Simplify LCD designs and reduce power consumption with ultra-low-power MSP430FR4x microcontrollers

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Liquid crystal displays (LCDs) are all around you. They are found throughout your home, office, or even on the portable devices you carry with you all the time. If you think about it, it is no surprise that the LCD industry is still rapidly growing. Of course, a lot of this growth is driven by televisions and portable devices including laptops and cell phones, but LCDs are also becoming prominent in other markets.

Take a look at products using infrared (IR) communications, for instance. IR is regularly integrated in remote controls for lighting, air conditioning systems, and even toys. The interesting commonality between all of these applications and other portable or battery-powered devices is they continue to add more functionality over time. For example, incorporating displays is a common way to provide consumers with more information, immediate feedback and an overall better product experience. This same concept can be applied beyond remote controls, to portable medical devices, in-home displays, security panels, and even smart metering. One key difference between these applications vs. televisions and portable phones is the use of segmented displays. When power and the amount of display data is limited or cost is a concern, segmented LCDs often offer the ideal solution. This might be the reason you see as high as a 10:1 ratio of segmented LCDs vs alternatives when you look around your house. In addition to the television and a tablet, take notice of all the segmented displays in things like the kitchen appliances, remote controls, thermostats, alarm panels and more!

While adding a segmented display to an application can add real value for customers, it does add complexity to system design. When designing a product with a display, three major requirements need to be considered:

- **System size:** How can you add functionality to a system given the same or even smaller physical product size than previous versions?
- **System power:** How can you drive a display while minimizing the cost and/or inconvenience of changing batteries for the consumer?

- **Data required:** Given the information you need to share with the consumer, what size display or how many segments on that display will be required? What inputs will the system use?

This paper will discuss these core LCD design considerations in the context of a television remote control application. It will then explain how the new ultra-low-power MSP430FRxx FRAM Microcontroller (MCU) family, and specifically the MSP430FR4x MCU series, can help minimize the physical footprint and power consumption of designs with segmented LCDs, while simultaneously providing the flexibility to simplify application development.

Everything is getting smaller

10 years ago, portable electronic devices were simply bigger. Not only are more connected devices being created with the expansion of the internet of things (i.e. now you may have a small sensor in your garden sharing humidity information with your smart phone), but product designers are also integrating similar or more functionality into much smaller packages. The latter is the case with universal remote controls. It wasn't long ago that you needed a remote for every item in your entertainment system. Do you remember turning on the television and then searching under couch cushions for the remote to change the volume? What about the 3rd remote for controlling your DVD player? Today, a single remote control can control every IR-enabled device in your home.

These universal remotes often have integrated segmented displays to simplify the user experience. For instance, you can press a single button next to "Watch TV" to setup the television, set-top box and sound system as opposed to individually pressing buttons for each. And a remote like this is no bigger than the remote that was used to control just one of these devices in the past. Much of this size optimization can be attributed to hardware layout.

Optimizing the hardware layout can be difficult, take a great deal of time, and cost money. The MSP430FR4133 microcontroller is available in small memory footprints of 4 KB to 16 KB of non-volatile ferroelectric random access memory (FRAM) and can help simplify layout further through integration and flexible pin assignments:

- **Integration:** Integrating components in an MCU can save board space and even power, which will be discussed later. The MSP430FR4133 MCU integrates a segmented LCD driver allowing direct connection from the microcontroller to a display and minimizing traces on a printed circuit board (PCB). Moreover, this MCU features a multi-channel integrated 10-bit analog-to-digital converter, which can be used for system monitoring of temperature or external sensors, in addition to a real time clock and timers that reduce the need for external components. Plus, integrated FRAM with fast write speeds and high endurance can eliminate the need for external memory such as EEPROM.
- **Flexible pin assignments:** Even with integration, laying out the pins from a microcontroller can take time. A developer could simplify layout with added PCB layers, but that can add valuable cost in a consumer market where lowering system cost is critical. Alternatively, a developer could modify the LCD position to simplify layout, but this may not meet the requirements of the remote control in terms of aesthetics or usability. The MSP430FR4133 MCU has software configurable LCD pins that enable the developer to layout an LCD in any position and still simplify routing on the PCB. Simplification of layout is just one benefit of the flexible pin-assignments on the MSP430FR4133 microcontroller. Designers can also explore multiple LCD options with a single chip to further reduce development time. If a

higher-end LCD is needed for a more intricate design, the same microcontroller and layout can be repurposed by simply reassigning the LCD pins in software to match the new display.

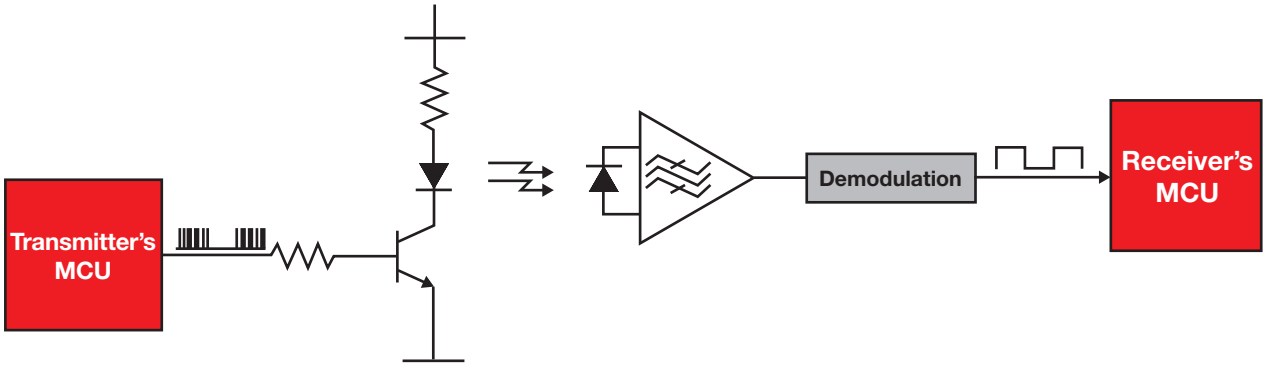
Integrated peripherals and flexible design can definitely help reduce size, but there is another key factor to consider. In remote controls and other portable devices, batteries are commonly the largest component in the system. When adding functionality to a system, increasing the battery size or amount is not usually an option, so power optimization is critical.

Power is not free

Beyond increasing system size, adding batteries or using larger batteries in a system increases the burden on the consumer. There could also be concerns related to convenience and the negative environmental impact for portable electronic devices that consume batteries too quickly.

So how can developers increase the functionality of a system, while using the same batteries or simply extend the time between charges? In a portable device like the remote, an MCU is often the primary system controller. As such, choosing the right device and optimizing software is extremely important. The MSP430FR4133 microcontroller is perfect for this type of application for a variety of reasons. Integrated non-volatile FRAM enables lower-power and faster writes when compared to traditional memory technologies like flash. When in active mode, the MSP430FR4133 MCU consumes only 126 uA/MHz of current. When running in standby mode with the LCD driver and real-time clock running, the MCU consumes only 770 nA, making it the lowest power MCU in the industry; however, low-power components are only effective when paired with power-efficient software.

Let's keep with our remote control reference. One big component of power efficient software in a remote control is the handling of IR communication. In order to send information, these devices emit light from an infrared light-emitting diode (LED) controlled by a modulated signal from the system controller. Modulation is useful in helping a receiver, such as a television, to determine what information is coming from the remote control or outside sources. Amplitude Shift Keying (ASK) and Frequency Shift Keying (FSK) are two of the most common modulation techniques. This modulation is traditionally implemented by software, requiring only a single timer to generate an accurate time slot. This time slot can be quite small, leading to large software overhead. The MSP430FR4133 actually uses IR Modulation Logic, a series of interconnected hardware resources, to lower this overhead and further reduce power consumption when performing ASK or FSK modulation. With IR Modulation Logic, a device only needs to wake up at very limited times for envelopes to automatically generate the carrier



signal without any intervention. This equates to as much as 60 times fewer MCU wake instances compared to a solution without IR Modulation Logic on-chip and can have a significant impact on overall power consumption!

Simplified power debugging can offer tremendous advantages to developers who may spend up to 75% of their development cycle optimizing their applications. Beyond IR, the MSP430™ microcontroller family offers optimizers to help reduce application power and development time. ULP Advisor software can be used to check code against a list of low-power rules to make sure common mistakes are avoided. The MSP430 tool chain really comes together with the new EnergyTrace™ technology that creates real-time power profiles to help developers better understand where energy is being spent.

Benefits beyond size and power

Size and power are definitely among the most important concerns in designing a portable electronic device, but defining inputs and outputs also plays a big part in creating a system. In a remote control, you may want to simply show a few numbers to display the selected television channel. You may also consider adding space to define various functions such as Watch TV, from the example above. The MSP430FR4133 MCU can handle many scenarios with a display driver that can support up to 256 segments. Plus, this MCU features an on-chip charge pump that can enable the display to maintain contrast in the low-power modes where it will primarily operate. The MSP430FR4133 MCU can even be connected to push buttons or capacitive touch buttons for enabling channel selection or Play and Pause functionality. With up to 60 general purpose input/output (GPIO) pins and a free capacitive touch library available, the possibilities are endless.

This same size, power and data requirement understanding can be applied to other applications and products, as well. For example, low-end portable medical devices often include segmented displays and could benefit from a small, low-memory footprint device like those in the MSP430FR4x MCU series. Integrated peripherals, ultra-low-power consumption and other features of the MSP430FR4133 microcontroller make it the ideal choice. Interested to learn more about the MSP430FR4x MCUs or the non-LCD variants in the MSP430FR2x series? Head over to www.ti.com/fram to learn more about these and the other devices in the Ultra-low-power MSP430FRxx FRAM microcontroller family. Then, start evaluating these devices for under $14 with the first MSP430 LaunchPad development kit to include an on-board LCD. TI also offers a number of other resources, such as training modules and TI Designs, to help you get started. Remote Control, Thermostat and Water Meter reference designs are already online with hardware design files, software and User's guides to help jumpstart development.

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