Engineering for Commercial Success

Critical business factors when integrating an embedded human machine interface

4D SYSTEMS
MAKING HUMAN INTELLIGENCE SMARTER

www.4dsystems.com.au

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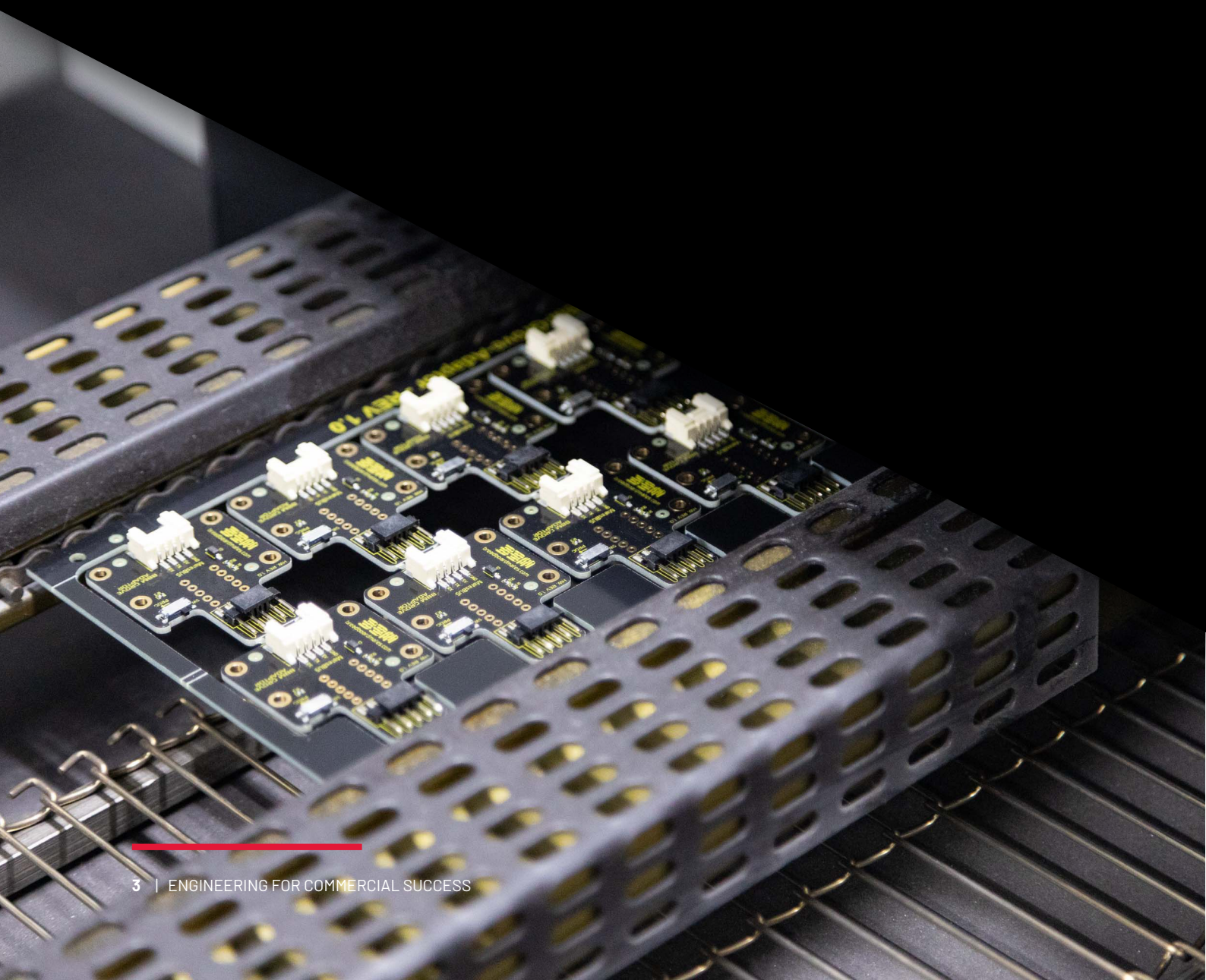

1.1 Starting the Journey

Choosing the HMI (Human-Machine Interface) components that your users interact with is a key part of the product development process. The right display module can give your device a competitive advantage, reduce user error and frustration – and help keep your device compliant.

But deciding how to produce your intelligent display, which display to buy, to what degree you customize it – and even considering building one from scratch – can be a tough commercial choice. In this whitepaper we provide a comprehensive overview of key commercial factors to consider when evaluating these options.

We outline how market dynamics like time-to-market, production volume, and cost control impact the build, buy, or customize decisions. We also explore how unique device specifications may necessitate customised HMIs, while off-the-shelf solutions can streamline development.

Other factors we discuss include available engineering expertise, risks like development delays, and the burden of ensuring regulatory compliance.

Equipped with these insights, you can make informed choices around building, buying, and customizing HMIs: reducing development time and costs while still meeting product requirements and compliance standards – all while minimising risk and getting your application into market.

1.2 What Can an HMI Achieve?

We are talking about a user interface or dashboard that connects a person to a machine, system, or device, allowing bidirectional interactions. For contemporary devices it is commonly a display – often using a touch interface.

HMIs are used in devices across industries, including industrial settings, the automotive environment, consumer goods, and healthcare. For example, in the manufacturing industry, HMIs are used to visually monitor production data, analyze production time, trends, and tags, oversee KPIs, and track machine inputs and outputs.

For automotive vehicles, the HMI is a key functional element that allows drivers to communicate with their vehicle – including instrument clusters and heads-up displays.

Likewise, in healthcare, HMIs enable various medical treatments, and are integral to the assessment, monitoring of patients, and administration of treatment, providing vital information and benefits to patients and clinicians alike.

5 KEY CONSIDERATIONS

1.3 Getting the HMI Right

When a display is well-designed (and well-chosen), it reduces the likelihood of user errors – errors which can lead to accidents, production losses, and other negative outcomes.

Production stability is also enhanced when the HMI is designed correctly, as it allows for more efficient monitoring and control of processes, leading to fewer disruptions and more consistent output.

In addition to these benefits, the HMI also has implications for compliance management. A well-designed HMI can help organizations meet regulatory requirements and industry standards, reducing the risk of fines, penalties, or other severe consequences - for example when data is linked to health or safety related factors.

Invest in the appropriate design and implementation of your HMI means an improved user experience, increased efficiency, and better risk management. These advantages ultimately contribute to the overall success of your product, and the competitiveness and sustainability of your business.

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2. CONSIDERATIONS I

Market conditions often guide your planning. Competitive benchmarks, how quickly you need to get your device onto the market, and the regulatory requirements in your market.

We're also referring to economic realities: will the volume of devices you sell be high enough to warrant a heavily customised solution? Will a small saving in the cost of an HMI display lead to a big jump in margins?

It doesn't make sense to over-engineer an HMI when you won't recover the costs – but on the other hand, the market that you enter may demand that you produce a device that's highly customised.

2.1 Time to Market

Even where factors such as in-house expertise, budget, or quantity aren't concerns, time to market can be the determining factor in your HMI strategy – and choice of display vendor.

If speed to market is paramount, consider purchasing as much of your HMI solution in one go as possible, rather than building anything in-house or heavily customizing a display. A product can be delivered to you within days, or even as soon as the next day.

In contrast, building your own solution or heavily customizing an existing solution could delay your product release – resulting in misalignment with market demand. Don't overlook the challenge of procuring reliable components and materials either.

Time constraint is something that can tilt the decision towards spending a bit more per unit to buy a solution that reliably meets your production timelines.

ECONOMIC CONSIDERATIONS

1. Factoring in indirect costs

2. Amortization of costs

3. Due diligence

4. Capital available

5. Cash flow

6. Unit numbers

2.2 Economic Factors

It's important to look beyond immediate economic considerations, such as per unit cost, or development fees. Broadly-speaking, industries that produce large volumes of products over extended periods tend to favour the build option or consider heavily customizing their HMI displays.

This is because, in the long run, building an HMI display can offer a better return on investment, especially when production scales are high. It's a complex choice, however, some key factors you should consider are:

- ***Infrastructure and maintenance:*** *While the economics might favour building or customizing heavily, it's worth considering the costs of maintaining ongoing infrastructure. That includes a manufacturing or fitting facility and skilled professional, which can become costly and resource-intensive in the long run.*

- ***Amortization:*** *Consider the long-term financial implications. Will the costs incurred during the build phase be recouped over the product's lifetime? How long will it take to recoup the investment – and are you assured of the product's success?*

- ***Cash flow:*** *Building an HMI system requires significant capital. Consider whether you have the financial capacity to bear the costs without straining cash flow. Though most critically, include a degree of flexibility for cost overruns, and consider a range of indirect costs we explore further in this paper, including those related to certifications.*

- ***Volume and cost control:*** *If you're producing HMI systems in large quantities, greate control over the hardware can be economically beneficial. High levels of customization mean you exercise ultimate cost control – though start-up costs would be higher.*

Overall, if you have a substantial budget and the expertise to manage the project, building is an option – and you may want to inventively customize a display.

3. CONSIDERATIONS II

Now that you know what your marketplace requires and have thought through economic implications, you need to have a closer look at the requirements of your device.

Are you building a commodity device, with associated commodity display requirements? Are you relying on a custom user experience to differentiate your product? These are the type of questions you should think about when evaluating buying something off the shelf and implementing as-is, vs. customising it, vs. building your own solution.

3.1 How unique or customized is your product?

While for a lot of devices one of the many off-the-shelf HMI solutions will be a perfect fit, there are specific requirements that may necessitate a customized approach:

- ***Environmental requirements:*** *Customization becomes essential if your product has unique environmental needs – coping with extreme conditions beyond standard thresholds, whether that's cold or perhaps humid for example.*

- ***Unconventional form factors:*** *If your product demands unconventional shapes or dimensions, like oblongs or triangles, custom fabrication could be your only solution.*

- ***High specifications:*** *Specific performance or aesthetic standards, such as high refresh rates or high dynamic range, may also call for tailored solutions.*

It's important to understand that when you opt for an off-the-shelf product, many of its features are set in place. Changing a connector may necessitate a complete board redesign, procurement of new components, creation of new factory stencils, and the assembly of new boards.

For example, to customize a 4D Systems display module, you need to make changes to its physical components and design. This customisation would involve changes to the connector used on the module or even modifying its physical layout. In this scenario, if you want to use a different type of connector, it might require changes to the PCB layout. Some customisations might seem like minor changes but they are not simple or trivial tasks. It involves multiple steps, including design, procurement, manufacturing, and assembling, each of which can be complex and require careful attention to detail.

However, there's one aspect of an HMI that is increasingly easy to customize: the visuals. Modern display units come equipped with SDKs and design studios that allow for extensive customization of the visual interface, while ensuring it can connect with any required data sources or connectivity options.

3.2 Can buying a solution meet your needs?

Pre-built solutions have significantly improved in quality over time, and are more customisable than ever before. Besides, when you buy a solution, you're not just purchasing a product; you're acquiring years of expertise and refinement from the manufacturer. This comprehensive quality often surpasses the value of one or two unique features that might be absent.

Furthermore, when considering code portability, "buy" solutions have an edge due to their standardized

interfaces and modular designs. In contrast, while "build" solutions offer more control and tailored functionality, they can be more closely tied to particular hardware and software components, reducing their portability.

The development path chosen also influences performance. "Buy" solutions can enhance the performance of the main controller by offloading some of its processing tasks. For instance, if the main controller doesn't have to manage the LCD on top of its primary functions, its overall performance can be significantly boosted.

The advantage of the buy solution could be the integrated graphics controller, particularly in the context of 4D Systems display modules and how they can simplify the design process and improve the user experience. The process is made efficient by offloading processing tasks from the main microcontroller to the integrated graphics controller. Due to this, the designers have more resources and time to enhance the system.

3.3 Customizing for competitive advantage

It's also worth noting that display vendors can provide highly customised solutions tailored to specific needs. For instance, if you require automotive-grade or industrial displays with a broader operating temperature range, your preferred vendor might offer a suitable solution or suggest modifications to their existing products.

However, even when customizing (rather than building on your own) it's essential to strike a balance. While customization can be beneficial, excessive customization can lead to challenges.
Purchasing standard units can offer more flexibility in adapting to product line changes. Over-customizing might result in support issues, potential conflicts with upcoming products, and other unforeseen technical complications.

Customizing could have substantial benefits – bearing in mind that you may be able to customize an off-the-shelf display with relatively little effort. And yes, it's possible that choosing the right HMI (indeed the right customizable HMI) could really elevate your offering.

The Sinclair, Fort Worth Texas

The Sinclair, Fort Worth Texas

CASE IN POINT:

Customized Display for Hospitality

'The Sinclair' Hotel underwent a stunning digital transformation and retrofitting of their Building Automation System. The original elevator doors and cigar boxes might fool one to think they have travelled back in time. It is anything but: from check-in to accessing your room, the hotel is futuristic and all digital.

Whilst innovation through data drives the hotel's digital infrastructure, it is the way humans interact with that data and choose to create the micro-environment most suited to them during their stay is what brings the hotel to life.

And this bridge – between data and the micro-environment - is the 4D SYSTEMS display solution, right at the fingertips of every guest in the same elegant aesthetics as the hotel itself boasts.

Customisation of the intelligent display module was tailored to suit The Sinclair's specifications, as well as to the project's partners like Intel, Cisco and Igor-Tech.

The Sinclair In-Room control interface, created using 4D SYSTEMS' 4Discovery-50

Customised Products *Vs* Integrated Product

CUSTOMIZED PRODUCTS

- Better Market Fit
- High Unique Selling Point
- Future Product Line Adaptive
- Proprietary Product Ownership

INTEGRATED PRODUCTS

- No Internal Team Required
- Lower Development Cost
- Supply Chain Reliability
- Compliance Included

4. CONSIDERATIONS III

When determining your approach to our HMI decisions, it's crucial to reflect on your past experiences. Ask yourself if over-customizing in the past led to complications in the production or post-production stages.

Determine whether there was a time when the product you offered was too simplistic, allowing competitors to surpass you. Think about deadlines as well; and identify instances where operations struggled to meet a deadline – and did it affect your time-to-market, or result in significant cost overruns.

It's invaluable to learn and adapt from your past experiences to avoid making the same mistakes again – and much of that depends on your internal capabilities.

4.1 Determine the hardware and software expertise required

Companies with extensive in-house engineering resources often prefer to handle projects internally but building an HMI from scratch demands a deep understanding of, and experience with, a number of engineering aspects – alongside manufacturing capabilities.

When starting from scratch with display modules, a comprehensive understanding of both hardware and software is essential. Teams must design hardware based on component datasheets and understand various display technologies, including LCD pixel management, colour coordination, and more. However:

- *With an embedded display, the complexities of understanding the display are eliminated. While electronics design and software development expertise remain crucial, the niche knowledge of displays becomes less critical.*
- *From a software perspective, development teams must be able to write software code to ensure seamless hardware integration, and libraries for pixel management. While some open-source libraries might be available, the task remains substantial.*
- *Buying a comprehensive solution mitigates many of the skills requirements, and can in many cases allow you to create highly customized interfaces tailored to your needs. In scenarios where a legacy system requires a new display that can't be customized, both 'buy' and 'build' solutions present challenges.*

The d.Drive PUMP controlled via the touch display gen4-uLCD-35DCT-CLB

In some cases, you may have legacy systems in place that were designed to work with different types of displays or interfaces. But if they are compatible with 4D Systems product offering, you can write custom code to make them work together. To make the old legacy system work with the new 4D Systems solution, you need to write code that understands the communication protocols used by the legacy systems. However, it should be noted that this might vary from case to case.

4D Systems display modules primarily support the UART interface. They can also work with other communication interfaces such as I2C, SPI, and GPIO pins. If the legacy system uses a communication protocol like Ethernet or Profibus, you may encounter challenges. In such cases where you cannot establish communication between the 4D product and the legacy system, you would need additional hardware or adapters that can translate between the communication protocols. This limitation is primarily hardware related.

In summary, while there's an overlap in the expertise needed for both options, opting for a 'buy' solution can significantly reduce the depth of expertise or hours required in house.

4.2 Assess availability of internal expertise

Embedded electronics and software programming are fundamental hard skills required before embarking on an in-house development journey – and before customizing too heavily – ask yourself whether your team possesses these skills, and whether the level of skills are sustainable.

If not, contracting could be an option – but verify that the contractor will be available to deliver support in the future. It's worth noting that even if you have the skills in-house, the dynamics of your engineering team could change.

Engineers might move on, and the expertise once available might no longer be there. This poses a significant risk, especially if the responsibility of a project rests on a single individual. If that person leaves, the company could find itself unable to support its product. Moreover, the company can focus on their core competencies rather than building HMI modules from scratch.

4.3 Advantages of buying a solution

So, while it might seem tempting to hire one or a few experts to work on a specific task, it's essential to consider the broader picture with regard to the focus of your resources.

Specialised vendors can offer comprehensive support with a team of experts in that field. In many cases, choosing a pre-built, tested solution from a trusted supplier can simplify the decision-making process, ensuring reliability and freeing up resources to focus on the business's core functions. When you collaborate with a solutions provider you:

- *Gain access to a vast amount of organizational intellectual property*
- *Benefit from a single, reliable point of contact*
- *Reduce the lead time for implementation, resulting in a quicker time to market*

Choosing a reputable supplier offers flexibility and can be more advantageous than attempting to handle everything in-house. The depth and breadth of technical support and documentation are crucial not only for launching the product but also for ensuring its long term servicing and optimal performance standard, aligning with market expectations.

The integrated 4D SYSTEMS' touch display

CASE IN POINT:

Supplementing Development Skills at Advancing Air Purification Technologies

From protecting vulnerable patients in hospitals to empowering research laboratories, Airinspace is setting new standards for clean air technologies. As the range of products grows, one challenge is always to make sure that the user's experience of the appliance is as simple and elegant as possible.

Airinspace partnered with 4D SYSTEMS to source an intelligent display solution to embed in all of their air purifiers.

"We looked for a supplier capable of supporting us in the development of the interface because it was a new subject for us and we were looking for a solution that was easy to implement", said Arnaud Le Laidier, Electronics Project Manager at Airinspace.

The importance of an intuitive and well-designed user interface cannot be overstated. According to Nicolas Klaczynski, Head of Development at Airinspace, "the interface is a real advantage over our competitors and a real comfort for our customers and users".

The Plaismair device with the 4D SYSTEMS' touch display

5. CONSIDERATIONS **IV**: THE RISK

Goals and objectives are one thing, though it will always be important to effectively model the risk factors that can have consequences on your development process, launch plans, or result in increased support costs and unhappy customers in the future.

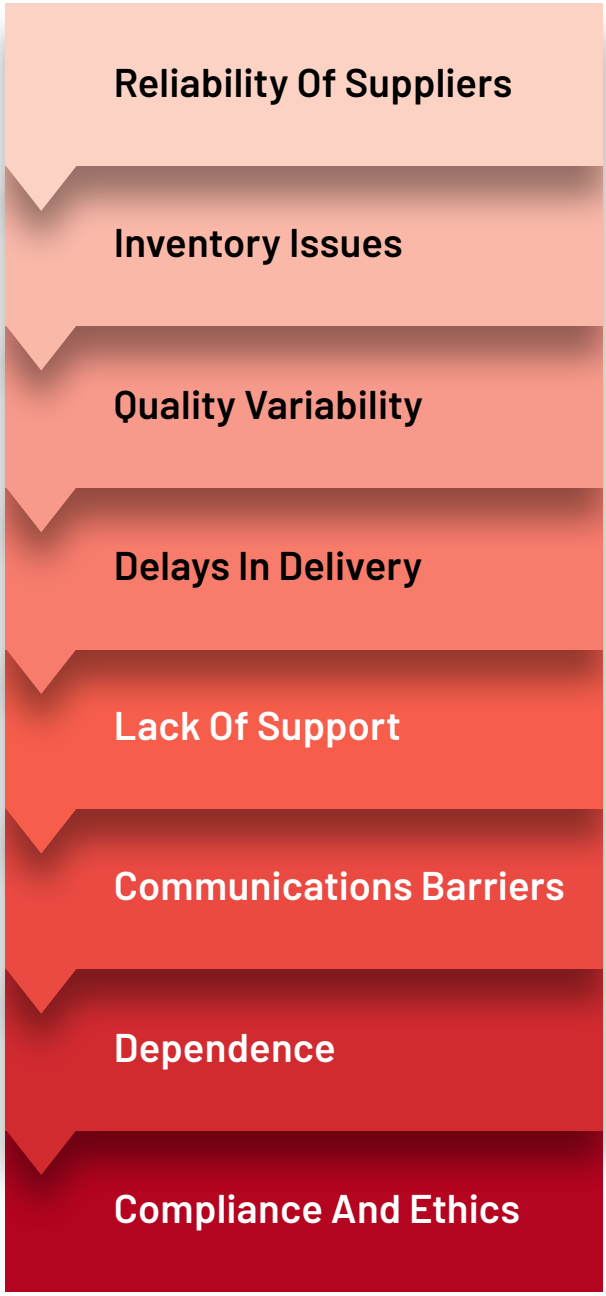
5.1 Monitor for hidden complexity

When considering display development, it's essential not to solely focus on immediate requirements for a swift market release. Instead, several critical factors need attention:

- **Documentation:** *Be aware that documentation for certain products, such as bare LCD models, might originate from non-English speaking countries. This can lead to potential mistranslations or even missing information.*
- **Scalability and customization:** *Ensure that the product can adapt to future demands without being constrained by its initial design.*
- **Long-term support:** *A well-designed solution's longevity is determined by the support it receives over time.*

Whilst building a solution might offer the opportunity to customize extensively, it could lead to increased complexity in the long run. Buying from a widely supported vendor often means that the solution will be compatible with both current and future product lines. In contrast, a custom-built solution might require continuous customization, posing a greater risk over time.

SUPPLY CHAIN **RISK** FACTORS



5.2 Glitches in the development process

Feature failures can sometimes only become apparent once the device is in the field. Your device may have a caretaker role, e.g., producing a complex medical device that's intended to monitor patients and detect conditions.

If you need to move quickly – if time-to-market is critical – we recommend that you don't try to develop an HMI internally, because developing something new inherently involves risk. Extensive customization can also mean that there is a significant chance you'll be delaying your launch plans.

Also consider the volume of features you're building: buy can bring all those features in one go, doing it yourself places success under a lot of risk.

5.3 Risks to the supply chain

Sourcing the components and units you need when you need them always involves risk – and you must consider and counter for supply chain risk.

A large aspect of this risk comes in when working with international suppliers, with COVID-19 highlighting how fragile supply chains can be. A single order that's held up can significantly delay a product roll-out, and you may not be able to find an alternative supplier that easily.

It's a risk that can be compounded if you choose to build most of the displays in-house. In contrast, an external HMI partner can mitigate supply chain risk by leveraging their technical expertise and supplier relationships to, for example, use a different processor for the display. A few other points you should consider:

- *Working with new suppliers can also contain an element of risk that you should factor in. There's an onboarding process and it will take time to find a rhythm.*
- *Proven dependability is also an issue: don't assume that just because you've found the right unit at the right price and volume that the supply will in fact flow consistently and reliably. The vendor may well over promise.*
- *Supply chain risk also implies technical risk. Despite LCD being available in the market, there are instances where a processor, or bare LCD manufacturer would need a significant change like for the LCD driver.*

When using a pre-made 'buy' solution, the display manufacturer deals with many of these challenges. While they are often subject to supply chain disruptions as the rest of us our in an integrated economy, they nonetheless are likely to have the relationships and buying power to be prioritised in their customer delivery.

A close-up of the graphic user interface on The Atena, utilizing the ***gen4-uLCD-70DT***

CASE IN POINT:

CEiiA Rapidly Develops a Ventilator in the Fight Against COVID-19

Prior to COVID-19, CEiiA, Centre of Engineering and Product Development, had never developed a ventilator before.

In response to the confronting reality that there were not nearly enough lifesaving ventilator machines to go around, the Portuguese company was determined to increase the supply of ventilators to help people survive coronavirus.

CEiiA's engineers had previously worked with 4D Systems' embedded displays and one display was already available at their production facility for use in prototyping. This was the gen4-uLCD-70DT Intelligent Display Module with Resistive-Touch and was ultimately used as the Atena's primary user interface.

"We required the graphic display to be intuitive, easy to program, feature-rich and most importantly, reliable for the project. The gen4-uLCD-70DT met all of these conditions and we programmed it using the 4D WORKSHOP4 PRO IDE and Visi Genie environment ," said Mr. Rebelo.
Within just 45 days, CEiiA had produced a Medical Invasive Ventilator.

The Atena – an Invasive Medical Ventilator

> **"We required the graphic display to be intuitive, easy to program, feature-rich and most importantly, reliable for the project.**

6. CONSIDERATIONS **V**: COMPLIANCE

Good HMI design means minimizing information processing load, addressing information management, enhancing operator situation awareness, and ensuring compliance with relevant standards.

Standards help enforce good design practice. For instance, in the automotive industry, ISO 26262 is a standard that defines the need for functional safety including for the displays used electronics in a vehicle.

Compliance with HMI design guidelines, such as the ASM guidelines, goes beyond merely selecting appropriate screen colors. It involves designing display hierarchies, creating effective control and monitoring displays, and implementing proper navigation and interaction mechanisms.

In addition to adhering to industry-specific standards, HMI displays must also comply with general regulations, such as those set by the Federal Communications Commission (FCC) for radio frequency emissions.

AIM FOR COMPREHENSIVE **COMPLIANCE**

REQUIRED

1. Cybersecurity
2. Glass Safety
3. RoHS Electromagnetic

RECOMMENDED

1. **Conflict Minerals**
2. **UV Radiation**
3. **Broader Environmental Regulation**

- Glass Safety
- Conflict Minerals
- UV Radiation
- Broader Environmental Regulation
- RoHS Electromagnetic

6.1 Consequences of Non-Compliance

Failure to comply with regulations and standards for HMI displays can lead to various negative consequences, including:

- **Safety hazards:** *Non-compliant HMI displays may pose risks to operators including accidents, injuries, or even fatalities.*

- **Poor performance:** *Poorly designed HMI displays can result in increased operator errors, negatively affecting the efficiency and effectiveness of the system.*

- **Financial losses and sanctions:** *Non-compliance can lead to fines, penalties, and legal actions; including license revocations, restrictions, or even forced closure of operations.*

- **Reputation damage:** *Companies that fail to comply with device regulations may suffer from a loss of credibility and trust among customers, partners, and regulators.*

- **Business disruptions:** *Non-compliant HMI displays may cause operational disruptions as you're forced to re-engineer to become compliant, affecting production rates.*

- **Loss of market opportunities:** *Non-compliant HMI displays may not be eligible for sale in certain markets or industries, limiting the potential for business growth and expansion.*

It's also worth noting that, even where it is not compulsory, the more compliance certification, and essentially the more self-accountability your product displays in this area, the better. Decision makers in companies may not explicitly state a standard as a requirement but it may well be included in the vendor selection process.

For example, adhering to conflict minerals compliance standards may be a very important aspect for large conglomerates, because it's all part of social responsibility.

So, when thinking about your buyers, understand that there are many different stakeholders within companies that look at compliance. And it's very important to have a comprehensive package of certifications and compliances to meet their requirements.

6.2 How do vendor solutions go through compliance

It's worth considering who it is that is going to take on the compliance burden – and whether your organisation necessarily wants to get involved in certifying HMIs for various compliance standards.

Vendors that provide comprehensive display solutions will do the compliance on your behalf, and are likely to stay abreast of new legislation such as the RoHS and REACH certification process – and keep updated with frequent changes to regulation.

As an example, the 4D Systems pixxiLCD display modules are certified to be in compliance with RoHS regulations and are also confirmed to meet the requirements for REACH SVHC compliance.

Solution providers have compliance teams that are involved in that part of the process, day in and day out. Rather than go for the minimum compliance, good vendors will be as comprehensive as possible and offer equally comprehensive compliance mitigating the risks associated with non-compliance.

Caretaker Medical with 4D SYSTEMS'
4DLCD-24320240-CTP-IPS

CASE IN POINT:

Compliant displays for Caretaker Medical

Caretaker Medical is an innovative digital health company focused on developing wireless patient-monitoring technologies that improve patient outcomes. All of Caretaker Medical's designs must follow rigorous standard operating procedures (SOPs), and in the healthcare field there is little more important than adhering to regulations.

Display engineering choices can significantly affect the ability of a device to pass compliance requirements. "Since the VitalStream platform is a regulated medical device, we must adhere to IEC, FDA and ISO design practices," says Justin McQuown, Director of Engineering at Caretaker Medical.

"We chose 4D SYSTEMS for the simplicity of implementation and cost of the semi-custom cover lens over a high-quality IPS display," says Justin. "The design of the display only requires a single power supply, while using standard display and touch drivers allowed us to quickly get the device up and running."

As a result, VitalStream has received FDA 510(k) clearance, is in full production and is already being sold throughout the US. Caretaker Medical is excited about launching the monitor globally next year after receiving CE-Mark clearance.

Caretaker Medical Device

7. WRAPPING IT UP

When deciding whether to buy, to buy and substantially customize, or to build, it's essential to weigh the pros and cons of each approach in the context of various business considerations.

As electronics evolve, displays offer more capabilities but also become more complex. This complexity demands more engineering resources and extended development time. Opting for complete solutions can significantly mitigate these challenges.

Purchasing a solution leads to a faster time to market, offers greater reliability, reduces risks, and comes with established support channels. These benefits can ensure a more consistent product that appeals to a broader audience.

It's therefore crucial to approach the choice of HMI display with risk management in mind. Be vigilant about hidden costs. Whether you choose to build or buy, unexpected expenses can arise, such as project overruns for 'build' solutions or high support charges from manufacturers for 'buy' solutions.

Always evaluate your decisions against these considerations to make an informed choice.

ABOUT 4D SYSTEMS

4D Systems is a global leader in the design, development, and manufacture of intelligent display solutions for high-tech industries ranging from medical, industrial, automotive, and commercial use. Our products and solutions utilise the latest state-of-the-art OLED and LCD technologies with embedded custom graphics processors that deliver stand-alone functionality, eliminate low level development requirements and provide unrivalled ease-of-use and time-to-market for developing virtually any application requiring a graphical user interface.

4D Systems started as an idea, which grew to become a global company that engineers real world solutions. We want to empower forward thinking engineers, designers, and organisations who, by using our products, also help solve real world problems and make a positive impact, one display solution at a time.

Contact 4D SYSTEMS

Get in touch to discuss your latest projects, display experience, our products or to request any information. We'd love to chat.

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