an OTA firmware update.

"The smart home market is at a tipping point and changing rapidly," says Jerome Gackel, Eve Systems CEO. "Support for HomeKit-over-Thread takes the entire Eve platform to the forefront of smart home innovation. We're thrilled to be among the first to bring this cutting-edge smart home technology to ... users' homes."

Thread is a low power wireless mesh networking protocol based on the widespread Internet Protocol (IP) and built using open and proven standards. As it is IP-based it offers product manufacturers the flexibility to choose one or multiple app layers for their use case to connect devices across multiple networks.

Thread networks also have no single point of failure and include the ability to self-heal. As a result, the networks are claimed to be simple to set up and use and can auto-reconfigure when a device is added or removed.

"The use of Thread in addition to Bluetooth LE in Apple HomeKit will improve the user experience and options," says Nordic Product Manager for Short Range IoT, Pär Håkansson. "It will really benefit people who use the Home app and Siri on their Apple devices.

"The smart home has seen a resurgence of interest this year because COVID-19 has meant many people spending a lot more time at home than before. As such, smart home devices have taken on much more importance and relevance."

EVE Systems' energy, lighting, security and outdoor products are based on Nordic's nRF52840 multiprotocol SoC. The products can now take advantage of HomeKit-over-Thread functionality

Smart Agriculture

Murder hornets meet their match in Bluetooth

U.S. scientists from the Washington State Department of Agriculture (WSDA) are using Bluetooth LE technology to track Asian giant hornets to their nests. The invasive pests, also known as murder hornets, are not native to the U.S. and prey on honey bees and other insects. According to WSDA, a small group of murder hornets can kill an entire honey bee hive in a matter of hours.

To address the problem, a network of traps was set throughout Washington State, and three captured hornets had miniature Bluetooth LE tracking devices strapped to their bodies using dental floss before being released. The devices transmit a 'chirp' picked up by a handheld receiver, allowing the entomologists to use the Bluetooth LE radio signal to track one of the three hornets to its nest inside a tree cavity. Once the nest was located, the scientists sucked 85 hornets alive from the nest and suffocated the rest with a combination of carbon dioxide and expanding foam.

"We've now demonstrated that we can actively trap, track, find the nest and take it out," Sven-Erik Spichiger, an entomologist with WSDA, said in a virtual press conference.

A murder hornet is fitted with a Bluetooth LE tracking device. The impressive insects are wreaking havoc on bee hives in the U.S.

"And that's really what we need to be able to do to win the war overall."

Radio technology has been used by biologists for many years to track mammals and birds, but it is only the miniaturization of these devices that has made tracking insects possible. The lightest tags weigh only 200 mg but still require an insect the size of the murder hornet to carry it and retain its aerodynamic capability.

Bluetooth connected prosthetics improve quality of life

A U.S. non-profit organization founded by former students of the University of Central Florida is creating personalized bionic arms for children suffering from limb differences, with built-in Bluetooth LE connectivity to allow the wearer to adjust their prosthetic via an app.

The prosthetic limbs developed by Limbitless Solutions employ electromyographic sensors (EMG) to pick up signals generated by muscle movements in the child's upper arm. Below this is a socket to hold the prosthetic in place, matched to the child, and which fits regardless of whether the elbow is present. The forearm section of the bionic arm contains a battery pack that powers the motors controlling the different movements. The hand unit contains the core electronics and motors for the fine control of the individual fingers. This unit includes a Nordic-powered Insight SIP module that allows easy setup, adjustment and monitoring. For instance, the degree of muscle flexing required to generate a certain force in the fingers can be adjusted via an app. The app also provides easy access to battery level status.

News Extra

Nordic adds Wi-Fi to IoT portfolio with acquisition of Imagination Technologies' expertise and IP

New Wi-Fi team meets demand for complementary capability and turns Nordic into one of few global tech companies offering all three key IoT technologies: short range wireless, Wi-Fi and LTE-M/NB-IoT

Nordic Semiconductor is adding Wi-Fi to its short range wireless and cellular IoT technologies through the acquisition of U.K.-based Imagination Technologies' Wi-Fi development team and associated IP tech assets. Imagination is a world-leading graphics, vision and AI processing company and its Wi-Fi technology is marketed under the Ensigma brand.

"As the global leader in short range Bluetooth wireless technology and the emerging leader in long range cellular wireless IoT, there has been a gap [in our product range] which our customers have been asking us to fill," says Svein-Egil Nielsen, Nordic's CTO. "Now we've addressed that need by being able to add Wi-Fi functionality to future generations of Nordic products."

The acquisition includes a team of engineers located in the U.K., Sweden, India and Taiwan. Also included are a number of Bluetooth LE experts who will strengthen Nordic's renowned Bluetooth LE team.

"[This is the] perfect Wi-Fi team with decades of ... Wi-Fi design experience and expertise from whom we can learn all there is to know about Wi-Fi wireless technology. We believe in owning every link in our product chain, and with the Imagination Wi-Fi team on-board, we will now be able to add Wi-Fi hardware and software [to the other products]," says Nielsen.

The acquisition brings engineering expertise and IP rather than Wi-Fi components but, according to Nordic's Director of Product Management, Kjetil Holstad, Nordic intends to use its decades of ultra low power engineering expertise to develop chips that take maximum advantage of Wi-Fi's low power wireless application potential.

"We intend to create a development platform and environment that unifies all our wireless technologies," explains Holstad. "[A platform] that will bring all the benefits our customers have come to expect from Nordic in terms of lowering barriers to entry, removing design complexity and making it very easy for Nordic customers to add high quality, low power Wi-Fi functionality to their products and applications."

The exchange leaves Imagination Technologies free to focus on its core competencies. "With Imagination's strong focus on graphics, vision and AI processing, we feel our Wi-Fi IP division will thrive much better long-term within a company that has wireless connectivity at its center," says Simon Beresford-Wylie, Imagination Technologies CEO. "It's a perfect match."

> "The company has addressed customer demand by being able to add Wi-Fi functionality to future generations of Nordic products

Wi-Fi 6 targets the IoT

Wi-Fi encompasses a suite of technologies but it's the latest version, Wi-Fi 6, that brings the most promise for the IoT. Wi-Fi 6 has been designed primarily for indoor networking for consumer, commercial and industrial applications. It brings a theoretical throughput of 9.6 Gbps (compared to 3.5 Gbps for Wi-Fi 5). Although this throughput will be lower in practice, the enhanced rate not only enables faster response from connected devices but also allows for more network connections while still maintaining good service.

Wi-Fi 6 also promises greater security. For example, the technology benefits from Wi-Fi Protected Access (WPA) 3 which uses the Simultaneous Authentication of Equals (SAE) protocol in place of the Pre-Shared Key (PSK) protocol common to older WPA2 protection. SAE boasts enhanced encryption technology compared with PSK.

In addition, Wi-Fi 6 brings better network support. Wi-Fi 5 can simultaneously support up to 250 devices from a single router; Wi-Fi 6 boosts that support to 1024 devices. Further, battery life of Wi-Fi 6 devices will be extended by "Target Wake Time" (TWT) functionality. This enables scheduled device sleep and wake times, saving energy.

The introduction of Wi-Fi to Nordic's product portfolio complements its existing short range wireless (Bluetooth LE, Thread, Zigbee and 2.4 GHz proprietary) and cellular IoT (LTE-M and NB-IoT) product ranges. Short range radio technologies are ideal for forming the IoT's low power mesh networks linking the sensors that gather raw data, while cellular IoT is a long range technology for transmitting sensor information to the Cloud. Wi-Fi 6 will add to Nordic's capability with a low power, fast, secure and scalable version of the IP interoperable technology that can leverage the routers already found in every home and business to send data to the Cloud.

Need to Know

Since Wi-Fi arrived in June 1997, the RF protocol has become a truly disruptive tech. Later versions increased range and throughput and made use of the 2.4 and 5 GHz spectrum. The Wi-Fi Alliance was founded in 1999 to commercialize the technology. TCP/IP was later added to the existing IEEE802.11PHY and MAC layers to enable Internet interoperability for Wi-Fi equipment. More than 4 billion Wi-Fi devices shipped in 2019 and today over 13 billion devices are in use

Smart Home

Project CHIP aims to unlock smart home potential

Widespread smart home adoption remains an ideal, but collaborations like Project Connected Home Over IP are fast-tracking a connected future

> Manufacturers will benefit from the assurance that their products can communicate with other smart home products, including Amazon Echo and Apple HomePod

Despite the lofty expectations, it has taken longer than many expected for the smart home–inspired lifestyle to be widely embraced. A fragmented sector has resulted in lingering developer and consumer frustrations, impacting the overall uptake of smart home solutions. Why does this fragmentation exist? Why does this fragmentation exist? Largely because major companies have been adopting different incompatible wireless technologies and application layers—for example, Apple with Bluetooth LE and HomeKit, Google with Thread and Weave, and Amazon with Zigbee and Zigbee clusters. Several of the competing wireless protocols—including well established standards-based technologies such as Wi-Fi, Bluetooth LE, Zigbee and cellular IoT, plus bespoke options like Thread (a short range wireless protocol based on the IEEE802.15.4 physical layer (PHY))—are each suited to particular smart home use cases. Rather than offering a one-size-fits-all solution for application developers or end users, each RF technology trades-off various technical parameters, such as range, throughput, power consumption and latency, to target one part of the smart home. And each trade-off weakens the prospect of a particular technology dominating.

Despite this fragmentation, industry stakeholders are confident it's a question of when—not if—the smart home will deliver huge benefits to consumers. The obvious advantages of the technology include energy efficiency, enhanced comfort and better security. From advanced surveillance cameras and smart locks to connected lighting, speakers, pet feeders and more, smart home solutions will improve users' lives. To accelerate this vision, leading smart home end-product companies and trade associations representing the interests of particular technologies are now working together.

Planning ahead with Project CHIP

A key collaboration, Project Connected Home Over IP (CHIP), could play a pivotal role in boosting the smart home market, which industry analysts estimate will be worth more than $50 billion by 2022. Promoted by the 150 companies forming the Zigbee Alliance, Project CHIP plans to invigorate the relatively nascent smart home sector by providing a standard application layer that can be used with a set of complementary wireless technologies agreed upon by the participants.

Initially the focus will be on Wi-Fi, Thread and Bluetooth LE, followed by other Internet Protocol (IP) supporting protocols such as Ethernet and cellular. Creating a universal application protocol on top of the mature IP and lower layer protocols will ensure interoperability between devices, platforms and ecosystems.

Project CHIP brings together consumer products firms Apple, Google, Amazon, Samsung and Comcast, together with several wireless chip vendors including Nordic Semiconductor (a Platinum Sponsor of the project). The project aims to make it easier for manufacturers to create secure and reliable solutions that are interoperable with the major smart home ecosystems like Apple's Siri, Google's Assistant and Amazon's Alexa. End-products like smart speakers and routers could then include support for the agreed wireless technologies and the CHIP application layer.

The change will bring many benefits to the consumer. For example, the interoperability would ensure a homeowner could move into a new property and continue using the existing smart thermostat even if the previous homeowner preferred Siri and the new owner uses Alexa. In turn, manufacturers will benefit from the assurance that their products will communicate with other smart home products, including Amazon Echo and Apple HomePod, supercharging the sector.

The royalty-free CHIP connectivity standard is ambitious in its scope, targeting devices in categories such as lighting and electrical, HVAC controls, access control, safety and security, window coverings, TVs, access points and bridges.

Project CHIP has extended its focus beyond the home to the commercial landscape, with several companies including Legrand, Qorvo, Schneider Electric and Nordic aligning to form the Project CHIP Commercial Strategy Group. Right out of the gate the working group plans to address numerous smart home use cases applicable to commercial ventures, from multi-tenant residential buildings, offices and hotels, to supermarkets, warehouses and retail malls.

All indications are this market should evolve rapidly alongside the smart home. The installed base of connected devices in the commercial buildings category is expected to grow from 1.7 billion in 2020 to nearly 3 billion by 2025, according to a May 2020 report by Research and Markets. (*The Internet of Things in Smart Commercial Buildings 2020 to 2025: Market Prospects in the Age of COVID-19.*)

Benefits to developers

With Project CHIP promising interoperability for smart home and commercial building devices, and the first CHIP release supporting both Thread at 2.4 GHz and IP implementations for Bluetooth LE, developers will benefit from a simpler development process and a wider market for their products.

Nordic's range of short range SoCs will be compatible with the new standards. Along with the company's SDKs for protocols such as Bluetooth LE and Thread, and software frameworks like HomeKit, developers will have the silicon and software to make the most of smart home interoperability. But perhaps the biggest benefit of Project CHIP for developers is the fact they will no longer need to code multiple versions of their application to support different ecosystems and lower-layer protocols. With CHIP, only a single generic application that interfaces with the CHIP application layer needs to be developed.

If Project CHIP flourishes, the smart home and related commercial building solutions will finally move from the preserve of the early adopter to making life and work easier for everyone.

Need to Know

IP is the most common network layer used in homes and offices because it's considered ideal for delivering end-to-end security and privacy in communication between a device and another device, app or service. But many smart home solutions use proprietary protocols, which requires them to be tethered to a home network and limits scalability. Building upon IP architecture would allow smart home devices to communicate with each other and the Cloud regardless of the base protocol

Kjetil Holstad
Director of Product Management: Nordic Semiconductor

One step closer to LE Audio

The Bluetooth SIG unveils the codec that will help power LE Audio's enhanced sound

Back in January this year, the Bluetooth Special Interest Group (SIG) announced work had started on a specification for LE Audio. Hailed as "the next generation" of Bluetooth audio, the organization claimed the new technology—which will support wireless audio streaming over Bluetooth LE—will bring higher quality sound and extended battery life from speakers and headphones.

LE Audio also brings other new functionality, including multi-stream synchronized audio for applications such as earbuds, and Audio Sharing, whereby a single audio source can be broadcast to multiple recipients. (*See WQ Issue 1, 2020, pg14.*)

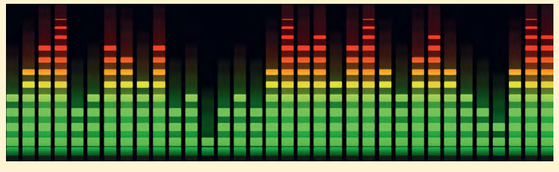
A key technical element of LE Audio, LE Isochronous Channels, was introduced as part of Bluetooth 5.2. The feature addresses a key drawback of Classic Audio by providing a mechanism that ensures multiple sink devices receiving data from the same source reproduce it at precisely the same time. (*See WQ Issue 1, 2020, pg29.*)

With the Bluetooth SIG's release of the specification detailing the Low Complexity Communications Codec (LC3), another key part of the LE Audio specification has arrived (a codec is an algorithm that compresses digital data to reduce the throughput of a wireless link while a companion algorithm decompresses the data at the other end). LC3 is an efficient Bluetooth audio codec for use in LE Audio applications. It is capable of encoding speech and music at various bitrates by supporting sampling rates of 8, 16, 24, 32, 44.1 and 48 kHz and sample resolutions of 16, 24 and 32-bits. Bit rate flexibility allows developers to trade-off sound quality against power consumption and in turn extend battery life or reduce battery size.

LC3 is not the first codec the Bluetooth SIG has unveiled. Back in 2003, Classic Audio was accompanied by a low complexity sub-band codec (SBC) designed to boost audio quality at low-to-medium bit rates. Although SBC was moderately successful, proprietary and manufacturer-defined codecs, such as Qualcomm's aptX and aptX-HD, and Sony's LDAC, found a successful niche supporting Classic Audio.

However, according to the Bluetooth SIG, extensive listening tests have shown that LC3 provides improvements in audio quality over SBC when compared at the same data rate, with the most notable improvements occurring at low data rates. *WQ* readers can check out the audible difference between LC3 and SBC by heading to an interactive listening demo on the Bluetooth website. (https://bit.ly/3op08sq.)

With good timing, Nordic is now offering its nRF5340 SoC in production volumes together with a production version of the nRF5340 DK. (The nRF Connect SDK now also provides nRF5340 support.) The nRF5340 combines a high performance application processor with a fully-programmable network processor, plus advanced root-of-trust and trusted execution security features. With an LE Audio-enabled software stack, the nRF5340's radio supports LE Isochronous Channels and LC3 runs efficiently on the SoC. The nRF5340 also has an onchip audio PLL for audio synchronization for true wireless stereo playback.



The IoT is the New Normal

To remain viable in a post COVID-19 world, businesses and whole industries are being forced to embrace the IoT on a massive scale. There will be no going back

In Short

COVID-19 is dramatically accelerating the adoption of IoT technologies in a way that wasn't happening previously

Sectors such as medical, food and air transport have adopted IoT-based solutions to limit human contact

The embrace of the IoT has not only helped fight the pandemic but also brought unintended benefits to firms such as productivity gains and cost savings

SARS-CoV-2 vaccine distribution could be the use case that cements the IoT in the public perception

There's been quite a bit of publicity recently about "long COVID", the symptoms and health issues that persist long after an individual has contracted COVID-19, even if they only had what was initially a relatively mild case.

As a recent news story published by the BBC, a U.K. public broadcaster, put it: "For most people, COVID-19 is a brief and mild disease but some are left struggling with symptoms including lasting fatigue, persistent pain and breathlessness for months [and this is] having a debilitating effect on people's lives, [with] stories of being left exhausted after even a short walk now common."

With such persistent bad news about COVID-19 it can be hard to see any positives coming from the pandemic that continues to threaten the physical and economic health of billions of people. Yet, as counterintuitive as it may first seem, the long-term impact of COVID-19 could be highly positive for the world.

The pandemic seems to be dramatically accelerating the adoption of IoT technologies in a way that wasn't happening before. This is ushering in a wave of long-promised connectivity benefits that were previously struggling to gain traction.

"COVID-19 has put a rocket under global IoT adoption," says Nordic Semiconductor CTO, Svein-Egil Nielsen. "What may have previously been regarded as a 'nice to have' has been transformed into a 'must have' for many businesses and organizations that wish to remain operationally viable during this pandemic. In fact, if a business or organization doesn't now embrace the IoT that organization may well not exist a few years from now."

IoT BECOMES MANDATORY

The view is echoed by a recently published survey by Vodafone, a U.K.-based global telecoms company, of 1,639 businesses worldwide. The survey found around seventy five percent of respondents expressed the belief that if they failed to embrace the IoT now, they expected to be lagging behind their competitors within five years.

In a separate survey, Gartner, a business analyst, found that around half of all businesses are now planning to increase their investment in IoT because of, rather than despite, the impact of COVID-19.

"IoT-driven changes that were previously years or decades away, are happening today," says Nielsen. "These changes will be permanent and extraordinarily far reaching. And probably most important of all they will happen at economies-of-scale that will have the potential to improve the lives of people around the world in previously unthinkable ways, far sooner than would have ever occurred otherwise."

Although video conferencing, remote working and online grocery shopping have been among the earliest high profile shifts, deeper and arguably more fundamental shifts are now occurring that will be equally impactful on how we will be living and working in the not-too-distant future.

A perfect example of such a shift is occurring in the healthcare industry. Pre-pandemic, the sector was notoriously conservative and riddled with inertia. Even though low cost medical IoT devices and solutions did exist, there was no real sense of urgency to adopt them beyond being forced by, for example, end-of-life equipment cycles. Pre COVID-19 the healthcare industry was reliant on multiple outdated—and often manual—processes that were all prone to human error and inefficiency.

Although it was never the intention of the medical industry's management, by failing to fully embrace the IoT they deprived patients of advanced modern technologies. Such technologies could speed up waiting times, make healthcare more affordable and accessible, improve patient comfort, reduce the risk of infections and improve chronic disease management and patient outcomes.

LOST AND FOUND

One example of the medical sector's failure to embrace the IoT is illustrated by asset tracking. According to one report, published by *Becker's Hospital CFO Report*, even the most diligent U.S. hospitals are losing around $12,000 per bed per year due to inefficiencies in the way they track and utilize medical equipment assets. Yet until COVID-19 struck the country with full force, there was no real drive to address this issue using modern IoT technology.

The pandemic changed everything. During the surge in SARS-CoV-2, hospitals quickly realized that even if they were lucky enough to have enough ventilators, for example, these were of no use if they couldn't be located when needed. Lives were being lost while staff searched for missing machines. But now the medical sector is turning to low cost wireless IoT solutions to solve the problem and are unlikely to stop. (*See* WQ *Issue 4, 2019, pg14.*)

There is also a wholesale shift towards wireless medical devices such as pulse oximeters. The devices are a particularly powerful diagnostic and monitoring tool for many diseases, including respiratory ailments like influenza and COVID-19, because a decrease of oxygen saturation in the blood is an early warning that the virus is getting on top. (*See* WQ *Issue 2, 2020, pg8.*)

Wireless pulse oximeters linked to the IoT allow patients to be monitored remotely and minimize the infection risk to front line staff, are much more comfortable for patients to wear, and enable continuous remote monitoring for the first time. This means any sudden negative health

By the Numbers

$21.8 billion
All-time record high in healthcare funding during Q3 2020 almost certainly triggered by COVID-19

1,500+
Number of global healthcare deals completed during Q3 2020

$2.8 billion
invested in telehealth funding in Q3 2020, a 73 percent increase over Q2 2020 to an industry itself worth an estimated $81 billion

$2 billion
invested into healthcare AI companies across 121 deals

4 of the 5
leading causes of death in the U.S. are due to chronic diseases that drive nearly 75 percent of total healthcare spending

Source: CB Insights

changes can be spotted immediately and health outcomes significantly improved. Wireless tech also means the end to tedious and repetitive manual observations of not only blood saturation, but also, with a range of commercially available wireless monitors, blood pressure, heart rate and rhythm, temperature and respiratory rate. The result is precise, timely and comprehensive monitoring that can go directly to a server for software analysis to pick up any worrying trends.

A second example, while somewhat more prosaic, nonetheless illustrates how the IoT is permeating the medical sector. Enter the world's first totally automatic, bladder function medical measurement device. Until now, taking accurate bladder function measurements was both a labor-intensive and notoriously inaccurate process involving patients keeping manual logs of urination (or 'voiding').

"Voiding measurements are to a bladder dysfunction doctor what blood sugar measurements are to [an endocrinologist]," explains Dr. Brent Laing, CEO of U.S. medical device startup, ClearTrac Technologies. "But until now, every time I sent 10 patients home to keep a voiding diary ... just one of the 10 would have successfully completed the task."

The answer is a small, battery-powered portable handheld device that allows patients to measure voiding patterns from anywhere. Called CarePath and using Nordic Semiconductor's nRF9160 SiP, the device is used in a similar way to a pregnancy test whenever a patient urinates.

Laing says COVID-19 has significantly increased interest in his device from hospitals that are now keen to minimize unnecessary patient contact as well as avoid having nurses tied-up doing labor-intensive manual medical measurements of any kind.

Tech Check

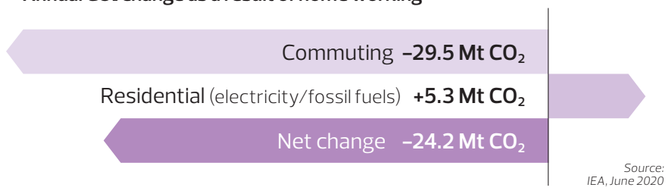
CarePath, from ClearTrac, remains in a deep-sleep state until a capacitive sensing grip in its handle and an accelerometer detect it's being used. It then makes high accuracy measurements automatically and collected data is sent directly to the Cloud via encrypted cellular IoT using Nordic's nRF9160 SiP. The process requires no patient interaction apart from voiding

State of Play

How SARS-CoV-2 curbs carbon emissions

Make no mistake, SARS-CoV-2 is a killer. To date, over 1.4 million people have tragically succumbed to COVID-19. But, paradoxically, the virus may also save lives by cutting global warming. The International Energy Agency (IEA) conducted an exercise to calculate the impact of home working during the pandemic on carbon releases. But the savings made by a dramatic decrease in commuting must be offset by the increase in emissions due to extra electricity consumption in the home. In the U.S., for example, the report (*Working from home can save energy and reduce emissions. But how much?*) showed that congestion in major cities was down by 65 to 95 percent. But on the negative side of the ledger, electricity consumption on weekdays was up by 20 to 30 percent. It turns out that home workers who formerly took public transport to work actually increase their carbon footprint. But overall, the savings are significant, with the report concluding that home working during the pandemic will lead to a cut of 24 Mt in annual CO_2 emissions during 2020.

Annual CO_2 change as a result of home working



Source: IEA, June 2020

THE TASTE OF COVID-19

Another area that COVID-19 is transforming is the food and restaurant industry. While there were some exceptions (*see* WQ *Summer 2019, pg18*), the sector's practices had by-and-large remained unchanged for decades – and not necessarily for the benefit of consumers. COVID-19 has enforced change and a prime example of this shift is the use of smartphone app-based ordering to minimize customer-to-server contact.

"Once restaurants start using this technology, it's unlikely they will go back to the old ways," stated a recent post on *The Wise Marketer* website. "[There are] plenty of restaurants where you can just scan a QR code at the table to access the menu, which is a safe and effective way of deciding what you want to order without interacting with a waiter."

The change accelerated by the IoT means that as a customer you no longer have to wait for a server to place your order, the possibility for 'lost in translation' errors in manual order taking is minimized and, because the order goes straight to the kitchen, the customer will probably get their food faster too. Contactless dining is here to stay.

Airline meals are another area of the food industry that COVID-19 has revealed was ripe for transformation (even though consumers and airlines had probably not realized it). The seated service dates back to the earliest days of the modern consumer airline business and a time when plane tickets cost a small fortune because the only class was first. Fast forward to today, and even pre COVID-19 airline tickets in economy class had fallen to such a low price that airlines were struggling to provide food. When they did it was notoriously low in quality and had to be manually ordered. Now, in a pandemic world, that dubious pleasure is not worth the risk of catching the virus.

Once again the IoT will provide the solution. When boarding a Transavia flight from Amsterdam (in a tie-up with Amsterdam Airport Schiphol, iFleat and Takeaway.com) customers can now order their in-flight food from their restaurant of choice (operating at or near the airport). Because these restaurants prepare and deliver the food to the plane, the airline doesn't have to worry about supplying food on a severely restricted budget and it gets paid a healthy sales commission by the restaurant.

Better yet, the customer gets a meal they genuinely enjoy. The power of the IoT means passengers can even leave it as late as up to one hour before their flight to order their food.

COVID-19 WILL CHANGE EVERYTHING

The examples above are but a few of the IoT-driven shifts now occurring across the world. While some changes brought about by COVID-19 will be temporary—for example, it's unlikely anyone will want to wear a face mask for a second longer than they have to—the transitions now being powered by the IoT look set to be permanent.

Because of the powerful benefits the IoT has brought in areas such as efficiency gains, cost reductions, staff safety and customer comfort, it's hard to see the world ever going back to how it was before the pandemic.

Take, for instance, working from home: *The Economist*, reports, for example, that Will Gosling from Deloitte, a professional-services company, believes the pandemic has brought about a "five-year acceleration" of a trend that was already under way. It has shown that working from home is feasible and has made it more acceptable. A fortuitous knock-on effect is less congestion and fewer flights and rail journeys leading to a major decrease in carbon emissions. (*See State of Play.*)

COVID-19 is propelling IoT adoption forwards with a sense of urgency that previously didn't exist. And if in the longer term the world regards COVID-19 as a turning point that generally made the world into a slightly better place via the IoT, then at least something positive will eventually have emerged from this terrible pandemic.

It could well be that the distribution of the SARS-CoV-2 vaccines themselves will prove to be the application that cements the IoT into the public perception. (*See sidebar COVID-19 vaccine distribution: The IoT's ultimate litmus test.*) When people are given the injections that return the world to normal, albeit a 'new normal', they will remember how it happened with fond and lasting memories. Then there there will be no going back.

> "COVID-19 has put a rocket under global IoT adoption. What was previously regarded as a 'nice to have' is now a 'must have' for firms and organizations to remain operationally viable

COVID-19 vaccine distribution: The IoT's ultimate litmus test

The pandemic has been a long haul that still has many months to run because lockdowns only work to damp down the infection rate. Once people are again free to go about their business, the virus strikes back, often more rapidly than before. That's why vaccines have received so much attention. A properly administered vaccination program has been proven to work again and again against diseases as varied as smallpox, measles and polio – eradicating one and all but wiping out the others. A SARS-CoV-2 vaccine will do the same for COVID-19.

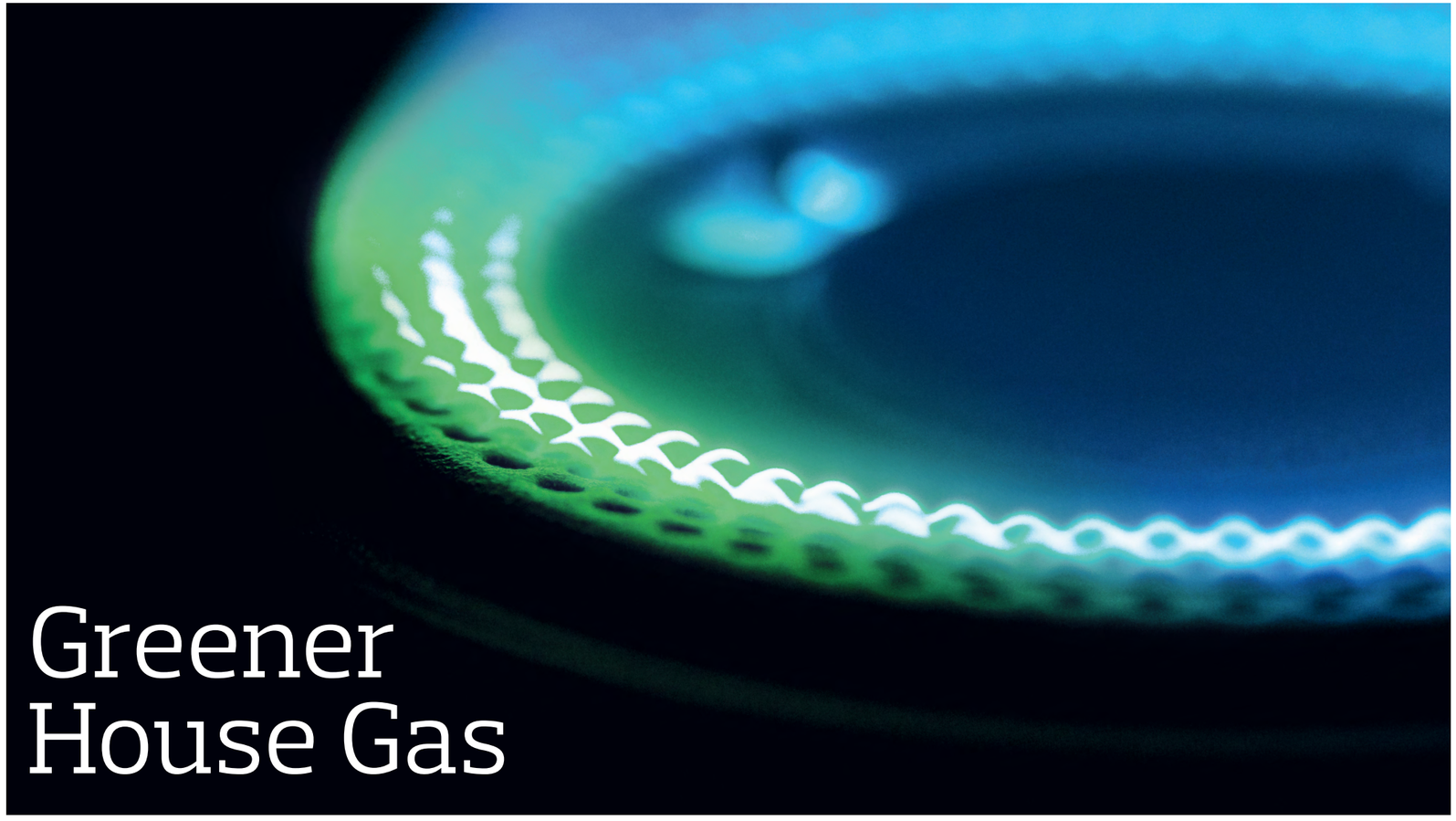
But while development of several vaccines is looking highly promising—U.S. pharmas, Pfizer and Moderna, for example, say trials show the firms' products are 95 percent effective against SARS-CoV-2—the toughest challenge is yet to come. Ensuring an effective vaccine makes it from the manufacturer to a medical facility in the U.S., Argentina, South Africa, India, China, Japan, New Zealand, Fiji and all points between is something never before attempted.

There are over 7.8 billion people on the planet. The exact number that need to be vaccinated before the world gains herd immunity is unknown. However, according to the World Health Organization, the herd immunity level for SARS-CoV-2 is likely be similar to polio (an 80 percent vaccination rate) and measles 95 percent). And each person will likely require two or three injections before the pandemic can truly be declared over.

So that's tens of billions of doses to be transported to every corner of the globe. According to the International Air Transport Association (IATA) the equivalent of 8,000 Boeing 747's will be needed to shift the vials just for the first injection.

To make things more complex, the effectiveness of the vaccine has to be preserved by maintaining the right temperature throughout the logistics chain. For many prospective vaccines that means storing it below 5°C, for the Pfizer vaccine it's a numbing -70°C. For all it means constantly monitoring the shipments to both track them and make sure the cool temperatures are maintained.

Wireless technology is already stepping up to the plate. For example, cellular IoT chip-maker, Nordic Semiconductor, and Dutch IoT development company, SODAQ, have completed a trial comprising 50 operational runs tracking the location and temperature of vaccine shipment containers using Nordic's nRF9160 SiP cellular IoT solution. The containers were successfully used to store dummy vaccines at between 2 and 8°C for at least 96 hours during transportation.



Greener House Gas

In Short

In the 1960s and '70s, the U.K. transitioned from 'town gas' to 'natural gas', phasing out hydrogen as a source of power for cooking, heating and lighting in homes

Net zero carbon emission targets are now driving the push to transition gas network infrastructure back to carrying the 'green gas' hydrogen

MeterTech has launched a smart meter that uses advanced ultrasonic functionality to make hydrogen metering practical

Hydrogen smart meters integrating cellular IoT connectivity enable utilities to remotely check what's happening at the meter

Thanks to cellular IoT-powered hydrogen smart metering, carbon-neutral fuel will soon be in the pipeline

Back in the 1800s, Great Britain led the industrial revolution with groundbreaking energy technologies, including the development of the world's first public gas networks. For 150 years, 'town gas'—a 50-50 mixture of carbon monoxide and hydrogen that was produced by local coal burning—was used for cooking, heating and lighting in British homes. Then, during the 1960s and '70s, massive reserves of 'natural gas' discovered in the North Sea encouraged a conversion program to the new readily accessible fuel source. Soon the whole country was using this new fuel, supplied through the same pipes as town gas albeit with modified burners in homes. Hydrogen was phased out.

While the transition from town gas to natural gas was accelerated by the discovery of North Sea reservoirs, it had been in the works for decades. In the 1930s, the natural gas industry even invented a catchphrase—"Now you're cooking with gas!"—to support a strategic marketing campaign for natural gas-powered stoves. The expression was heard often enough on popular radio shows to enter the vernacular, and it is still commonly used today to suggest one is making good progress on a tricky endeavor. It's with some irony, therefore, that switching from natural gas back to hydrogen is firmly back on the 21st century agenda as a way to cut carbon emissions.

Limiting global warming to below 2°C requires that CO_2 emissions are cut by around 25 percent by 2030, compared to 2010 levels, and continue to be cut to net zero by around 2070, according to the Intergovernmental Panel on Climate Change (IPCC). As part of the drive to cut carbon emissions, there's a growing push to transition gas networks to net zero carbon emissions. Key to reaching this goal is the adoption of two 'green gases': biomethane and hydrogen. Biomethane is made from organic compounds, with the carbon released during combustion captured before it makes it into the atmosphere. Hydrogen on the other hand burns when combined with atmospheric oxygen to release its energy with only water as a byproduct — no soot, no nitrous oxides, and perhaps best of all, no carbon dioxide with its high potential for environmental warming.

Hydrogen is the simplest and most abundant element in the universe. On Earth, hydrogen is virtually non-existent in its elemental form because the planet's gravity is too weak to prevent the lightweight atoms leaking into space. But it is simple to obtain the gas by renewable-energy-powered electrolysis of water (the process of using electricity to split water (H_2O) into oxygen and hydrogen) or by 'reforming' methane, with the carbon dioxide byproducts captured, compressed and stored. The combination of zero-carbon production of hydrogen and its clean-burning nature would help to drastically cut carbon emissions and help protect the planet. (*See panel: Hydrogen: The fuel of the future.*)

Better yet, hydrogen yields the most energy per unit volume of any fuel source. However, this in turn means it is highly flammable, which has tended to cause safety concerns among consumers. For a massive worldwide transition to hydrogen to take place, stakeholders must first overcome public skepticism. This means educating the consumer that, with the right safety protocols in place, the risks of hydrogen gas accidents are actually very low.

THE DECARBONIZATION PLAN

For now, several developed nations plan a stealthy introduction of hydrogen as part of a decarbonization strategy; initially blending up to 23 percent of the gas with natural gas. At this level consumers are unaware their gas supply has been affected. When used on a gas stove, for example, the gas blend burns identically to natural gas, just with 23 percent lower carbon emissions.

Combining up to 23 percent hydrogen is an acceptable and realistic target; a higher proportion would call for significant investment in infrastructure, mainly to prevent leaking of the ultra-lightweight gas.

In the U.K. as well as other countries, pilot schemes with hydrogen/natural gas 'blending' are underway as a means to meet demanding carbon-emission targets. In June 2019 the U.K. became the first major economy in the world to pass laws to end its contribution to global warming; resolving to bring all greenhouse gas emissions to net zero by 2050. As part of this initiative, feasibility projects are investigating the wider potential for the use of hydrogen as a major source of renewable energy in buildings.

The estimated $2.8 billion 'H21' program, launched in 2016, is a suite of gas industry projects designed to support conversion of the U.K. gas networks to carry 100 percent hydrogen. The pioneering H21 Leeds City Gate Proof-of-Concept, led by Northern Gas Networks, confirmed that the existing grid has the capacity and could be gradually repurposed with minimal disruption to the public. After all, the country succeesfully negotiated the reverse process around half a century ago.

H21 started the discussion around hydrogen for heat. And over the past four years, the program has inspired several new gas industry projects to demonstrate the benefits of this energy transition. Most notably, the U.K. government's £25 million ($33.3 million) 'Hydrogen for Heat' (Hy4Heat) program, a three-year feasibility study commissioned by the Department of Business, Energy and Industrial Strategy (BEIS), is exploring the potential use of hydrogen "downstream of the meter" in appliances, homes and businesses. The project aims to define a hydrogen quality standard, develop and test domestic and commercial hydrogen appliances, and explore potential technological solutions to address safety risks and minimize disruption.

In November 2019, the U.K. Health and Safety Executive (HSE) approved an alternative hydrogen energy project, 'HyDeploy', to run a live test of a hydrogen and natural gas mix on part of the private gas network at Keele University's 600-acre campus in Staffordshire. HyDeploy aims to determine what proportion of the conventional domestic gas supply could be substituted by hydrogen without requiring modification of existing appliances. The hydrogen content has so far reached 15 percent and will eventually be up to 20 percent.

In the drive towards a carbon-neutral world, households and businesses could look to hydrogen as a source of clean energy. However, challenges remain.

For one, no domestic hydrogen gas meters are currently available to measure and charge for gas usage. In conventional meters, gas flow is measured using a mechanical system based on a diaphragm, but because of the small molecular size of hydrogen, diaphragm meters for that gas would need to be about three times the size of a

> "Limiting global warming to below 2°C requires that CO_2 emissions are cut by around 25 percent by 2030, compared to 2010 levels, and continue to be cut to net zero by around 2070

By the Numbers:

Energy-related CO_2 emissions account for

two thirds

of global greenhouse gas emissions

Source: International Renewable Energy Agency (IRENA)

In 2019 the average U.K. gas bill was

£610

($815) per year for a dual fuel household

Source: Department for Business, Energy & Industrial Strategy (DBEIS)

By the Numbers:

Renewable hydrogen from electrolysis costs about

$6/kg

Source: The Hydrogen Council

All major British cities could be using hydrogen by

2052

at a cost of £50 billion ($66.8 billion)

Source: Northern Gas Networks

81%

of people with a smart meter would recommend them to others, and 82 percent have taken at least one step to reduce their energy use

Source: Smart Energy GB

conventional meter – that makes them impractical.

One option is to replace mechanical diaphragm meters with ultrasonic devices. These rely on accurate 'Time of Flight' (ToF) measurement of the speed of sound to determine the speed of flow of the gas through a home's pipes. But because the speed of sound in hydrogen is around three times faster than that in natural gas, significantly better timing precision is needed.

ADVANCED HYDROGEN METERING

In response to this challenge, U.K.-based MeterTech has launched a smart meter that, unlike conventional gas meters with diaphragms, uses advanced ultrasonic functionality to make hydrogen metering practical.

The new MeterTech smart meter not only employs a more advanced technique for the 'recovery' of the ultrasonic signals in hydrogen, it also features timing circuits capable of precise measurement of ToF in hydrogen. Furthermore, the meter has been designed to meet the highest safety requirements in Europe and elsewhere in the world.

All smart meters require robust and reliable connectivity. And because hydrogen meters will be the most advanced domestic meters available to date, they need to incorporate the latest data communications technology, according to Eric Beattie, CTO of MeterTech. Meters require a low power, long range applications that only transmit small amounts of data infrequently. That requirement is perfectly met by cellular IoT – an LPWAN technology supported by two versions, LTE-M and NB-IoT. Cellular IoT also represents the simplest, most secure, standardized, and future-proofed connectivity solution for the smart metering industry. For these reasons, MeterTech has selected cellular IoT for the wireless connectivity of its hydrogen smart meter.

Another significant advantage of cellular IoT is that the base stations, cell towers, buildings and power supply that comprise the networks are already in place, so very little new infrastructure needs to be installed. Plus, unlike some competitive options, the technology has the potential to cover hundreds of thousands of IoT devices per square kilometer; in the case of smart meters, that means effective coverage across even the most densely populated urban areas.

The technology provides reliable Cloud connectivity from the meter to the utility. And by eliminating manual meter reading, accurately billing customers, initiating dynamic pricing, monitoring grid losses and optimizing grid performance, utilities and governments can achieve optimal efficiency and maximize profit potential. (At the same time, Bluetooth LE connectivity incorporated into smart meters can provide a user friendly, smartphone-compatible link between the consumer and their consumption/tariff data when needed.)

"LPWAN is the future for wireless communications. And unlike alternative data transfer techniques, NB-IoT/LTE-M is ubiquitous worldwide and as such must be used for a meter to be deployed across the globe," says Beattie. "With its mature infrastructure support, low-power consumption and good penetration through obstacles such as walls, NB-IoT lends itself very well to stationary, battery powered devices like gas meters which require tariffs and other data to be collected and transmitted."

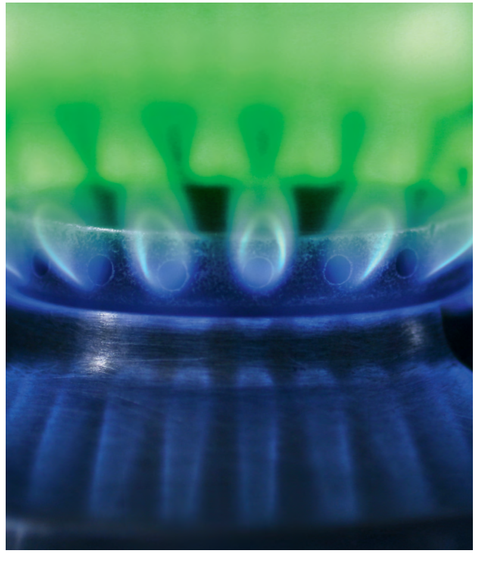
The MeterTech product integrates Nordic's nRF9160 SiP to provide cellular connectivity enabling utilities to remotely check what's happening at the meter and gather accurate information over an extended period. Traditional ultrasonic-based meters consume on average around 30 to 40 microamps. In part because the nRF9160 has been designed from the ground up for low power consumption to extend battery life, MeterTech has managed to reduce the average current of its meter to less than 15 microamps, even though the new ultrasonic gas measuring technique requires a lot of computation, explains Beattie.

"These currents may at first glance seem very low anyway, but given a meter needs to operate for around two decades on a single battery, every microamp of continuous average power saved is vital," he says. "From a technical hardware and software perspective, MeterTech chose Nordic's nRF9160 because of the SiP's renowned reliability and especially its low power consumption."

IN THE PIPELINE

Although smart metering based on cellular IoT wireless connectivity remains a developing sector, the needle is moving in the right direction. Supported by advanced hydrogen smart meters, a zero-carbon future that once appeared a pipedream could already be in the pipeline.

But a successful hydrogen smart meter economy will still rely on active participation and considerable engagement

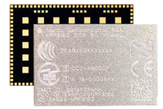


Blending up to 23 percent hydrogen with natural gas can be done without upgrading existing infrastructure

from all parties – including policy makers, regulators, consumers and the energy industry itself. Beyond this it will also take advancements in the available and affordable technology.

Cellular IoT smart meters could well provide the boost the hydrogen energy sector needs. In the immediate term, smart metering affords opportunities related to enhanced data access, greater billing transparency, energy efficiency, grid performance and compliance. Looking further ahead, IoT enabled analytics can help energy and utility companies deliver smart energy solutions that take the customer experience to higher levels. Potential benefits include significantly improved grid intelligence and the ability to provide projection models—based on historical data, weather forecasts and other factors—to integrate the supply of renewable resources like hydrogen.

As consumer acceptance of hydrogen as a power source catches up with the innovative smart meter technology, enabling hydrogen to replace hydrocarbon gas in existing networks, societies and governments can edge closer to their net zero energy targets. Then the whole planet could be saying: "Now you're cooking with ... hydrogen!".



Tech Check

Nordic's nRF9160 is a highly-integrated, low power SiP with integrated LTE-M/NB-IoT modem and GPS. The nRF9160 incorporates an Arm Cortex-M33 application processor, a full LTE modem, RF Front End (RFFE) and power management system. It is the most compact, complete and energy-efficient cellular IoT solution on the market. The integrated modem supports both LTE-M and NB-IoT wireless connectivity and can operate globally, removing any need for regional variants

Hydrogen: The fuel of the future

Hydrogen is currently experiencing accelerated momentum. The number of policies, projects and Proof-of-Concept initiatives based on hydrogen technology is multiplying around the world. And with good reason; as a light, storable, renewable source of power that produces no direct greenhouse gas emissions, hydrogen has become a major part of the conversation about building a clean, secure and affordable energy future. For example, hydrogen for heating is an important growth area, especially in the U.K. where it could one day be used in place of natural gas for heating in millions of homes and businesses.

Yet the potential of hydrogen flows far beyond heating and power for residential and commercial buildings. Numerous sectors and applications are now looking to take advantage of this alternative fuel. One market with a promising future is hydrogen-fueled transport and vehicle refueling stations. More than 18,000 hydrogen fuel cell vehicles were sold or leased globally by year-end 2019, according to industry analyst Research and Markets. Research company, Information Trends, projects that cumulatively, 6.56 million hydrogen fuel cell vehicles will be sold or leased globally between 2014 and 2032.

While hydrogen cars and buses are already on the roads, to this point take-up has been limited by the popularity of electric cars and, more pertinently, a shortage of hydrogen refueling stations. But there's every reason to expect hydrogen—which can be used to create electrical power in a fuel-cell—will eventually emerge as a genuine alternative in the sustainable mobility market. There are several potential benefits of hydrogen vehicles over electrically powered vehicles relying on the energy from Li-ion batteries; most importantly, drivers of hydrogen vehicles can refuel faster and travel much further per fill up.

Infrastructure to support the hydrogen-powered car manufacturing industry is also expanding, with over 100 hydrogen fueling stations now available across Europe and more than 300 stations in operation worldwide. Hydrogen fueling station deployment is particularly advanced in Japan, which reached 100 stations in 2018, and Germany, where a joint venture between Air Liquide, Linde, Daimler, Shell, Total and OMV is aiming to develop a nationwide network of 400 stations by 2023. Germany is also home to pilot tests of hydrogen-fueled trains. Meanwhile, in 2018 there was policy support for hydrogen deployment in buses across ten countries and in trucks across five countries, according to the International Energy Agency's *The Future of Hydrogen* report.

Consumer take-up of hydrogen fueled vehicles has so far been limited by the popularity of electric versions. But that may be about to change

Music Unplugged

Making music in the 21st century is a merger of artistic talent and sophisticated technology. And increasingly it is possible without wires

The saying claims music is the purest form of art, but what is the purest form of music? It's a debate endlessly played out on online forums by music buffs, academics and scientists alike, with cases made for everything from tribal percussion and plainsong through to Mozart and even the monotonic noise your cellphone ringtone made in the 1990s. Must it be acoustic, can it be electric, does there need to be any music at all? There are serious musicologists who argue that nothing can be purer than experimental composer John Cage's piece, 4'33", that instructs the performers not to play a single note, but rather allow the sound of the restless audience and other ambient noise to be the music. It's perhaps a discourse without an answer.

And one that has been running for some time because the Smithsonian Institute in the U.S. suggests humans have been making music for at least 35,000 years. The last 100 of those years has seen the most profound change in how music is performed, produced and heard. Technology has changed music entirely and continues to do so. The first electric synthesizer was devised in the 1870s, an accidental by-product of attempts to invent the telephone. Also significant was the arrival of the Audion thirty years later, the first widely used electronic device to amplify sound.

Music technology advanced in the 1920s—again by accident—when a Russian scientist and spy happened upon what is now considered the world's first electronic instrument when researching proximity sensor technology for the Soviet Union. But curiosities aside, the iconic marriage of music and technology was really born in 1932, when jazz guitarist Jack Miller performed in Los Angeles with what is widely accepted as the first electric guitar, and was cemented in 1950 when self-taught electronics enthusiast, Leo Fender, perfected it. Since the invention of the electric guitar, music technology never looked back.

THE INTERNET OF MUSICAL THINGS

In a market valued at $7.5 billion in 2018, digital musical instruments are still very much the junior partner to traditional instruments but a shift is occurring. Analyst Grand View Research said an increase in the penetration of digital musical instruments would drive the market in the next five years, particularly among millennials and hobbyists. This in turn is forging a new subset of the IoT – the Internet of Musical Things (IoMusT). According to Luca Turchet, a researcher in the Department of Information Engineering and Computer Science at the University of Trento in Italy, IoMusT demonstrates emerging networks of computing devices embedded in musical 'things' dedicated to the production and reception of musical content.

"More daily objects are becoming embedded with sensors, actuators and processing elements, and are gaining the ability to communicate wirelessly," says Turchet. "However, the application of IoT technologies in musical contexts has received remarkably little attention compared to other domains such as consumer electronics, healthcare, cities and geospatial analysis.

"The IoMusT vision predicts that in the future, a new class of musical devices will be connected to the Internet, which could have a transformative effect on how humans involved in musical activities conduct these activities and interact with musical objects."

What this transformation will look like for both artists and their audiences is still emerging, but technology-mediated fan participation is already capitalizing on IoT technologies to increase audience engagement. One example is the SoundShirt, developed by U.K.-based CuteCircuit, and nominated by *Time* Magazine as one of the best 100 inventions of 2020. The shirts, embedded with tiny haptic actuators, vibrate in proportion to the intensity of sound, allowing wearers to experience live music in an entirely new way. Sensors placed throughout a venue collect data about the intensity of the sound and relay it to the embedded actuators in the shirts using Bluetooth LE wireless connectivity. The actuators then begin to vibrate with a rhythm and intensity proportional to the music being played. A gimmick for some perhaps, but certainly not for deaf people for whom it provides an opportunity to 'feel' music and enjoy it in a way previously not possible.

Bluetooth LE-powered beacons are also widely used to engage audiences at live music events. Canadian musician Dallas Green has employed beacons at his concerts since 2014 to broadcast alerts about free seat upgrades, signed posters and free merchandise to the smartphones of attendees.

If the SoundShirt and beacons are designed to help an audience's enjoyment and engagement at a live music event, the IoMusT also offers a host of potential benefits to the artists and production team, according to Turchet. For example, wearables equipped with sensors of the type we normally use at the gym to track our movement and physiological parameters, could also be used to interface with a system that collects, processes and interprets that data in a live music setting to predict the 'mood' of the audience. "[This can be] used in different ways. To help musicians decide on the next songs in their playlist or by choreographers to create real time live visualizations responding to the mood of the audience," Turchet said. "[Or] to control some of the performance experience attributes such as lighting effects."

CUTTING THE CORD

Despite the convenience of wireless technology in an industry bedeviled by tangles of wires and cabling—and the technology's ability to allow performers and producers to engage with their art in ways never previously imagined—wireless has been a divisive topic among musicians.

The stage at a rock concert can resemble a viper's nest—with over 300 wired inputs appearing to create a complex and efficient trip hazard—but to musicians and sound engineers it has long been considered a necessary evil because of the throughput, reliability, latency and quality concerns of wireless alternatives. That said, dedicated frequency high bandwidth wireless interfaces—alongside the technical expertise to run and maintain them—allow guitars, handheld microphones, in-ear monitors and performers to roam freely. Nonetheless, cutting the cord completely in a live musical performance by musicians

In Short

Music and musical instruments date to the Stone Age, but the advent of technology in the past 100 years has completely reshaped how music is produced and heard

A new subset of the IoT, the Internet of Musical Things, is creating emerging networks of computing devices embedded in musical 'things' and connected to the Internet

MIDI-over-Bluetooth LE is powering the next generation of smart instruments, allowing low latency wireless freedom for a growing range of musical applications

> "The Internet of Musical Things could have a transformative effect on how humans conduct musical activities and interact with musical objects

Tech Check

Nordic's nRF52832 Bluetooth LE multiprotocol SoC enables low latency MIDI-over-Bluetooth LE wireless connectivity for smart instruments and music peripherals. The SoC's powerful 64 MHz, 32-bit Arm Cortex M4 processor with floating point unit supports the complex computations of sophisticated devices

playing wireless smart instruments is still some way off.

If the professional music industry remains tethered for now, for everyone else wireless smart instruments are not only viable, but also rapidly growing in popularity since the inclusion of MIDI-over-Bluetooth LE in the official MIDI specification (*see sidebar* The Making of MIDI). Smart instruments demand hardware and software communication solutions that guarantee low latency and constant variability, while preserving transmission reliability. While MIDI-over-Bluetooth LE can't get close to replicating the less than a millisecond latency of a wired MIDI connection, the addition of a millisecond timestamp to each packet allows the exact signal acquisition time to be transmitted with a MIDI message over the Bluetooth LE link. This means despite the longer latency it is possible to preserve the exact timing characteristics of the signal, enabling applications where timing accuracy overcomes any latency challenges.

SMART INSTRUMENTS

One company pioneering the smart instrument movement is Icelandic start up, Genki Instruments. The company recently released a gesture-controlled wearable device called Wave, that can communicate with and control a range of devices using MIDI-over-Bluetooth LE. Designed for producers, composers or performers, Wave is worn on the finger and integrates a nine-degrees-of-freedom (9DoF) inertial measurement unit (IMU) to detect distinct hand gestures, alongside a Nordic Semiconductor nRF52832 SoC to power the wireless connectivity between the ring and a smart instrument or a Digital Audio Workstation (DAW). For example, by moving their hand horizontally or vertically a musician can control reverb or

Freedrum allows the user to play their virtual drumkit anywhere and listen to the generated audio in real time

resonance, while tapping a surface can trigger a kick drum or play a sample. The smart ring also includes pushbuttons that can be user-configured to begin playback or switch between presets, for example.

"Without the wireless functionality, users would be tethered to a cable while performing," says Ólafur Bogason, CEO of Genki Instruments. "Instead, users are in full control to change sounds, parameters and effects without having to go back to the computer. Wave adds a layer of creativity to any instrument and is designed to enhance the user's current instruments and setup ... [and] make use of everything MIDI technology has to offer."

Another start-up in the Nordic region challenging traditional music conventions is Swedish company, Freedrum, whose virtual drumkit of the same name is being embraced by drummers—and their next door neighbors—alike. Freedrum comprises four lightweight devices, two fitted to a pair of drumsticks and two to the drummer's feet, wirelessly connected to a partner app using nRF5232 SoC-powered MIDI-over-Bluetooth LE.

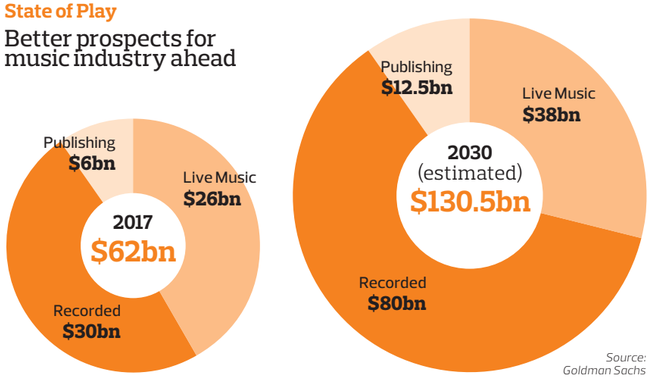
Built-in gyroscopes and accelerometers track the direction and angle of the drumsticks, and the drummer's feet movement, then detect 'impacts' that are translated to actual drum sounds across six 'hit' areas – snare, floor tom, ride cymbal, high tom, crash and hi-hat.

From the app the user can view the positions and directions of the drumsticks in relation to the virtual drum zones they are hovering over or striking. They can also listen to their drumbeats in real time without requiring an expensive drumkit, or an equally expensive soundproofed studio to avoid alienating housemates or next door neighbors.

"Without the wireless functionality of MIDI-over-Bluetooth LE this product would be impossible," says August Bering, Freedrum's founder and inventor. "Cables would take the 'free' out of Freedrum. We're an alternative for people who don't want to buy a bigger house to have a room for their hobby."

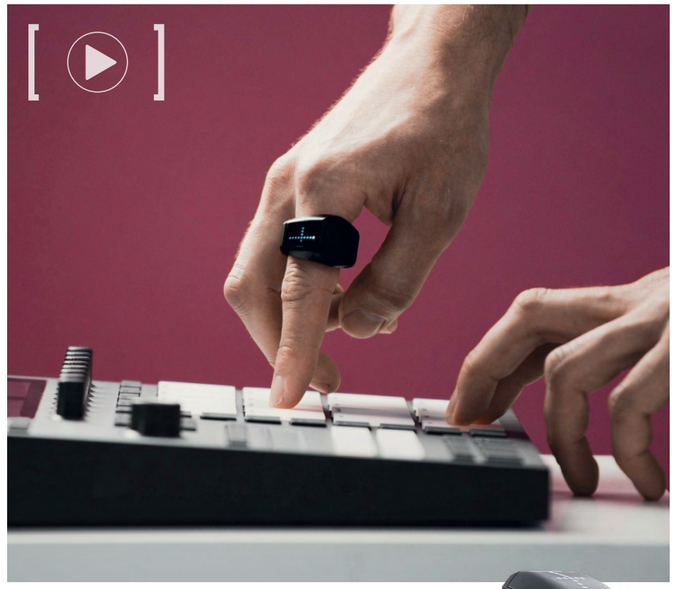
State of Play

Better prospects for music industry ahead



Source: Goldman Sachs

In 2019 the global music industry was valued at more than $62 billion with two major income streams—live music and recorded music—contributing approximately equal revenue to the total pool. In the wake of COVID-19, the industry has been struck hard. Physical sales of recorded music are down by a third, while digital sales have fallen around 11 percent. Bans on public gatherings have cut live performance revenue to almost zero, but the longer term outlook is rosy, with the whole sector expected to grow significantly to 2030



PRESERVING THE PAST

Wireless technology is not only providing musicians with new instruments, it is also helping them preserve their old ones. Chinese smart technology company, Qingping, recently released a sensor device that continuously monitors the temperature and humidity levels inside and outside wooden instruments such as guitars and violins.

Keeping such instruments within carefully defined temperature and humidity tolerances—20 to 25°C and 40 to 50 percent relative humidity—is essential to prevent the instrument deforming, cracking or delaminating over time; the sort of fate you don't want to befall your average acoustic guitar let alone a multi-million dollar Stradivarius violin.

Magnetically attached to the panel near the sound hole of the instrument, the Lee Guitars Bluetooth Thermo-Hygrometer reports temperature and humidity status changes back to an app on the owner's smartphone using Bluetooth LE connectivity provided by an integrated Nordic nRF52832 SoC.

"Drastic leaps in temperature or humidity, even within a short timeframe, could have serious consequences, such as warped parts, cracks, fret sprout and failed bridges," says Bin Du, Co-Founder and COO at Qingping. "Faced with these risks, maintaining a guitar in good shape starts with constant accurate monitoring. Traditionally this has been done using a household thermometer but that's [not practical] unless physically checking the instrument, and it doesn't provide any evidence of changes in environmental conditions over time. This device and Bluetooth LE connectivity completely changes how this routine but necessary monitoring is performed."

While purists will continue to debate what role technology should play in the artform of music, the Internet of Musical Things is on an unstoppable roll. Like it or not, wearables, edge computing, AI and smart instruments are all firmly part of music's future, and it's a future that is looking increasingly wireless.

The Wave wearable smart ring turns musicians' gestures into instrument control

Qingping's thermo-hygrometer continuously monitors an instrument's temperature and humidity levels

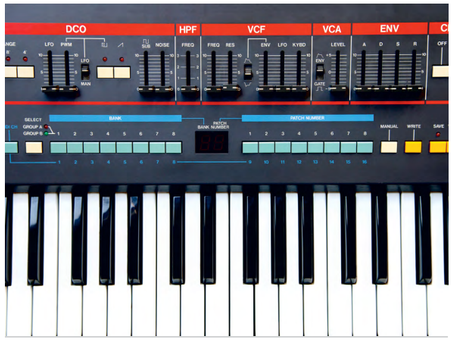
The making of MIDI

In the late 1970s the music industry had a problem. Electronic music was about to enjoy its heyday and the advent of the microprocessor-based polyphonic synthesizer—enabling keyboards to play multiple independent melody lines simultaneously—had manufacturers of the likes of Yamaha, Roland and Casio falling over one another to supply the electronic instruments that would power the next musical revolution. The problem was that there was no standardized means of synchronizing instruments manufactured by different companies because each defined pitch and timing data in their own way.

The companies began to design their own digital interfaces that would allow musicians to connect several synths together irrespective of brand but there remained a concern that this general lack of compatibility would restrict synthesizer use, and, more to the point, sales. In 1982 the leading U.S. and Japanese synth makers got together to draft a universal digital communication system for musical instruments, and later that year Musical Instrument Digital Interface (MIDI) was born.

The original MIDI specification was limited and defined only basic instructions for how to send data between two synthesizers—for example how to play notes or control output volume—but MIDI was just getting started. Now MIDI is a fully-fledged technical standard that describes a communications protocol, digital interface and electrical connectors that connect a wide variety of electronic musical instruments, computers and related audio devices for playing, editing and recording music. MIDI is everywhere, and, without hyperbole, is frequently described as the most powerful tool in music. "MIDI has gone far beyond what anyone had envisioned," says the MIDI Association's Craig Anderton. "It's on the least expensive home keyboards and the most sophisticated studio gear. It has gone way beyond its original idea of allowing a separation of controller and sound generator."

MIDI-over-Bluetooth LE is now widely viewed as a viable solution for any sensor interface that requires extensive interoperability with existing MIDI-compatible applications and explains the rapidly growing number of consumer-oriented musical interfaces and smart instruments that have adopted Bluetooth LE.



Feature: Patents

Patent Debate

Designed to ease the introduction of new products based on technology standards, SEPs are not working as they should

Two and a half millennia ago the Classical Greek Empire was in full swing. The foundations of Western civilization were being laid with modern democracy, scientific thought, literature and philosophy all deriving from Grecian history. The Greeks came up with the idea of patents too; innovation was encouraged by rewarding inventors for their ideas to improve citizens' lives.

Fast forward through years of development and legalization by the Florentines, Venetians, British and Americans, and today's patent system is in rude health. (*See sidebar* A brief history of legal protection for inventions.) For example, the World Intellectual Property Organization (WIPO) reported that global patent filings in 2018 exceeded 3.3 million, 5.2 percent higher than 2017.

That said, things are a little less rosy in the world of tech innovation protection. For example, according to Harvard Business School, tech patent litigation is rife and being driven by so-called "nonpracticing entities" (less politely known as "patent trolls"). These firms buy up patent portfolios just for the sake of making money by suing cash-rich firms for alleged patent infringements.

Second is a problem with Standard Essential Patents (SEPs). These are granted for tech incorporated into an industry standard (a technical specification designed to promote interoperability and widen the reach of innovative products). A company that then designs products adhering to the standard—for example, Bluetooth, Wi-Fi or LTE—then pays a license fee to the SEP holder. The fee is supposed to reflect "fair, reasonable and non-discriminatory [FRAND] terms" to stop SEP holders gaining commercial advantage over competitors by ramping up the price. But this depends on the way FRAND is applied — and not everyone sees it the same way. Today's disagreement threatens to stifle innovation — particular in the wireless chip sector.

ESSENTIAL TO THE STANDARD

The history of SEPs is murky, but, for example, the Institute of Electrical and Electronics Engineers (IEEE), the standards organization responsible for specifications such as IEEE802.15.4 (WPANs) and IEEE802.11 (WLANs), first permitted the inclusion of patented tech in its standards when justified by "technical reasons" back in the 1980s.

However, according to Jorge L. Contreras of the University of Utah, terminology relating to "essential" patents was only introduced to IEEE's policies in 2005, when the organization required each holder of a patent or application that "might be essential to the implementation of" an IEEE standard to submit a letter committing to license that patent for the common good.

> SEPs have played an important role in the development and promotion of new technology especially in the telecom, IT and consumer electronics industries

The idea took hold and SEPs have played an important role in the development and promotion of new tech especially in the telecom, IT and consumer electronics industries. Today, organizations must use the relevant tech SEPs in order to comply with many electronics industry standards.

This all sounds reasonable in principal but in practice, problems have arisen with some companies reverting to strong-arm tactics to hold down competition. Regulators are especially concerned about the misuse of market power by SEP holders in the electronics and telecom sectors because of the large number of patents covering key tech that are owned by just a few major players.

Some Standard Setting Organizations (SSOs), including IEEE, try to counter this problem by introducing policies which require their members to make licenses available for SEPs on FRAND terms. (If the SEP holder is not willing to play ball, then the technology covered by the patent isn't incorporated into the standard.) In addition, SSOs typically require standards participants to disclose whether they have a pending or live SEP covering technology that's likely to be incorporated into a standard to avoid later "patent ambushing". Problem solved then. Well, not quite.

For example, the *Journal of Competition, Law & Economics* reported on a legal case involving the popular short range standard, Bluetooth. The Bluetooth SIG, custodians of the standard, required that licenses for SEPs used therein be granted "without monetary compensation", making Bluetooth a so-called royalty-free standard. All was well until Rembrandt, a "patent assertion entity", started making a fuss. The firm owned a patent that it alleged had found its way into the Bluetooth standard and it had nothing to do with the Bluetooth SIG. At trial, the SIG said it had never heard of the invention. Yet Rembrandt won the case by persuading a jury that devices implementing Bluetooth 2.0 infringed its patents and that those patents were valid and enforceable. And as an outsider to the Bluetooth SIG, Rembrandt was not bound by the Bluetooth SIG's royalty-free licensing rules.

EXTRA PROBLEMS FOR CHIP MAKERS

While the current system for SEPs is hardly watertight, it is a framework for sensible negotiation ... unless it isn't.

"The problem with the current SEP FRAND system [for chip makers] is that it's focused on the end-product," explains Marianne Frydenlund, Legal Director with Nordic Semiconductor, a wireless chip maker (including products made to industry standards such as Bluetooth and LTE-M). "The reason is patent law only allows the rights holder to reap one license fee per product [using] the patent. Licensing at the chip level rules out licensing the end-product, whereas the end-product license will mostly cover chips too through 'have-made' rights. The second reason is licensing the end-product brings higher fees, as the licensor feels entitled to [benefit from] the added value the standard brings to the end-product."

The situation looks unlikely to change any time soon. According to Frydenlund, discussions with some major SEP owners indicates reluctance to create a chip-level licensing platform. "The impression is that these large SEP-holders aren't keen to offer licenses to chip makers, due to their one shot in the supply chain where they traditionally have gone for licensing end-products," she says. However, there is hope. "But others are at least open to discussing the problem. One sticking point is that the current offer is to make the chip royalty rate the same as the end-product rate. With the thousands of IoT products that enable cellular functionality, this is going to be a lengthy process."

SUSTAINABLE SEP LICENSING

Patent battles typically end up in the courts, or at least in drawn-out legal battles ending in (expensive) negotiated settlements. Chip makers are trying to avoid these legal confrontations by engaging in more dialogue. For example, in Europe, the Fair Standards Alliance (FSA) sets out to pursue reasonable outcomes in SEP chip disputes. The FSA's mission is "[to build] a balanced framework for sustainable licensing of SEPs that fosters creativity and innovation". Crucially, the alliance believes that licenses for SEPs should be available at any point in the value chain.

Frydenlund serves on the Board of the FSA and aims to strengthen the voice of tech companies, including Nordic, to ensure licensing of SEPs is done on a FRAND basis. "Nordic's cellular IoT chips can end up in items as diverse as lawn mowers, ovens and helmets - things made by companies that are often not even aware of SEPs," she explains. "It would be tough for them to negotiate licenses with SEP holders. If we could get agreement on chip-level SEP licensing, Nordic could negotiate the fee on behalf of its non-tech savvy customers, so they won't need to worry."

That would work very much in the spirit of that Greek ideal dreamt up all those centuries ago.

By the Numbers

3,326,300
Global patent applications in 2018

46.6%
China's share of global patent applications 2018 (U.S.=18 percent)

83,954
Global semiconductor patents 2017

0.5%
Global semiconductor patent growth 2007 to 17

WIPO, World Intellectual Property Indicators 2019

Need to Know

Europe is the major player for the development of key standardized technologies. For example, patents declared at European Telecommunications Standards Institute (ETSI) represent 70 percent of worldwide SEPs. More than 23,500 patents have been declared essential to GSM and 3G, and the royalty income for 2, 3 and 4G standards is around €18 billion ($21.8 billion) per year

European Commission

Patent pending: A brief history of legal protection for inventions

The idea of patents stretches back to the ancient Greeks. Online encyclopedia *Wikipedia* notes that in 500 BC, in the Greek city of Sybaris "encouragement was held out to all who should discover any new refinement in luxury, the profits arising from which were secured to the inventor by patent for the space of a year". The first few patents were granted for new food recipes.

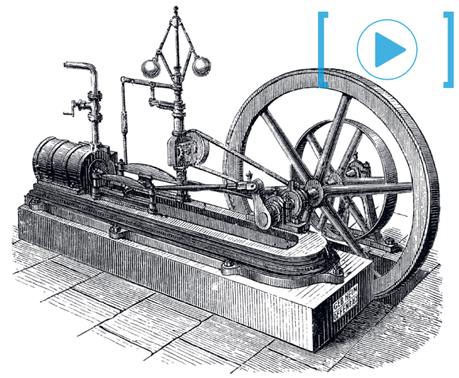
In 14th century England, patents in the form of letters from the King were made with the purpose of providing the recipient with a monopoly to produce goods or provide particular services.

The first Italian patent was awarded in Florence in 1421 to the Florentine architect Filippo Brunelleschi who received a three-year patent for a barge with hoisting gear. Patents were granted in Venice from 1450 as a way of informing the authorities of new inventions (most were for glass making techniques) in order to gain legal protection against infringers. The Venetian Act is often cited as the foundation for modern international patent statutes.

King Henry II of France introduced the concept of publishing the description of an invention in the form of a patent in 1555.

The medieval English patent system evolved into the first modern legal model for protecting inventions and "recognized intellectual property in order to stimulate invention". In 1624, the English parliament enacted a "statute of monopolies" that limited patents to inventions that were novel rather than well-established methods that had been lucky enough to benefit from royal patronage. The move governed English patent law for more than two centuries and formed the basis of the modern British patent system which in turn evolved into the legal foundation on which the Industrial Revolution emerged and flourished.

The English system also served as the example for U.S. patent law. The U.S.'s first Patent Act was ratified in 1790, just a year after the constitution. More major reform came with the U.S. Patent Act of 1952, which introduced "non-obviousness" as part of the requirement for a patent. The U.S. dominated patent filings until 2012, when, according to Reuters, China's State Intellectual Property Office overtook the U.S. Patent and Trademark Office as the largest patent office in the world.



The British patent system introduced the legal foundation upon which industrial inventions like the steam engine emerged

Education

Sphero RVR

This Bluetooth LE programmable robot enables coders of all skill levels to create sensor-based applications

Science, technology, engineering, arts and mathematics (STEAM) educators are increasingly turning to user-friendly wireless tech and connected educational tools to engage students, enhance the learning process and introduce the next generation of digital pioneers to the world of coding, programming and ICT

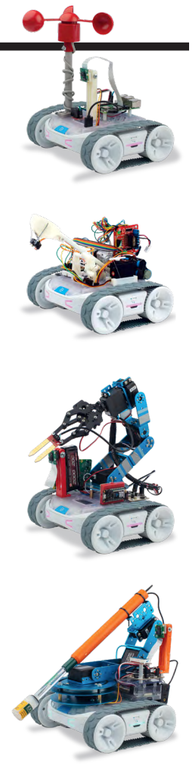
The Nordic SoC-enabled Bluetooth LE connectivity allows the user to wirelessly code RVR from the Sphero Edu app on a smartphone or tablet. Coding options within the companion app are based on the user's skill level. Alternatively, RVR can be coded using a Raspberry Pi, Arduino, a Nordic-powered micro:bit or Sphero's own littleBits platform

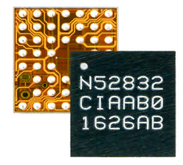
The first mobile robot was developed at the Artificial Intelligence Center of Stanford Research Institute in California between 1966 and 1972. For its time it was relatively sophisticated and featured an antenna for a radio link, sonar range finders, a television camera, on-board processors and collision detection sensors. A precarious and wobbling tower of equipment on wheels, the researchers named it 'Shakey'

The first digitally operated and programmable robot was invented by American George Devol in 1954 and was called the Unimate. The Unimate worked on a General Motors assembly line and welded die castings on to car bodies, a job considered a dangerous task for humans. Unimate laid the foundations of the modern robotics industry

The two most recent Mars Exploration Rovers—Spirit and Opportunity—landed on the planet in January 2004. While the robots were only expected to perform 90 day missions, Spirit kept working until communication was lost in March 2010 having become embedded in soft sand a year earlier, while Opportunity kept going strong until June 2018 when it ceased to respond following a planet-encircling dust storm

Sphero RVR is an all-terrain programmable and expandable product that can be customized for unique use cases and applications. For example, RVR could be used as a home security sentry, autonomous metal detector or wirelessly controlled environmental sensor, among a range of user-coded applications. It features a diverse suite of sensors enabling the robot to interact with its environment including ambient light, color, infrared, accelerometer and gyroscope





Tech Check

The Nordic nRF52832 multiprotocol SoC's 64MHz, 32-bit Arm Cortex M4 processor with floating point unit (FPU) has ample computational power to handle Sphero RVR's power control, battery management, color sensing, ambient light sensing and RGB LED animations

Wearables

LTE-M smart watch enables GPS, HR monitoring and SOS alerts for athletes

Supported by Nordic nRF9160-SiP enabled LTE-M cellular connectivity, the ProGuard Secure Positioning Watch sends SOS alerts to first responders without the need for a smartphone

> In the case of an emergency, ProGuard's positioning feature can assist first aiders to reach the person in need quickly

Extreme sports are risky. If an accident occurs, the ProGuard watch (inset) sends out an SOS alert alongside a GPS reference

For performance tracking and participant safety reasons, it can be important to continuously monitor the location and physiological state of athletes in action, as well as individuals at risk during organized outdoor events. Whether running, cycling or engaging in any other strenuous physical activity, participants are in danger of experiencing sudden and potentially serious health issues, being involved in accidents or even getting trapped by hazardous conditions. These concerns are particularly valid for remote events and environments where access to urgent medical support may be limited or delayed.

Taiwan-based technology company, ProMOS Technologies, has developed its ProGuard Secure Positioning Watch to monitor the safety of athletes and others in challenging situations. The 40g, 43.5 by 41 by 13.2 mm wearable is designed primarily for sports and safety applications, including any events or situations where monitoring the precise location and physiological parameters of individuals—such as runners, children or vulnerable and elderly people—is advantageous.

The ProGuard watch provides built-in GPS positioning with cellular IoT, an LPWAN technology, as well as heart rate/blood oxygen level monitoring via integrated sensors. For example, the smart watch could be used to remotely monitor an amateur or professional athlete's heart rate during a training session or a competitive sports event or, in the event of a serious problem, send SOS alerts alongside GPS to first responders. Additional devices could also be used to track the position and status of the first responders themselves from a permanent or temporary base throughout a rescue operation.

To ensure the safety of the wearer, all the key data is automatically relayed in real-time from the smart watch to an associated smartphone app and then to a Cloud-based server platform. Through the companion app, the participant's friends, family members or trainers can engage with the user by viewing live activity updates.

"The wearer's status can be monitored from anywhere to ensure that participants of sports activities are behaving normally, thus reducing accidents during events or competitions," says Min-Liang Chen, Chairman and President of ProMOS Technologies. "In the case of an emergency, the device's positioning feature can assist first aiders to reach the person in need quickly, providing a better and safer sports environment for all participants."

Cellular IoT benefits

For developers, there are numerous benefits of using cellular IoT over alternative protocols to provide the wireless connectivity for a sports/safety wearable like the ProGuard Secure Positioning Watch. For example, a user does not need to carry their smartphone or rely on Wi-Fi for Cloud connectivity. By using cellular infrastructure—which is not only secure and reliable but also established and widespread—cellular IoT enables Cloud connectivity for battery-constrained devices without the need for a gateway device.

"We selected cellular IoT over competitive LPWANs as cellular IoT already has complete geographic and wide-area coverage features and it is possible for these devices to connect to 5G in the future," says Chen.

This functionality represents a significant advantage in certain applications, notably including the adventure and extreme sports market. For example, a cross country skier, rock climber or base jumper who gets injured, lost or trapped in a precarious position on a mountain would be able to call for help simply by hitting the SOS button on the wearable — removing the need to access or even carry a smartphone during the activity, regardless of location.

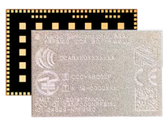
To power its position, physiological parameter monitoring and SOS alert capabilities, the ProGuard Secure Positioning Watch employs Nordic's nRF9160 SiP with integrated LTE-M/NB-IoT modem plus GPS. The SiP is certified for global cellular IoT applications and provides a number of advantages for wearable devices in a compact 10 by 16 by 1 mm package. As well as supporting the LTE-M version of cellular IoT, which is ideal for tracking moving objects in outdoor environments, the nRF9160 features market-leading low power consumption. This extends the life of the wearable's 350 mAh lithium battery and provides the watch with up to eight hours of battery life under continuous operation — a key feature in sports/safety applications where frequent recharging is difficult.

The integrated LTE-M modem offers a maximum output power of 23 dBm and 108 dBm RX sensitivity. The link budget enables the ProGuard watch to use the nRF9160 to reliably send data to the Cloud over a significantly longer range than competitive solutions. In addition, the nRF9160 SiP features a powerful Arm Cortex-M33 dedicated application processor which communicates with the LTE modem and supports the application layer protocol as well as the application itself.

"We selected Nordic's nRF9160 for the ProGuard watch due to the SiP's level of integration, multimode capability, large memory capacity and wireless sensitivity," says Chen.

"In terms of software, the nRF9160 provides key features including built-in Zephyr OS for multi-tasking, bootloader for OTA-DFU [over-the-air device firmware update] functionality, encrypt and decrypt algorithm, and useful network operation examples such as the MQTT [Message Queuing Telemetry Transport]."

With Nordic nRF9160 SiP enabled LTE-M cellular connectivity performing a critical role, the ProGuard watch is on course to boost participant safety in a full range of extreme sports events.



Tech Check

Nordic's nRF9160 SiP is supported by the nRF9160 DK, a precertified single board development kit and the nRF Connect SDK, a software development kit which includes application layer protocols, application examples, and LTE modem firmware offered as precertified and precompiled downloads

Marko Kadunc
CEO, MDCN Technologies

Health wearables must do more than just monitor

Health awareness is on the rise and the wireless devices powering the boom are becoming more sophisticated

Personal health and wellness technology owes a lot to the step counters, heart rate monitors and fitness wearables that blazed the trail for the sector. They completely changed the way millions of people looked at their health. These early solutions have helped us all become far more mindful of what goes on with our health, and that's been an incredibly important step.

In the case of MDCN Technologies, our journey started because we became fascinated by how external factors can have a huge influence on mental and physical health. Our NeoRhythm smart headbands stimulate brainwaves and are based on U.S. Food and Drug Administration-approved pulsed electromagnetic field (PEMF) technology. PEMF produces frequencies which encourage the human mind to function in an individual's preferred state, and is proven to help people sleep better, de-stress or focus.

> Bluetooth LE is essential to maximize battery life and improve the user experience

We are passionate about wireless technology because traditionally a lot of medical and wellness devices were huge machines not meant for home use, making them inaccessible to the average person. Now wireless technology has become accessible, and manufacturers really don't have the luxury of choosing between wired and wireless anymore. Put simply, if a developer wants their device adopted on a large scale, it has to be wireless.

By combining wireless technology into a small form factor device, you not only make it more accessible and more affordable but also easier to use. Changes in consumer behavior stemming from other technology like smartphones and earphones,

that everyone has become really accustomed to and are easy to use, has meant people don't find it hard to adopt a wireless wellness wearable either. And with Bluetooth in practically every single smartphone, connectivity couldn't be easier.

Quantum leap

As to the future, at some point health and wellness wearables will have to move beyond simply monitoring and a quantum leap in value will have to be made to grow the sector further. Manufacturers will have to figure out how to not only provide data about what's going on but also provide a direct solution that solves a given problem. We think we're going in the right direction with NeoRhythm, as it's designed to influence physical and mental health directly.

At the moment the industry is still in a bubble. The use of health and wellness devices are on the rise but there are consumers who believe in this technology and then people who are major skeptics. The challenge is to win over the skeptics and that can only be done with a quality device.

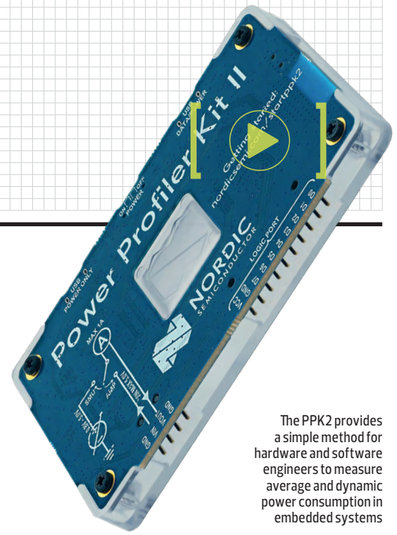
It's a consumer-focused market, more so than any other market in our opinion because, when it comes to health, you really need to know what you're doing and what effect it's going to have on your customer. In the near future, there's going to be a lot more providers of wearable devices and the ones that really know their customers, and do everything with them in mind, will survive, while the others won't.

The Holy Grail is a device that not only hooks the user but also gives them a positive health outcome. If we as an industry can make that, then we've done everything we can.

[Tech Zone]

An in-depth look at Nordic's wireless IoT solutions

Power Profiler Kit II samples ten times faster



The PPK2 provides a simple method for hardware and software engineers to measure average and dynamic power consumption in embedded systems

Nordic Semiconductor has released an enhanced Power Profiler Kit that enables easy power measurement during wireless product development with its nRF51, nRF52 and nRF53 Series multiprotocol SoCs, and the nRF91 Series low power multi-mode cellular IoT SiP.

The Power Profiler Kit II (PPK2) provides a simple method for hardware and software engineers to measure average and dynamic power consumption in embedded solutions and supports power profiling of systems from 200 nA up to 1 A at a resolution that varies between 100 nA and 1 mA depending on the measurement range.

The PPK2 can be powered from an independent 5 V USB source, with the external device under test (DUT) optionally powered from a separate 0.8 to 5 V source integrated in the PPK2. An ammeter mode can measure current on the DUT and the PPK2 features 10 times quicker sampling compared with the previous PPK, extending bandwidth and enabling a continuous trigger window. An advanced auto-ranging analog measurement circuit supports high speed current measurement across a large dynamic input range.

The associated PC software is bundled as a separate app inside Nordic's cross-platform development software, nRF Connect for Desktop. The app provides a unified GUI for both the PPK and the PPK2, and provides several ways of assessing the power consumption, both instantaneous and averaged over a set time period.

"Continuous power consumption measurement at all stages of development ensures power problems are identified early in the engineering cycle making it easier to avoid time-consuming revisions of code at a later stage," says Pål Kastnes, Technical Marketing Manager with Nordic.

Turnkey production test solution for Nordic's nRF9160 SiP

German test and measurement specialist, Rohde & Schwarz, has added turnkey support for cellular IoT products employing Nordic's nRF9160 SiP to its R&S CMW100 communications manufacturing test set.

The R&S CMW100 is used by the majority of the world's biggest cellular device manufacturers for high-volume production tests, often on around-the-clock manufacturing lines that need ultra high speed testing and reliability without compromising on test quality.

According to Franz Obermayr, a Production Project Manager at Rohde & Schwarz, any product designed to operate on a cellular network has to conform to an independent set of strict physical layer test and conformance standards. "You can't have a cellular chip out in the world that's wrongly calibrated because it will cause major problems in both the product application in which it sits and/or on the local cellular network in which it operates," says Obermayr.

"You have to test each and every single cellular product. And in high-volume applications typical of the IoT this is extremely challenging to do at a commercially viable minimal per unit test cost."

The R&S CMW100 is designed to production test all cellular technologies up to and including 5G, as well as any product employing ultra low power, Wi-Fi, LPWAN and satellite wireless technologies.

The test capability allows any cellular IoT product employing another wireless technology such as GPS, Bluetooth or Zigbee, to be regulatory tested for these protocols at the same time.

Internet of Things

SmartBug helps select IoT sensors

InvenSense has launched its SmartBug IoT module. The product allows OEMs to better understand real application signatures, environmental variations and sensor algorithm behaviors in order to develop good algorithms and evaluate what sensor types will be best suited to specific uses.

Designed to be used during the prototyping/development stage, the kit enables the dedicated wireless collection of raw sensor data and intelligent algorithm-based insights for research, clinical trials, education or industrial testing. The module integrates multiple sensors—including an accelerometer, gyroscope, magnetometer, pressure sensor, temperature sensor and humidity sensor—to remotely monitor IoT applications. Nordic's nRF52840 SoC relays this data to Windows 10 app/GUI via Bluetooth LE connectivity.

Tech Briefing

Inside the nRF Connect SDK

Nordic's latest Software Development Kit brings together a code base and a tool chain for the nRF52, nRF53 and nRF91 Series all in one place

The nRF Connect SDK is Nordic's Software Development Kit for cellular IoT and short-range wireless. This SDK is designed for developers creating applications for Nordic's nRF91 and nRF53 Series. (For the nRF52 Series, the developer has the choice between using the nRF Connect SDK and the nRF5 SDK.)

The SDK comprises two parts: a code base (*see Figure 1*) and a tool chain. The code base consists of application code, protocols, stacks and drivers. These are organized into multiple repositories including: nRF (application and connectivity protocols); nrfxlib (RTOS independent modules); Zephyr (RTOS and board configuration); and MCUBoot (Bootloader). Developers can also access code stored in their own repository. The west tool ensures that all repositories are easily synchronized.

On the toolchain side, the SDK offers: The SEGGER Embedded Studio Nordic Edition Integrated Development Environment (IDE) for configuration, coding and debugging; enterprise toolchains such as git and CMake to configure, build and continuously integrate; and hardware development boards from Nordic and third parties to prototype, develop and test applications.

Within the toolchain is the Kconfig software which is used to configure the system (for example, GPS or MQTT settings). In addition, the toolchain includes Device Tree which describes hardware pin layout and allows flexible hardware modifications via an overlay file.

Cellular IoT and short range wireless support

The nRF Connect SDK supports applications using LTE-M/NB-IoT, Bluetooth LE, Bluetooth mesh, Thread and Zigbee. Support for Bluetooth Direction Finding and LE Audio will be added. The SDK includes a migration of Nordic's Bluetooth SoftDevice Controller Subsystem from the company's proven SoftDevices (Bluetooth LE RF protocol 'stacks') used with the nRF52 Series. This SoftDevice Controller Subsystem is optimized for Nordic products and enables best-in-class interoperability between the SoCs, smartphones and other Bluetooth products.

The SDK accelerates product development and shortens time-to-market. To make development easier, the SDK includes samples and Proof-of-Concepts. There is also fully-integrated code for application examples to build a product, and short range and cellular IoT connectivity with complete, verified and optimized wireless stacks, drivers and protocols.

One of the main ways the nRF Connect SDK shortens development time is through modular programming. For example, Zephyr includes all the main wireless protocols, including Bluetooth LE, Bluetooth mesh, CoAP, UDP, MQTT, IPv4, IPv6 and more. By including these robust protocols, Nordic has been able to focus on bringing other value-adding features to the SDK such as modem and application firmware over-the-air updates for the nRF9160 SiP.

With the SDK, developers have access to a comprehensive code base even if they only need some layers for an application using certain RF protocols.

Modular programming also allows the developer to optimize memory efficiency by deciding which modules, libraries and drivers to support. In turn, this allows the nRF Connect SDK the flexibility to support small, memory-constrained applications as well as sophisticated and richly-featured software for advanced applications.

In addition, the single code base for both short-range wireless and cellular IoT products allows easy code reuse between multiple applications, minimizing the time investment for customers developing several applications using the nRF Connect SDK.

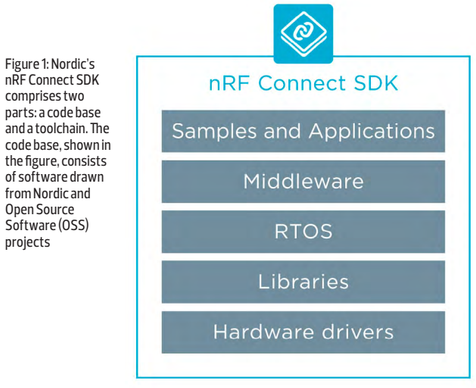


Figure 1: Nordic's nRF Connect SDK comprises two parts: a code base and a toolchain. The code base, shown in the figure, consists of software drawn from Nordic and Open Source Software (OSS) projects

The best of Nordic and open source software

The software in the SDK's single code base is a mix of the best code from Nordic and that from Open Source Software (OSS) projects. Nordic regularly updates the OSS components in the nRF Connect SDK to synchronize with the OSS versions. The company's engineers then perform integration tests of the entire nRF Connect SDK delivery, including the toolchain, as a single entity before the product is released. The tests ensure that tagged versions of nRF Connect SDK work as a seamless, single delivery.

The nRF Connect SDK is continuously updated and includes not only updates of the Nordic repositories but also the OSS projects. The latest version of the SDK (v1.4), released late 2020, included some useful additions for both Nordic's short-range and cellular IoT products. Notable enhancements on the short-range side include Bluetooth samples for Alexa gadgets (*see pg3*); a Bluetooth 5.2 specification qualified controller subsystem and host, and Thread production support for nRF52833 and nRF52840.

For cellular IoT support, enhancements include Microsoft Azure IoT hub library and sample support, improved low power features, serial LTE modem improvements and new modem firmware (v1.2.2) with GPS improvements.

For further information about the nRF Connect SDK, see the Nordic webinar, *nRF Connect SDK – The next generation for Nordic wireless solutions*, at https://bit.ly/2K4SVPo.

> "Build and configuration tools are readily available to allow developers to focus on the components required for their specific designs

Zephyr™

Tech Check

The Zephyr RTOS controls application complexity in large memory by ensuring predictable and deterministic execution pattern in embedded systems with strict timing requirements. The scheduler determines which task to execute at which time by setting a priority for each execution thread. Zephyr is designed and built for low power wireless and is an independent project governed by the Linux foundation with contributions made by over 600 industry embedded experts. Nordic is a platinum member of the Zephyr project

Tech Briefing

nRF5340 now ready for high-volume designs

Nordic's dual Arm Cortex-M33 SoC is now available in volume and is accompanied by a production version of its development kit

Nordic Semiconductor's nRF5340 high-end multiprotocol SoC has entered production and is now available from Nordic's extensive distribution network for high-volume designs. The production release of the nRF5340 brings the world's first dual Arm Cortex-M33 processor, multiprotocol wireless SoC within reach of all. The chip combines a high-performance application processor with a fully programmable, ultra low power network processor, plus advanced root-of-trust and trusted execution security features. It supports complex IoT applications—in the professional lighting, industrial automation, advanced wearables and other sectors—that were previously not possible with a wireless single-chip option.

The SoC supports Bluetooth LE, Bluetooth mesh, Thread, and Zigbee and is based around two Arm processors (*see panel*). Nordic provides customers full access to both these cores and freedom to use each as they want - which is not always the case for comparable products on the market. The developer can combine the computational power of the application processor with the efficiency of the network processor to optimise performance and battery life by selecting elements of the application software to run on each core.

For example, some customers may require just simple Bluetooth LE connectivity and as such will be able to fit the complete Bluetooth LE stack in the network domain, while others might target multiprotocol solutions where the upper layers will only fit in the application domain. (Developers requiring end-to-end encryption are best served by the CryptoCell-312, which only resides in the application domain.)

In addition to the Arm processors and associated memory resources, the nRF5340 features a new, power-optimized multiprotocol 2.4 GHz radio with a TX current of 3.4 mA (0 dBm TX power, 3 V, DC/DC) and RX current of 2.7 mA (3 V, DC/DC). Sleep current is as low as 0.9 µA. The SoC features a wide range of interface peripherals including NFC, USB, QSPI and High Speed SPI. The QSPI peripheral is augmented to interface with external memory at 96 MHz. The nRF5340 is designed for extended operating temperature up to 105°C.

Development tools

The nRF5340 Preview Development Kit (PDK) has now been replaced with the nRF5340 DK (built around the production version of the nRF5340). Like the SoC, the nRF5340 DK is now available through Nordic's distribution network.

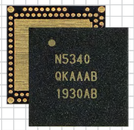
The nRF5340 DK incorporates everything needed to get started with nRF5340 development, on a single board. To make the most of the nRF5340's extensive protocol support, the DK includes features such as Bluetooth LE high-throughput 2 Mbps, Advertising Extensions and Long Range. Moreover, mesh protocols like Bluetooth mesh, Thread and Zigbee can run concurrently with Bluetooth Low Energy. NFC, ANT, 802.15.4 and 2.4 GHz proprietary protocols are also supported.

The DK is bundled with an NFC antenna that enables testing of nRF5340's NFC-A tag functionality. A SEGGER J-Link debugger is included on the board, enabling programming and debugging of both the nRF5340 SoC and external targets.

All analog and digital interfaces, and GPIOs are available via headers and edge connectors. The DK is Arduino Uno Rev3 hardware compatible, allowing it to easily interface with external device shields. An on-board external memory is connected to the 96 MHz QSPI peripheral in the nRF5340 SoC. The nRF5340 DK is typically powered via USB but can be powered by a wide range of other sources. Current consumption can be measured by using the dedicated current measurement pins, using, for example, Nordic's Power Profiler Kit II. (*See pg28.*)

Application software development is supported by the nRF Connect SDK. (*See pg29.*)

> The production release of the nRF5340 brings the world's first dual Arm Cortex-M33 processor, multiprotocol wireless SoC within reach of all

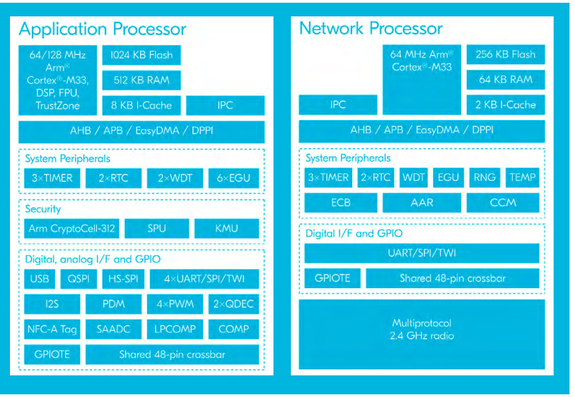


Tech Check

The nRF5340 is a good option for next generation wireless audio. With an LE Audio-enabled software stack, the nRF5340's radio supports LE Isochronous Channels and LE Audio's Low Complexity Communication Codec (LC3) runs efficiently on the SoC. The nRF5340 also has an onchip audio PLL for audio synchronization for true wireless stereo playback

nRF5340 dual processor architecture

The nRF5340's application processor is optimized for performance and runs at either 128 or 64 MHz. The highest performance (514 CoreMark) is achieved at the fast clock rate, while greater efficiency (73 CoreMark/mA) is achieved at the lower rate. This processor has 1 MB Flash, 512 KB RAM, a floating point unit (FPU), an 8 KB 2-way associative cache and DSP instructions. The network processor is clocked at 64 MHz and is optimized for low power consumption and efficiency (101 CoreMark/mA). It features 256 KB Flash and 64 KB RAM. The network processor runs the RF protocol while the device's programmability allows the developer to select application software elements that can take advantage of the processor's high efficiency



Product Summary

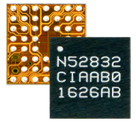
Full product details at: www.nordicsemi.com/Products

		nRF 9 SERIES	nRF SERIES 53	nRF 52 SERIES							nRF 5 SERIES		
		nRF9160	nRF5340	nRF52840	nRF52833	nRF52832	nRF52820	nRF52811	nRF52810	nRF52805	nRF51822	nRF51422	nRF51824
WIRELESS PROTOCOL	LTE-M	●											
	NB-IOT	●											
	GPS	●											
	BLUETOOTH LOW ENERGY		●	●	●	●	●	●	●	●	●	●	●
	BLUETOOTH 5.2		●	●	●	●	●	●	●	●			
	LE AUDIO		●										
	DIRECTION FINDING		●		●		●	●					
	2 MBPS		●	●	●	●	●	●	●	●			
	LONG RANGE		●	●	●		●	●					
	BLUETOOTH MESH		●	●	●	●	●						
	THREAD		●	●	●		●	●					
	ZIGBEE		●	●	●		●						
	ANT		●	●		●			●			●	
	2.4 GHZ PROPRIETARY		●	●	●	●	●	●	●	●	●	●	●
	NFC		●	●	●	●							
TYPE	SYSTEM-ON-CHIP		●	●	●	●	●	●	●	●	●	●	●
	SYSTEM-IN-PACKAGE	●											
CORE SYSTEM	CPU	64 MHz Arm Cortex-M33	128 MHz Arm Cortex-M33 +64 MHz Arm Cortex-M33	64 MHz Arm Cortex-M4	64 MHz Arm Cortex-M4	64 MHz Arm Cortex-M4	64 MHz Arm Cortex-M4	64 MHz Arm Cortex-M4	64 MHz Arm Cortex-M4	64 MHz Arm Cortex-M4	16 MHz Arm Cortex-M0	16 MHz Arm Cortex-M0	16 MHz Arm Cortex-M0
	FPU	●	●	●	●	●							
	DSP INSTRUCTION SET	●	●	●	●	●	●	●	●	●			
	CACHE	●	●	●	●	●							
	MEMORY	1 MB Flash, 256 kB RAM	1 MB Flash, 512 kB RAM +256 kB Flash, 64 kB RAM	1 MB Flash, 256 kB RAM	512 kB Flash, 128 kB RAM	512 kB or 256 kB Flash, 64 kB or 32 kB RAM	256 kB Flash, 32 kB RAM	192 kB Flash, 24 kB RAM	192 kB Flash, 24 kB RAM	192 kB Flash, 24 kB RAM	128 kB or 256 kB Flash, 32 kB or 16 kB RAM	128 kB or 256 kB Flash, 32 kB or 16 kB RAM	256 kB Flash, 16 kB RAM
	CLOCKS	64 MHz / 32 kHz	128 MHz / 64 MHz / 32 kHz	64 MHz / 32 kHz	64 MHz / 32 kHz	64 MHz / 32 kHz	64 MHz / 32 kHz	64 MHz / 32 kHz	64 MHz / 32 kHz	64 MHz / 32 kHz	16 MHz / 32 kHz	16 MHz / 32 kHz	16 MHz / 32 kHz
SECURITY	ARM TRUSTZONE	●	●										
	ARM CRYPTOCELL	310	312	310									
	ROOT-OF-TRUST	●	●	●									
	SECURE KEY STORAGE	●	●										
	AES ENCRYPTION	●	●	●	●	●	●	●	●	●	●	●	●
RADIO	LTE-M/NB-IOT/GPS MODEM	●											
	CERTIFIED LTE BANDS	1-5, 8, 12-14, 17-20, 25-26, 28, 66											
	FREQUENCY	700-2200 MHz	2.4 GHz	2.4 GHz	2.4 GHz	2.4 GHz	2.4 GHz	2.4 GHz	2.4 GHz	2.4 GHz	2.4 GHz	2.4 GHz	2.4 GHz
	MAXIMUM TX POWER	23 dBm	3 dBm	8 dBm	8 dBm	4 dBm	8 dBm	4 dBm	4 dBm	4 dBm	4 dBm	4 dBm	4 dBm
	RX SENSITIVITY	-108 dBm (LTE-M), -114 dBm (NB-IoT), -155 dBm (GPS)	-97.5 dBm (1 Mbps)	-95 dBm (1 Mbps)	-95 dBm (1 Mbps)	-96 dBm (1 Mbps)	-95 dBm (1 Mbps)	-97 dBm (1 Mbps)	-96 dBm (1 Mbps)	-97 dBm (1 Mbps)	-93 dBm (1 Mbps)	-93 dBm (1 Mbps)	-93 dBm (1 Mbps)
	ANTENNA INTERFACE	50 Ω single-ended	Single-ended	Single-ended	Single-ended	Single-ended	Single-ended	Single-ended	Single-ended	Single-ended	Differential	Differential	Differential
PERIPHERALS	HIGH SPEED SPI		●	●	●								
	TWI, SPI, UART	4xTWI/SPI/UART	4xTWI/SPI/UART +TWI/SPI/UART	2xTWI/SPI, SPI, 2xUART	2xTWI/SPI, SPI, 2xUART	2xTWI/SPI, SPI, UART	2xTWI/SPI, UART	TWI/SPI, SPI, UART	TWI, SPI, UART	TWI, SPI, UART	2xTWI/SPI, UART	2xTWI/SPI, UART	2xTWI/SPI, UART
	QSPI		●	●									
	USB		●	●	●		●						
	PWM	4	4	4	4	3		1	1				
	PDM	●	●	●	●	●		●	●				
	I2S	●	●	●	●	●							
	ADC, COMPARATOR	ADC	●	●	●	●	COMP	ADC, COMP	ADC, COMP	ADC	ADC, LPCOMP	ADC, LPCOMP	ADC, LPCOMP
	TIMER, RTC	3, 2	3, 2 + 3, 2	5, 3	5, 3	5, 3	4, 2	3, 2	3, 2	3, 2	3, 2	3, 2	3, 2
	TEMPERATURE SENSOR	●	●	●	●	●	●	●	●	●	●	●	●
APPLICATIONS	AGRICULTURE	●											
	ASSET TRACKING	●	●		●		●	●					
	AUTOMATION		●	●	●	●	●		●		●	●	●
	BEACON			●	●	●		●	●	●	●	●	●
	CONSUMER ELECTRONICS		●	●	●	●	●		●	●	●	●	
	DIRECTION FINDING		●		●		●	●					
	GAMING / VR + AR		●	●	●	●	●		●		●	●	
	HEALTHCARE & MEDICAL		●	●	●	●			●	●	●	●	
	INDUSTRIAL SYSTEMS	●	●	●	●		●						
	MESH NETWORKS		●	●	●	●	●				●		
	PC PERIPHERALS			●	●	●	●		●	●	●	●	
	PROFESSIONAL LIGHTING		●		●		●						
	SMART BUILDINGS	●	●	●	●		●						
	SMART CITY	●	●										
	SMART HOME	●	●	●	●	●	●	●	●		●	●	
	SMART METERING	●											
	SPORTS & FITNESS	●	●	●	●	●			●		●	●	
	TOYS		●	●	●	●			●		●	●	
	WEARABLES	●	●	●	●	●			●		●	●	
CERTIFICATIONS		GCF, PTCRB, CE, FCC, Verizon ++	CE, FCC	CE, FCC	CE, FCC	CE, FCC	CE, FCC	CE, FCC	CE, FCC	CE, FCC	CE, FCC	CE, FCC	CE, FCC
OPERATING TEMPERATURE		-40 to 85 °C	-40 to 105 °C	-40 to 85 °C	-40 to 105 °C	-40 to 85 °C	-40 to 105 °C	-40 to 85 °C	-40 to 85 °C	-40 to 85 °C	-40 to 85 °C	-40 to 85 °C	-40 to 105 °C
SUPPLY VOLTAGE RANGE		3.0 to 5.5 V	1.7 to 5.5 V	1.7 to 5.5 V	1.7 to 5.5 V	1.7 to 3.6 V	1.7 to 5.5 V	1.7 to 3.6 V	1.7 to 3.6 V	1.7 to 3.6 V	1.8 to 3.6 V	1.8 to 3.6 V	1.8 to 3.6 V
DEVELOPMENT KITS		nRF9160 DK, Nordic Thingy:91	nRF5340 DK	nRF52840 DK nRF52840 Dongle	nRF52833 DK	nRF52 DK Nordic Thingy:52	nRF52833 DK	nRF52840 DK	nRF52 DK	nRF52 DK	nRF51 DK, nRF51 Dongle	nRF51 DK, nRF51 Dongle	nRF51 DK, nRF51 Dongle
PACKAGES		10x16x1 mm LGA	7x7 mm aQFN94 (48 GPIOs), 4.4x4.0 mm WLCSP95 (48 GPIOs)	7x7 mm aQFN73 (48 GPIOs), 3.5x3.6 mm WLCSP94 (48 GPIOs)	7x7 mm aQFN73 (42 GPIOs), 5x5 mm QFN40 (18 GPIOs), 3.2x3.2 mm WLCSP (42 GPIOs)	6x6 mm QFN48 (32 GPIOs), 3.0x3.2 mm WLCSP50 (32 GPIOs)	5x5 mm QFN40 (18 GPIOs) 3.175x3.175 mm WLCSP44 (18 GPIOs)	6x6 mm QFN48 (32 GPIOs), 5x5 mm QFN32 (17 GPIOs), 2.48x2.46 mm WLCSP33 (15 GPIOs)	6x6 mm QFN48 (32 GPIOs), 5x5 mm QFN32 (16 GPIOs), 2.48x2.46 mm WLCSP33 (15 GPIOs)	2.48x2.46 mm WLCSP28 (10 GPIOs)	6x6 mm QFN48, WLCSP48, Thin CSP	6x6 mm QFN48, WLCSP48	6x6 mm QFN48, WLCSP48

Tech Profile

nRF52832

nRF 52 SERIES

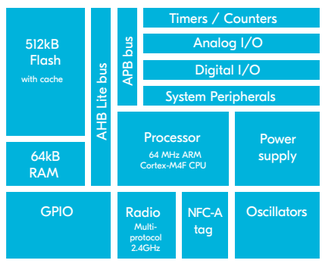


Description: The nRF52832 is a general-purpose multiprotocol SoC. It meets the challenges of a broad range of applications that need advanced Bluetooth LE connectivity, protocol concurrency and a rich and varied set of peripherals and features.

Hardware: The nRF52832 is based around a powerful 64 MHz 32-bit Arm Cortex-M4 processor and includes 512/256 KB Flash plus 64/32 KB RAM. The multiprotocol radio offers up to +4 dBm power output and -96 dBm sensitivity (1 Mbps Bluetooth LE throughout). The radio's peak power draw is only 5.3 mA TX (0 dBM) and 5.4 mA RX (1 Mbps) and the SoC's current draw is as low as 0.3 µA in System OFF. The nRF52832 has an array of peripherals and interfaces to enable complex single chip applications. All commonly found serial interfaces are supported (for example. SPI, I²C and UART). Additionally, there are dual PDM digital microphone inputs, and QDEC and PWMs included onchip. An internal intelligent automated power distribution system ensures only system blocks that are required to carry out operations are energized. The SoC operates from a 1.7 to 3.6 V power supply.

Software: The nRF52832 is supplied with either Nordic's S112 or S113 SoftDevices, memory-optimized Bluetooth 5 RF protocol stacks, the S132 SoftDevice, a Bluetooth 5 RF protocol stack for building advanced Bluetooth LE applications, the S212 ANT stack or the S332 Combined Bluetooth 5 and ANT protocol stack. The S132 SoftDevice, for example, features Central, Peripheral, Broadcaster and Observer Bluetooth LE roles and supports up to twenty connections. With a Bluetooth 5 SoftDevice, the SoC supports the high-speed 2 Mbps feature and improved coexistence through CSA #2. In addition, Bluetooth mesh can be run concurrently with Bluetooth LE, allowing smartphones to provision, commission, configure and control mesh nodes. NFC, ANT and 2.4 GHz proprietary protocols are also supported. The nRF52832 boasts an over-the-air device firmware update (OTA DFU) feature.

Development tools: The nRF52832 uses the nRF5 SDK and nRF Connect SDK for software development. The SDKs bring developers a wealth of varied examples, including Bluetooth LE profiles and driver support for all peripherals. Applications can be evaluated using the nRF52 DK. This is a versatile single board development kit for Bluetooth LE, Bluetooth mesh, NFC, ANT and 2.4 GHz proprietary development on the nRF52832 SoC. The DK includes an NFC antenna that quickly enables utilization of the NFC-A tag peripheral on the nRF52832. All GPIOs are available via edge connectors and headers, and 4 buttons and 4 LEDs simplify output and input to and from the SoC. The DK is Arduino Uno Revision 3 compatible and comes with an on-board SEGGER J-Link debugger. The DK also interfaces directly with the Power Profiler Kit II (PPK 2). (*See pg28.*)



The nRF52832 SoC incorporates a 64 MHz 32-bit Arm Cortex-M4 microprocessor, 512 (or 256) KB Flash and 64 (or 32) KB RAM, multiprotocol 2.4 GHz radio, power supply, peripherals and a range of interfaces in a 6 by 6 mm QFN or 3.0 by 3.2 mm WLCSP