Introduction to OLED Displays Design Guide for Active Matrix OLED (AMOLED) Displays

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Introduction

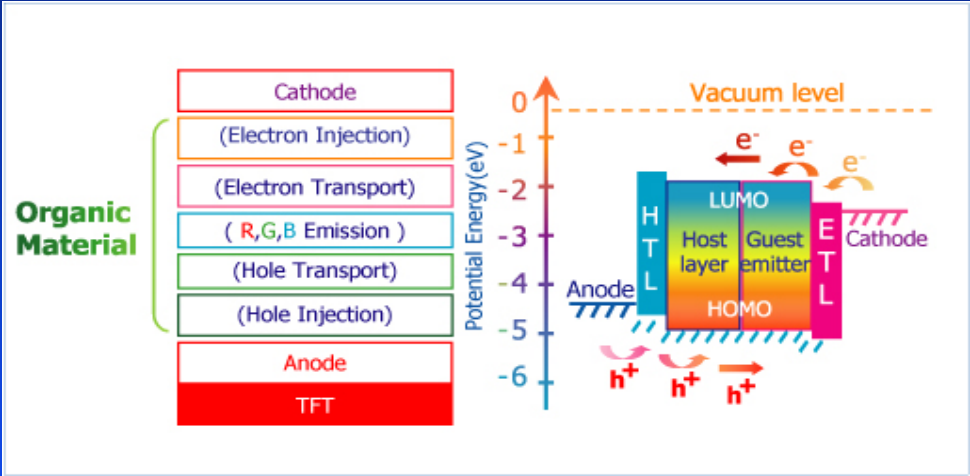
- Active Matrix OLED (AMOLED) is a new display technology that is rapidly becoming viable for many applications.
- It has some undoubted benefits over competing technologies.
- 4D holds no responsibility or liability for the accurateness of the information and how it is applied to any design.

What is an OLED?

- OLED (Organic Light-Emitting Diode) is a self light-emitting technology composed of a thin, multi-layered organic film placed between an anode and cathode. In contrast to LCD/TFT technology, OLED does not require a backlight.

How does an OLED emit light?

- OLED's basic structure consists of organic materials positioned between the cathode and the anode, which is composed of electric conductive transparent Indium Tin Oxide (ITO). The organic materials compose a multi-layered thin film, which includes the Hole Transporting Layer (HTL), Emission Layer (EML) and the Electron Transporting Layer (ETL). By applying the appropriate electric voltage, holes and electrons are injected into the EML from the anode and the cathode, respectively. The holes and electrons combine inside the EML to form excitons, after which electroluminescence occurs. The transfer material, emission layer material and choice of electrode are the key factors that determine the quality of OLED components.



Comparison between OLED and TFT Display

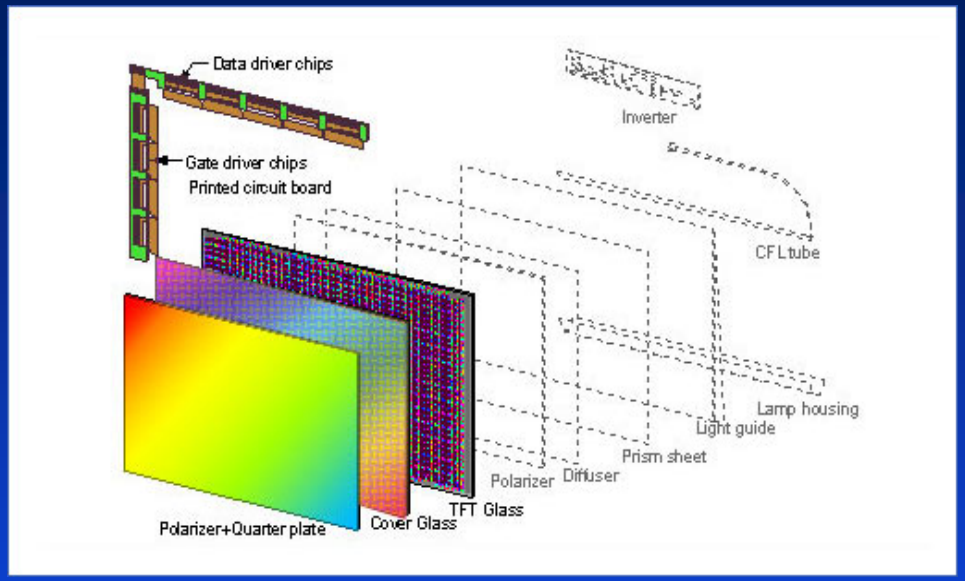


Figure 1 - AMOLED

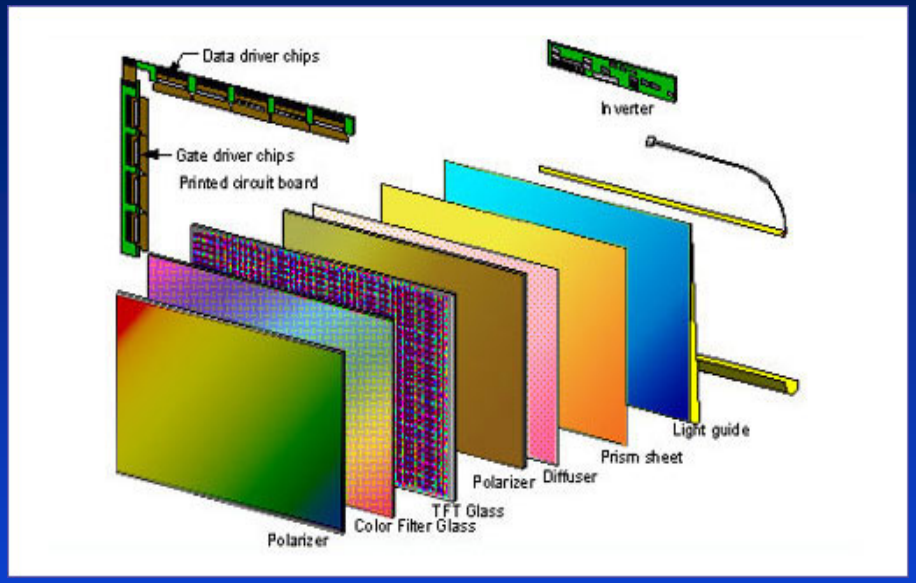


Figure 2 – TFT Display

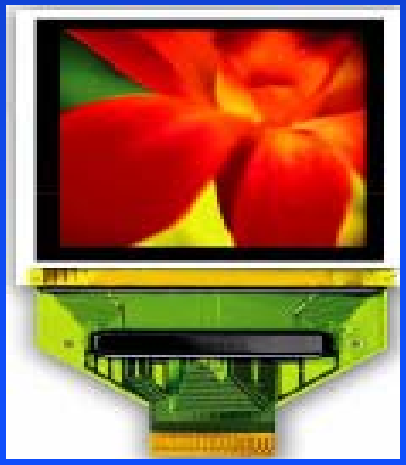
AMOLED has less complexity so is much thinner

Active vs Passive Matrix

- 4D Systems offers both the Active Matrix and the Passive Matrix OLED modules.
- Passive Matrix is low cost but can only be manufactured economically in colour to a size of 1.69” (160x128pixels). Standard industry sizes for colour PMOLED is 0.95” (96x64) and 1.5” (128x128). Most of the new development is in Monochrome Displays using White, Blue or Yellow colouring.

So what’s the difference?

- AMOLED, the array is divided into a series of row and column lines, with each pixel formed at the intersection of a row and column line, just as in a passive-matrix display. Each pixel now consists of an OLED in series with a thin-film transistor (TFT). The TFT is a switch that can control the amount of current flowing through the OLED. In AMOLED, information is sent to the transistor in each pixel, dictating the brightness of the pixel. The TFT then stores this information and continuously controls the current flowing through the OLED. In this manner the OLED is operating continuously, avoiding the need for the very high currents necessary in a passive-matrix display.
- In PMOLED to illuminate any particular pixel line a passive-matrix display, electrical signals are applied to the row line and column line. The more current pumped through each pixel diode, the brighter the pixel.



Advantages of AMOLED

The major competing technology for AMOLED is TFT displays. AMOLED is higher priced (anywhere from 50-100% depending on the comparable screen size), so why would you choose AMOLED? Here are 8 compelling reasons:

1. High C/R
2. Wide Temperature Operation
3. Fast Response
4. High and Constant colour Gamut
5. Wide Viewing Angle
6. Peak Brightness
7. Low Power Consumption
8. Very Slim design

Each of these advantage will be discussed in more detail

However AMOLED does have some technology issues which means it is not suitable for all applications.

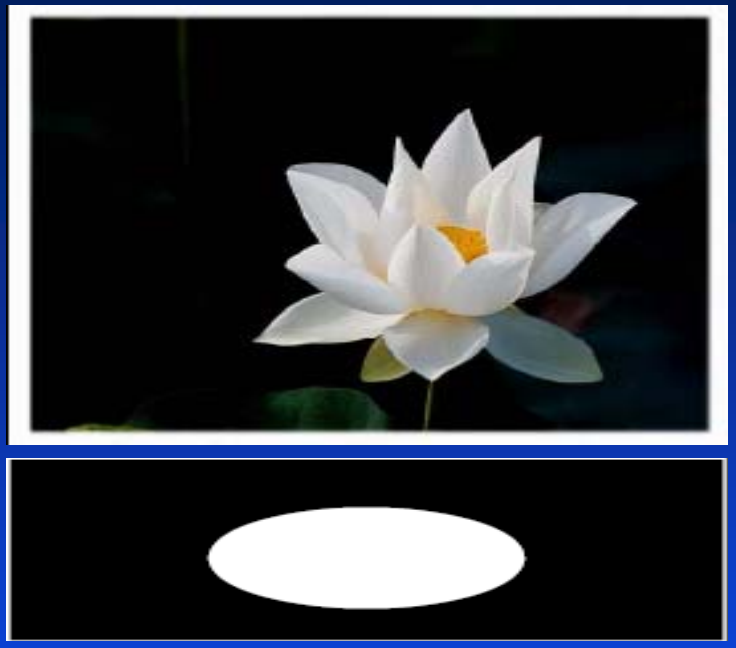
1. Price
2. Image Sticking/Image Retention
3. Lifetime

A description of the issues and design guidelines about how to overcome these are also discussed.

Remember: 4D also offers many TFT solutions and we are not degrading the technology in anyway. It is important that you choose the best technology for your application and your budget.

High Contrast Ratio

OLED

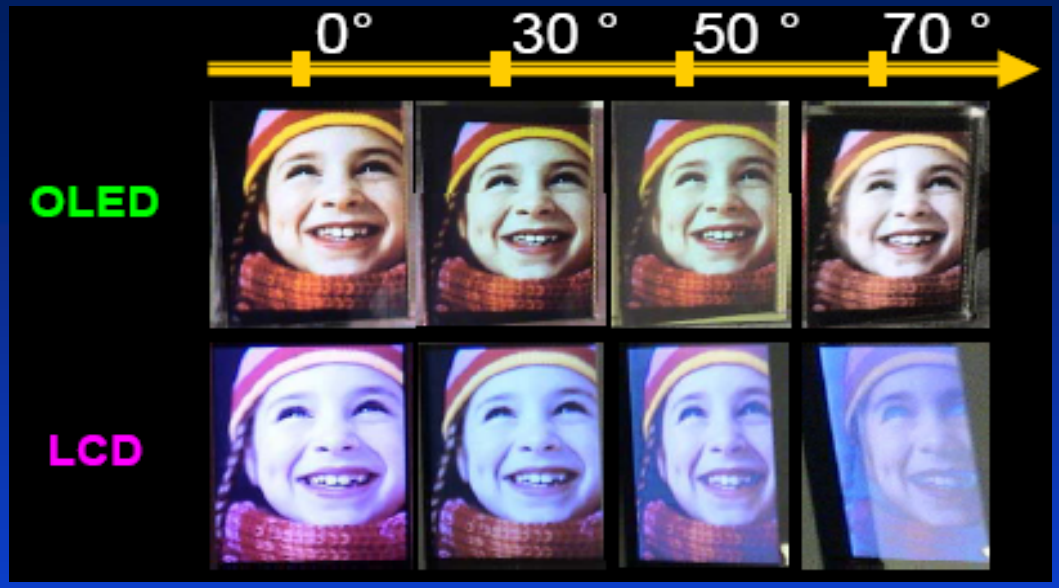


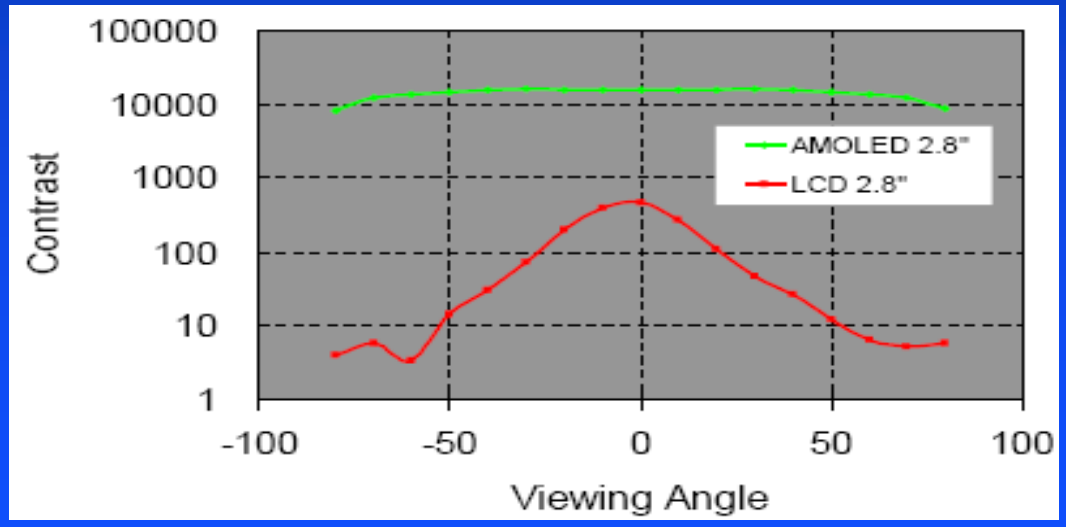
TFT

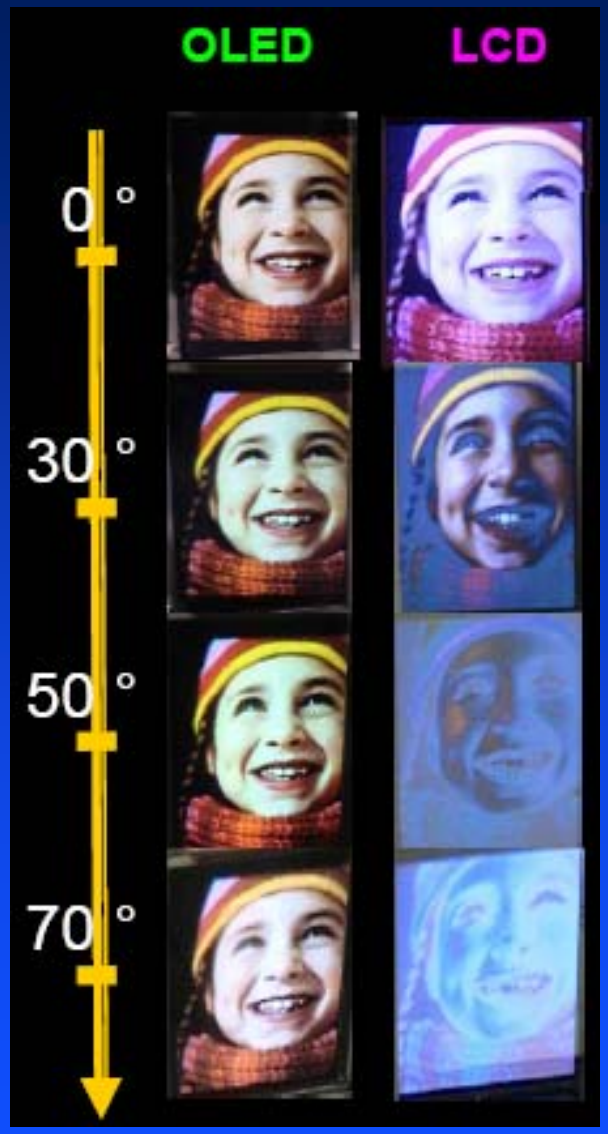
Item		OLED	TFT-LCD
Contrast Ratio (Sunlight Readable)	Dark Room	>10,000:1	300
	Rainy	400	130
	Cloudy	190	10
	Sun light	50	4

Conclusion – higher contrast ratio gives impression for higher brightness. OLED is much better than Transmissive TFT for Sunlight readability

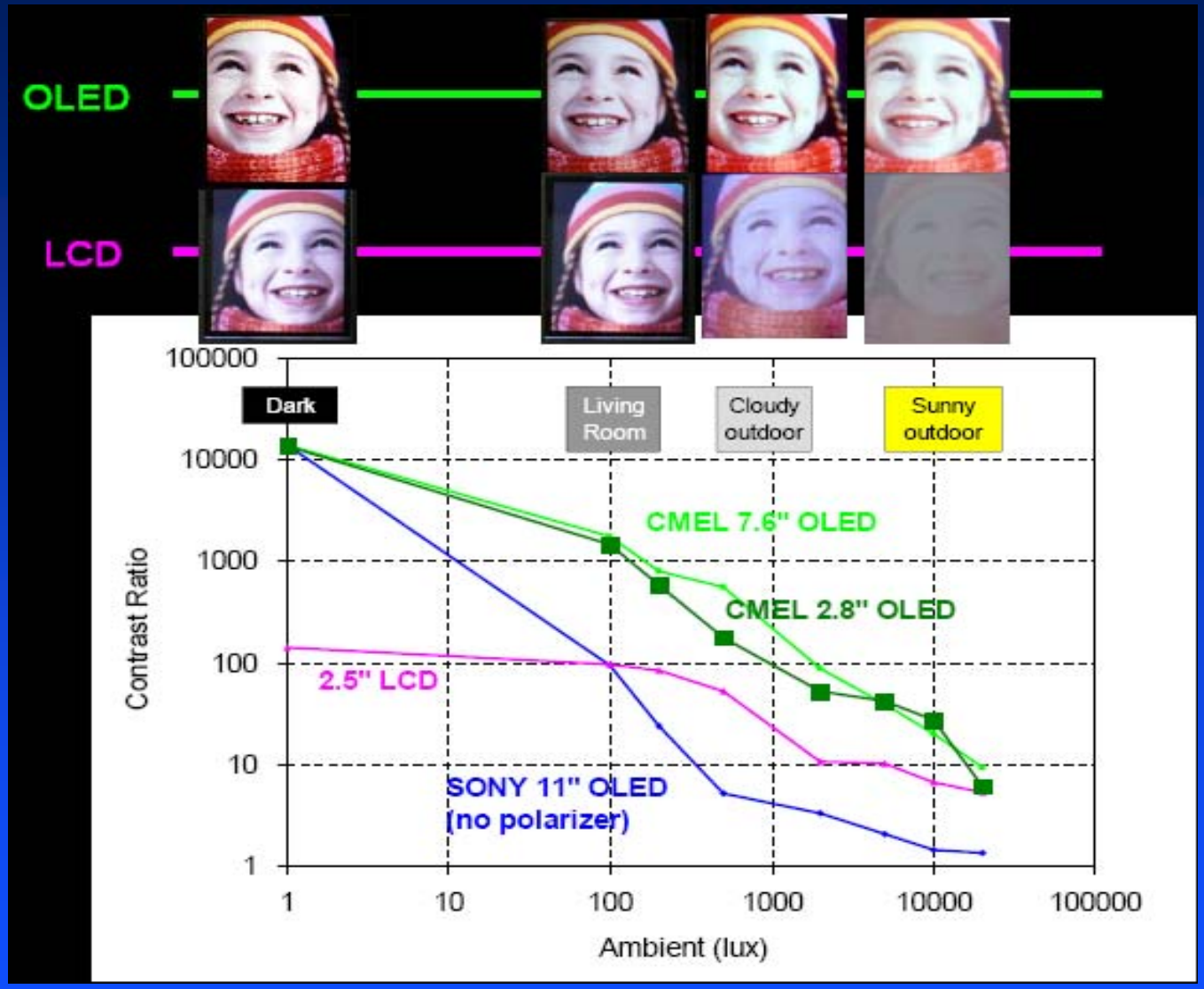
Constant Contrast Ratio – wide viewing angle







High Ambient Contrast Ratio



CONCLUSION

OLED Looks better in all conditions

FAST Response Time

OLED

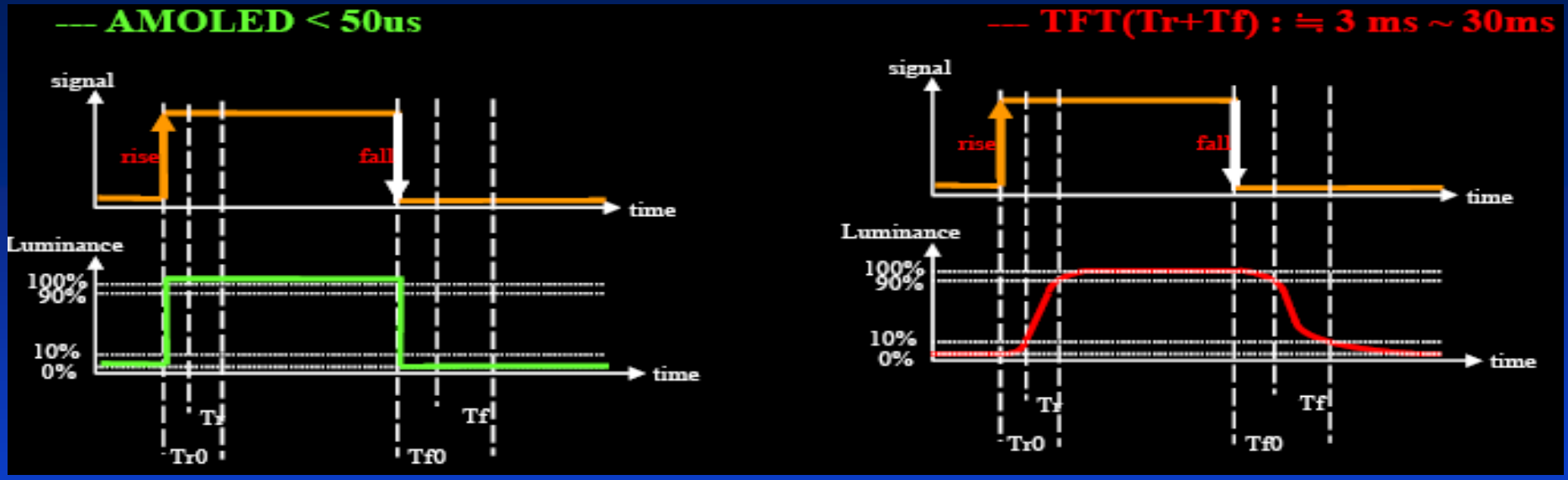
<50uS

LCD TFT

3000~30000uS

Fast response time means full motion graphics can be displayed

FAST Response Time



Wide Temperature Operation

OLED can work from

-40 ~85C

TFT can work from

-20 ~70C

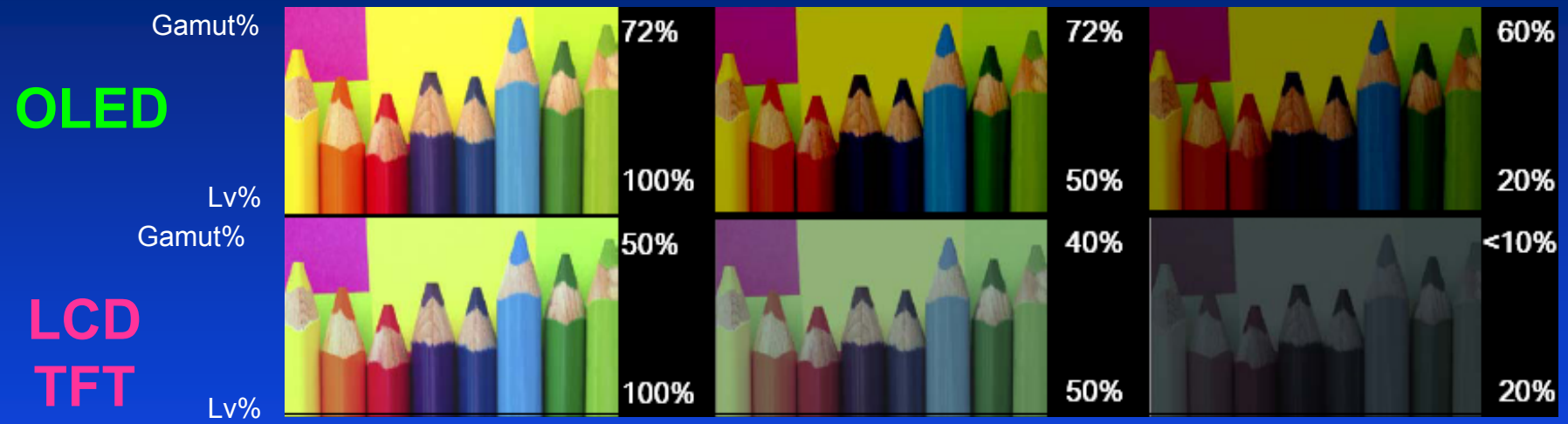
Other technologies (e.g. CSTN, Mono LCD) have significant problems at temperature extremes

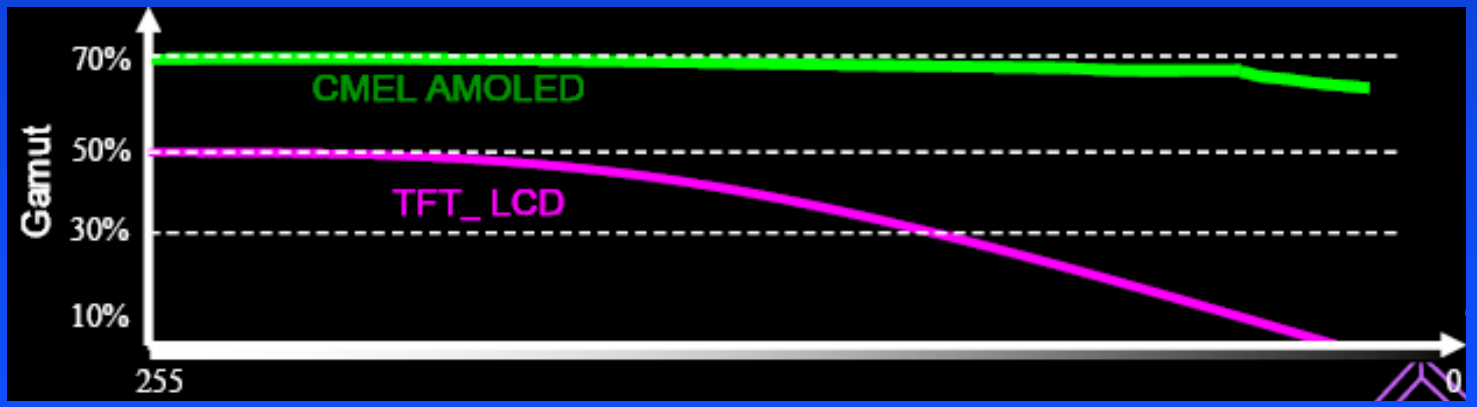
High Temperature – Liquid Crystal is disturbed and can't be controlled by an electric field

Low Temperature - Liquid crystal is unresponsive and becomes slow

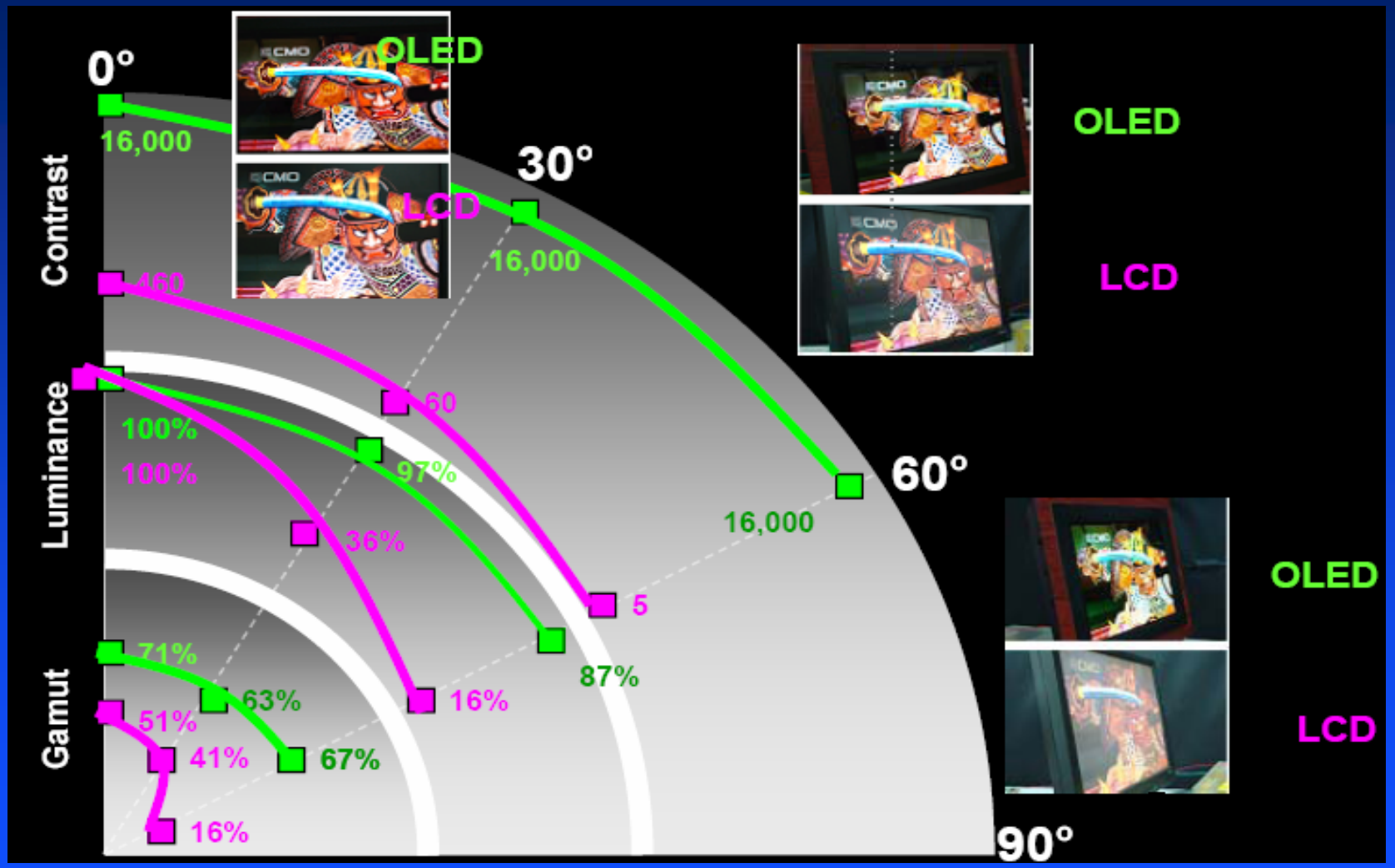
Significantly higher Colour Gamut

Constant Colour Gamut at all gray levels
OLED looks brighter, sharper and more visually pleasing



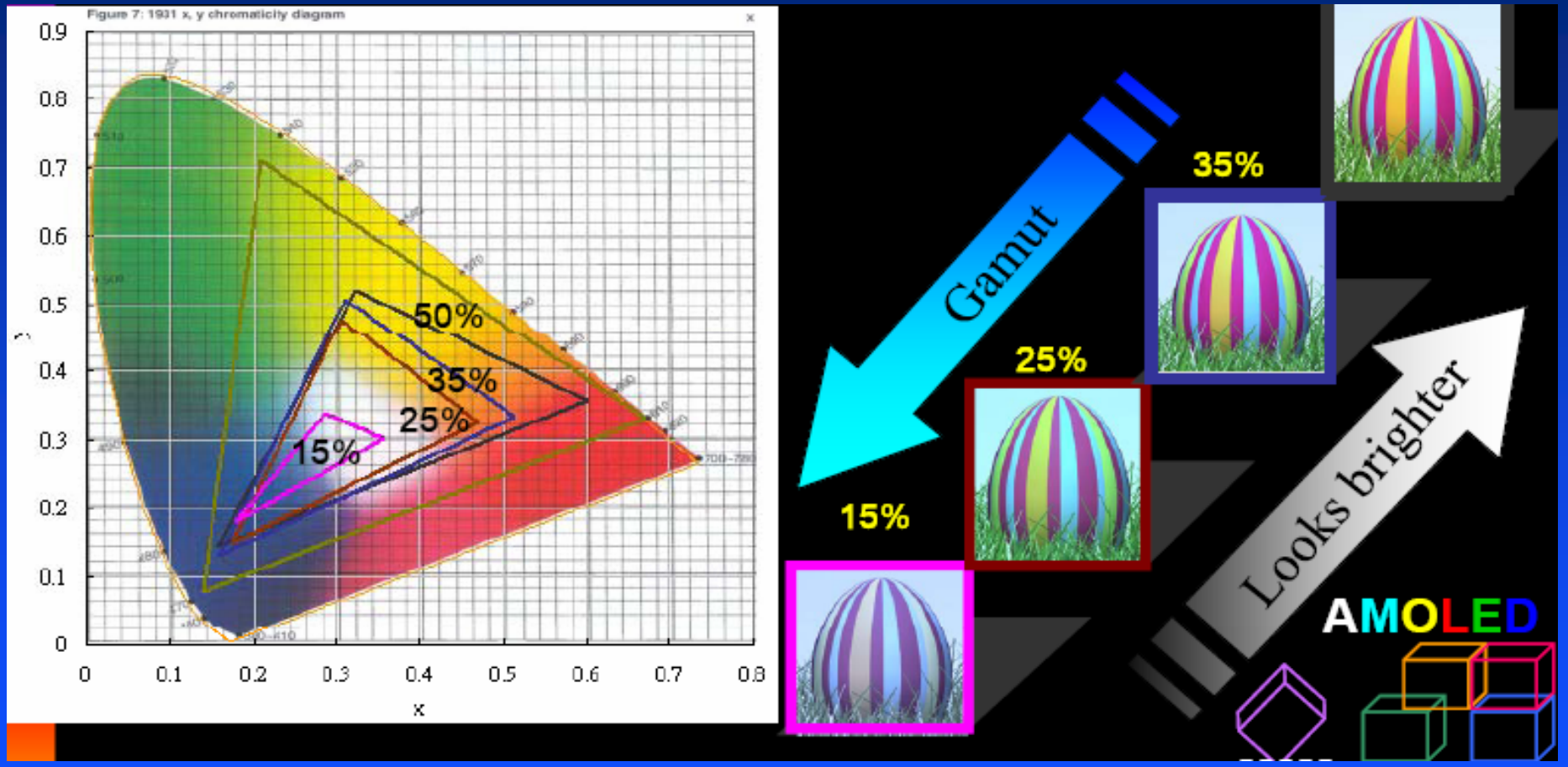


Wide Viewing Angle with Smaller Degradation of Optical Performance



Visually Perceived Brightness

- Even at the same luminance, High C/G image looks brighter.
- High C/R image looks brighter.



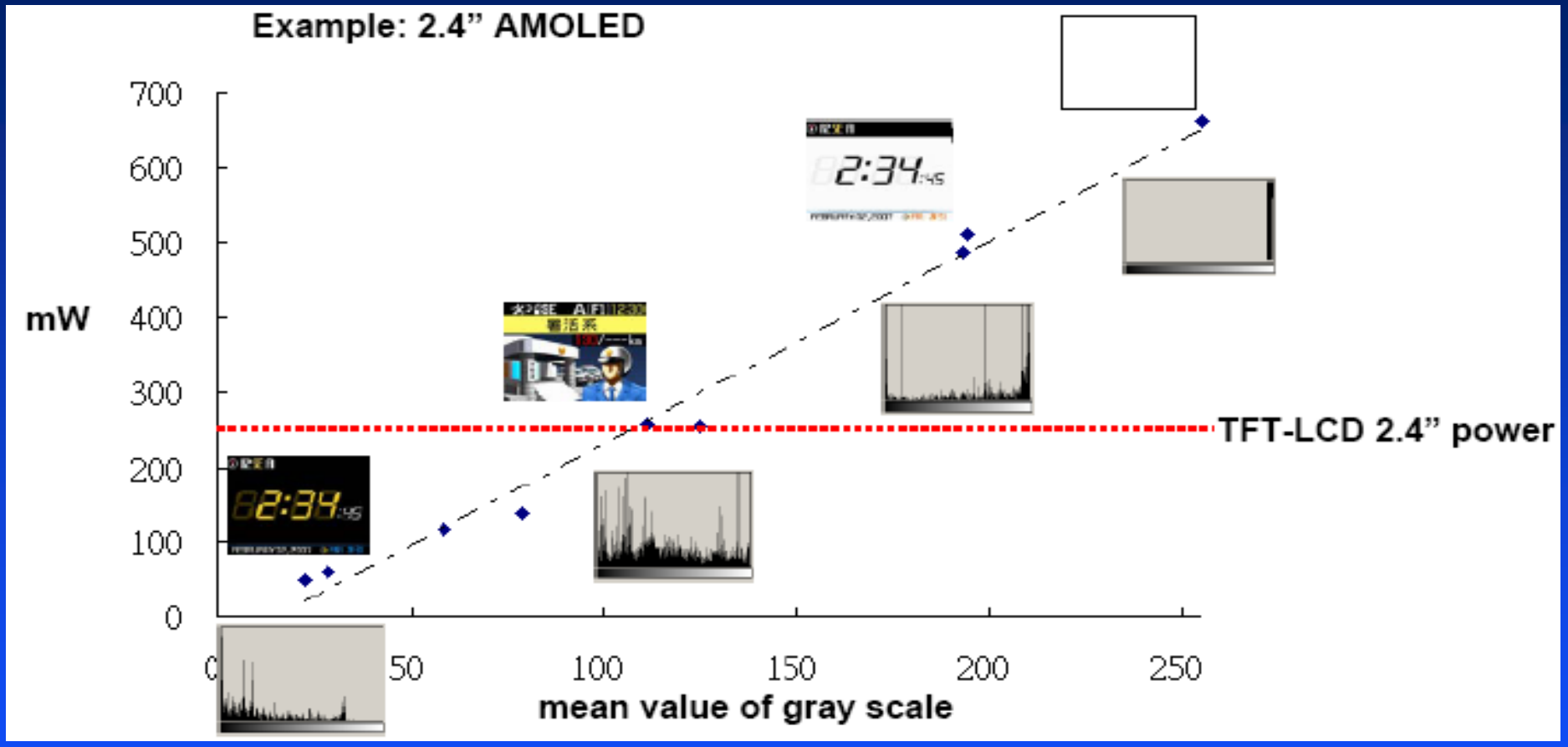
Power Consumption

Pattern / Power Con.					
AMOLED	738.00mW	176.25mW	90.75mW	146.25mW	126.75mW
TFT-LCD	224.17mW	224.17mW	224.23mW	224.24mW	224.25mW
% (AMOLED/ TFT-LCD)	330%	78.62%	40.27%	65.22%	56.52%

Brightness based on 200nit 2.4” AMOLED Display

- TFT display has constant current as backlight which must be on no matter what picture is displayed.
- Conclusion – use Black background on OLED to minimise power

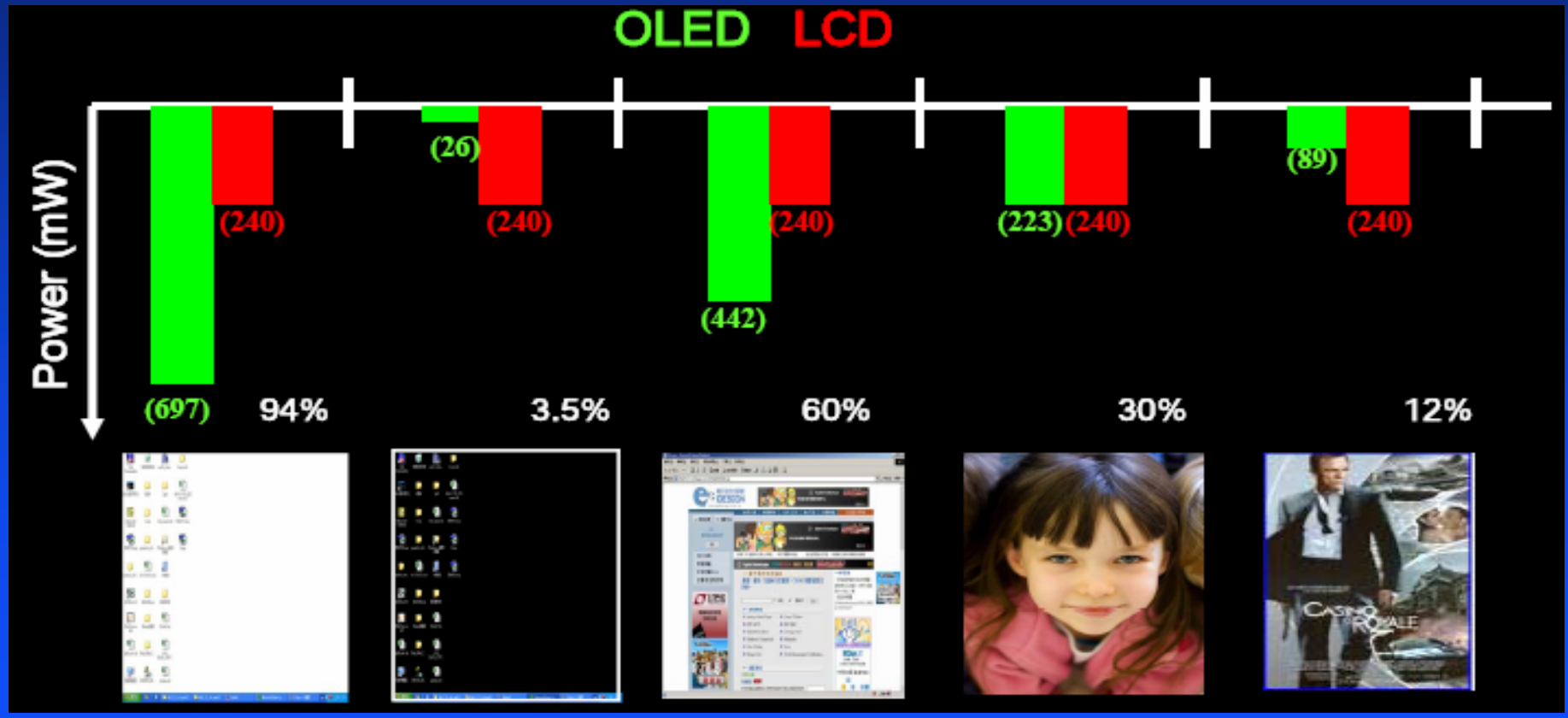
Power Consumption



Average Power Consumption

AMOLED power consumption depends on image content & application.

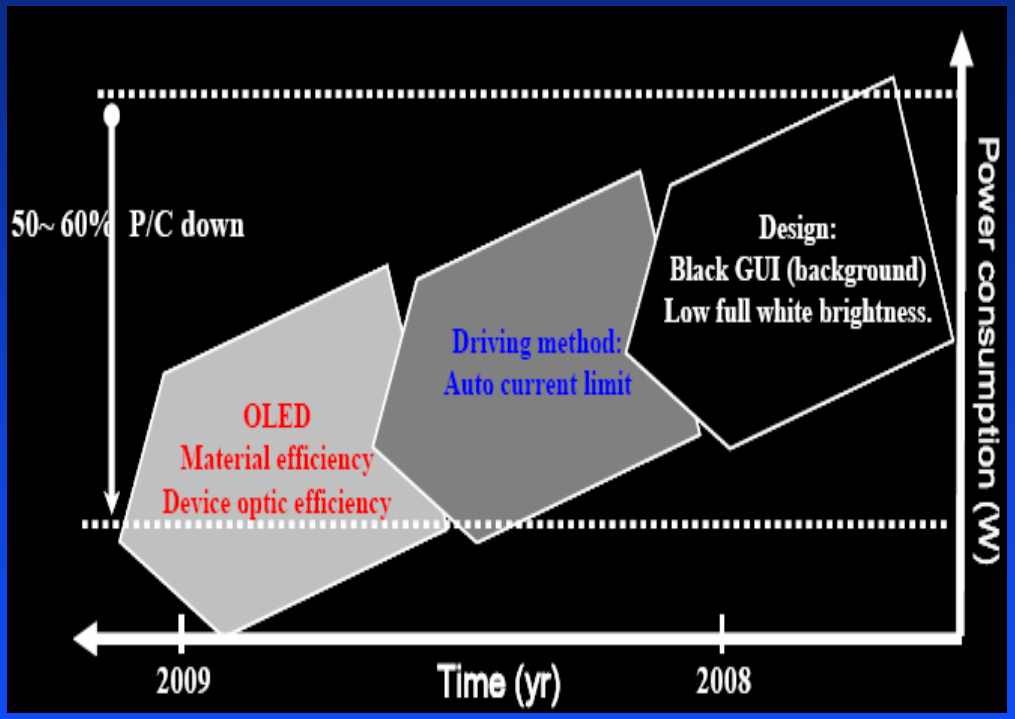
- Black background can save more power.
- Moving image is a good application.



How to Lower Power Consumption

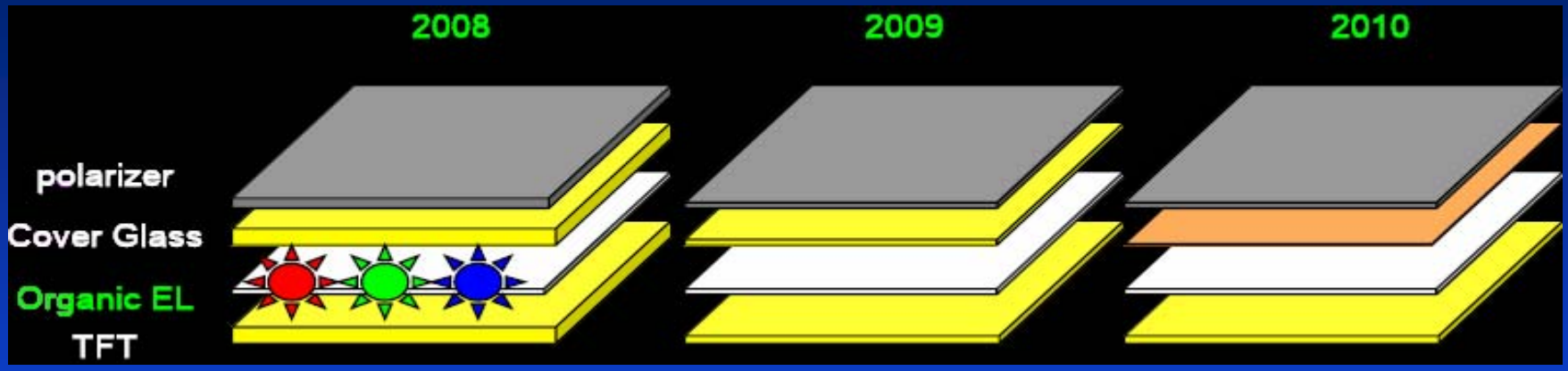
AMOLED power consumption can be decreased by:

- 1. Black background. (50%~80%) ↓
- 2. Lower full white brightness. Ex.200 nits 160 nits. (20%) ↓
- 3. Auto current limit driving method. (20%) ↓
- 4. OLED material & device efficiency increase. (30%) ↓



Slim Thickness

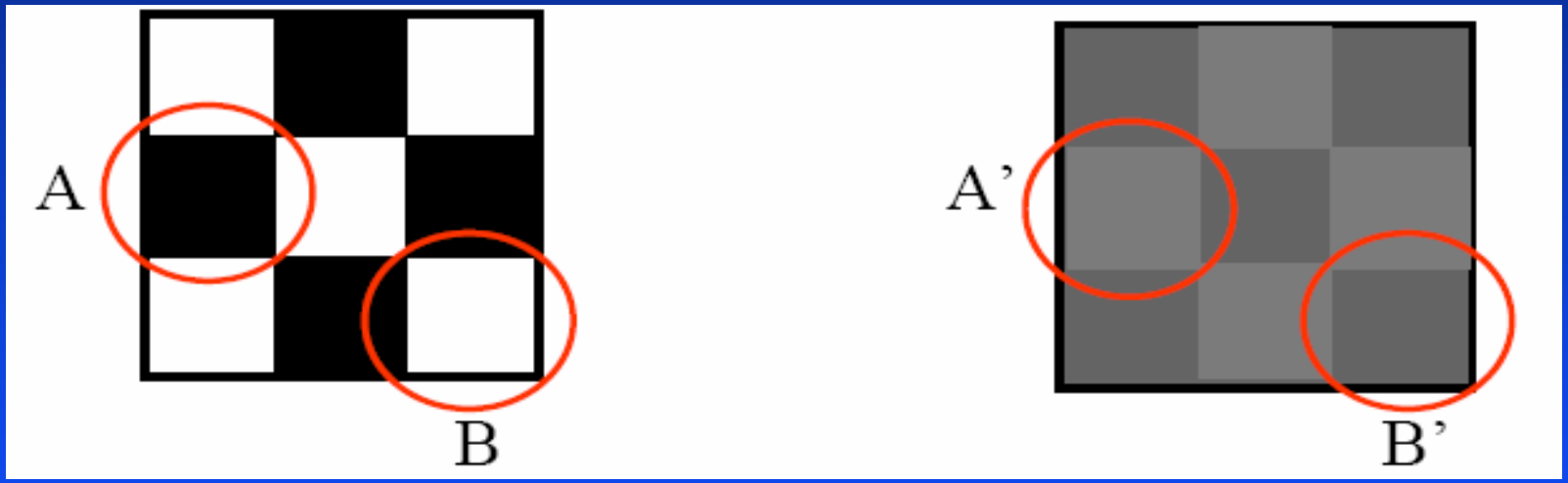
- **Future improvements**



mm	2008	2009	2010
polarizer	0.2	0.15	0.15
Cover glass	0.4~0.5	0.3 (hybrid)	0.02 (thin film)
TFT	0.4~0.6	0.3 (slimming)	0.3
total	1.0~1.3	0.75	0.47
frame	0.35	0.25	0.2
Total module	1.35~1.65	1.00	0.67

IMAGE STICKING

- Image sticking is the terms used to describe the image retention occuring when a fixed pattern is displayed over a prolonged period of time.
- For example, if we continuously displayed the checker board pattern like the picture shown on the bottom left for a long time, and switch to 50%Gray of full white pattern, we can see the image like the right one, the phenomenon we call is Image Sticking. (Full White is 200nits, 50% is 100nits)



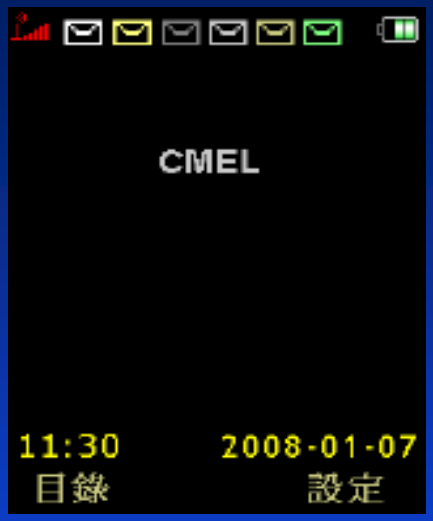
Unit : nits	A	A'	B	B'
Brightness	0	100	200	95

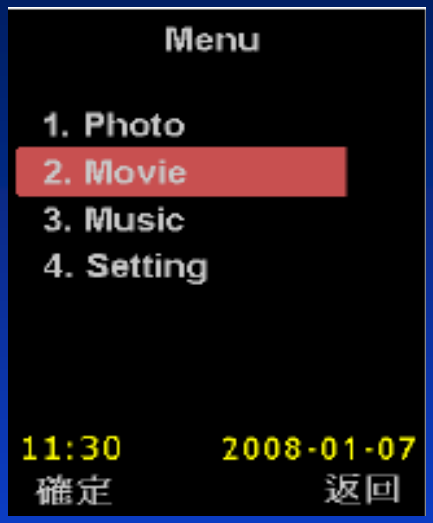
For techniques to overcome image sticking see slides in the design guide

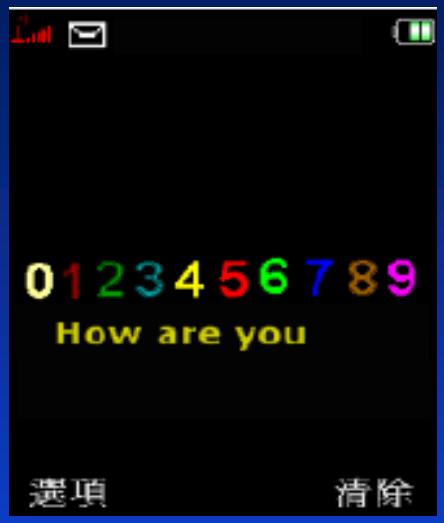
DESIGN USER GUIDE FOR AMOLED DISPLAYS

- With some of the advantages and features of AMOLED it is important to consider these in your design to maximise the benefits of the technology.
- The following pages give design guidelines, recommendations and tips. Methods to overcome some of the technical limitation are also given for your reference.

Design Guide







In any good Graphic User Interface (GUI) design you need to consider : power saving, image retention & image sticking.
Therefore it is recommended the GUI has a Black Background, with white or coloured text & icons because of:

- Lowest power consumption
- No image sticking problem

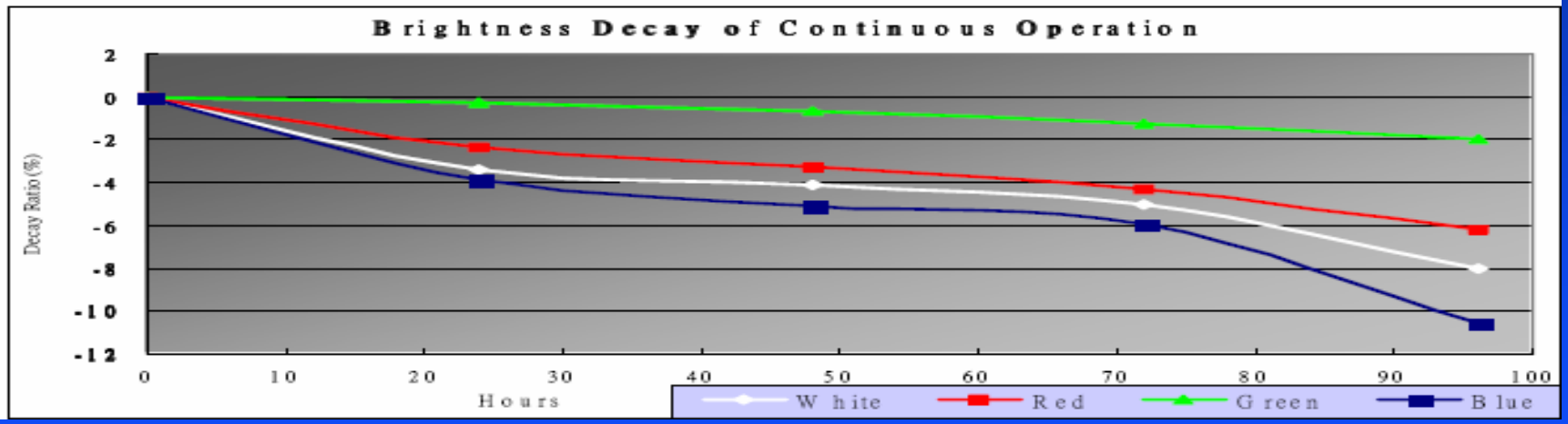
In case of white or colour words & icons, R,G,B gray scale should be less than 80% of full gray scale. Because of the high contrast ratio between background and foreground, the perceived brightness is brighter than it really is. Meanwhile power consumption is further lower and it is good to reduce any image sticking.

IMAGE Sticking - Testing

Test using 2.8” AMOLED was made and decay ratio after 24 hours was measured

Brightness Decay Trend (150nits)						D2 Set
Day		Day0	Day1	Day2	Day3	Day4
Operation Hours		0	24	48	72	96
Decay Ratio (%)	White	0	-3.43	-4.1	-5	-8
	Red	0	-2.38	-3.3	-4.3	-6.2
	Green	0	-0.3	-0.7	-1.27	-2
	Blue	0	-3.88	-5.13	-5.92	-10.55
Judgement	White	◎	○	○	△	△
	Red	◎	○	○	○	○
	Green	◎	◎	◎	◎	◎
	Blue	◎	○	○	△	×

◎ : OK, ○ : Slight, △ : Middle, × : Failed.



Conclusion – if displaying static images e.g. for industrial data-logger application – use Green to minimise image sticking. Avoid Blue

Image Sticking

Low brightness is good; especially for small icons & text.

Because of OLED peak brightness & higher contrast, when we show text or small icon on black background, the icon brightness can be decreased by lower gray scale.

3.8"_Group 348 T1PCP002 NG0222	RGB_Gray Scale Ratio			Optical_Full On (With PL)					Icon (With PL)			Burn in 428hrs			
	R	G	B	Lv	CIEx	CIEy	Icc	Color Temp.	Lv	CIEx	CIEy	W	R	G	B
1	100%	100%	100%	200.81	0.3080	0.3300	107.4	6870 K	235.81	0.3059	0.3411	△	■	■	✕
2	78%	78%	78%	120.07	0.3103	0.3328	64.5	6663 K	138.93	0.3090	0.3412	□	■	■	△
3	50%	50%	50%	44.29	0.3098	0.3276	25.5	6822 K	43.42	0.3069	0.3303	■	■	■	■

Low colour Temperature < 6500K design for small icon & text.

Image sticking comes more from Blue since its OLED life time is shorter than Red and Green. Using lower colour temperature for text or small icons on black background is good for preventing the Image from sticking.

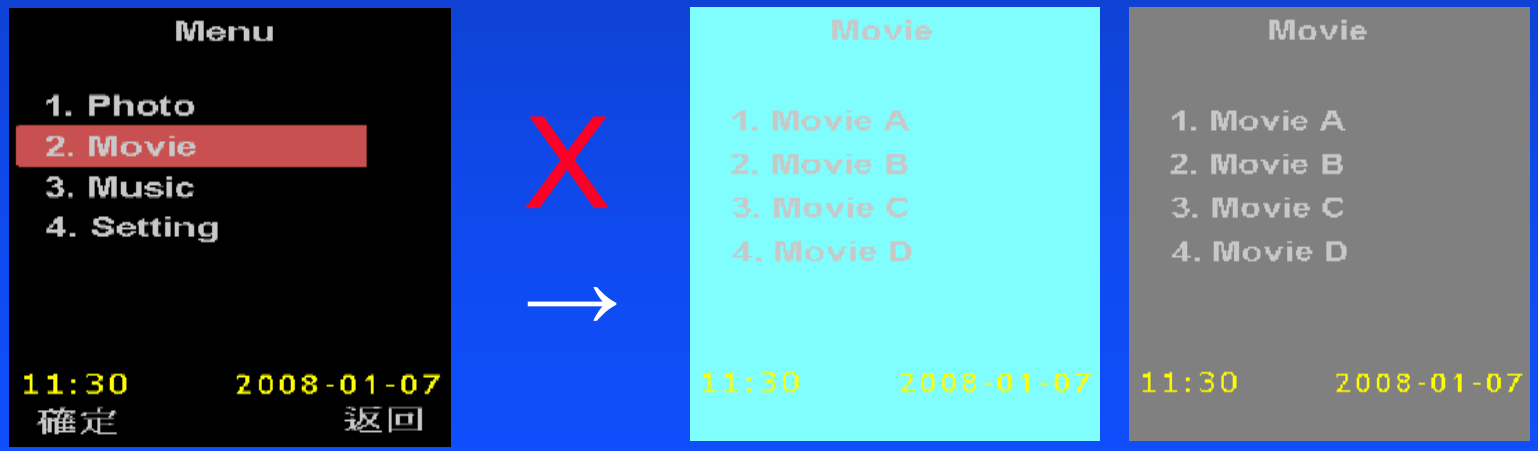
3.8"_Group 348 T1PCP002 NG0222	RGB_Gray Scale Ratio			Optical_Full On (With PL)					Icon (With PL)			Burn in 428hrs			
	R	G	B	Lv	CIEx	CIEy	Icc	Color Temp.	Lv	CIEx	CIEy	W	R	G	B
4	100%	100%	50%	176.80	0.4232	0.4524	69.3	4009 K	195.72	0.4105	0.4556	□	□	■	■
5	78%	78%	50%	107.85	0.3928	0.4180	46.2	4183 K	114.39	0.3857	0.4176	■	■	■	■
6	50%	78%	50%	87.71	0.2964	0.4468	36.8	6557 K	100.32	0.2941	0.4537	■	■	■	■

Reducing Image Sticking and Retention Tips

Always use white or coloured text with black background during operation.

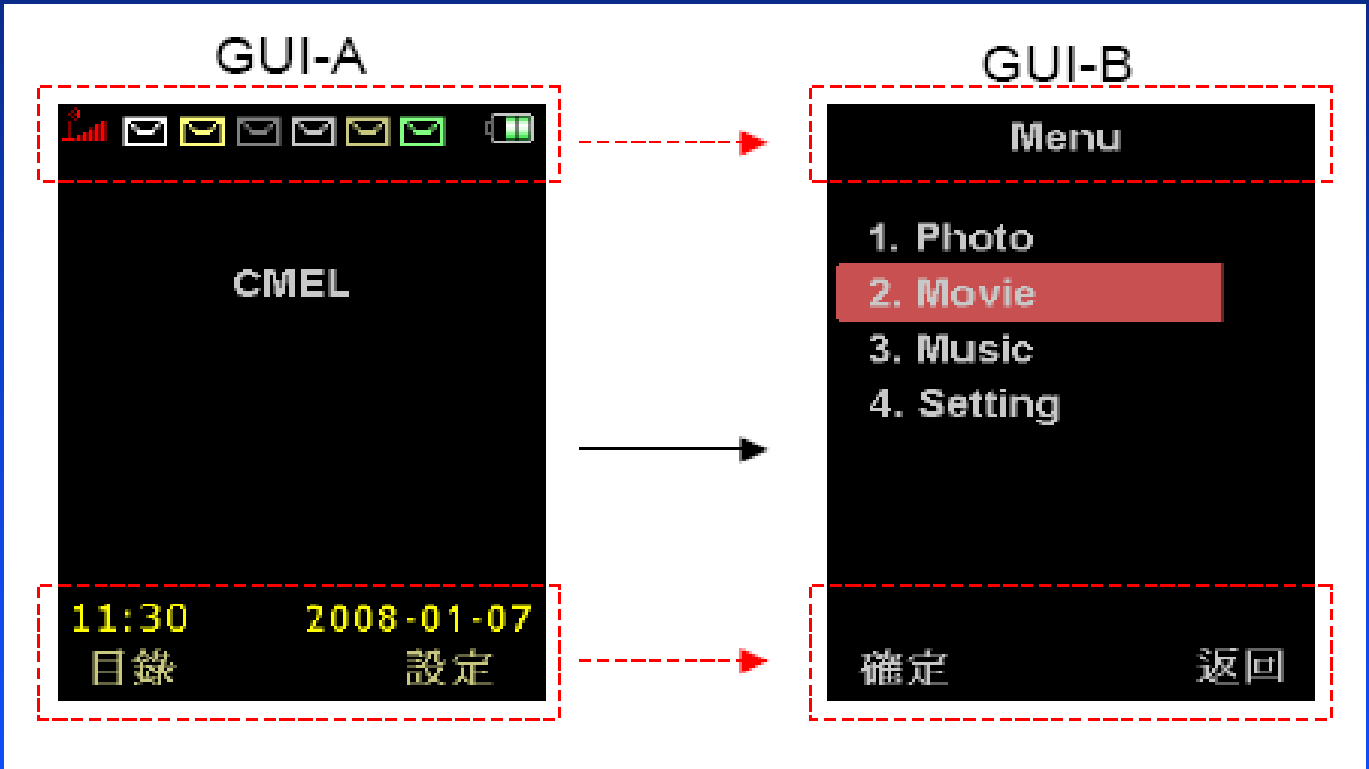
Good Design

Bad Design



Reducing Image Sticking and Retention Tips

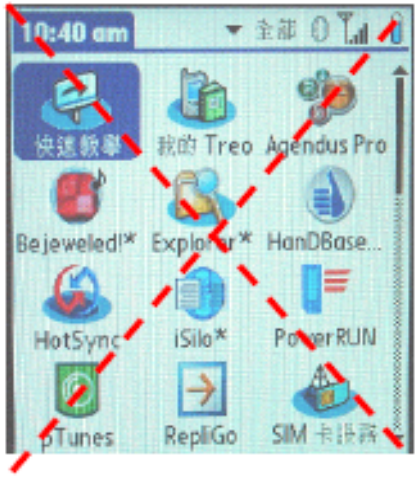
Avoid using the same icons on different GUI. This will ensure that image sticking is minimised.



Power Consumption Minimisation

To minimise power consumption, select black, colourful or graphic backgrounds . Do not use a white background.

- Bad Design.



- Good Design

Design Guidelines

- Do not use black words with white selection bar since white has the highest power consumption.
- White words with colour selection bar is a better design to minimise image sticking.

- Bad Design.

- Good Design

Lifetime

- Panel lifetime specification is currently 20K hours (time to half intensity)
- However each colour RGB has a different lifetime.
  - Green is the best at 40K hours, Red is 25K and Blue is 12K hours.
- With this in mind it is important to consider your colour choices on your GUI. Where possible avoid blue.
- When you consider image sticking and lifetime of each of the colours you can quickly see most of the technology limitations are reduced significantly if you avoid blue! For example in an industrial application where you might have data displayed for long periods, display in green to avoid image sticking.

Summary of Design Guidelines

- GUI with black, graphic or colourful background is necessary for AMOLED display.
- For white text & icon, it is not necessary to use full gray scale (N= 64 or 255). 80% (N<50 or <200) is enough.
- Try to design colourful text or icons, where the colour temperature is lower than 6500K. On the other hand, decrease the blue gray scale as much as possible. (NB<30 or <125)
- Always use white or coloured text in black background during operation.
- When GUI is changing, the black to black background change is recommended to minimise image retention.
- Try not to let the icon remain fixed at the same location.
- The panel should be turned off automatically whenever possible to increase lifetime and eliminate image sticking.