

The rise of the smart kitchen

Connected living in the heart of the home

Whitepaper
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Abstract

The smart kitchen is here to stay, with Internet of Things-enabled appliances such as fridge-freezers, ovens, washing machines and dishwashers becoming part of intelligent home automation networks. This whitepaper charts the rapid rise of the smart kitchen and looks at how advances in electronic solutions have resulted in a new generation of quieter and more energy-efficient appliances driven by intuitive sensor-based operation. This trend has delivered higher levels of functionality, making life more convenient for tech-savvy consumers.

1 Introduction – the importance of connected living

We live in a connected world. The emergence of the Internet of Things (IoT) and the proliferation of the smartphone means a broad range of products can now be linked seamlessly together, forming widespread digital networks with intelligence and communication built in.
Nowhere is this trend more notable than inside the modern home. According to the latest research [1], the smart home market – where lighting, climate, entertainment systems and appliances can be digitally monitored and controlled for user convenience – is expected to grow rapidly over the next five years, from $78.3 billion in 2020 to $135.3 billion by 2025.
This remarkable uptake does not just reflect the development of new products and systems. It represents a fundamental shift in consumer attitude towards home automation, with a growing enthusiasm to embrace new technology to enhance our day-to-day lives. It also reflects rising consumer satisfaction with connected products, with improved reliability and functionality, delivering greater added value for the end user.
Indeed, with many of us spending more time indoors in recent months, it is the kitchen that has emerged as the heart of the smart home. Open-plan kitchens/diners have become increasingly sought-after by homeowners, and now represent the most popular layout for new build homes. No longer just a place to cook, the kitchen is now seen as the center of social interactions – a place to gather to eat, drink, talk and make future plans.
These activities can be underpinned by smart kitchen solutions that can mimic human senses such as touch, sight, hearing and smell. Tech-savvy consumers have high-performance expectations of such products, looking for devices that make less noise, consume less energy, work intuitively in a safe and secure manner, and connect to other devices without complex set-up procedures. It is only by meeting, and then exceeding, these consumer expectations that the trend towards kitchen automation will continue to grow.

2 Smart kitchen functionality in practice

So, let us look at how smart kitchen technology is already transforming our lives. In addition to highly controllable heating and air conditioning, which apply to all rooms in the house, there are some incredible advances in kitchen appliances designed to save time and effort, and maximize user convenience.
Imagine a smart fridge with a camera that allows you to check the fridge contents via a mobile phone at any given time. The fridge could even use object recognition to suggest how best to store produce, keeping them fresher for longer. Such an appliance could perhaps be operated by voice control, with a digital screen that acts as a modern take on the traditional ‘note on the fridge door’ - presenting users with information such as recipe ideas based on the food inside.
Then there are app-controlled ovens, which can be operated remotely, allowing users to start the cooking process while returning home from work. Cameras or radar with artificial intelligence could also recognize the type of food being cooked, and suggest timings.
Meanwhile, connected dishwashers can auto-dose salt and cleaning powder and set themselves to start each cycle during off-peak electrical hours, saving energy and money.
Smart kitchen technology could also be deployed to grow food. Vertical aeroponic gardens taking up less than three square feet grow nutrient-rich greens and herbs with only water rather than soil, making them

particularly suited to urban environments. The garden towers are precisely dosed with smart pumps and irrigation systems, allowing plants to grow three times faster than they would under traditional methods, producing 30% greater yields on average.
None of these examples of smart kitchen automation is limited to the realms of science fiction. In each case, the technology already exists today. The applications are a genuine reflection of the 'art of the possible,' showing just how quickly the smart kitchen concept has come to fruition, and the sorts of benefits it can bring.

3 Quieter and more energy-efficient appliances

But while smart kitchen appliances might vary dramatically, there is one unifying factor underpinning performance: they all depend on first-class systems and components to operate safely, efficiently, and effectively. From power, sensing and connectivity, to security, system control and HMI displays, smart kitchen appliances rely on the seamless integration of a broad range of technologies that deliver reliability and interoperability and meet end-user satisfaction.
Let us look at some of the performance criteria in turn. Firstly, from a product development perspective, there are two critical aspects of smart kitchen appliance performance – namely noise and energy use – that are increasingly governed by national and international regulations. Whereas once quieter and more efficient performance might have been deemed 'nice to have,' there are now mandatory limits that need to be met when seeking accreditation for certain markets. In the European Union, for example, the Ecodesign Directive establishes a framework for mandatory environmental requirements for energy use and energy-related products sold in all member states. For the end user, selecting appliances with better performance in these areas can result in financial recompense through specific national rebates aimed at driving the uptake of more environmentally friendly products.
These requirements have increasingly led to the development of more advanced intelligent power modules (IPMs) whose integrated control and protection features provide more design flexibility. Available with a broad range of semiconductors in different voltage and current classes, the highly integrated nature of these IPMs means they can be packaged into extremely compact designs – driving motors effectively and efficiently across a whole host of home appliances.
The CIPOS™ Nano IPM from Infineon, for example, is an ultra-compact, three-phase or half-bridge MOSFET™ IPM, which is ideal for high-efficiency appliance applications, designed for the rectifier, converter, and inverter stage in power management circuits and motor drives. By implementing an innovative Power QFN package, which utilizes PCB copper traces to dissipate heat from the module, the CIPOS™ Nano achieves a significant advancement in miniaturization and device size, offering up to 60 percent smaller footprint than existing three-phase motor control power IPMs.
Whenever a more flexible, but less integrated solution is preferred, the inverter stage can be built by means of discrete components from Infineon. The 600 V Reverse Conducting Drive 2 (RC-D2) family of IGBT is well-suited for low-power consumer drives, like refrigerator compressors and small pumps. Infineon also offers a wide portfolio of power MOSFETs, like the CoolMOS™ PFD7, if the main goal is to

improve the light-load efficiency of the inverter. Both RC-D2 and PFD7 product families are offered in DPAK and SOT-223 packages[1].

All power electronics applications employ power device switches, which require optimum gate drive solutions, whether they are in discrete form or in a power module. Infineon gate drivers provide a wide range of typical output current options, from 0.1 A up to 10 A, suitable for any power device size. Robust gate drive protection features such as fast short-circuit protection, programmable dead-time, shoot-through protection, and active shutdown, make the drivers well-suited for all power devices.

The EiceDRIVER™ gate driver ICs, for example, serve as the interface between control signals and power switches. The integrated nature of the gate-driver design helps to reduce complexity, development time, bill of materials (BOM), and board space while improving reliability.

Every switch needs a driver, and every driver needs a switch. Infineon's portfolio of driver ICs come in a variety of configurations, voltage classes, isolation levels, protection features, and package options. These flexible gate driver ICs are complementary to IGBT discretes and modules, silicon and silicon carbide MOSFETs, gallium nitride HEMTs, or as part of integrated power modules.

Noise and energy efficiency performance is also achieved through improvements in digital motor control technology. Again, integration is the key – with, for example, the iMOTION™ digital motor controller from Infineon, offering appliance developers fast and accurate 'out of the box' control of variable speed drives. The addition of a field-proven motor control engine (MCE) eliminates the need for software coding of the motor control algorithm from the inverter development process. Implementing a variable speed drive can be quickly achieved by configuring the MCE for the respective motor. Assisted by powerful tools like MCEwizard and MCEDesigner, it is possible to have the motor up and running in less than an hour.

Infineon also provides a proven system understanding that ensures that a broad portfolio of power modules, motor controllers and associated components work seamlessly together. This sort of knowledge and intellectual property enables appliance manufacturer to accelerate the design of quieter and more efficient smart kitchen solutions, shortening the time to market.

4 Smaller and more intuitive sensors

The second critical element to any smart kitchen solution is sensors used in kitchen appliances to emulate the human senses of sight, sound, touch, and smell. Radar, for example, acts as the 'eyes' for a multitude of applications, enabling functions such as presence detection, gesture sensing, and tracking people as they move around the room. Hall sensors, meanwhile, provide highly accurate weight and imbalance measurement, and can support functions such as lid opening and closing.

Then there are MEMS microphones, which drive voice recognition functionality by listening to users' voice commands, and can provide alerts of any unexpected noise variations – therefore supporting predictive maintenance methodologies. Finally, pressure sensors can be applied to detect clogged filters in several applications, while time-of-flight sensors can count the number of people in a room. In all, smart

[1] For RC-D2, the latter package will be available from the last quarter of 2021.

kitchen appliances employ an extensive range of sensing products – often linked together through networking standards such as Bluetooth Mesh as a medium for communication – making consumers' lives easier by analyzing and understanding the environment in real-time, and then acting upon it.

Indeed, sensor capability has improved rapidly in recent years, with step-change improvements in sensitivity, accuracy and robustness being matched by advances in miniaturization. It is worth taking a closer look at some specific sensing products in closer detail to illustrate this point.

The XENSIV™ IM69D130, for example, is a high-performance MEMS microphone, based on dual backplate technology, which delivers noise-free audio raw data with a 69 dB(A) signal-to-noise ratio. The distortion-free audio signal is <1% total harmonic distortion to 128 dBSPL. This performance baseline provides smart kitchen system developers with significant benefits, such as high fidelity and far-field audio recording; and matched, noise and distortion-free audio signals for advanced audio signal processing, with no analog components required.

In terms of application, the XENSIV™ IM69D130 has been deployed for noise monitoring, sound anomaly and audio pattern detection in equipment such as heating, ventilation and air conditioning. But it could also be used in other smart kitchen appliances as a means of 'listening' for specific variations that could indicate the imminent failure of a component. Integrated as part of a broader IoT-based network, this insight could allow appliance manufacturers to initiate predictive maintenance programs, eliminating breakdowns and boosting end-user satisfaction.

The high signal-to-noise ratio of the XENSIV™ IM69D130 means it can also be deployed to drive voice recognition functionality in noisy kitchen devices and from long distances. This is critical in a world where voice activation has become high on the wish-list of technology-savvy consumers, driven in no small part by the widespread adoption of virtual assistant AI devices such as Alexa.

Meanwhile, the development of next-generation radar sensors is delivering advances in motion sensing capability. Infineon's BGT60LTR11AIP is the first completely autonomous 60 GHz microwave motion sensor including antenna-in-package technology, as well as integrated detectors for motion and direction of motion. A state machine enables operation of the device without any external microcontroller. In this autonomous mode, it detects a human target up to 5 m with a low power consumption of less than 5 mW. These features make the small-sized radar solution a smart and cost-effective replacement for conventional passive infrared sensors in low-power or battery-powered applications.

The BGT60LTR11AIP is finding increasing application in smart kitchen environments. It can be integrated into appliances to 'wake' them up, put them to sleep or auto-lock when no motion is detected for a defined amount of time. The sensor can also be used to trigger other functionality based on motion or direction of motion detection.

Interestingly, CO_2 sensors are also finding a role in smart kitchen environments. The trend towards open-plan living means many people spend a lot of their time in the kitchen/diner, and air quality is becoming a more important issue. Also, with COVID in mind, effective monitoring of indoor air quality has put renewed emphasis on well-proven sensing technologies.

One of the most reliable air quality indicators is CO_2 concentration: if a room is badly ventilated, the CO_2 concentration level starts to rise. Infineon's XENSIV™ PAS CO2 is a real CO_2 sensor based on photoacoustic spectroscopy, delivering highly accurate measurement in a design which is 4 × smaller (14 mm × 13.8 mm × 7.5 mm) and 3 × lighter (2 grams) than typical NDIR sensors. This allows for more than 75% space savings in customer systems, helping to drive the trends towards miniaturization in the connected kitchen as well as other home appliances.

5 Safety in the heart of the home

So far, we have looked at how technology can be deployed in the smart kitchen to make users' lives more convenient and environmentally friendly. But the concept goes far beyond that. It can also deliver advances in personal safety – particularly in relation to non-invasive presence detection solutions. For example, this technology can monitor vital signs such as heartbeat, which is especially relevant in an aging society where older and more vulnerable people are likely to live alone.
Increasingly, radar-based systems are being used to monitor people for health and well-being purposes, where the absence of expected activity can be used to trigger an alarm. Radar can also be used to provide large amounts of privacy-sensitive information – in an unobtrusive manner – related to body movement at a distance, even in poor lighting. Assisted living research and development has also shown that it can be used for fall detection activities.
This is clearly an exciting area of development. Infineon meets the demand for radar solutions in smart kitchens with a mmWave Doppler and FMCW radar sensors portfolio in the 24 to 60 GHz range. These offer significant advantages over PIR and other motion-sensing technologies, including smaller size, greater accuracy, and more precise measurement.
In the 24 GHz range, the bandwidth for FMCW radar operations covers 250 MHz within the regulated ISM band. In the 60 GHz regime, an unlicensed ultra-wideband of up to 7 GHz can be used for short-range applications. Consequently, 60 GHz FMCW radar systems can offer a better resolution and therefore allow additional use cases such as human tracking and segmentation - even the monitoring of various vital functions such as respiration, heartbeat or even blood pressure.

6 Convenience through human / machine interfaces

With energy efficiency, functionality, and safety discussed, it is worth looking at advances in how smart kitchen appliances 'feel' to the user in their everyday use. Just like with smartphones, consumers expect to operate devices in increasingly intuitive ways. For example, when it comes to touch, capacitive technology characterized by digital buttons, sliders and touch pads have become constituent parts of appliance displays – eliminating the need for mechanical knobs that are not ideally suited to the rigors of the kitchen environment. With sensors protected by glass or plastic screens, capacitive technology provides a sleeker and more reliable solution, which helps to meet higher consumer expectations.
Infineon underpins the development of advanced human-machine interfaces through the supply of CapSense® and TrueTouch® controllers via the PSoC Creator's CapSense component or mechanical button replacement portfolio – which has replaced over 6 billion mechanical buttons to date. These products delivering capacitive-sensing solutions with industry-leading noise immunity and water tolerance, allowing effective operation even when the display is wet; and proximity sensing, enabling detection at up to 30 cms.
The technology consists of a capacitive sigma delta sensing algorithm, which provides both self and mutual capacitive sensing through the use of a switched capacitor technique with a delta-sigma modulator that converts the sensing current to a digital code. This patented algorithm provides extremely high sensitivity to ensure accurate touch detection through thick overlays in harsh and noisy environments typi-

cally encountered in the kitchen, along with fast scan times. It also comes with SmartSense™ auto-tuning, which continually optimizes a device's performance, provides robust noise immunity and flexible adaptation to changing environments without the need for manual calibration.
But it is not just about capacitive touch sliders and buttons. The latest PSoC 6 microcontrollers integrate touch plus graphics capability on a single chip, driving highly intuitive touch screen functionality. PSoC 6 can also host digital voice assistants – such as Alexa or Google Assistant.
Historically, voice assistants in smart kitchens have required cloud connectivity for interpretation of most context-aware commands. However, indeterminate latency can result in poor user experience, depending on what else is connected to the network. Next-generation products will make the most of advances in artificial intelligence and machine learning, allowing voice commands to be processed on the chip without the need for cloud connectivity. This will make voice-operated appliances smarter and more intuitive, with the end-user functionality more accurately imitating natural language processing.

7 Seamless connectivity and failsafe security

The final piece in the smart kitchen jigsaw is secure connectivity. Each of the connected appliances needs to be able to talk to each other quickly and safely – if need be – and technology needs to enable a 'handshake' between devices that malicious hackers cannot compromise. Indeed, in recent years, Wi-Fi has proved a highly-effective means of providing whole home coverage, over-the-air updates, cloud connectivity, and data back-hauling for predictive maintenance.
Now, though, bluetooth low energy (BLE) is increasingly being used to establish local wireless links between kitchen products. As a relatively recent Bluetooth standard outlined by the Bluetooth special interest group, BLE is notable for delivering low energy performance, with BLE chips programmed for fast connection and low standby times. Indeed, the energy and cost-efficient nature of BLE is driving uptake in the connected kitchen – especially where devices use batteries.
So how might BLE find application in smart kitchen environments? One significant challenge for appliance makers, at present, is low connectivity rates. The existing method of connecting appliances to a network using a software-enabled access point can be complex and time-consuming. It is prone to manual input error of details such as passwords, resulting in connection failure – and frustration for the end-user. BLE onboarding is a faster process that involves establishing a connection between the appliance and mobile phone, and then simply selecting the correct Wi-Fi network. BLE onboarding can therefore provide interactive real-time feedback and be an effective tool for driving up connection rates in smart kitchens.
BLE also offers other advantages such as with service person diagnostics. Previously, appliance faults have often been diagnosed through audio technology. If an appliance has developed a fault, a service technician might ask the customer to hold a phone up to it and press a number sequence to create a tone which could then be decoded to identify the problem. Service diagnostics might also require a technician to have access to a customer's Wi-Fi network, creating security concerns. Now it is possible to create a local connection via BLE to the appliance, which the service technician can use to access appliance data. Looking into the future, the smart kitchen is likely to see the wider adoption of BLE Mesh, a mesh networking standard that incorporates the BLE protocol and enables many-to-many device communications. This technology provides high reliability, scalability, security and interoperability, which ensures compatibility with a broad range of devices – both legacy and new.

Infineon can help kitchen appliance makers use this infrastructure to enable even greater interaction between a broader array of equipment, for example, enabling appliances and smart utensils to talk to each other. So, for example, future functionality might see a smart saucepan with a built-in thermostat communicating with a smart hob – ensuring that your desired cooking heat is controlled to facilitate a perfectly cooked meal.
This functionality is built upon Infineon technology availability such as Wi-Fi/Bluetooth/BLE combo chip for IoT applications, enabling reliable, robust and power-efficient performance, with worldwide certifications and certified interoperability, offering connectivity that can be made to be robust enough for harsh kitchen environments. Moreover, Infineon also offers the products and expertise to 'future-proof' smart kitchens from potential congestion issues around connectivity through the provision of next-generation Wi-Fi 6 controllers which will be Tri-band (2.4 GHz, 5 & 6 GHz) capable.
Finally, there are tools available to provide appliance makers with valuable information around onboarding and connectivity over the long term. Infineon's Cirrent Mobile App Intelligence provides granular visibility into onboarding cycles, quickly identifying the root causes of any failures. The simple client that easily integrates into the customer app breaks down the onboarding process into multiple stages, allowing appliance makers to establish what particular actions are proving to be unclear. Troubleshooting can then be implemented to deal with the key problem areas.
Cirrent IoT Network Intelligence, meanwhile, is a purpose-built, connected-product analytics platform, which allows appliance makers to solve customer connectivity issues quickly and efficiently. The highly scalable platform can be deployed to identify trends and issues across potentially millions of devices, allowing the manufacturer to work out whether connection problems are related to a single appliance or to broader network issues.
Ultimately, there is no value in smart appliances that are difficult to connect or reconnect. These tools can smooth the onboarding process and ensure that appliances continue to perform as they should.

8 Infineon and appliance makers: the power of partnership

It is evident that there is a revolution taking place within the home, as the concept of the smart kitchen grows in popularity and ever-more imaginative technologies come to the market. However, consumers have high-performance expectations, demanding quiet and energy-efficient devices that work safely and intuitively, with seamless connection to wider networks. Appliance makers are challenged to meet these customer requirements in a fast-paced sector where speed-to-market in new product development is a critical consideration.
Infineon has long-standing expertise in electronic systems solutions and integration, and can partner with appliance makers to bring their visions to life. This is supported by an unrivalled portfolio of technologies, covering power, sensors, semiconductors, wireless communications, and much more. It is the merging of this know-how and system solutions that can support appliance makers and help them fulfill the exciting promise of the smart kitchen - both now and in the future.

References

[1] https://www.marketsandmarkets.com/Market-Reports/smart-homes-and-assisted-living-advanced-technologie-and-global-market-121.html

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