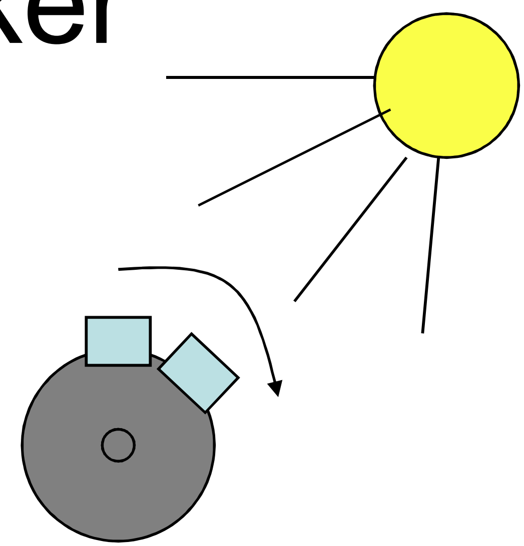
Project: sun tracker



- 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

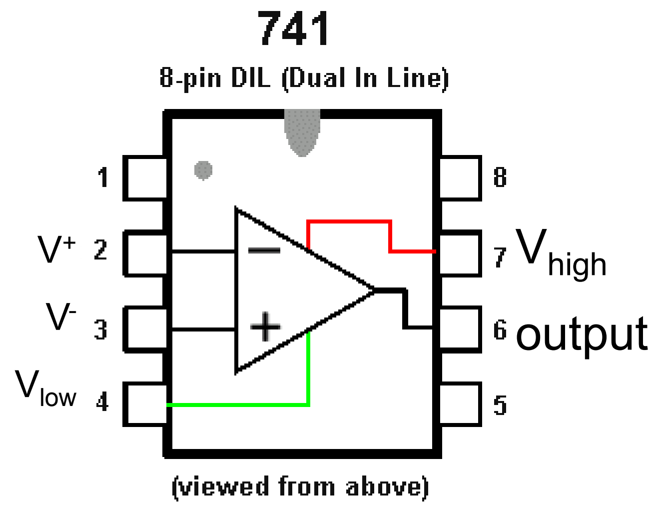
Component list

Component name	Digi-key number*	Number needed**
Bread boards		2
Wire (jumper) pack***		1
Flexible wire		1
Shift register	296-9183-5-ND	1
555-timer	LMC555CN-ND	1
741 op-amp		2
Stepper motor	403-1013-ND	1
Photoresistor		2
Resistor pack***		1
Capacitors		4
LEDs		7
Switches		2
Battery packs		2
Batteries		8

** 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

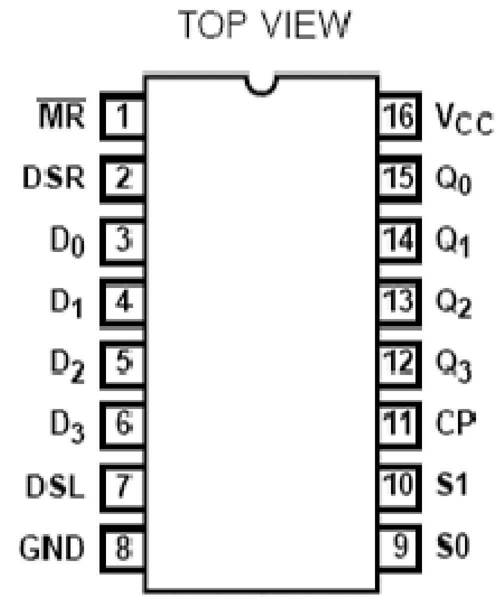
- Built using an op-amp (a 741 will do)
- Compares it's "+" and "-" inputs
  - If $V^+ > V^-$ then output = V_{High} (a digital "1")
  - If $V^+ < V^-$ then output = V_{low} (a digital "0")
- Useful for converting small analog voltages into big, digital signals
- To power up, attach V_{low} to -6V, V_{high} 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

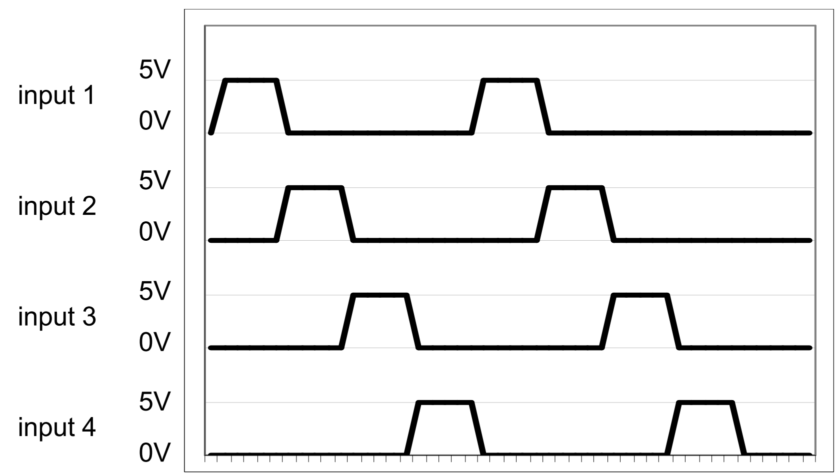
Shift register (2)

- 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

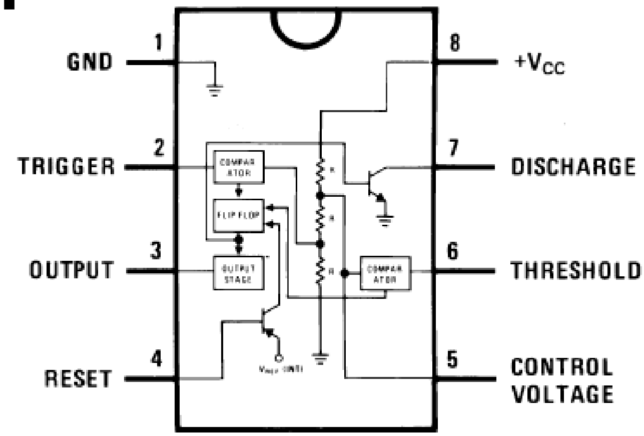
- This motor has 4 inputs that are 75Ω to ground.
- Each input goes to an electromagnet:
  - current flows in one magnet at a time,
  - a fixed magnet on the rotor aligns with that magnet, rotating the motor
- So motor rotates depending on which input is set to a high voltage.
- The rotor is attached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

Signal sequence for rightward rotation:



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

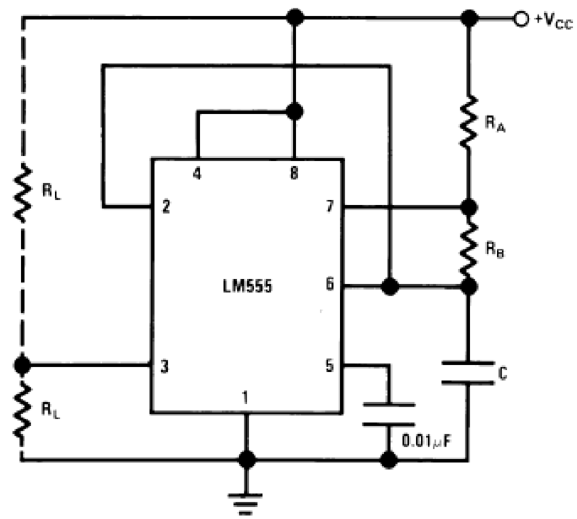
LM555 Timer



- Used as an oscillator
- **Trigger:** when < $^{1}/_{3}$ Vcc, the output is high (Vcc)
- **Threshold input:** when > $^{2}/_{3}$ Vcc and the trigger is > $^{1}/_{3}$ Vcc, the output is low (0V). If the trigger is < $^{1}/_{3}$ 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

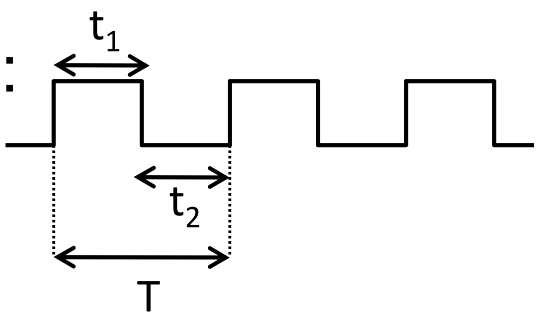
- Astable operation: The circuit oscillates on its own.
- With the output high, the capacitor C is charged by current flowing through R_A and R_B.
- The threshold and trigger inputs monitor the capacitor voltage and when it reaches $^2/_3$Vcc (threshold), the output becomes low and the discharge pin is connected to 0V.
- The capacitor discharges with current flowing through R_B into the discharge pin. When the voltage falls to $^1/_3$Vcc (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 Vcc here. You will need change the connection for light sensitivity.



From http://www.national.com/ds/LM/LM555.pdf

LM555 Timer

- Some equations for astable operation:



The charge time (output high) is given by:

$$t_1 = 0.693\ (R_A + R_B)\ C$$

And the discharge time (output low) by:

$$t_2 = 0.693\ (R_B)\ C$$

Thus the total period is:

$$T = t_1 + t_2 = 0.693\ (R_A + 2R_B)\ C$$

The frequency of oscillation is:

$$f = 1/T = 1.44/\ (R_A + 2R_B)\ C$$

And the duty cycle is:

$$D = t_1/(t_1 + t_2) = (R_A + R_B)/(R_A + 2R_B)$$