Light sensors for microcontroller digital inputs

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About the author

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What I wanted to accomplish

For some time I had been looking for a way to show our customers how to activate the digital inputs of our microcontroller boards safely and inexpensively when line voltage is present at an AC receptacle, and hopefully, using UL approved components for the line voltage components as well.

One obvious and simple way to do this is to use a UL approved wallblock transformer to power a relay, and simply have the relay contacts do the work, but who doesn't dislike the fact that most wallblock transformers are large enough to block adjacent receptacles? Wallblocks also produce voltages that are higher than their listed rating when they are lightly loaded, which would be the case with a single relay, so picking the proper wallblock and relay combination is not easy. For cost and reliability reasons I wanted as few components as possible, so including a voltage regulator was not a good design choice either.

So the best choice I had left was to design an inexpensive light sensing circuit that can be placed on or near a source of light that is present when line voltage is present. Once that was accomplished all I had left to do was to find the ideal line powered light source.

Digital input circuitry

One of the most common ways a digital input is used on a microcontroller is to have a "pullup" resistor with a value in the range of 1K to 10K connected from +5 to the input pin. The microcontroller will read a logic "high" level until a switch or other contact closure "pulls" the pin to ground (or at least below the threshold for a logic "high" level), when it will read a logic "low". (Some microcontroller boards have this pullup resistor included on the board, but others will require that you add your own.) The following circuits are based on this design of switching this small current from a pullup resistor to ground.

A simple light sensor circuit

If the pullup resistor used on the digital input is of a high enough value, a photoresistive Cadmium Sulphide (CdS) photocell might be all that is needed. As shown in Figure 1, the photocell is connected from the input to ground, and when activated with light, its resistance decreases, and pulls the input to ground. Just how low the input will be pulled will depend on the value of the pullup resistor compared to the resistance of the photocell when it is activated by the desired amount of light. If the value of the pullup resistor is too low the sensitivity of this circuit may not be high enough for the light level used to activate it.

The light specifications given by photocell manufacturers can be difficult to use without knowledge of these specifications and special test equipment, so sometimes it is easier to perform simple resistance tests with the light sources you expect to use. One photocell I used was Mouser Electronics part number 338-76C348. It is specified to have a light resistance of 3000 to 20,000 ohms. When tested it was measured at 60 ohms when placed directly on a fluorescent lamp, 400 ohms when placed 3 feet from a fluorescent lamp, and 900 ohms when placed on the brightest part of a neon nightlight (2000 ohms on the dimmest part). This same photocell, which was specified to have a dark resistance of 500K, was measured at over 600K ohms when in a dark place and over 10 megohms when placed in total darkness. Similar measurements were found with all of the photocells in Radio Shack part number 276-1657, an assortment of five CdS photocells.

A more sensitive circuit

For light sources that are not very bright another type of circuit can be used that has only two more components. A versatile and sensitive light activated switch can be made using a photoresistive Cadmium Sulphide (CdS) photocell, a fixed resistor, and a common NPN switching transistor like a 2N3904, 2N2222, or 2N4401. When light activates the photocell it turns on the transistor which acts as a switch to ground. The nice thing about this type of circuit is that it can be used with nearly any light source as long as there is a significant difference in the brightness of the light source when it is on and when it is off.

Figure 2 shows the circuit diagram, where R1 is the CdS photocell and R2 is a fixed resistor. To determine the value for R2, connect an ohmmeter to the photocell and place the photocell against the light source that you intend to use to activate the circuit. (You will need to shield the photocell from ambient light while making this measurement.) The value for R2 should be from 3 to 10 times the resistance of the photocell at that light level, and can be adjusted for how sensitive you would like the circuit to be.

Of course, the sensitivity of this circuit also comes with a price. To insure that ambient light or other stray light sources do not activate the circuit when it is in place, the photocell must be protected from these light sources by some physical means. This is usually not at all difficult, and there are some simple and inexpensive ways to do this.

Another simple circuit

Another simple light sensor circuit that requires only one component is the phototransistor, although the disadvantage to common, inexpensive phototransistors is that they require quite a bit of light to turn on the transistor. Nevertheless, they will work in some applications.

Figure 3 shows how a phototransistor can be connected to switch a digital input to ground. A common phototransistor that is sensitive to visible light is the Panasonic PN168, which looks like an LED but is actually an NPN transistor that is light activated.

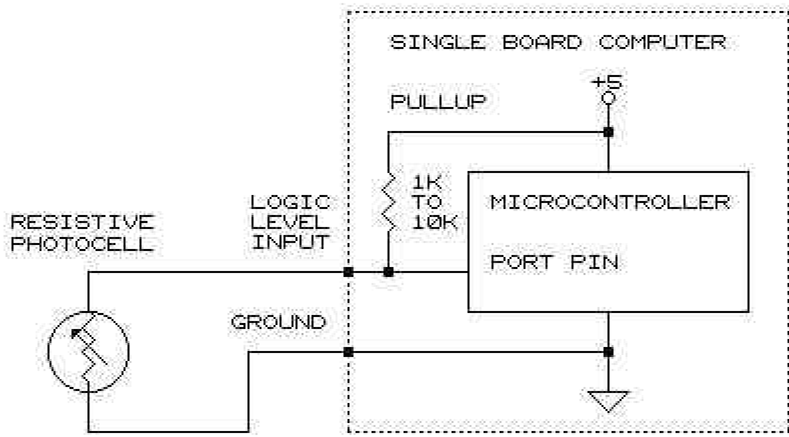


FIGURE 1

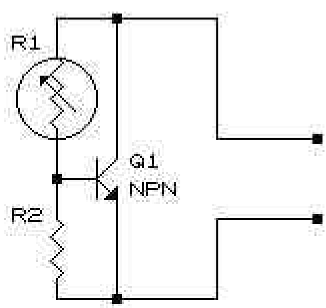


FIGURE 2

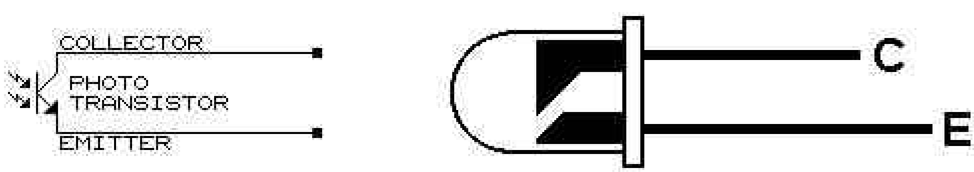


FIGURE 3

The night-light line voltage sensor

While searching for an inexpensive UL approved line voltage light source for my sensor I found an interesting product shown in Figure 4. It is a neon bulb based night-light that I found at a number of stores. It is packaged as a set of two lights and is distributed under different names. The packaging with one of the sets of lights specified the life of the light as 10,000 hours and another as 30,000 hours. Since neon lights lose their brightness with time it would be hard to tell at exactly what point the manufacturers consider the light to fail. However, 10,000 hours divided by 24 hours in a day equals 416 days, which is a long time, and in most cases the light will not always be on.

Being neon bulb based, the light takes very little current, a quarter watt according to one manufacturer. It is also barely larger than the diameter of an AC receptacle into which it is plugged, and only 3/4 of an inch thick. But the really interesting thing about it is that the light producing part of the light slides neatly into the body of a plastic film can. By using the most sensitive light sensor circuit that I designed, along with the night-light and film can, I could make the inexpensive, UL approved light sensor for a microcontroller digital input that I was looking for.

Figure 5 shows how the components of the sensor circuit were soldered together, along with wires that go to the microcontroller. Figure 6 shows how the circuit was then glued to the night-light, with the photocell placed directly on the surface of the light. Hot-glue was used for the sensor pictured but silicone sealer could be used as well since both seem to stick well to the plastic surface of the light. A hole was then made in the bottom of a plastic film can and the wires routed out the hole. The light slid into the film and was taped with black tape to keep ambient light from entering the side of the light that was still exposed. Figure 7 shows the completed sensor.

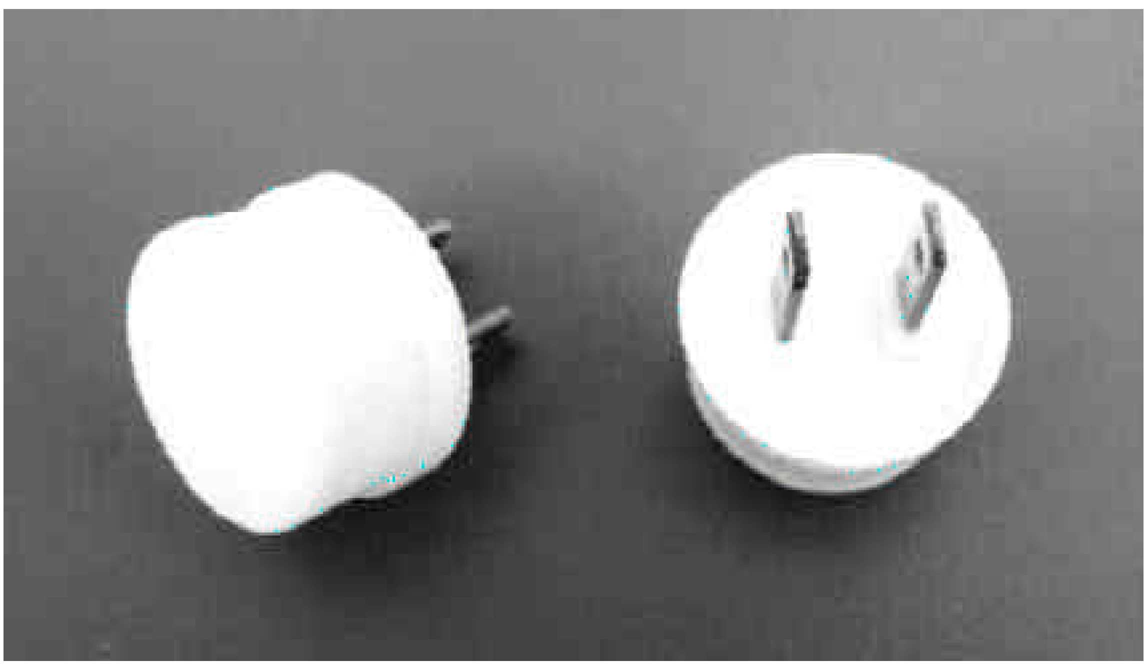
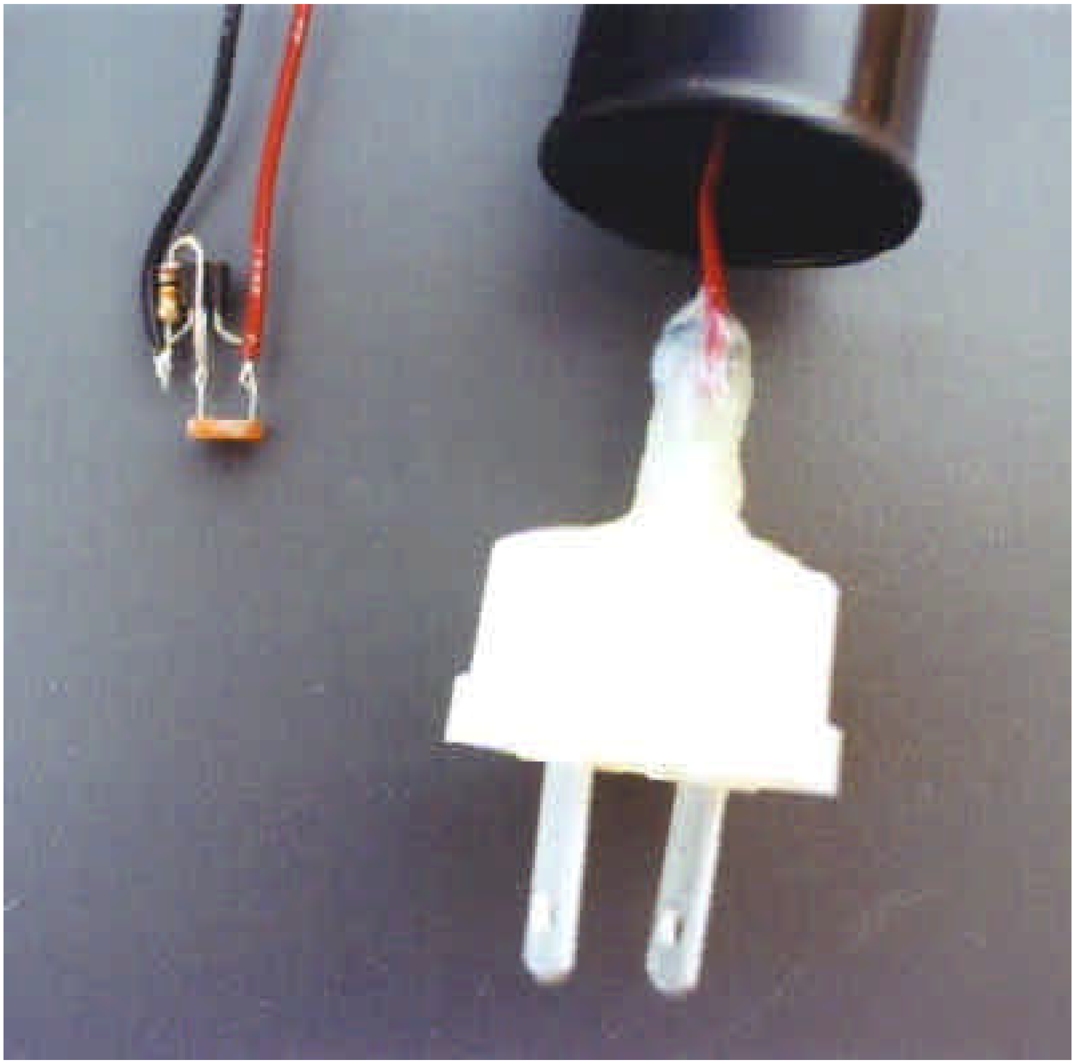


Figure 4



Figures 5 and 6

Figure 7

Sources of night-lights

Walmart, American Tack and Hardware, Monsey, NY, #71050, Neon Guide Lights, 2@$3
KMart, GE Home Electric Products, Cleveland, OH, 8472, Night Light, 2@$3
Walmart, East West Distributing Company, Item 805765, Guide Light, 2@$2