IMPLEMENTING A TRACK WIRE DETECTION CIRCUIT

PURPOSE:
This document leads you through each of the stages of the Track Wire detection circuit, and how to implement them using various circuit blocks.

SETUP:
You will be prototyping your circuit at first on the protoboards. Be neat and tidy, and give yourself room around each stage such that you can add components, hook it together, probe signals, etc. This is a “cookbook” approach. It is not intended to give you much understanding, but how exactly these things go together.

In this document you will first analyze then build small circuits that do specific things (pieces that you need). These will come in handy in later parts of the lab; take the time to figure out what is going on and see how they each work. These are all useful in the “sine wave to digital signal conversion” block. It is sound practice to divide the circuit into smaller functional units, and test each one individually.

REFERENCE MATERIAL:
- CKO Ch. 14
- Oscilloscope Tutorial from the class website
- Sparkfun Oscilloscope Tutorial (if you are unfamiliar with O’scopes)

BUMPS AND ROAD HAZARDS:
Polarized capacitors must be plugged in correctly. If you reverse polarity them, they will be damaged (and pop like a firecracker). Reversing polarity on any IC will usually destroy it (letting out the magic smoke). You want to operate your OpAmps in single-ended mode (0-5V power).

OUTLINE:
You will be building several modules here for use with the Track Wire detector. Build them each neatly and test them extensively. Make sure there is room around each module to hook things up and test them; use a separate chip for each module (you have tons in your kits).

**Solenoid/Inductor:** The track wire carries a current which oscillates at a frequency of 24-26 kHz with peak-to-peak amplitude of about 150mA. This in turn generates an oscillating magnetic field around the wire. If you put a coil of wire in this oscillating field with the right orientation, the coil will experience an oscillating EMF, which you can detect as a voltage.

Verify that this is the case by hooking up the solenoid/inductor directly to an o-scope probe with ground on one end and the probe on the other and observe the resulting traces. Include those traces in your lab report with a short paragraph on what you observed.

**Tank Circuit:** A tank circuit is an LC oscillator (a simple harmonic oscillator: imagine water sloshing back and forth in a tank). The sensor solenoid can double as both a signal source and a tank inductor. In this case, the resonant frequency of the oscillator is close to 25kHz, so the track wire will induce large oscillations in the tank. That is, the tank circuit is a passive amplifier.
The resistor is a “Q-killer” resistor: it lowers the quality factor of the filter, at the cost of gain. This resistor is not necessary for this lab, but you may find it useful if you want the same circuit to give consistent results from track wires driven at slightly different frequencies.

Build the Tank Circuit and hook it up to your solenoid and see what it looks like on the o’scope when you are sensing the track wire circuit.

**Split Rail Buffer**: In many circuits, it is useful to have a rail whose voltage is between two power rails. One option is to use a voltage divider, but this makes the divided voltage sensitive to current draws (i.e., a voltage divider has a high output impedance). By using an OpAmp as a buffer the voltage divider is impedance isolated from the output. The output now has the impedance of the OpAmp (effectively infinite).

Create a Split Rail Buffer with an output of 2.5V from a 5V rail. What is the purpose of the capacitor in the circuit?

**Non-Inverting Amplifier**: The non-inverting amplifier has very high input impedance, ensuring that the input has very little load on it (important for sensors that cannot source much current). The non-inverting amp is used extensively in filtering circuits, but has a limit that it cannot have a gain of less than one (no attenuation).

Design and build a non-inverting amplifier that has a gain of 2. Hook the output of your tank circuit to the input of the non-inverting amplifier, and check both traces on the scope.

**Peak Detector**: A peak detector is an active rectifier that follows the voltage up to the highest point and holds there. The peak detector stores charge on the negative input using a capacitor. The diode prevents discharging,
so the op-amp can only raise the voltage on the capacitor, but cannot lower it (which isn’t particularly useful). A switch/FET can be used to drain the capacitor, or a simple resistor can be used to make the peak detector “leak” charge off of the capacitor.

![Active Rectifier Diagram]

The time constant of the “leak” is the RC time constant. Choose a reasonable time constant that you can make using the parts in your lab kit. Build the peak detector and verify that it works. Hook the output of the non-inverting amplifier to the peak detector and look at the traces of the track wire through the stages on the oscilloscope.

**Comparator with hysteresis:** The comparator is an open collector (open drain) output device that is very similar to an OpAmp, but has been tuned for fast non-linear response. This is used to snap the output hard over from one side to the other (shorting to ground or letting go). The comparator (LM339) can be used to create a hysteresis bound on the input (sometimes called a Schmitt Trigger).

![Comparator Diagram]

A regular OpAmp can be configured to act like a comparator (see this app note for details), but the hysteresis bounds are not nearly as easy to set, nor does it work as well as the actual comparator. See Appendix A to the lab for calculations on comparator threshold setting.

Design and build an inverting comparator with a low threshold of 1V (5V output) and a high threshold of 1.8V (0V output). Use one of the variable power supplies to verify it trips at the right levels.

**LED and Voltage Shift:** The output of the comparator swings from 0-5V, but the input to the Uno32 needs to be between 0-3.3V. This means you need to level shift your output voltage in order to stay within the specs of the Uno32. Additionally, it is very useful to have an LED which indicates if you have the signal or not without having to read a pin on the Uno32. It is important to note that the comparator cannot drive the LED directly without altering the hysteresis bounds, so you will need to insert a buffer (non-inverting OpAmp with a gain of 1) between the output of the comparator and the LED-Level shift stage.
This circuit consists of a voltage divider to scale the output, along with a drive stage to light the LED when the signal line goes low. Ensure that a 0V input lights the LED, and that a 5V input results in 3V output.

Hook all of these together and you should have a working track wire sensor.