TECHNICAL ARTICLE

High-Scan LED Display I: Analysis of the 64-Scan Driver IC

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High-Scan LED Display I:
Analysis of the 64-Scan Driver IC

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Introduction

As LED displays march toward smaller pixel pitch, time-multiplexing, became the technology of choice for displays to overcome the dimensional limitation of the printed circuit board (PCB), where highly-integrated driver ICs are incorporated into high-end display products to reduce the number of components on the PCB and to save on PCB layout space.

Observation of driver IC development in the recent years shows that the highest scan number supported by time-multiplexing LED displays has stalled at 32 scans. Although the market expects for higher-scan LED displays to be produced, there exist the technical challenge that when the number of scans increases, the display quality and performance decreases.

Fortunately, with recent breakthrough in time-multiplexing technology, driver ICs can now support up to 64-scan design without sacrificing much of the display performance. This advancement also enables a better balance between the number of driver ICs deployed on the PCB, and the total power consumption of the display modules. Thus making the miniaturization of LED display pixel pitch smaller than 1mm a more feasible option.

This article discusses the technical challenges in higher-scan LED displays, and helps readers understand Macroblock's driver IC solutions through the use of actual design examples.

The Two Challenges in High-Scan Displays

Challenge 1: increasing scan number causes insufficient LED brightness

When using a time-multiplexing design, the LED display is shown in a row by row scanning sequence. Fig. 1 illustrates the number of scans that corresponds to the channels turn on time in one frame. Using a driver IC that supports 32 scans as an example, one row is refreshed each time and 32 rows is one scan cycle. Thus, when the number of rows scanned is increased to 64 scans, then 64 rows will be one scan cycle.

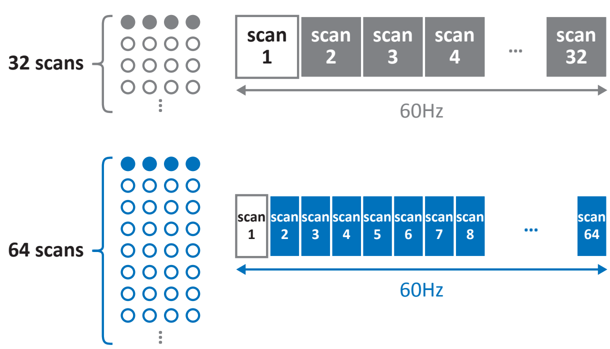

Figure 1 Using traditional cascade driver ICs

Thus, to maintain the same grayscale output in a single frame duration (T_{Frame}) as the scan number increases, the display's grayscale display time (T_{GCLK}) needs to be reduced, which results in reduced brightness.

Fig. 2 shows a generic SMD1010 LED current-efficiency curve. The turn-on current of the LED and the luminosity is an incremental relationship. When the scan number of the driver IC increases, the supplied current to the LED also has to be increased to maintain the same grayscale, frame refresh rate, and brightness conditions. However, because of the non-linear aspect of the LED current-efficiency relationship, increasing the current of the LED driver IC must be tuned to different LED luminous efficacy to achieve an ideal brightness and white balance.

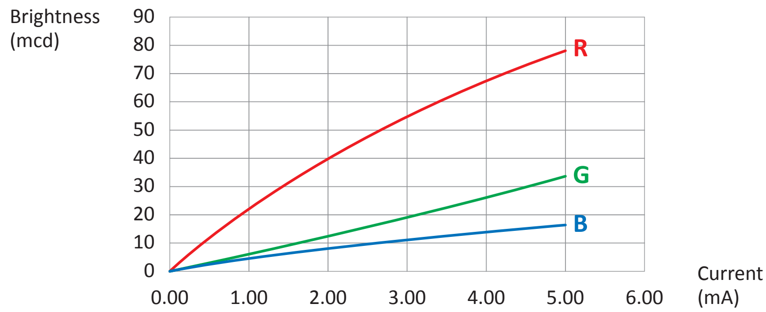

Figure 2 LED luminous efficacy

Challenge 2: Not Sacrificing Display Performance

There are mostly seven common problems in fine-pitch displays, which consists of dim lines, ghosting, gradient dim line, LED cross, color shift at low grayscale, non-uniformity at low grayscale, and high contrast interference. The problem that is directly related to increasing the scan number is high contrast interference.

The root cause of high contrast interference is parasitic capacitance of LED. The capacitance will form a circuit loop between channels. As shown in Fig. 3, when a LED is turn on for high grayscale, it changes the channel (V_{OUT1}). An interfering signal will affect the low grayscale channel's voltage (V_{OUT0}) through the circuit loop of LED parasitic capacitance, and changes the brightness of the LED that is displaying a low grayscale.

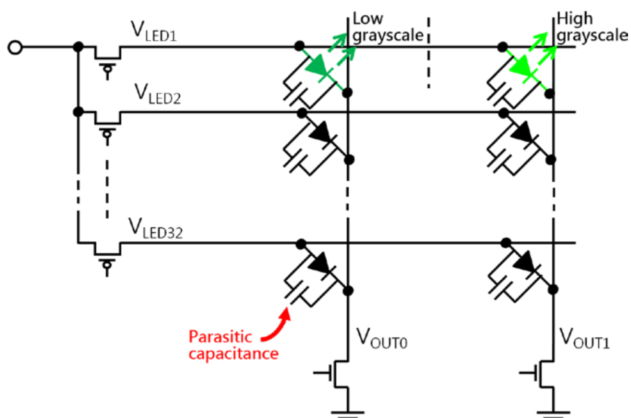

Figure 3 High contrast interference

By using a driver IC that supports higher scans, LED module designers are able to utilize more LED pixels into a scan area of a driving circuit. However, the increase of parasitic capacitance of LEDs will elevate the high contrast interference effect. All driver ICs from Macroblock that support 64-scan are equipped with a "novel low grayscale processing circuit", which would effectively reduce the negative effect of high contrast interference that plagues all LED displays using time-multiplexing driver ICs with high scan numbers.

The demonstration below compares three different P1.5 LED modules by their abilities to solve the high contrast interference problem. There are two modules each using 32-scan driver ICs and 64-scan driver ICs from another maker. And the third module that utilizes the Macroblock 64-scan driver IC. When comparing the two modules, the module with the 64-scan driver ICs shows a more apparent high contrast interference problem than the one using the 32-scan driver IC (Fig. 4, right side). However, with Macroblock's solution, since Macroblock's 64-scan driver IC has the "novel low grayscale processing circuit," to solve the high contrast interference problems, the negative effects were much alleviated comparing to the competing solutions (Fig. 5, right side).

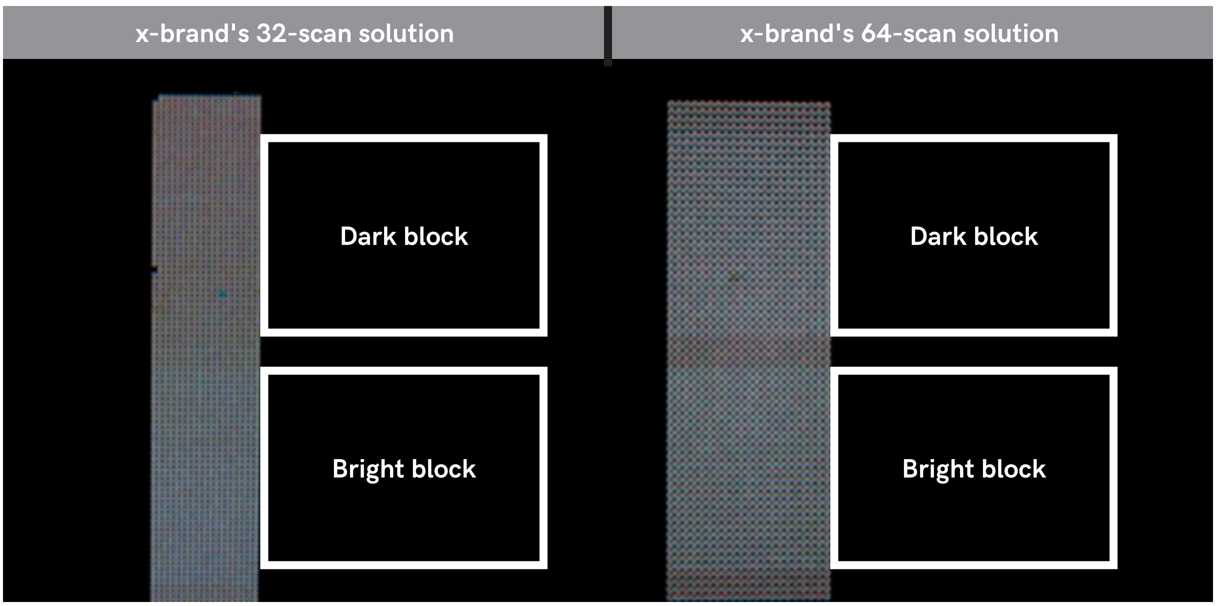

Figure 4 The LED module with x-brand's 64-scan driver IC has clear high contrast interference problems

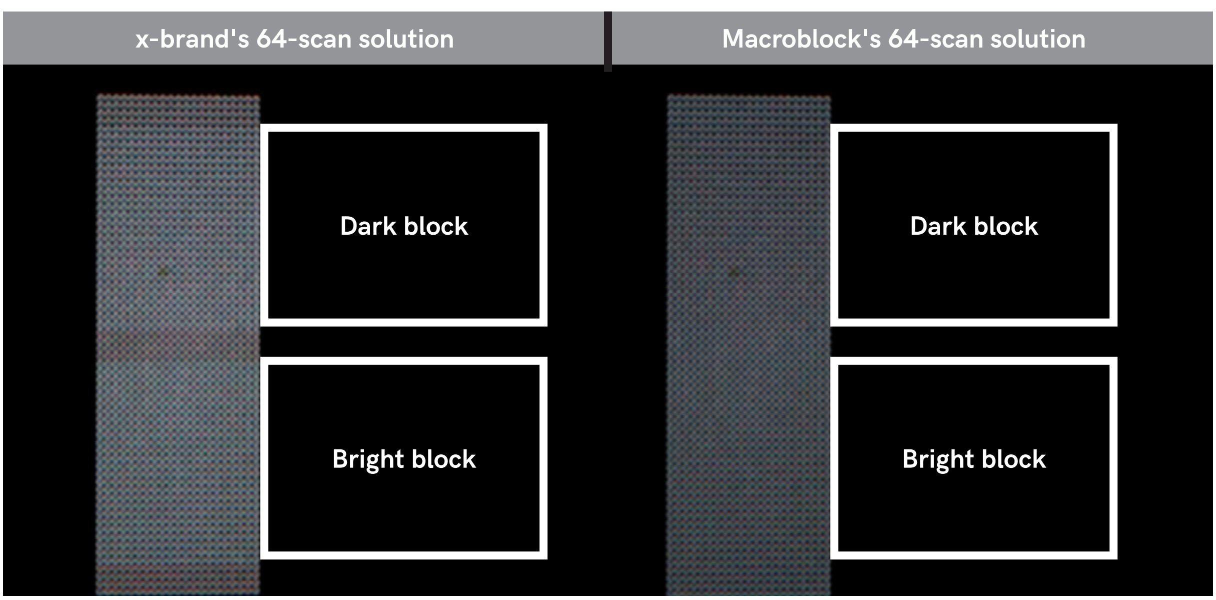

Figure 5 Macroblock 64-scan driver IC can help improve high contrast interference problems

The next demonstration a linear gradient grayscale pattern was used to test the performance of the display modules. Color shift problems at the module-crossing area are found on modules using the other maker's 64-scan driver IC, (Fig. 6, right side). In contrast, the LED module with Macroblock's 64-scan driver IC significantly improved the performance of the gradient pattern, with no apparent color shift.

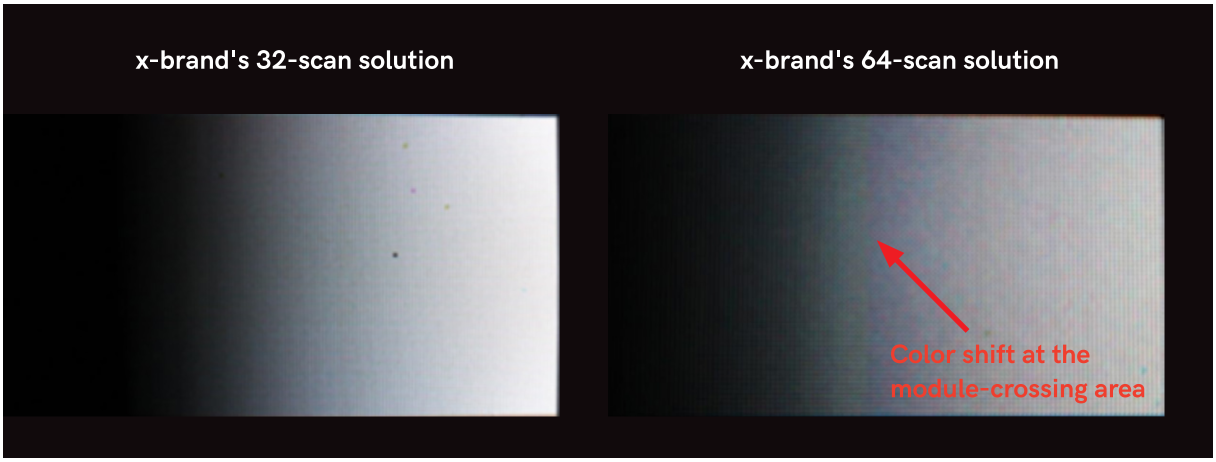

Figure 6 LED module with x-brand's 64 scan driver IC
showed poor linear gradient image and color shift problem at the module-crossing area

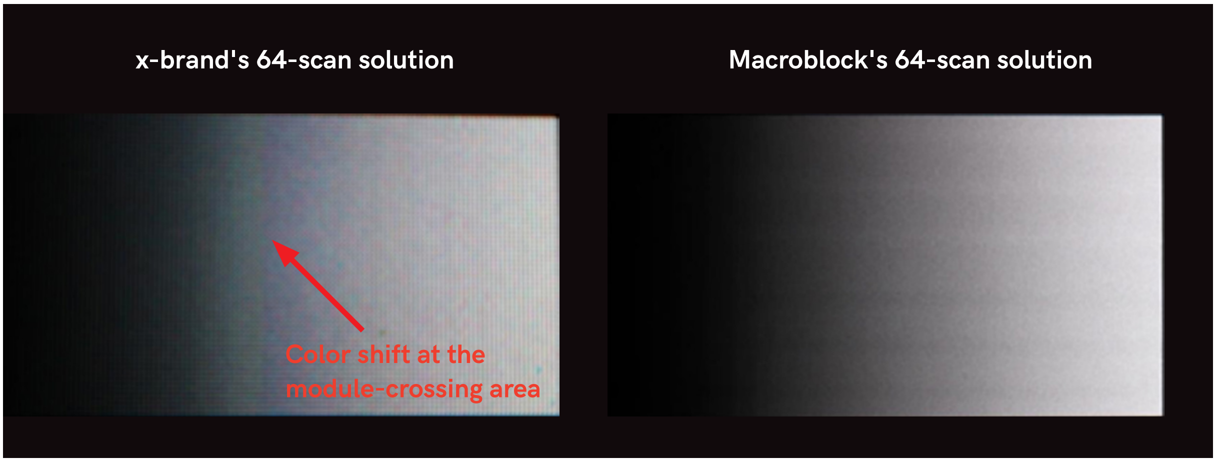

Figure 7 The LED module with Macroblock's 64-scan driver IC
shows superior linear gradient performance and improved color shift at the module-crossing area

Actual Use Case Comparison

The previous section demonstrated how Macroblock's 64-scan driver IC solution can overcome display performance issues originated from high-scan number time-multiplexing framework. The following section of the paper will use the LED module with MBI5253/27-scan (16-channel driver IC that supports up to 32-scan) and the LED module with MBI5254/54-scan (16-channel/driver IC that supports up to of 64-scan) as examples to show how Macroblock's high-scan driver IC solution is advantageous in terms of the amount of driver ICs required, power consumption, and data transmission.

Amount of Driver ICs per Module

From the vertical and horizontal resolution listed in Table 1, the LED module with MBI5253/27-scan solution requires the use of 72 driver ICs, while the LED module with MBI5254/54-scan solution only requires the use of 36 driver ICs. Thus, increasing the scan number supported by the driver IC can effectively reduce the amount of driver ICs needed by the LED display module.

Table 1 P1.5 LED module specification comparison

Solution	MBI5253	MBI5254
Module vertical resolution	108	108
Module horizontal resolution	96	96
Scan numbers	27	54
Total number of ICs used (PCS)	72	36

Difference in Module Power Consumption

Aside from LED display performance, the power consumption is also a major concern from the end-users. High power consumption not only increases electricity costs, but also create thermal problems for LED display cabinets. When large amount of heat is generated by driver ICs on the module PCB, it can cause LED to have degenerated color and color shift while operating.

The module's total power consumption consists of the following four parts: MOS switching power (P_{SW}), LED driving power (P_{LED}), driver IC knee voltage power (P_{knee}), and the sum of power consumption from all the driver ICs on the LED module (P_{ICs}).

Next, the power consumption between the MBI5253 module with 27-scan, and the MBI5254 module with 54-scan are compared. The modules were set to 800 nits with a white balance color temperature at (0.31, 0.31).

The current through the system's LED conduction path is used to calculate the MOS switching power (P_{sw}), the LED driving power (P_{LED}), and the driver IC knee voltage power (P_{knee}), respectively. Furthermore, the driver IC's working current and voltage can be derived from the grayscale and refresh rate conditions that are set to the display specifications. The total amount of driver ICs can then be used to calculate the power consumption from all the driver ICs on the LED module (P_{ICs}), as shown in Table 2.

Table 2 P1.5 LED module specification comparison

LED modules	MBI5253	MBI5254	Difference (%)
MOS switching power (W)	0.09	0.21	133.3%
LED driving power (W)	4.23	4.76	12.5%
Driver IC's knee voltage power (W)	2.94	2.79	-5.1%
Power consumption from all the driver ICs on the LED module (W)	1.75	1.04	-40.6%
The module's total power consumption (W)	9.01	8.8	-2.3%

As shown in Table 2, the total LED module power consumption for MBI5254 is 2.3% lower than that for MBI5253. This is because the power consumption for the all the driver ICs on the LED module decreased by 40.6%. The pie chart below (Figure 8) breaks down the module's total power consumption and shows that MBI5254 solution's overall power consumption composition were lower than that of MBI5253 while the other system power consumptions were slightly higher. The reason is that when scan number increases, the LED driving current must also be increased to maintain the same brightness, which resulted an increased in power consumption.

When an LED display is used for indoor high-resolution (4K, 8K display) and the pixel pitch is reduced to 1mm, the amount of driver ICs placed on the module will have to increase. This has a considerable impact on the total driver IC power consumption. Thus, when the proportion of the power consumption from all driver ICs on the LED module to the total module power consumption increases, the use of driver IC that can support a high-scan number would help lower the total module power consumption and save energy.

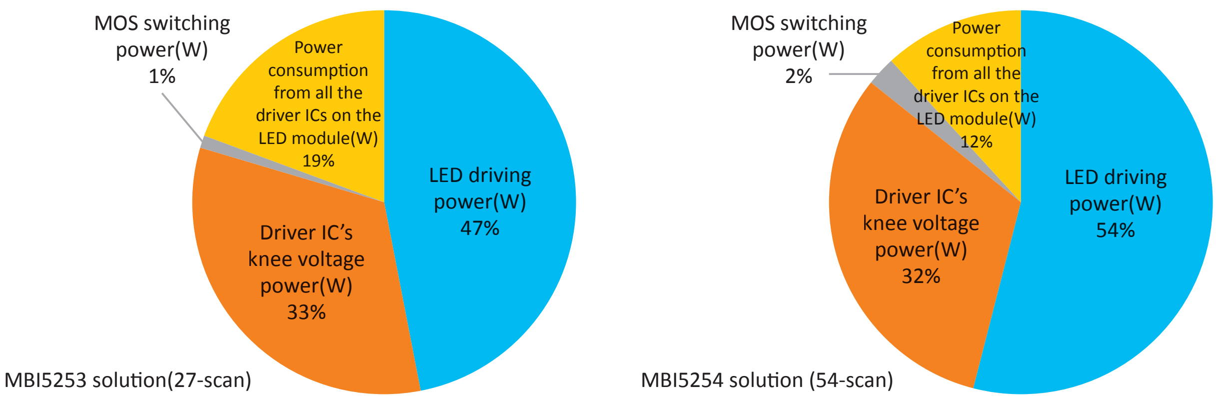

Figure 8 LED module power consumption distribution

Data Transmission

When the driver IC's under normal operation, it is crucial to complete the transmission of all DCLK data to the driver IC in one frame's time (TFrame;16.6 ms). If the data transmission is incomplete, the display will show artifacts or flickers. Thus, the DCLK frequency must be high enough to ensure the integrity and accuracy of the data transmission.

$$DCLK = \frac{Scan \cdot Channel \cdot IC_{\text{series numbers}} \cdot Grayscale}{T_{Frame}}$$

"Grayscale" is the PWM resolution, and the unit is Bit
"DCLK" is the data clock frequency
"Channel" is the number of output channels of the driver IC
"IC series numbers" is the number of cascaded driver ICs that compose a scan area on the module

From this formula, DCLK = 2.5MHz when a driver IC of 27-scan solution that is single edge triggered. When the scan number increases to 54 scans, the DCLK would have to be increased to 5MHz in order to maintain the same data transmission throughput. However, as the DCLK frequency increases, EMI also increases in the system. Designers may need to consider EMI, and add components such as a low-pass filter, which might affect the data signal integrity because of the filter circuit.

Therefore, Macroblock's driver IC provides double edge triggered DCLK to the original single edge triggered DCLK. This enables both the positive and negative edge of the data clocks to be use as logic triggers, and effetely doubles the throughput of data transmission. The benefit of this is that with the same lower data clock frequency, the integrity of transmitted data is preserved, all while remains low on EMI (as shown in Table 3).

Table 3 Data transmission time

	Channels	IC series connection number	Scan number	External DCLK (mhz)	Data transmission time (ms)
27-scan(single edge trigger)	16	6	27	2.5	11.5
54-scan(double edge trigger)	16	6	54	2.5	11.5

Matching Receiving Card

For matching the receiving cards to the driver ICs, the maximum number of pixels supported by a single receiving card may vary with different receiving card models. When developing LED display system with a high-scan number driver IC, the designer will need to consider the pixel capacity supported by the receiving cards. Table 4 shows the NovaStar receiving cards that are paired with some common applications on the market using driver ICs that supports 32 scans. When the scan number of an application is increased beyond 32 scans, the method described in the previous section can be used to calculate the pixel loading capacity that are required for a particular receiving card (Table 5) from a controller maker. The matching receiving card models used in the 64-scan solution does not need to be upgraded from the particular controller maker.

Table 4 Corresponding NovaStar's receiving card versions
for different pitches and driver IC solutions that support 32 scans

Support 32 scans					
Pitch	Resolution XxY	Single card with module x4	Scan number	Receiving card interface number	Suitable receiving card (using NovaStar as an example)
P1.9	80x90	160x180	30	12	Higher than A5s
P1.58	96x108	192x216	27	16	Higher than A5s
P1.27	120x135	240x270	27	20	Higher than A5s
P0.9	160x180	320x360	30	24	Higher than A7s

Table 5 Corresponding NovaStar's receiving card versions
for different pitches and driver IC solutions that support 64 scans

Support 64 scans					
Pitch	Resolution XxY	Single card with module x4	Scan number	Receiving card interface number	Suitable receiving card (using NovaStar as an example)
P1.9	80x90	160x180	45	8	Higher than A5s
P1.58	96x108	192x216	54	8	Higher than A5s
P1.27	120x135	240x270	45	12	Higher than A5s
P0.9	160x180	320x360	60	12	Higher than A7s

Cost Effective to Use Driver ICs with High-Scan Support

Using a one square meter display as an example, the total number of components, such as the LED driver ICs, current setting resistors (REXT), and voltage stabilizing capacitors, can be obtained by the display's horizontal and vertical resolution, the driver IC's scan number, and the number of output channels. Table 6 shows that only half of the components are required for a 54-scan LED module with MBI5254 compares to a 27-scan module with MBI5254 solution. The reduction of required components directly affect the component and production cost of the display.

Table 6 Component quantity estimation

Pixel pitch	Scan number	number of LEDs	Driver ICs (using 16-channel product as an example)	Resistors 0402	Capacitors 0805
1.5	27	444,444	3,086	3,086	3,086
1.5	54	444,444	1,543	1,543	1,543

Macroblock's High-Scan Number Driver IC Solution

Macroblock introduces a new generation of 64-scan driver IC solutions (Fig. 9) that tackles the challenges presented by high-scan LED displays. The 16-channel common-anode LED driver IC (MBI5254) is suitable for P1.0 to P4 pixel pitch displays. The 48-channel common-anode LED driver IC (MBI5354) is suitable for P0.9 to P4 pixel pitch displays and the 16-channel common-cathode LED driver IC (MBI5754) is suitable for P1.2 to P4 pixel pitch displays.

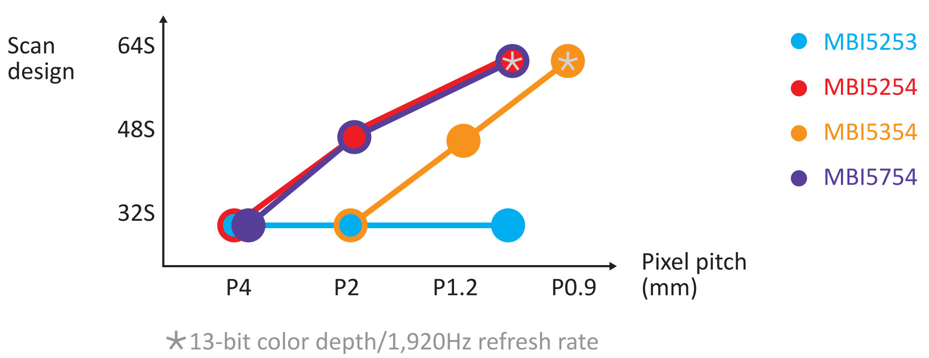

Figure 9 Driver IC scan numbers vs. pixel pitch

Conclusion

LED driver ICs with high-scan support can significantly reduce the number of components required of LED display system, lower production costs while maintaining display performance and reduce the display module's total power consumption. Macroblock's next generation of 64-scan driver IC solutions provides the advantages of high-scan displays while overcoming corresponding difficulties, enabling cost effective solutions to designers and developers of LED displays

As the market constantly demands for higher quality LED displays, the driver IC technology will also advance with the trends. Macroblock is always striving to develop better technology that would supply the industry with superb LED driver IC solutions. Our goal is not only to assist our customers to solve any problems in display applications, but also to stand out in the next generation of high-scan LED display market.

About Author

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Work in the development of LED display driver IC. Using system analysis and system simulation experience combined with current display market trends to improve new product technology.

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Plenty of semiconductor processing expertise gained through years of R&D in semiconductor technology and processing. In charge of new product development and technology breakthrough for Macroblock's LED display driver ICs.