Oscilloscope Pong

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I. INTRODUCTION

The very first arcade game was Pong, created in the late 1970s. In its time, it was the height of digital technology. We return to this historic video game from a slightly different point of view. In the following pages we will construct an entirely analog version of Pong that can be played using a modern oscilloscope with an X-Y setting (which draws channel 1 on the X axis and channel 2 on the Y axis).

II. CIRCUITS

Here we look at the circuit from the top-down, starting with the big picture fitting all the subcircuits together, and then analyzing each individual subcircuit.

A. Big picture

In Pong, there are three objects which must be drawn: the ball and the two paddles. We select the object to draw using a very fast triangle wave. At the extents, either paddle is drawn. In the middle, the ball is drawn. This is represented in FIG. 1. The lines CB, CP_1, and CP_2 serve as controls, allowing the corresponding signals ($B_{x,y}$, P_1, and P_2, respectively) to pass on to the scope only when the control is high. Thus, at any time, we need exactly one of CB, CP_1, or CP_2 to be high.

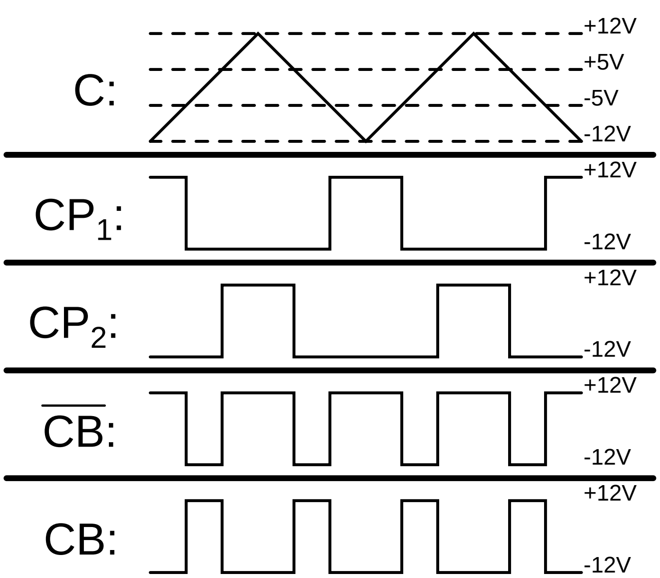

FIG. 1: The voltage at C, CB, $\overline{\text{CB}}$, CP_1, and CP_2. The horizontal axis is time.

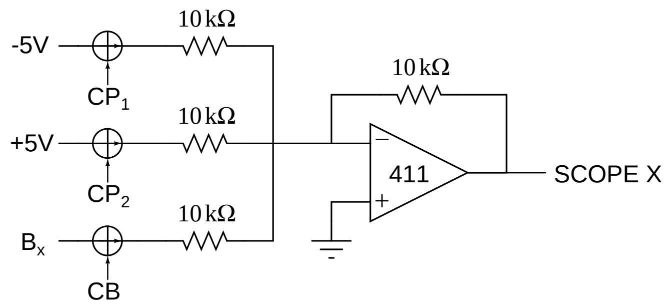

FIG. 2: The big picture for the x-coordinate sent to the scope.

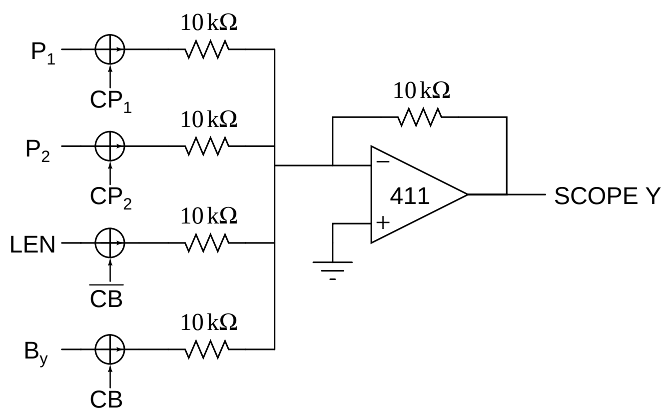

FIG. 3: The big picture for the y-coordinate sent to the scope.

The main circuit consists of two parts. We need to have an output for the scope x position and the scope y position, shown in FIG. 2 and FIG. 3, respectively.

B. Analog Switch

The main workhorse of an analog Pong is the analog switch, denoted in the above schematics as $\oplus$. Using a series of analog switches, we can draw multiple objects on the oscilloscope at once. The analog switch we use here is constructed from an op-amp and an nJFET shown in FIG. 4. It allows the input signal to pass if and only if the control lead is above +5V. The input is sufficiently blocked when the control is grounded. More discussion of this circuit is given in the next section. We can add the output from several analog switches using an op-amp addition circuit.

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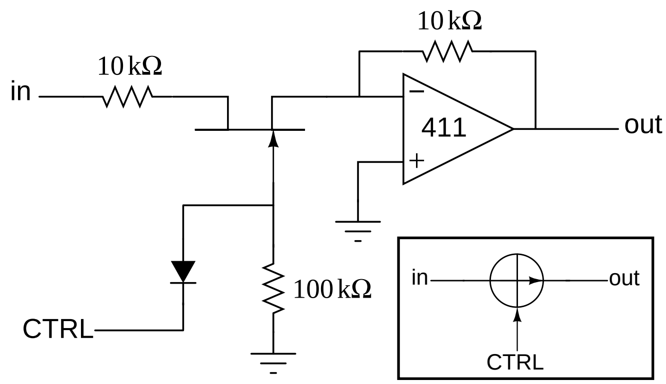

FIG. 4: The analog switch, with an abbreviated schematic symbol inset.

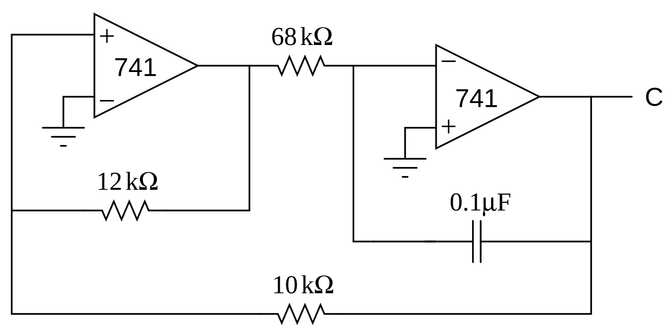

FIG. 5: Triangle-wave generator for the master control signal C.

C. Control Signal

The control signals CB, CP_1, and CP_2 are generated from a master control signal C. This master control signal, as explained above, is simply a fast triangle wave (I've forgotten the frequency), generated by the circuit shown in FIG. 5. We then generate CP_1 and CP_2 by comparing C to $\mp$5V, such that CP_1 is high when C< -5V

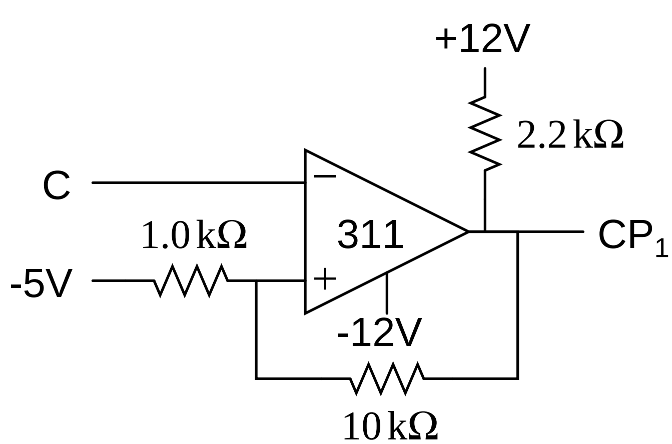

FIG. 6: Comparator to generate the square wave signal CP_1.

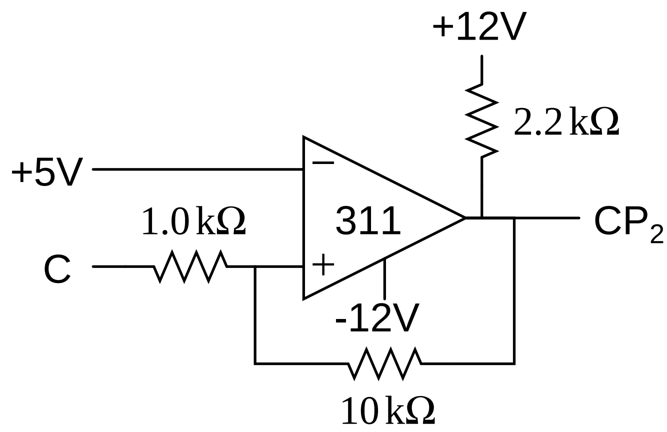

FIG. 7: Comparator to generate the square wave signal CP_2.

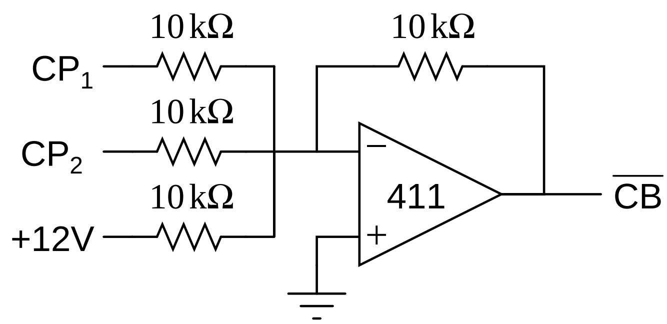

FIG. 8: Triangle-wave generator for the master control signal C

and CP_2 is high when C$> +5$V, as shown in FIGS. 6 and 7.

We must be very careful to prevent any possible overlap in the control signals. Thus, we generate CB as $\overline{CP_1 + CP_2}$, as shown in FIGS. 8 and 9.

D. Ball Position

We generate the ball position from a pair of slow ($\frac{1}{3}$–3Hz) triangle waves, shown in FIGS. 10 and 11. These

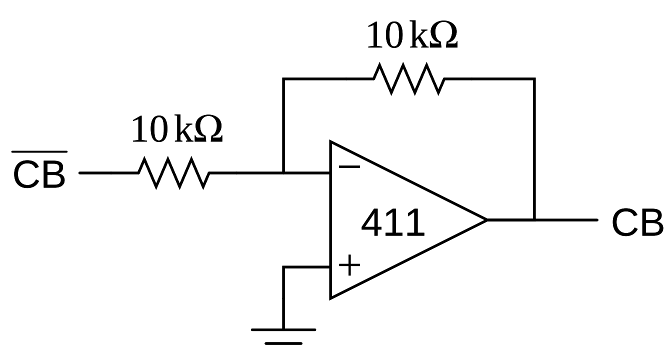

FIG. 9: Circuit to generate CB from $\overline{\text{CB}}$.

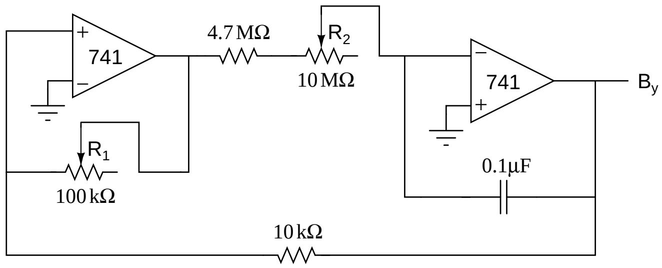

FIG. 10: Triangle-wave generator for the y-position of the ball.

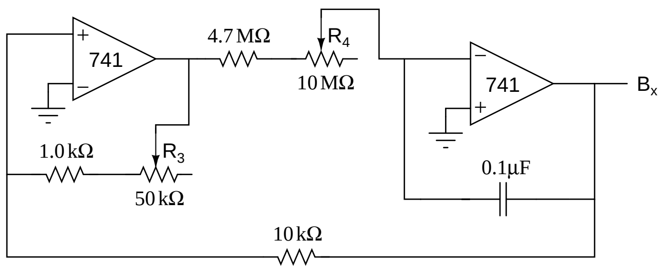

FIG. 11: Triangle-wave generator for the x-position of the ball.

circuits each have a pair of potentiometers: R_1 and R_3 adjust the y- and x-amplitudes of the ball's motion and should be adjusted so that the ball's motion fills the oscilloscope screen, currently designed to be ±4V vertically and ±5V horizontally. R_2 and R_4 adjust the y- and x-speeds.

E. Paddles

The vertical paddle positions are given by the lines P_1 and P_2, which we construct with a voltage divider, shown in FIG. 12. The potentiometers R_8 and R_9 should be large and easy to adjust (i.e., a joystick) and are used to move the paddles up and down. R_6 and R_7 control the

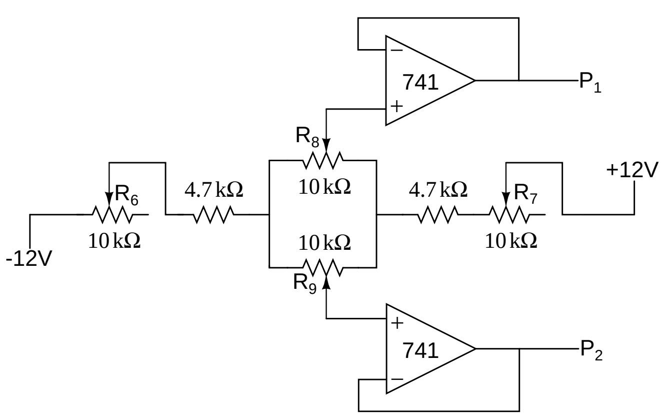

FIG. 12: Voltage divider for paddle positions.

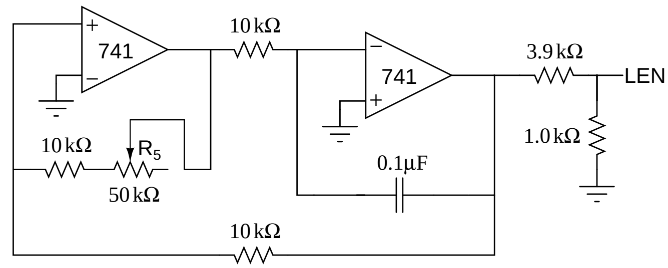

FIG. 13: Fast triangle wave for paddle lengths.

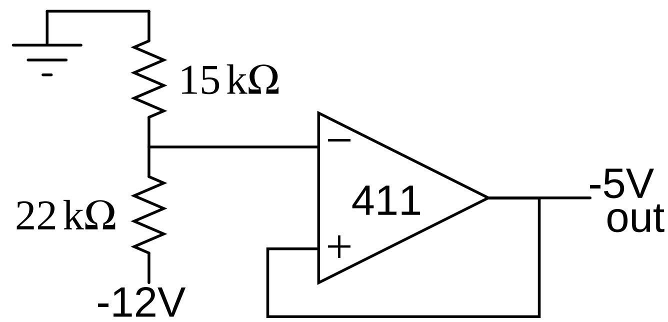

FIG. 14: Generating a low-impedance 5V power supply.

vertical range of the paddles' motion (i.e. from −3V to +3V). Whlie there's no theoretical problem with using them, small potentiometers are hard to find, so we insert an op-amp buffer to decrease the output impedance instead.

In order to make the paddle appear as more than a point, we add a fast (about 10kHz, so that the entire length of the paddle is drawn each time CP_i is high) triangle wave signal LEN, shown in FIG. 13, to the y-output whenever we're drawing the paddles (i.e. when $\overline{CB}$ is high). The potentiometer P_5 controls the size of the paddles (around ±1V).

The horizontal positions are fixed at ±5V—that is, either edge of the screen.

F. Power Supply

We assume that the breadboard setup includes ±12V and ground, but we may need to generate our own ±5V lines, which we do as shown in FIG. 14

III. IMPROVEMENTS

A. Hit detection and scoring

The circuit shown so far is more of an interactive movie than a game. The controls can alter the size and position of the paddles, but can't react differently if the ball is hit or missed. I attempted to add logic to deal with this case using a D-type flip flop as shown in FIG. 15, where B'_x

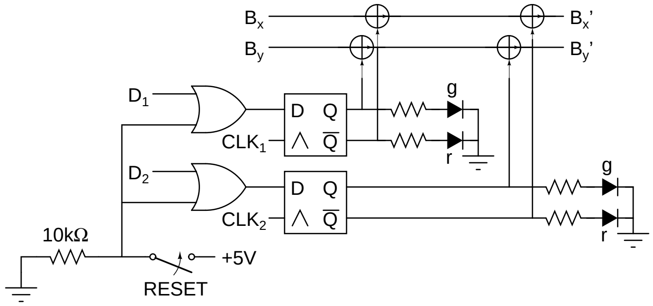

FIG. 15: Hit detection.

and B'_y are sent to the scope instead of B_x and B_y. As the design currently stands, it simply hides the ball until a reset button is pressed. The inputs D_i must change when B_y is within ℓ_p of the P_i, and the clock signals CLK_i should go off only at the very tips of the master control signal C. Finally, the 'g' and 'r' diodes should be green and red LEDs to show who missed.

Unfortunately, this addition caused some impedance problems and smeared the whole picture terribly, and I was never able to fix it.

B. Dynamic ball speeds

One other modification that would be nice would be to allow the ball speeds (at least the vertical speed) to change based on how the paddles hit it. If there was some way to lock-in a "resistance" based on, say, $B_y - P_i$ at a certain point, rather than using semi-fixed potentiometer, then it might not be so difficult. Likely we'd want another sort of flip flop, but I never looked very far into how that might be accomplished.

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