

AC 2010-406: EXPERIMENTS WITH A SIXTEEN-DIGIT SEVEN-SEGMENT OSCILLOSCOPE DISPLAY

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Experiments with a Sixteen-Digit Seven-Segment Oscilloscope Display

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Abstract

This paper describes experiments performed by students in a second-semester digital design laboratory using an output display device that shows up to sixteen hexadecimal digits in seven-segment format on a standard analog oscilloscope. The display device itself has been described in an earlier ASEE paper¹, and is the latest in a series of display innovations that the author has used in his advanced digital laboratory^{2,3}. This display relieves students from implementing an output interface for circuits under study, and allows them to concentrate on the core circuit they are designing, whether it be a multiplier, a hardware data structure, or other special-purpose application. This output device, when combined with a similarly-designed keypad input device not described here, provides a universal input/output system that interfaces in a standard way to student digital designs.

The display device used here employs an analog oscilloscope screen as the display medium. Analog oscilloscopes are found these days collecting dust in academic electronics labs, as they have generally been replaced with more modern digital instruments. However, these old oscilloscopes still have long lives remaining, and applications such as this make innovative use of their characteristics. This unusual use for a familiar test instrument intrigues students and makes them wonder how a standard oscilloscope can be made to produce such a display. This leads to opportunities to demonstrate to students that “outside-the-box” approaches sometimes result in successful innovation.

The course using this display device in its lab is a second course in digital circuit design. The course emphasizes functional units that are often found in digital computers, such as arithmetic circuits (multi-digit adders, multipliers), hardware data structure implementation (stack, queue), and memory circuits. Examples of each of these types of experiments and how they use this oscilloscope display are presented in this paper.

The Display

The sixteen-digit seven-segment display instrument used in the applications described here produces an oscilloscope display as shown in Figure 1. The circuit that generates this display is shown in Figure 2. This circuit has been described in detail in an earlier ASEE paper¹ and so will not be carefully described here. It is used as an output device for the various applications to be documented in this paper.

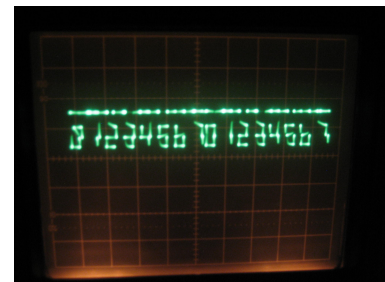
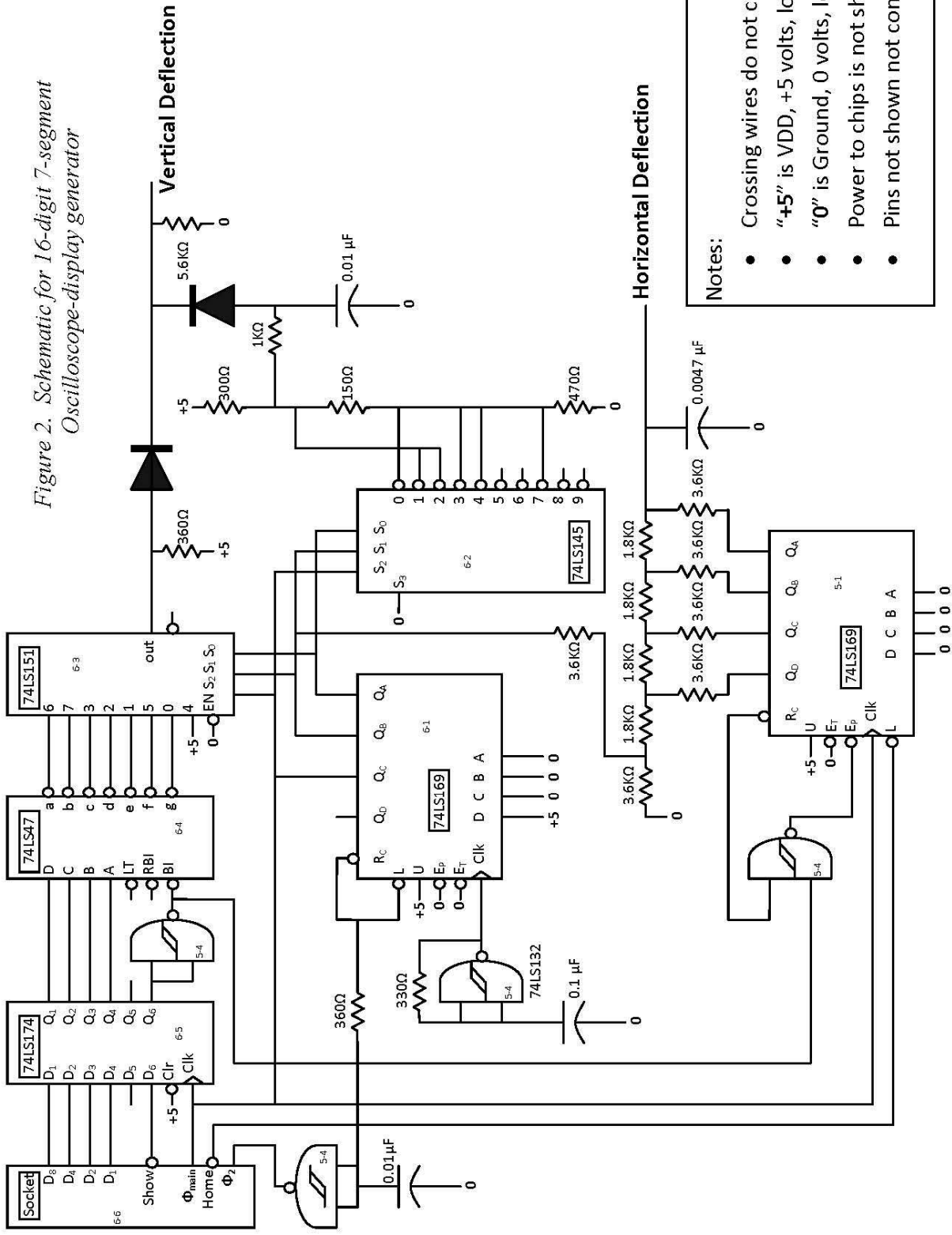


Figure 1. Display

Figure 2. Schematic for 16-digit 7-segment Oscilloscope-display generator



Notes:

- Crossing wires do not connect
- "+5" is VDD, +5 volts, logic 1
- "0" is Ground, 0 volts, logic 0
- Power to chips is not shown
- Pins not shown not connected

As the schematic in Figure 2 shows, the oscilloscope display is produced using minimal circuitry by controlling the X- and Y- deflection signals to a standard analog oscilloscope operating in X-Y mode. The display generator interfaces to user circuits through a very simple interface involving four data wires, $D_8D_4D_2D_1$, to specify the digit to be displayed on each clock cycle, and two control wires, 'Show' and 'Home', to manipulate when and where the digit is shown on the display. These interface signals connect the user's application to the display generator through the socket shown in the upper left corner of Figure 2.

Applications that use the oscilloscope display usually are entirely synchronous, using a single main clock signal, Φ_{main} , generated by the display circuitry. An additional clock phase, Φ_2 , is generated by the display circuitry for applications that require operations occurring between edges of the main synchronous clock, such as write-enables to RAM components, etc.

This easy interface to the display generator alleviates student concerns about displaying the results of the application under study. Instead, the student can focus on the core circuit being designed, and need not worry about the details of showing results. This has the advantage of relieving students from mundane tasks from which they learn little, and encouraging them to work instead on the core topic under study in the lab exercise.

Display Applications

This display generator is meant to serve as an output device for digital circuits that produce a numeric result. This includes a wide variety of different applications. The simplest example of such a device is a simple counter that sequences through a prescribed set of states. Such counters would use this display generator to show the count sequence through which the circuit counts. The application used to generate the display in Figure 1 is an example of this type of circuit, a simple sixteen-state counter that continually and unconditionally counts through a fixed sequence of states.

Arithmetic circuits form a second class of applications that can use this display generator as an output device. Adders and multipliers have served as the focus for lab exercises, and more complicated arithmetic circuits are possible. To accomplish this sort of design, some kind of input device such as a keypad (not described here) is required to enter data and commands to the circuit. One could envision a complete full-function calculator using this output device to show results, although the complexity of the circuit probably exceeds what could be designed in a lab exercise in a second-semester digital design class.

Another category of digital circuits that might use this output generator includes a variety of hardware data structures. Stack (Last In First Out) or queue (First In First Out) data structures are interesting design exercises for students, and the display generator can be used to show the contents of the stack or queue as data is entered or removed from the data structure. Whatever the application, if it produces a result that can be shown as a multi-digit hexadecimal value, this display can serve as the output device.

Initial Design Assignments

At the beginning of the semester in this second course on digital system design, students need to refresh their prerequisite “gates and flip-flop” design skills through some easy lab exercises. Simple counters that unconditionally advance through a specified sequence of states are easy tasks that can be assigned which should remind students of lab exercises performed in an earlier introductory digital design course. However, these tasks provide an opportunity to introduce the seven-segment oscilloscope display and give students an opportunity to learn to use it, using the $D_8D_4D_2D_1$ data signals and the Show’ and Home’ control signals to generate various display patterns on the oscilloscope.

Arithmetic Assignments

Another class of assignments that has used this display is arithmetic circuitry, such as multi-digit adders or multipliers. The display is capable of showing up to sixteen digits of arithmetic results, but little is learned by simply replicating circuits to get more digits. A typical multiplier lab assignment, for example, takes two one-digit hexadecimal numbers and multiplies them, to produce a two-digit hexadecimal result, displayed on the oscilloscope. These arithmetic circuits, and the other examples to be described below, require a keypad input device for entering operands and/or control information to the student’s circuit. That keypad is not described here, but is an important part of the digital test “station” required to exercise student designs, and relieves the students from concerns about inputting data in the same way that this display relieves output concerns.

Data Structure Assignments

A fun category of lab assignments that needs digital input and output is hardware implementation of data storage mechanisms. Data structures such as stacks (Last In First Out) or queues (First In First Out) as tools to store information are effective lab assignments. Students have already seen software implementations of these structures, but these exercises require students to design and build hardware implementations. The display can show the contents of stacks or queues up to sixteen elements deep, but little is gained pedagogically beyond about four levels of storage. Lab exercises in which the contents of a four-level stack or queue are displayed as four digits on the oscilloscope are instructive for students, particularly when elements are added or removed from the data structure. Designing the hardware to support these data structures provides much more insight into their operation than merely using pre-designed software structures that students generally have seen in microprocessor applications.

Memory Assignments

Lab assignments using standard memory components such as static RAM devices are popular. Students, of course, are familiar with conventional memory, but typically only on the “board” or “system” level. Interfacing with individual memory components, requiring careful timing especially during write operations, is new to students, and can form the focus for several different lab exercises. Using the keypad to input address and data information, and to keep things manageable, limiting address and data to just four bits (one hexadecimal keystroke) each,

a number of different lab assignments arise. For example, students can enter two-key sequences where the first key identifies the address in memory to modify, and the second key supplies data to store at that address, with the display showing the address and data at that address as a two-digit value. Or, the display can show sixteen digits stored in sixteen locations of the memory, and by entering a one-digit address from the keypad, a selected digit can be incremented. These operations require students to read and write the memory component, and require understanding of the required detailed timing relationships among the RAM signals.

Display Pedagogy

The display device described here whose schematic is shown in Figure 2 clearly does not use the latest available hardware. Certainly a microcontroller or some programmable logic device could have been used to minimize this design. As implemented, however, the display generator provides a good example of how basic digital components can be combined in innovative ways to produce a result that is not intuitive. Students who are initially dazzled by the puzzle of creating a seven-segment display on an analog oscilloscope learn something by understanding and using this circuit. That's the goal.

Described here are some applications that have been used in a digital design laboratory that each employ a distinctive seven-segment display produced on a standard analog oscilloscope. The display is unconventional, and probably not suitable for commercial implementations, but it is a wonderful tool for inspiring students to study and understand digital applications. When students see a familiar oscilloscope producing clearly unusual displays, they are prompted to ask questions, certainly the goal of any educational endeavor. This experience not only encourages students to consider unconventional design approaches, but also demonstrates to students what is possible when thinking “outside the box” of traditional design techniques.

References

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