

# How to Design with a Programmable Switch

### Introduction

In the movie Apollo 13, astronaut Jack Swigert is seen taping a large note with the word “NO” over a particular switch controlling the release of the Lunar Escape Module (LEM) from the main spacecraft. Later in the movie, fellow astronaut Jim Lovell has the [following exchange](#) with Swigert:

*Lovell: [pointing to a large “NO” note on the control panel] What is that?*

*Swigert: Oh, I was getting a little punchy and I didn’t want to cut the LEM loose with you guys still in it.*

*Lovell: That’s good thinking.*

Programmable switches may not have been available to Apollo 13 astronauts, but the consequences of complex decision making in certain environments show the significance of the choices engineers make in designing the human-machine interface.

When selecting the individual components of a project, special attention should be given to the human-machine interface – specifically how each switch will be incorporated into a design. By carefully considering the conditions surrounding the switches’ design into the end product, engineers can ensure that their design will accomplish its intended purposes and that the device will be easy and simple to operate.

### More Designs to Move to Programmable Human-Machine Interface

“Disruption” is a big buzzword for a reason. Devices today must balance function and design, so they enhance the user experience without requiring too much change in the user’s behavior.

Good design is invisible to the user – it’s the sweet spot between function and design that makes a device intuitive. It requires no compromise between the users and the technology. However, devices are increasingly more complicated because users want more functionality. But if users don’t understand how to utilize all these extra features, they just won’t employ them.

As such, more designs today stand to benefit from a programmable human-machine interface that delivers added functionality with a seamless user experience. A programmable interface is user-friendly and requires less operator training. It can also accommodate multiple languages in one design.

User experience is not the only reason designs are moving to a programmable human-machine interface. Today's devices are also smaller, which means designs need to do more with less space. In the past, adding functionality often meant adding more traditional switches dedicated to those functions, which added cost. A programmable switch can reduce costs by reducing the number of switches required and thereby the panel size.

Many devices require similar user interfaces and features. A programmable human-machine interface enables designers to create one user interface that can be used in many devices.

Designers also use a programmable interface to control the operator selection in order to prevent error that can damage the device.

### **Available Technology for Programmable Human-Machine Interface**

Traditional switches create the human-machine interface with a central display that provides information for the operator. This may be suitable for simple applications, but it is not an intuitive solution. Traditional switches also have the lowest initial cost in the design. However, the initial cost of the switch is not the only consideration. Often the operating cost due to operator training and mistakes outweighs the initial savings.

Consider the function keys of the computer keyboard before Windows improved the user interface on the screen. Users required extensive training for each program such as Excel and Word. Additionally, each program needed a template for the function keys to describe the functions.

An inferior device with an easy interface will outsell the best device with a difficult user interface every time.

Touch screens can be a step up in some designs. They are programmable and well suited for many applications in which wrong touches do not have catastrophic consequences. The cellular phone is a good example. The worst that can happen from the wrong touch is calling a wrong number.

However, lack of tactile feedback, the central location and the mode of switch not being visible from a distance make touch screens unsuitable for many applications. Additionally, the repair cost of touch screens is much higher than programmable switches because programmable switches are modular and can be easily repaired or replaced.

Programmable switches incorporate a small graphic display in their keycap. The display can change at any time, which helps engineers to create devices that are dynamic. This ability to change and accommodate varying functions simplifies the design and reduces operator error. Additionally, it does not allow certain commands to happen out of sequence. Each switch can be programmed to have a different function at any time and will display the function name.

Programmable switches can be designed in any number of clusters. They also can be separated out on the panel based on the location of the functions they control. In addition to displaying functions for the operator to select, programmable switches can display various status information such as temperature, pressure, RPM and more.

### Applications for Programmable Switches

There are many applications for programmable switches, such as NKK's [SmartDisplay™](#) line of products. Often programmable switches can reduce user error in high-stress, fast-paced or real-time environments, such as broadcasting, military/aerospace, health care, food services and other automation applications.

Programmable switches help equipment operators' interface with the device to make quick decisions when needed despite the barrage of distractions and commotion in their environment. As a result, programmable switches can have a dramatic impact on a user's ability to perform complex multi-decisional operations and complete tasks correctly. With the capability to display changeable full-motion video, animated sequences, graphics and alphanumeric characters, confusion about the task at hand is dramatically decreased – particularly in these fast-paced critical environments.

NKK's customers have used SmartDisplays to create programmable human-machine interfaces in hundreds of designs. The use cases for these switches vary as widely as the devices themselves.

One of the most obvious applications for programmable switches is to reduce the number of switches and thereby panel size. In one such application, a hydroelectric power plant reduced 1,600 switches to 116 programmable switches in a single control panel. They were configured in a way that all 1,600 functions could be selected with a maximum of just two keystrokes.

SmartDisplay devices are the smallest graphic display in the market. A communication company put one switch at the edge of the communication board for diagnostics. The programmable switch can be pressed to easily check various statuses as well as displaying error code.

Programmable switches can be dispersed on the panel to simplify use for the operator. A medical device manufacturer put one SmartDisplay next to each control knob on the panel. The SmartDisplay displays the status of the function and warns the operator by various colors if they are selecting an out-of-range setting.

Programmable switches can be used to guide operators to perform a task. For example, in the food services industry, they used NKK's SmartDisplay on a grease cooker and coffee maker and configured it to change color from green to amber, and from amber to red, to prevent overcooking, reflect changes in temperatures and otherwise let equipment operators know that immediate action is needed.

Another example is a broadcast company using 16 OLED switches in a 1U rack mount. Each OLED displays the video feed from a camera. The operator selects which feed goes to live broadcast by pressing the switch. This system allows an alternative control when not enough monitors are available.

Programmable switches used in equipment by emergency call dispatch operators can help ensure that processes are followed appropriately – dispatching the correct vehicles and personnel in the right order. Video on switches in home medical devices can help educate users on how to properly use the equipment, increasing safety and reducing the misuse of such equipment.

### Selecting Programmable Switches

Programmable switches have two main options for graphic display: LCD and OLED. There is an LED programmable switch in market, but large power consumption and price make it unsuitable for most applications.

Selecting the right programmable switch depends on what is required from the device in a given application. Specification such as size, contrast, brightness, power consumption, environmental and field of view must be evaluated.

There are two types of OLED programmable switches: OLED color and OLED monochrome. OLED technology boasts the best contrast, best viewing angle at 180 degrees, best response time, low power consumption and widest temperature range. However, the disadvantage is the life span is significantly shorter compared to LCD programmable switches. OLEDs have a life of about 15,000 hours to 50,000 hours at 40 percent pixels ON.

OLED technology is advancing rapidly in that its life span has advanced from 10,000 hours back in 2008 to 50,000 hours now.

OLED switches have vivid colors and are capable of running video. Normally these devices require two voltages, about 3V for logic and 16V for OLED. Another consideration for OLED color is the large sizes of image data. For example, a 64 x 48 color OLED requires 6,144 bytes of data for one image.

If still images are used, OLED color switches require attention to the images that will be displayed because the pixels get dimmer as they are used. A design that does not allow the pixels to age consistently will result in a ghost image when all pixels are ON. Proper location of still images to age the pixels consistently as well as dimming and running a screen saver when there is no switch activity extend the OLED life drastically.

LCD programmable switches can be selected with the controller onboard or with only a driver.

The benefits of an LCD with controller onboard include long life, ease of control and only one voltage. However, these programmable switches are limited to 64 backlight colors and 10mA power consumption due to the onboard controller even when backlight is OFF.

LCD with only driver feature long life and user control backlight. These LCDs can be daisy-chained, allowing many switches to be controlled with 4 control lines. LCDs with only driver are the best choice for battery operation without backlighting and lowest cost.

Given these specifications, any comparison should critically consider the needs of the application. The objective should be to determine which programmable switch technology is best suited for that application, while also looking for ways to achieve the best balance between power consumption and functionality at the lowest cost possible.

The table on the following page outlines various available programmable switches and features that differentiate them. The specifications are approximate and provided for comparison purposes.

### **Not all Programmable Switches are Created Equal**

Although it seems that programmable switches are a simple integration of a display and a switch, it takes a lot of experience and trial and error to perfect them.

There are many factors that will not show up on the specifications, which should be evaluated. Designers need to consider if the switch's feel/feedback, backlighting and display contrast are consistent and if the switch is durable. How many years the switch has been available should also be a factor, as well as the reputation and longevity of the manufacturer. Gauge if the manufacturer will be around by the time you go to production and assess how they provide support if there is a problem.

After selecting a switch, you should check with other users of the switch you have chosen. Actual users can provide you with the answers to many of the questions outside of specifications and save designers from a terrible experience.

### **Design Considerations**

There are a number of questions designers need to ask themselves when designing a system with programmable switches, including:

- How many controller pins are required to control them?
- Unless the images are made on the fly using a character look up table, how much memory will be needed to keep the images?
- How long does it take to update all the switches?
- Do the switches meet the environment requirements?

All the programmable switches are controlled via serial communication therefore they require clock, data and one to three additional control lines. There are specific design considerations for each type of programmable switch of which designers should be aware.

Specification	LCD with only Driver Onboard	LCD with only Controller Onboard	OLED Monochrome	OLED Color
Typical Sizes	36 x 24 Pixels	64 x 24 Pixels 36 x 24 Pixels 32 x 16 Pixels	96 x 64 Pixels	64RGB x 48 Pixels 96RGB x 64 Pixels
Number of Switches	One	One	Three	One
Contrast	Good	Good	Excellent	Excellent
Viewing Angle	90 degree	90 degree	180 degree	180 degree.
Video	No	No	Yes - Animation	Yes
Operating Life (Hours)	50,000+	50,000+	50,000+ at 30% Brightness	30,000 to 50,000 at 40% Brightness
Power Consumption	5V: 1 to 30mA 7.3V: 1mA	5V: 10 to 60mA	3.3V: 0.6mA 16V: 0.1 to 13mA	3.3V: 0.19mA 16V: 0.1 to 11mA
Image Size	120 Bytes	256 Bytes	768 Bytes	3,072 to 12,288 Bytes
Backlight	User Control	Software Control	NA	NA
Sunlight Readable	Yes, but backlight fades	Yes, but backlight fades	Possible if direct sunlight is blocked	No
Warning Alert Visible to Operator from a Distance	Blinking backlight visible from long distance	Blinking backlight visible from long distance	Not easily visible	Not easily visible
Operating Temperature	-20° to +60°C	-15° to +50°C	-20° to +70°C	-20° to +70°C
Cost	X	1.2X	1.8X	1.7X

## LCD with Only Driver Onboard

With LCD programmable switches with only driver onboard, the LEDs are controlled discreetly. The LEDs are common anode so one cathode is provided for controlling each LED. While backlights can be controlled via current limiting resistors, it is better to control them with constant current LED driver such as MAX6957 or STP16CP05MTR for better color consistency. Additionally, these controllers require only a few control lines to control many switches.



The LCD is controlled with four pins of the micro controller. The LCD displays can daisy-chain, enabling many switches to be controlled via four pins. The four control lines are data, clock for shifting data, LP toggled to go to the next row pixels, and FLM toggled for starting on the first row of pixels.

The LCD must be refreshed. The program should be written in a timer interrupt. Each timer interrupt shifts the data for one row of pixels. For multiple switches the data for the last switch is shifted first. There is need for RAM to keep the images or characters if the images are not created on the fly using the character look up table.

### **LCD with Controller Onboard**

The LCD programmable switch with control onboard is controlled with two pins of a micro controller: data and clock. A select line provides control of many switches with the same clock and data. It is also possible to connect switches to clock and data in an XY matrix to reduce the number of controller pins used.

These LCD switches require only 5V and, upon power up, are ready to go. There are three commands and each of the commands can be used at any time. The status is kept until it changes via another command. The three commands select one of eight backlight brightness levels, one of sixty-four backlight color options and transmit 256-byte graphic image.

### **OLED Monochrome and OLED Colors**

Both the programmable OLED monochrome and OLED colors switches are controlled with five pins of the micro controller: clock, data, reset, select and command/image data. Each additional switch requires another select line. A power up sequence needs to be observed, which means the 16V must be under the software controller. The initialization values need to be sent to the switches before the switches are ready for operation. The onboard controller has many features such as selecting the direction of sending the data or sending data only for a portion of the display, as well as setting many brightness levels.

### Application Consideration

Two of the biggest mistakes made with programmable switches are, first, the tendency to reduce the number of switches just because it can be done; and second, the urge to put too many features and functionality into the interface of the design.

The number of keystrokes to select a function should be considered. For diagnostic applications the number of keystrokes may not matter, but for some real applications the number of keystrokes should be kept under five.

In some cases, reducing the number of switches can make the design more difficult to use. Design engineers should determine how many switches need to be used to achieve a logical and easy-to-use design. For example, we still use three different lights in stoplights even though the technology has been around for decades to use only one. The placement of each color is essential to preventing accidents. In the same vein, in some high-paced fast food environments a single programmable switch letting operators know when to modify or remove cooked food based on temperature may be more confusing than three sequential switches that can easily be understood based on both color and placement.

Putting too many features and functionality in the programmable switch can sometimes make it less effective for users. For example, there is a tendency to use OLEDs for things other than video applications that are not appropriate. Sometimes forcing an operator to watch a five second safety video each time a switch is actuated on the equipment may add time to a process that needs to be streamlined, whereas making them watch a video at the beginning of a shift away from the equipment may be more effective. And, because it has a life of 50 percent of other technologies, it may not always be appropriate – particularly if it will be used for static images. If OLED is specified for static images, they should be changed from time to time – or colors changed and combined often – in order to preserve the life of the switch.

### Conclusion

There are many considerations and options that engineers need to take into account when designing or selecting a programmable switch. And, knowing that this interface is such an important aspect of the overall interface design process, it can be overwhelming for some engineers. It is also perhaps the most exciting stage of the design because switches are the components that will actually meet with user contact and control the processes the machine is intended to accomplish.

To help with this important part of the design, good switch manufacturers have trained staff who can suggest switches and custom design solutions based on specific needs and applications. Many times, an engineer may not immediately consider a programmable switch. However, switch manufacturers can help engineers to see that it is worth evaluating programmable switches for more designs than is currently done.

Using programmable solutions in the right applications can eliminate situations where a “NO” sign taped to a mission-critical switch may or may not prevent user error. Instead, engineers can leverage dynamic programmable switches to simplify the design, streamline processes, reduce operator error and increase the safety of equipment operators and those that their decisions impact.