E-TARANG

KIET ECE E-MAGAZINE

Vol. 1, Issue: I, 2018-19

Amar Gopal Bose

Department of Electronics and Communication Engineering
KIET Group of Institutions, Ghaziabad
(NAAC 'A' Grade, NBA Accredited and ISO 9001-2000)

KIET Group of Institutions, Ghaziabad, U.P.

Department of Electronics & Communication Engineering

VISION AND MISSION OF THE INSTITUTE

Vision statement

To become a leading institution nationally in the area of professional education, research & innovation for serving the global community.

Mission statements

- To impart quality professional education, skills and values through outcome-based innovative teaching learning process in all spheres.
- To undertake collaborative interdisciplinary research as a co-requisite for professional education and simultaneously solve problems faced by society and industry.
- To create an ambience of innovation, entrepreneurship and consultancy for future leaders and innovators.
- To keep faculty members enthusiastic by continuous professional development and positive working environment.

KIET Group of Institutions, Ghaziabad, U.P.

Department of Electronics & Communication Engineering

VISION AND MI SSION OF THE DEPARTMENT

Vision:

To become a leading center of excellence in the technical education of Electronics & Communication Engineering and create competent professionals in thrust areas for the development of society and nation.

Mission:

- To educate the students with the state of the art technologies through innovative teaching-learning process.
- To enable the graduates to develop the skills required to solve complex real time problems using tools and techniques of Electronics & Communication Engineering practice.
- To develop the spirit of innovation and creativity by collaborating with industries and research establishments to fulfill the needs of society.
- To practice high standards of human values, professional ethics and accountability.

KIET Group of Institutions, Ghaziabad, U.P.

Department of Electronics & Communication Engineering

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs) OF B.TECH.

(ELECTRONICS & COMMUNICATION ENGINEERING)

Graduates of the program will:

I. Acquire fundamental knowledge of Electronics & Communication Engineering to become employable and capable of pursuing higher studies.

II. Have sound foundation required to develop hardware & software solutions necessary for analysis, design and implementation of modern Electronics & Communication Engineering systems

III. Develop effective communication skills and interpersonal behavior to become a cooperative team member and able leader.

IV. Provide quality and worthy service towards their profession with societal and ethical values.

V. Inculcate the habit of life -long learning needed for higher studies and research and continue to develop new methodologies and technologies.

KIET Group of Institutions, Ghaziabad, U.P.

Department of Electronics & Communication Engineering

PROGRAMME OUTCOMES (POs) and (PSOs) OF B.TECH. (ELECTRONICS & COMMUNICATION ENGINEERING)

Program Outcomes (POs)

PO1: Engineering Knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems

PO2: Problem Analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3: Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4: Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions

PO5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.

PO6: The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO7: Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9: Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10: Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO11: Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12: Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes (PSOs)

PSO1: Formulate the real-life problems and apply the concepts of semiconductor technology, signal processing and communication systems, VLSI etc., in the design and development of application-oriented engineering systems.

PSO2: Ability to identify, formulate and analyze complex problems in the field of Electronics and Communication Engineering using modern engineering tools, along with analytical and managerial skills either independently or as team.

KIET Group of Institutions, Ghaziabad, U.P.

Department of Electronics & Communication Engineering

GRADUATE ATTRIBUTES

The Graduate Attributes of Engineering Programs as identified by NBA are:

1. **Engineering knowledge:** Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

2. **Problem analysis:** Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

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Dr. A Garg

Message

I am delighted to note that the Department of Electronics and Communication Engineering, KIET Group of Institutions, Ghaziabad is publishing (Online)Volume. No. I, Issue: I, of KIET ECE E-Magazine, "E-TARANG".

I appreciate the efforts on the part of the Editorial Committee in bringing out Volume. No. I, Issue: I, of E-TARANG on various domains of Electronics & Communication Engineering.

I understand that the articles contributed for publication in the Volume. No. I, Issue: I, based on almost all the current aspects of Communication Systems, Electronics systems and several others.

I share great pleasure in congratulating the Editors of KIET ECE E-Magazine, "E-TARANG" for their untiring efforts in bringing out this Volume. No. I, Issue: I, of E-TARANG which will be a valued treasure for all students in Communications, Networking, Microwave and Electronics Engineering areas.

Let me close with warmest regards.

Dr. A Garg

PresidentKIET ECE E-Magazine, "E-TARANG"

FROM EDITOR'S DESK

It gives me immense pleasure in issuing the Sixth volume, Issue: I, of the KIET ECE E-Magazine, "E-TARANG" being published by the Department of Electronics and Communication Engineering, KIET.

This magazine is targeted towards KIET ECE students to share innovative ideas, issues, recent trends and future directions in the field of Electronics and Communication Engineering. Furthermore, it will enable the students in the various domains to foster the exchange of concepts, prototypes, research ideas and the results of research work which could contribute to the academic arena and also benefit business and industrial community.

I am sure that this magazine would greatly benefit ECE student's community of KIET. Young students and technocrats will find the contents of the magazine helpful to set roadmaps for their future endeavors.

Dr. Sanjay Sharma
Professor & Head, ECE
Department KIET Group of
Institutions

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NEWS

Toshiba unveils 130nm Fit Fast Structured Arraydevelopment platform

Toshiba Electronics Europe has made the first customer shipment of a new 130nm manufacturing process node based FFSA (Fit Fast Structured Array) development platform. This high-performance System-on-Chip (SoC) development platform supports custom solutions that feature low power consumption at a low-cost point.

Toshiba's ASIC (Application Specific IC) and FFSA platforms deliver efficient solutions for custom SoC development. All FFSA devices have a common silicon-based master layer that is used in combination with upper metal layers that are reserved and allow device customisation.

The FFSA platform looks to meet customer requirements for high performance and low power consumption; however, by limiting the customisation to just the metal layer masks, it also drastically reduces development costs. As a result, samples and mass-produced devices can be delivered in a significantly shorter time than for conventional ASICs.

Customers using the FFSA ASIC design methodology and library will be able to secure higher performance and lower power consumption than is possible with Field Programmable Gate Arrays (FPGAs), according to Toshiba.

The FFSA 130nm process is added to Toshiba's current 28, 40, and 65nm process portfolio adding another option for industrial equipment. The 130nm node process offer different master slices for up to 664kb of RAM and around 912,000 gates per device.

Devices designed on the platform will be manufactured by Japan Semiconductor, a subsidiary of Toshiba Electronic Devices & Storage Corporation. Which has a long record in manufacturing ASIC, ASSP and microcomputers. This will ensure long-term supply continuity and meet or exceed the needs of customer business continuity plans.

Devices based on the new FFSA 130nm node process will be able to deliver the performance and integration needed for multiple application sectors including industrial equipment, communication technology, OA equipment and more.

BY: ADARSH SONI

Plastic Logic achieves breakthrough in mass production of flexible plastic displays

Plastic Logic, a specialist in flexible plastic electrophoretic displays (EPD), has developeda new mass production-capable technology and manufacturing process in collaboration with the organic electronics specialists from BASF.

Demonstrating this breakthrough, Plastic Logic has produced prototypes of two new mass-producible 6" display products in 300dpi greyscale and 150dpi colour variants respectively.
This has been achieved through advances in Plastic Logic's transistor matrix backplane, and BASF's innovative organic semiconductor (OSC) materials. The optimised formulation and combination of semiconducting and dielectric materials results in greatly increased carrier mobility, necessary for high resolution display and is also contributing to the overall flexibility of the device which is the key feature of plastic EPDs. BASF's material set can be easily deployed in low-level clean room environments, a must for mass-production.
Commenting Tim Burne, CEO, Plastic Logic, said: "Flexible plastic EPDs offer many fantastic advantages over traditional glass displays – their power consumption, durability, daylight readability, etc. – but the pixel density is often perceived as a limitation. Plenty of R&D work has been spent on improving plastic EPD pixel density, culminating in some impressive prototypes. However, these prototypes have always been very difficult and/or very expensive to produce commercially. Our mass production- capable prototypes, developed in cooperation with BASF is breaking that mould!" Burne adds: "With this new capability and products we're breaking down barriers, creating competitive advantage and widening the potential appeal of ePaper technology."

As well as improving the definition of general imagery, Plastic Logic's true 300dpi display will also make written text much sharper – something particularly beneficial for symbol-based languages such as Chinese and Japanese where character details have previously been lost due to pixel density limitations. The process co-development with BASF, will also have a positive impact on other applications for Plastic Logic's backplane technology. It is being applied to several other highly flexible and durable electronic applications such as sensors and detectors.

BY: ADARSH SONI

New standards provide public assurance on safety, security and etiquette for use of drones

The first ever worldwide standards for the drone industry are being released by the International Standards Organisation (ISO).

After several years of global collaboration between standards institutions from across the world, the long-awaited drone standards have been developed.
These regulations are expected to trigger rapid acceleration of growth within the drone industry as organisations throughout the world are galvanised to adopt drone technology against a new background of reassurance on safety and security. The new standards will play an essential role in guiding how drones are used safely and effectively in a framework of regulatory compliance.
The ISO Draft International Standards for Drone Operations have been formally released today (21 November 2018) for public consultation, with drone professionals, academics, businesses and the general public being invited to submit comments by 21 Jan 2019. Final adoption of these Standards can be expected in the US, UK and worldwide next year.
The announcement is the first important step in the standardisation of the global drone industry,

encompassing applications for all environments - surface, underwater, air and space. Today's standards are particularly significant for the general public and Government, in that they address Operational Requirements of the more recognised and prevalent aerial drones, including protocols on safety, security and overall etiquette for the use of drones, which will shape regulation and legislation going forward. They are the first in a four part series for aerial drones, with the next three addressing General Specifications, Manufacturing Quality and Unmanned Traffic Management (UTM).

Air safety

A prime characteristic of the ISO Standards announced today, is their focus on air safety, which is at the forefront of public attention in connection with airports and other sensitive locations. The new standards act as a new etiquette for drones which promote and reinforce compliance regarding no-fly zones, local regulation, flight log protocols, maintenance, training and flight planning documentation. Social responsibility is also at the heart of the standards, strengthening the responsible use of a technology that aims to improve and not obstruct everyday life. The effectiveness of the standards in improving air safety will be further strengthened by the rapid development of geo-fencing and of counter-drone technology, providing frontline protection against 'rogue' drone use.

Privacy and data protection

The standards are also set to address public concerns surrounding privacy and data protection, demanding that operators must have appropriate systems to handle data alongside communications and control planning when flying. The hardware and software of all related operating equipment must also be kept up to date. Significantly, the fail-safe of human intervention is required for all drone flights, including autonomous operations, ensuring that drone operators are accountable.

BY: ADARSH SONI

Meet Raspberry Pi 3 Model A+, and Raspbian gets amedia player

Raspberry Pi has released a cut-down version of its high-end Pi 3 Model B+, and has added avideo player to its Raspbian Linux-based operating system.

On the processing side, the Raspberry Pi 3 Model A+, as it will be known, shares the same 1.4GHz quad core Arm Cortex-A53 as the top-end 3B+, but loses memory (512Mbyte instead of 1Gbyte), Ethernet and has only one USB port instead of four.

On the positive side, it is shorter (HAT-sized - 65 x 56mm, instead of 86 x 56mm), and costs less ($25 rather than $35) - and it keeps both Wi-Fi (2.4 and 5GHz) and Bluetooth.

Pi 3 Model B+

In a nod to potential professional users, production is guaranteed until at least January 2023 and the board board is FCC certified as a Wi-Fi and Bluetooth radio module to ease conformance testing when it is built into a product.

Raspberry Pi 3 Model A+ at a glance

- Broadcom BCM2837B0, Cortex-A53 (ARMv8) 64-bit SoC @ 1.4GHz
- 512MB LPDDR2 SDRAM (Pi 3 Model B+ has 1Gbyte)
- 2.4GHz and 5GHz IEEE 802.11.b/g/n/ac wireless LAN, Bluetooth 4.2/BLE
- Extended 40-pin GPIO header
- Full-size HDMI
- Single USB 2.0 ports (Pi 3 Model B+ has four USB 2.0 ports)
- CSI camera port for connecting a Raspberry Pi Camera Module
- DSI display port for connecting a Raspberry Pi Touch Display
- 4-pole stereo output and composite video port
- Micro SD port for loading your operating system and storing data
- 5V/2.5A DC power input (same as Pi 3 Model B+)
- No Ethernet (Pi 3 Model B+ has Gbit Ethernet (300Mbit/s max)
- 65 x 56mm (Pi 3 Model B+ is 86 x 56mm)

Rasbian, the Linux-based operating system for Raspberry Pi, now has a built-in media player. The team chose VLC, and customised it to work with the main processor's built-in hardware accelerators. In another software change, Python's integrated development environment is now Thonny 3.

Henceforth there will be two Raspbian download options:

Default will be a stripped-down version to reduce download time for users.

'Raspbian Full' adds LibreOffice, Scratch, SonicPi, Thonny and Mathematica amongst other packages - all of which are available to extend the smaller version.

By: DIVYANSH DHEER

OriginGPS demos GNSS and IoT modules

Origin GPS, the small-format GNSS module and cellular IoT specialist, is presenting live, customizable demos featuring its speed-to-market Origin IoT system, at Electronica.

The demos are from a range of vertical markets, such as asset tracking, agritech, smart cities, consumer IoT, wearables, healthcare, industrial IoT and homeland security, and were developed in-house in 6 weeks or less, including 3D printing of the casing. Many were developed in 3 weeks.

“In addition to the demos, we have set up a workshop for the Electronica show where every developer, idea person, CTO, product or project manager may communicate their project needs and watch while our IoT product manager builds a demo according to their requirements,” says OriginGDPs Robert van Tilburg.

OriginIoT systems use OriginGPS patented IoT technology to enable rapid development of connected products without writing additional embedded code, while configuring all data from the cloud of their choice.

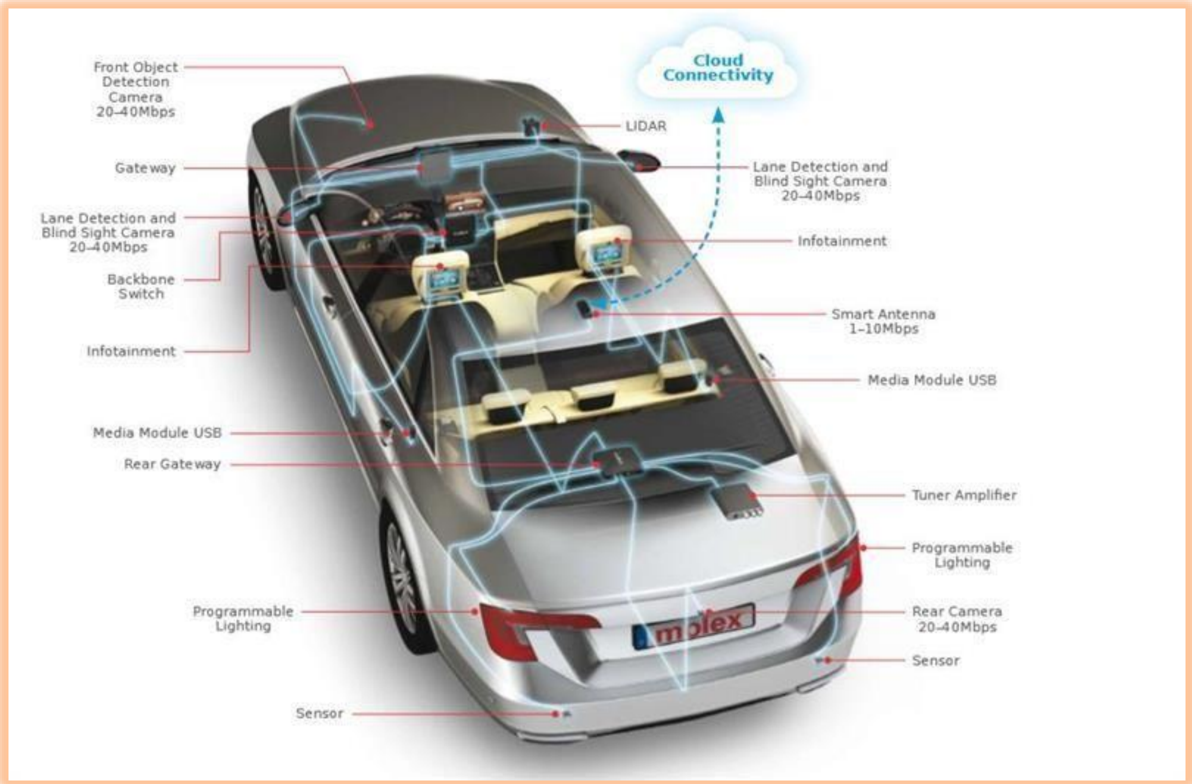
The demos show real-life examples of IoT applications from a variety of niche markets and include a high-value asset tracker, connected baseball, IoT RC car, smart lock, espresso machine monitor, crop irrigation monitor, fingerprint scanner, smart water meter, and ECG monitor.

Also shown is a GPS fish finder demo with an ultra-sensitive GPS module.

OriginGPS is presenting its IoT and GPS demos at Electronica Hall C3, Booth 107.

By: DIVYANSH DHEER

High-Speed Network Solutions for the Next Generation of Connected Vehicles



'In response to growing data acquisition and computational needs, in-vehicle networks are going to have to go through some radical changes.

The inclusion of ever greater numbers of on-board sensors, combined with uptake of a plethora of new data-intensive multimedia technologies, will set major challenges for the networking hardware incorporated into our cars. There will be implications in terms of supporting adequate bandwidth, as well as cabling weight, system complexity and overall cost.

Back in the 1980s, the average car had just a handful of electronic control units (ECUs), while today there can easily be well over a hundred present. The advent of advanced driver assistance systems (ADAS) and in-vehicle infotainment (IVI) have already led to a substantial ramp up in the data overheads of vehicle models. At first this was mainly seen in luxury models, but it has now proliferated further down into medium end and economy models too. Figure 1 gives an indication of the scope of functionality that is now being expected.

The migration towards semi-autonomous driving, with a much greater breadth of features consequently being added to the ADAS capabilities initially available, means that this is still only the beginning. A vast range of new functionalities will soon be required - in particular increasing use of cameras (featuring heightened pixel resolutions), plus other forms of imaging technology (such as LiDAR) and various traffic-sign recognition mechanisms. In addition to such developments, there are various wireless protocols which will be used for providing both vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) connectivity that also need to be taken into account. All of these will have heavy data demands onthe supporting communications network.

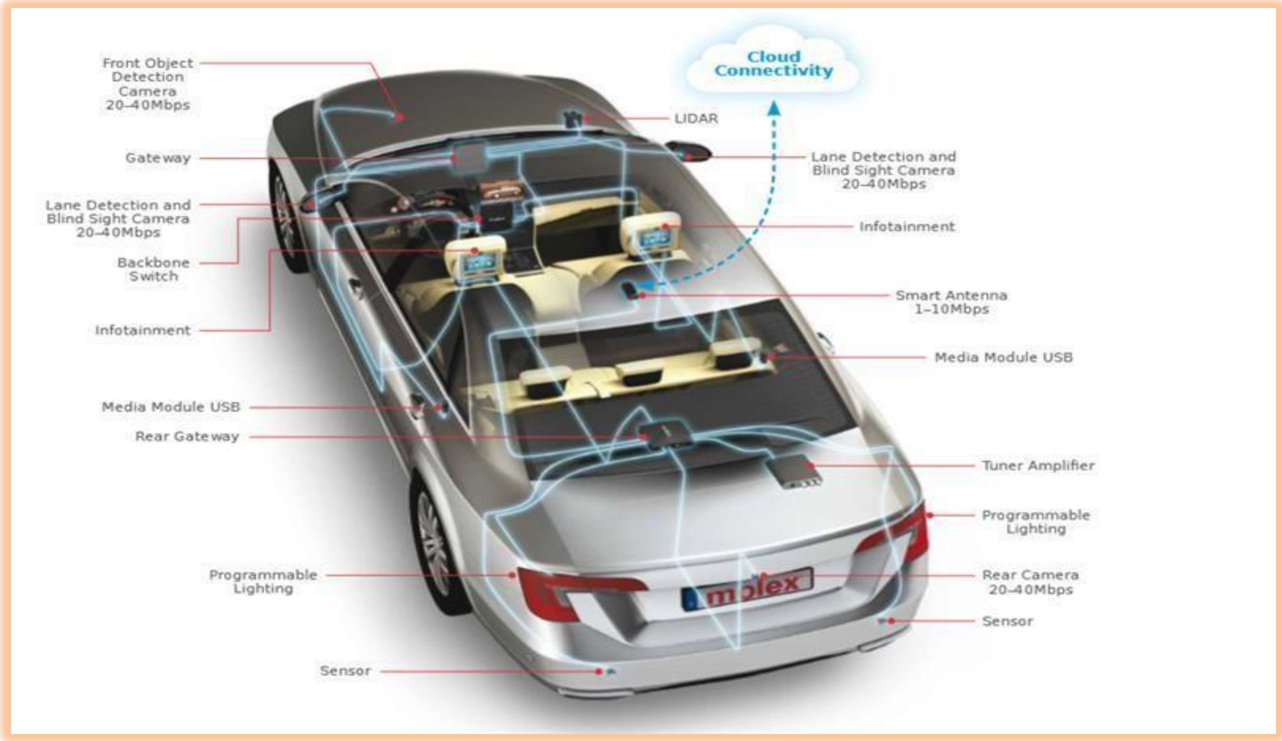


Figure 1: The complex nature of modern car design.

Many automotive systems are of course time-critical. The effects of improper timing can lead to potentially life-threatening situations. Vehicle stability control and collision avoidance are both classic examples of where the timeliness of information transmission is of prime importance to ensuring the safety of passengers and other road users.

It should also be noted that the cable harnessing currently constitutes the second heaviest part of a modern vehicle (after the chassis itself) and is among the most expensive too. Finding a way to implement weight and cost savings is therefore essential, as it will lead to a reduction in the vehicle's price tag and significant improvements its fuel economy being realized. This will thereby increase its appeal to customers and help it to comply with increasingly stringent environmental legislation. Automotive engineers recognize that there are huge operational advantages to be gained if data communication infrastructure can be made more streamlined. Ideally, this will be centered around a single all-encompassing protocol (although this will admittedly take time to actually happen). Because of the accelerated data rates that it can deliver and its deterministic operation, Ethernet is emerging as the main protocol for future in-vehicle networking activity.

The Rise of Automotive Ethernet

Ethernet is a communication bus that has been the stalwart of the information technology world for nearly 3 decades. In the last few years, for the reasons already described, it has started to witness strong design uptake within the global automobile industry too - with support of speeds up to 10Gbps (and provision to go higher than this in the future). It offers a lightweight, economical and scalable solution, through the use of single unshielded twisted-pair (UTP) cabling, which makes it very attractive from an automotive standpoint.

As well as operating at elevated speeds and respecting the cost, space and weight constraints already outlined, another of Ethernet's key attributes is the fact that it is a mature and stable technology. It benefits from the presence of a wide range of system and component suppliers with longstanding expertise built up by serving the enterprise data communication and factory automation business sectors. Numerous security features and authentication algorithms have been developed over the years for Ethernet because of its widespread use in data centre and industrial environments. This has given engineers something of a head start when it comes to meeting the exacting demands that relate to automotive networking.

In other respects, automotive Ethernet is quite distinct however. It has to deal with far harsher surroundings than conventional Ethernet implementations would - such as high temperature levels and exposure to electro-magnetic interference (EMI). In addition, it must also be robust enough to not be affected by the influence of vibration, shock or high degrees of humidity.

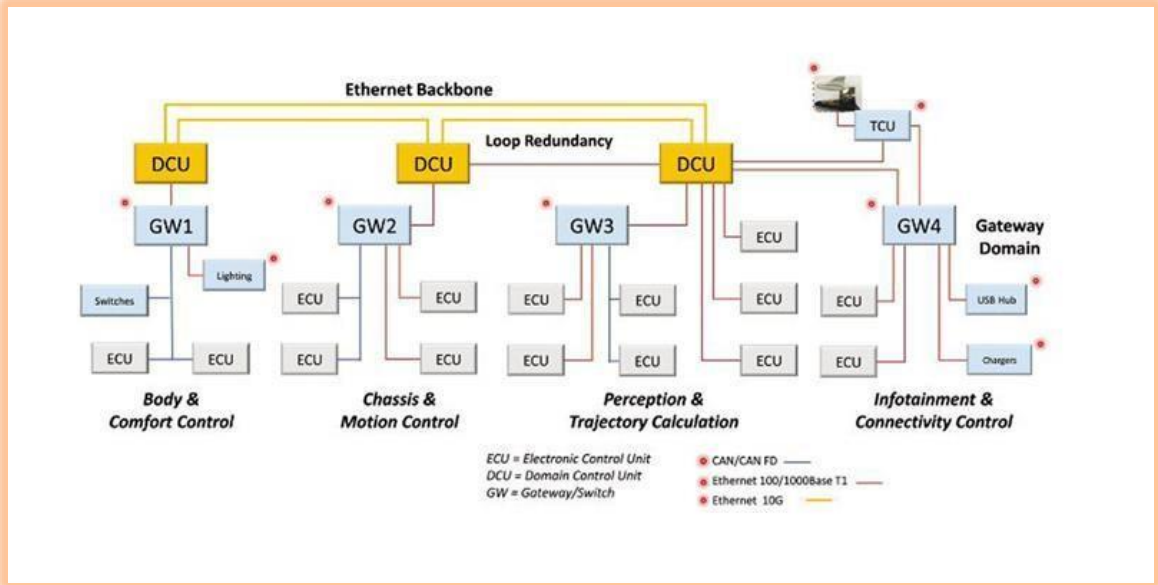


Figure 2: Ethernet-based architecture for automotive systems.

Any in-vehicle network system that is based on Ethernet technology will need to employ automotive-grade gateways with access to cloud connectivity platforms that integrate various hardware and software elements with legacy automotive protocols (such as LIN, CAN, FlexRay, LVDS, etc.). Molex has developed multi-Gigabit technologies in order to keep data flowing smoothly, safely and securely within vehicles and when interfacing with the cloud, thus avoiding the build up of network bottlenecks. 10Gbps Ethernet network systems have subsequently been demonstrated which can offer the end-to-end V2V/V2I connectivity needed to cope with huge quantities of captured sensor data while simultaneously delivering 4K video content to the vehicle's back seat displays. These systems are made up of Molex Ethernet gateways (with built-in legacy protocol support - such as CAN, LIN, LVDS, etc.) and media modules, along with IP67/IP69K-rated, EMI-protected connectors and cables.

As a result of increased vehicle connectivity, potential attack surfaces and entry points are going to be opened up. The security algorithms employed by the Molex system are managed by a Blackberry QNX suite. This offers a microkernel architecture with Certicom elliptic curve cryptographic (ECC) techniques for communications between on-board systems and connected cloud services. The sophisticated public-key service that is employed ensures that secure and authenticated communication is maintained between all the constituent ECUs and peripherals within the network, and thus safeguards against the potential threat of denial of service (DoS) attacks or another kind of security breach.

Conclusion

Current automotive network architectures simply cannot keep up with the huge demands that are now being placed upon them. Traditional protocols are already struggling to meet the bandwidth requirements of the multitude of sensors and sub-systems needed for ADAS and IVI. As we move to greater vehicle autonomy, their shortfalls will become even more apparent. Given that the camera, radar and LiDAR functions will generate much larger amounts of data, a considerable proportion of which will need to be responded to in real time, Ethernet is now recognized as the best way forward.
The development of autonomous driving clearly needs a new architecture to support rising bandwidth requirements caused by the ramp up in sensor resolutions and increased vehicle connectivity. The redundancy of all critical components and sub-systems will also be necessary to ensure the ongoing safety of vehicle occupants. The end-to-end 10Gbps Ethernet network platforms that Molex is now demonstrating are able to showcase the company's comprehensive product portfolio targeted directly at the new breed of connected cars which manufacturers are now looking to.

By: DIVYANSH DHEER

The future of farming is small robots

According to both the Government and farmers, the future of farming is one in which small robots will have a crucial role to play.

Both Government and the farming industry are looking to use robots to bring efficiencies and benefits to farms, as well as ending some of the more back-breaking jobs handled by farm employees.

A growing number of 'farmbots' are under development, which are capable of complex tasks that have not been possible with traditional large-scale agricultural machinery.

One company involved in developing agricultural robots is the Small Robot Company, a start-up focused on 'revolutionizing' the way in which robots and artificial intelligence (AI) are being deployed and used.

Set up by Ben Scott-Robinson, an experienced entrepreneur and technologist, and Sam Watson-Jones, a fourth-generation farmer, the company has been inspired by the work of Professor Simon Blackmore who lectures at the National Centre for Precision Farming at Harper Adams.

"Professor Blackmore has been heavily involved in developing the concept of 'precision farming', the aim of which is to raise productivity by using technology to influence the growth of individual plants," explains Joe Allnutt, head of the technical team at Small Robots.

Prof Blackmore has a vision in which the work done by tractors in fields will be replaced with a series of highly accurate, smart, lightweight robots that will be able to use, for example, optical recognition for harvesting, 'spot' application of herbicides and weeding techniques using low-energy lasers.

Despite considerable investment going into things like plant breeding, biotechnology and chemicals, little has been spent on new mechanization systems and, when it comes to agricultural robots, too many companies seem more interested in the technology rather than the solution.

"Small Robot is different. It came about from the specific needs of an individual farmer. One of our founders, Watson-Jones, is a farmer and, as a result, approached technology out of necessity. When he crunched the numbers, he realized that without a radically different approach to farming, the economics of arable farming weren't sustainable."

The costs for farmers are increasing and arable farmers are faced with shrinking margins.

Talking to farmers and technologists, Watson-Jones concluded that most farmers felt they were being poorly served by existing machinery manufacturers and new technology, whether in the form of hardware or software.

His research suggested that the farming community has a very mixed relationship with technology.

"Farmers have been sold a lot of technology in the past. Bigger machines covering larger areas, but now that scaling-up is no longer delivering the returns they need to remain economic. We found a community increasingly frustrated with the support manufacturers were offering them," suggests Allnutt.

By: BHAWNA SINGH

From the farming community

Smart Robot is of, and from, the farming community, says Allnutt.

"Our focus is on delivering precision farming which involves caring for the crop at a level of detail never previously possible. And, crucially, it will involve little input from the farmer.

"Precision farming and the use of robots to deliver that will mean crops will be healthier, the soil from which they are grown will be in a better condition, and yields will be significantly higher. Bills for fuel and chemicals will be reduced dramatically and farmers will no longer have to do basic farm work, rather they will be able to concentrate on getting the most out of their crops and farm."

The research carried out by Watson-Jones showed that there was a 'clear appetite' among farmers for working with early stage technology, but only if it could be accessed in a way that limited their exposure to the risk of functional failure and obsolescence.

"They're pragmatic and want technology that's good for their business and not a risk. What they don't want is a technological solution that's a burden, goes wrong, or causes problems when it's deployed.

"So, when you offer them a solution that combines robotics with AI, they don't want to have the responsibility for operating or maintaining it," Allnutt explains.

"To address that, we're offering Farming as a Service (FaaS) model. It links together a series of robots which collect accurate and up-to-date information about a crop, plant by plant.

"By 'digitising the field' the information generated can be automatically analysed using data and then used to give instructions on what should happen to each plant, and each patch of soil for other robots to carry out."

As for the robots, they are called Tom, Dick and Harry.

"Tom autonomously monitors the crop and soil, and keeps an eye on weeds. It monitors on a plant-by-plant basis, "Allnutt explains. "Dick and Harry then take care of all the feeding, seeding, and weeding. When one of these robots is needed, it turns up and does its job. When it is finished, we can take it away – they are easy to transport."

Because of the work they are assigned, the Dick and Harry robots need to be bigger.

"The tools they need and the way they interact with the ground mean that they need bigger platforms," Allnutt explains, "but they are smaller than the farm machinery used at present."

Tom can be left on a farm, where it can be charged and where the data generated can be collected and then analyzed.

Tom works alongside a comprehensive digital crop data model, in combination with WILMA, the company's AI driven operating system.

"WILMA, which is the brains of the system, is predominantly Cloud based. It provides the farmer with access, via a portal, to the data being generated by the robots, as well as the ability to interact with the robots and take actions. WILMA combines and draws on extensive farming knowledge, and applies it to the information gathered about the crop."

Tom, which is currently undergoing extensive field trials, knows exactly where plants are, whether they germinated, what they need, and identifies what fertilizer or chemical is required to support the health and growth of individual plants.

All three robots use GPS and sensors to give an accurate fix on the ground.

"The robot's autonomous navigation system does require an Internet connection, so if farmers can provide access to a 3G or 4G network, that's great. If not, we can use a local radio beacon. We don't need high bandwidth when pulling data off our robots and local decisions can be made on the device. The majority of image processing is done afterwards, having been retrieved from a USB drive."

Small Robots looks to use lots of 'small robots' working long hours in the field.

"They have less environmental impact, they're smaller and lighter, and don't damage the soil. By using multiple small machines, we can better manage their deployment and ensure that only those needed are deployed."

The use of robots in the field and the development of Tom, Dick and Harry have not been without their challenges, according to Allnutt.

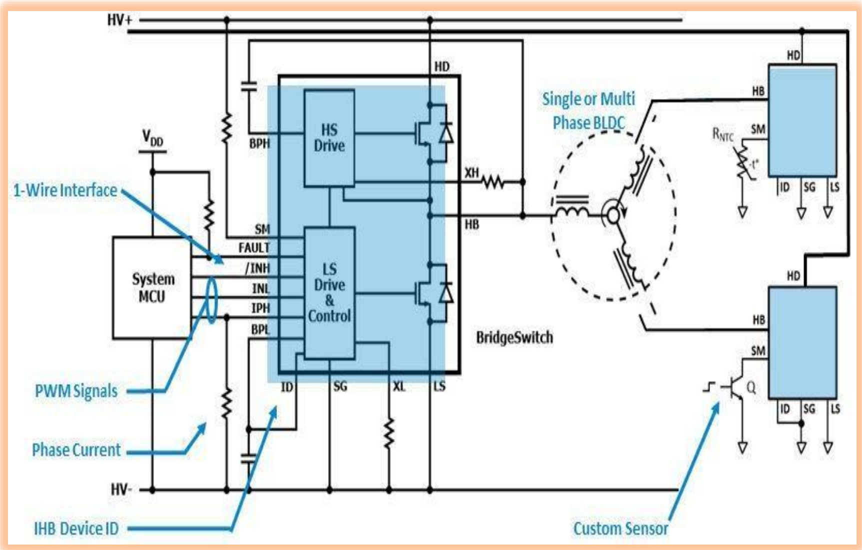
"While there were plenty 'run of the mill' problems to contend with, the breadth of the problems was a challenge - we're not just dealing with robotics, we're having to address AI, Cloud computing, practical engineering and data handling.

"The robotics industry, however, has a strong open source community to call on, which means that we've been able to leverage technology more easily."

BY: BHAWNA SINGH

E- PRODUCTS

Power Integrations makes 600V half-bridge motor driver



Power Integrations has introduced a 600V half-bridge motor driver with integrated high-side and low-side drive FredFets (fast recovery diode field effect transistors).

Branded Bridge Switch, the parts can be used in inverters of up to 98.5% conversion efficiency in brushless DC (BLDC) motor drives up to 300W.
Home-appliances such as refrigerator compressors and HVAC fans are the intended application, said the firm, as well as light commercial pumps, fans and blowers.
The pair of integrated 600V FredFets have fast soft-recovery body-diodes. "This drastically reduces losses during switching and reduces noise generation, which simplifies system level EMC," said the firm.
A single-wire status update interface is included, and enables communication between a microcontroller and up to three Bridge Switches for a three-phase drive.
Each Bridge Switch may be configured with different cycle-by-cycle high-side and low-side current limits to deal with open or shorted motor windings.

"Integrated loss-less current monitoring provides hardware-based motor fault protection, which simplifies the task of providing protection under motor-fault conditions to satisfy IEC60335-1 and IEC60730-1 requirements," said Power integrations.

Switching is up to 20kHz and a small signal output that provides real-time reporting of transistor drain current, which is an analogue of the positive motor winding current.

Safety features include two-level device over-temperature detection, and both protection and reporting of DC bus over-voltage and DC bus under-voltage.

Devices are compatible with control algorithms including: field oriented control (FOC), sinusoidal, and trapezoidal modes with sensor and sensor- – see reference designs DER-654, DER-653 and DER-749.

It comes in a InSOP-24C surface-mount package with creepage distances >3.2mm. PCB heat sinking is via two exposed pads.

Samples are available now.

BY: BHAWNA SINGH

Integrated inertial sensors improve pedestrian tracking

Bosch Sensortec has launched a Position Tracking Smart Sensor that utilizes integrated inertial sensors to improve GPS location tracking.

When used with a GPS or GNSS module, the BHI160BP enables users to take full advantage of pedestrian position tracking with up to 80% saving in system power consumption compared with a typical GNSS-only solution, without compromising on accuracy.
This new position tracking approach is set to enable a new class of compact devices with smaller batteries.

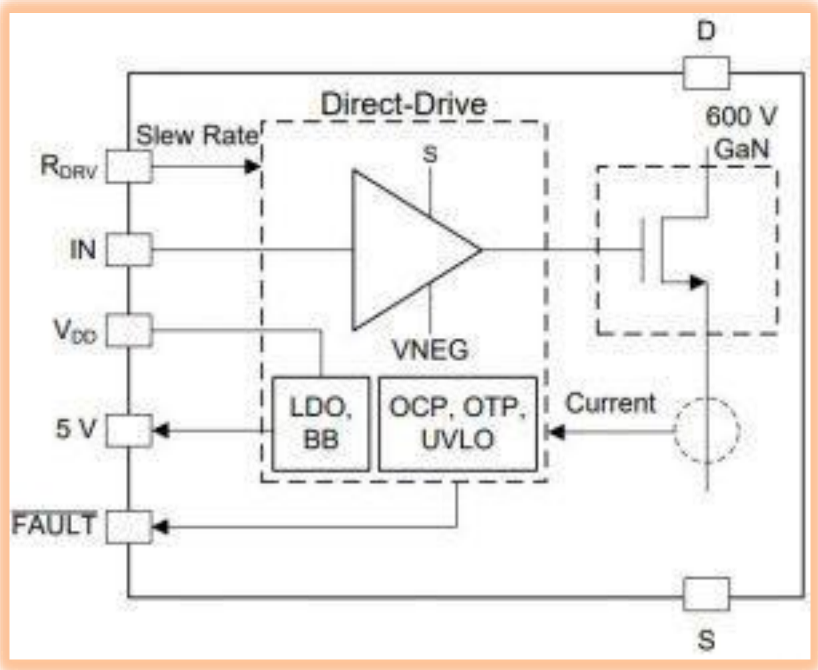
The device tracks a person's position by intelligently applying an inertial sensor based algorithm for Pedestrian Dead Reckoning (PDR).
To maintain accuracy, it calculates the user's relative location based on data collected from the inertial sensors and then re-calibrates itself every few minutes to obtain the absolute position provided by the GNSS/GPS module.
This means that the GNSS/GPS module can be kept in sleep mode for most of the time, which drastically reduces a device's power consumption and extends its operating time.
The position tracking capability provided by the BHI160BP also means that a device can maintain solid accuracy even when the GNSS signal is blocked or weak, e.g. near tall buildings or indoors. This ensures accurate pedestrian navigation at all times, even in shielded indoor areas such as subways.
While the current configuration is optimized for use with GNSS receivers (such as GPS), the BHI160BP can also support most of the common global localization technologies.
As well as improving localization, the BHI160BP can also serve to handle gesture recognition and 3D orientation, with 3D calculations performed by the sensor itself rather than by an application processor.
The device draws 1.3 mA in active operation mode and integrates the Fuser Core (MCU) and a 6-axis Inertial Measurement Unit (IMU).
Additionally, the Position Tracking Smart Sensor offers a variety of customized virtual sensors, such as a calibrated accelerometer, orientation and wake up gesture, within a single device.
Furthermore, the BHI160BP can be extended by connecting additional physical sensors, such as a magnetometer, over a secondary interface.

The BHI160BP comes in 3 x 3 x 0.95 mm^3 LGA-package and is pin-to-pin compatible with the BHI160.

BY: GAURAV KUMAR

600V GaN fets have built-in drivers for easy use from 100W to 10kW

Texas Instruments has announced ready-to-use 600V gallium nitride (GaN) power transistors with built-in driver stages.



The 50 and 70mΩ devices are intended for applications from 100W up to 10kW.
While GaN transistor have the potential to increase the efficiency and shrink the size of power supplies, their high speed and somewhat fussy characteristics mean that they need careful driving if clean operation is to be obtained.

"TI's family of GaN FET devices provides a smart alternative to traditional cascade and stand-alone GaN FETs by integrating unique functional and protection features to simplify design, enable greater system reliability and optimise the performance of high-voltage power supplies," said the firm. "With integrated <100ns current limiting and over-temperature detection, the devices protect against unintended shoot-through events and prevent thermal runaway, while system interface signals enable a self-monitoring capability."

The devices are LMG3410R050, LMG3410R070 (latched over-current protection) and LMG3411R070 (cycle-by-cycle over-current). According to the firm, each device is capable 1MHz switching and slewing up to 100V/ns.
Slew-rate is user adjustable from that 100V/ns down to 25V/ns, according to component distributor

Mouser, which is stocking the device. It added that propagation delay is 20ns and 150V/ns slew rate immunity is provided, as well as over-voltage lockout protection on all supply rails.
Packaging is 8 x 8mm QFN, and there are evaluation modules: LMG3410EVM-018, LMG3410-HB-EVM and LMG3411EVM-029.

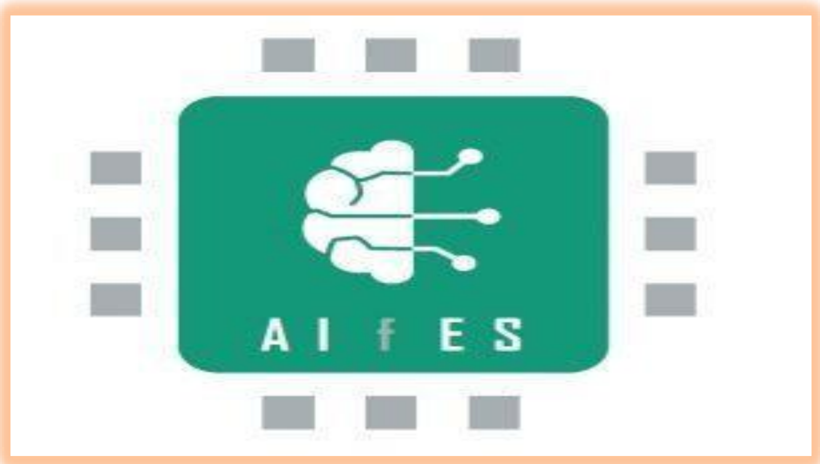
Applications are foreseen in ac-dc power supplies, robotics, renewable energy, grid infrastructure, telecoms and personal electronics.
At Electronica, TI will have a 10kW cloud-enabled grid link demonstration in Hall C4 (Booth 131).

Developed with Siemens, it uses a LMG3410R050, is 99% efficient, and offers "up to 30% reduction in power component size compared to a traditional silicon design", claimed TI.

BY: GAURAV KUMAR

Platform-independent neural net for self-learning microcontrollers processing sensor data

German research organisation Fraunhofer IMS has developed a platform-independentl feed- forward artificial neural network, written in C.



"By using standard libraries based on the GNU Compiler Collection (GCC) and a source code reduced to a minimum, even integration including learning algorithms on a microcontroller is possible," said the organisation. "The artificial neural network is superficially not focused towards big-data processing, but should offer the possibility of implementing self-learning microelectronics that do not require a connection to a cloud or more powerful computers."
Applications are expected around sensors and condition monitoring for Industry 4.0 applications, as well as more general IoT purposes.

The network is modular to suit it to different tasks - parameters from the normalisation of sensor data, the structure of network, the most appropriate activation function, and the learning algorithm are configurable.
As a learning algorithm, an online multi-option back-propagation algorithm has been implemented, and an evolutionary learning strategy is under development.
"Programming with the GCC allows porting to almost all platforms," said the Fraunhofer. "This enables fully self-contained integration including a learning algorithm on an embedded system. The classic variant, in which the learning phase is performed on a more efficient unit, is possible as well. The advantage in this case is that the same source code can be used for different platforms - it only has to be compiled for the respective platform."
When using Windows, for example, the source code is compiled as a dynamic link library (DLL) allowing it to be integrate into tools like Labview, Matlab or Visual Studio.
For initial development, a PC is suggested for fast calculation. Once the configuration is correct it can be implemented on the embedded system.
Versions of the neutral network have already been demonstrated on Raspberry Pi with Raspbian and an ATMega32U4 - that latter was the subject of 'Smart self-sufficient wireless current sensor', a paper presented at the European Conference on Smart Objects, Systems and Technologies. Another implementation will be presented in Fraunhofer IMS' stand at SPS IPC Drives 2018 in Nuremberg.

BY: GAURAV KUMAR

Li-Ion battery ICs in WLCSP

Ricoh has launched single cell Li-Ion battery protection ICs in a Wafer Level Chip Scaled Package (WLCSP).

They are especially designed for use in rechargeable smart watches, hearing aid instruments, fitness trackers, wireless earbuds and other small portable devices.

Wearable devices incorporate a small rechargeable Li-Ion battery with a capacity in the range from

50 to 100 mAh and have new challenging requirements for its internal components, like an ultra-small package size, low current consumption in On and Standby mode but also sophisticated safety circuits. The R5441 and R5443 fully comply with these requirements. The R5443 is the smallest version and has a board space area of 1.05 mm2 and a thickness of 0.36 mm, it is considered as one of the smallest single cell Li-Ion protection ICs available today. It is around 53% smaller compared to the popular protection ICs in a 1.4 x 1.4mm DFN package.

Significant detail for the R5441 / R5443 is that the current consumption of the ICs is equal or lower than most other available solutions on the market and contributes reducing the self-discharge rate of the battery pack. In normal operation, the current consumption is respectively 3.5 μA and 2.5 μA.

As soon the battery voltage decreases below the over-discharge voltage threshold, the product enters a standby mode and disables several internal circuits to lower the current consumption to 0.04 μA, ensuring further discharge of the battery is kept to a minimum. Li-Ion batteries are safe in general when used according to the specifications but can become a potential hazard in case of an internal or mechanical malfunction.

Overheating, emitting fumes or even worse can be the result; therefore, the protection IC monitors the charge and discharge process and interrupts as soon the process is at risk of going beyond the safe operation range of the battery cell. The following processes are monitored:

- Over-charge voltage: Battery voltage exceeds the charge threshold for a certain period.
- Over-discharge voltage: Battery voltage exceeds the discharge threshold for a certain period.
- Over-discharge current: Battery current exceeds the discharge threshold for a certain period.
- Over-charge current: Battery current exceeds the charge threshold for a certain period.
- Short current: Battery current exceeds the short discharge threshold for a certain period.

Both the R5441 and R5443 have an improved over-charge voltage threshold accuracy of ±10 mV versus ±30 mV for regular products. The idea behind this feature is to increase the charge voltage whilst maintaining the same safety level. As a result, the battery voltage will increase with 40 mV and extends the battery lifetime, which is important for applications with a small battery capacity. Traditionally one makes use of the MOSFET on-resistance in order to measure the current flow of the battery pack. However, the on-resistance level is most inaccurate as it depends on various criteria such as ambient temperature, gate voltage and MOSFET type.

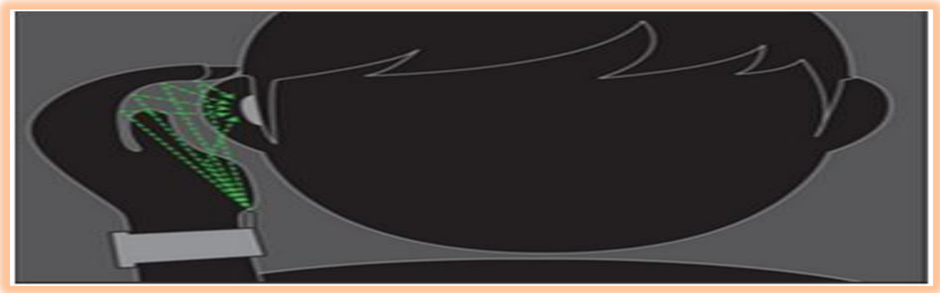
In order to achieve a higher standard of current sensing, theR5441 and R5443 make use of an external current sense resistor.

Such resistor can be ordered with your preferred resistance value and accuracy level. The great advantage of using an external resistor is that the over-current threshold margin improves significantly in comparison to the MOSFET current sense method. The R5441 has an additional circuit to monitor the temperature of the battery pack by connecting an external NTC resistor to the Tin pin. In case of an over-temperature event, the charging or discharging process is interrupted. It is possible to set different temperature threshold settings for the over-charge and over-discharge threshold.

BY: HAMZA SHAMIM

WEB PULSE

H-Band - Where Your Hand Becomes the Phone



H-Band is a luxury leather watch strap which is compatible with most of the smart watches. It has a built-in Bluetooth audio fob which compensates the need of a phone during a call. This compact Bluetooth headset is embedded in the watch strap and is ultra slim and easily removable from the strap, thereby making it both audio on the wrist and headset on the wrist. . It is a product that is designed and made in India for global market.

The private calling feature-

The evolution of mobile phones has been advancing to such an extent to putting call features in the smart watches. This helps the scenarios when the phone is lost and solves some of the usual mobile phone issues, but none of them provides call handling in a private mode. H-Band completes Apple or other Smart watch by adding the private call feature which they lack. H-Band uses the patented hands on talk technology to provide private calling experience. The user would just have to flip open fob and raise his hand to ear to take the phone call without reaching for his or her phone. The user's hand becomes the phone answering device. H-Band provides phone call convenience in two ways that are the hands-on mode and the headset mode.

Hands on and headset mode

When user gets a phone call, he flips open the fob on this watch, holds the hand to ear and starts taking on the call. There is no need to reach for his phone and rush to pick it up; his call is always on his wrist. This is called hands-on mode and is the ideal solution for a quick phone call. If he must take a longer call, he can pull out the fob from the watch strap, insert in the ear and use the device like a normal Bluetooth headset, his Bluetooth headset is always on his wrist watch. This is called the headset mode.

The mechanism

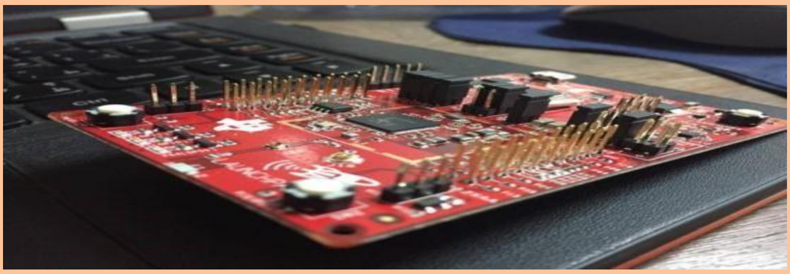
The directional audio is fired from the bottom of the wrist at higher volume and pressures with sufficient back-volume towards to the palm of the user. When the palm is held in cupped position to ear, the palm acts like a parabolic reflector and redirects the sound to the ear. H-Band uses a micro speaker with suitably designed acoustics to provide partial directivity to sound fired towards the user's ear. Although the typical audio is Omni-directional, by firing at close range with proper openings, partial directivity can be given to the audio. H-Band uses normal micro speakers with suitably designed back volume, front volume and opening to provide partial directivity. This method thereby gives partial to full private sound.

Bluetooth and the microphone

The electronics and the technology used are similar to the basic Bluetooth headset. To meet the higher volumes required for hands
on private calling, the amplification circuits of a basic headset is modified. A couple of hardware used to make this concept possible, the first essential one being the Bluetooth communication module to have two-way audio to the phone. A directional speaker is used to fire the audio to the user's hand and an omnidirectional microphone placed beside the speaker reads the user's speech. There are noise cancellation algorithms are included to cancel the wind and other surrounding noise. The watch strap is made of high quality Italian leather with quick snap magnetic buckle. The buckle also provides docking for the Bluetooth audio fob.

By: HAMZA SHAMIM

Electro saver - Save the Unknown Loss



India vows to be the third largest producer of electricity by producing around 1,200 billion units of electricity every year, yet this amount fails to serve around 400 million Indians among the total population of 1.3 billion. The main cause for this acute shortage is the wastage of the power for which the reasons are plenty, but that includes carelessness and busy schedule to be one of the main ones. Of course, we do not switch off the air conditioner or lights when we move from a room to another for a short while, we love to keep our laptops and phones plugs on even after charging, we do not realize but all these small acts count to almost 25% of your total electricity used. In the recent past, Internet of Things emerged as a saver for this power wastage issue by means of home automation systems. These intelligent devices automate your home by sensing your presence and understanding your requirements and acting accordingly. Taking this concept a step ahead, Electro saver was designed.

The rescue hand

The main motto of Electro saver, as the name suggests is to save electricity. This is done by installing an Electro saver board behind the switches in the switch board, which automatically makes your existing electrical system smart. As easy as it sounds, this happens without changing the infrastructure of the existing house. Once the hardware is installed the user can use Electro saver app and have detailed access of their power consumption habits, which was never available to them before. When a user turns on the "Electro Saver" mode, all the switches that have the product installed will turn off, except for the refrigerator. With this, the user wouldn't have to think about the appliances that they thought were not turned off when they left the house, be it a hair dryer, water heater, mobile charger, TV, fan, bathroom light, etc.

The process in the backend

The current and voltage are sensed by considering the phases and therefore the power consumed is obtained. The board is designed in such a way that it calculates the voltage drop and this measure can be integrated to obtain the power consumed per second, per hour and also the real-time power. There are a couple of signal processing algorithms to understand the prevalent harmonics in the system. The communication is based on Hart topology and the IC used in the system is CC3200, which is used in trans receiver mode to configure the Wi-Fi in different modes as required to communicate data.

To allow encrypted data exchange, Advanced Encryption Standard (AES) engine is enabled and the key will be updated as coordinated by the server at intervals. The data received from these devices will help the users understand the power consumption of the house as well as the quality of power in the house. These features can be extended for automation and fault detection in the industrial applications.

How do the switches talk?

The board is placed behind the switchboard connecting the switches. Wi-Fi mesh network used here enables the intercommunication between the switches. All the switches are monitored and controlled by the main switch that is connected to the web server. These switches communicate with each other by sending signals to each other over the internet, thus making the whole network smarter. In other words, it is the appliances that talk to each by means of the switches. Passing on the message occurs when a switch is not in range. For example, when switch one wants to communicate with switch three, but switch three is out of range, then switch one sends the message to the nearest switch to switch three and that switch communicates the message to switch three.

Multitasking chip

The multitasking of the CC3200 is managed by the Free RTOS and the gateway to the system is given a Global System for Mobile communication (GSM) module as a backup. This GSM module allows connection to the internet in situations where the Wi-Fi password is reset or there is any issue with the Wi-Fi connection. The designed board can be available in various dimensions, the basic one being 6X5cm and a height of 2 cm. This can operate 4 switches and there can be smaller or larger boards designed depending on the number of switches needed to be operated.

BY: HAMZA SHAMIM

Why is system-in-package (SIP) becoming a moreviable option for system design engineers?

The system-on-chip (SoC) is arguably the biggest misnomer of today's electronics industry. The core integrated circuit may well have onboard much of the logic circuitry needed to support the needs of the final system. But to get that SoC to function, the manufacturer of the final system needs to surround it with a host of support components, from power management to passives.

Gene Frantz, chief technology officer at Octavo Systems, says: "If you look at the world of integrated circuits and the impact that Moores law has had, it has had the significant positive of driving cost downand performance up."

But scaling, Frantz points out, is not the same for all types of device. "The semiconductor process development necessary to maintain progress in the microprocessor world is different to what it has been in the memory world or power management world."

To a limited extent, semiconductor suppliers could integrate power management, analogue, processing and memory as long as the combined device could justify the various compromises required. And many devices exist that make those trade-offs.

Steve Drebohl, vice president of microcontrollers and technology development at Microchip, points to parts in the company's range that are primarily analogue but with an embedded 8bit microcontroller to perform control functions. In those devices, the emphasis is on the analogue capability, not the processing power or density. "There can be less than 15 percent digital content on an 8bit microcontroller now. It's more about the peripherals."

As the requirements on the various parts of the system become tougher to meet, monolithic integration quickly begins to break down. PCB integration has provided the route to bringing together disparate devices together and continues to meet many designers' needs, whether through custom design or off-the-shelf single-board computers (SBCs). But size and performance issues are now making the PCB option more difficult to handle, even for those with the ability to turn around custom layouts.

Tyson Tuttle, CEO of Silicon Labs, points to the many competing requirements of IoT devices. They need low-energy operation, access to wireless networks, enough memory to support regular updates and the processing power to perform local signal processing.

"For the IoT, it's all got to go into a single device," he says, to meet size constraints. "But wireless stuffis hard: there are a lot of issues around the antenna design. The RAM doesn't necessarily go with the flash memory. And you need energy management that is more than just an LDO [low dropout regulator].It's got to be able to power different sections up and down quickly and retain state when powered down." In higher-end systems, issues arise with the requirements of advanced processors. The number of signal, power and ground pins needed to feed a dense die become difficult to handle without specialised production methods. Frantz says: "You can get so small with an integrated circuit that it's no longer useful to put it on a PCB: the ball pitch is too tight."

Another issue with multicore processors made on advanced semiconductor technologies is one of power management. These devices now call for multiple power rails that can adjust the voltage dynamically to the pipeline's workload. The activity is now so tightly coupled to the processor design that Apple wound up buying the operation that makes the power-management integrated circuits (PMICs) for its own SoCs from supplier Dialog Semiconductor. But, because it is extremely difficult to put the equivalent of efficient PMICs onto the processor, they have to remain separate.

System-in-package

This is where the system-in-package (SIP) is becoming an increasingly viable option for system designers: as a packaged device that sits between a monolithic integrated circuit and a module assembled on the fibreglass substrate of a PCB.

"As you integrate more into the SIP, you can take advantage of the fact that you don't have to have a layout expert or a power-management expert. It makes it a whole lot easier to do your thing," Frantz argues. He points to the SIPs Octavo has put together that bring together multicore processors, memory and I/O and which, if they were assembled on a regular PCB, would demand a relatively sophisticated stack-up. "With the SIP, if you are clever with your board layout, do it with four instead of six layers and have no components on the back side."

A number of suppliers are building SIPs into their portfolio of off-the-shelf modules, often sitting alongside regular PCB-based designs. Among others, Microchip and Silicon Labs have introduced SIP-based variants into their families of modules. "We are steadily offering more SIP products," says Drebohl.

Tuttle adds: "Microcontroller plus wireless is where we see a lot of volume coming in. When you integrate the wireless into the microcontroller [package] you get not just a BOM saving but also benefits in terms of lower power if you do this well."

In the near term, processor-based SIP suppliers aim to offer a variety of readymade parts. They can take advantage of the lower cost of customisation by mixing and matching parts inside the package.

This is viable for runs of tens or hundreds of thousands compared to the millions often needed to justify producing variants of parts based on monolithic integration with advanced processes. In the long term, Frantz believes that it is possible to change working practices to get to the point where customers can order one-offs without it incurring a premium in terms of manufacturing cost.

Unusual starting point

Octavo is attempting to carve out a niche from an unusual starting point. It does not make its own silicon, although Frantz and others in the company are alumni of chipmaker Texas Instruments. Octavo's work involves convincing the outsourced semiconductor assembly and test providers (OSATs) to work with devices from a variety of manufacturers rather than working with an existing chipmaker. It can be difficult for third parties to get the required test data needed to take bare chips and place them on the extremely finely toleranced substrates used for SIP.

One approach might be to work closely with a primary supplier but it's almost impossible to find a single semiconductor vendor who can provide everything. "There are a couple of companies that come close and Texas Instruments happens to be one of them. But we've got to go to a separate vendor for memory," Frantz says.

The answer does not lie in new technology, Frantz argues. "We have to work this a different way. Not change the process but change the management of those processes."

Within a SIP, the individual chips are carefully aligned and bonded on a silicon or high-quality substrate using much smaller solder bumps than those needed for the bottom of the package. The electrical environment can be very tightly controlled, which reduces the need for the full testing that conventional packaged chips go through. Frantz says when Octavo started putting together SIPs the first wafer the company obtained did not have a map detailing the positions of good and bad die. Only post-packaged tests would reveal them. “But there were no failures,” Frantz claims.

The tests run by a chip supplier need to cover operation over a wide range of voltage and frequencies that different customers will want to employ. With control over the PMIC and electrical environment, Octavo could operate all the devices well within their comfort zone. So, marginal devices that might fail because they could not guarantee operation across the full datasheet specification become usable in the more tightly constrained environment of the SIP.

Over time, Frantz expects suppliers like Octavo to gain more benefits from the techniques used by OSATs and the learning curve-driven nature of semiconductor processing. “Because of the high-volume nature of semiconductor lines, you can gain a lot of advantages in yield, testability and reliability for the final packaged device that you may not find on the lower-volume assembly lines. We believe we are going to get a lot of side benefits.”

BY: HAMZA SHAMIM

Autonomous driving

According to Arm, without safety there is no future for autonomous driving.

The barriers to self-driving cars are significant, from costs needing to come down to regulations needing to be clarified around certain self-driving car features. Talk of millions of self-driving cars on the roads within the next few years seems remote, depending on the definition you use, but Lexus, BMW, Apple and Google are all developing, or rumoured to be, automated technology.

Fully-driverless cars are still some way off but partially automated technology has been with us for many years.

While there is significant investment being made in driverless technology, manufacturers need to tackle a range of ethical and technical issues - chief among them safety.

“Safety is the highest priority for car makers we talk with, for both the obvious technology factors associated with autonomous systems controlling all aspects of driving, but also to ensure that human passengers can trust their automated driver. If consumers don’t trust the autonomous systems in their cars are safe, then mass market acceptance of this technology will be slow to happen,” says Lakshmi Mandyam, VP Automotive, Embedded & Automotive Line of Business, Arm.

Mandycam makes the point that development costs are increasing exponentially as, “the software complexity and volume for autonomous systems is rising dramatically. To put this into some perspective, it’s predicted that a Level 5 vehicle will require a billion lines of code. Compare that to a Boeing 787 Dreamliner, which ‘only’ requires 14 million lines of code.”

When it comes to the safety of autonomous vehicles, however, most of the accidents involving them have been due to human error, so the bigger issue for the industry is what should autonomous vehicles be doing to reduce accidents?

“We are in constant discussion with car makers and our extended automotive ecosystem, which comprises of the top 15 automotive chip makers that license Arm’s IP, about progressing toward fully-autonomous driving,” says Mandyam. “While we certainly talk about how we can address their performance, power and security requirements, most of the discussions we have tend to focus on safety.”

According to Mandyam, autonomous driving is expected to eliminate human error.

“Ninety four per cent of all accidents are a result of driver error and so we expect fully-autonomous driving to significantly reduce the number of accidents and fatalities.”

Autonomous vehicles will be dependent on sensors to detect what is happening around them and today engineers are defining the right mix of sensors that need to be implemented - but they need to also take into account the costs and computing power required, both are limiting factors.

The other key to vehicle safety will be how the software handles unexpected situations. All self-driving vehicles will have to make many hundreds of decisions every second in order to make adjustments necessary to keep the driver safe.

Vehicles equipped with high levels of autonomy are expected to require 100 times more compute performance by 2024 than is currently the case.

Car makers need to ensure that when it comes to the deployment of autonomous vehicles they are able to provide a safe and efficient compute platform.

“That is why safety cannot be an afterthought or be relegated when it comes to developing autonomous-class SoCs and systems,” says Mandyam.

“Unfortunately, the path to level 5 autonomy has tended to be paved with prototypes, often based on power-hungry, expensive data centre CPUs which lack even the most basic functional safety features.”

Prioritising safety

Arm has sought to prioritise safety over many years and that is why, according to Mandyam, the company’s IP is now in 65 per cent of the silicon used in ADAS applications.

“Our automotive ecosystem has access to the industry’s broadest array of functional safety IP with the latest ISO certifications,” she explains.

In fact, Arm’s Safety Ready programme encompasses not only existing safe but new and future products which have been through a rigorous functional safety process, including systematic flows and development in support of ISO 26262 and IEC 61508 standards.

Safety Ready is a one-stop shop for software, tools, components, certifications and standards which is intended to simplify and reduce the cost of integrating functional safety. By taking advantage of the programme’s offerings, partners and car makers are assured that their SoCs and systems will incorporate the very highest levels of functional safety that are necessary for autonomous applications, says Mandyam.

Ensuring that the company’s silicon partners are better supported, Arm is evolving its Safety Ready program and is looking to centralise the company’s on-going investment in safety, enabling its silicon partners and the entire automotive supply chain to accelerate individual timelines for bringing safer products to market much faster.

While Arm is looking to integrate the latest certifications and standards in a significant move designed to help the development of autonomous vehicles, it has made available what it says is the first autonomous-class processor with integrated safety, the Cortex-A76AE.

“This processor has been designed for automotive and includes Split-Lock technology, which is available for the first time in application processors and cold be a game changer,” says Mandyam.

The Cortex-A76AE is a CPU that has been uniquely designed for automotive and optimised for 7nm process nodes.

The AE stands for “Automotive Enhanced” and any Arm IP with the AE designator will include specific features addressing the requirements of in-vehicle processing.

“A high level of processing capability is required for autonomous driving, with inherent safety as standard,” explains Mandyam, “and the Cortex-A76AE delivers both. It’s the industry’s first high-performance application processor with Split-Lock capability, combining the processing performance required for autonomous applications and high-integrity safety.”

While Split-Lock is certainly not new to the industry, Arm is the first to introduce it to a processor that has been designed specifically for high performance automotive applications such as autonomous drive.

“Split-Lock delivers the flexibility that’s not currently available in previous lock-step CPU implementations; it means that CPU clusters in an a SoC can be configured either in ‘split mode’ for high performance, where two (or four) independent CPUs in the cluster that can be used for diverse tasks and applications or r ‘lock mode’ where CPUs are in lock-step, creating one (or two) pairs of locked CPUs in a cluster, for higher safety integrity applications,” Mandyam explains.

The CPU clusters can also be configured to operate in a mix of either mode, post silicon production.

Automotive makers can also design their autonomous systems to require watts and not the kilowatts required for today’s prototypes due to the power-efficient computing available in the Cortex-A76AE.

“Lower power also enables a more energy-efficient use of vehicle battery power combined with thermal efficiency to aid the packaging of compute capability while extending the range of vehicles for a lower total cost of driving,” according to Mandyam.

Arm is also introducing new Automotive Enhanced system IP for designing a comprehensive autonomous-class SoC.

The new Core Link GIC-600AE, CoreLink MMU-600AE and Core Link CMN-600AE will provide critical elements such as high-performance interrupt management, extended virtualization and memory management, and connectivity to multiple CPU clusters to scale performance in safe multicore systems.

“These products have been designed to enable high-performance systems, targeting ASIL-B to ASIL-D safety integrity, and support the Split-Lock and systematic capabilities for functional safety designed into the Cortex-A76AE.”

The Cortex-A76AE is the first in a roadmap of “Automotive Enhanced” processors which will deliver the fullest functional safety capable IP portfolio in the industry. The new roadmap includes “Helios-AE” and “Hercules-AE”, all optimised for 7nm. More details will be available, as these products are launched.

According to Mandyam, “Arm and its developer ecosystem are simplifying and reducing costs acrossall layers of automotive software stacks and providing tools on a common architecture.

“Our aim has to be to ensure that safety is not an afterthought and to help car makers earn the consumer trust required for the mass deployment of safe and fully-autonomous vehicles.”

BY: HARSHIT VERMA

Data will drive the smart transport revolution

Quality data, in real-time, will be critical to making the concept of Mobility as a Service (MaaS) a reality.

When it comes to encouraging more people to use public transport what can be done? Recent figures from Transport for London (TfL) suggest that people are actually making fewer tube, bus and train trips while traffic volumes are increasing, if only marginally, so what needs to happen to drive down this seemingly growing dependency on private vehicles?

According to Johan Herrlin, CEO, Ito World, the key to encouraging this is to provide good and accurate data, so that people will start to put their trust in alternative modes of transport.

"There's a mobility revolution taking place in in urban transportation which is being driven by the availability of smart phones," explains Herrlin. "Smart phones have changed the way in which people engage with one another" and has underpinned a shift from privately owned assets to shared forms of transportation, we're seeing a move away from traditional forms to demand responsive forms of transportation."

Ito World works with a variety of agencies and operators to align their real-time data to timetables, with the aim of delivering a single, integrated real-time service for cities and regions.

Go to a bus stop or a train station and there are running boards and countdown clocks that make a journey easier and apps have been developed that complement the physical infrastructure of the transport network.

"But while these services work, they could be vastly improved," according to Herrlin. "Transport operators need to ensure that as more data becomes available it is used to provide more accurate and relevant information to the end user.

"However, in cities like London, where specific rules dictate who can work and operate, there is a degree of complexity that is challenging to operators looking to access data to the benefit of the customer. With multiple operators customers need different apps to access different services. How many are required to provide an accurate service?"

In London, for example, there are at least four different apps for bike-sharing services simply to find out where these bikes are located.

When travellers know they can trust what their app is telling them they will be far more likely to take in the information they're being provided with, according to Herrlin, and then they will be able to decide what mode of transport is best suited to them - whether a traditional mode of public transport, such as a bus or tram, or an on-demand service.

"People need seamless journey planning and in a fragmented market that's hard to achieve. Transport is undergoing rapid change and fragmentation is a consequence. As more players move in to the market there will be consolidation, we're seeing that already with the likes of Uber moving into bike sharing."

It is critical that high-quality information is delivered in real-time and made available for all parts of a journey. That information informs decision-making but, as we increase access to data and more data is generated, its quality needs to be increased.

"This is crucial," says Herrlin, "not only does it benefit the commuter but it will make it easier to distribute public services more efficiently."

Mobility as a Service (MaaS) brings multiple modes of transportation together through a service app interface, removing all the points of friction from booking to payments, and ultimately reducing or eliminating the need for private ownership of cars entirely.

"Ito World has partnered with many cities and transport providers and by making more data available, people have been able to make better choices in how they move around their city. It is up to transport and city authorities, to share that data and put measures in place to guide the behaviour of individuals to drive wider societal goals," Herrlin explains.

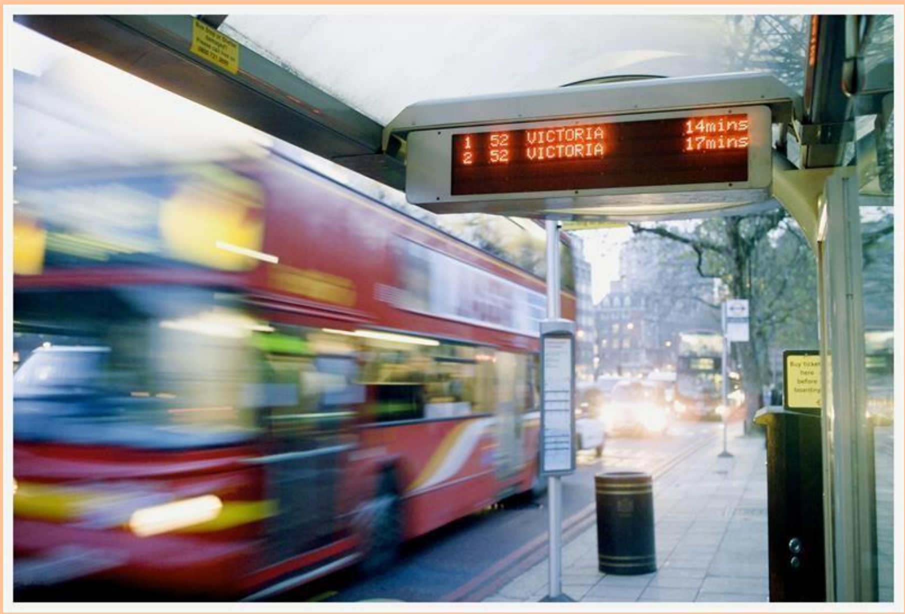
Ito World takes operational data from transport operators and city authorities and turns it into human navigable data, but not only that it enhances the quality of that information to ensure people have access to seamless experiences when travelling across cities.

"This involves us taking data that is operational in nature and designed to manage fleets of vehicles and delivering detail enriched data. We do this for the likes of Apple and Google, taking public transport data and ensuring that it is usable. To ensure the quality of the data we provide we make upwards of 130,000 changes to scheduled data as it passes through our systems.

"Those changes include updating the physical location of assets or compensating for the fact that no data is available in a specific area. Likewise, when maintenance work is taking place and disruption is expected, we take that into account to ensure that the apps we support don't end up sending people to those locations. Essentially, we are taking scheduled data and overlaying it with real time data."

Data from multiple sources

"Open data is a great source but insufficient for our needs, so we have access to proprietary data sets, although certain standards and regulations can cause problems."



According to Herrlin, the company doesn't just work with the likes of Apple or Google, but is increasingly working with the authorities themselves.

"The aim being to get the data right in the first place."

Tech-driven disruptors such as Uber and Lyft offer a much more demand-responsive, flexible service for customers and, as such, traditional public sector operators are now having to adapt and look to data for some of the answers they need in order to keep up, and compete with, these new players.

Arriva and Go Ahead, two of the UK's largest national bus operators, have invested in making their real-time bus data more accessible to potential consumers by opening it up to one of the largest journey

planning apps in the world, Google Maps.
“That has meant they have been able to significantly increase their reach and ridership,” according to Herrlin.

The UK government has also recently launched a consultation to legally require operators to share their data so passengers can get real-time information on routes, timetables and fares to ensure that passengers have the information they need, regardless of their location and the company running the service.

“More open data is, without a doubt, key to making MaaS happen,” says Herrlin.
However, both governments and organisations have struggled when it comes to deciding which types of data are appropriate to share with the public and what risks might be associated with opening up access to data. There are some very real issues at play, relating to costs, privacy and security.
MaaS providers need transit accurate data that reflects the real-life customer experience as closely as possible, as well as to ensure the efficient operation of public services.

By working with data experts, such as Ito World, who can leverage open and proprietary data to improve and augment real-time data, authorities and operators will be able to deliver a single integrated real-time feed for entire cities across the globe.

“Our platform has been evolving over many years. We are able to aggregate and ingest the data supplied by our clients, remodel it to cover all forms of transportation, and then put it into a representation of our own design. Not many companies can do that.
“In a complex world schedules, or the intended outcomes or what is planned, do not always survive coming up against the real world. We look to reconcile the two to the benefit of providers and consumers.”

When asked about the accuracy of their data Herrlin says that they provide each user with a scorecard against which they measure the improvement, accuracy and consistency of the data supplied.
“Working with authorities we regularly outperformed their own engines, not only because of the sophistication of the algorithms underpinning our applications but because we are able to look at the entire system.

“People are willing to embrace alternative modes of transport,” says Herrlin,” so now it’s up to transport agencies and authorities to meet their expectations and deliver the accurate information needed for effective journey planning.”

Keeping track of railway track maintenance

The Konux 'KORA' is a wireless sensor that sits on the railway track collecting data on acceleration and vibration to help provide a more efficient train service

With more trains running on the UK's railways, effective track maintenance has become essential.

With the number of trains using the rail network doubling in the last 10 years and the number of passengers anticipated to rise by a further 40% by 2040, managing increased capacity is its biggest challenge, according to Network Rail.

The rail network in the UK was not designed to cope with this level of demand, which is causing track lifetime to tumble and raise the importance of effective maintenance.
As technology has developed, rail maintenance has become easier to perform and manage, allowing a transition from traditional, labour-intensive, manual upkeep to much faster, safer, more accurate and efficient solutions.

Sensors, for example, are being used to monitor areas of the track such as point machines and track circuits, and their use is growing, according to Network Rail.
The sensors are fixed 'in location' and comprise of Edge processing which is transmitted via GSN with o2 sim cards to Network Rail's SCADA system, Wonderware.
"This allows us to monitor the condition of the track and prioritise where we need to focus our efforts," Tim Flower, Head of Maintenance at Network Rail, says.

"Rail maintenance is about understanding that failure is going to happen," he adds. "We use the data gathered by technology, like sensors, to trend failure, so accurate predictions can be made. That way we can identify what's going to fail, when it's going to fail, and hopefully, why it's going to fail."

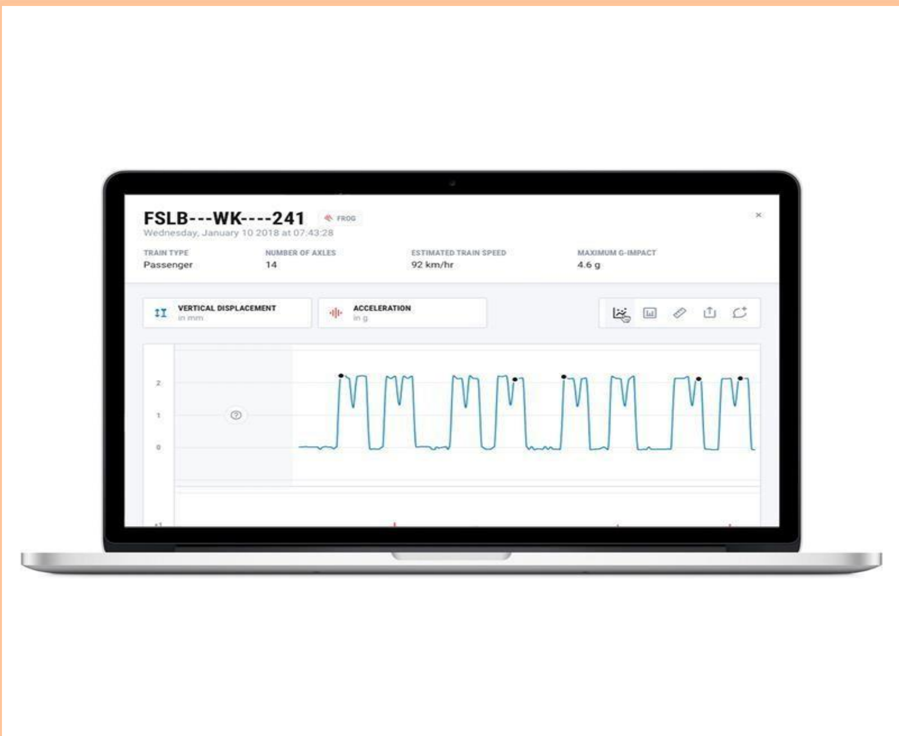
To support rail operators, Konux, a German sensor company, has developed an intelligent, IoT sensor solution system called KORA that monitors and analyses switch health.
The switch or 'point', according to its CEO, Andreas Kunze, is "one of the most crucial elements of the

track", and accounts for 20% of train delays in Europe.
As one of the only movable sections of the track, the switch can be a fragile component, but is integral to the railway line as this is where the tracks connect.
"If it fails, it causes a chain reaction, with multiple parts of the track becoming unusable," Kunze explains.

On some of Network Rail's busiest lines, over 100 trains will pass over just one set of points in a single day, so ensuring these remain well maintained is essential to the train service.
KORA monitors the condition of rail assets, wirelessly measuring elements like acceleration, vibration and communication via GSM. The raw data is pre-processed in the sensor, selecting only the necessary data needed to allow for more efficient transmission. This data is then sent into the Konux backend system and fused with the data Konux has received from its customers. For example, information about weather, schedules, and the point machines (the closing and opening of the track).

Artificial intelligence is then used to identify and assess issues in this data - with the system comparing the 'digital footprint' of the healthy assets with the results of continuous monitoring, flagging up any anomalies.

"This is how we help train companies move away from the very costly inspection protocols that were previously needed," Kunze contends.
He points to the importance of a wireless system. "In rail, you don't want cable everywhere - every metre costs thousands. But, going cable-free means battery management is vital.



"The development of both low powered systems and communications have really helped rail maintenance to progress," he continues.
"Advancements in communication technology enables us to send more data, more quickly. While the control we have over power, means we can limit the maintenance of the sensor device itself. Rail companies don't want to have to go out every month to replace parts."
According to Kunze, the materials used were another crucial consideration. "It has to be robust, not just from a mounting perspective, but the whole device has to be able to cope with shock and adverse weather conditions."

Whilst developing its piezoelectric MEMS hybrid sensors, Kunze explains that Konux dedicated three years to proving the product could survive in the harsh environment.

Harsh conditions

A harsh environment, however, isn't always a problem. In fact, Network Rail actually uses these conditions to its advantage. Its sensor system, supplied by Perpetuum, harvests energy from the movement of the train to power itself.

Along with the 60thousand sensors it has deployed, Network Rail also uses machine vision systems and ultra-sonic testing to inspect track damage – a task that is difficult, time-consuming and unsafe for human workers.

Network Rail has a series of trains that measure different types of equipment to understand how they're performing against baseline parameters. This technology is used to measure the track geometry and plain line pattern using linescan, 3D and thermal imaging cameras to scan the track as it passes below the 'measurement train'.

These cameras record raw images at up to 76kHz, allowing images to be captured at speeds up to 125mph. The cameras store the information on the device and this is then downloaded to an on-board computer and decoded by a machine vision software, synchronised with real-time positioning system and geometry data, and analysed by an on-train inspector. Reports are dispatched to the ground teams, helping them locate any faults.

Ultra-sonic testing is used to identify cracks naked to the human eye, which often occur in the railheads, due to stress concentrations at these geometrical discontinuities.

One team of researchers from the University of California is developing a solution to overcome the issue of 'air gaps' currently experienced in traditional probing methods.

According to Assistant Professor Sheng Xu of the University of California, due to the curved nature of railheads, it's difficult to get solid interfacial contact and therefore, good coupling with irregular nonplanar surfaces. This can lead to large acoustic energy reflections and wave distortions, resulting in unreliable test results. Defects, like detail fracture and transverse fissure, can't be tested from thetop of the railhead, and require the operator to hold the transducer on the side of the track. Accordingto Assist Prof. Sheng, this is time-consuming, labour intensive and can result in inaccurate measurements.

Assist Prof. Sheng and his team are developing a low-profile membrane-based stretchable ultrasonic probe which exploits an array of thin 1-3 piezoelectric composites as transducers, multi-layered serpentine metal traces as electrical interconnects, and low-modulus elastomer membranes as encapsulation materials.

"The soft elastomer encapsulation materials allow the device to intimately conform on the side of the railhead, providing excellent acoustic coupling. The 'island-bridge' layout offers biaxial stretchability of more than 50% with minimal impact on the transducer performance so that the device can work on nonplanar complex surfaces railway tracks," Hongjie Hu, part of the California team, explains.

Despite being "close to commercialisation", the team say they need to first improve the spatial resolution to enhance the accessibility and image accuracy.

According to Flower, the most valuable transformation electronics has enabled is the real-time monitoring of asset performance. "We can monitor not just on a day-to-day basis," he says, "but by the hour and minute. This has reduced the number of point failures by around 30% and track circuit failures by 25%."

Flower believes the rail infrastructure will one day move completely away from manual maintenance to an "almost factory-type inspection system". He points to big plans with Network Rail and technology, including automated tunnel inspection and pantograph monitoring.
The challenge, he says, is finding a balance between accuracy, repeatability, information and cost. "We need to improve maintenance without providing the person who has to deal with it, huge amounts of data to analyse," he concludes.
And with Network Rail planning to introduce 7,000 new carriages on the railway network by 2021 and 6,400 new train services, let's hope the balance is found quickly and these big plans keep on track.

BY: HARSHIT VERMA

How can sensors contribute towards more efficientfarming?

The MTi-7 has three sensors each with three axes - a, y and z. Together, this can be usedto calculate the roll, pitch and yaw

There are currently 7.6billion people on the planet. By 2050 this is estimated to rise by a further 2bn.

Resources are already being stretched and farming processes are struggling to cope with not just increased demand, but the pressures of climate change which is impacting on production methods. Now, farmers are having to find innovative ways to cope, while addressing environmental concerns.
Much of this innovation is being driven by the Internet of Things (IoT), which has given rise to 'smart farming' or 'agri-tech' and the introduction of intelligent robots to help address these challenges.
The Small Robot Company, an agri-tech start-up, is among those looking to inspire traditional farmers

to adopt new farming practices. According to the company, 95% of energy is used to plough – a technique that is only needed due to heavy machinery crushing soil. The Small Robot Company is building intelligent machines that it says will seed and look after each plant in a crop, feeding and spraying accurately and only when necessary. This precision farming will limit wastage, providing individual plants with specific care and support. In theory, this should reduce chemical usage while increasing yield and farmers' revenues.

At the heart of precision farming are sensors, an element that the likes of Xsens Technologies – an innovator in 3D motion tracking technology – provide for smart farming vehicles, among other autonomous-based applications such as drones.

The company recently launched the MTi-7 – a small, low-power sensor with an external Global Navigation Satellite System (GNSS) receiver. The GNSS helps provide an accurate, real-time position, velocity and orientation data stream, but as Arnout Koelewijn, Key Account Manager EMEA – Inertial Sensor Modules at Xsens, explains: "It won't tell you where that object is looking or the angle" – an essential piece of

information needed for autonomous farming vehicles due to the environments they encounter, that is, the uneven and soft texture of a field.

"If you have a tractor on a tilted plane of land, it will be positioned at an angle," Koelewijn says. "The GNSS receiver will be at the top of the vehicle, which could be positioned at, say, 5 degrees. The top of the GNSS receiver where the antenna is located, is not in the same position as the wheels due to this angle. Therefore, additional sensors are required to compensate for the position error you get from the elevations and contours that an autonomous tractor would meet on a field."

To overcome this challenge the MTi-7 features a gyroscope, an accelerometer and a magnetometer – which according to Koelewijn are key elements to a successful farming navigational system.

"The gyroscope senses rotation; the accelerometer senses acceleration; and the magnetometer, magnetic field," he explains. "These readings enable us to calculate the roll, pitch and yaw angles."

Imagine an aeroplane with three lines running through its body, meeting at right angles at the plane's centre of gravity. Rotation around the front-to-back axis is the roll, side-to-side is the pitch, and the vertical axis is known as the yaw. These allow for precise navigation in tricky environments – the challenge is calculating them in such an environment.

For Koelewijn accuracy is critical as the demand for real-time data processing increases.

"Low latency is vital," he clarifies, "if you have a drone in the air and there is a gust of wind, you need it to compensate for that immediately. The longer it takes for the sensor to calculate and provide feedback, the longer it will take for the autopilot or stabilisation mechanism to compensate for that." A delay means the data will be inaccurate, and for autonomous vehicles this could result in an accident.

Smart farming challenge

Koelewijn compares smart farming to the challenges associated with driverless cars. "Generally, a road is fixed and flat, but a field can be muddy and slippery. It's a very uncontrolled environment. Imagine a tractor pulling a heavy load across the field, it may be 'dancing' left and right because of the unevennessand softness of the ground. GNSS alone wouldn't be able to identify the direction precisely. That's why the gyroscope, accelerometer and magnetometer are so vital."

To achieve the low latency Koelewijn speaks of, the MTi-7 module uses a high update frequency and "fuses" the sensor readings with the GNSS receiver. The high update frequencies are enabled by the accelerometer, which, according to Koelewijn, can achieve results much quicker than a GNSS receiver, and allow for more samples per second.

"We sample each sensor internally, getting a rate of 3 turns per sample, so essentially, we're collecting 9 samples at 1,000Hz per second, together with an orientation estimate" Koelewijn says.

But low latency does come with a price – it's more power hungry. "We are limited by the individual sensors elements available to us," Koelewijn contends. "If we implemented a low power mode within our technology, we would have to decrease the same frequency, meaning the accuracy of the sensor would also lower."

Alongside the sensors, there is also a small microprocessor which gathers all the data. "Each of the sensors have 3 axes – a, y and z," Koelewijn says, "so internally it actually acts as 3 gyroscopes, 3 magnetometers, 3 accelerometers."

The sensors output a voltage depending on the acceleration or magnetic field or rotation. These voltages are then converted into a digital signal and processed by Xsens' algorithms.

"Anything which is happening physically is obviously not digital," he says, "what Xsens does, is provide data which can be processed by a computer that says: 'this vehicle moved from location a to b via this route, and during that travel it had this orientation, at this time'. In a sense, we digitise motion."

According to Koelewijn the sensors must be “adaptable” to work in accordance with the user’s needs. “The MTi-7 has a lot of settings which can be modified. An engineer can configure it as they would like it to act.”

Despite the well-publicised issues concerning Uber, Koelewijn believes the autonomous market will only get bigger due to its convenience. “It means you’ll need less people to operate your business, and it will cheaper in the long run. It can make farming much more efficient. One farmer can deploy 10 autonomous tractors at a single time, instead of having to do it all themselves.

“The population is growing and there are more mouths to feed, so food production needs to become cheaper and one way to achieve this is through autonomous farms.”

The sensor technology Xsens is deploying is just one part of this solution. To be fully autonomous requires many different types of components working together with the sensors, for example a steering angle.

Consequently, Xsens is working towards accepting new data sources and Koelewijn believes camera integration is the next step.

“Cameras are typically measuring the same things as an inertial measurement uni (IMU), just in a different way. The inertial sensor measures the rate of turns and the camera measures the pixels - they’re moving in the same direction, so they could assist each other.

“There are all sorts of technology that could be interesting to combine and fuse in our algorithms to make everything easier and work together. A camera is a logical step because it’s being implemented in most devices already.”

Whatever the next stage, accuracy will be the key to feeding an over-populated world, and sensors will have a big role in delivering that.

BY: KARAN GUPTA

Implantable interface innovation

Credit: The lightwriter / Alamy Stock Photo

The NESD programme is looking to develop technology that can interface with single neurons in the brain.

In April 2013, when he was US president, Barack Obama launched a research initiative aimed at revolutionising our understanding of the human brain. With a budget of around $100million, the BRAIN – Brain Research through Advancing Innovative Neurotechnologies - Initiative looked to develop and apply technologies that explore how the brain records, processes, uses, stores and retrieves information.

As part of this so called Grand Challenge, the US Defense Advanced Research Projects Agency (DARPA) launched a set of programmes designed to understand the dynamic functions of the brain and to demonstrate breakthrough applications based on these insights.

One element is the Neural Engineering System Design (NESD) programme, announced in January 2016. This aims to develop an implantable neural interface capable of providing 'unprecedented' signal resolution and data-transfer bandwidth between the brain and the digital world and to do this in a biocompatible device which has a volume no larger than 1cm3.

One goal of the NESD programme is to develop a 'deep understanding' of how the brain processes hearing, speech and vision simultaneously with individual neuron-level precision and at a scale sufficient to represent detailed imagery and sound.

DARPA's Dr Al Emondi, currently NESD program manager, explained in more detail. "To succeed, NESD requires integrated breakthroughs across disciplines including neuroscience, low-power electronics, photonics, medical device packaging and manufacturing, systems engineering and clinical testing.

"In addition to hardware, NESD performer teams are developing advanced mathematical and neuro-computation techniques to first transcode high-definition sensory information between electronic and cortical neuron representations and then compress and represent those data with minimal loss of fidelity and functionality."

From the applications, DARPA awarded contracts to five research organisations and one company (see box).

In DARPA's opinion, NESD involves significant technical challenges, but it believes the teams it has

selected not only have feasible plans to deliver coordinated breakthroughs across a range of disciplines, but also to integrate those efforts into end-to-end systems.
But this isn't a new area of investigation for DARPA. "DARPA has been a pioneer in brain-machine interface technology since the 1970s," said Justin Sanchez, director of DARPA's Biological Technologies Office. "We've laid the groundwork for a future in which advanced brain interface technologies will transform how people live and work and DARPA will continue to operate at the forward edge of this space."

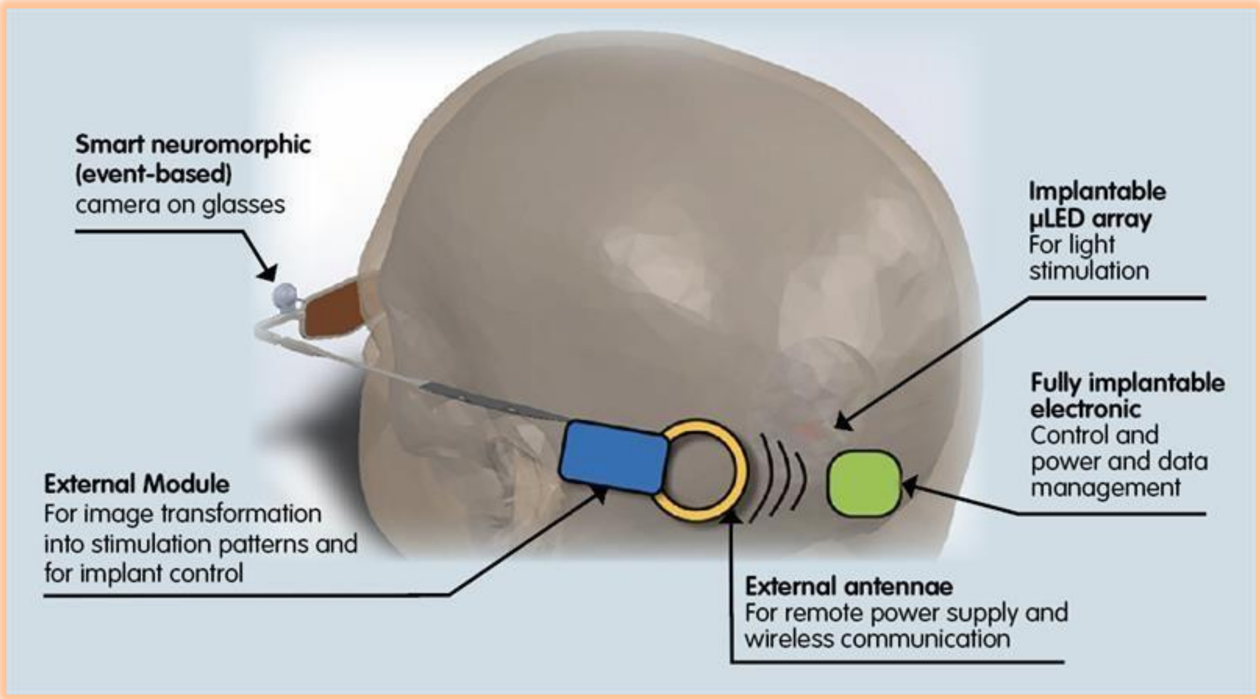
Taking advantage of optogenetics
One of the six projects selected by DARPA is led by the Fondation Voir et Entendre (FVE), a Paris based organisation looking to use technology to overcome sensory handicaps linked to vision and hearing.
Its project - called CorticalSight - will use optogenetics techniques to enable better vision for those with poor sight. And there are many who could benefit. Estimates suggest there are almost 300million people suffering from visual impairment. Of these, 40m are blind and 246m have low vision. There are many reasons why people's sight is impaired. For some, it's a birth defect, but for others, it's something that develops as they age - 65% of the visually impaired are believed to be 50 or older.
CorticalSight will develop a system that allows communication between a camera-based, high-definition artificial retina worn over the eyes and neurons in the visual cortex. Targeted at those who have lost the eye to brain connection, the project will entail developing a system of implanted electronics andoptical technology.
Recognising the complexity of what it's looking to achieve, CorticalSight has brought in expertise from Paris Vision Institute, Chronocam, Gensight, Stanford University, Inscopix and the Friedrich Miescher Institute. French research centre CEA-Leti will also make a significant contribution, leading the development of the active implantable device that will interface with the visual cortex.
Fabien Sauter-Starace is leading Leti's part of the project. He said: "The idea is to develop a brain-computer interface that can restore vision by stimulation of the visual cortex. "Accomplishing that needs a lot of knowledge."

In FVE's model, information would be captured by a camera, then sent to an external device worn on the head which would transform the images into stimulation patterns. These would then be transmitted wirelessly to a high density microLED stimulator array for the visual cortex.

Optogenetics in this instance will attempt to modify neurons in the visual cortex so they convert specific wavelengths of light into electrical activity. The light captured by a camera will be computed to integrate information processing from the eye to the brain. Images will then be transmitted to the implanted LED stimulator, which then activates neurons.

Sauter-Starace said there are two main options. "You can either stimulate the cortex via electronics, but the more difficult approach is to use optogenetics. Neurons are sensitive to different wavelengths; it's about balancing chemical and optical resolutions."

The 'camera' in the FVE project is likely to be a prosthetic eye created by French company Chronocam, recently renamed as Prophesee. Sauter-Starace said: "This gives a very good and accurate image. Whatwe're doing at Leti is working on a system to transfer that image to the brain."



In doing so, Leti is building upon existing technology. "There are some 'technological bricks' which we can use" Sauter-Starace observed. "Others will be generated or updated; for example, to increase thedata rate."

At the other end of the system, there will be the need for something which can drive a dedicated system of micro optical sources. "We're using technology originally developed for micro displays," Sauter-Starace continued. "We're adapting this to the project's needs by changing the wavelengths of light generated and reducing power consumption. And we also face thermal constraints."

Neurograins

The team led by Brown University aims to create what it calls a 'cortical intranet'. This will comprise tens of thousands of wireless micro-devices - each about the size of a grain of salt - that can be implanted onto or into the cerebral cortex. These implants - neurograins - will operate independentlyand be capable of interfacing with the brain at the single neuron level. The neurograins will be controlled wirelessly by an electronic patch worn on or beneath the skin.

"What we're developing is essentially a micro-scale wireless network in the brain, enabling us to communicate directly with neurons on a scale that hasn't previously been possible," said Professor Arto Nurmikko.

The project will provide many technical challenges, according to Prof Nurmikko. "We need to make the neurograins small enough to be minimally invasive, but with extraordinary technical sophistication." The solution, he believes, will require state-of-the-art microscale semiconductor technology. "Additionally, we have the challenge of developing the wireless external hub that can process the signals generated by large populations of spatially distributed neurograins at the same time."
While the best brain-computer interfaces of the moment work with around 100 neurons, the team wants to start at 1000 neurons and build to 100,000.

"When you increase the number of neurons tenfold, you increase the amount of data you need to manage by much more than that because the brain operates through nested and interconnected circuits," Prof Nurmikko said. "So this becomes an enormous big data problem for which we'll need to develop new computational neuroscience tools."

Silicon nanoelectronics

At Columbia University, Professor Ken Shepard is looking to develop an implanted brain-interface device that could transform the lives of the hearing and visually impaired.

"If we are successful," he said, "the tiny size and massive scale of this device could provide the opportunity for transformational interfaces to the brain, including direct interfaces to the visual cortex that would allow patients who have lost their sight to discriminate complex patterns at unprecedented resolutions."

In Prof Shepard's opinion, the DARPA project is working to aggressive timescales. "We think the only way to achieve this is to use an all-electrical approach that involves a massive surface-recording array with more than 1million electrodes fabricated as a monolithic device on a single CMOS integrated circuit. We are working with TSMC as our foundry partner."

The implanted chips will be conformable, very light and flexible enough to move with the tissue. "By using state-of-the-art silicon nanoelectronics and applying it in unusual ways, we are hoping to have big impact on brain-computer interfaces," Prof Shepard said.

Cortical modem

Researchers in the UC Berkeley team call the device they are developing a cortical modem – a way of 'reading' from and 'writing' to the brain.

"The ability to talk to the brain has the incredible potential to help compensate for neurological damage caused by degenerative diseases or injury," said Professor Ehud Isacoff. "By encoding perceptions intothe human cortex, you could allow the blind to see or the paralysed to feel touch."

Reading from and writing to neurons will require a two tiered device, according to the Berkeley team. Its reading device will be a miniaturised microscope mounted on a small window in the skull. Capable of seeing up to 1million neurons at a time, the microscope will be based on the 'light field camera', which captures light through an array of lenses and reconstructs images computationally.

For the writing component, the team is looking to project light patterns onto neurons using 3D holograms. This, it contends, will stimulate groups of neurons in a way that reflects normal brain activity.

"We're not just measuring from a combination of neurons of many, many different types singing different songs," Prof Isacoff said. "We plan to focus on one subset of neurons that performs a certain kind of function in a certain layer spread out over a large part of the cortex. Reading activity from a larger area of the brain allows us to capture a larger fraction of the visual or tactile field."

Challenging timeframe

The NESD programme is expected to last four years, with three phases. "The six projects are competing with each other," Sauter-Starace concluded. "We're in the first phase of NESD and it maybe that teams will be merged in the future. But, for the moment, we're in a parallel competition and it's a challenging timeframe."

BY: KARAN GUPTA

Combining the physical with the virtual

HoloMeeting can bring remote teams together, simplifying collaboration and communication

Mixed reality is starting to have an impact on the commercial world bringing the physical and virtual together.

Let's start with the basics. When we talk about mixed reality what do we mean and how should it be defined? According to Matthew Bumford, Head of Sales and Marketing at Kazendi, a HoloLens Development Studio, mixed reality (MR) is, "a technology that looks to blend the physical world with the virtual and providethe user with a better understanding of the real world."

Recognising real objects and then allowing holograms to physically and accurately interact with them, Kazendi is among a number of businesses that are using MR to work with clients to create and deliver mixed reality projects.

"Initially, we focused on the Amazon Echo and Google Glass," explains Bumford, "applying these technologies to the needs of commercial clients and providing prototypes. With the arrival of Microsoft's HoloLens in 2016 we saw a shift in focus and started to explore the commercial application of the Hololens."

HoloLens is a virtual reality (VR) headset with transparent lenses and Kazendi is using it to create solutions that look to address real-world corporate problems.

Comparing mixed reality (MR) to VR and augmented reality (AR) Bumford suggests they support very different applications.

"VR requires a closed tethered helmet that provides the user with a fully immersed, pre-built environment. AR, by contrast, overlays digital displays in the real world, using pre-set digital markers. When it comes to MR it blends the two. You get to see the real world without the need for pre-set digital markers to formulate content.

"MR does everything in real time, merging real and virtual worlds to produce new environments and visualisations," he contends.

Crucially it enables physical and digital objects to co-exist and interact in real time.

"From a commercial perspective VR may be great for training, gaming and immersive entertainment, but beyond that it's currently limited by the need for massive computing power and the fact that users will need to be tethered to powerful computing systems," Bumford suggests. "By contract AR can live in your pocket on your mobile phone but tends to be limited when it comes to large scale digitisation, currently it just isn't supportable."

Bumford says that MR and AR are likely to merge in the future, "It's early days and we're still playing with the terminology," he insists.

As hardware gets smaller and more ergonomic we'll be able to fit into glasses or contact lenses and that will open up the technology to more applications and end markets.

"At the moment these technologies are cumbersome to wear. The large headsets are limiting, but for engineering and construction that's not an issue. In fact, Microsoft are developing a specific hardhat for use in the industrial space."

According to Sriram Chilamkurthi, Business Development, Kazendi "Many industries will benefit from using Mixed Reality and HoloLens users will gain from having access to the HoloLens ecosystem."

HoloMeeting app

Remote collaboration and communication are viewed as the "next big thing," according to Bumford and Kazendi has developed the HoloMeeting app for HoloLens, supported by Windows' Mixed Reality ecosystem.

"HoloMeeting has been designed to bring dispersed teams together by simplifying remote communication and collaboration," explains Chilamkurthi.

"It can be used in remote work spaces and allows for much greater and more fluid collaboration and comes with a variety of features," he explains.

HoloMeeting offers a live view feature, for example, which allows it to be used in the field as a form of remote assistance or as a training tool.

"It can be used in a manufacturing process to assist engineers with these remote assistance capabilities," Bumford suggests.

HoloMeeting allows the integration of holograms within a real-world environment which means that individuals are able to meet in a holographic space. They can also interact with 3D and 2D content.

"That capability is new and is supported by a gaze tracker and spatial sound," explains Bumford.

"Each person in a meeting will wear a HoloLens and will see a holographic cube in their view which is the immersive collaborative space."

Whatever is shared in the workplace becomes visible to everyone else in the meeting.

"Whether that's a pdf or a 3D model, for example, once placed in the cube it becomes visible. It will also be possible for participants to manipulate the document of model."

Once the object is taken out of the cube, however, only the host will access to it providing a degree of control and direction to the meeting and means that agendas can be adhered to.

According to Chilamkurthi, HoloMeeting has access to a variety of 3D modelling software such as Revit, Maya, Rhino and AutoCad but work is being carried out to make the HoloMeeting app compatible with over 60 different file types.

"HoloMeeting comprises of three elements," says Chilamkurthi. "The first element is the shared workspace itself which increases the immersive and collaborative potential of holographic meetings." The second feature is the gaze input.
"When someone dials in to a meeting they are represented by an avatar that moves as they do," he explains.

If a person decides to walk around the shared workspace, other users are made aware of their position, relative to themselves, and where they are looking.
The laser gaze allows movement and helps to make the meeting a more immersive and collaborative experience, according to Bumford.

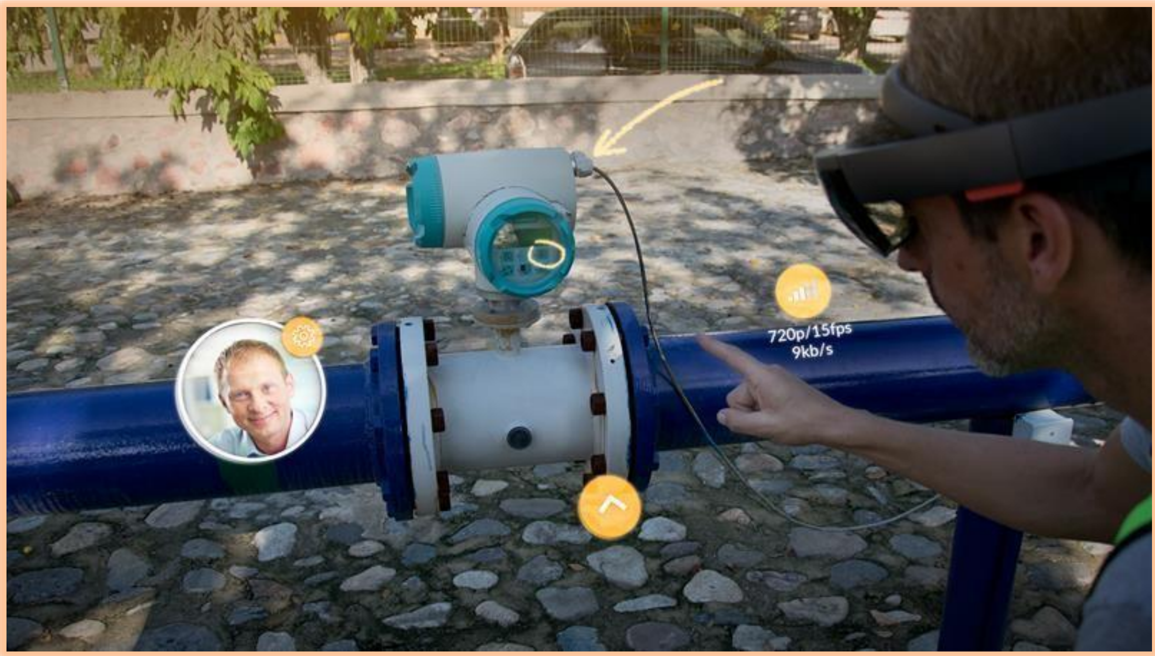


Fig: Holo Meeting has a live view feature, which means it can be used in the field

"Not only can participants view models, prototypes, charts, visualisations, and documents but they can do so from a range of different angles which helps to enhance the working experience.
"It also means that all participants, not just the host, can be made aware of what everyone is doing. We're targeting upwards of 20 users, beyond that and the advantages are limited," Bumford suggests.
The final key feature of HoloMeeting is its use and deployment of spatial sound. As users move around the shared space, the direction from which they are heard changes as they move.
"If a colleague walks from the right to the left, the sound will also transition from your right ear to your left and if multiple people talk at the same time it's now possible to clearly hear all parties instead of dealing with a blur of noise," Bumford says.

The HoloMeeting app provides a significant improvement on current videoconferencing and remote meeting solutions, but it's the use of spatial sound that makes for a more realistic conversation which has tended to be the main problem when it comes to remote meetings.

According to Bumford, HoloMeeting provides the opportunity for real time collaboration in ways that were not possible before.

"We're looking to work with academia and companies from across different industries. Clients are varied but one, in the automotive space, is using the HoloMeeting app so that their internal design teams can now meet more regularly. They no longer have to travel between their offices in the UK and Europe, which they are currently doing every two weeks."

Global design teams, for example, will now be able to work together; can complete individual tasks; check progress with their peers and, ultimately, deliver a far more collaborative project.

"Our aim," according to Bumford, "is to use this technology to change the way teams and companies organise their work processes."

BY: KARAN GUPTA

EMC basics and practical PCB design tips

Though often used as synonyms, Electromagnetic Compatibility (EMC) is really the controlling of radiated and conducted Electromagnetic Interference (EMI); and poor EMC is one of the main reasons for PCB re-designs. Indeed, an estimated 50% of first-run boards fail because they either emit unwanted EM and/or are susceptible to it.

That failure rate, however, is not across all sectors. This is most likely because of stringent regulations in some sectors, such as medical and aerospace, or because the products being developed are to join a product line that has historically been designed with EMC in mind. For instance, mobile phone developers live and breathe wireless connectivity and are well versed in minimising the risk of unwanted radiations.

Those most falling foul of EMC issues are the designers of PCBs intended for white goods - such as toasters, fridges and washing machines - which are joining the plethora of internet-enabled devices connected wirelessly to the IoT. Also, because of the potentially high volumes involved, re-spinning PCBs can introduce product launch delays. Worse still, product recalls could be very damaging to the company's reputation and finances.

Where's noise coming from?

There is no shortage of guidance on designing with EMC in mind, and many companies have their own in-house PCB design and EMC rules. Guidance can also come from external sources, such as legislative bodies, IC vendors and customers. However, accepting all guidelines at face value can lead to an over-defensive EMC strategy, and introduce project delays. Rules should be evaluated individually to determine if they apply to the current design.

That said, your basic, common sense rules will always apply. For instance, to supress noise sources on a PCB you should:

• Keep clock frequencies as low as possible and rising edges as slow as possible (within the scope of the requirements spec');

• Place the clock circuit at the centre of the board unless the clock must also leave the board (in which

case place it close to the relevant connector);
• Mount clock crystals flush with the board and ground them;
• Keep clock loop areas as small as possible;
• Locate I/O drivers near to the point at which the signals enter/leave the board; and
• Filter all signals entering the board.

While the above measures will help mitigate against some of the most common EMI issues, every powered PCB will still radiate EM energy. This is because every current produces a magnetic field and every charge causes an electric field. The total radiation will be the sum of signal loop differential-mode radiation, common-mode radiation (both voltage- and current-driven) and radiation produced by the Power Distribution System (PDS).

Looking at these in more detail

• Differential mode radiation is caused by transmission line loops, and the signals creating differential currents (see Figure 1). Countermeasures include using shielded layers (Vcc or Ground), placing critical signals on inner layers (also known as striplining), avoiding long parallel runs for signals and, as mentioned above, minimising the loop area and keeping signal rise and fall times as slow as possible.

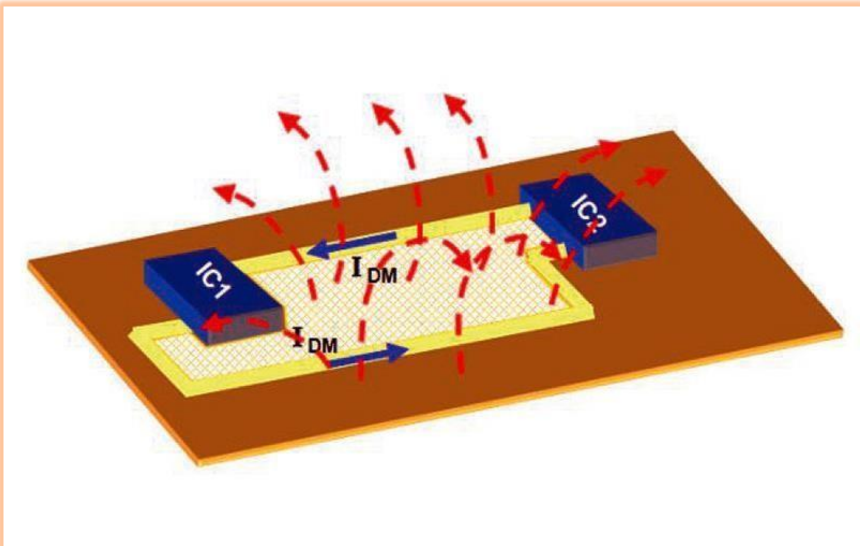


Figure 1: Differential mode radiation

• Common mode radiation is often the more critical EMC design aspect as the EMI is more 'visible' in the far field. It is created from parasitic currents (for example, switching currents or inducted currents by flux couplings) or parasitic voltages (such as crosstalk voltages to active IO-signals). The countermeasures include removing the sources of those parasitic currents and voltages - hence avoiding crosstalk between fast-switching signals - and smarter component placement and routing to avoid flux coupling and wrapping effects.

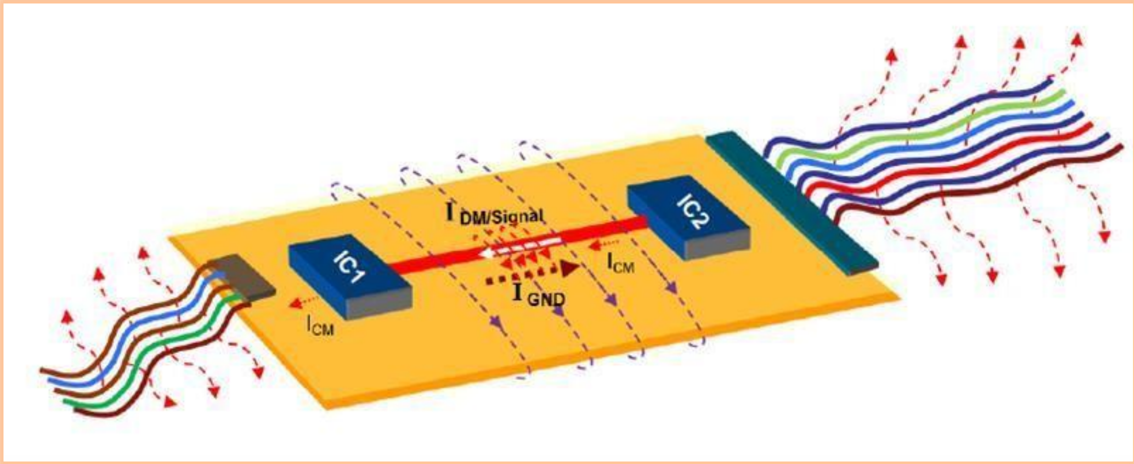


Figure 2: Common mode radiation

• As for PDS, it can radiate because the PCB is essentially an LCR resonator, comprising inductive elements (the tracks), capacitance (ground and voltage planes are like the plates of a capacitor) and resistance. Countermeasures for PDS EMI include lowering the board impedance, avoiding inductance and ensuring sufficient decoupling.
In addition, ICs are also a source of EMI and will contribute to the PCB's EM profile. This must be factored in during IC selection, and chip vendors should be able to provide you with information on the EMI behaviour of the circuits.

Rule checkers and simulations
Many PCB design tools include EMC rule checkers. Checks include looking at the design data geometry for instances where signal crosstalk may occur (because of parallel-routed traces), instances of little or no shielding, and where decoupling may be required.
The rules will incorporate the 'know-how' of many EMC engineers. However, it is important to know their origin and how they were implemented by the CAD tool vendor; and you are in your rights to ask to seethe vendor's rule books. The tools should also allow you to highlight PCB areas where EMI suppression and EMC integrity are key - you tell the tool what your priorities are.
But let's not forget, these are post-layout checks. It is always best to design with EMI and EMC in mind rather than embark on a trial-and-error exercise. Also, you will receive little if any steer on what the EM radiation levels are likely to be.
For a more advanced analysis, simulation is required. As with EMC design rule checkers, the meaningfulness and therefore value of the results will depend on how well the digital representations of the board and its behaviour have been rendered, plus of course how well the variety of EM equations have been implemented as software algorithms. Again, the tool vendors should be able to supply information. You should also take some representative measurements to validate the simulation methodology, and compile metrics to act as the basis for interpreting future results.
There are many numerical 3D EM simulation tools on the market, some of which are dedicated to specific activities such as antenna design. They are well-suited to what-if studies and the optimisation of structures. They can model all EMI effects for a given structure, but they do require considerable computation power (memory and CPU time) and tend to cost a lot. In addition, an in-depth understanding of EMI is needed to understand the results, as it can sometimes be difficult to explain using 3D EM results alone the reason for a particular radiation peak, for example.
However, for the types of PCBs used in white goods, we are not seeking to optimise antenna structures

or produce a particular RF profile; we simply wish to verify that the board design exhibits good EMC - and a PCB design CAD tool with good EMC rule checkers will suffice.

Designing out EMI

While there is no silver bullet to EMC, good design work should include the identification of parasitic EMI antennas, such as electric and magnetic dipoles. Also, identify the current paths, as current flows in loops and will always look for the path of least resistance. Accordingly, plan for a proper return path (noting that 'ground' is not an accepted technical term in EMC engineering) and avoid crossing splits/gaps (even for differential pairs) and return path discontinuities (see Figure 3).

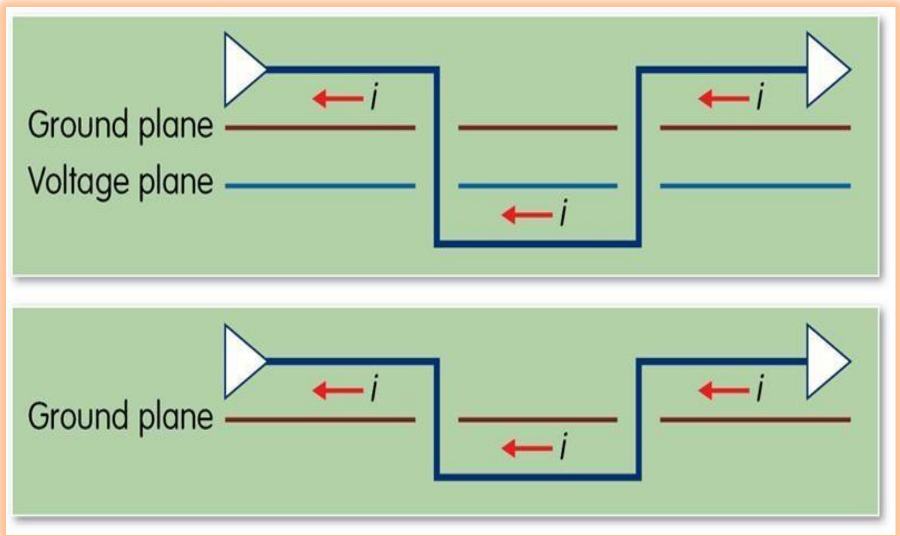


Figure 3: In the top diagram, the reference layer changes from the ground plane to the voltage plane for part of the trace. This creates an EMI antenna. Keeping with the same reference plane, as in the bottom diagram, avoids/reduces return path

In summary, it's always best to design with EMC in mind, rather than risk board re-spins, but you must have a clear understanding of which EMC rules will apply to your project. Also, having an EMC analysis capability embedded within the PCB design CAD tool can greatly reduce the risk of EMC compliance failure once the board is manufactured; but make sure the tool's rule checker is based on well-documented and verified EMC principles and explanations. And never simulate unless a) you trust the simulator and b) you have a feel for what the results will be.

BY: LATA JOSHI

Bringing on bioelectronics

As part of the UK's Healthcare Technologies strategy, the Engineering and Physical Sciences Research Council launched a competition in 2016 to identify promising research projects addressing challenging issues. Among the eight winners, announced in 2017, were Dr Rylie Green of Imperial College London and Dr Frankie Rawson of the University of Nottingham. Dr Green's efforts centre on implantable polymer bioelectronics for devices such as bionic eyes and cochlear implants. Her aim is to create a soft and flexible conducting polymer.

"Cochlear implants currently have 22 channels of stimulation - a limitation caused by the fact they are made from metals," Dr Green said. "Metal conducts electricity using electrons, while the body uses ions. The material we're using can conduct electricity using both.
"Metal limits size," she continued. "You can't make the device smaller without compromising safety and you can't push more current through the metal as it could cause unwanted chemical reactions, such as changing the pH in the tissue."

The polymeric material allows current to be pushed into the body at a 'faster rate, more efficiently and at a lower voltage', lowering the risk of electrical changes or degradation significantly.

"This provides better perception of sound for a cochlear implant patient, or allows someone with a bionic eye to see not just with 40 or 60 points of light - which is the current limitation of metal electrodes - but with hundreds and thousands of points of light."

Dr Green's other challenge was to develop a polymer which could be accepted by the body. This involved modifying the properties of conductive polymers to create a soft interface that interacts more readily and reduces the foreign body response. According to Dr Green, this has been accomplished by hybridising a conductive polymer with hydrogels and elastomers.
The bionic eye developed by Dr Green comprises a camera, fitted to sunglasses, connected to a processor that converts the analogue signal into a digital format that is then delivered into the body.

The electronic package sits behind the ear under the skin. An electrode lead is inserted into the eyeball, where it can stimulate cells to create a perception of vision. A chip interprets the information received.The implants are powered via inductive coils; one remains outside the body, with a matching coil inside. When clipped together magnetically, it can be used for data transmission.
"A wireless inductive link powers the implant, sends processed information to it and gets reverse telemetry data on how the device is working inside the body," Professor Nigel Lovell of the University of New South Wales, explained. Prof Lovell, who has been leading an R&D programme to develop a retinal neuroprosthesis and collaborates with Dr Green, continued: "The chip encodes image information from the camera into electrical pulses. The brighter the image spot, the larger the amplitude of the electric pulses. There are 99 electrodes in our array; more electrodes means better visual acuity."

Dr Green's polymeric material will coat the electrodes to make them work more effectively and, potentially, enable devices with more electrodes, something which is not possible with metal electrodes. "The electronics package (where data transmission and signal generation occurs) is implanted at a distance from the sensory organ (eye or ear), but the interfacing electrode array must be implanted incontact with the cells that require activation and connected to the electronics package via a cable or tracks." Dr Green said.
"The more tracks and channels, the better the patient experience. Once you reach the tissue, you need to be able to stimulate and separate those channels."
According to Dr Green, making sure that polymer-based tracks can carry electricity across these lengths is a challenge, hence the development of new polymer chemistries and fabrication techniques.
"Hydrogels are best for interacting with tissue when looking to stimulate them, but the elastomers are needed to create long tracks. The biggest challenge is creating a continuous electrical path that doesn't break with movement. We've achieved that, but need to make it commercially competitive."
Bioelectronics appears to have a role to play in future medicine and, while Dr Green is working on improved audio and visual perception for diseased cells, Dr Rawson is looking to use bioelectronics to communicate with cells wirelessly.
Instead of implanting an electronic device near the nerve tissue and applying a current to modulate cell

proteins and stimulate communication, Dr Rawson has other plans.
"By inputting electric fields, we plan on modulating electron transfer, which can then be used to sense and actuate chemical reactions. We've demonstrated that cancer cells efflux electrons and metabolise more quickly and grow faster than normal tissues. If you can modulate that external electron flux electrically, we may be able to treat cancer."
There are three methods for treatment that Dr Rawson is looking to address.

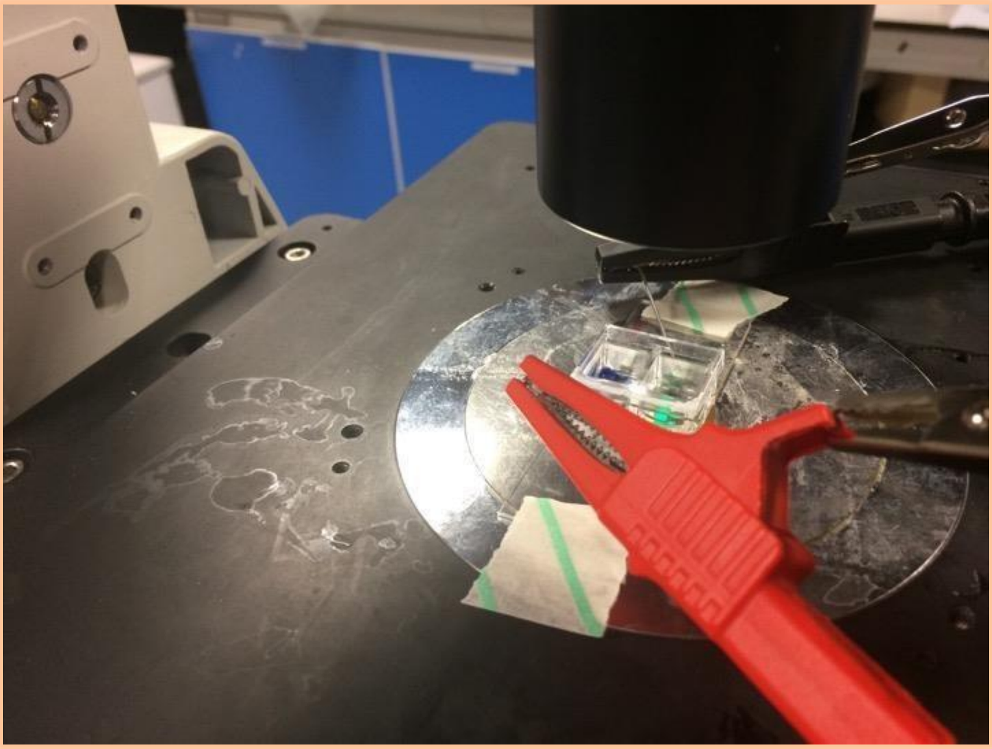
"First, we plan to develop nanotechnology and use conducting nano/micro particles that are functionalised with a bioactive molecule. The cells take up these nanoparticles and when an external electric field is applied, the redox state on the surface of that nanoparticle is changed. When the state of the bioactive molecule changes, it causes a modification in the cell's metabolism, telling it to kill itself.

"Secondly, we think that, by using wireless electrochemistry to self-assemble conductive wires around brain tumours, you can inhibit cell proliferation, which should theoretically extend the patient's life.
"Thirdly, we plan on using artificial conductive porins."

Porins – a type of protein – create channels through cellular membranes large enough to allow ions to pass. "The basis of a lot of electrical talk between cells is from porins opening or closing, depending on the electrical fields," he continued. "By putting in artificial conductive channels and applying external electric fields, we believe we can modulate the potential that cells see and, therefore, the way they communicate."

These conductive wires are created by printing electrode systems on a glass substrate. When printing with conductive inks, Dr Rawson found an electrochemical reaction caused atoms to diffuse into the solution and self-assemble into nanoparticles. These then aligned at the conductive bipolar electrode, which has no physical connection to the circuit, creating conductive wires.
Current bioelectronics therapeutics require standard electronic materials, which need invasive surgery. Dr Rawson proposes to 'grow electronic devices potentially in situ and avoid the need for thatsurgery.'

He said there are ‘no current commercial examples of treating cancer in the way we propose’, but it is likely this technology could be developed and applied in the next 10 years.
Dr Rawson’s vision is a wearable device, such as a skin patch, that modulates the electric field and targets the area of disease. To do this, the next step is to develop a device to modulate that electrical behaviour and, therefore, control cell proliferation and communication.

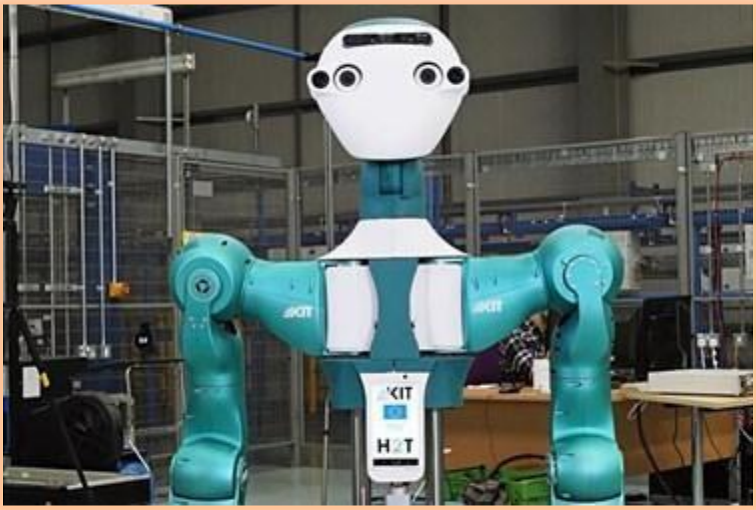


An experimental set up for the induction of electrochemical microwave wireless growth

Although bioelectronics appears to have numerous benefits, there isn’t a mass market for the technology as yet. This, Dr Green concludes, is due to a combination of ‘high cost and regulation’. But she remains optimistic, believing that demand and growth for this technology will soon see commercial applications.

BY: KAUSHANGI GOEL

How collaborative robots can work alongside humansand offer assistance proactively



With automation accelerating around the world, according to the International Federation of Robotics, one of the fastest growing segments of the industrial robotics market is that associated with collaborative robots.

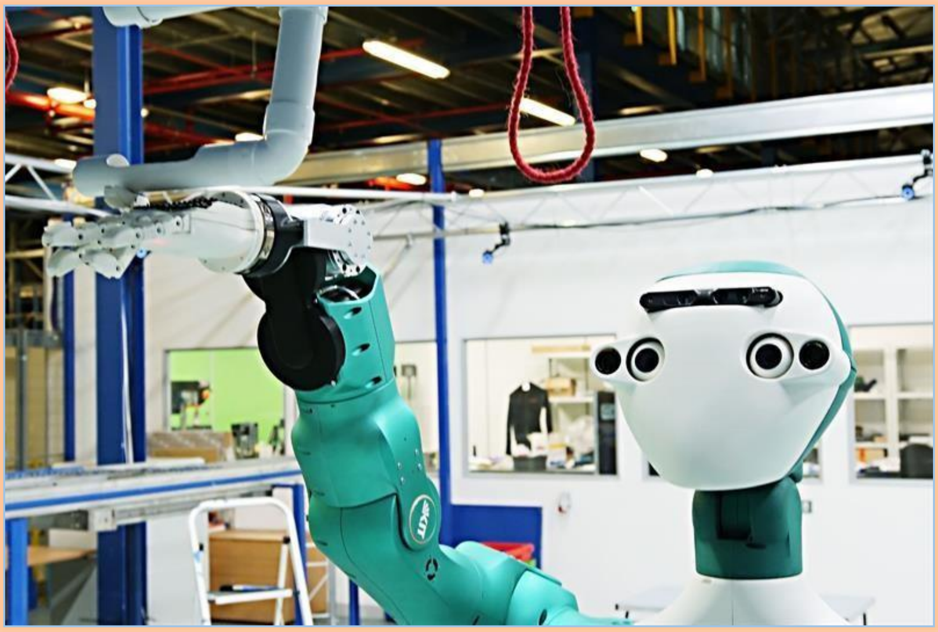
Growth is being driven by a combination of stronger-than-expected growth in the global economy, faster business cycles, greater variety in customer demand and the scaling up of Industry 4.0 concepts.
One of the leading UK developers of 'collaborative robotics' is Ocado Technology, which develops the software and systems that power the online grocery retail platforms of ocado.com and Morrisons, the UK's fourth largest supermarket chain.
Ocado is involved with a growing number of high-profile research projects, including the SoMa soft manipulation system and the Second Hands technician collaborative robot.

Humanoid robots

While the SoMa project is looking to develop smart and generalised solutions and systems capable of picking out thousands of different grocery items safely and reliably, the Second Hands humanoid robotic project is being developed to help engineers fix mechanical faults and even learn on the job.
"The Second Hands project is intended to assist Ocado's maintenance technicians and crucially, and most excitingly, anticipate the needs of human operatives," explains Graham Deacon, who heads Ocado's robotics research team.

"The robot is intended to be completely autonomous and to be able to perform a variety of tasks from fetching tools to holding objects as well as assisting with cleaning and engineering tasks."
The robot - described as a 'second pair' of hands - will be able to assist technicians and, through observation, augment human capabilities.
"It is intended to complete tasks that require levels of precision and physical strength that are not available to humans," Deacon says.

“The Second Hands project is a European collaboration between Ocado and four EU universities and it would be fair to say that it is one of the most advanced assistive robot projects in the world,” according to Deacon.



European project

Ocado is co-ordinating this European-wide project, funded by the EU to the tune of €7million. The investment forms part of its Horizon2020 initiative to encourage researchers to work more closely with industrial partners.

“While we are co-ordinating and contributing to the research, Ocado will ultimately be the end user and the robots have been designed specifically for our warehouses, or Customer Fulfilment Centres (CFCs).” explains Deacon.

A Second Hands robot prototype was delivered to Ocado’s robotics research lab in late 2017 and, earlier this year, a prototype robot was put through its paces in front of EU officials.

“While there is still plenty of work to do,” concedes Deacon, ”the past few months have provided us with the opportunity to evaluate and then integrate the various research components from the various project partners.”

Those research partners have combined to develop what is described as a real-world solution which has required them to not only take into account the design of a new robotic assistant, but also one that facilitates proactive help, supports a degree of human-robot interaction and the development of advanced perception skills to function in dynamic industrial environments.

Ocado’s research partners include: École Polytechnique Fédérale de Lausanne (EPFL); Karlsruhe Institute of Technology’s (KIT) Interactive Systems Lab (ISL) and its High Performance Humanoid Technologies Lab (H^2T); the Sapienza Università di Roma; and University College London (UCL). Various research groups have been focused on computer vision and cognition, human-robot interaction, mechatronics, and perception.

"We want to demonstrate the versatility and productivity that human-robot collaboration can deliver in practice," explains Deacon.
The research contributions for each of the project partners include:

- **EPFL**: human-robot physical interaction with bi-manipulation, including action skills learning;
- **KIT (H^2T)**: Development of the ARMAR-6 robot, including its entire mechatronics, software operating system and control as well as robot grasping and manipulation skills;
- **KIT (ISL)**: the spoken dialogue management system;
- **Sapienza University of Rome**: visual scene perception with human action recognition, cognitive decision making, task planning and execution with continuous monitoring; and
- **UCL**: computer vision techniques for 3D human pose estimation and semantic 3D reconstruction of dynamic scenes.

"Ocado is responsible for the integration of these different functionalities and for the evaluation of the platform," says Deacon.

While Deacon concedes that while more work needs to be done following the presentation to the EU representatives, it was important that the platform was pulled together.
The Second Hands robot is based on KIT's next-generation ARMAR robot. "The fact the Second Hands robot has been developed across various sites using different laboratories, tools and facilities, means the project has been complex. But, despite that, everything was ready for January this year."
As robots evolve from industrial machines performing repetitive tasks in isolated areas of large-scale factories to more complex systems powered by deep neural networks, the Second Hands project has been set the challenging goal of developing, collaborative robots that can interact safely and intelligently with their human counterparts in real-world environments.

"When it comes to maintenance tasks in Ocado's network of warehouses," says Deacon, "when something goes wrong with a mechanical component, we want the Second Hands robot to step in and help engineers carry out repairs quickly and safely.

"It should be able to operate in areas deemed too dangerous for humans – examining high-speed conveyors at close quarters, for example, or handling toxic material."
More importantly, the team expect the robots to track what an engineer is doing, understand the task the engineer is trying to perform and then synthetically understand its own capabilities as a robot to offer assistance proactively.

"Second Hands' potential for high-level reasoning," Deacon explains, "is a work of artificial intelligence." He explains that software will help the robot construct a vast knowledge base around the tasks it carriesout to better understand how they can be applied to problems. "In this sense, the robot will learn on the job," he concludes.

BY: KAUSHANGI GOEL

The best way to generate a negative voltage for your system

MC3x063A 1.5-A Peak Boost/Buck/Inverting Switching Regulators datasheet (Rev. N)

Modern active components, such as A/D and D/A converters and operational amplifiers, typically don't require a negative supply voltage. Op amps in particular are available with rail-to-rail inputs and outputs, and in most cases, input and output voltage can swing to close enough to GND.

However, there are still some cases where a negative voltage is required, including:

- high performance/high speed A/D and D/A converters
- gallium nitride power transistor bias
- laser diode bias in optical modules
- LCD bias

Typically, these applications are powered by one or more positive supply rails with step-down converters and LDOs as point of load regulators. In most cases, the mains supply does not provide the negative voltage, which means it has to be generated from a positive rail.

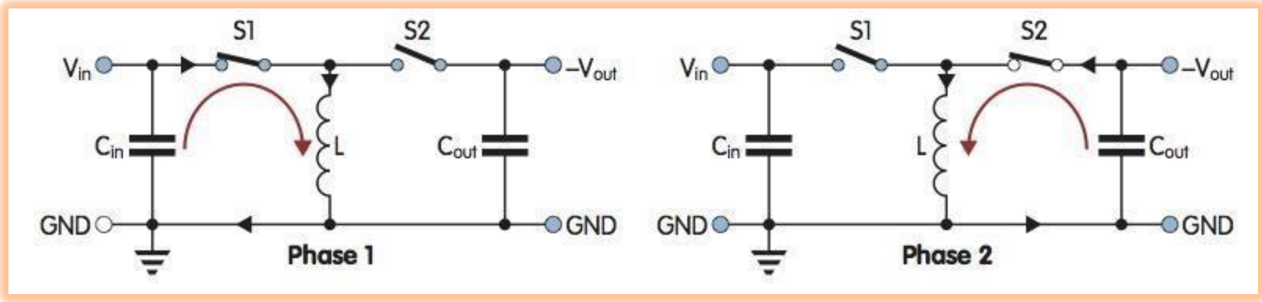
There are a number of ways to generate a negative voltage, mainly dependent on the input voltage, output voltage and output current required. Examples include: inverting charge pumps; inverting buck-boost converters; and CUK converters. Each has its advantages and disadvantages.

Inverting charge pumps

Inverting charge pumps, which can be regulated or unregulated, are typically used for output currents of about 100mA. They follow a simple two step conversion principle and only require three capacitors.

- Charge a capacitor from a positive input voltage
- Discharge the capacitor to an output capacitor while reversing the connection, so the positive terminal is connected to the negative and vice versa.

This approach generates a negative voltage equal to the input voltage – for example, -5V from a +5V supply. The TPS60400 family is an example of such a device. The absolute value of the output voltage can only be equal to or smaller than the input voltage. So, if a lower absolute output voltage is required, an LDO can be added. The LM27761, which has an integrated LDO, is a suitable device whose output voltage can be adjusted from -1.5V to -5V from a 5.5V supply.



Schematic of an inverting buck-boost converter

Inverting buck-boost converters

For larger output currents, inductive solutions - such as the inverting buck-boost converter - are used. These generate a negative output voltage which can be greater or smaller than the input voltage and provide an advantage over charge pumps.

In the first step, when S1 is closed, an inductor is charged with current. In the second step, S1 is opened and S2 is closed. The current in the inductor continues to flow in the same direction and charges the output negative. Typically, S2 can be implemented as an active switch, but is a diode in most cases.

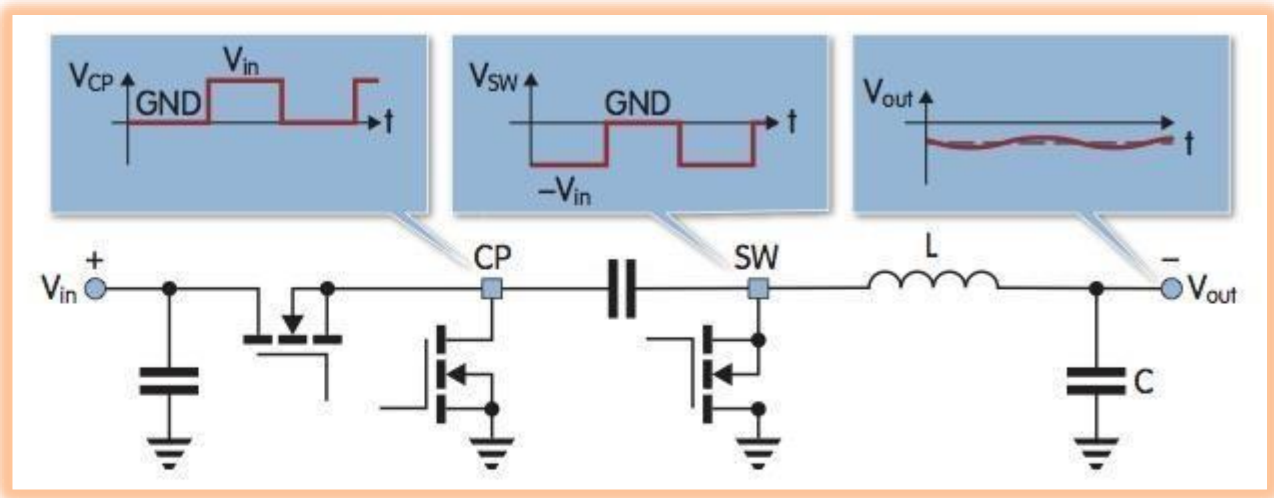
The output voltage depends on the duty cycle (D). With:

D=T*on*/T *and* t*on*.Vin=t*off*.|Vout|

The output voltage is defined as

|V*out*|=V*in*.*[D/(1-D)]*

In figure 1, input current only flows when S1 is closed and the output capacitor is only charged when S2 is closed. Therefore, the input and output currents are discontinuous and the peak inductor current is much larger than the average output current. The topology has a low loop bandwidth because a delay in the system's response sets a limit for the control loop bandwidth. If the system demands higher current, the duty cycle has to be increased, which means a shorter toff. This decreases the amount of current transferred to the output in that switching cycle, so the output voltage drops even further. The control loop therefore needs time until the inductor current in the ton phase rises to the level where there is a higher current in the shorter toff phase delivered to the output. This effect, referred to as right half plane zero, makes the response of the control loop somewhat slow. The loop bandwidth of an inverting buck-boost converter is typically in the order of 10kHz.



Schematic of an inverting buck converter

CUK converter

A CUK converter combines a boost converter with a step-down converter, with the two stages coupled by a capacitor. This topology requires two inductors or one coupled inductor, but supports continuous input and output current and therefore offers advantages for systems that demand low input and output voltage ripple. The control loop bandwidth, and therefore its speed, is lower than the inverting buck- boost converter.

For applications that require low 1/f noise in frequencies ranging to 100kHz, the CUK or the inverting buck-boost converter are not optimal solutions because their control loop bandwidth is much less than 100kHz. A solution to this issue is the inverting buck converter.

Inverting buck converter

Replacing the input inductor of the CUK converter with a high side switch leads to a new topology; the inverting buck converter. This consists of a charge pump inverter followed by a step-down converter and requires only one inductor. The control loop regulates the output voltage of the step-down converter and, because the charge pump stage is combined with the step-down converter's power stage, it runs with the inverse of the step-down converter's duty cycle.

In figure 2, the voltage at CP is switching between VIN and GND while the voltage on SW is between -VIN and GND. As the charge pump stage does not boost the input voltage, the voltage across the internal switches is only VIN, so lower than in the inverting buck-boost or CUK converter. This means more efficient low voltage switches can be used. The output LC of the buck-stage filters the output voltage so output voltage ripple becomes very small.

The TPS63710 offers several advantages over classical topologies, including:

J. a control loop bandwidth of about 100kHz gives fast transient response

K. continuous output current for low output voltage ripple

L.low gain in the gain stage, so the noise level is not increased after the noise filter by a high gain of the gain stage a low 1/f noise reference system, The voltage of a bandgap (VBG) is amplified and inverted to generate a negative reference voltage on VREF using an external voltage divider formed by R1 and R2. This reference voltage is set to a voltage slightly less than (in absolute value) the output voltage. This voltage is filtered by an RC filter consisting of an internal 100kΩ resistor and an external capacitor (CCAP) for low 1/f noise up to 100kHz. The gain stage is formed by an inverter combined with a step-down converter with a voltage gain of 1/0.9.

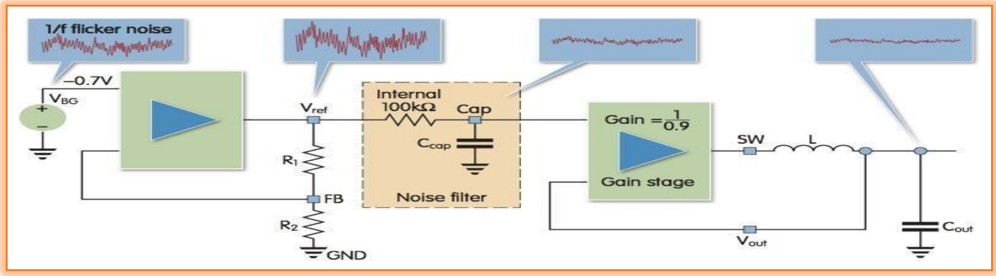
In most converters, the voltage divider to set the output voltage is on the output side between VOUT andGND, which sets a certain gain of the output stage of VOUT / VREF. This increases 1/f noise on the reference voltage. In TPS63710, the gain is 1/0.9, which keeps 1/f noise at nearly the same level as the reference voltage on CCAP.

The TPS63710 accepts inputs ranging from 3.1 to 14V, with an output voltage ranging from -1V to -5.5V. As the TPS63710 uses a buck topology, the input voltage, in absolute value, needs to be larger than the output voltage by a factor of 1/0.7 at least.

Figure 3 shows the schematic of an inverting buck converter optimised for a typical 5V input voltage generating a -1.8V supply at up to 1A. Small size ceramic capacitors used on the input, the CP pin and the output have small electrical series resistance and therefore provide lowest output voltage ripple.

TPS63710 provides the highest efficiency of comparable solutions. The QFN package with thermal pad provides a low thermal resistance to the pcb. This keeps the junction temperature low, even when the device is Capable of operating in high ambient temperatures, the TPS63710 provides:

JJ. A 1/f noise of ~30mVRMS
KK. A full power efficiency of more than 86%
LL. An output voltage ripple of less than 10mVpp



Block diagram of the principle behind the TPS63710

BY: KAUSHANGI GOEL

Next generation stacked cell structures and new standards are taking flash memory into the future

Peter Lieberwirth, Vice President, Toshiba Electronics Europe

With the explosive growth in mobile devices and society's reliance on data processing and storage, it is no surprise that the demand for memory is skyrocketing. Nor is it a surprise that such a dynamic market is changing rapidly. Next generation stacked cell structures and new standards are taking flashmemory into the future.

At the turn of the Century, optical storage (primarily CD and DVD) was the dominant media. However, today hard disk drives (HDDs) represent two-thirds of all storage media in terms of installed bytes, according to research firm IDC.

IDC also estimates the total storage within the digital universe to be 16Zbyte (Zettabytes: 10^{21}byte) – or 16billion Tbyte of data. While HDDs represent the largest portion, flash memory is clearly the fastest growing sector of this market. Flash, which currently represents around 10% of installed memory, is on a rapidly growing trajectory as technology innovation drives both capacity and reliability and the use of flash-based solid-state storage devices (SSD) becomes more prevalent.

Entering the third dimension

Since its inception, NAND memory has become the non-volatile memory of choice. As a result significant effort (and investment) has been directed to continually squeezing the geometries of the base silicon. In the first 20 years of NAND production, lithographic scaling created ever denser memory chips, leading to process node sizes dropping from 350nm to 15nm. During this time, leading manufacturers moved production to larger wafers and found other ways to drive more automation and efficiencies intotheir processes.

While die shrinking continued to drive capacities to even higher levels, there were consequences. Cell durability declined as geometries shrunk and the controllers - specifically the error correction code (ECC) engines - became ever more complex. Indeed, controllers were often on the critical path in bringing new technologies to market. primary drive about shrinking geometries ever closer to the bounds of physics. Instead, innovation increasingly focused on devising ways to occupy the *volume* and not just the *area* - especially for devices with a capacity of more than 128Gbit.

Enter3DNAND

A new 48 layer 3D structure termed BiCS-Bit Column Stacked – was developed, with early prototypes being shown in June 2007. This was a quantum leap forward in terms of memory density, replacing the doped polycrystalline silicon of planar NAND with a new silicon nitride layer of charge trap cells. The immediate benefit was to allow far greater capacities in the same footprint.

However, the move was accompanied by substantial performance and reliability benefits. BiCS allows for larger lithographic processes to be used – reversing the trend for die shrinking and increasing cell spacing while reducing cell-to-cell noise and interference. Consequently, write/erase reliability and endurance can be increased dramatically, as can write speeds. Where a typical 15nm 2D NAND device would have sequential write speeds of 20 to 30Mbyte/s, a 3D BiCS process can achieve up to 40Mbyte/s. This equates to a data transfer rate of more than 500Mbit/s.

Toshiba's first commercial BiCS based flash memory device was a 48 layer 128Gbit (16Gbyte) 3D NANDchip announced in March 2015. Later that year, Toshiba unveiled the first 256Gbit (32Gbyte) 48 layer BiCS flash device, employing an industry leading 3bit/cell triple level cell (TLC) technology. Thanks to these innovations, it had become possible for BiCS TLC to rival the reliability that had come to be expected from eMMC/MLC NAND flash solutions.

Since then, 3D NAND flash has evolved rapidly and the latest iteration of the technology comes in the form of a 64 layer device that incorporates TLC technology and which offers a capacity of 256Gbit (32Gbyte). This significant advance underscores the potential of this proprietary architecture.

The new 64 layer technology, which is already sampling and will go into mass production in 2017, succeeds the 48 layer BiCS flash, with its leading edge stacking process producing 40% greater capacity per unit chip size than its predecessor. This capacity increase not only reduces the cost per bit, but also increases the manufacturability of memory capacity per silicon wafer. As a result, 64 layer BiCS NAND flash memory can meet the demanding performance specifications of applications ranging from enterprise and consumer solid state disks to smart phones, tablets and memory cards.

Manufacturing support

In order to implement the new processes – and to cope with the anticipated demand for the ultra dense 3D NAND devices, Toshiba continues to make significant investment in facilities and infrastructure.

At Yokkaichi, in the Mie prefecture of Japan, the company operates the world's largest single complex dedicated to manufacturing NAND flash memory. Here, the company's capabilities cover more than 50 flavor's of flash, with the latest facility – known as Fab 2' – focusing on the manufacture of 3D BiCS flash memory.

Technology supported by standards

As technology develops, new applications emerge. In order to ensure interoperability, standards are defined, upgraded and, in some cases, superseded. That's why getting the best out of the new NAND flash memory technology and optimizing NAND technologies for a given application will also require selection of the most appropriate interface standards.

With flash memory there are two primary standards that are available to take advantage of the new power of NAND flash: eMMC (Embedded MultiMedia Card) was designed to cover a wide range of applications in consumer electronics, including smart phones, tablets, servers, printers and navigation systems, as well as some industrial and automotive applications.

Systems defined by eMMC contain the flash memory itself, along with a flash memory controller thus freeing the host processor from the task of low-level memory management. The result is simplified interfaces, faster development times and processor capacity that can be used for application oriented tasks.

eMMC is a viable, low cost solution for mobile and other small-footprint applications and has recently seen uptake beyond the consumer world

in automotive and industrial applications. However, to take real advantage of the power that 3D NANDcan bring to high-performance, high-density mobile, automotive and industrial applications requires a migration to another standard – UFS.

UFS (Universal Flash Storage) is based on the SCSI architecture model and is heavily focused on embedded and removable flash storage in smartphones and tablets. A key feature of UFS is efficiency: power levels are low when active and drop to near zero when idle. When combined with the specifications for mobile interfaces developed by the MIPI Alliance, this delivers a very low-power architecture that is ideal for today's power-sensitive mobile devices. With its roots in SCSI technology, UFS (unlike other systems) supports multiple commands, command queuing and multi-thread programming. The key difference between eMMC and UFS is performance. eMMC supports half-duplexing, meaning the host can read and write, but not at the same time. UFS, on the other hand, supports full duplex operation where the host can read and write simultaneously. This means that UFS is positioned to take full advantage of the capabilities of 3D NAND. The latest version of the standard – UFS 2.0 – doubles the bandwidth to 600Mbit/s and this, combined with multi lane support, facilitates data transfer rates of 1.2Gbit/s.

What's next ?

Looking to the future, 3D NAND seems to be a technology with few limitations. Embedded flash memories with capacities approaching 1Tbit are on the horizon and ruggedized versions suitable for deployment in automotive applications are being planned. The next milestone on the development roadmap is a 512Gbit, 64-layer device and, with BiCS flash now a tried, tested and proven technology, the ambition is to head to 100 layers and beyond.

BY: KAUSHANGI GOEL

MAN OF THE ISSUE

Amar Gopal Bose

Amar Gopal Bose: (November 2, 1929 – July 12, 2013) was an American academic and entrepreneur. An electrical engineer and sound engineer, he was a professor at the Massachusetts Institute of Technology (MIT) for over 45 years. He was also the founder and chairman of Bose Corporation. In 2011, he donated a majority of the company to MIT in the form of non-voting shares to sustain and advance MIT's education and research mission.

Early life and education

Bose was born in Philadelphia, PA,to a Bengali Hindu father, Noni Gopal Bose and an American mother of French and German ancestry, Charlotte. His father was an Indian freedom revolutionary who, having been imprisoned for his political activities, fled Bengal in the 1920s in order to avoid further persecution by the British colonial police. His mother, Charlotte, is described as an American schoolteacher of French and German ancestry, but Bose described her as "more Bengali than me. She was a vegetarian and deeply interested in Vedanta and Hindu philosophy".

Bose first displayed his entrepreneurial skills and his interest in electronics at age thirteen when, during the World War II years, he enlisted school friends as co-workers in a small home business repairing model trains and home radios, to supplement his family's income.

After graduating from Abington Senior High School in Abington, Pennsylvania, Bose enrolled at the Massachusetts Institute of Technology, graduating with an SB (Bachelor of Science) in Electrical

Engineering in the early 1950s. Bose spent a year at Philips Networking Laboratorium in Eindhoven, Netherlands; and a year as a Fulbright research student in New Delhi, India, where he met his future first wife. He completed his PhD in Electrical Engineering from MIT, writing a thesis on non-linear systems under the supervision of Norbert Wiener and Yuk-Wing Lee.

Career

Following graduation, Amar Bose became an assistant professor at the Massachusetts Institute of Technology. During his early years as a professor, Bose bought a high-end stereo speaker system in 1956 and he was disappointed to find that speakers with impressive technical specifications failed to reproduce the realism of a live performance. This would eventually motivate his extensive speaker technology research, concentrating on key weaknesses in the high-end speaker systems available at the time. His research on acoustics led him to invent a stereo loudspeaker that would reproduce, in a domestic setting, the dominantly reflected sound field that characterizes the listening space of the audience in a concert hall. His focus on psychoacoustics later became a hallmark of his company's audio products.

For initial capital to fund his company in 1964, Bose turned to angel investors, including his MIT thesis advisor and professor, Y. W. Lee. Bose was awarded significant patents in two fields that continue to be important to the Bose Corporation. These patents were in the area of loudspeaker design and non-linear, two-state modulated, Class-D power processing.

The company Bose founded employed 11,700 people worldwide as of 2016 and produces products for home, car, and professional audio, as well as conducting basic research in acoustics and other fields. Bose never took his company public, and since the company was privately held Bose was able to pursue risky long-term research. In a 2004 interview in *Popular Science* magazine, he said: "I would have been fired a hundred times at a company run by MBAs. But I never went into business to make money. I went into business so that I could do interesting things that hadn't been done before."

Starting in the 1980s, Bose developed an electromagnetic replacement for automotive shock absorbers, intended to radically improve the performance of automotive suspension systems, absorbing bumps and road shock while controlling car body motions and sway.

Bose said that his best ideas usually came to him in a flash. "These innovations are not the result of rational thought; it's an intuitive idea.

In 2007, he was listed in Forbes 400 as the 271st richest man in the world, with a net worth of $1.8 billion. In 2009, he was no longer on the billionaires list, but returned to the list in 2011, with a net worth of $1.0 billion

Personal Life

He married Prema Bose but they later divorced. They had two children, Vanu and Maya. He had one grandchild, Kamala. Amar Bose did not practice any religion, though he used to meditate for a short while every day. Vanu Bose was the founder and CEO of a software-defined radio technology company. Bose died on July 12, 2013 at the age of 83 in Wayland, Massachusetts.

Legacy

In addition to running his company, Bose remained a professor at MIT until 2001. He earned the Baker Teaching Award in 1963–64, and further teaching awards over the years. The Bose Award for Excellence in Teaching (1989), and later the Junior Bose Award (1995) were established in his honour, to recognize outstanding teaching in the MIT School of Engineering.

In 2011, Bose donated a majority of the company's non-voting shares to MIT on the condition that the shares never be sold. Because these shares are non-voting, MIT does not participate in operations or governance of Bose Corporation.

Honours and Awards

- Fellow, IEEE, 1972 – for contributions to loudspeaker design, two-state amplifier-modulators, and nonlinear systems.
- Honorary member, Audio Engineering Society, 1985.
- Honorary Doctorate of Music from Berklee College of Music, 1994.
- Bose was inducted into the National Inventors Hall of Fame in 2008.
- The 2010 IEEE/RSE Wolfson James Clerk Maxwell Award, for "outstanding contributions to consumer electronics in sound reproduction, industrial leadership, and engineering education".
- In 2011, he was listed at #9 on the MIT150 list of the top 150 innovators and ideas from MIT.
- Beryllium Lifetime Achievement Award, Association of Loudspeaker Manufacturing & Acoustics International, 2014.
- Founders Award at The Asian Awards 2015.

BY: KAUSHANGI GOEL

COMPANY OF THE ISSUE BOSE CORPORATION

History of Bose Corporation

Early History

The Bose Corporation's founder, Dr. Amar G. Bose, was born in 1929 to a political refugee from India and his wife, a Philadelphia school teacher. Bose would later suggest, in an interview in*USA Today*,that defending himself as a young boy in a racially prejudiced America equipped him with the fighting spirit important to his success. When his father's import business suffered during World War II, the teenaged Amar Bose convinced his father to begin a radio repair facility in the family business. There, the self-taught Amar did the repair work. Following this early experience in the electronics field, Bose attended the Massachusetts Institute of Technology (MIT), where he earned a doctoral degree in electrical engineering in 1956.

Bose Corporation arose in part from Dr. Bose's dissatisfaction when he attempted to buy speakers for his home stereo system in 1956. As an engineer, he had expected that laboratory measurements would indicate sound quality. To his dismay, however, he realized that measured sound and perceived sound differed. Dr. Bose directed his research efforts into psychoacoustics, the study of sound as humans perceive it, and psychophysics, the study of the relationship between measurement and perception. His research led to numerous patents and the creation of Bose Corporation in 1964 to develop and market products using those patents. Despite the later financial success of his company, Dr. Bose, professor of electrical engineering and computer science, remained on the staff at MIT, teaching acoustics and mentoring undergraduate and graduate thesis students.

Bose started his company at the suggestion of MIT professor Y.W. Lee, who provided Bose with $10,000 in start-up capital. That investment would later be worth an estimated $250,000, when the company repurchased Lee's stock in 1972. So that he could continue his teaching career, Bose hired one of his students, Sherwin Greenblatt, to help develop and market a product. During their first year of business, according to a company publication, Greenblatt was the company's only employee, and 'Bose, who was [still] teaching, was paying Greenblatt more than he, himself, was earning as a professor at MIT.' Greenblatt would later become president of the company.

Bose produced its first 901 direct/reflecting loudspeaker in 1968, and its first customers were secured through contracts with the military and NASA. The 901 was based on Bose's earlier research, which indicated that in excess of 80 percent of what audiences heard at a concert, for example, was reflected sound; sound bouncing off walls, floors, and ceilings apparently contributed to the quality of the listening experience. Bose determined that his disappointment in speakers then on the market resulted from the fact that speakers only directed sound straight forward. To achieve a better spatial distribution of sound, therefore, Bose developed the 901, which aimed eight of the nine transducers in the speaker to the rear of the speaker where the sound could bounce before it reached the listener. The 901 employed an active equalizer to allow the speaker to reproduce the audio spectrum.

Bose's 901 series was not an immediate success. In fact, *Consumer Reports* dismissed the product in 1970, alleging that 'individual instruments heard through the 901 ... tended to wander about the room.' Wounded by such criticism, Dr. Bose filed a lawsuit against the magazine, claiming that it had unfairly disparaged his speaker system. Litigation continued for nearly 13 years, and although Dr. Bose ultimately lost his case at the U.S. Supreme Court level in 1983, the 901 series had long since gained a reputation as one of the finer products on the market.

Critical to Bose's success was the company philosophy, itself a reflection of its founder. Company literature stated: 'Bose believes that audio products exist to provide music for everyone, everywhere--that music, not equipment, is the ultimate benefit. The Bose goal is to create products that combinehigh technology with simplicity and small size, to create the best possible sound systems that are easyto use and accessible to all consumers.' From the beginning, Bose directed all profits back into research and development, avowing a greater interest in producing excellent speakers than in money, and keeping his company privately held, and therefore not responsible to stockholders. Dr. Bose and company officials also stressed the importance of creativity at the company. In *Operations* magazine, for example, Greenblatt stated 'Our challenge is to prod people into being innovative and using their creativity to do something that's better. In the long run, this is the source of sustainable advantage over our competition.'

Since its introduction in 1968, the 901 speaker series underwent several revisions in which sound quality was improved and the speakers were made suitable for the digital age. Bose also applied the direct/reflecting concept to lower priced speakers in the company line and began marketing speakers to the general public for use in home stereo systems.

1970s: Car Stereos and Japanese Expansion

In 1972 Bose Corporation began selling loudspeakers for professional musicians. Later in the decade, Dr. Bose became interested in developing sound reproduction systems for automobiles, having noted that consumers, dissatisfied with the stereo equipment then standard in American cars, were purchasing Japanese systems for installation. The project seemed to present particular challenges given the glass, upholstery, and plastic surfaces in a car's interior. Bose, however, was optimistic, later recalling in a 1990*Electronic Business* article: 'I thought I could actually create better sound in a car than in a room, [since] we can control where the sound goes in a car.'

Bose's auto sound system ideas were presented to General Motors Corporation in 1979, and a verbal agreement was reached between Dr. Bose and Edward Czapor, GM's Delco Electronics president, which resulted in four years of Bose research at an estimated $13 million to adapt car audio systems to the acoustic environment of the automobile. At the conclusion of the successful research, Bose formed a joint venture with GM to design and manufacture car audio systems for certain Cadillac, Buick, and Oldsmobile models.

Although initially slow to realize profits, Bose's car stereos and the Original Equipment Manufacturer (OEM) division they necessitated at the company, eventually became highly successful, leading to Bose partnerships with Honda, Acura, Nissan, Infiniti, Audi, Mercedes Benz, and Mazda. In many cases, Bose was able to design products not only for a specific model of car but also for specific options packages offered by the automakers. Bose was even able to meet Honda's requirement that product failure ratenot exceed 30 parts per million, an exacting standard. By 1995, Bose's car audio systems represented about one-fourth of its total sales.

Also in the 1970s, Bose began efforts to introduce its products to the Japanese consumer audio market, an effort begun with much frustration. Bose's initial efforts in the Japanese market were failures; in fact, the company lost money its first eight years in Japan. Then, Dr. Bose recognized the problem as one in which Bose market representatives had neglected to establish close personal relationships with

Japanese distributors. Bose decided to hire a native Japanese to head the company's sales efforts in Japan. After interviewing several unsuitable American candidates, Bose made a few trips to Japan, during which he established social and business contacts. Eventually he hired someone who would have great success introducing Bose products to Japan and would later become a vice-president in the corporation.

1980s: Acoustic Waveguide and Other Innovations

Further Bose innovations involved acoustic waveguide technology, through which Bose engineers eventually developed smaller, portable speakers and sound systems capable of producing 'big sound.' Specifically, acoustic waveguide technology showed that bass notes could be reproduced through a small tube or pipe, similar to that employed in a pipe organ, instead of the much larger 'moving cones' used by traditional stereo manufacturers. Amplifying the bass notes via an 80-inch tube folded into less than one cubic foot of space, Bose's Acoustic Wave Music System was introduced in 1984. The stereo system won praise for its compact, simple design as well as sound that many reviewers found rivaled that of larger and more costly stereo speakers and components.

In 1985 Bose began investigating the market for its products in television. As he had with General Motors, Dr. Bose approached a major television manufacturer, Zenith Electronics Corporation, and proposed that his engineers design a sound system, incorporating their acoustic waveguide technology to produce high fidelity sound in Zenith televisions. Zenith agreed, and the two companies entered into a joint venture that resulted in the deluxe Zenith/Bose television, a set that featured rich sound, and that, since its tube was folded inside, was only about an inch larger than Zenith's earlier 27-inch screenmodel.

Company innovation continued in 1986 with the introduction of Acoustimass speaker technology. Proving that bigger is not always better, the line featured compact yet high-quality speakers, some of which were so small they could fit in the palm of one's hand.

During the late 1980s, Bose introduced its Acoustic Noise Cancelling headset, a sealed headset designed to cancel out unwanted sound. Remarking on the need for the headset, one writer for *New Scientist* magazine quoted Dr. Bose: 'The US government pays out $200 million a year in compensation for hearing loss caused by military service Hearing loss is a common reason for early retirement of pilots, second only to psychological stress.' Indeed, the headset proved valuable in military use, particularly among pilots and tank drivers. The headset also had civilian applications and could be used by small aircraft and helicopter pilots. Bose donated two of these headsets to Dick Rutan and Jeanna Yeager, who piloted their light plane the *Voyager*on a nonstop around the world flight in 1986. Moreover, the technology Bose developed could be tailored to cancel out noise in several environments, such as airline passenger compartments or city streets.

By 1989 Bose's sales were estimated at $300 million, a figure that some analysts suggested was conservative. Also at this time, nearly half of Bose's sales were derived from foreign markets; indeed, Bose speakers were outselling all other brands in Japan, including those of the Japanese manufacturers. The early 1990s saw steady gains for Bose, with net revenues increasing to $424 million by 1992.

The 1990s and Beyond

The acoustiwave technology in Bose speakers and stereo systems made Bose products popular in the 1990s at concerts, theaters , and nightclubs. A Bose loudspeaker was even used at the 1992 Winter Olympics in Albertville, France. On the consumer front, the decade began with the introduction of a new line of speaker systems called Lifestyle. Featuring an integrated design, the Lifestyle system was designed to provide high quality sound while offering ease of use for both home music systems and theburgeoning market for home theatre systems.
In 1993 consumers were introduced to the Bose Wave radio, a small remote-controlled clock radio suited for use in the home. The Wave boasted rich, full sound not found in other portable radios and could also be hooked up to a television or CD player, enhancing the sound capabilities of the user's existing stereo components. Expensive for a radio and featuring an unusual design, the Wave befuddled retailers, leading the company to sell the product directly to consumers via direct mail and newspaper and magazine advertisements. It went on to be a huge success; by 1998 the company was able to boast sales of 200,000 Waves in a single year.

At its manufacturing facilities, Bose became a subscriber to the total quality management concept (TQM) introduced by W. Edwards Deming. Toward that end, Bose assembly line workers were cross-trained and promoted based on performance. Moreover, Bose sought to build teams based upon mutual trust and respect, operating according to principles of responsibility and quality consciousness. Describing the company's management style in a 1993*Production*article, Bose's vice-president of manufacturing, Tom Beeson, asserted: 'Communicate. Spend a lot of time on the factory floor. Micromanage every aspect. Involve all of the people. Fool proof the system so mistakes can't be made. Find the root cause of problems. Operate manufacturing with the fundamental principle: Do it right the first time.'

In 1994 Bose unveiled the Auditioner audio demonstrator, a computer system that enabled builders, architects, and facility managers to hear the acoustics of a building's proposed sound system, working from as little input as the building's blueprints. This technology was under development for ten years, and became reality only after computer technology caught up with the imagination of Bose engineers.

The mid-1990s also saw Bose undertake a $150 million expansion of its corporate headquarters in Framingham, Massachusetts, known as The Mountain for its commanding view of the countryside. The expansion included construction of a new six-story, all-glass-facade, ultramodern headquarters building, which had room for 800 employees and was completed in 1997. At the same time, the company phased out its factory in nearby Westboro, Massachusetts, citing the high cost of manufacturing in thatstate. (The company did continue to maintain a small manufacturing operation at the Framingham campus.) The production at Westboro was transferred to facilities in Hillsdale, Michigan, and Columbia, South Carolina. By the late 1990s, Bose had eight manufacturing sites, including the three aforementioned along with sites in Yuma, Arizona; Sainte Marie, Quebec, Canada; San Luis Río Colorado and Tijuana, Mexico; and Carrick macross, Ireland.

Starting with the company's long legal battle with *Consumer Reports*, Bose gained a reputation for litigiousness. In the mid-to-late 1990s the company was involved in a number of lawsuits with Cambridge Sound Works, Inc. (CSW), which was based in nearby Newton, Massachusetts. In 1994 Bose sued CSW after the latter claimed that its speakers were 'better than Bose at half the price.' After that suit was settled, Bose soon filed another lawsuit against CSW, this time alleging patent violations. In early 1999

CSW filed a countersuit alleging that Bose had made false advertising claims when it stated that its Wave radio was the best reviewed product of its kind on the market.

Other developments in the late 1990s included the expansion of the company's car audio business in 1998 to include more popular and lower priced vehicles, such as the Chevrolet Blazer and the Oldsmobile Intrigue; the launch of online sales of Bose products at the company web site the following year; and the introduction of a new version of the Wave radio that included a built-in CD player. According to research firm NPD, the Bose brand at decade's end was the number one speaker brand in the United States, with a market share of 20 percent, while the company's closest rival, Harman International Industries, Inc., claimed only 13 percent with its two top brands, JBL and Infinity, combined. Bose also held the number one position worldwide in speakers, with a 25 percent share of that market. For the fiscal year ending in March 1999, Bose had estimated operating profits of $170 million on sales of nearly $1 billion. The company reported its sales for the following year at more than $1.1 billion. With its innovative product development, streamlined manufacturing and delivery, and wide array of marketing channels, Bose was likely positioned to retain its top rank well into the 21st century.

Principal Subsidiaries: Bose AG (Switzerland); Bose A/S (Denmark); Bose Australia; Bose B.V. (Netherlands); Bose Canada, Inc.; Bose GmbH (Germany); Bose K.K. (Japan); Bose Ltd. (Canada); Bose N.V. (Belgium); Bose S.A. de C.V. (Mexico); Bose S.A.R.L. (France); Bose S.p.A. (Italy); Bose U.K., Ltd.

Principal Competitors: Harman International Industries, Inc.; Kenwood Corporation; Koss Corporation; Bang & Olufsen Holding a/s; Boston Acoustics, Inc.; Cambridge Sound Works, Inc.; Carver Corporation;Cerwin-Vega Inc.; Jamo A/S; Matsushita Electric Industrial Co., Ltd.; Koninklijke Philips Electronics N.V.; Pioneer Electronic Corporation; Polk Audio, Inc.; Recoton Corporation; Snell Acoustics Inc.; Sony Corporation; Telex Communications, Inc.

BY: MANVI VASHISHTHA

Achievements

1929: Birth of Amar Gopal Bose

Born in Philadelphia, PA, to a Bengali father (Noni Gopal Bose) and a U.S.-born mother of English and German ancestry (Charlotte).

1930s: Developing a keen ear

For many years, young Amar Bose studies violin, (reluctantly, like many children), developing a keen ear and a lifelong appreciation for classical music.

1940s: From first startup to city's largest radio repair shop

Though just a teenager, Amar Bose repairs broken radios in his parents' basement to support his family when his father's import business collapses during World War II.

1947: A father's dream—accepted at MIT

Amar Bose fulfils his father's dream for his son to attend the most prestigious technical university, as well as his own desire to pursue learning how to design electronics, rather than merely to repair them.

1948: Temporarily outclassed at MIT

Amar Bose finds himself much less prepared for MIT than his peers. In order to focus on his studies, he limits his free time (including listening to music) to only a few hours per week. By year's end, he earns a full scholarship and will go on to earn a BS and MS in electrical engineering.

1953: Joins MIT's legendary Research Laboratory of Electronics [RLE]

Amar Bose works on statistical communication theory at the RLE with three professors who become his lifelong mentors: Jerome Wiesner, Yuk Wing Lee and Norbert Wiener.

1956: Amar becomes Dr. Bose

Amar Bose earns his doctorate in electrical engineering with a ground-breaking mathematical thesis "A theory of nonlinear systems" based on material originally sketched by world-renowned mathematician Dr. Norbert Wiener.

1956: The passion for better sound begins

Dr. Bose celebrates earning his PhD by buying himself a new hi-fi. Though he chooses the system based on his analysis of specifications, the sound quality of the winning design disappoints him. His curiosity about the discrepancy compels him to study and research acoustics at MIT in his spare time.

1957: Reluctant teacher

Dr. Bose is recruited to join the faculty at MIT to teach "Introduction to network theory." Despite his preference for research, he resolves to become the best teacher he can. In the process, he revolutionizes what becomes the school's largest undergraduate course.

1964: Founding of Bose Corporation

Rather than look for an established company to license his loudspeaker patents, Dr. Bose launches his own company. By day, he and his two employees develop power-regulating systems for the military and other government agencies. By night, they explore acoustics and speaker design.

1966: First consumer product: 2201 speaker

The company introduces its first loudspeaker. Though the product technologically leapfrogs conventional speakers, its high price, plus the company's naiveté in matters of marketing and sales, makes it largely unattractive to consumers. As a result, sales are dismal. Lesson learned: products need to be practical as well as innovative.

1968: Revolutionary 901 speaker changes the way people listen to music

Based on extensive research in the fields of speaker design and psychoacoustics, the ground-breaking speaker system wins immediate acclaim for its extraordinary ability to more closely approximate the essence and emotional impact of a live concert. A new focus on explanation and demonstration at retail helps to propel the 901 speaker to becoming a major commercial success.

1972: Beginning of global expansion

Through a relationship with an audio retailer in Bad Homburg, Germany, Bose products are sold outside the U.S. for the first time.

1972: Realizing a dream

Early in the company's history, Dr. Bose had expressed a desire to one day move his company's headquarters from its offices in Natick to The Mountain, a prominent location in Framingham, MA. Though it required a major financial investment for a company of its size at the time, his persistence in pursuing this goal is finally rewarded.

1972: Birth of Professional Products Division

After noting that professional musicians were using Bose 901 speakers as PA speakers and onstage monitors, the company develops the Bose 800, which maximizes sound quality through use of an equalizer and eight 4 1/2" drivers. A new division is born that will make a number of major technological advancements in the coming years.

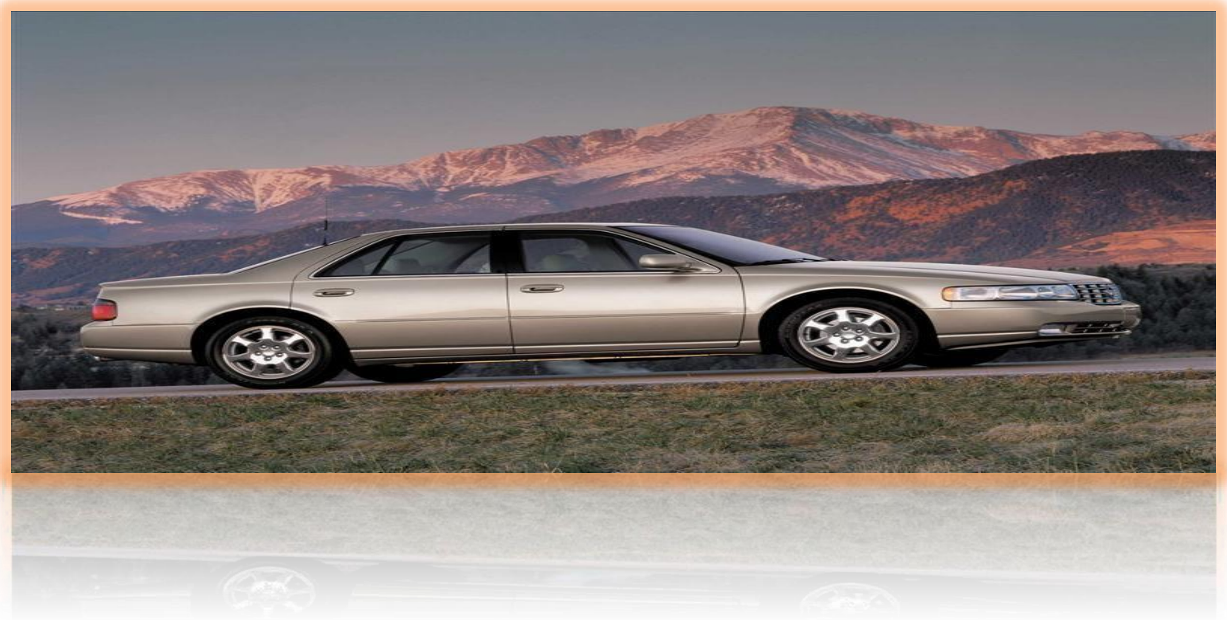
1975: World's top-selling loudspeaker introduced

Bose makes lifelike sound available in bookshelf-size speakers. Thanks to its quality and affordability, the Bose 301 Direct/Reflecting speaker becomes the world's best-selling speakers for many years to come.

1978: Quest for noise cancelling technology begins

On a transatlantic flight aboard Swiss Air, Dr. Bose is disappointed by how the sound produced by the then-new electronic headphones he's been given is marred by airplane noise. He conceives the mathematics for noise cancelling headphones before the flight touches down hours later.

1982: First premium sound system debuts in a Cadillac Seville



Bose launches an entirely new sound category, becoming the first company to offer factory-installed sound systems custom-engineered to the acoustics of a specific vehicle model.

1984: Ground-breaking high-fidelity room-filling sound from a compact tabletop system

A decade of Bose research results in patented acoustic waveguide technology that packs the performance of a large, multi-component system into a compact, all-in-one system. The Acoustic Wave music system is introduced and immediately receives high praise.

1986: Prototype noise cancelling headphones make historic flight

Though Bose active noise-reducing headsets are still in development, the company makes two prototypes available to preserve the hearing of pilots Dick Rutan and Jeana Yeager on their record-breaking, non-stop, around-the-world voyager flight.

1987: Acoustimass 5 redefines home stereo

Using newly patented Bose technologies, tiny cube speakers are able to deliver concert-like sound, while the bass module, which provides the deep low frequencies, can be hidden out of sight. Within a few years, Acoustimass systems become a new standard in home hi-fi and go on to dominate the emerging home theatre market.

1987: Inventors of the year

Dr. Bose and Dr. William R. Short win the Intellectual Property Owners Education Foundation's Inventor of the Year Award for the waveguide loudspeaker system.

1988: First-ever official Olympics sound system supplier

Bose becomes the first company contracted to provide sound systems for every event at the winter Olympics in Calgary, Canada.

1989: First commercial Acoustic Noise Cancelling headset

Bose revolutionizes flying for pilots by introducing a headset that provides effective noise reduction and communication, as well as comfort.

1990: A new standard in home audio

Bose Lifestyle systems take home audio to a new level of performance and simplicity, eliminating the need for the massive speakers and racks of components.

1991: Investigating cold fusion

Assembling a team of physicists, chemists and materials scientists, Bose conducts several years of experiments in an attempt to prove or disprove cold fusion. The research exposes a flaw in the original research and precisely accounts for the erroneously reported excess energy effect in cold fusion theory.

1993: Bose Wave redefines radio

Bose patented acoustic waveguide speaker technology is reintroduced in a small table top music system. It redefines the concept of a radio by delivering rich, deep sound not previously heard from such a small unit. Though at $349, it costs nearly ten times the price of an ordinary clock radio, the Wave radio goes on to become a product beloved by owners, and a huge commercial success.

1993: First Bose store

Bose opens its first retail store in Kittery, ME.

1994: A breakthrough in sound predictions

Bose announces a new technology and tool that allows acoustical engineers and their clients to hear the sound a listener will experience in any particular seat in a venue—before the building is built or any sound equipment is installed. Over the years to come, the Auditioned audio demonstrator is used on thousands of projects throughout the world, including sound systems at the Sistine Chapel, St. Peter's Cathedral in Rome, the Grand Mosque in Mecca, and at Olympic and World Cup venues.

1997: First automotive usage of Bose Nd woofer

This ground-breaking Bose technology, which delivers powerful sound while taking up less space than an ordinary woofer, debuts in the Chevrolet Corvette.

1998: Aviation headsets get smaller, lighter, better

The new Headset X with innovative TriPort technology improves pilot comfort while providing a level of noise reduction that's comparable to the larger, heavier Bose models that had first established the active noise reduction category. The Headset X will go on to dominate the category, with Bose being voted as the no. 1 headset manufacturer for nine consecutive years in the Professional Pilot magazine survey.

1998: First international Bose store

First international store opens in New Delhi. In time, Bose will operate hundreds of its own stores on four continents.

1998: Audio Pilot technology takes in-vehicle listening to new level

This revolutionary noise compensation circuit technology, which monitors and adjusts the music signal in response to vehicle speed and external noise, is introduced in the Cadillac Seville STS.

2000: Pioneering Bose technology changes the way people fly

Building on the success of Bose Acoustic Noise Cancelling headset technology, the Quiet Comfort headphones forever change air travel for passengers by drastically reducing noise and providing better in-flight entertainment sound quality than ever before.

2001: A beloved and renowned MIT professor retires

In addition to being CEO of the company he founded, Dr. Bose was a professor at MIT for 45 years. Awarded many times by students and faculty for his teaching, Dr. Bose's classes were renowned as some of the most challenging—and most popular at the institute.

2003: An entirely new way to amplify live music

By replacing conventional PA, floor monitors and backline amps, the Bose L1 system creates a breakthrough in live music amplification. It relies on the unusual properties of a special loudspeaker, 7 feet tall and only 5 inches wide, which is placed behind each individual musician.

2004: New Bose division: Electro Force linear motion systems

Bose applies its linear-motion actuator technology to a new area and begins a new business through the Bose Electro Force Systems Group, a leading supplier of materials testing and durability simulation instruments to research institutions, universities, medical device companies and engineering companies worldwide.

2004: Secret, multi-decade non-audio research project unveiled

Bose shares the results of a secret project with the press and the automotive industry—a revolutionary automotive suspension technology that uses electromagnetic actuators instead of springs or hydraulics, for a ride that's smoother than a luxury car and offers better handling than a sports car.

2004: Sound for iPod

The SoundDock digital music system quickly becomes the sound standard for iPod-compatible speaker systems, allowing iPod owners to listen unrestrained by earbuds, and share their music with others.

2008: Hall of Fame induction

Dr. Bose is inducted into the National Inventors Hall of Fame in Akron, Ohio, for achievements in audio technology that "have significantly influenced the quality of how we live."

2008: International Design Team of the Year

Bose receives the prestigious Red Dot International Design Team of the Year award for continuous innovation and achievement in design.

2009: New standard in noise cancelling headphones

Already the market leader in noise cancelling headphones, Bose introduces the QuietComfort 15 headphones, a major advancement in noise cancelling technology. The product quickly become the gold standard for frequent flyers and becomes a major commercial success.

2009: First Energy Efficient Series sound system

The Chevrolet Volt becomes the first car to offer this technology, which delivers high-quality acoustic performance while using 50% less energy than conventional systems.

2010: New technology protects long-haul drivers from punishing road vibration

Utilizing Bose seat suspension technology, the Bose Ride system replaces conventional air-suspension truck seats to provide over-the-road drivers with an unprecedented level of protection from harmful road-induced vibration.

2010: Better in-flight experience for pilots: A20 Aviation Headset

Bose introduces its most advanced aviation headset ever, featuring greater noise reduction, improved comfort and *Bluetooth*® connectivity for GPS and cell phones.

2010: Home theatre experience is simplified and improved

Bose introduces the VideoWave entertainment system, a high-definition television delivering home theatre sound from a 16-speaker audio system built entirely behind the screen, and combines it with a totally new kind of remote control that drastically reduces complexity.

2010: Controlling vehicle noise through Active Sound Management (ASM)technology

Leveraging over 30 years of Bose research into acoustics and noise cancellation, this new technology debuts in the Cadillac Escalade and Infiniti M. It enables automakers to more effectively control vehicle cabin noise without compromising the vehicle's desirable sound characteristics.

2011: A new standard in mobile sound

The SoundLink wireless mobile speaker wirelessly connects to a smartphone or other *Bluetooth* enabled device, so that music can be shared out loud almost anywhere. It delivers an unprecedented combination of performance, mobility and durability.

2011: Dr. Bose's gift to MIT

Dr. Bose donates a majority of Bose Corporation's non-voting shares to MIT. The dividends on those shares are used to sustain and advance MIT's education and research mission. The company will remain private and independent and continue to operate according to its values and guiding principles.

2013: Dr. Amar Gopal Bose dies at age 83

"Dr. Bose founded Bose Corporation almost 50 years ago with a set of guiding principles centered on research and innovation. That focus has never changed, and never will." Bob Maresca, president and newly appointed CEO, Bose Corporation.

2013: Another breakthrough in noise cancelling headphones

The QuietComfort 20 headphones are the first in-ear noise cancelling headphones from Bose that deliver a stunning breakthrough in noise reduction, audio performance and comfort, and offer two ways to listen—one to shut out the world, and one to keep you connected. The company has been granted more patents for this product than for any other in its history.

2013: Sound Link Mini takes off

The ultra-compact SoundLink Mini *Bluetooth®* speaker fits in the palm of your hand, connects wirelessly to a smart device or tablet, and delivers a new level of performance for personal, out-loud listening. It becomes the fastest-selling product in Bose history.

2013: Revolutionizing Wi-Fi® music listening at home
SoundTouch Wi-Fi music systems brings lifelike sound to every room in the home. Users can now stream music wirelessly from the internet, music libraries and other music services, at the simple touch of a button.

2013: Premium sound: now in 15 global auto brands
30 years after Bose partnered with General Motors to pioneer the premium automotive sound industry, Bose systems are featured in over 100 vehicle models, from more than 15 manufacturers.

2014: Voted one of the "5 most innovative brands" for the 7th consecutive year
Bose wins its seventh Plus X Award since 2007. The award is the world's largest competition for technology, sports and lifestyle brands.

2014: Official Headphones and Headset of the NFL

Bose brings noise cancelling technology to the NFL, improving coaches' on-field communication and enhancing the in-game experience for fans in the stadium and at home.

2014: The most respected name in sound

Bose is known globally as the most respected name in sound. From two employees in a small office in Natick, MA to a business that spans continents and categories.

Today, the company remains private and independent, as committed to its founding principles and customers as it was in 1964. And today, Bose celebrates, honors and humbly thanks the millions of people around the world who have chosen Bose for the last five decades.

2015: The Panaray system moves passengers and critics alike

No matter what music you listen to in the Cadillac CT6, what you're really hearing is Bose's greatest hits. To create a truly premium experience worthy of Cadillac's flagship vehicle, we adapted some of our best-performing innovations from all corners of the company. We used our headphone's noise cancelling technology to help silence the noise of the road. To create sound where there were no speakers, we leveraged the array speaker breakthroughs first pioneered for home theatre products. We even featured anti-reverberation technologies from our own automotive research. The system is so finely tuned, it took our engineers three years to perfect it.

2016: Blurring the line between industry-defining performance and modern art

Constantly learning from our past achievements, we've developed a reputation for creating more powerful — yet somehow smaller — versions of our products with each new generation. But with the Lifestyle 650 home entertainment system, it's not just the sound that turns heads. The glass top of the Acoustic mass bass unit was custom crafted by the same company that's famous for making windshields for Italian super cars. The satellite speakers are fashioned from a single piece of extruded aluminium with 4,000 precision-drilled holes.

When presenting the prestigious Red Dot 'Best of the Best' Design Award in 2017, the jury said, "All elements of this system have been perfectly matched in terms of form and function. The compact and reduced design allows users to concentrate fully on the delivered sound quality."

2017: Our software engineers begin working by a new code

When we released our first wireless headphones with active noise cancelling technology, they quickly became our bestselling product of all time. Just a year later, we introduced the QC35 Series II, which gave our listeners instant access to the Google Assistant. But to embed voice control into the QC35 II, we first needed to embed a team at Google. Working "bench to bench" with their coders, we did more than create the world's first headphones with a dedicated Google Assistant button — we launched a whole new process for collaborative design.

2017: Improving conversations by hearing our customers

In 1997, a letter arrived on the desk of Dr. Bose. Inside was a handwritten note from a customer asking if it would be possible for the company to develop a headphone that could help people hear their conversations as clearly as their music.

Meanwhile, across our campus, some of our R&D engineers had already wondered the same thing — and had begun work on their prototype. Simple as our customer's question was, the answer was

incredibly complex. Before headphones were ready to share with the world, it would take multiple teams and nearly 20 years of intermittent experimentation to develop and adopt the various new technologies we needed, including in-ear noise cancelling and user-adjustable tuning. But based on the letters we've received since launching Headphones, it was worth the wait.

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