SESSION XI MICROCOMPUTER HARDWARE

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Universal one- and two-component interfacing techniques

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Many psychologists avoid using microcomputers in teaching and research laboratories because they lack the experience and knowledge necessary for interfacing. A \$1 electronic component can connect external circuits into any computer. For output interfacing, circuits are available to control external devices with one or no additional components.

One of the primary factors that has kept some psychologists from switching from electromechanical relays to computerized programming has been the difficulty of interfacing existing electromechanical laboratory equipment to electronic circuitry. When electronic programming was first introduced, it was difficult to interface and very susceptible to noise. Now, new solid state devices are available that greatly simplify interfacing and virtually eliminate false pulses due to noise.

Digital electronic circuitry has become widely standardized on transistor-to-transistor logic (TTL). The TTL standard specifies that a logic "0" must be a voltage between 0 and .8 V. A logic "1" must be between 5.0 and 2.0 V. All signals that activate modern electronic circuits must be converted into TTL in order for the logic circuits to recognize them as inputs. Outputs are also sent out as TTL signals and must be converted to appropriate levels of voltage and current to drive external devices.

The simplest, safest, and most economical way to perform these conversions is to use an optoisolator, which costs about \$1 and consists of two components in a small sealed package. One component is a light-emitting diode (LED) that lights up whenever an adequate voltage is applied; the second is a phototransistor, an isolated light-sensitive transistor that acts like a switch and closes a circuit whenever light stimulates it.

When an optoisolator is used as an input interface, any dc voltage such as the typical 24 V dc found in most psychological laboratories is applied to its LED. A series resistance large enough to limit the amount of current going through the LED is used to protect the diode from destruction. Most LEDs require about 20 mA of current; using Ohm's law, the resistance of the series resistor is calculated by dividing the applied voltage by the current through the diode. For example,

the resistance used in a circuit supplying 24 V to a 20-mA LED is 24 divided by .020, or 1,200 ohms. In practice, any resistor within $\pm 25\%$ of this value works.

Whenever the LED is activated, it causes the isolated output transistor to switch on. Since one side of the transistor is usually connected to ground, it pulls the other lead to ground, thus asserting a TTL logic "0" in the digital circuitry. Whenever the LED is not illuminated, the output transistor becomes an open circuit and allows the logic circuit to be pulled up to +5 V to assert a logic "1." A pull-up resistor of typically 1,000 ohms is used for this purpose. With this type of input interface, any applied voltage can be converted to TTL voltage levels. Noise and possible circuit damage due to high-input voltage levels are not a problem. Since it takes a significant amount of current to light the LED, small, short-duration noise impulses are suppressed. The isolation between the LED and the phototransistor is typically in excess of 20,000 V, so regardless of the applied voltage, the diode cannot affect the electronic circuitry.

The simplest and easiest place to connect such an input interface is directly across a key on the computer's keyboard. First, a dc voltmeter is used to determine which of the two key contacts is positive. The positive terminal of the optoisolator's output transistor is connected to the positive key and the negative terminal to the negative key contact. Now, whenever the optoisolator is activated by an external voltage, it closes the keyboard contact. Software is then used to continually check the keyboard and perform the desired program operations when the key is activated by the optoisolator.

This technique works with keyboards ranging from hand-held calculators (which become inexpensive, sophisticated electronic counters and data loggers when interfaced with optoisolators) to elaborate computer systems. Regardless of whether the keyboard keys

switch dc or clock pulses, a correctly installed optoisolator will duplicate the function of the keyboard key.

In a few cases, a series resistor must be added between one lead of the optoisolator's phototransistor and the key contact. This is necessary only if the deactivated optoisolator holds the key contacts closed. The value of the resistor is chosen by trial and error. Starting with 50 ohms, the resistance is increased until the key is no longer activated. Activation of the optoisolator closes the contact, and deactivation opens the contact.

A simple and safe output interface can also be constructed using optoisolators. The TTL output levels of the computer are directly connected to the LED, and the isolated output transistor is used to turn on any desired external circuit or relay. The General Electric H13B1 is a typical, inexpensive optoisolator. The output phototransistor is typically rated at 25 V and .1 A. An external relay or power driver must be used if higher currents or voltages are to be switched. Numerous so-called solid state relays are available that require very low input voltage and are capable of switching very high currents and voltages. Some of these devices incorporate an optoisolator and can switch currents at 5-10 A at several hundred volts. Whenever an optoisolator is attached to digital circuitry as an output interface, the LED should be the only load on the TTL circuitry, since it usually takes most of the available TTL power to illuminate the diode.

An additional interfacing technique that is often

overlooked involves using existing output lines that normally perform some dedicated function. These lines are usually permanently interfaced to some external device and need only be disconnected from the device and connected to another device. For example, most microcomputers use a cassette tape recorder that can be turned on and off under program control. The switching is done by a relay or optoisolator. The same program instructions that control the external tape recorder can easily be made to control any other device by attaching the device to the wire that controls the tape recorder. For the TRS-80 microcomputer, the BASIC command OUT 255, 4 switches on the recorder, and OUT 255, 0 switches it off.

A careful look at the output system of a computer will usually reveal other outputs that can be utilized. Any light on the computer's front panel or peripheral device can be paralleled or replaced by an optoisolator's LED to allow external circuits to be controlled. With this technique, the lighting of a single digit or segment of a digit in the digital display of even a hand calculator can be used to control external events. With optoisolators attached to keyboard keys and to the display digits, even a simple programmable hand calculator or a digital stopwatch can become a versatile laboratory control system. All of these techniques avoid the necessity of decoding internal address lines and data lines to perform a specific function and should simplify interfacing for all but the most complex applications.