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Advantest IR Technical Briefing

Test Needs and Solutions in the Display Driver IC Market

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NOTE

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Agenda

- ✓ Display Driver IC (DDIC) Tester Business Environment
- ✓ DDIC Test Needs & Solutions

Display Driver IC (DDIC) Tester Business Environment

The Evolution of Display Technology & Changes in Our Lifestyles

Liquid crystal panels and organic EL panels (OLED) have made thinner and lighter displays possible. This enables us to easily obtain information anytime, anywhere, and to enjoy beautiful, dynamic images. Displays have become an indispensable part of our business and private lives.

TVs

Large Events
Digital Signage

Smartphones
Tablets

PCs

Wearable Devices
Smartwatches/AR Glasses

VR & Metaverse

Automotive
HUDs

With the evolution of display technology, display applications continue to expand

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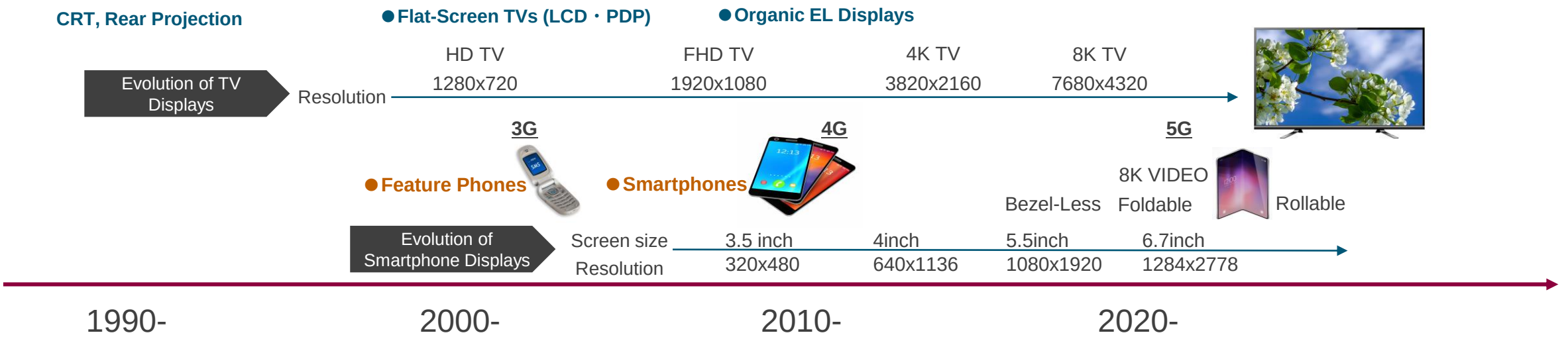
DDICs Continue to Support the Evolution of Display Technology



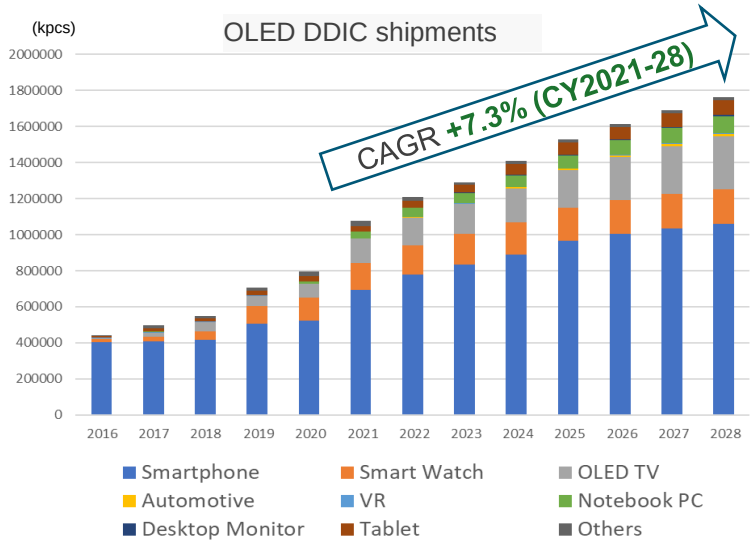
Turning-Points in the DDIC Market

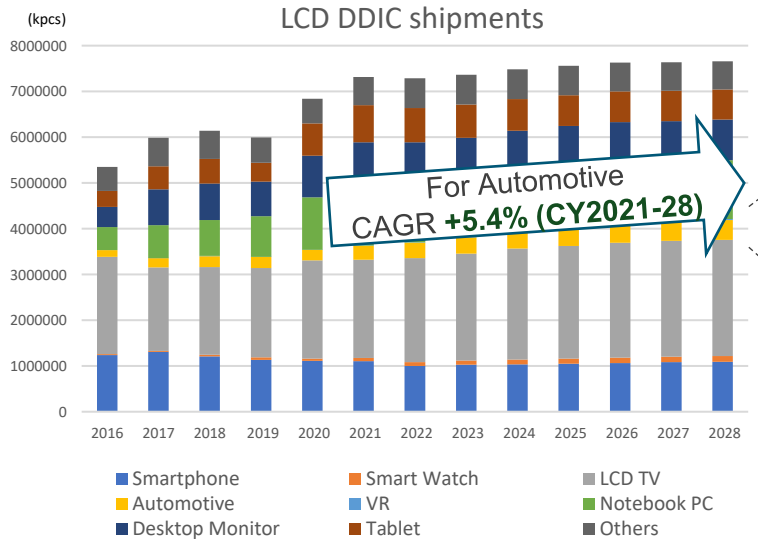
- ✓ In 2000, the advent of flat-screen TVs boosted DDIC demand
- ✓ In 2007, OLED displays began to deliver thinner, lighter screens and higher image quality than LCD displays
- ✓ Smartphone usage exploded around 2010, while new generations of communication standards have accelerated demand
- ✓ Smartphone makers are adopting full-screen (bezel-less) displays for differentiation, boosting demand for in-cell touch sensors
- ✓ TVs have entered the era of high-definition to ultra-high-definition. DDIC count per unit doubled from FHD to 4K, and is still increasing

Higher TV and smartphone functionality is driving DDIC market growth

High Growth Potential Applications in the DDIC Market

- **OLED adoption is expanding to meet needs for higher image quality, mainly for smartphones and TVs → DDIC demand growth**
- **Greater use of automotive displays → DDIC demand growth**
- **Expansion of 5G infrastructure raises expectations for explosive growth of the "near eye" display market for metaverse products**





Automotive DDIC CAGR (CY2021-28)	
Side Mirror	31.6%
Room Mirror	15.3%
Head Up Display	13.8%
Center Stack Display	5.2%
Others	2.6%

Increased adoption of OLED technology leads to increased demand for DDICs. Automotive applications are also expanding, and demand is growing, mainly for LCDs

How Advantest's Strengths Support the DDIC Market

➢ Overwhelming market dominance powered by industry-best technology

- ✓ DDIC tester (semiconductor test equipment) market share >90% (our estimate)
- ✓ Applying our measurement technology, honed by experience in the measurement instruments field, to tester development, we launched our first dedicated DDIC tester in 1990. We have consistently provided unrivaled high-precision solutions to this sector for the last 30 years
- ✓ Industry-leading MTBF (Mean Time Between Failure)

T73 series (1990~2000)

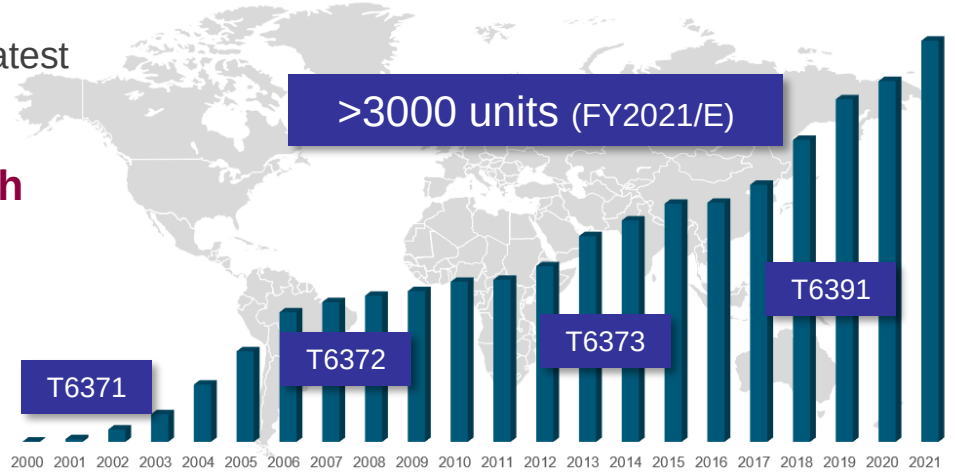
T63 series (2000~present)

➢ Industry's No.1 customer base and largest installed base

- ✓ Strong relationships with companies across the test supply chain (fabless, foundries, OSAT) spanning Asia (Taiwan, China, South Korea)
- ✓ Number of volume production systems in operation worldwide is industry's greatest

➢ Tester functionality tracks device evolution while maintaining high backwards compatibility

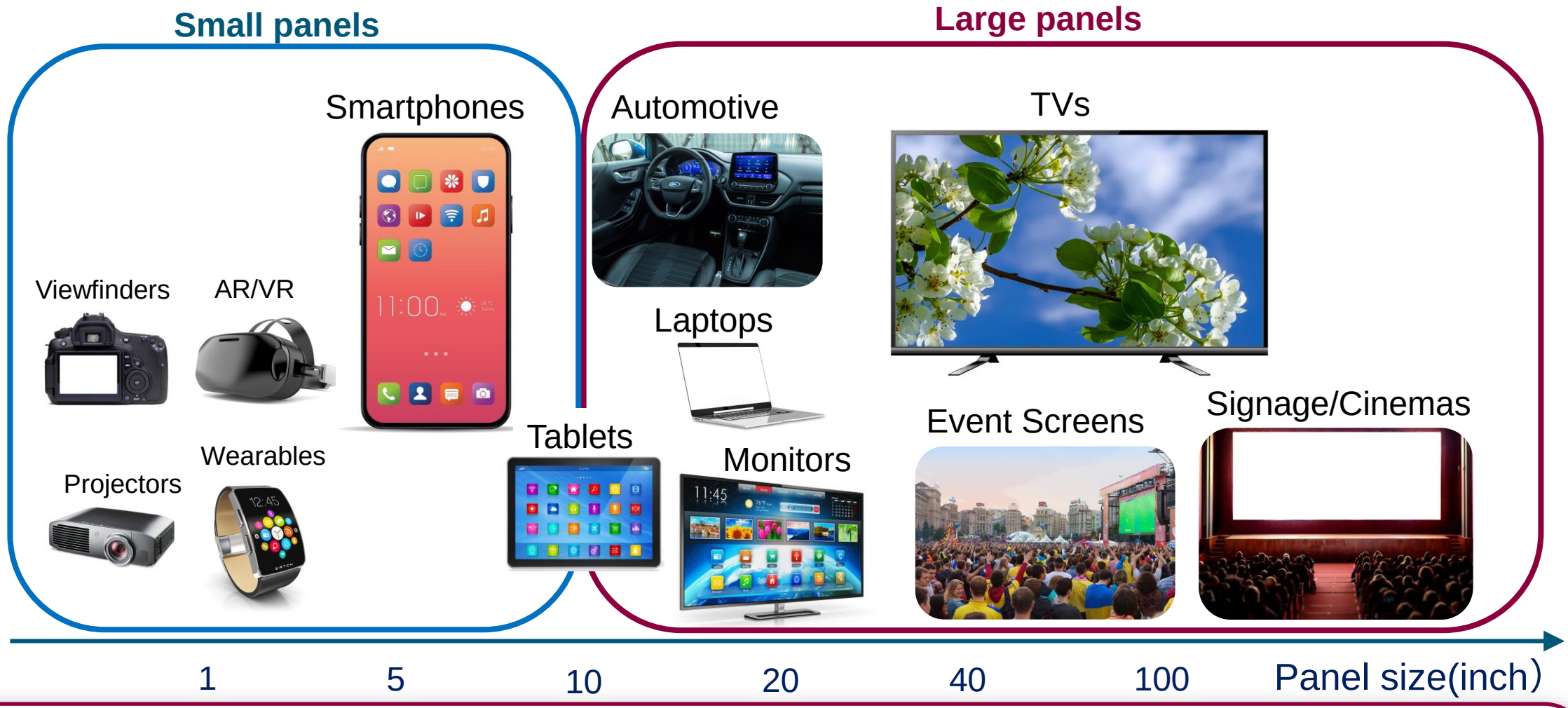
- ✓ Industry-highest number of LCD channels
- ✓ Supports the latest smartphone and TV displays with higher speeds and more functions
- ✓ Enables effective use of customer assets (test program development environment, device interfaces, etc.)



T63 series cumulative shipments

DDIC Test Needs & Solutions

Panel Usage From the DDIC Perspective

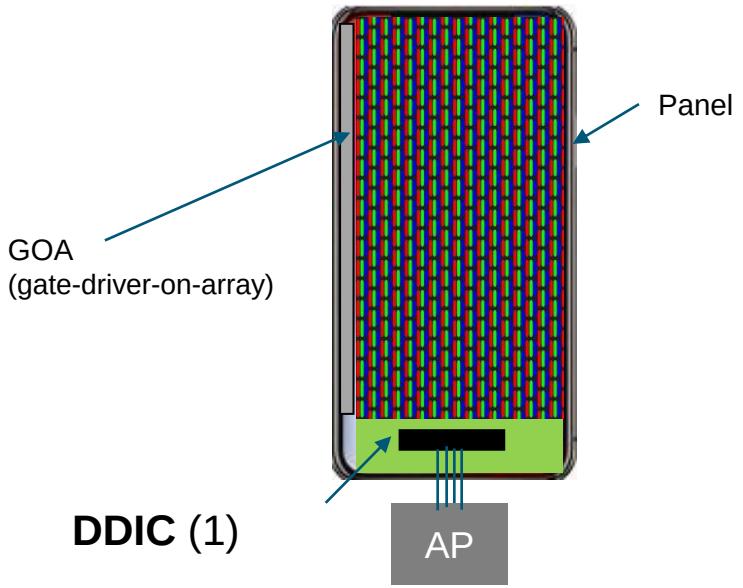


The DDICs that transmit image signals to the panel differ greatly depending on the size of the panel

The Role of DDICs

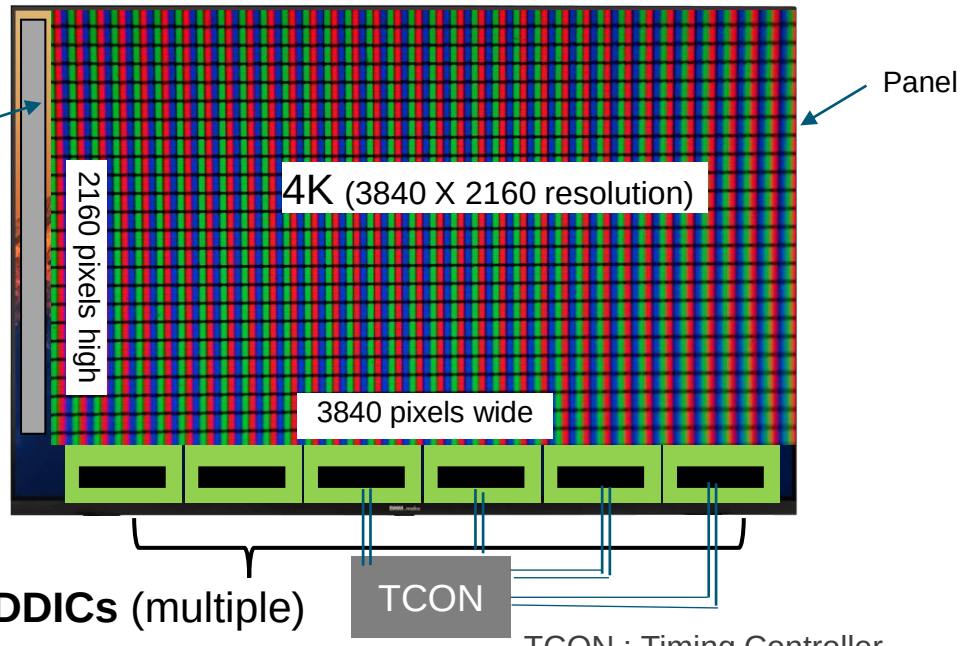
DDICs receive digital image data from application processors (AP) and timing controllers (TCON), convert them into pixel-by-pixel analog signals (gradations), and input them to the panel (screen). The signals are input to all pixels of one horizontal column of the panel simultaneously, and the gate-on-array (GOA) displays the image in full screen by sequentially switching which vertical columns are input. The functions of DDICs, the number of them used per product, and their mounting method vary by application.

Small panels (smartphones, wearables)



DDIC (1)

Large panels (TVs, PC monitors)



DDICs (multiple)

AP : Application Processor

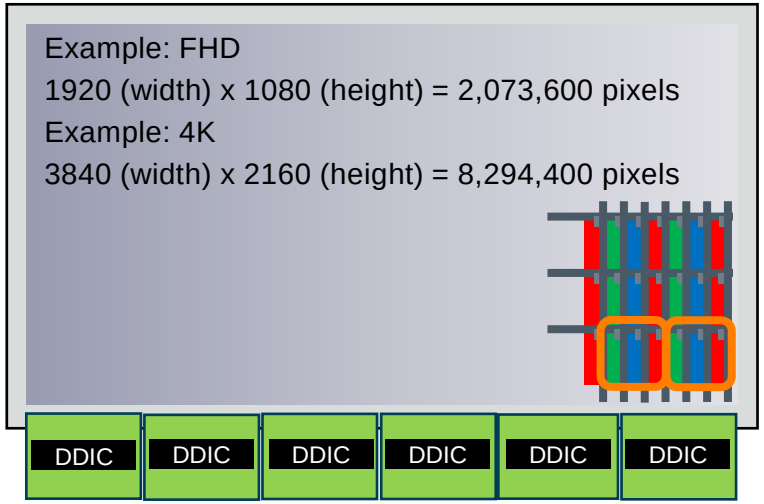
TCON : Timing Controller

Higher DDIC functionality is indispensable to better display image quality

DDICs Control Display Quality

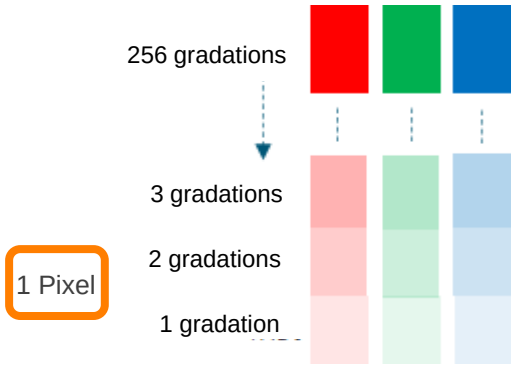
Pixel count (resolution)

Pixel count indicates the total number of pixels (the smallest units in a graphic display) that make up the screen. A typical pixel consists of three bytes representing the primary colors of light: red (R), green (G), and blue (B).



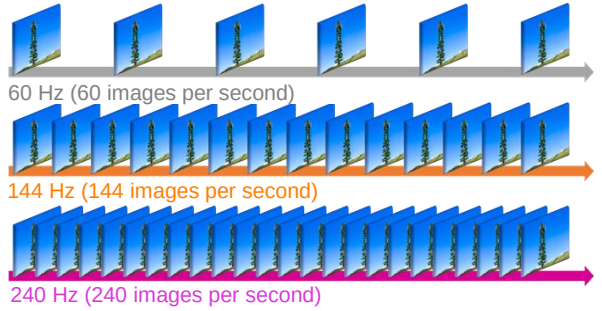
Color (gradations)

The most widely-used (8-bit) RGB components each have 256 possible values, ranging from 0 to 255. Such a pixel can express 256x256x256 = 16,777,216 color gradations.



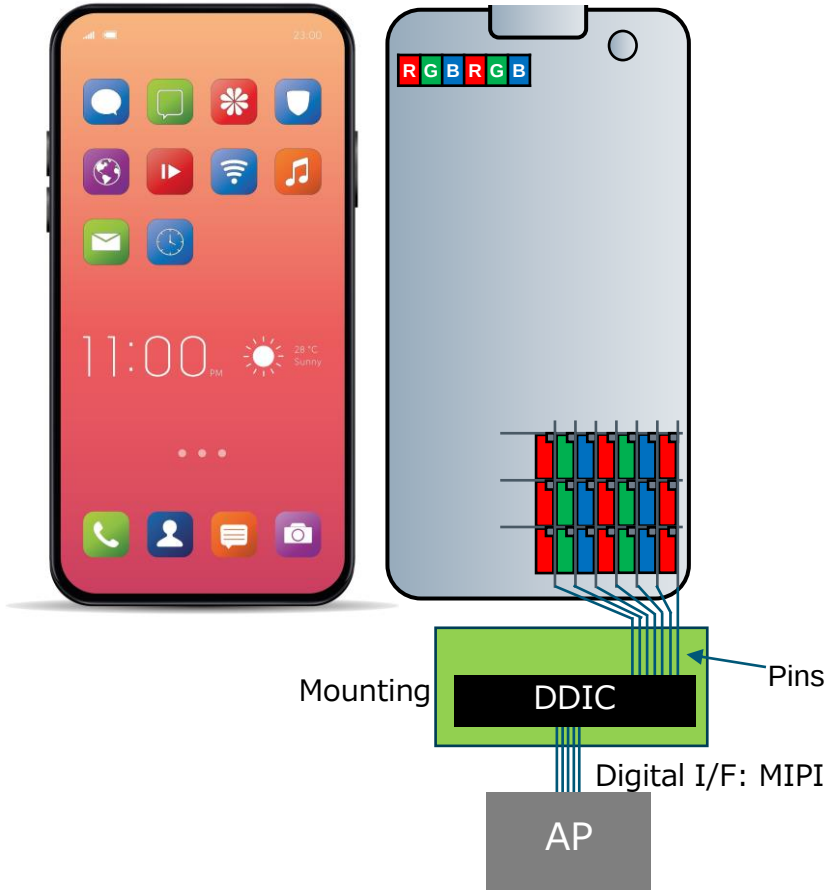
Refresh rate

Videos are just strings of still images displayed one after the other, like flip books. The more still images per unit time, the smoother the video will look. The number of still images per second is called the refresh rate.



Increasing the resolution, number of gradations, and refresh rate improves image definition and video smoothness

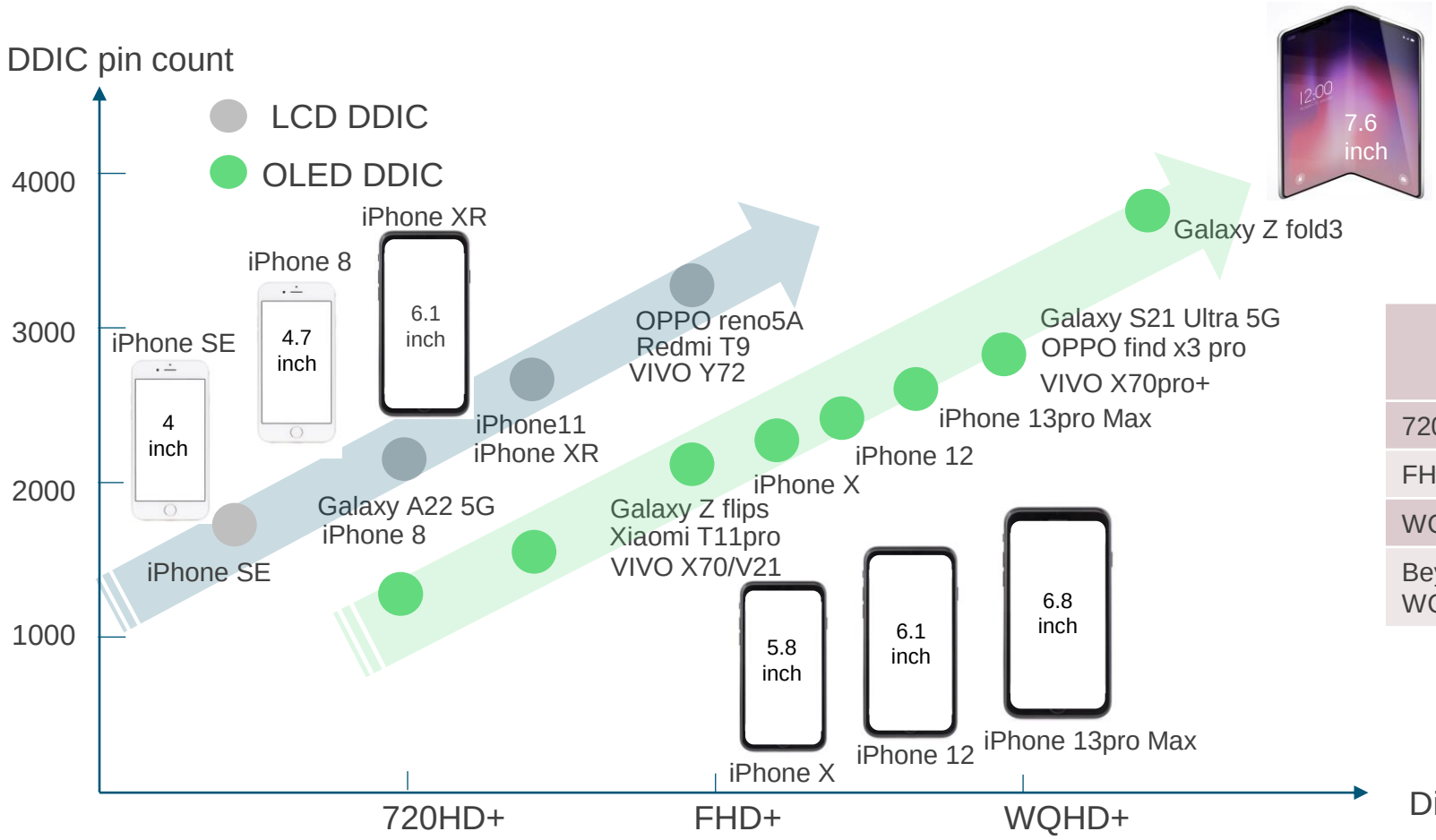
Smartphone DDIC Trends



Smartphone DDIC Features	
Number used	1 per smartphone (Foldable phones may use two)
Pin count	Tends to increase with resolution Generally 2160~2880pin
Digital I/F	The MIPI specification defines the interface between the application processor (AP) and the display
Mounting	Chips can be mounted on glass, plastic, film, and other materials (COG/COP/COF)
Functions	Display driver Image compression data processing Image memory Touch function (TDDI products) OLED-specific functions (uniformity correction, high voltage reference precision, etc.)

Smartphone DDIC pin counts are increasing to improve resolution and boost multifunctionality, saving power and space. Another new feature is a mounting method that enables bezel-less displays

Smartphone DDIC Pin Counts



Display resolution & DDIC pin count

Resolution (width x height)		DDIC pin count	
		LCD	OLED
720HD+	1280～1640 x 720	2160	1440
FHD+	1920～2640 x 1080	3240	2160
WQHD+	2560～3200 x 1440	-	2880
Beyond WQHD+*	3000< x 1440<	-	3000<

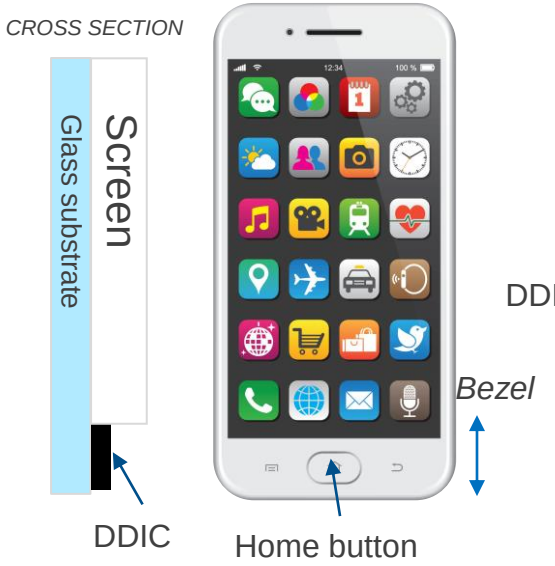
* Foldable

WQHD: Wide Quad High Definition.
Smartphone / monitor display resolution.

DDIC pin counts have increased as the resolution of smartphone displays has improved

Smartphone DDIC Mounting Methods (COG/COP/COF)

COG (Chip On Glass)



Bezel

Wafer test

COP (Chip On Plastic)

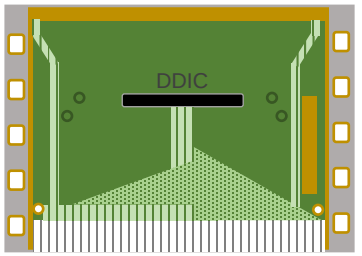
Bezel-less

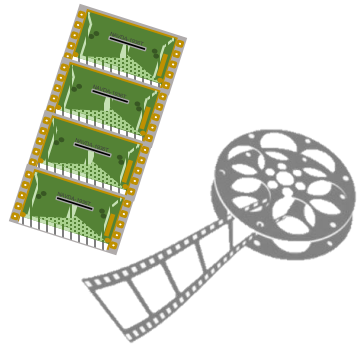
Wafer test

COF (Chip On Film)

Bezel-less

Wafer test
Final test





For COF mounting, testing on film is mandatory and a final test is added.

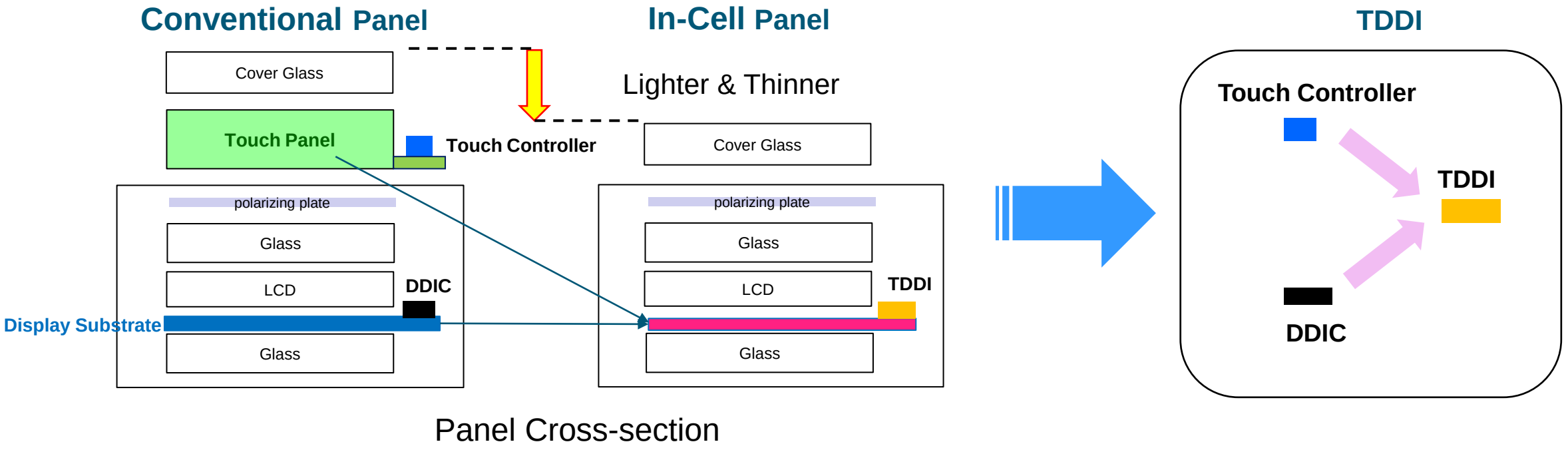
Smartphone DDIC mounting methods

	Bezel	Bezel-less
LCD	COG	COF
OLED	-	COP/COF

Three types of DDIC mounting methods for smartphones exist (COG / COP / COF), and a final test is added for COF

More DDIC Multifunctionality: TDDI (Touch and Display Driver Integration)

In-Cell Panel technology, which combines the touch panel and the display substrate into a single layer, is gaining popularity with makers of smartphones and tablets, as it makes displays lighter and thinner. Thus, more and more products are now equipped with TDDI chips, which integrate DDIC and touch controller functions into a single package.

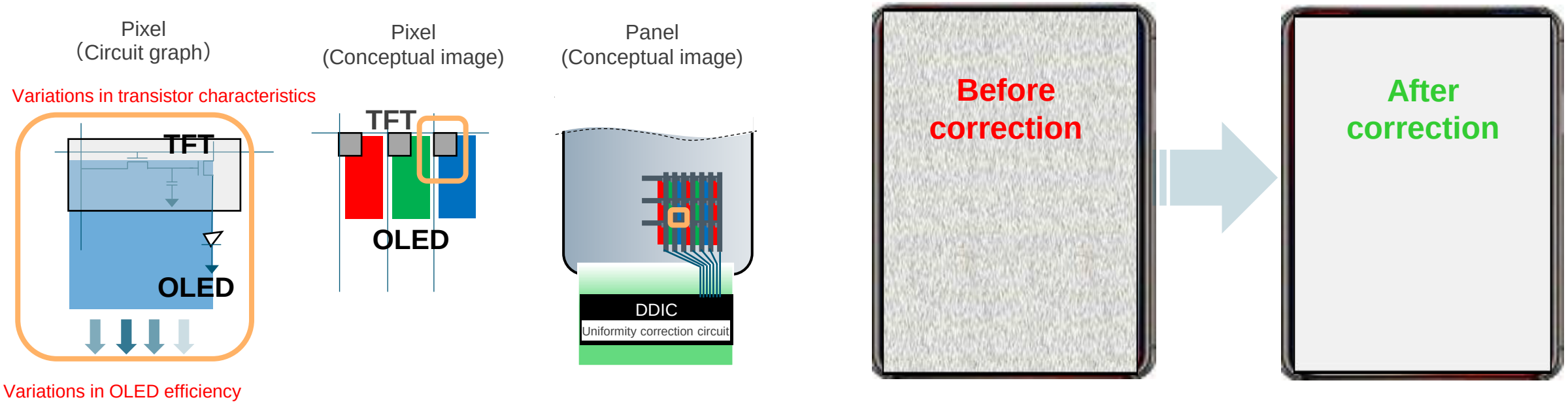


Panel Cross-section

Adoption of TDDI, which integrates touch controller functions into LCD DDICs, is accelerating. Adoption for OLED DDICs, as well, is expected to grow in the future

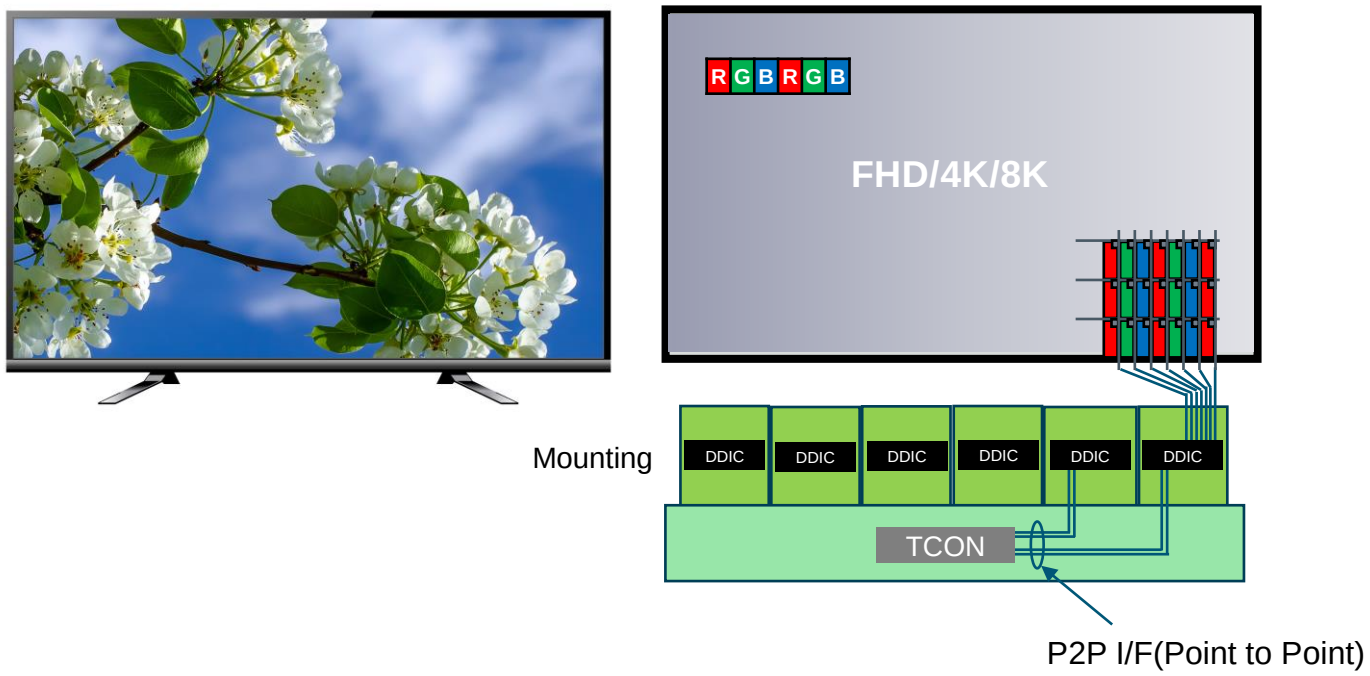
More DDIC Multifunctionality: OLED Display Uniformity Correction

OLED displays sometimes have manufacturing issues with color uniformity: color tones may differ at various points on the screen, due to variation in the characteristics of the transistors built into the substrate and the light emitting efficiency of the OLED elements in each pixel. OLED DDICs can correct this lack of uniformity by minutely adjusting the voltage of the signal input from the DDIC for each pixel.



OLED DDICs have special circuits to enable OLED-specific functions

TV DDIC Trends

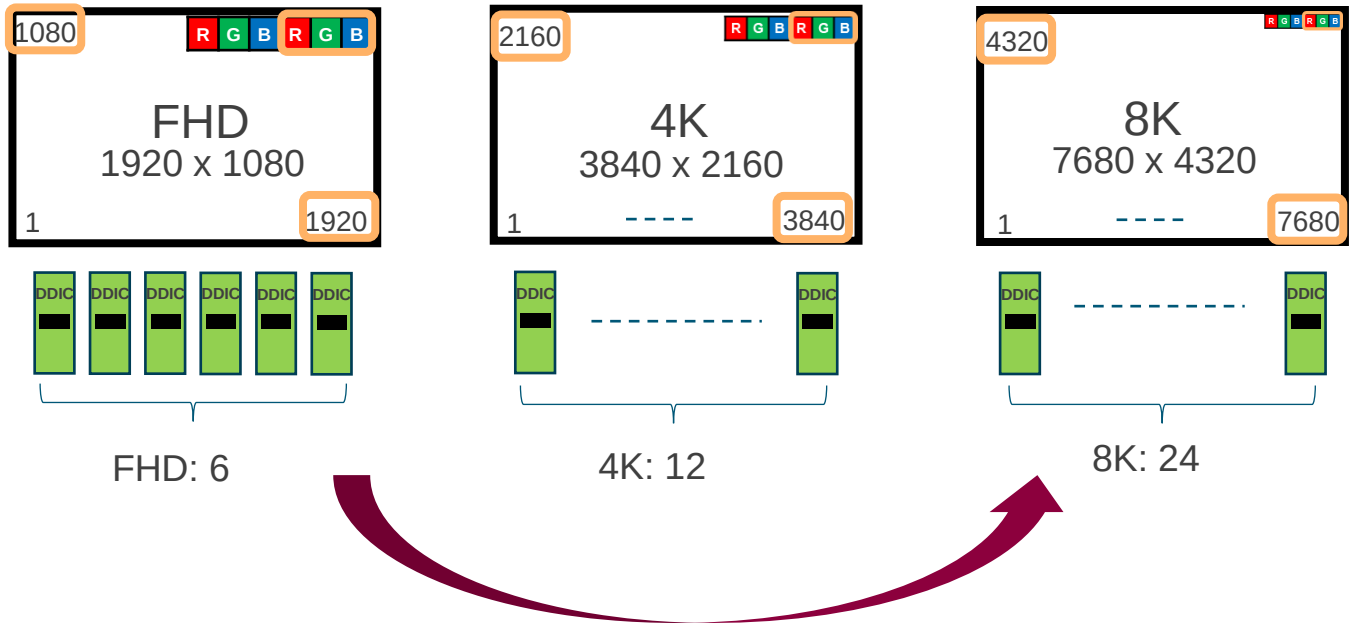


TV DDIC Features	
Number used	Multiple, depending on the resolution of the display
Pin count	Generally 960pin-1440pin
Digital I/F	P2P. As display resolution increases, the speed of communication between the TCON and DDIC also increases.
Mounting	COF
Functions	Display driver OLED life extension

The number of DDICs required per TV is increasing due to higher resolution. Digital I/F speeds are also increasing

How Many DDICs Per TV?

Number of DDICs needed for FHD/4K/8K resolution



Resolution (width x height)		DDICs (960 pin)
FHD	1920 x 1080	6
4K	3840 x 2160	12
8K	7680 x 4320	24

960-pin DDICs are standard for TV displays. 1920x3 (RBG) = 5,760 pins needed for FHD resolution, so given that one DDIC has 960 pins, 5,760/960 = 6.

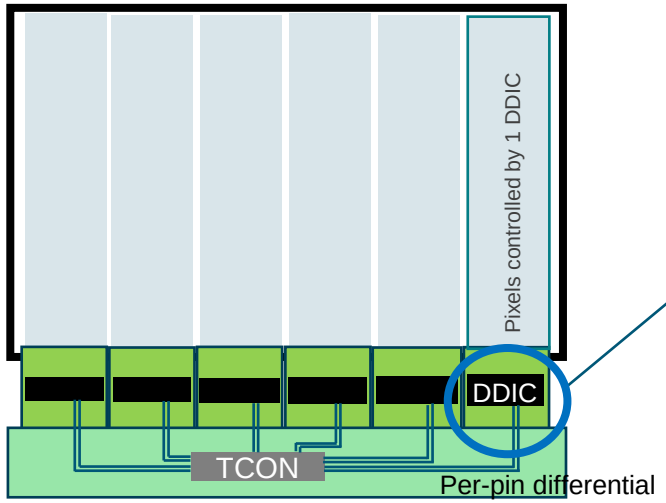
Display resolution is a numerical value that indicates how many dots (pixels) are on the screen, thus it is calculated as "the number of dots horizontally x the number of dots vertically". Full HD (FHD) is 1,920 x 1,080 (2,073,600 pixels), and 4K is 3,840 x 2,160 (8,294,400 pixels). 8K is an order of magnitude higher at 7,680 x 4,320 (33,177,600 pixels).

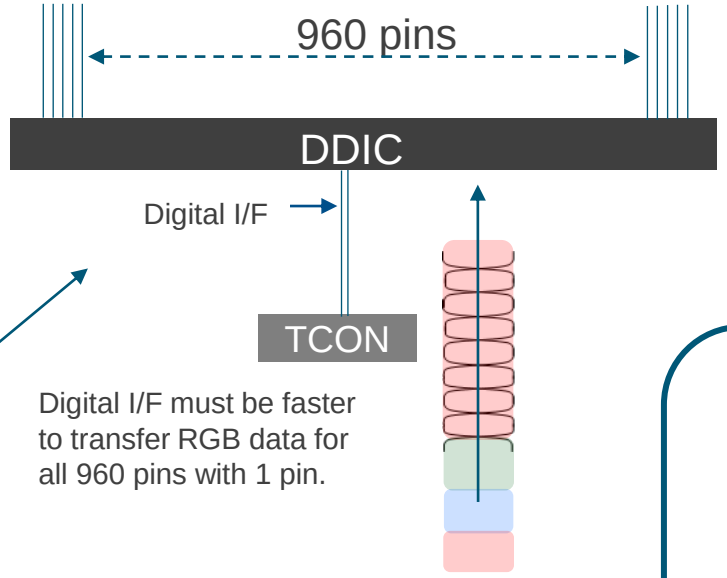
Four times as many DDICs are needed for an 8K TV compared to FHD!

The number of DDICs used varies depending on resolution. High-resolution displays require more DDICs

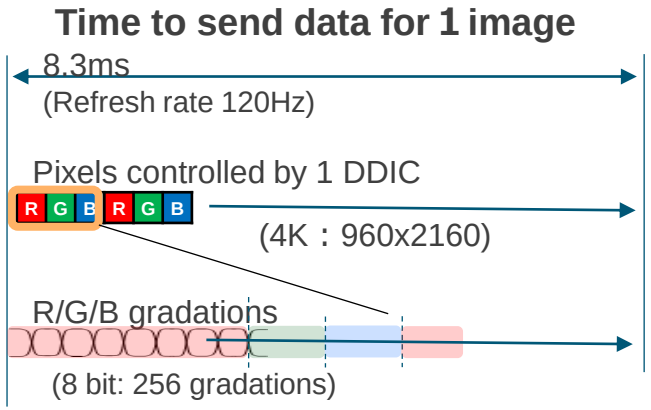
TV DDIC Digital I/F Speeds Increasing

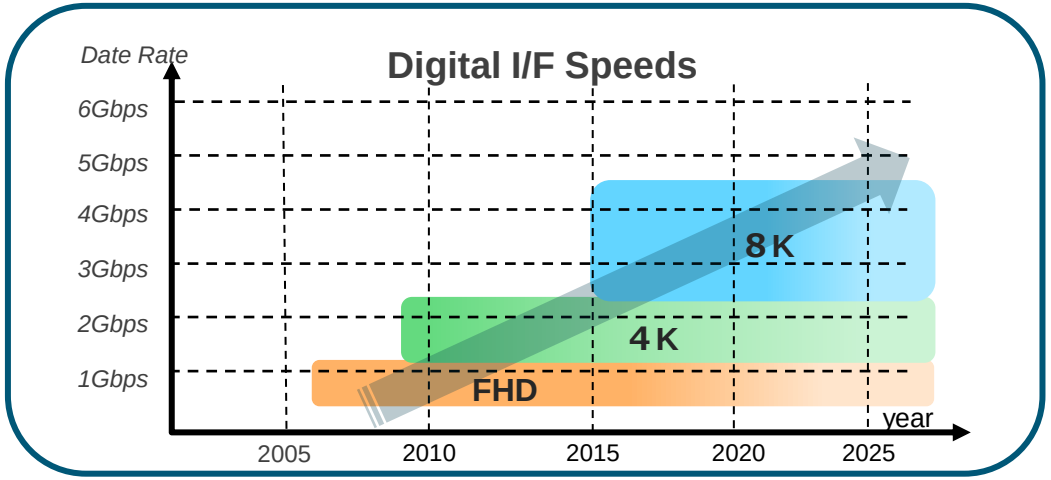
Digital I/F speed is determined by the number of pixels, the number of gradations, and the refresh rate.





Digital I/F must be faster to transfer RGB data for all 960 pins with 1 pin.

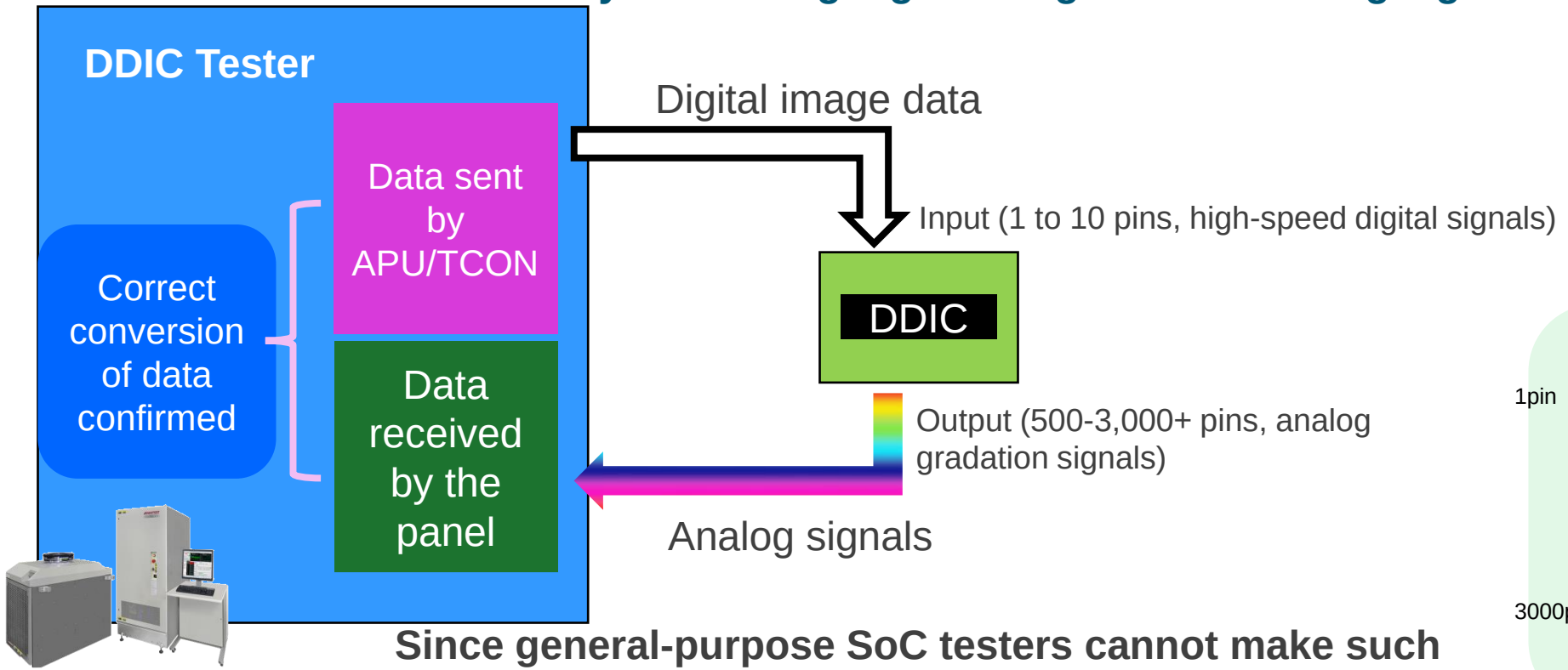


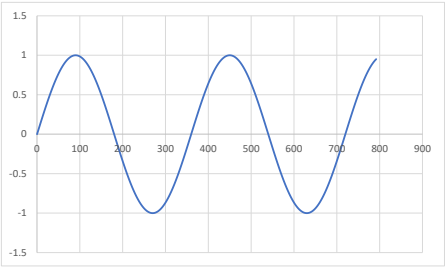


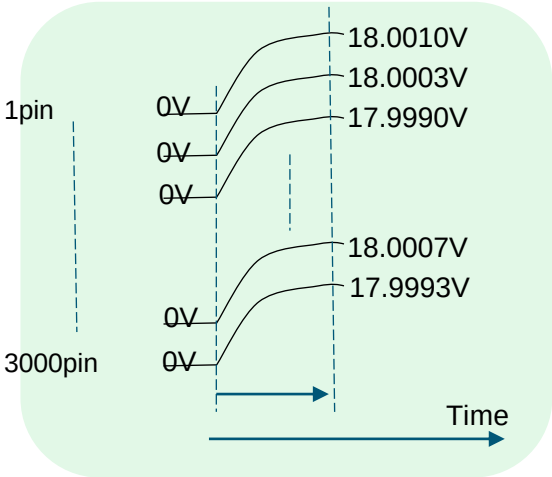
I/F speeds are accelerating as display image quality improves

DDIC Test

Confirms that the DDIC is correctly converting digital image data to analog signals for the panel.







Since general-purpose SoC testers cannot make such a large number of simultaneous analog measurements, a dedicated DDIC tester is required.

A DDIC tester simultaneously measures analog waveforms for more than 3000 pins and determines whether the device under test is operating correctly

Advantest DDIC Test Solutions: T6391

➢ Delivers all the functions needed to address DDIC test challenges

Faster digital IF for higher resolution, higher gradation count, higher refresh rate

High-speed digital IF

- Equipped with a high-speed IF measurement option (6.5 Gbps) that supports test of all high-speed IF standards for smartphones and TVs

Higher display resolution increases pin counts

Supports DDIC pin count growth

- By applying our SoC multi-pin contact technology, we achieved the industry's highest LCD channel count of 3,584 pins
- DDICs for high-resolution smartphones can be tested in one shot

Multi-functionality; e.g. touch controller test

Analog measurement option

- Equipped with analog measurement option required for testing touch sensor and fingerprint sensor functions

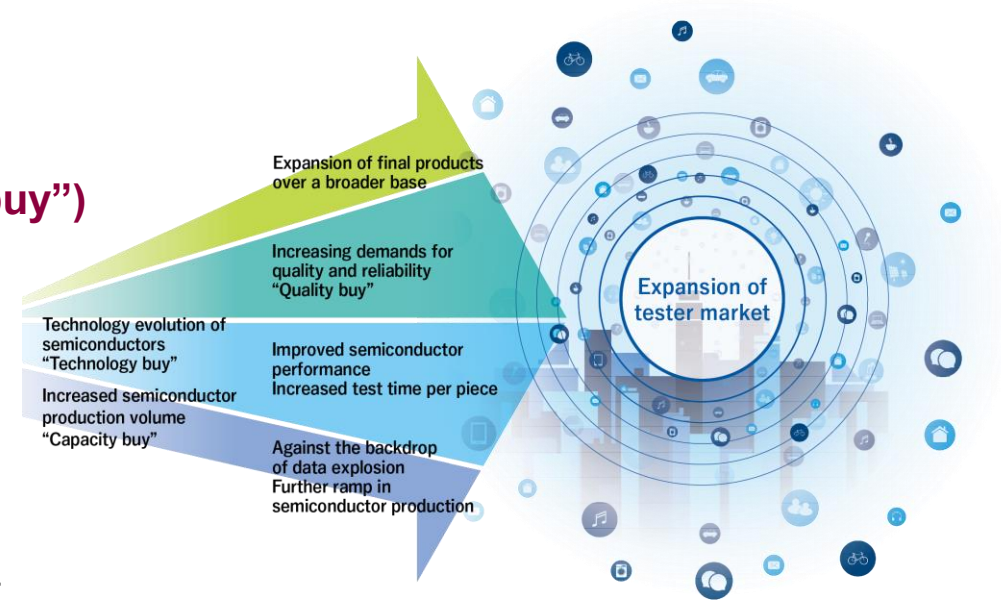
Efficient use of customer assets

Flexible system configuration & compatibility

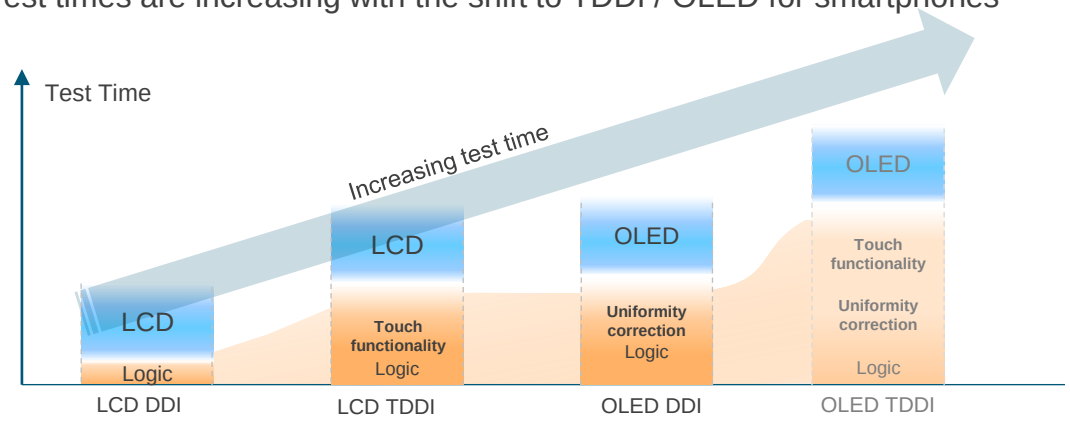
- Test programs and device interfaces for previous systems can be used
- Wafer test and final test are interchangeable, making it easy to respond to fluctuations in COG / COP / COF production volumes

The DDIC Market So Far & Expansion of the Test Market

- **More end products every day**
  - ✓ TVs, smartphones, wearables ...
- **Stronger requirements for product quality and reliability (“Quality buy”)**
  - ✓ Due to the widespread adoption of automotive displays, stronger quality assurance guarantees, such as high test coverage, are required
- **Increased tester functionality and longer test times due to upgraded DDIC performance (“Technology buy “)**
  - ✓ Widespread use of OLEDs, higher pin counts, multifunctionality, TDDI, higher speeds
  - ✓ Addition of final test demand for COF mounting
- ✓ **Higher semiconductor production volumes (“Capacity buy”)**
  - ✓ Increased number of DDICs per TV for high-definition and increased demand for PCs due to work-from-home



Test times are increasing with the shift to TDDI / OLED for smartphones



Unending Display Evolution

Diversification and ongoing technological evolution

Automotive displays

Tested by Advantest

Metaverse

Coming Soon: HMI* Devices

* HMI : Human-Machine Interface

Advantest contributes to social progress by supporting the innovative evolution of displays