Digital Test Equipment

The ins, the outs, and the architecture of digital test equipment.

Paul Danzer, N1II

All test equipment is going digital. However, before we look at equipment, let's talk about digital technology and digital computers. There are two inventions that make today's digital equipment so widespread. The first is not the transistor, which most people would assume; it is a loom. In 1801, French weaver and merchant Joseph Marie Jacquard demonstrated a loom controlled by a set of cards punched with holes. When the loom was active, the cards designated the fabric cords that would be raised for every shuttle pass. In other words, this was a programmable machine with a stored program. If a different pattern was needed, the new program was run with a new set of cards. The second invention uses the same memory to hold both program and data. This is part of what is called von Neumann architecture. Before, early computers like the Electronic Numerical Integrator and Computer, which was operational in the 1940s, used a combination of fixed wiring and plugboards to set the program. This approach made it very slow to reprogram these machines for different tasks, just like the looms. Figure 1 illustrates the basic von Neumann architecture, whereby the same memory holds both program and data. John von Neumann, a mathematician and computer scientist, wrote a paper in 1945 outlining this type of computer architecture. This eventually became the basic design for small computers, including home and personal computers.

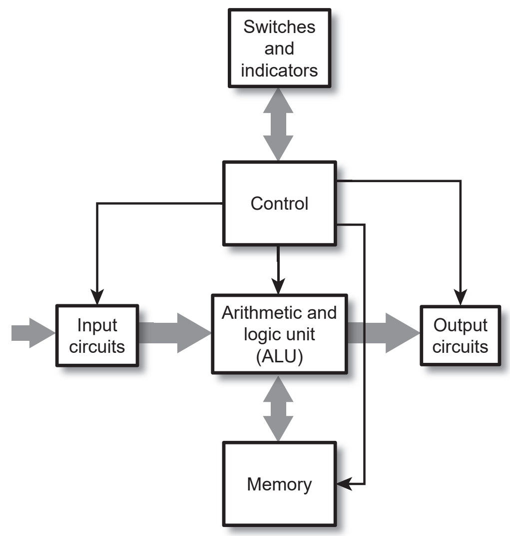

Figure 1 — A basic computer block diagram.

Figure 2 shows the building blocks of Figure 1 and how they talk to each other to form digitally based test equipment, as well as small computers. Each element or section has an address, which is a digital number

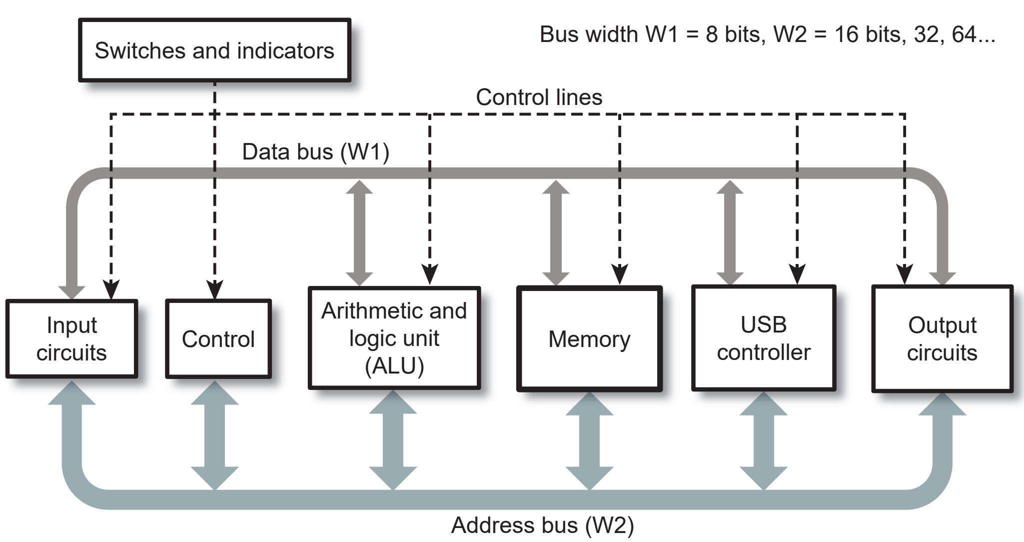

Figure 2 — The signal path in a bus system.

Figure 3 — A digital meter front panel. You can see the LCD panel (left), the soft switches (middle), and the mechanical switches (right).

that identifies it. For example, if the arithmetic and logic unit (ALU) wants to send information to an output circuit, it places the selected output circuit address on the address bus: a set of 8, 16, 32, 64, or more wires.

The data it wishes to send goes to the data bus. Finally, the command to either send or receive data goes through the control lines; this set of wires is usually unique to the particular system design.

Most current digital computer-based instruments include a USB connection to provide input, output, and occasional power supply connections. In the following sections, typical instrument block diagrams are shown. However, every manufacturer optimizes their hardware to meet the requirements of their various customers.

A Digitally Based Multimeter

The front panel of a representative unit (the Owon XDM1241) is pictured in Figure 3. Three input jacks plus a ground jack are on the lower right, similar in function to older non-digital units. From here, things get much different. “Hard” switches on the right-hand side can have either single or multiple functions. The LCD has a set of “soft” switches whose functions depend

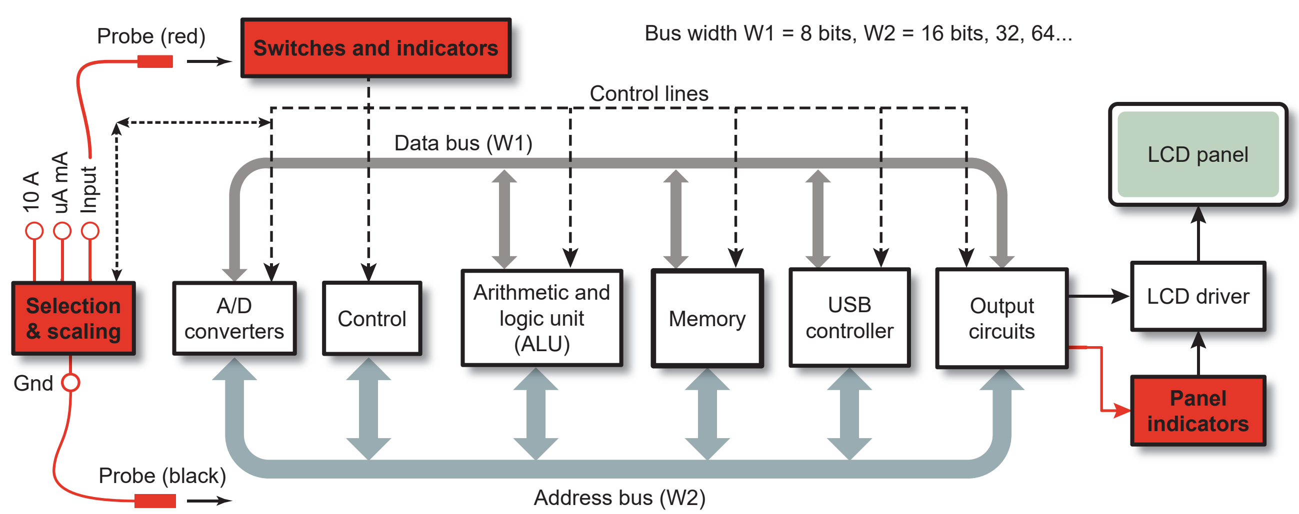

Figure 4 — Signal flow in the digital multimeter. The items in red are those added to the computer hardware to turn it into a multimeter.

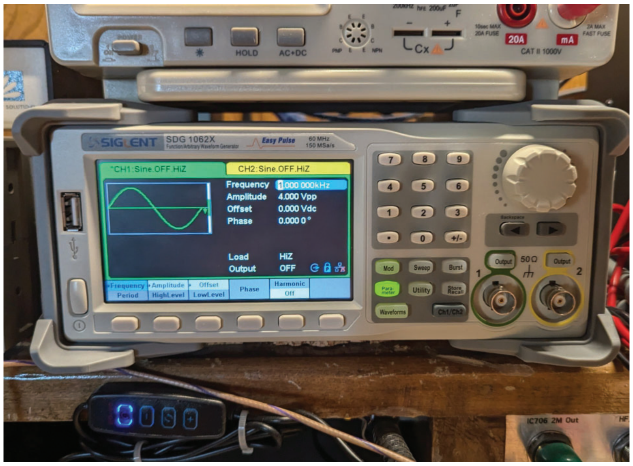

Figure 5 — Compare this signal generator panel to the digital multimeter panel.

on the selected hard switch. The switch selections and settings are typically displayed in text on the LCD. Some manufacturers elect to have this information sent directly from the control block, while others send it by way of the data bus.

The similarity between the general-purpose computer of Figure 2 and the digital multimeter of Figure 4 explains why these multimeters can store a sequence of values and perform arithmetic operations on them. The combination of an analog front end with a follow-on digital processor also allows features such as autoranging and automatic calibration. Some displays also include a bar graph so that peaking or nulling voltages is easily accomplished.

Figure 7 — The Siglent Technologies SDS1104X-E. The LAN and USB connectors on the lower left are used to input programs, control the unit, update the firmware, and save screen data.

Waveform Generation

The capabilities of today's digital signal generators are much greater than older analog generators, which could offer only a limited variety of waveforms. As an example, the Siglent Technologies SDG1062X (see Figure 5) can supply two simultaneous waveforms at a maximum frequency of 60 MHz.

The signal generator block diagram in Figure 6 is slightly different than previous figures due to the way waveforms are generated. Any particular waveform is generated by an equation stored in memory. Here, the use of memory can offer several hundreds of waveforms because they are stored not in memory-occupying sequences, but in software form commands.

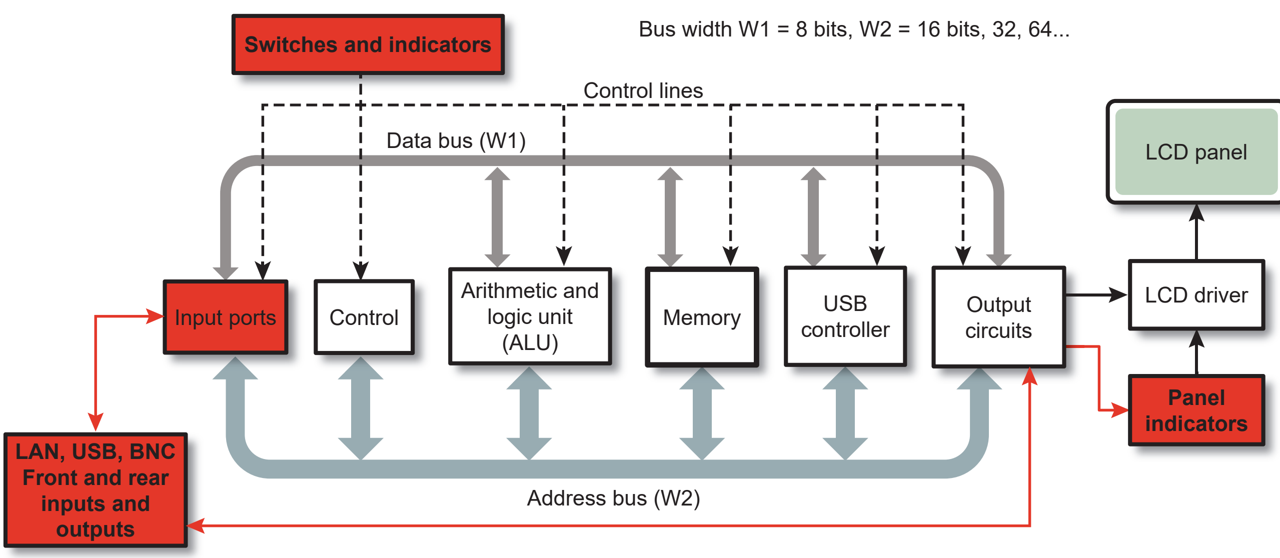

Figure 6 — A block diagram of a modern digital signal generator. The items in red are those added to the computer hardware to turn it into a waveform generator.

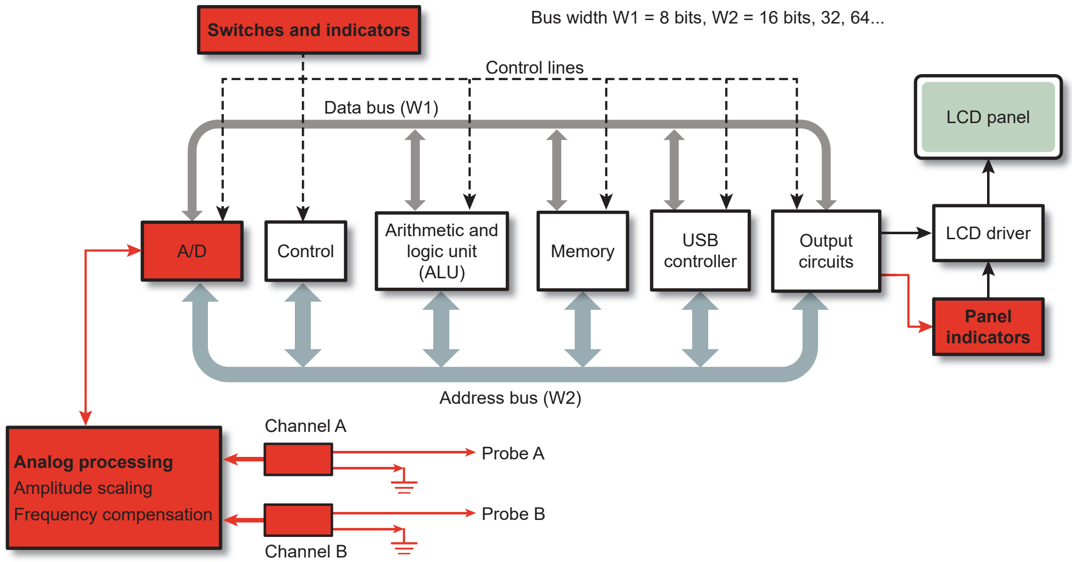

Figure 8 — The signal flow remains the same for the oscilloscope, although the diagram shows only two of the four probes. New software and control information are generally made through an interface module connected to the bus system or the USB controller. The items in red are those added to the computer hardware to turn it into an oscilloscope.

The block diagram also shows that the various ports (BNCs, USBs, and LANs) can be set as inputs or outputs. The LCD panel can illustrate the selected waveform, as well as its frequency and amplitude. A user can also define a custom waveform. The commands or equations that generate these outputs can be entered through the I/O block shown in the lower-left corner of the figure.

Digital Oscilloscopes

Digital oscilloscopes, such as the Siglent Technologies SDS1104X-E (see Figure 7), have similar layouts: mechanical switches on the right, soft switches on the right side of the LCD, and the LCD display on the left. The SDS1104X-E is a four-channel unit, so there are four BNC inputs and four channel-selection switches. It can be used as two dual-channel oscilloscopes or as four independent oscilloscopes.

The block diagram in Figure 8 shows the primary difference being the use of two A/Ds at the end of the analog processing block. While limited by the size of the memory and the processing speed, the same basic design is shared for the four-channel capability.

In Summary

The three examples in this article show that most test instruments can be designed and built around the same architecture as a personal computer. Because most measurements are analog except for communication waveforms, the block diagrams show instruments built up with an analog processing front end and A/D conversion, as well as memory to either capture values or process them, or to hold programs to generate a set of values. And, of course, there is a display or readout to display pictures, graphs, and text.

Finally, with today's technologies, the unit size is usually less than 1 cubic foot with a weight of only a few pounds. If you carefully examine the specifications of an instrument, you may find that you can often add additional capabilities for just a few dollars more, such as a waveform generator built into an oscilloscope.

All photos provided by the author.

Paul Danzer, N1II, an electronics engineer, started out as a teenage radio amateur in 1953. He spent 33 years working in the defense industry on radars and digital equipment and was awarded 11 patents. After leaving these positions, he telecommuted to the ARRL offices in Newington, Connecticut for 3 years, where he edited several ARRL books and wrote several articles for *QST*. Paul then embarked on a second career for 18 years as a college professor, teaching computer-related electronics and PC applications. Now retired, he spends his time writing and testing various amateur-related kits and equipment, fishing, and dog-walking. ARRL has twice awarded him the Bill Orr, W6SAI, Technical Writing Award. You can reach Paul at **n1ii@arrl.net**.

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