Hall sensors and flip-flop sustain pendulum's swing

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This circuit offers a simple way to control and sustain oscillatory motion in a simple pendulum and in many other types of mechanical oscillators. Using Hall-effect sensors to detect the instantaneous position of the pendulum and to call for delivery of an energy burst through a flip-flop to keep it swinging, the circuit is a good alternative to the complicated electromechanical arrangements frequently employed. The cost of the entire circuit is also relatively low, making it especially attractive.

When the small permanent alnico magnet that is part of the pendulum support rod comes into sufficiently close proximity to Hall sensor S_1, the sensor generates a negative-going pulse. This pulse sets the R-S flip-flop formed by two cross-coupled 74LS00 NAND gates, A_1 and A_2. The Q output of the flip-flop, now at logic 1, energizes electromagnet L_1, thereby delivering energy to the pendulum via the field between the steel pendulum bob and L_1.

When the pendulum bob reaches the lowest point in its trajectory, L_1 is deenergized by the negative-going pulse generated by sensor S_2, which clears the flip-flop. Simultaneously, one-shot A_5 is triggered. Hence, as long as the Q output of A_5 remains active low, the flip-flop cannot be retriggered because gate A_4 cannot move to logic 0. This action prevents L_1 from energizing and thus creating any drag effect on the pendulum. Also, it conserves power by limiting the time L_1 is on.

In order to initialize the circuit at a relatively small pendulum swing, the period of the one-shot should be set for $t = T/4$, where T is the natural period of the pendulum. Because the oscillation frequency of a simple pendulum is $\omega^2 = g/L$, where $\omega = 2\pi f$, $g = 32.2$ feet per second squared, and L = the distance from the point of support to center of mass of the pendulum bob, it may be seen that $T = 2\pi(L/g)^{1/2}$, and so t should be in the range of 0.32 to 0.36 s in a practical configuration, for T = 1.44 s.

As for component considerations, L_1 is constructed from 100 feet of AWG 24 enameled wire wound on a steel core 1 1/16 inch long and 3/8 in. in diameter. The alnico magnet is situated only about 0.45 in. above the top surface of the pendulum bob—in terms of metric units, approximately 12 millimeters away. The magnet is 3 mm wide, 3 mm high, and 8 mm long. The clearance between the magnet's pole face and the Hall-effect sensor's surface should be between 1/32 in. and 1/16 in. for best results. A small decoupling capacitor (0.033 μF, disk ceramic) is connected between the supply lead and ground of the 74LS00 chip to keep circuit transients caused by S_1 or S_2's firing from inadvertently setting the flip-flop to the wrong state.

Light-emitting diode D_1 serves as a visual monitor, being lit when L_1 is energized. When mounted at the base of the electromagnet, it facilitates a qualitative check on the performance of the system. □

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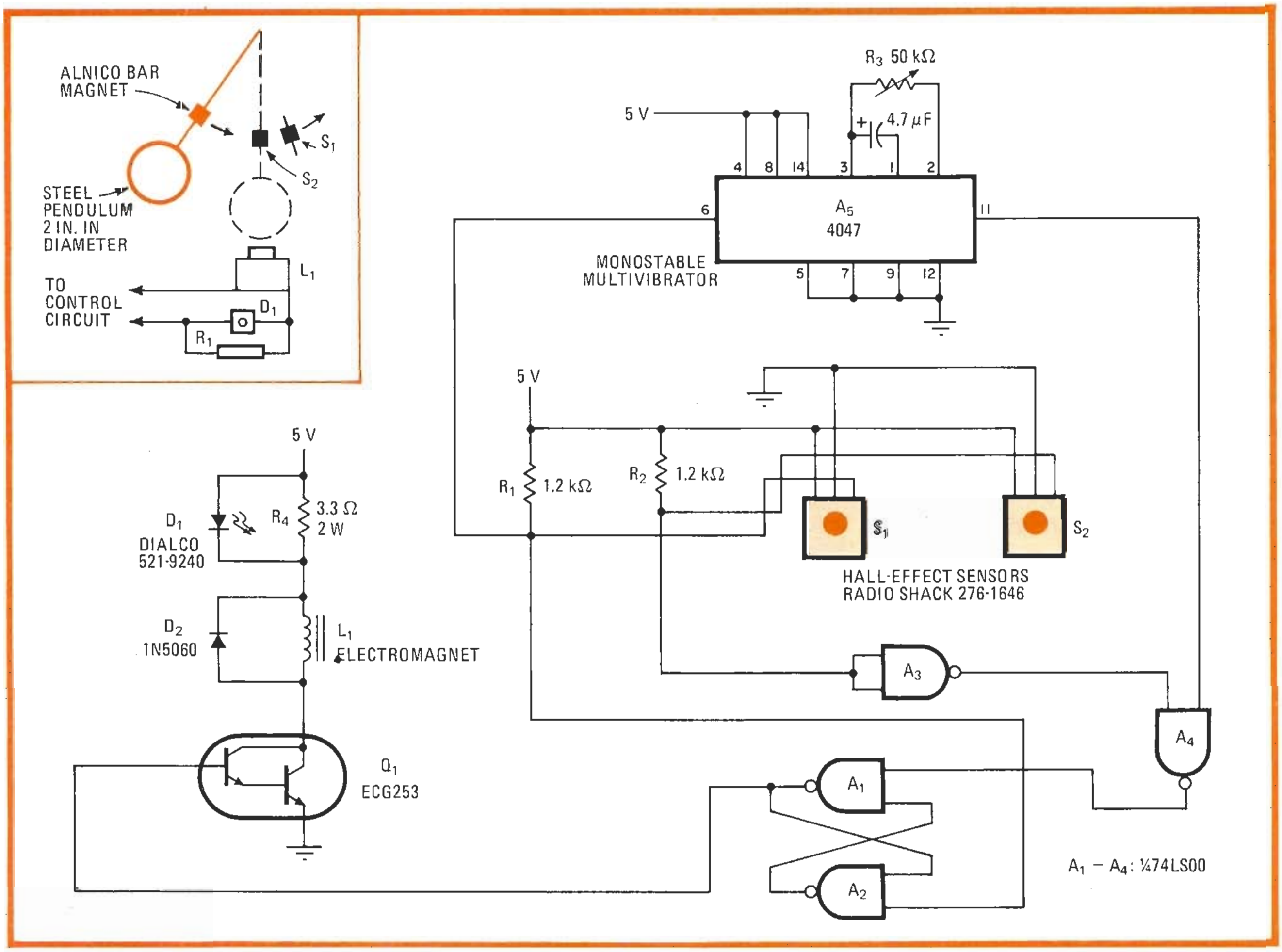

Keep swinging. Hall-effect sensors detect instantaneous position of pendulum, direct flip-flops A_1-A_4 to generate energy pulse via field between L_1 and alnico magnet in order to keep pendulum moving. One-shot A_5 prevents flip-flop refiring in any given cycle, thus stops pendulum drag, and conserves energy. Inset illustrates physical relation of bar magnet to pendulum and interface elements.