Project: sun tracker

• Idea:
  – Use two photodiodes to detect where the sun is
  – Control a motor to turn toward the sun
  – When sun is “half-way” between PD, stop.

• Potential uses: solar cell tracking

• Components:
  – Stepper motor
  – Shift register
  – Photodiodes
  – Comparators

• Optional: build clock circuit and power with batteries to take outside
# Component list

<table>
<thead>
<tr>
<th>Component name</th>
<th>Digi-key number*</th>
<th>Number needed**</th>
</tr>
</thead>
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<tr>
<td>Bread boards</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Wire (jumper) pack***</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Flexible wire</td>
<td></td>
<td>1</td>
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<tr>
<td>Shift register</td>
<td>296-9183-5-ND</td>
<td>1</td>
</tr>
<tr>
<td>555-timer</td>
<td>LMC555CN-ND</td>
<td>1</td>
</tr>
<tr>
<td>741 op-amp</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Stepper motor</td>
<td>403-1013-ND</td>
<td>1</td>
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<tr>
<td>Photoresistor</td>
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<tr>
<td>Resistor pack***</td>
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<tr>
<td>Capacitors</td>
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<td>4</td>
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<tr>
<td>LEDs</td>
<td></td>
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<tr>
<td>Switches</td>
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<td>2</td>
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<tr>
<td>Battery packs</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Batteries</td>
<td></td>
<td>8</td>
</tr>
</tbody>
</table>

* What we used, many of these can be replaced with other equivalent parts
** Recommend that you buy more than listed, as parts can burn out
*** easily shared between projects
Comparator

- Built using an op-amp (a 741 will do)
- Compares its “+” and “-” inputs
  - If $V^+ > V^-$ then output = $V_{\text{High}}$ (a digital “1”)
  - If $V^+ < V^-$ then output = $V_{\text{low}}$ (a digital “0”)
- Useful for converting small analog voltages into big, digital signals
- To power up, attach $V_{\text{low}}$ to -6V, $V_{\text{high}}$ to +6V
- Test: attach output to LED in series with a 1kΩ resistor to ground
- Set $V^+$, $V^-$ with SMUs, confirm that LED turns on when $V^+ > V^-$
Shift register (1)

- A shift register is a kind of digital memory
- It has 6 data inputs:
  - Parallel data D0, D1, D2, D3
  - Serial data DSR, DSL
- It has three controls:
  - Shift controls, S0, S1
  - Clock
- It has 4 outputs:
  - Q0, Q1, Q2, Q3
  - These outputs change only when the clock changes from 0 to 1

Set VCC to 5V, VSS to 0V, pin 1 to 5V
Shift register (2)

- The shift register has 4 modes, set by S0, S1, and triggered by the clock
  - When S0=1, S1 =1,
    - Q0 = D0, Q1 = D1, etc
  - When S0 = 0, S1 = 0
    - Q0,Q1,Q2,Q3 hold their value
  - When S0 = 0, S1 = 1
    - Data shifts left: Q1 = Q0 (from before clock) Q2= Q1, etc
      - Q0 = DSR
  - When S0 = 1, S1 = 0
    - Data shifts right: Q2 = Q3 (from before clock) Q1= Q2, etc
      - Q3 = DSL

- Test:
  - attach Q0-Q3 to 4 LEDs in series with 1kΩ resistors to ground
  - Set function generator to make a 5V square wave (2.5V offset) with frequency = 1Hz, attach it to the clock input
  - Short D0, D2, D3, and SDR to ground, short D1 and SDL to 5V

- Try different combinations of S0, S1.
- What happens?
  - You should see things shift left or right.
Stepper motor

- This motor has 4 inputs that are 75Ω to ground.
- Each input goes to an electromagnet:
  - current flows in one magnet at a time,
  - a fixed magnet on the rotor aligns with that magnet, rotating the motor
- So motor rotates depending on which input is set to a high voltage.
- The rotor is attached to gears so that each motor rotation only turns the output by ~3 degrees.

Test: attach ground to 0V, attach, one at a time, inputs 1-4 to 5V: does the motor rotate?

Signal sequence for rightward rotation:
LM555 Timer

- Used as an oscillator
- **Trigger:** when $< \frac{1}{3} \text{Vcc}$, the output is high (Vcc)
- **Threshold input:** when $> \frac{2}{3} \text{Vcc}$ and the trigger is $> \frac{1}{3} \text{Vcc}$, the output is low (0V). If the trigger is $< \frac{1}{3} \text{Vcc}$, it overrides the threshold input and holds the output high.
- **Reset input:** when less than about 0.7V, all other inputs are overridden and the output is low.
- **Discharge pin:** This is connected to 0V when the timer output is low and is used to discharge the timing capacitor in astable operation.
LM555 Timer as an oscillator

- Astable operation: The circuit oscillates on its own.
- With the output high, the capacitor C is charged by current flowing through $R_A$ and $R_B$.
- The threshold and trigger inputs monitor the capacitor voltage and when it reaches $\frac{2}{3}V_{cc}$ (threshold), the output becomes low and the discharge pin is connected to 0V.
- The capacitor discharges with current flowing through $R_B$ into the discharge pin. When the voltage falls to $\frac{1}{3}V_{cc}$ (trigger) the output becomes high again and the discharge pin is disconnected, allowing the capacitor to start charging again.
- Adjust duty cycle (time on : total time) by adjusting the ratio between $R_A$ and $R_B$.
- Note that pin 4 (reset) is held at $V_{cc}$ here. You will need change the connection for light sensitivity.

LM555 Timer

- Some equations for astable operation:
  The charge time (output high) is given by:
  \[ t_1 = 0.693 \left( R_A + R_B \right) C \]
  And the discharge time (output low) by:
  \[ t_2 = 0.693 \left( R_B \right) C \]
  Thus the total period is:
  \[ T = t_1 + t_2 = 0.693 \left( R_A + 2R_B \right) C \]
  The frequency of oscillation is:
  \[ f = \frac{1}{T} = \frac{1.44}{R_A + 2R_B} C \]
  And the duty cycle is:
  \[ D = \frac{t_1}{t_1 + t_2} = \frac{R_A + R_B}{R_A + 2R_B} \]