Experiment # 6

FERROUS MOTION SENSORS

INTRODUCTION:

Ferrous motion sensors have many important industrial applications. As the title reveals only ferrous metal items that actually move can be sensed. A large metal object of the size of an automobile can be sensed several meters from the sensor and could be used with an electronic counter to find the total number of vehicles passing a given point. This may be used by traffic authorities to estimate how busy is a junction or a roundabout. The sensor can be placed near a conveyor to count the number of ferrous items passing by, or to initiate a relay operation to stop the conveyor or to flash a warning light. The sensor can be used to detect nails, wire, and other ferrous metal objects that could damage an expensive saw blade moving through the sensor. A special version of the sensor large enough to encircle a doorway could be used as a weapon detector. This can be used by security authorities in airports. Obviously there is a wide range of applications for this sensor.

CIRCUIT OPERATION:

Fig. 1 shows the circuit of a ferrous motion sensor. The idea is very simple. A ferrous object moving near a coil carrying a DC current (do you know how the coil gets its DC current? Think about it) will disturb the magnetic field produced by the coil. This will result in an induced voltage in the coil windings. This small voltage signal is fed to a high gain amplifier. The signal is boosted over 200 times with the first amplifier, and its output is connected to the circuit gain control, R_5. The second amplifier boosts the signal over 400 times and the output is connected to the input of the third amplifier where the signal is increased even more by a gain factor of 100 times. The theoretical gain of the three amplifiers is a staggering 8000000 times.

If the amplifiers were connected in a standard audio amplifier configuration, the circuit would go into oscillation due to the high gain and would not be useful, but with the addition of capacitors C_2, C_3 and C_5 the frequency response of the three-stage amplifier is **reduced to near DC** (try to obtain an expression for this frequency response and see how low is the high frequency poles). The ultra-low frequency response also helps reduce the possibility of interference from the 60 Hz line frequency.

When a ferrous object passes by the ferrite pickup loop a small magnetic signal is detected and boosted by the three-stage amplifier as a low frequency **pulse**. The 0-1 milliammeter reads about one-half scale without any input signal (do you know why is this?), but can drop nearly to zero or rise to full scale as an object passes the pickup loop. Also, the LED will flicker off and on as the object passes the loop. Power for the circuit is supplied by a 9-volt transistor battery

BUILDING THE MOTION SENSOR:

If the pickup loop is to be located at a distance from the main circuit, use a shielded lead in connecting the loop to the circuit (why?). In the laboratory we will use a readymade ferrite core loop. For your interest a procedure to construct a loop is given here. Remember that the loop can be so big to allow a person to pass through it. To construct you own loop, place two rubber grommets on a ferrite rod as shown in Fig. 2, spaced 2 ¼ inches apart (about 5 cm). Approximately 120 meters of number 37 enameled copper wire is wound on the ferrite rod between the two grommets. This is about 3000 turns, but the actual number is not very important. A coil would with only one half the number of turns, or one with twice the turns would work out all right, so do not waste too much time trying to determine the actual number of turns when winding the pickup coil.

A fast way to wind the coil is to place the ferrite rod material in the chuck of a variable-speed hand drill and mount the wire spool where it can turn freely. Start the drill at slow speed condition and slowly increase the speed while winding the coil. Even though the coil is jumble-wound try to keep it neat and as evenly spaced on the rod as possible.

EXPERIMENTAL WORK:

Any twisted two-wire cable can be used to connect the pickup to the circuit, but if a long run is needed use a shielded two-wire cable and connect the shield to the battery negative of the circuit.

Place the pickup in a fixed position and turn S_1 on. The meter should read about one-half scale after the circuit becomes stable. The stabilizing time should be no more than a few seconds for the three amplifiers, even with the gain set to its maximum. A good test for the ferrous motion sensor is to take a small, permanent magnet and wave it back and forth in front of either end of pickup loop. Any other ferrous material can do the job. The meter and LED should respond in a “bang-bang” action. Keep moving the magnet back and forth while slowly moving away from the pickup. The motion sensor should still see the magnet’s field one or more meter away from the pickup coil (in our laboratory this will be about few centimeters because of the pickup coil used). All other ferrous metals will cause a similar effect, but any item that is **magnetic** will produce the greatest effect on the detector.

If the detector fails to operate, check the DC voltage at the output pins of the three operational amplifiers. All three pins should read about the same voltage, and will be closed to ½ the battery voltage (why?). Another item to check is the resistance of the pickup coil. The resistance should be between 150 and 250 ohms. The coil is the most likely place for a broken or poorly soldered wire, so check it out carefully. Also, do not let the coil drop or hit a hard surface, as the ferrite rod material will break if mishandled.

QUESTION:

The motion sensor described and tested can sense only moving ferrous materials. Can you think of a motion sensor for moving nonferrous materials? Please report your idea directly to me.

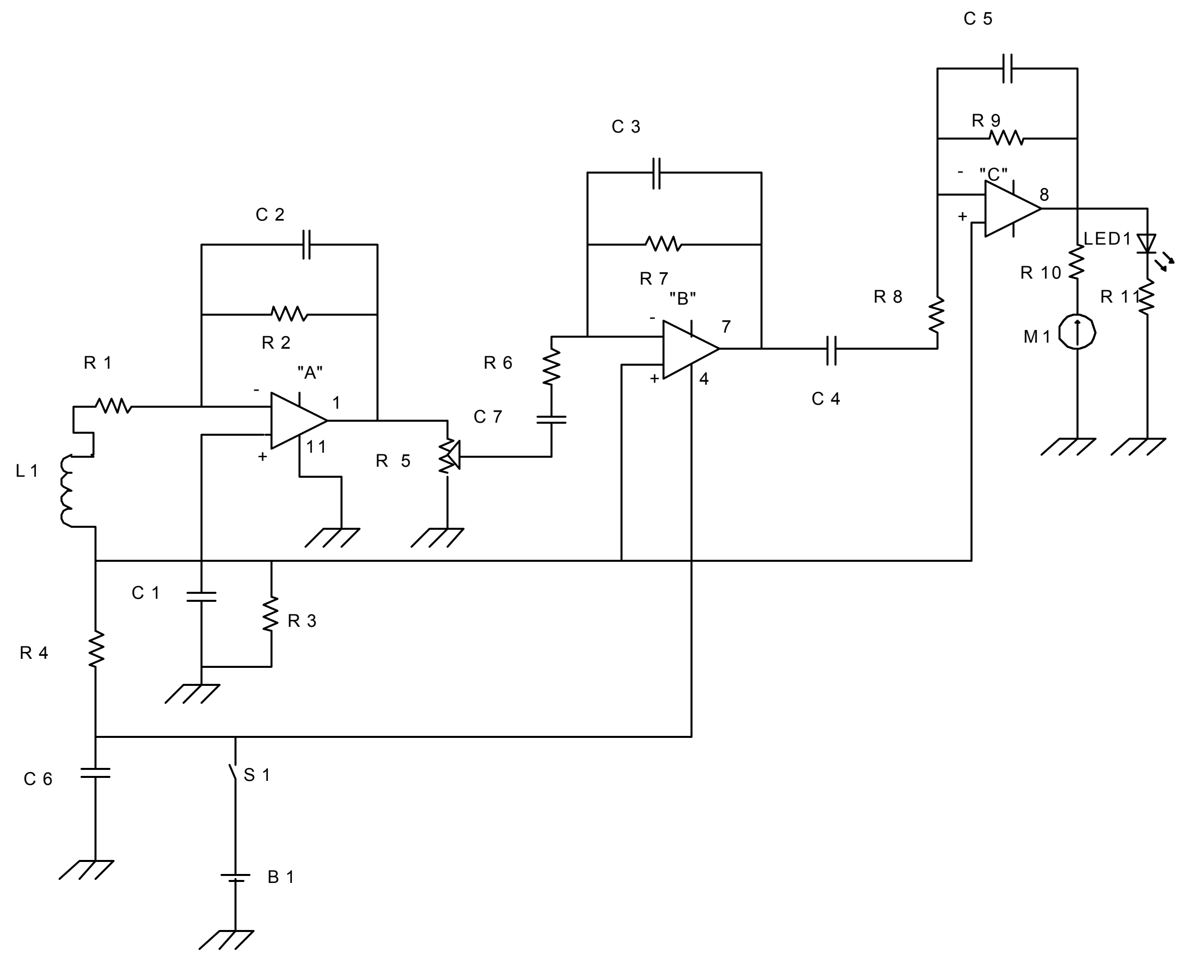

Fig.1: Ferrous Motion Sensor Circuit Diagram (A,B,C : 741 OA)

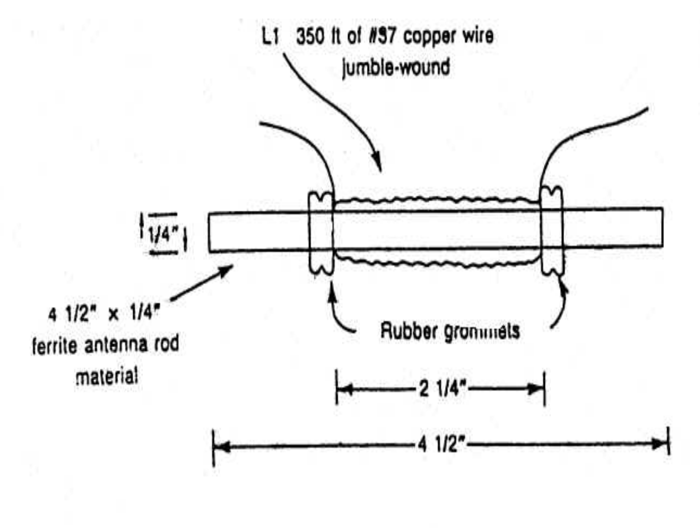

Fig.2: Motion Sensor Schematic Diagram