Chip-on-Glass LCD Driver Technology

Well-proven Approach from NXP Reduces Medical System Design Costs

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Executive Summary

Progress in Liquid Crystal Display (LCD) medical imaging technology has led to its increasing adoption for diagnostic viewing of medical images. Although LCD monitors have many advantages over cathode-ray tube monitors, cost continues to be a factor when medical professionals choose equipment. The rising overall cost of medical care adds further urgency to decrease equipment cost where possible.

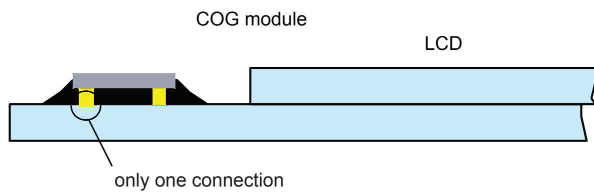
For systems that require LCD displays, a typical design approach has been to mount the display glass as well as the integrated circuit driving the display directly onto a printed circuit board (PCB). This approach results in a complex and area-intense PCB design. To address this issue, NXP has developed a Chip-on-Glass (COG) LCD driver approach whereby the integrated circuit mounts directly on the display glass, with the overall impact being a reduction in system cost. COG is a very reliable and well-established technology, which is often used in the automobile industry.

Use of LCD Displays in Medical Imaging

The need for imagery displays in medicine is vast, with technology such as digital X-ray, CT, MRI, and ultrasound just a few examples. Technological advances in areas such as minimally invasive surgery, where imaging provides doctors guidance also drive more display use. As LCD technology continues to progress and improve, digital imaging techniques are replacing analog-based cathode-ray tube monitors for medical uses. LCD monitors have many advantages over CRTs, including sharper imagery, reduced eyestrain, longer life, space efficiency, energy efficiency, reduced radiation, lighter weight, and better overall product quality. The one drawback to rapid and widespread adoption has been cost.

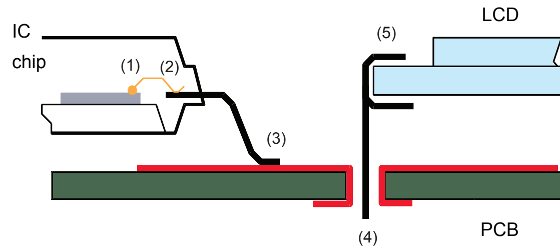
Pressure to reduce cost also increases as device portability requirements grow. Portable devices enable more efficient use of medical resources, and can even enable in-home care. To make a portable device feasible for in-home use, however, it must be offered at a reasonable price point. Thus manufacturers must find ways to cut cost wherever possible. One way to cut cost is by an innovative LCD design technology called

a. COG LCD module



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

b. SMD display



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.

Figure 1. COG and SMD LCD

"Chip on Glass" (COG). Whereas today, manufacturers often implement LCDs by connecting a cased[1] LCD driver integrated circuit with the physical display via a PCB, COG technology is an alternative design methodology in which the LCD driver mounts directly on the display glass. The overall impact is a reduction in system cost.

The Chip-on-Glass Value Proposition

The current surface mount approach (connecting a cased LCD driver integrated circuit with the physical display via a PCB) provides a robust mechanical solution, but requires a more complex and more area intense PCB design.

The alternative design approach of Chip-On-Glass technology (where the LCD driver mounts directly on the display glass) reduces the number of tracks and layers on the PCB (cutting the board size and complexity) and eliminates the integrated circuit package. (See Figure 1 for an illustration of the two approaches.)

COG results in a reduction in system cost, but requires tight production and design coordination between IC and LCD module manufacturers. NXP supports COG applications through strong relationships with major LCD module manufacturers worldwide and benefits from more than 10 years of experience in designing LCD drivers for COG applications.

Understanding the Conventional Surface Mount Method

In the surface mount method, manufacturers mount the display and display driver directly onto the printed circuit board. Either fixed-pins or elastomeric connectors (ZEBRA) enable the connection between the display and the printed circuit board. With an LCD segment driver featuring up to 240 segments in multiplex 1:4 mode, this approach 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 using a 128 segment display and 36 connections.)

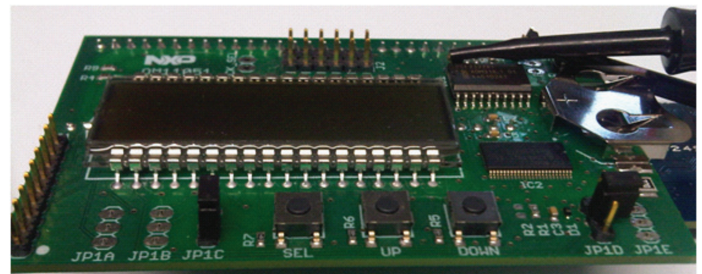


Figure 2. SMD LCD display with fixed pins

1. An LCD driver IC in a package.

Figure 3 illustrates the construction of an SMD LCD with elastomeric connectors (ZEBRA). The SMD display consists of the LCD cell and a metal or plastic bezel that clamps the LCD cell down 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 two isolating strips. The metal or plastic bezel squeezes the ZEBRA slightly to guarantee a firm contact between the LCD and the PCB.

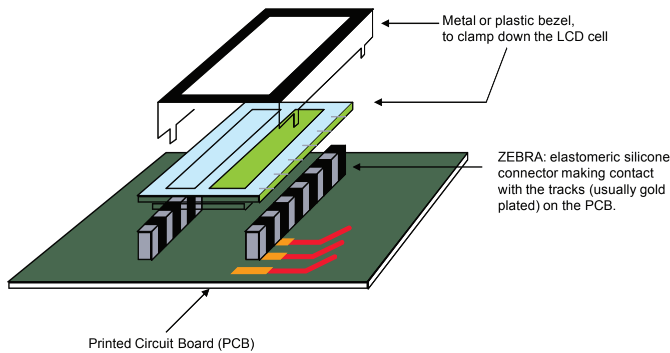


Figure 3. Illustration of an SMD LCD with elastomeric connector

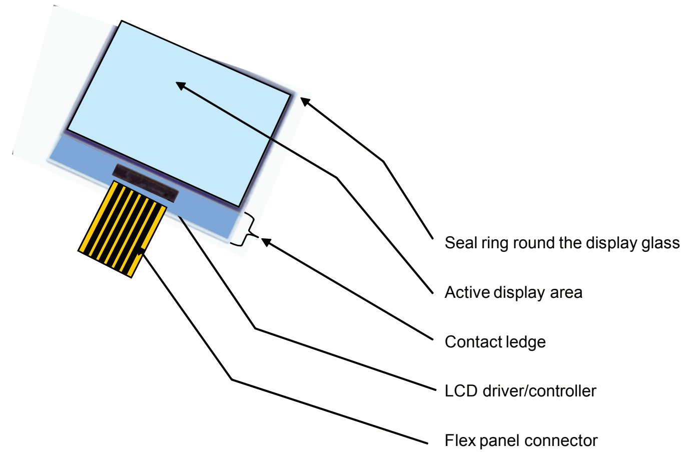


Figure 4. COG LCD module

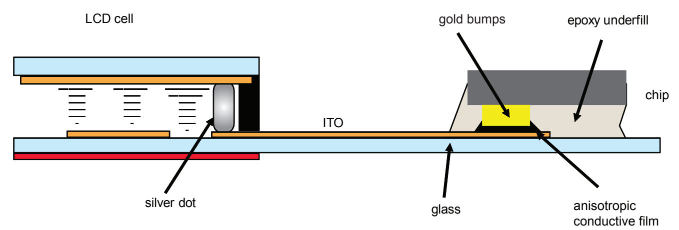


Figure 5. Illustration of a COG LCD module

The Alternative Chip-on-Glass Concept

A Chip-on-Glass LCD module consists of:

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

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

Liquid crystal displays are created by sandwiching liquid crystal between two glass substrate plates. To create a COG module, one of the two glass plates that make up the LCD is extended to give room for mounting an LCD driver and providing connections to it (see Figure 4 and Figure 5). Indium Tin Oxide (ITO) electrodes, which are integrated on the surface of the glass plates, connect via an Anisotropic Conductive Film (ACF) to the gold bumps mounted on the connecting pads of the driver IC to enable the display connections.

The COG approach increases design flexibility for the LCD module in a number of ways:

- 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 indium tin oxide tracks on the LCD glass.
- The placement of the LCD driver IC can be on any side of the active display area. This flexibility allows placement of the LCD driver IC on the smaller side to minimize the required contact ledge area, which reduces cost.
- The COG technology allows the cascading of several LCD driver ICs directly on the contact ledge in order to support 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.

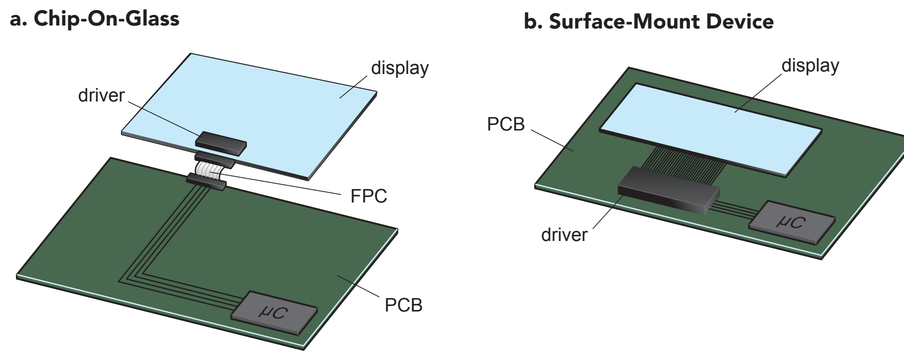


Figure 6. Chip-On-Glass compared to Surface-Mount Device

Comparing Design Effort Associated with COD and SMD Approaches

In the SMD approach, the display and the display driver mount directly onto the PCB (see Figure 6). For the COG approach, the display driver mounts onto the display module and connects to the PCB via a Flex Panel Connector (FPC).

The two systems require the components listed in Table 1. While the COG approach does require additional glass surface area, it provides flexibility for future upgrades, while reducing both PCB area and the number of connections required. The design and effort differences are summarized in Table 2.

Table 1. Components

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

Table 2. Design and effort considerations

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

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

Cost Benefits of the COG Solutions versus the SMD Approach

Four key components[2] determine the cost of a COG or SMD display. These components include:

- Printed circuit board
- LCD driver
- Display glass
- Material and assembly

The following examines each of these contributing components in more detail, and Table 3 provides a cost comparison summary for the two approaches.

Table 3. Key Components Cost Comparison Summary

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

Printed circuit board: 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 display module and the display driver can be off-loaded from the PCB, saving board area and reducing board complexity. These reductions in board area and complexity help to reduce overall system cost.

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). (Figure 7 doesn't reflect the additional cost for the gold bumps needed for a COG LCD module.)

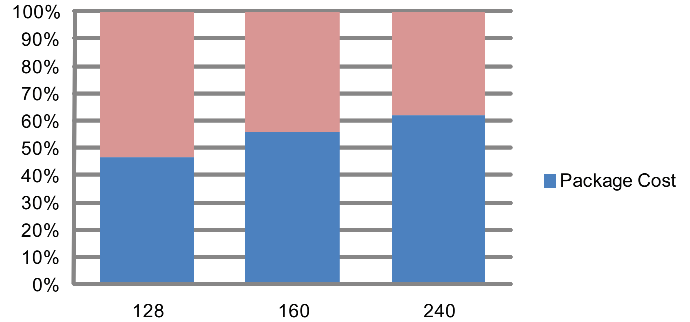


Figure 7. Share of package cost on total display driver cost as function of total number of display elements

Also, higher package pin counts result in exponentially higher package cost (see Figure 8). 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):

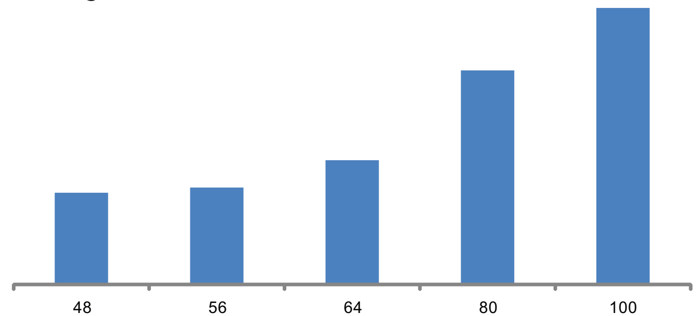


Figure 8. Package cost as function of number of pins

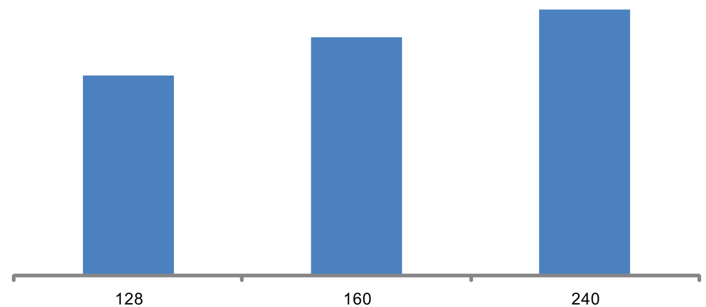


Figure 9. Package cost per display element as function of total number of display elements

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. The COG approach requires additional glass area to accommodate the LCD driver IC. The size of this additional area heavily depends on the physical

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

dimensions of the driver IC and the X-Y-dimensions of the LCD cell. The ideal driver IC design maximizes length while minimizing width. Such long and narrow driver ICs require less additional glass area. NXP designs most COG LCD driver ICs with this objective in mind—long and narrow for the lowest glass cost (see Figure 10).

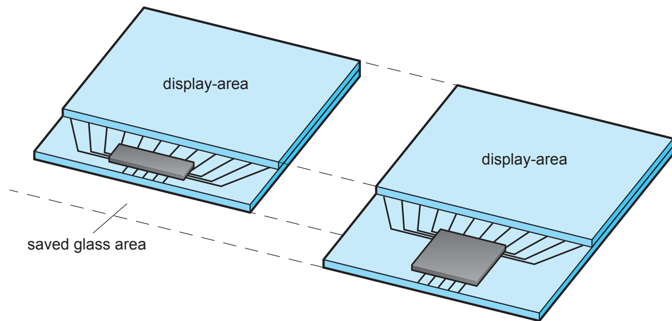
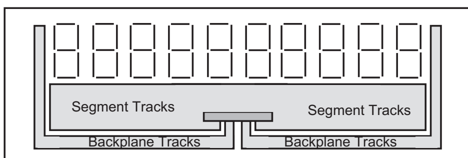


Figure 10. Required display area depending on the driver IC size

To reduce cost even further, the display driver IC should ideally always be placed on the smaller side of the active display area (see Figure 11). For full flexibility in display driver placement, the display driver IC should ideally have backplane outputs on both sides. NXP designed all of the latest NXP COG display driver ICs with this objective in mind—two sets of backplane outputs, one on each long side of the IC (see Figure 12).

• Suboptimal arrangement: display driver IC placed on the long side of the display



• Optimized arrangement: display driver IC placed on the short side of the display

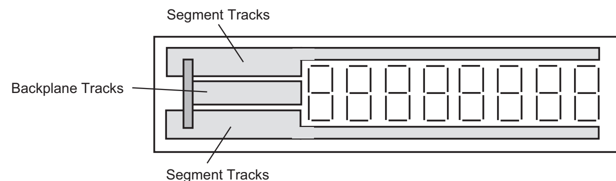


Figure 11. Placing of display driver IC on the display

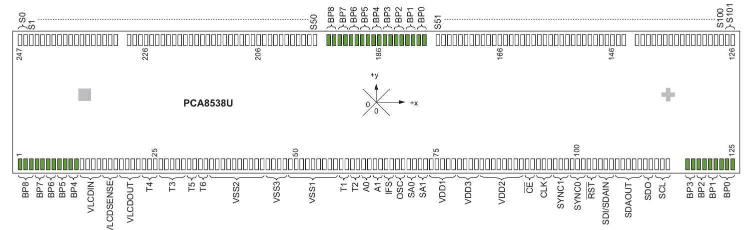


Figure 12. Example of backplane location on an NXP COG display driver

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 in the SMD case, a considerable number of connectors (supplies, segments, backplanes) are required between the PCB and the LCD cell (depending on the number of connections to the display), whereas in the COG case, only the supplies and interface pins must be connected.

Example Case for Cost Comparison

To illustrate the cost of a COG versus an SMD approach, this section provides example calculations based on a 160 segment twisted nematic (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.

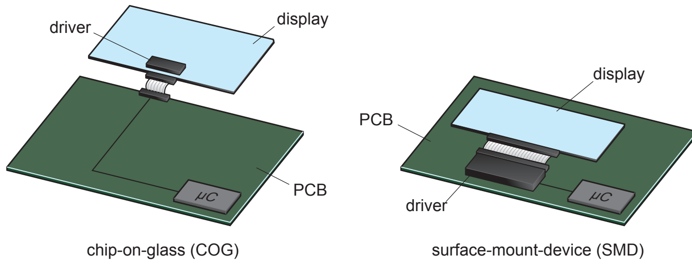


Figure 13. LCD modules for cost comparison

To compare cost, we focus on the following parameters: (1) LCD glass, (2) LCD driver IC, (3) PCB area, and (4) material, assembly, and testing (see Table 4).

Table 4. Cost parameters

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

Table 5 provides a cost and share structure comparison of SMD versus COG approaches. It shows the cost structure and the percentage share of the different components listed in Table 4.

Table 5. Cost and share structure

Matter of expense	Type	X (mm)	Y (mm)	A (cm²)	Quantity	Cost share (%)
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
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

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 provides a comparison of one on one costs for each 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.

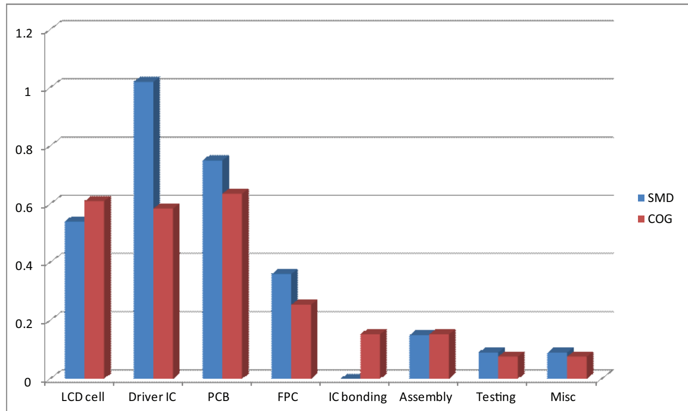


Figure 14. Normalized COG and SMD cost share structure

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.

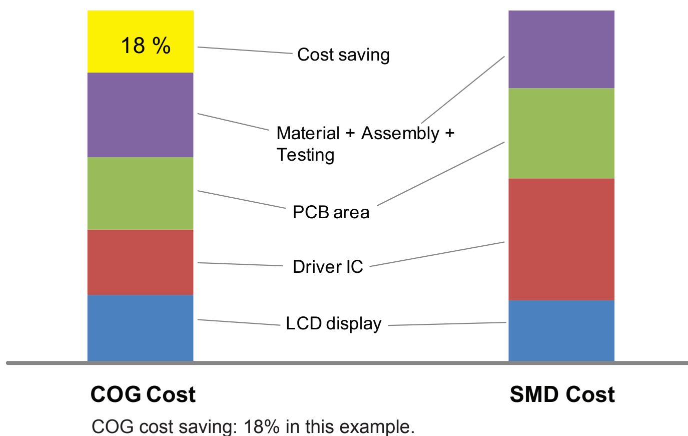


Figure 15. Cost comparison COG vs. SMD

Conclusion

The Chip-On-Glass (COG) technology, an alternative LCD design methodology where the LCD driver mounts directly on the display glass, provides cost and design advantages for medical applications. COG advantages compared to conventional methods such as Surface-Mount Device (SMD) include the ability to remove the LCD driver from the PCB, which relaxes the complexity of the PCB, ruggedizes the reliability, enhances the flexibility of the application design and redesign, and lowers the system costs. COG is a very reliable and well-established technology, which is often used in the automobile industry. NXP has more than 10 years of experience in designing LCD drivers for COG application and offers a wide and continually broadening portfolio of COG display drive ICs. Contact NXP for more details.

Table 6. Summary of COG advantages over SMD

Chip-On-Glass (COG)	Surface-Mount Device (SMD)
• Uncased LCD driver IC: bare die mounted directly on the display	• Cased LCD driver IC: in a package soldered directly on the PCB
• The LCD module contains everything to drive the display	• All connections have to be designed on the PCB
• 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	• Erratic arrangement of PCB and LCD
• Lowered costs by – Reduced bill of materials – Reduced development expenses – Leaner inventory	• Increased bill of materials
	• More complex inventory handling

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 — I2C-bus specification and user manual

Acronyms

Table 7. Abbreviations

Acronym	Description
ACF	Anistropic Conductive Film
COG	Chip-On-Glass
ESD	ElectroStatic Discharge
EMC	ElectroMagnetic Compatibility
FPC	Flex Panel Connector
I2C	Inter-Integrated Circuit (2 wire) bus
IC	Integrated Circuit
ITO	Indium Tin Oxide
LCD	Liquid Crystal Display
PCB	Printed-Circuit Board
SMD	Surface-Mount Device
TN	Twisted Nematic (Type of Liquid Crystal)

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