R_10015

Chip-On-Glass (COG) - a cost-effective and reliable technology for LCD displays

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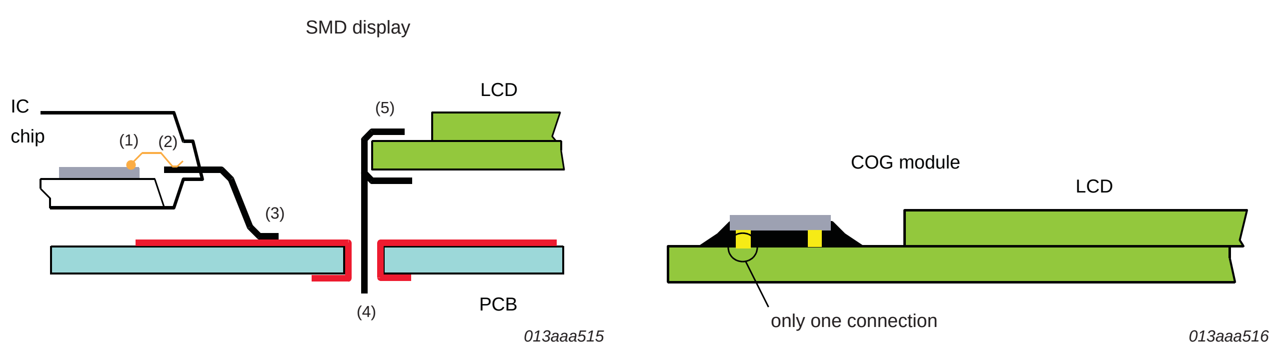
1. The Chip-On-Glass value proposition

Today, many LCDs are implemented by connecting a cased[1] LCD driver IC with the physical display via a Printed-Circuit Board (PCB) (see Figure 1a). This concept - referred to in the following as the Surface Mount Device, or SMD concept - provides a robust mechanical solution but requires a more complex and more area intense PCB design.

Chip-On-Glass (COG) technology is an alternative design methodology in which the LCD driver is mounted directly on the display glass (see Figure 1b). This concept - in the following referred to as COG concept - reduces the number of tracks and layers on the PCB, cutting the board size and complexity, and eliminates the IC package used in the SMD concept. The overall impact is a reduction in system cost.



In SMD displays, five connections are needed:
(1) and (2) wire bond from chip to lead frame,
(3) solder connection to PCB,
(4) and (5) connection from the PCB to the LCD.

a. SMD display

In COG modules, only one connection from driver to display is needed.

b. COG LCD module

Fig 1. SMD and COG LCD

In contrast to the SMD concept, COG requires tight production and design coordination between the IC and the LCD module manufacturers. NXP is well-positioned to support COG applications based on its strong relationships with major LCD module manufacturers worldwide and has more than 10 years of experience in designing LCD drivers for COG applications.

1. An LCD driver IC in a package.

2. The Surface Mount Device concept

For an SMD LCD, the display and the display driver are directly mounted onto the PCB. The connection between the display and the PCB is made by using either fixed-pins or elastomeric connectors (ZEBRA). With an LCD segment driver featuring up to 240 segments in multiplex 1:4 mode this results in up to 64 connections between the display driver and the PCB as well as between the PCB and the display. (see Figure 2 for an example with a 128 segment display and 36 connections).

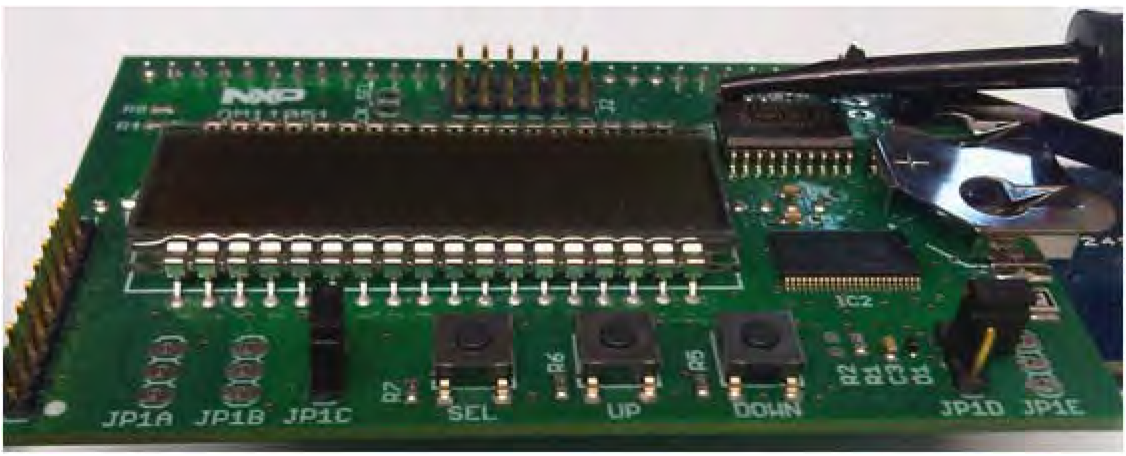


Fig 2. SMD LCD display with fixed pins

In Figure 3 the construction of an SMD LCD with elastomeric connectors (ZEBRA) is illustrated.

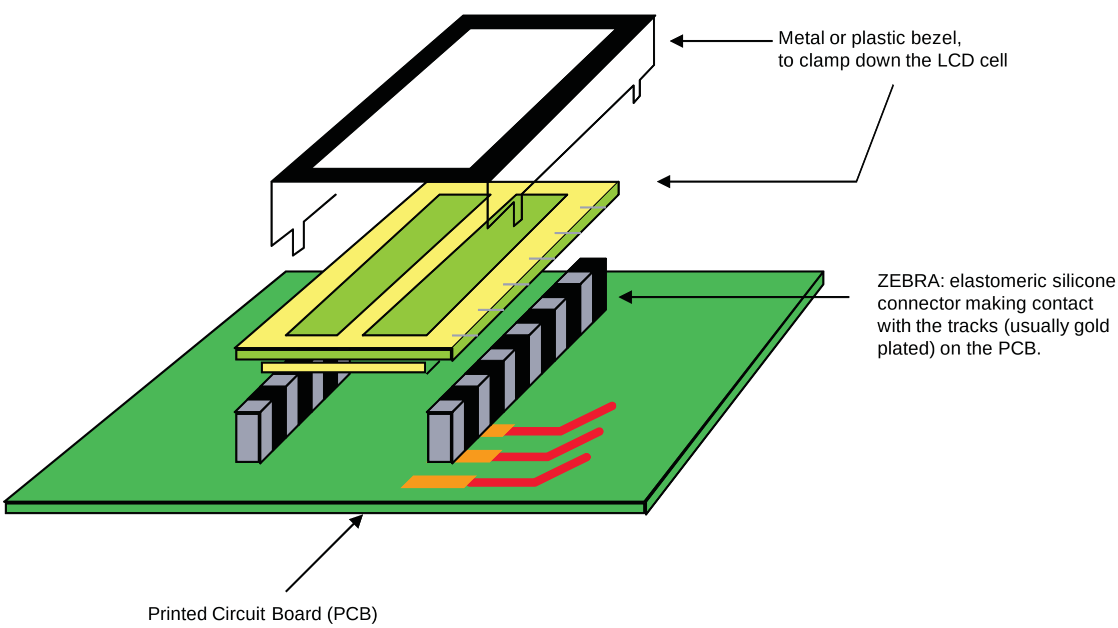


Fig 3. Illustration of an SMD LCD with elastomeric connector

The SMD display consists of the LCD cell, a metal or plastic bezel which clamps down the LCD cell onto the elastomeric connector (ZEBRA) which then makes the contact with the tracks on the PCB. The ZEBRA connector is composed of fine pitch conductive segments alternating with isolating segments, embedded between 2 isolating strips. The bezel, metal or plastic, applies as a force and squeezes the ZEBRA slightly to guarantee a firm contact between the LCD and the PCB.

3. Chip-On-Glass LCD concept

A COG module consists of:

- A display glass that represents the active display area.
- A seal ring around the display glass which protects and seals the display glass.
- A contact ledge which gives room for the LCD driver IC.

The LCD driver IC itself generates the display control and the driving signals. A Flex Panel Connector (FPC) connects the display driver IC to the microcontroller (see Figure 4).

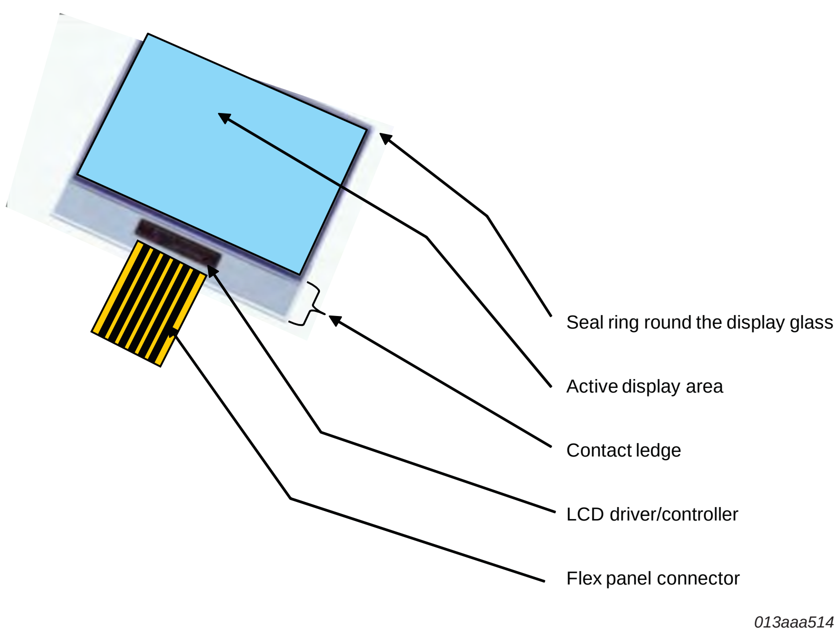


Fig 4. COG LCD module

In a COG module, one of the two glass plates that make up the LCD is extended to give room for an LCD driver to be mounted and connected (see Figure 4 and Figure 5). The connections to the display are realized with Indium Tin Oxide (ITO) electrodes which are integrated on the surface of the glass plates and connected via an Anisotropic Conductive Film (ACF) to the gold bumps mounted on the connecting pads of the driver IC.

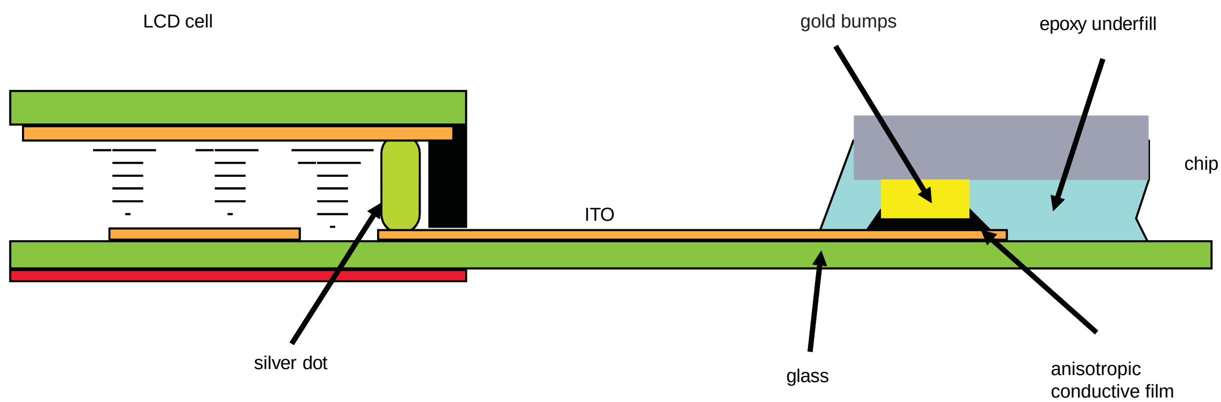


Fig 5. Illustration of a COG LCD module

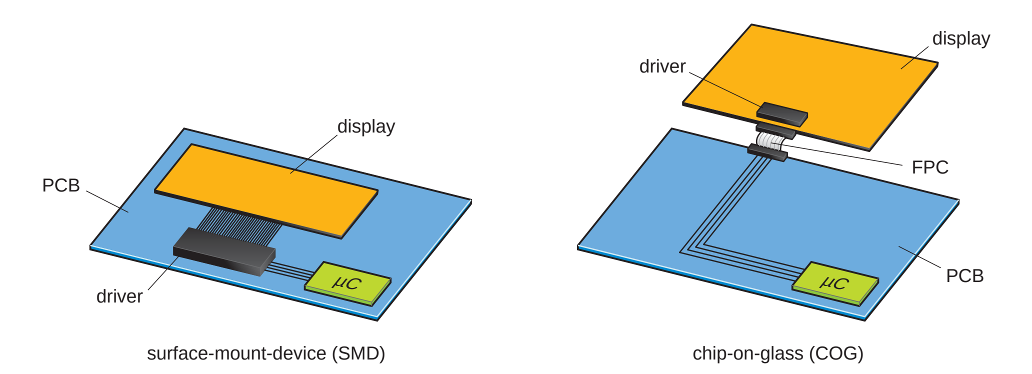
COG technology sets very few limitations on the LCD module design:

- For COG, an uncased display driver IC (display driver without a package) is sufficient; the only requirements are that the display driver IC has gold bumps to enable the contact to the ITO tracks on the LCD glass.
- The placement of the LCD driver IC can be on any side of the active display area. This allows placing the LCD driver IC on the smaller side to minimize the required contact ledge and with that save cost.
- The COG technology allows the cascading of several LCD driver ICs directly on the contact ledge in order to allow for driving larger display resolutions.
- COG technology allows for connecting the display to the PCB wherever it is most suitable, even some distance away from the microcontroller.

4. Surface-Mount Device compared to Chip-On-Glass

4.1 Components and design effort

In the following an SMD and a COG display system will be compared (see Figure 6). In the SMD concept, the display as well as the display driver are directly mounted onto the PCB. In the COG concept, the display driver is mounted onto the display module and also connected to the PCB via a Flex Panel Connector (FPC).



a. Surface-Mount Device b. Chip-On-Glass

Fig 6. Surface-Mount Device compared to Chip-On-Glass

The two systems require the following components (see Table 1).

Table 1. Components

Surface-Mount Device (SMD)	Chip-On-Glass (COG)
• PCB • Microcontroller • Cased LCD driver IC • SMD display, consisting of (see Figure 3): – Bezel – LCD cell – Elastomeric connectors (ZEBRA)	• PCB • Microcontroller • COG display module, consisting of (see Figure 5): – LCD cell – Uncased LCD driver IC (die with gold bumps) – Anisotropic Conductive Film (ACF) – FPC

Given these components, the following design and effort considerations must be taken into account (see Table 2).

Table 2. Design and effort considerations

Surface-Mount Device (SMD)	Chip-On-Glass (COG)
• PCB space: – Sufficient space on the PCB is required to accommodate the cased LCD driver IC as well as the SMD display	• PCB space: – No space on the PCB is required for the LCD driver IC or for the COG LCD – Space is only required for the Flex Panel Connector (FPC)
• Connectors and Connections: – Many connections (supplies, segments, backplanes) are required on the PCB between the cased LCD driver IC and the SMD display – An elastomeric connector (ZEBRA) or fixed pins are required to mount the SMD LCD cell onto the PCB	• Connectors and Connections: – Only very few connections (supplies, bus) are required between the microcontroller and the connector of the COG LCD module – Flex Panel Connector (FPC)
• Display location: – The location of the display cell is bound to the PCB	• Display location: – Location of the COG LCD module is unconstrained
• Driver IC location: – The cased LCD driver should ideally be placed as close to the SMD display as possible to avoid disturbances on the LCD driving signals	• Driver IC location: – The uncased LCD driver must be located on the COG LCD glass
• Flexibility/upgradability: – No flexibility/upgradability to replace/upgrade the cased LCD driver IC and/or SMD display easily	• Flexibility/upgradability: – High flexibility in changing/upgrading the COG LCD module (simply exchange the module and the driver software)
• Soldering, inspection and verification: – Soldering, inspection and verification of cased LCD driver IC and SMD display is required	• Soldering, inspection and verification: – Soldering, inspection and verification of the LCD driver IC and the Flex Panel Connector (FPC) to the COG LCD module required

Remark: In the Chip-On-Glass case specific design guidelines have to be followed to ensure sufficient ESD and EMC immunity of the LCD module (see Ref. 1 “AN10170” and Ref. 3 “AN10853”).

4.2 Considerations with respect to cost

With respect to cost, the following considerations can be made (see Table 3):

Table 3. Cost considerations

Surface-Mount Device (SMD)	Chip-On-Glass (COG)
• More complex and likely larger PCB • Cased LCD driver (with package) required • Soldering, inspection and verification of the LCD driver and the SMD display required • Smaller display glass (no extra space to the active area needed) • Bezel and elastomeric connector required to connect the SMD display to the tracks on the PCB	• Less complex and likely smaller PCB • Uncased LCD driver (die with gold bumps) is sufficient • Only soldering, inspection and verification of the connector to the COG LCD module required • Larger LCD glass required to accommodate the uncased LCD driver • Anisotropic conductive film required to connect the uncased LCD driver to the ITO tracks on the display glass

From Table 3, four key parameters[2] can be identified which are determining the cost of an SMD or COG display system:

1. the PCB,
2. the LCD driver,
3. the display glass,
4. material and assembly.

1. **PCB:** The PCB is a major cost factor; the larger and the more complex a PCB (number of layers, number of vias), the more costly. By moving from an SMD LCD module to a COG LCD module, the PCB can be off-loaded from the display module and the display driver, saving board space and reducing board complexity. This will help to reduce overall system cost.
2. **LCD driver:** The LCD driver is also a major contributor to the cost. A large portion of the driver cost originates from the package. When moving from a cased LCD driver to an uncased LCD driver, considerable cost can be saved (see Figure 7). However Figure 7 doesn't reflect the additional cost for the gold bumps which are needed for a COG LCD module:

2. Note: For the following, the microcontroller is excluded.

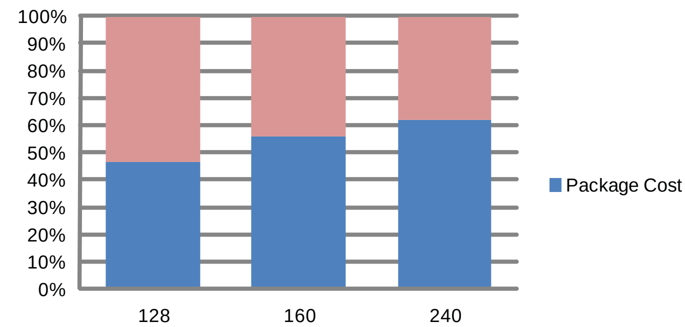


Fig 7. Share of package cost on total display driver cost as function of total number of display elements

Moreover, the higher the number of package pins, the higher the package cost, whereby the relationship is exponential (see Figure 8):

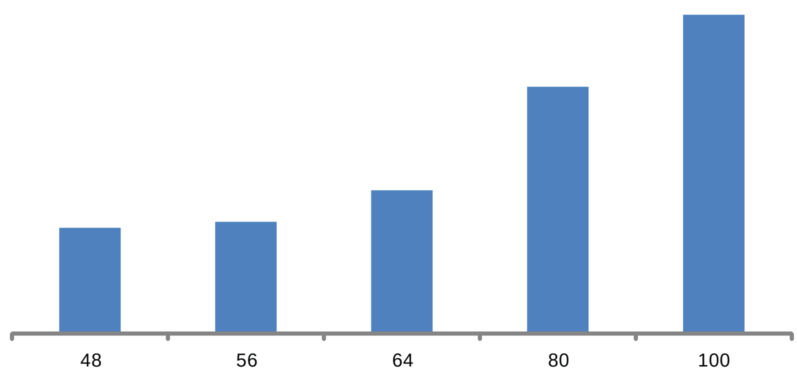


Fig 8. Package cost as function of number of pins

As a result, the package cost per display element increases when the number of display elements driven from a single package increases (see Figure 9):

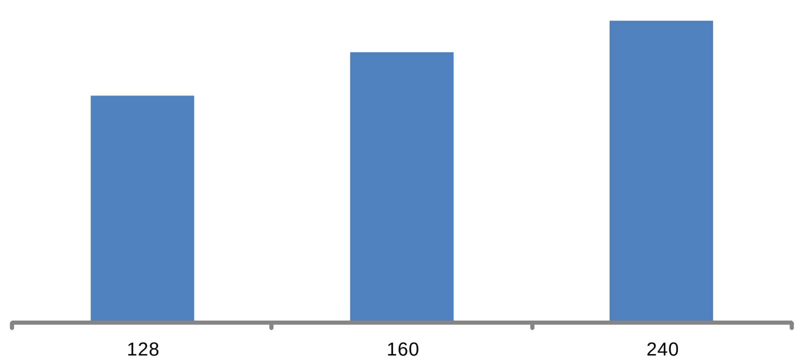


Fig 9. Package cost per display element as function of total number of display elements

3. **Display glass:** The display glass is the next major contributor to the cost of the LCD module and is directly proportional to the display area. In the COG case, additional glass area is required to accommodate the LCD driver IC. The size of this additional

area heavily depends on (1) the physical dimensions of the driver IC and (2) the X-Y-dimensions of the LCD cell. Ideally the driver IC is designed as long as possible to minimize its width. The less wide the driver IC, the less wide the additionally required glass area. Most NXP COG LCD driver ICs are designed with this objective in mind - long but less wide for lowest glass cost (see Figure 10).

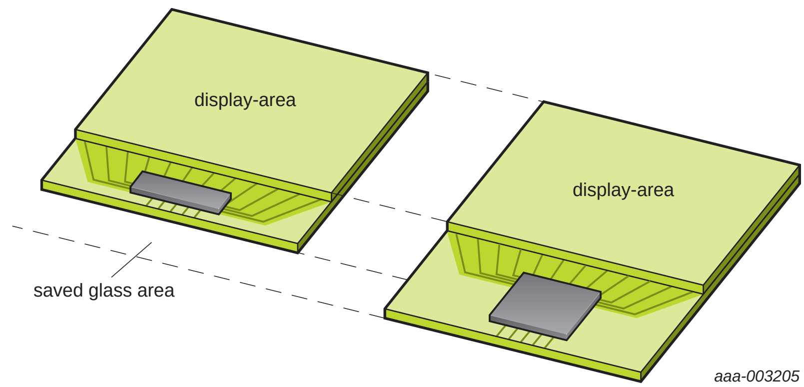


Fig 10. Required display area depending on the driver IC size

To reduce cost further, the display driver IC should ideally always be placed on the smaller side of the active display area (see Figure 11):

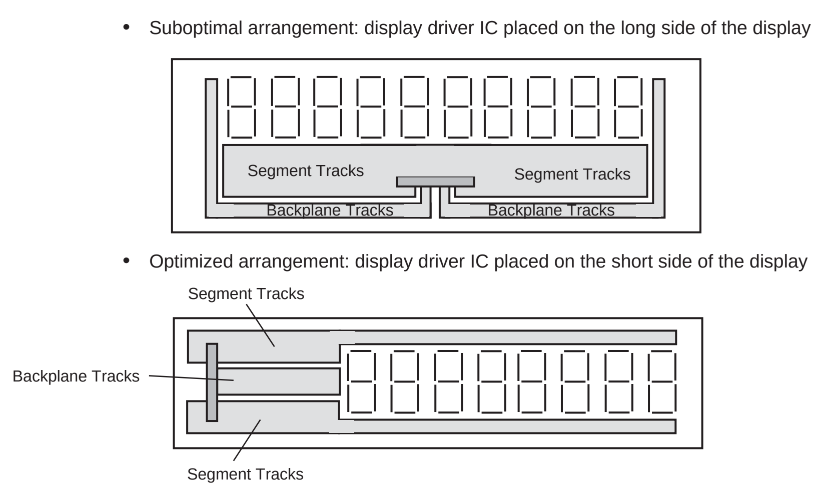


Fig 11. Placing of display driver IC on the display

To have full flexibility in doing so, the display driver IC should ideally have backplane outputs on both sides of the IC. All latest NXP COG display driver ICs are designed with this objective in mind - two sets of backplane outputs, one on each long side of the IC (see Figure 12).

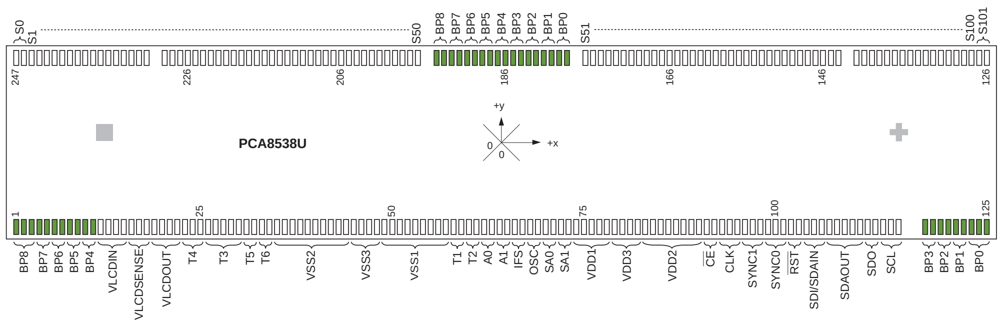


Fig 12. Example of backplane location on an NXP COG display driver

4. **Material and assembly:** In terms of material and assembly a COG LCD solution is more cost-optimized compared to an SMD LCD solution. In the COG case, there is no need for placing and soldering the LCD cell and the LCD driver onto the PCB, avoiding the cost of this processing step along with the cost for inspection and verification. Also in terms of material, depending on the number of connections to the display, in the SMD case a considerable number of connectors (supplies, segments, backplanes) are required between the PCB and the LCD cell whereas in the COG case only the supplies and interface pins must be connected.

4.3 Case Study: Cost-structure of SMD compared to COG

In the following, the cost structure of SMD versus COG shall be further analyzed and compared, based on a calculation model of a 160 segment TN LCD with a size of 40 mm × 24 mm. The display is assumed to be driven by a PCF8576DU in the COG case (40 × 4 LCD segment driver), and a PCF85176 in the SMD case (40 × 4 LCD segment driver for industrial applications, housed in a TSSOP56). In the SMD case, the display has its original size (40 mm × 24 mm). In the COG case, the display area is slightly bigger (40 mm × 26 mm) as the driver has to be placed on the glass, which requires 2 mm additional width. In this example, a PCB type FR4 is taken as a basis. The area in the SMD case is assumed to be 80 mm × 40 mm; in the COG case the area is 64 mm × 40 mm.

For an equivalent comparison both modules (SMD and COG) use Flex Panel Connectors (FPC) as shown in Figure 13.

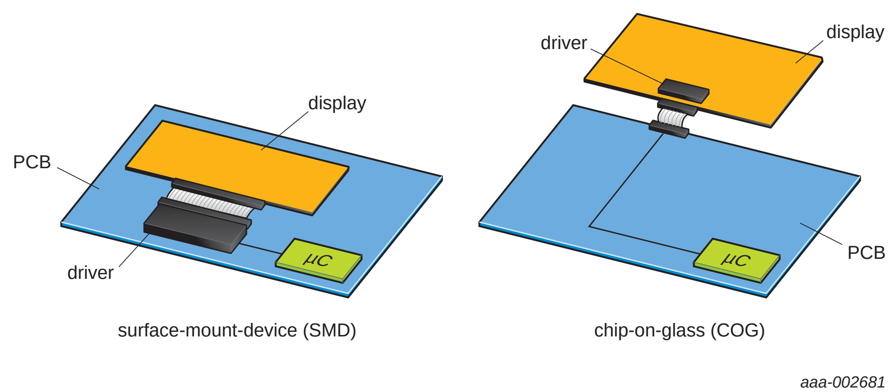


Fig 13. LCD modules for cost comparison

A qualitative and quantitative analysis is done for the following cost parameters (1) LCD glass, (2) LCD driver IC, (3) PCB area, and (4) material, assembly, and testing (see Table 4).

Table 4. Cost parameters (see Figure 13)

Surface-Mount Device (SMD)	Chip-On-Glass (COG)
• LCD: – type TN	• LCD: – type TN
• LCD driver IC: – PCF85176 cased in TSSOP56	• LCD driver IC: – PCF8576DU as bare die with bumps
• PCB area – PCB type FR4	• PCB area – PCB type FR4
• Material, assembly and testing: – Flex Panel Connector (FPC) – Assembly FPC – Testing – Soldering – Misc.	• Material, assembly and testing: – Flex Panel Connector (FPC) – Assembly FPC – IC bonding – Testing – Misc.

In Table 5, the cost and share structure of SMD versus COG will be compared. It shows the cost structure and the percentage share of the different components as listed in Table 4.

Table 5. Cost and share structure

Matter of expense	Type	X (mm)	Y (mm)	A (cm^2)	Quantity	Cost share (%)
Surface-Mount Device (SMD)						
LCD	TN	40	24	9.6	1	18
Driver IC (TSSOP56)	PCF85176	-	-	-	1	34
PCB	FR4	80	40	32	1	25
Flex Panel Connector (FPC) (number of tracks)	-	-	-	-	44	12
IC bonding (ACF)	ACF	-	-	-	0	0
Assembly (FPC)	FPC	-	-	-	1	5
Testing	-	-	-	-	1	3
Misc.	-	-	-	-	1	3
Total	-	-	-	-	-	100
Chip-On-Glass (COG)						
LCD	TN	40	26	10.4	1	24
Driver IC (bare die with bumps)	PCF8576DU	-	-	-	1	23
PCB	FR4	64	40	25.6	1	25
Flex Panel Connector (FPC) (number of tracks)	-	-	-	-	5	10
IC bonding (ACF)	ACF	-	-	-	1	6
Assembly (FPC)	FPC	-	-	-	1	6
Testing	-	-	-	-	1	3
Misc.	-	-	-	-	1	3
Total	-	-	-	-	-	100

[1] Source of the cost content of the driver and driver type is NXP; an established module manufacturer provided the cost and characteristic of the display, PCB, material, assembly, and testing.

Figure 14 compares one on one the costs on each matter of expense. It shows that the largest cost saving can be achieved with the display driver IC because in the COG concept, it doesn't have a package. On the other hand the COG concept requires an increased display glass area. This reflects the increased cost on the COG side of the balance. As shown in Figure 7, the package represents between 47 % and 62 % of the driver cost, depending on the number of display elements.

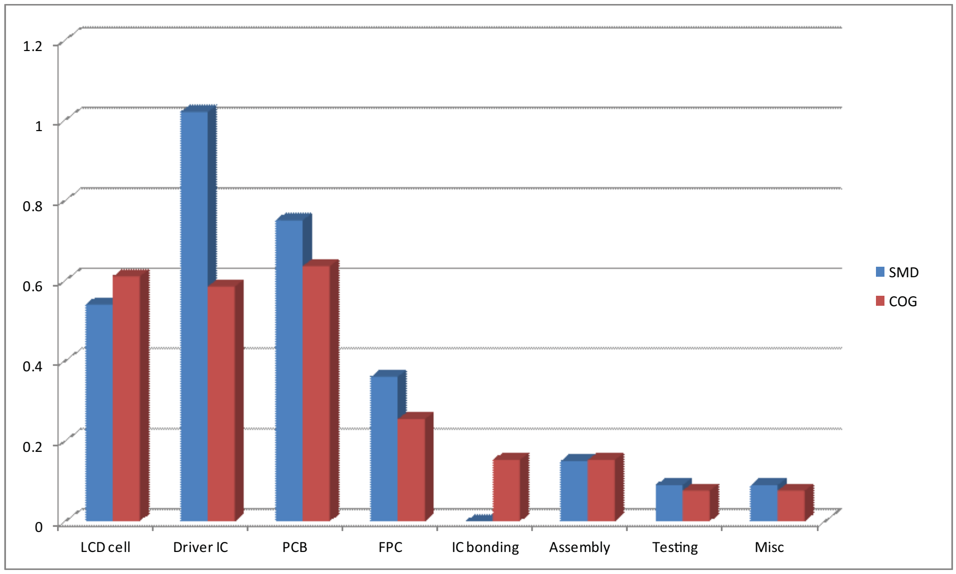
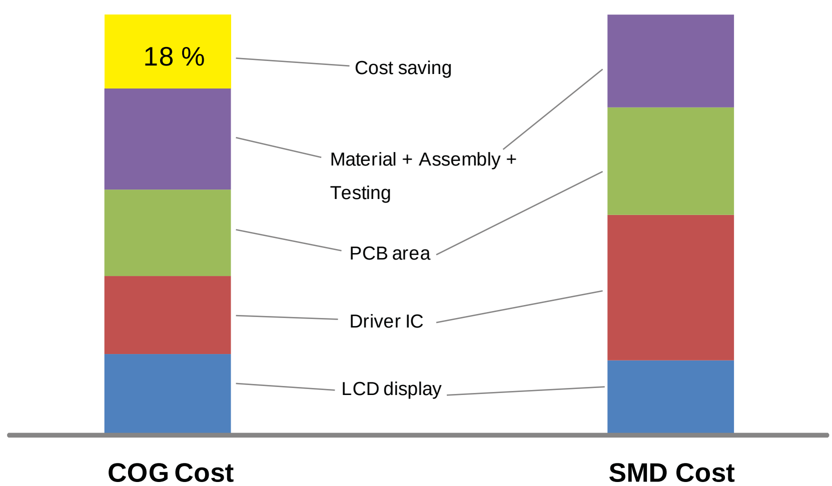


Fig 14. Normalized COG and SMD cost share structure

In this example, the overall cost saving amounts to 18 % in favor of COG (see Figure 15). However, the actual cost savings depend on many parameters including the profit margins of the respective component suppliers which have not been taken into account in this model; altering these parameters will also alter the cost savings.



COG cost saving: 18 % in this example.

Fig 15. Cost comparison COG vs. SMD

5. Summary and Conclusions

The Chip-On-Glass (COG) technology is an alternative design methodology where the LCD driver is directly mounted on the display glass. COG has significant advantages compared to conventional methods like Surface-Mount Device (SMD). Removing the LCD driver from the PCB relaxes the complexity of the PCB, ruggedizes the reliability, enhances the flexibility of the application design and redesign and therefore lowers the system costs. COG is a very reliable and well established technology, which is often used in the automobile industry.

Table 6. Summary of SMD compared to COG

Surface-Mount Device (SMD)	Chip-On-Glass (COG)
• Cased LCD driver IC: in a package soldered directly on the PCB • All connections have to be designed on the PCB • Erratic arrangement of PCB and LCD • Increased BOM • More complex inventory handling	• Uncased LCD driver IC: bare die mounted directly on the display • The LCD module contains everything to drive the display • The modularized construction – separates the functional parts of the PCB from the display connected via a Flex Panel Connector (FPC) – increases the flexibility in the design of the PCB and the application – allows the reuse of the LCD module in the case of a redesign or in a new application design – simplifies the assembly process • Lowered costs by – reduced BOM – reduced development expenses – leaner inventory

NXP has more than 10 years of experience in designing LCD drivers for COG application and offers a wide and continually broadened portfolio of COG display drive ICs (see Table 7).

6. NXP solutions for Chip-On-Glass

Table 7. Parametric comparison table of LCD segment driver for COG technology[1]

Product	Max number of elements								AEC Q100 compliant	V_{DD} (V)	V_{LCD} (V)	T_{amb} (°C)	f_{fr} (Hz) typ
	in total	in static drive mode	in MUX 1:2	in MUX 1:3	in MUX 1:4	in MUX 1:6	in MUX 1:8	in MUX 1:9					
PCA8576DU	160	40	80	120	160	-	-	-	Y	1.8 - 5.5	2.5 - 6.5	–40 - 85	77
PCF8576DU	160	40	80	120	160	-	-	-	N	1.8 - 5.5	2.5 - 6.5	–40 - 85	77
PCA85133U	320	80	160	240	320	-	-	-	Y	1.8 - 5.5	2.5 - 6.5	–40 - 95	SEL[2]
PCF85133U	320	80	160	240	320	-	-	-	N	1.8 - 5.5	2.5 - 6.5	–40 - 85	SEL[2]
PCA85132U	640	160	320	480	640	-	-	-	Y	1.8 - 5.5	1.8 - 8.0	–40 - 95	SEL[2]
PCF85132U	640	160	320	480	640	-	-	-	N	1.8 - 5.5	1.8 - 8.0	–40 - 85	SEL[2]
PCA85232U	640	160	320	480	640	-	-	-	Y	1.8 - 5.5	1.8 - 8.0	–40 - 95	SEL[2]
PCA8538U	918	102	204	-	408	612	816	918	Y	2.5 - 5.5	4.0 - 12.0	–40 - 105	SEL[2]

[1] All of the LCD segment driver listed in this table can be cascaded for larger display configurations.

[2] Selectable by programming or wiring.

7. References

[1] **AN10170 —** Design guidelines for COG modules with NXP monochrome LCD drivers

[2] **AN10706 —** Handling bare die

[3] **AN10853 —** ESD and EMC sensitivity of IC

[4] **UM10204 —** I^2C-bus specification and user manual

8. Abbreviations

Table 8. Abbreviations

Acronym	Description
AEC	Automotive Electronics Council
ACF	Anistropic Conductive Film
BOM	Bill Of Materials
CMOS	Complementary Metal-Oxide Semiconductor
COG	Chip-On-Glass
ESD	ElectroStatic Discharge
EMC	ElectroMagnetic Compatibility
FPC	Flex Panel Connector
I^2C	Inter-Integrated Circuit bus
IC	Integrated Circuit
ITO	Indium Tin Oxide
LCD	Liquid Crystal Display
MUX	Multiplexer
PCB	Printed-Circuit Board
SMD	Surface-Mount Device
TN	Twisted Nematic

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