EIGHT-PIN MICROCONTROLLER HANDLES TWO-DIGIT DISPLAY WITH MULTIPLE LEDs

Dhananjay V. Gadre and Anurag Chugh
NETAJI SUBHAS INSTITUTE OF TECHNOLOGY, NEW DELHI, INDIA

The Best Idea for Design for 2007 comes from an academic and a working engineer. And in this IFD, originally published in our May 24 issue, they've reworked an idea for driving many LED segments when you have only a few microcontroller output pins.

The authors found the basic concept through that prolific source of clever circuitry, Don Lancaster. Maxim Integrated Products uses it in MAX695x LED display drivers. In fact, Charles Allen at Maxim invented the technique, so it's often called "Charlieplexing."

Everything you'd find in all the links that a Google search turns up is summarized in the Wikipedia entry for "Charlieplexing." The primary source is Maxim Applications Note AN1880, but there are instructional sites that are interesting as well.

Gadre's and Chugh's IFD is clear enough. But briefly, in Charlieplexing, the microcontroller's I/O pins are made to alternate between driving digits and driving segments, with a flicker rate too fast for the eye to follow. ***Don Tuite***

Eight-pin microcontrollers offer numerous peripheral features. However, the maximum number of I/O pins available is often limited to six, since two pins would be required for the chip's power supply. So, it can be challenging to design systems based on these devices, especially if they involve a significant display requirement.

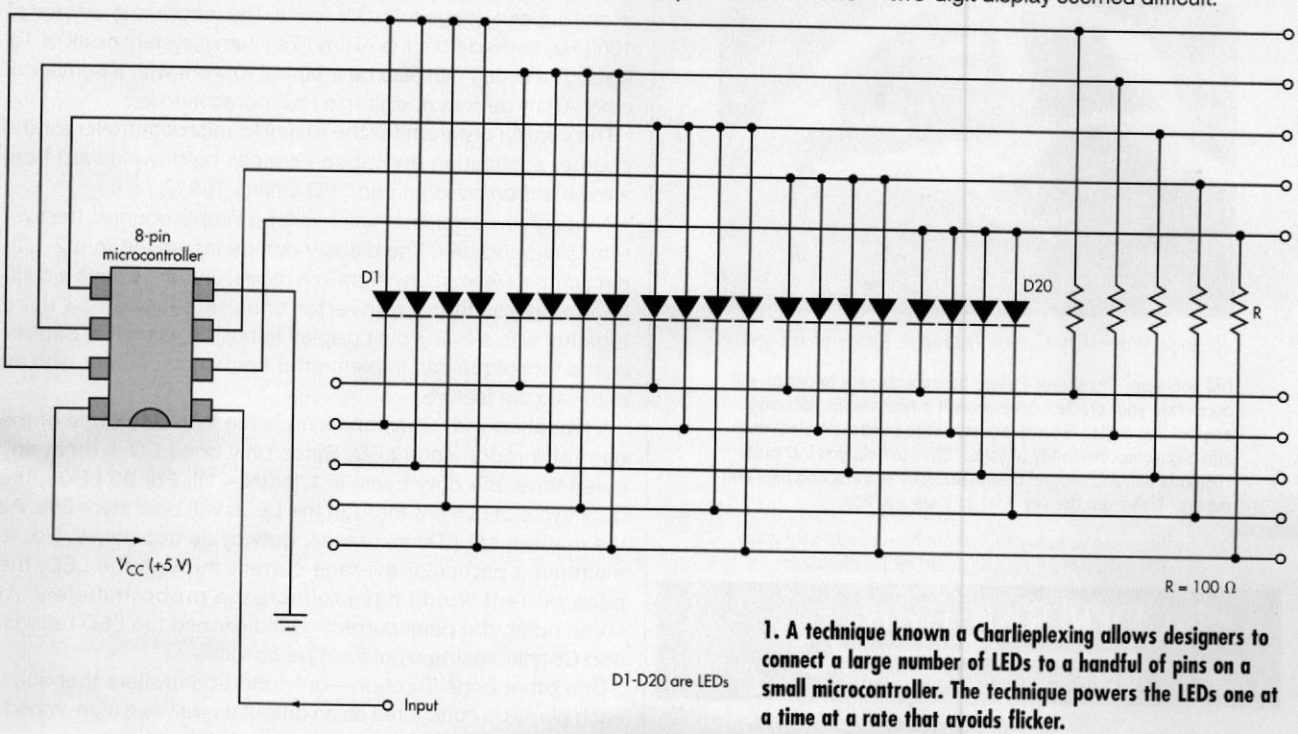
For instance, controlling a large number of LEDs is a problem with eight-pin microcontrollers, unless you resort to a method called "Charlieplexing." This idea was originally described in Don Lancaster's August 2001 Tech Musings *(www.tinaja.com/glib/muse152.pdf)* in addition to Maxim Integrated Products application note AN1880 *(http://pdfserv.maxim-ic.com/en/an/AN1880.pdf)*.

In general, Charlieplexing allows N I/O pins to control N*(N – 1) LEDs. For example, Figure 1 shows five pins of a microcontroller connected to 20 LEDs. In this Charlieplexed display, one of the pins is an output pin set to logic 1 and another pin is an output set to 0. The rest of the pins are set as inputs in a high-impedance state.

Thus, at any given time, only one of the LEDs is turned on. After a suitable delay, this LED is turned off by changing the pin configuration and the next LED is turned on. The rate at which each LED is turned on must be more than 50 Hz to avoid any noticeable flicker. So for 20 LEDs, the overall display refresh rate should be at least 1000 Hz.

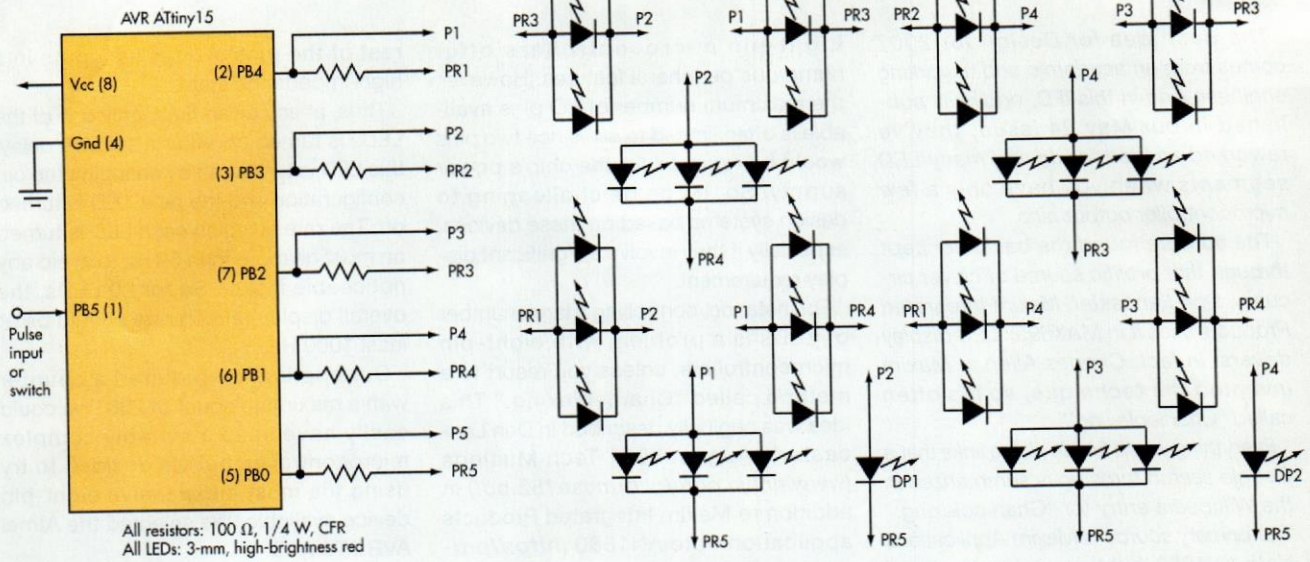
Our application required a counter with a maximum count of 200. We could easily have used a suitably complex microcontroller, but we decided to try using the most inexpensive eight-pin device available. We selected the Atmel AVR ATtiny15.

The counter input was from a pushbutton switch, so only five of the six I/O pins would be available for the display. Because the counter was meant for hexadecimal-literate engineers, we decided to have a two-digit display with the count going from 00 to FF(Hex). Even so, fitting a two-digit display seemed difficult.



1. A technique known a Charlieplexing allows designers to connect a large number of LEDs to a handful of pins on a small microcontroller. The technique powers the LEDs one at a time at a rate that avoids flicker.

2. This schematic implements a two-digit counter using the Charlieplexing technique and an eight-pin microcontroller.



We used a Charlieplexed display to arrange the LEDs in the required two-digit, seven-segment format, which would serve our purpose *(Fig. 2)*. We chose 3-mm, high-brightness LEDs. Each segment of the seven-segment display consists of three LEDs set in parallel.

All resistors are 100-Ω, 1/4-W CFRs. The peak current through the LEDs is about 30 mA with a 5-V supply, but the system works at any supply voltage from 3 V to 6 V. The refresh rate was set to 1000 Hz, derived from the ATtiny15's internal system clock of 1.6 MHz. The circuit can also be adapted to work with a number of other ATtiny devices or eight-pin PIC microcontrollers.

The control program for the ATtiny15 microcontroller for the counter application described here can be downloaded from *www.electronicdesign.com*, ED Online 15512.

Although our implementation is for a simple counter, the system is expandable. The display can be increased to a 2-1/2-digit format. Also, many eight-pin microcontrollers have a built-in analog-to-digital converter channel that can be used together with a 2-1/2-digit display to build a voltmeter. Similarly, the technique can implement a frequency counter with an auto-ranging feature.

A limitation with Charlieplexing is the low duty cycle of the current through each LED. Since only one LED is on at any given time, the duty cycle is 1/[N*(N – 1)]. For 20 LEDs, the duty cycle of current through the LEDs will be a mere 5%. As the number of LEDs increases, duty cycle decreases. So, to maintain a particular average current through the LED, the peak current would have to increase proportionately. At some point, the peak current would exceed the LED ratings, and Charlieplexing would not be possible.

One other consideration—only microcontrollers that allow each pin to be configured as an output as well as a high-imped-

ance input can be used. Thus, a typical 8051 isn't suitable to control a Charlieplexed LED display.

DHANANJAY V. GADRE, *assistant professor at Netaji Subhas Institute of Technology, New Delhi, India, completed his MSc (electronic science) from the University of Delhi, India, and his MEngr (computer engineering) from the University of Idaho, Pocatello.*

ANURAG CHUGH, *who works from Larsen and Toubro's Embedded System Division, Mumbai, India, received a bachelor's degree in electronics and telecommunication engineering from the University of Mumbai.*

ED ONLINE 15512

HIGH-SPEED FULL-WAVE RECTIFIER REQUIRES NO DIODES, FEW PARTS

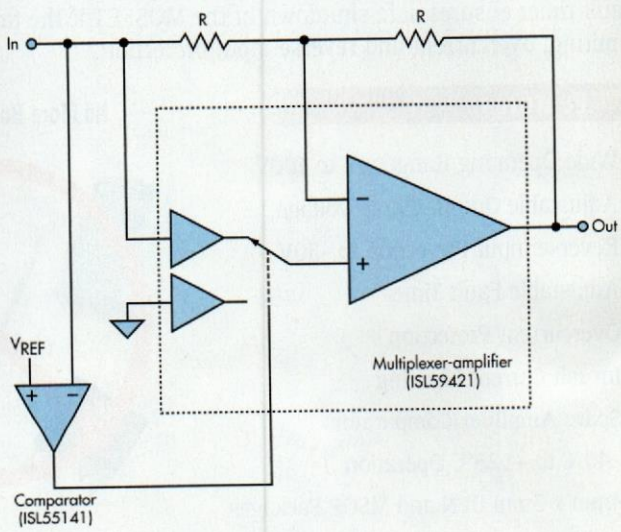
Michael Wong and Tamara Papalias

INTERSIL CORP.

The functionality of our runner-up (originally published in our June 7 issue) is easy to understand, identifying Intersil's ISL59421 as the design's central component. But where did that part come from? Surely it was not developed for this particular application. It turns out that the authors took a rather specialized chip and applied it to a more general problem in a clever and original way.

The ISL59421 data sheet says it "is a 865-MHz bandwidth multiplexing amplifier designed primarily for video switching." Not used in the IFD are the chip's user-settable gain capabilities nor its "high speed three-state function [that enables] the output of multiple devices to be wired together." Other specs validate the part's utility as a video switch.

Don Tuite



1. A multiplexer-amplifier IC combined with an external comparator offers a good alternative to a diode-bridge circuit for full-wave rectification. It saves board space while still allowing a relatively high operating frequency