

Device Solutions Proposed for the Mixed-signal Area

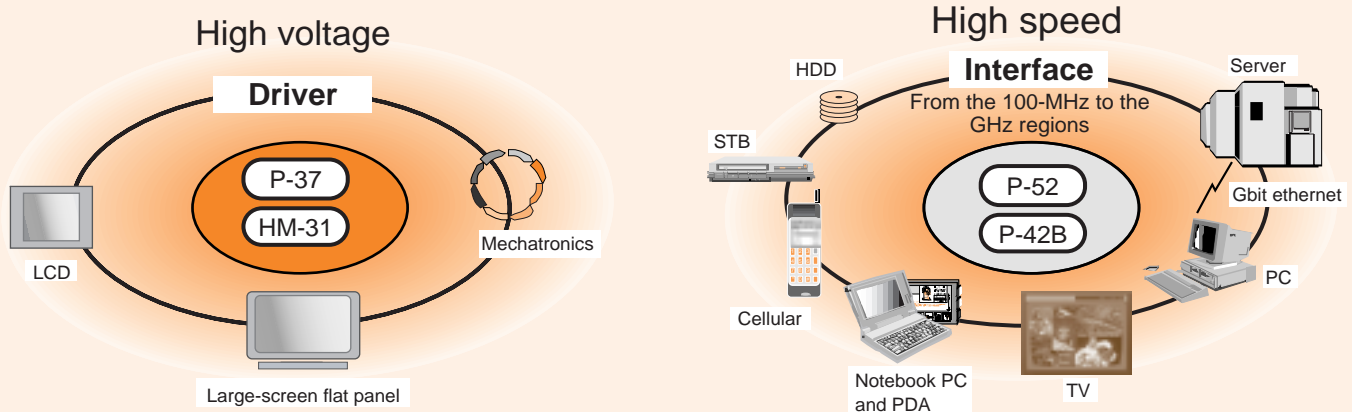
Next Generation High-speed High-voltage Process Technologies

- **P-52**
Supports frequencies in the GHz band
High-speed BiCMOS process
- **P-42B**
Ultrahigh-speed photo IC process
- **P-37**
Supports a 50-V supply voltage
High-speed bipolar process
- **HM-31**
90-V CMOS process

The use of digital processing in portable telephones, PDAs (Portable Digital Assistant), video cameras, and even TV sets is increasing rapidly. On the one hand, the information that we receive from the natural environment is all analog in nature, and therefore analog signal-processing technology is also indispensable in electronic equipment. Therefore mixed-signal ICs, which rule in the sections of these systems in which analog signals are converted to digital and in which digital signals are converted to analog, that is, the man-machine interface, play a critical role, and have contributed to the increased use of digital processing in recent years. Given this background, Sony has made a point of providing device solutions for the mixed-signal area.

In this article, we would like to introduce Sony's high-speed, high-voltage process technologies for the mixed-signal area as shown in figure 1. In particular, we will focus on high-speed and high-voltage process technologies that support the high-speed interfaces required by portable telephones, personal computers, and PDAs, and the types of high-voltage drivers required by displays.

- P-52 is a high-speed bipolar process that achieves the high speed and low power of an f_{Tmax} of 25 GHz and a power consumption 1/2 that of earlier process technologies. As an option, CMOS devices can be included on chips fabricated in the P-52 process.
- P-42B is a bipolar process that supports the formation of on-chip high-speed photodiodes, and achieves ultrahigh-speed photo IC operation with a cutoff frequency of 100 MHz. These devices can be applied to the next generation of data storage devices, such as 60× speed CD-ROM and 10× speed DVD-ROM drives.
- P-37 is a complementary high-voltage bipolar process that achieves the high-speed operation of an f_{Tmax} of 2 GHz while still providing the high voltage handling capability of a 50-V maximum rating.
- HM-31 is a complementary high-voltage MOS process that allows 5-V CMOS logic to be included on the same chip and that achieves both a high maximum rating of 90 V and a low ON resistance.



■ Figure 1 Mixed-signal Regions Provided by the P-52, P-42B, P-37, and HM-31 Technologies

High-speed BiCMOS Process P-52

Mixed-signal Process with a High Cost-performance Ratio

Sony has now added the newly-developed “P-52” high-speed low power bipolar process to its process lineup. The P-52 process can take full advantage of all of Sony’s extensive analog assets, and allows the creation of high-performance mixed-signal analog ICs.

- **Achieving a high-speed low-power bipolar process**

Both bipolar NPN transistors that support high frequencies ($f_{Tmax} = 25 \text{ GHz}$) and low-noise low-power NPN transistors that support linear applications can be included in P-52 devices. Sony has now achieved 0.6- μm rule fabrication in this process, reducing the cell size to 2/3 its previous size. Sony has also achieved a reduction of 1/2 in power consumption as compared to earlier Sony fabrication processes by adopting self-aligning emitter/base formation technology and by optimizing the emitter, base and collector impurities profile. (See figure 2.)

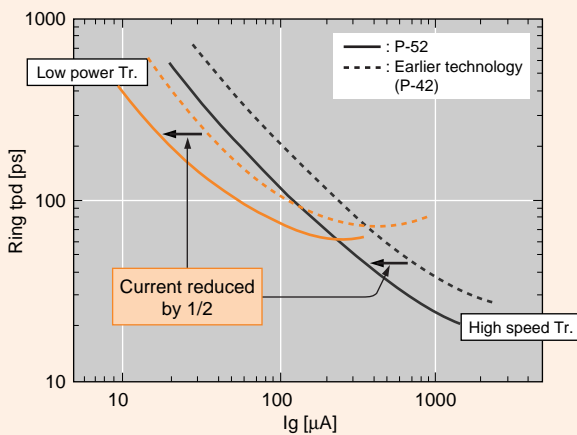
- **High-performance mixed-signal IC achieved by using BiCMOS**

Additionally, to achieve high-performance mixed-signal ICs, Sony has achieved the ability to include CMOS devices with a minimum number of additional process steps. (This ability is optional.) The CMOS devices included in this process achieve the same speed as CMOS devices of the same generation while achieving an even lower operating voltage. (See table 1.) This allows this process not only to support low-power logic circuits, but also to support the formation of circuits that take advantage of interface and switching elements.

- **Various devices to support structures and a wide range of circuit structures**

To support a wide range of applications, from linear applications to high-speed communication applications, Sony provides high-performance PNP transistors and passive devices such as resistors (ρ_s : 2k, 400, or 100 Ω/\square) and capacitors (2.8 fF/ μm^2). By achieving these various devices, this process can take advantage of existing analog assets for reduced power consumption and increased functionality without sacrificing performance, and thus respond to an even wider range of product requirements.

The addition of this high-performance bipolar process allows the implementation of mixed-signal ICs that take advantage of the features of Sony’s analog technology, an area where Sony excels. Sony will be applying this process starting with the portable communication equipment area, the high-speed communication area, and the data storage area.



■Figure 2 NPN Transistor tpd Curves

■Table 1 P-52 CMOS Characteristics

Item	Condition	P-52	
		Nch.	Pch.
Gate Ox (nm)		16	
W/L (μm)		10/1.1	10/1.2
Vth (V)	1 μA , 0.1 V	0.55	0.60
Ids (mA)	3.3 V, 3.3 V	2.2	0.9
β ($\mu\text{A}/\text{V}^2$)	3.3 V, 25/100 μA	950	300
ON R (Ω)	0.5 V, 3.3 V	500	1.8k
Drain structure		Single drain	

Ultrahigh-speed Photo IC Process P-42B

Sony has achieved an ultrahigh-speed photo IC process that will handle the next generation of optical devices

Recently, the demand for personal computers and OA equipment has been increasing. And the size and capacity of software and databases have been growing at ever accelerating rates due to, among other factors, the use of digital image processing technologies. Due to these trends, the importance of the data storage field, and in particular optical devices such as those used in CD and DVD systems, is increasing. Thus increased capacity and faster read-out rates are required in optical devices. One of the key devices in the optical device area is the photodetector, and the photodiode is used for that function. Thus photodiodes must be able to handle the shorter wavelength lasers used (for example, CDs use a 780 nm

wavelength which DVDs use 650 nm) and the faster readout rates used (for example, the audio CD reads at 1× speed, 8× speed CD-ROM drives are common, and 60× speed CD-ROM drives are about to appear). (See figure 3.)

- **300-MHz high-speed photodiode**

The P-42B photo IC process just developed by Sony carries out making a high-speed photodiode by process structure optimization. This allows photodiodes that achieves a frequency response of 300 MHz and an optical sensitivity of 0.4 A/W (@ $\lambda = 650$ to 780 nm). (See figures 4 and 5.)

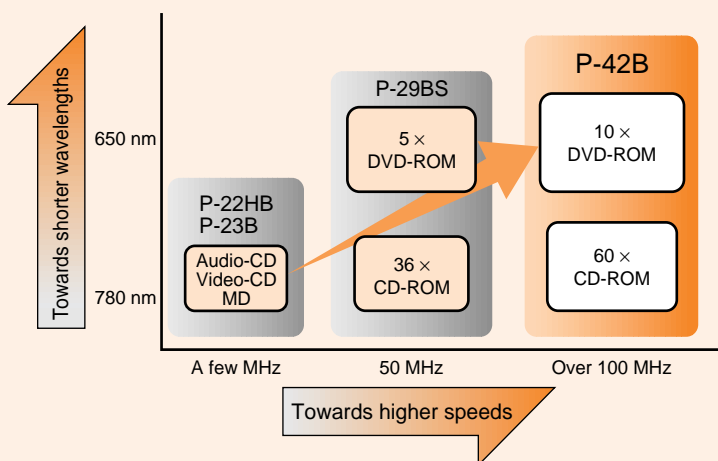
- **High speed and low noise achieved by creating “photo ICs”**

Another point of P-42B process is that the photodiodes are fabricated not as discrete devices but as part of an IC, i.e. a photo IC, and the photo IC is built on the P-42 (Sony’s fastest bipolar IC

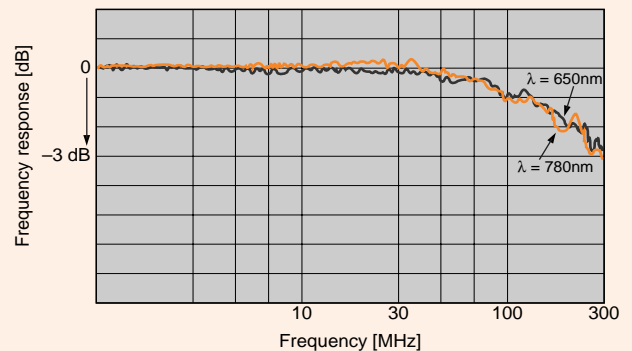
process) platform. This means that high-speed photo ICs with cutoff frequencies in excess of 100 MHz can be fabricated without losing the high-speed characteristics of either the photodiode or the bipolar IC.

- **Future developments**

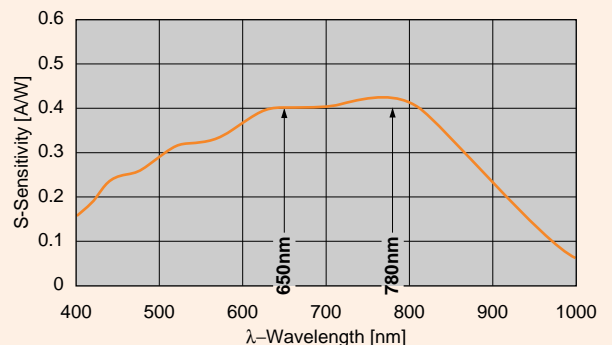
Due to the desires for even larger capacity optical discs, laser wavelengths will be reduced from the current 650 to 780 nm to shorter wavelengths around 400 nm. Sony will be developing photo IC products to support these shorter wavelengths while not losing the high-speed characteristics developed in the P-42B process. Furthermore, Sony will be applying this technology to the optical communication area.



■ **Figure 3 Trends in Photo IC Fabrication Processes**



■ **Figure 4 Photodiode Frequency Response**



■ **Figure 5 Photodetection Sensitivity Laser Wavelength Dependency**

High-speed Bipolar Process that Supports a 50-V Supply Voltage P-37

The world of drivers expanding from discrete to monolithic

- High-voltage operation at up to 50 V possible due to the inclusion of V-PNP transistors

The latest bipolar process technologies used for highly integrated circuits features even finer design rules and improvements in the frequency responses of the individual transistors. Furthermore, the junction voltage continues to be reduced and now is as low as a few volts. At the same time, circuits that require high supply voltages and high output voltages (and currents) are normally formed from discrete devices. Until now it has been difficult to increase the voltage handling capability of complementary processes that can include PNP transistors with characteristics equivalent to those of the NPN transistors. This has been the main reason that it has been necessary to use discrete devices.

To respond to these desires for reduced costs and miniaturization in circuits such as these that require high voltages and high power, Sony has developed the P-37 complementary monolithic bipolar process that allows V-PNP transistors to be included on chip despite these devices having the high voltage handling capability of a 50-V maximum rating.

- Highest level of operating speed achieved

While the transistors included in P-37 fabricated devices achieve high voltage handling capability by the use of a thick but low density epitaxial layer, a deep graft base, and other techniques, they aim for operating speeds increased by up to an f_{Tmax} of 2.0 GHz or higher by adopting a polysilicon emitter structure. Thus these devices achieve superlative characteristics in both the increased voltage and increased speed aspects, which have a tradeoff relationship. (See figures 6 and 7.)

- Superlative current drive capability

The current drive capability of the transistors included in P-37 fabricated devices is even better than that expected when trends in earlier processes are extrapolated. (See figure 8.) This is because it is possible to set the emitter density higher and improve the current transport efficiency by adopting a polysilicon emitter structure as mentioned above.

Also, the recombination current in the base region is suppressed by making the base layer shallower. These devices also allow efficient supply to the collector side of carriers injected from the emitter by the adoption of a dual collector embedded structure. This superlative current drive capability is achieved because these devices are bipolar devices. Thus we are convinced that this process is optimal for implementing a wide range of driver circuits as monolithic ICs.

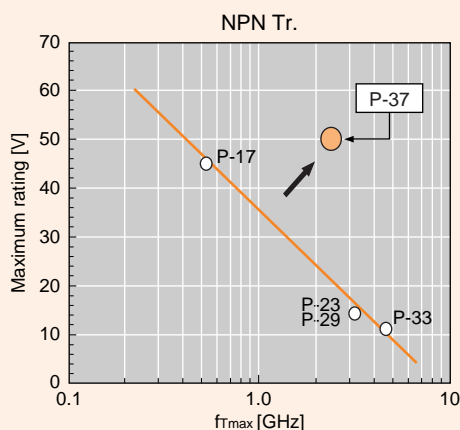


Figure 6 Relationship between f_{Tmax} and Maximum Rating (NPN transistor)

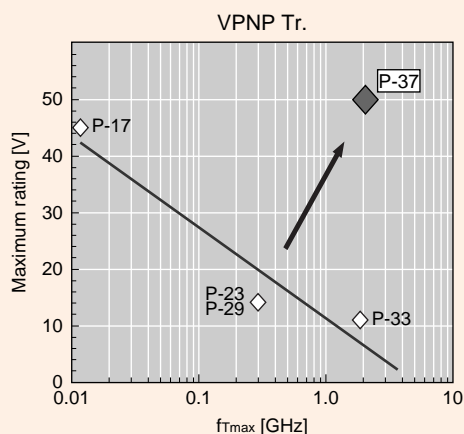


Figure 7 Relationship between f_{Tmax} and Maximum Rating (V-NPN transistor)

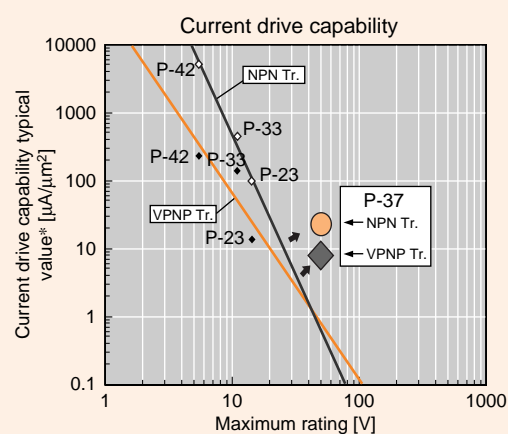


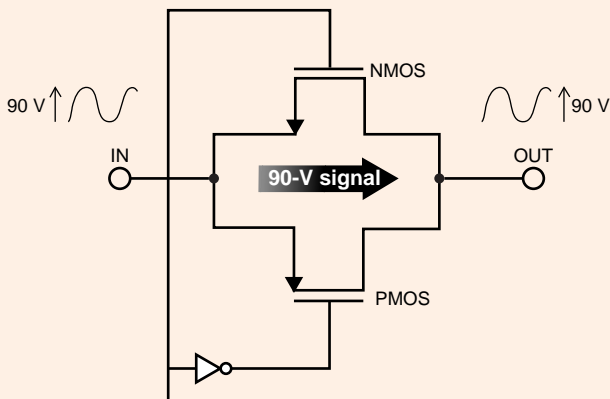
Figure 8 Transistor Current Drive Capability Comparison

CMOS Process that Handles 90 V HM-31

Hybrid process for both 90-V CMOS and 5-V CMOS devices

The market for display devices has seen rapid growth recently due to the increasing demand for personal computers and for larger screen sizes in home TV sets. While the CRT is currently the most common display device, several devices, such as the plasma display, PALC*1, FED*2, and EL*3 are receiving attention for the next generation of display devices. Associated with this demand for display devices, the demand for high-voltage display driver ICs is also increasing. Sony has now developed a new 90-V CMOS process, the HM-31 process, to respond to this demand.

- *1: Plasma Addressed Liquid Crystal
- *2: Field Emission Display
- *3: Electro Luminescence



* Allows 90-V linear signal processing.

■ Figure 9 Analog Switch

- 90-V CMOS transistor for analog switching developed

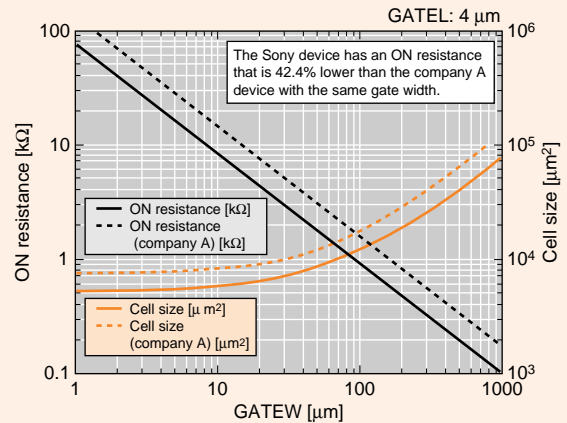
In previous technologies, there were no low ON resistance MOS devices that could handle input signals with voltages as high as 90 V, and forming analog switches for 90-V input signals was difficult, as shown in figure 9. Now, Sony has developed a CMOS transistor that achieves both a 90-V voltage handling capability and a low ON resistance by using Sony's unique high-voltage technology. This device makes it possible to create an analog switch that can handle 90-V inputs.

- 90-V source follower CMOS transistor developed

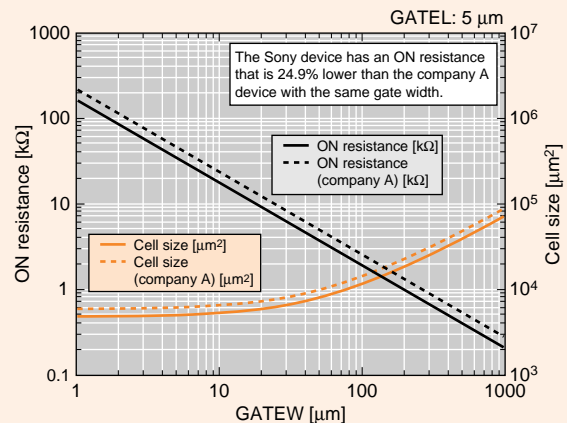
This transistor makes it possible for the source to take on an arbitrary potential that is higher than the substrate potential (ground), and to achieve source follower operation at 90 V. A low ON resistance was achieved in this device by optimizing the device structure and the impurity diffusion layers, and thus this device achieves both a 90-V voltage handling capability and a low ON resistance at the same time. (See figures 10 and 11.)

- 5-V logic CMOS included

This process also achieves the on-chip integration of 5-V CMOS logic by separating the high-voltage areas and the 5-V logic areas. Existing 1- μm CMOS assets can therefore be made use of effectively.



■ Figure 10 Comparison of ON Resistance and Cell Size with Other Manufacturers' Products (NMOS)



■ Figure 11 Comparison of ON Resistance and Cell Size with Other Manufacturers' Products (PMOS)

Future Developments

Sony is now focusing its energy on the development of processes that can respond to needs of applications in the mixed-signal area, and will continue to do so.

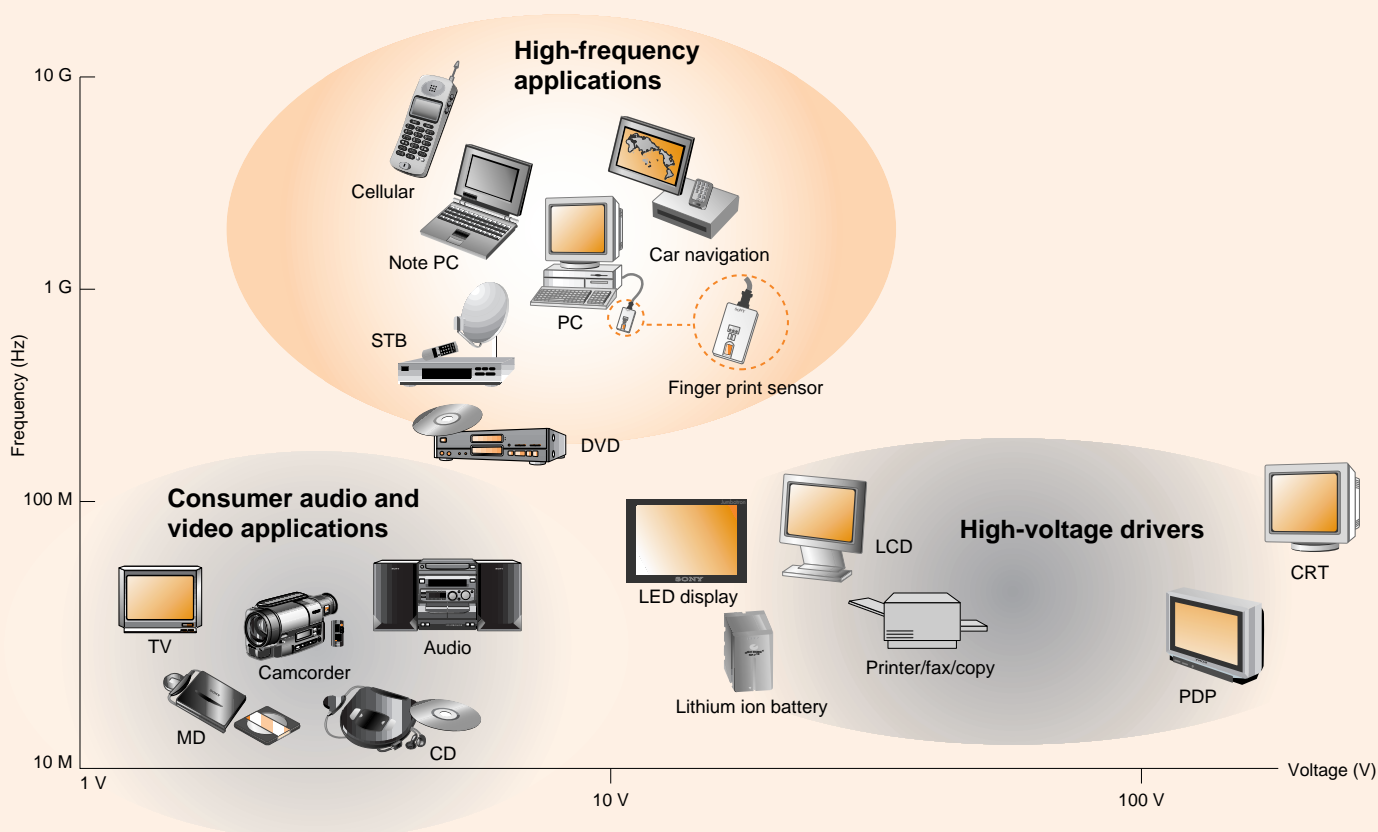
In the high-speed area, Sony is now actively engaged in developing high-speed bipolar and BiCMOS processes that can support the next generation of high-speed communication interfaces, and in developing photo IC processes that can support the short wavelength lasers that will be used in the next generation of large-capacity data storage devices. Other development efforts that we have not presented here include the

development of MMICs that feature ultrahigh frequencies and low loss and are optimal for portable telephones, ITCs, and other forms of portable communication.

In the high-voltage area, Sony is now developing processes that can support applications such as the next generation of displays.

Other areas where Sony is developing new process technologies include the sensor process area, where Sony is developing processes that provide superlative cost performance ratios for devices such as fingerprint sensors, which are expected to be the key device in security management systems in personal computers and other electronic equipment.

Keep your eye on Sony's mixed-signal ICs for continuing technological advances.



■ Figure 12 The Limitlessly Expanding World of Mixed-signal Applications