# TOSHIBA REVIEW

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## Special Reports 1

### Core Technologies and Cloud Services Supporting Evolution of TVs

**Evolution of REGZA LCD TVs**
OMI Kunio

**Trends in TV Broadcasting Systems and Technologies and Toshiba's Approach**
ABE Hirotoshi
In recent years, technologies for both TV broadcasting and enhancement of picture quality have entered a transitional stage in the development of next-generation systems, whereas technologies for TV products have currently reached maturity. Following the advent of 4K broadcasting with its resolution of 3,840 × 2,160 pixels, four times that of digital high-definition broadcasting, the fields of broadcasting and contents distribution services are about to enter the era of 8K (7,680 × 4,320-pixel) broadcasting. In the fields of technologies to enhance the picture quality of TVs, a wide variety of elemental technologies related to color gamut, quantization numbers, and dynamic range, as well as resolution such as 4K and 8K, are advancing to the next stage. Toshiba is not only responding to technology trends to enhance picture quality, including a wide color gamut technology and a high dynamic range (HDR) technology, but also developing advanced TV products with higher picture quality by reproducing TV signals degraded by transmission, etc. based on the technology concept of "restoration."

**REGZA Z20X Series High-End 4K LCD TVs with High Contrast and Wide Color Gamut**
SATO Seiichi
Toshiba launched its REGZA Z20X series of high-end 4K (3,840 x 2,160 pixels) liquid crystal display (LCD) TVs in November 2015, incorporating the following advanced technologies developed to achieve its uniquely high levels of picture quality and sound quality: (1) the "REGZA Power Display System," a range of 4K LCD panels for 50-, 58-, and 65-inch models; (2) the "4K REGZA ENGINE HDR PRO," a video processing engine; and (3) the "REGZA Power Audio System," an audio system with a front-firing dome tweeter and high-efficiency full-range speakers. The Z20X series allows users to enjoy a wide variety of contents, including 4K broadcasts, 4K video content distribution services, and high dynamic range (HDR) contents, by making full use of the enhanced recording functions.

**"4K REGZA ENGINE HDR PRO" Video Processing Engine Realizing 4K Picture Quality**
SATO Makoto
The dissemination of 4K ultra-high definition television (UHDTV) with a resolution of 3,840 x 2,160 pixels, four times that of full HD TV, has recently been expanding. Since Toshiba launched the REGZA 55X3 as the world's first 4K UHDTV for consumer use in December 2011, the REGZA series has been continuously playing the role of a technology leader for 4K picture quality. Attention has been increasingly focused on a high dynamic range (HDR) technology that can significantly expand the dynamic range of luminance in conjunction with the progress of liquid crystal display (LCD) technologies to achieve both higher luminance and wider color gamut.
With this as a background, we have now developed a video processing engine that supports HDR technology called the "4K REGZA ENGINE HDR PRO." Incorporating new 4K image processing technologies that offer improved image analysis and picture processing performance, this video processing engine further enhances 4K picture quality.

**Image Reproduction Technologies for REGZA to Realize 4K Picture Quality**
MITSUYA Kota / SUGIYAMA Toru / HONDA Yuichi
High dynamic range (HDR) is now attracting attention as a vital technology to improve the picture quality of video contents for TV due to its wide luminance range and high contrast. Differentiation from competitors' products will be dictated by the application of image reproduction technologies adapting HDR.
Toshiba launched the REGZA Z20X series as its flagship 4K (3,840 × 2,160 pixels) ultra-high definition (UHD) TV of the REGZA lineup in November 2015. The Z20X series attains the highest level of 4K picture quality through our proprietary image reproduction technologies cultivated in the development of REGZA models up to now, including a high-brightness and high-contrast liquid crystal display (LCD) panel and a newly developed algorithm to control the LCD panel corresponding to HDR as well as the latest video processing engine to improve fineness.

**Latest High-Quality Sound Technologies for REGZA**
KUWABARA Mitsutaka
In the field of flat-panel TVs with thinner profiles, downsizing of speakers accompanying the reduction in thickness of liquid crystal display (LCD) panels has resulted in the degradation of sound quality. In recent years, however, there has been a tendency to place greater emphasis on sound quality in high-end products. In order to achieve high-quality sound, it is necessary to incorporate technologies that realize excellent low-range performance as well as complementary technologies to prevent degradation at high-frequency bands caused by the speakers, which are often installed facing downward.
The REGZA Z20X series, a flagship product of the REGZA lineup, achieves high-quality sound through an advanced audio system developed by Toshiba that incorporates the following technologies: (1) a full-range speaker that secures sound pressure in the low-frequency range by expanding the maximum permissible input power, (2) an amplifier system that efficiently supplies electric power for the reproduction of pulsive sound, and (3) a front-firing dome tweeter that improves the reproduction of high-frequency sound. Furthermore, in combination with the RSS-AZ55 REGZA sound system, the Z20X series offers higher quality sound through synchronous driving of its speaker system and the RSS-AZ55.

**New "MilColle" Service of "TimeOn" Regza Cloud Service with Enhanced Content Discovery Functions**
NAKAMURA Takashi / TSUJI Masashi / ISHIGAKI Satoru
The "TimeOn" Regza cloud service for REGZA series liquid crystal display (LCD) TVs has been providing various additional services to users in collaboration with applications and data on the network since the introduction of TimeOn in 2012. In recent years, the volumes and types of video contents available to network connected TV systems have been increasing in line with the ongoing expansion of the number of video contents, including over-the-top (OTT) contents via the Internet as well as conventional linear and nonlinear TV programs. Despite the increasing opportunities for users to watch their preferred contents, it is often difficult for them to find a particular content that they would like to watch. This is not only because of the large number of contents available, but also due to insufficient collaboration between the graphical user interfaces (GUIs) of individual content delivery services.
To resolve these issues, Toshiba has now launched the "MilColle" service as a new function of TimeOn. MilColle makes it possible for users to avoid missing their favorite TV programs and assists them in finding new contents across all types of linear and nonlinear TV programs and OTT video contents that are available on REGZA series TVs but have not yet been discovered by them.

## Special Reports 2

### Novel Energy Systems Focusing on Hydrogen

**Toward Realization of Hydrogen Society**
MAEKAWA Osamu

**Trends in Technologies Related to Hydrogen Energy and Toshiba's Approach**
OTA Hiroyuki / NAKAJIMA Ryo
A movement toward the realization of a hydrogen society has recently been progressing in Japan in line with the "Strategic Road Map for Hydrogen and Fuel Cells" compiled by the government in June 2014.
Toshiba has already developed various technologies for hydrogen energy. These include fuel cells, an area in which we have been conducting research and development since the early 1960s, hydrogen production and storage technologies, and a hydrogen energy management system for the effective utilization of hydrogen called $H_2$EMS™. Combining these technologies, we released $H_2$One™, a hydrogen-based autonomous energy supply system that produces hydrogen using renewable energy and utilizes the produced hydrogen as a fuel for power generation, in 2015. We are also promoting demonstration tests of the hydrogen supply chain and the development of $H_2$Omega™, a high-efficiency large-scale hydrogen energy storage system applying a high-temperature steam electrolysis technology. We are making efforts to contribute to the realization of a hydrogen society through the market deployment of these solutions.

**$H_2$One™ Hydrogen-Based Autonomous Energy Supply System**
KITTAKA Daigo / TANOUE Tetsuharu / KATO Shin
Toshiba has been making continuous efforts to realize a hydrogen society through the development of a variety of technologies for fuel cells, hydrogen production and storage systems, and energy management systems (EMS). As part of these efforts, we have developed the $H_2$One™ lineup, which is a hydrogen-based autonomous energy supply system free of carbon dioxide ($CO_2$) emissions that makes use of renewable energy and produces hydrogen as a fuel for power generation.
$H_2$One™ uses renewable energy sources, including a photovoltaic (PV) power generation system as the primary energy source, and produces hydrogen while utilizing the generated power by leveling variations in the amount of PV power generated. Once the hydrogen is stored in a hydrogen storage tank, $H_2$One™ can supply facilities with electricity and hot water produced by a hydrogen fuel cell using the stored hydrogen, as needed. We are now developing the following two models in the $H_2$One™ lineup: (1) a business continuity plan (BCP) model to supply electricity and heat in the event of a disaster, and (2) a resort model to realize self-sufficiency in electricity for facilities in hotels and resorts.

**Hydrogen Production and Hydrogen Power Storage Systems Using Solid Oxide Electrolysis Cells**
MATSUNAGA Kentaro / YOSHINO Masato / WATANABE Hisao
The Japanese government is promoting improvement of the country's energy self-sufficiency rate to approximately 22–24% in 2030 in line with the "Long-Term Energy Supply and Demand Outlook" released in July 2015, and is planning to achieve a 26% reduction in emissions of greenhouse gases including carbon dioxide ($CO_2$) by 2030 compared with the level in FY2013 in accordance with the Paris Agreement adopted at the 21st Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP21) in December 2015. Furthermore, in the Revised Version of the "Strategic Road Map for Hydrogen and Fuel Cells" released by the government in March 2016, targets have been set for the costs of stationary fuel cells and for the numbers of fuel cell vehicles (FCVs) and hydrogen stations to be introduced, and a working group has been established toward the realization of a "$CO_2$-free hydrogen society." To achieve these goals, the development of hydrogen production, storage, and transportation technologies has recently been progressing aimed at the introduction of large-scale renewable power generation systems and the reduction of $CO_2$ emissions.
With this as a background, Toshiba is promoting the development of water electrolysis systems as key technologies for $CO_2$-free hydrogen production, including a solid oxide electrolysis cell (SOEC) that achieves approximately 30% higher efficiency compared with conventional polymer electrolyte membrane electrolysis cells, as well as high-efficiency large-scale hydrogen power storage systems realized by combining SOECs with solid oxide fuel cells (SOFCs).

**Pure Hydrogen Fuel Cell Systems Based on Technologies for ENE-FARM Residential Fuel Cell Systems**
OGAWA Masahiro / KANEKO Takayuki / MATSUDA Shohei
The Toshiba Group has been devoting continuous efforts to the development of technologies for the dissemination of fuel cell (FC) systems, with the aim of contributing to protection of the global environment by energy conservation and the reduction of carbon dioxide emissions. Following the accomplishment of positive results through the development of large-scale phosphoric acid fuel cell (PAFC) systems for industrial use starting in the 1970s, the Toshiba Group began developing polymer electrolyte fuel cell (PEFC) systems for residential use through participation in various national projects from 2000. As a result of these efforts, Toshiba Fuel Cell Power Systems Corporation released a residential FC system called ENE-FARM in 2009. We introduced fourth-generation models of ENE-FARM in 2016, and have now shipped more than 70,000 units in total.
Based on these technologies for ENE-FARM achieving a balance between low cost and high durability, we have been developing industry-leading pure hydrogen FC systems through verification tests in various projects such as the Kitakyushu Hydrogen Town Project. We have been working to enhance the power generation efficiency and strengthen the system lineup, including a model with 100 kW-class capacity, by accelerating our development efforts since 2014 toward the realization of a hydrogen society.

**Development of $H_2$EMS™ Hydrogen Energy Management System**
SATO Junichi / KATSUYAMA Minoru / YAMANE Fumiyuki
Since the opening of the Hydrogen Energy Research & Development Center at its Fuchu Complex in April 2015, Toshiba has been accelerating the development of a hydrogen energy management system called $H_2$EMS™ and conducting verification tests of the system in combination with a photovoltaic generation unit, a storage battery unit, a water electrolysis unit, a pure hydrogen fuel cell unit, and hydrogen tanks at this center. $H_2$EMS™ makes it possible to level out fluctuations in renewable energy output and achieve efficient operation of a hydrogen-based energy supply system. We have also developed a hydrogen demand prediction technology to facilitate the production of hydrogen through the planned and efficient use of renewable energy.

**Development of Technology for Solar Fuels Using Photoelectrochemical Cell**
SUGANO Yoshitsune / ONO Akihiko / MIKOSHIBA Satoshi
Toshiba is promoting the development of a technology for solar fuels using a photoelectric conversion device as one of the future technologies for the realization of a hydrogen society that efficiently uses renewable energy. This technology, known as artificial photosynthesis, has the potential to generate carbon compounds including useful chemical resources and carbon-based fuels with high transportation and storage performances from water and carbon dioxide ($CO_2$) by means of solar energy. It has been attracting considerable attention in recent years as a countermeasure against the future depletion of fossil fuels and global warming caused by increased demand for energy worldwide.
By applying a photoelectrochemical cell, we have developed a technology to continuously convert $CO_2$ into carbon monoxide (CO) that achieves a high $CO_2$ photoreduction efficiency of 2.0%.

## Feature Articles

**Next-Generation Speech Synthesis Technology with Enhanced Voice Quality and Speaker Similarity Based on Statistical Parameter Selection**
TAMURA Masatsune
The application of text-to-speech (TTS) systems with high voice quality and speaker similarity has been expanded to various fields in which the reproduction of more natural synthesized voices is required, such as speech dialogue systems using synthetic speech similar to that of a specific person. Furthermore, the use of TTS systems is expected to expand in the content production field to realize synthetic speech with high quality comparable to that of a narrator's voice in the future.
With this as a background, Toshiba has developed a next-generation speech synthesis technology incorporating precise speech analysis that uses phase spectrums representing the shapes of waveforms along with power spectrums and a parameter selection method that selects acoustic feature parameters based on statistically trained acoustic models. We have conducted evaluation experiments and confirmed that this next-generation speech synthesis system provides synthetic speech with higher voice quality and speaker similarity compared with conventional methods.

**Investigation of Spin-Dependent Transport Mechanism in Semiconductor/Tunnel Barrier/Ferromagnetic Metal to Enhance Performance of Spin MOSFETs**
INOKUCHI Tomoaki / SUGIYAMA Hideyuki / SAITO Yoshiaki
The spin metal-oxide-semiconductor field-effect transistor (MOSFET) is a device based on a new principle. This device is expected to provide high added value by overcoming the limits of conventional devices through the integration of both memory and transistor functions in a single device. Increasing the magnetoresistance ratio corresponding to variations in the magnetization direction by effectively injecting spin-polarized electrons into the semiconductor from the ferromagnetic metal is a critical issue in order to achieve the practical use of spin MOSFETs.
Toshiba has conducted studies on improving the performance of spin MOSFETs, and clarified the spin-relaxation mechanism that causes the deterioration of spin injection and detection efficiencies by measuring the dependence of the second-order differential conductance on the magnetic field and DC bias voltage.

**Low-Platinum-Loaded Electrodes for Fuel Cells**
MEI Wu / FUKAZAWA Taishi / YOSHINAGA Norihiro
Although polymer electrolyte fuel cells (PEFCs) have already been commercialized for fuel-cell vehicles (FCVs) and residential fuel cell systems, a technology to reduce the amount of platinum (Pt) catalyst in PEFCs without compromising their power generation efficiency and durability holds the key to their full-fledged dissemination.
To realize this goal, Toshiba has already proposed a technology called the alternating catalyst layer structure (ACLS) that achieves a low-Pt-loaded catalyst layer for PEFCs by means of a unique stacking structure. As part of this research, we have now developed a variation of this technology called the modified ACLS (hereafter abbreviated as M-ACLS) by reconsidering the catalyst composition and fabrication processes of the ACLS electrode, resulting in substantial improvements in the oxygen reduction activity and durability against load fluctuations. Experiments on a PEFC unit cell using the M-ACLS electrode have confirmed that it reduces the amount of Pt to 0.15 mg/cm$^2$ in the cathode, about one-third of that using conventional platinum-cobalt ($Pt_3Co$) catalyst, and to 0.025 mg/cm$^2$ in the anode.

**Method for Work Analysis Using Human Activity Sensing Based on IoT Technology**
HYODO Yasuyoshi / KOHASHI Takehiro / YAMANAKA Taisuke
In recent years, concrete efforts have been increasingly focused on offering services tailored to individual characteristics acquired through the analysis of human activities using data obtained by Internet of Things (IoT) devices, such as wearable sensing devices.
As part of this approach, Toshiba has developed a technology that uses a wristband accelerometer to easily grasp the daily work performance of individual workers who are moving around a wide area. By enhancing the accuracy of analysis through the collation of evaluation results concerning the workers' movements with log data recorded in the production management system, it has become possible to predict work performance degradation factors. We have conducted verification tests applying this technology and confirmed its effectiveness in improving work efficiency.

**Commencement of Commercial Operation of Small-Scale Adjustable-Speed Hydropower Generation System at Dashidaira Power Station of The Kansai Electric Power Co., Inc.**
MATSUMURA Akiko / WATANABE Noritaka / YAMASHITA Yoshinori
The Dashidaira Power Station of The Kansai Electric Power Co., Inc., equipped with an adjustable-speed hydropower generation system, entered commercial operation in November 2015. The Dashidaira Power Station utilizes water discharged from its dam in such a way that a good environment is maintained for the river on which it is located. However, the large variations in the head and flow rate of the water would impede stable operation under certain operating conditions in the case of a conventional hydraulic turbine with a fixed rotation speed.
To resolve this issue, Toshiba developed an adjustable-speed system for small-scale hydroelectric power generation plants and delivered it to the Dashidaira Power Station. This system makes stable operation possible over the full range of operations by allowing the rotation speed of the hydraulic turbine to be adjusted over a wide range through the connection of a frequency converter to the output terminal of the generator. As a result, the power station efficiently utilizes water resources that have not been effectively used up to now.

**Vacuum Interrupter Type On-Load Tap Changer for Large-Capacity Transformers**
KOGURE Yosuke / EGUCHI Naoki / SHINODA Masayuki
On-load tap changers (OLTCs) are used to change the tap of a transformer as a means of adjusting the operating voltage when it is in an energized condition. In the case of diverter switches employed in conventional OLTCs for oil-immersed transformers, arc interruption in the oil during tap changing operations leads to the need for regular maintenance and inspection work due to wear of the contacts, as well as the need for a hot-line oil purifier to remove sludge. Diverter switches used in vacuum interrupter type OLTCs (VI-LTCs), on the other hand, can provide a longer maintenance interval and longer lifetime because no arc interruption takes place in the oil. VI-LTCs have therefore been attracting considerable attention in recent years.
Toshiba has now developed the T-type, a VI-LTC for 1,000 MVA-class large-capacity transformers, as an addition to its lineup of VI-LTCs consisting of the S-type for 30 MVA-class transformers, which was released in 2000, and the M-type for 100 MVA-class transformers, which was released in 2012. The first retrofit unit of the newly developed T-type was applied to the replacement of a diverter switch in an existing transformer in April 2016, and the T-type was installed in a new transformer for the first time in July 2016.

**TOSVERT™ VF-AS3 Series High-Performance Inverters Contributing to Realization of Smart Industrial Drive Systems**
HOSOKAWA Masanori / KERA Takashi
Accompanying the ongoing introduction of smart operations applying Ethernet (†) in large-scale industrial plants using drive systems for processes and utilities, such as oil and gas, mining, and water supply and sewerage applications, customer requirements for inverters with dedicated functions to be used in such drive systems have become increasingly diversified in recent years.
Under these circumstances, the VF-AS3 series for overseas markets has been released as a new addition to the TOSVERT™ high-performance inverter lineup for industrial use. The features of this series include various functions for achieving enhanced functional safety, Ethernet (†) ports as a standard network interface, and dedicated functions for each application to contribute to the construction of a smart industrial drive system. These inverters also offer superior environmental performance including the suppression of power supply harmonic current, measures to secure electromagnetic compatibility (EMC), and robustness in various ambient environments.

**Integrated Embedded Reference System for Small Autonomous Mobile Robots**
KAYASHIMA Shimon / WATANABE Yuichiro / SATO Yuichi
With the improvement in performance of large-scale integrations (LSIs) in recent years, rapid progress has been made in the development of autonomous equipment in the field of cyber-physical systems (CPS), such as autonomous cars and robots, by integrating intelligent processing into recognition and actuator control technologies aimed at practical realization.
In response to this trend, Toshiba has been developing and supplying LSI products for a variety of elemental technologies required for such autonomous equipment. To introduce the advantages of these LSIs to users in an easy-to-understand manner, we have now developed both a software development framework for the LSIs and an integrated embedded reference system running on the framework. This system, which features small, two-wheeled autonomous mobile robots and a tablet to control them, is equipped with an automatic tracking function and a remote control function that can visualize the internal information of the robots.

## Frontiers of Research & Development

Drift Anomaly Detection Technology for Sensors Linked with Building Air-Conditioning Systems