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K47 Introduction to Sensors

rev. 13-Jun-18

Sensors are electronic and mechanical components that convert physical phenomena into signals that can be detected by circuits and computer programs. Sensors are everywhere, from the switch that detects a car door is still open, to the computer keyboard and mouse that detect your various finger motions and translate them into specific computer actions. This kit includes a large collection of sensors that can electronically detect, or measure, many different physical phenomena, including many that you can sense with your own body (like touch, sound, light, and heat) as well as some that you can't (such as magnetism or invisible infrared radiation). *Sensing* the world is the first step in building circuits, or computer programs, that sensibly *interact* with the world! You will have fun imaging creative new applications for the many sensors in this kit.

Analog vs. Digital Sensors. Sensors act as inputs to an electronic system. They communicate an external, physical phenomenon or event to some sort of host circuit or software program, often by transmitting a voltage along a wire that connects the sensor to the circuit or software.
At the lowest level, sensors come in two different designs: analog and digital. Each flavor of design corresponds to a different interpretation or meaning of the voltage on the wire. Analog designs look at the relative *strength* of the signal, and answer questions such as "*how much?"* or "*how strong*?" Digital designs, by contrast, consider only the presence or absence of the signal (voltage), and so answer questions of "*whether*" or "*if*." Where digital signals *detect* a phenomenon, analog signals *measure* it.

Consider, for example, designs for a heat sensor (like a thermometer). In an *analog* design, this sensor might report the current temperature as an electrical voltage. The designer or manufacturer might choose no voltage—or a very low voltage—on the wire to indicate a very cold temperature. And some appropriate maximum voltage, perhaps 3.3V, might be used to indicate a very hot temperature. Then any of the infinite range of intermediate voltages between those extremes would represent the infinite range of temperatures possible between cold and hot. Even before you calibrate the thermometer to a well-known temperature scale (like Celsius or Fahrenheit), you would know that a signal of 1.80V indicates *hotter* conditions than a signal of 1.79V, because greater voltage corresponds to greater heat, in this analog design. Wherever a physical phenomenon corresponds to a range or spectrum of possibilities (like temperature, in this example), an analog signal is an effective electronic model of that phenomenon.

By contrast, consider a *digital* heat sensor that only warns you when the temperature falls below the freezing point (perhaps so you turn on an alarm or a heater). Here neither the heat sensor, nor you, are interested in the exact temperature, just in the question of whether that temperature currently falls below freezing. Where analog signals represent (through varying voltage) an unlimited number of continuously-related choices or possibilities, digital sensors instead indicate one of only a limited (or *discrete*) number of possible choices—often just two.

Digital sensors are therefore good at answering questions that have only a few answers. Where an analog thermometer answers “how cold is it?”, a digital thermometer instead answers “is it below freezing?” Sometimes the digital answer can correspond to a simpler question to ask, and a simpler question can mean building a less complicated, or less expensive, circuit or program to act on that question’s answer.

Hybrid Sensor Designs. This kit includes analog and digital sensors, as well as a third *hybrid* type of device which reports *both* an analog signal and a digital signal. The analog signal reports the current amount of the phenomenon that is being sensed (*how much?*), and the digital signal reports whether that *current amount* exceeds some specific threshold (*if/whether*). So, for example, a hybrid thermometer reports *both* the current temperature (analog) *and* if that temperature is above freezing (digital).

These hybrid designs exist primarily for designers’ *convenience*. With both signals available, you can use whichever type of signal (and ask whichever type of question) makes best sense for your application. Also, on a hybrid sensor, the “threshold” that the digital signal detects is often adjustable, using a hardware control dial called a potentiometer. You can tweak this dial to adjust the sensitivity of your sensor’s digital signal in the field. By contrast, if you were working directly with an analog sensor value, and using software to determine whether its present value exceeded some fixed threshold, you’d likely need to change your software and reprogram your hardware to change the threshold value. It’s easier to twist the hybrid sensor dial!

Analog-to-Digital Conversion. Because the Raspberry Pi is a digital computer, when you work with purely analog sensor signals, you will need an *analog-to-digital converter* (ADC) to translate the variable analog voltage into a digital quantity usable by your computer. An ADC is a separate electronic component that sits between the sensor and the computer. This kit includes one, the ADC0832, and you’ll find instructions on how to connect it to specific sensors with the documentation for those sensors.

Kinds of Components. The following table lists all of the many components in this kit, grouped by the kind of physical phenomena they measure or detect. Each sensor is also noted by input *type*, which indicates whether it delivers an analog, digital, or hybrid input to your computer or circuit. Finally, many component designs are *industry standards*. Different manufacturers build very similar components (identical designs), so that you can use them interchangeably in your circuits, and so you can use *your* sensors in circuits designed by others. Unfortunately, some of the conventional names for these standardized components are not very descriptive, and sometimes even not very accurate. For instance, if you are new to working with electronics, you probably don’t know what a “DHT11” or a “4bit_digital_tube” is. These conventional names don’t help describe them! In this kit, we try to use descriptive names for each component to help you understand its purpose. But where there is a different common conventional name, we list that too, so you can recognize your components even in descriptions or circuit designs you find online or elsewhere.

Kind	Name	"Conventional" Name	Input Type
sound & light displays (These components are not sensors at all; they are indicators and displays that you can use to *report* the phenomena that sensors sense. Use them as *outputs* rather than *inputs* to the experiments you build and the programs you write.)	01_2colorLED		output
	02_RGB_LED		output
	03_RGB_SMD_LED	3colorLED	output
	04_7colorLED		output
	05_activeBuzzer		output
	06_passiveBuzzer		output
	07_laser		output
	08_1digitLEDdisplay	8segment_digital_tube	output
	09_4digitLEDdisplay	4bit_digital_tube	output
light & infrared sensors	10_photoResistor		analog
	11_infraredEmitter		output
	12_infraredReceiver		digital
	13_lightBlock		digital
	14_flameSensor		hybrid
	15_obstacleAvoidance		digital
	16_trackingSensor		digital
touch & impact sensors	17_buttonSwitch		digital
	18_touchSensor		digital
	19_tiltSwitch		digital
	20_metalTouchSensor		hybrid
	21_knockSwitch		digital
	22_shockSwitch		digital
	23_joyStick		analog (x2) + digital
sound sensors	24_bigSoundSensor		hybrid
	25_smallSoundSensor		hybrid
magnetic sensors	26_miniReedSwitch		digital
	27_hybridReedSwitch	reedSwitch	hybrid
	28_analogHall		analog
	29_digitalHall	hallMagnetic	digital
	30_hybridHall	linearHall	hybrid
temperature sensors	31_analogTempSensor		analog
	32_hybridTempSensor		hybrid
	33_digitalTempSensor	DS18B20	digital
	34_tempHumiditySensor	DHT11	digital
miscellaneous	35_smokeSensor		hybrid
	36_rotaryEncoder		digital
	37_relay		output