Design Ideas: Basic Sensors

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1 Infrared Reflective Sensor

In general, dark colors absorb infrared and light colors reflect infrared, although this may not always be the case. A basic IR reflective sensor consists of an IR LED and a phototransistor. Both of these components are available in directional dome-lens packages. A phototransistor behaves much like a normal transistor, except that light photons serve as the base current. In order to get a voltage from the phototransistor, you will need a transresistance amplifier. Also consider transmitting and detecting an AC signal because this allows you to filter out interference. Figure 1 illustrates a possible system layout. Of course, you will need filters and other circuitry to get a useful signal out of the sensor.

![Infrared Reflective Sensor](image)

2 Magnetic Sensor

As you may remember from basic electromagnetics, a changing magnetic field will induce a current in a loop of wire. This concept forms the basis for a simple AC magnetic field detector.

You could build this detector with a simple loop of wire. This may sound like a useful fact, but in reality it may turn against you because this means that every wire in your circuit will behave like a magnetic sensor. If you need to measure the magnetic field at a specific point in space, this could become a problem. One solution is to use a coil of wire since the induced current is proportional to the number of turns. But don’t stop there.

In order to build an effective sensor, you want to construct a circuit that will capture the magnetic energy with maximum efficiency. If you think that resonance is the answer, you are correct! If you can build a circuit using a coil which will resonate at the frequency you would like to detect, then the slightest amount of magnetic energy will generate a significant signal in the circuit. As you remember from intro electronics, a simple resonance circuit can be constructed using a parallel inductor and capacitor. The resonant frequency is given by \( \omega_0 = \sqrt{\frac{1}{LC}} \). Since a coil acts as an inductor, all you need to make a resonant magnetic detector is a coil and a parallel capacitor. Approximations for the inductance of various coil geometries are commonplace in E&M textbooks. But don’t stop here either.

Any wire-wrapped coil can be modeled as shown in figure 2. This means that you should not even need a capacitor! Unfortunately, it is not easy to calculate the self-resonance of a coil. (The capacitance of the coil arises from the capacitance between each wrap of wire and every other wrap of wire—a difficult problem to solve even with simple geometry.)

To get an idea for the numbers involved, the self-resonant frequency of a single layer solenoid can be approximated by equation 1, where \( f_0 = \text{self-resonance in MHz} \), \( h = \text{coil height in meters} \), \( d = \text{coil} \)}
diameter in \textit{meters}, and $n =$ total number of turns. (Ramo, Whinnery, Van Duzer, \textit{Fields and Waves in Communication Electronics}).

\[ f_0 = \frac{29.85(h)}{nd} \]  \hspace{1cm} (1)

A ferrite core will increase the inductance and decrease the self-resonance, but not by more than 20% or so. As you can see, a single layer solenoid with $f_0 = 75kHz$ will require far too many wraps. Luckily, layering the solenoid greatly increases the capacitance and results in a reasonable coil, but you have to measure the self-resonance experimentally.

How you build the sensor is up to you, but remember that connections between the coil and any external capacitors and other circuitry will behave as antennas and channel energy into your resonant circuit. This means that the response of your sensor will not accurately reflect the location of your coil unless you minimize the area of connections outside the coil. Magnet wire works best for winding coils because of its thin insulation (thin insulation = tighter wraps = more capacitance.)

Positioning the magnetic coils are key to the usefulness of your magnetic sensors. (Remember the right hand rule?) Consider every reasonable coil configuration, orientation, position, and shape when you design the magnetic sensor. Consider the following questions: What information do you want to extract from the sensor? What sort of response do you want from the sensor? How does coil orientation effect the resulting signal? How does coil location effect the resulting signal? Would more than one coil be useful? How can you process the signal from the coil to extract useful information?