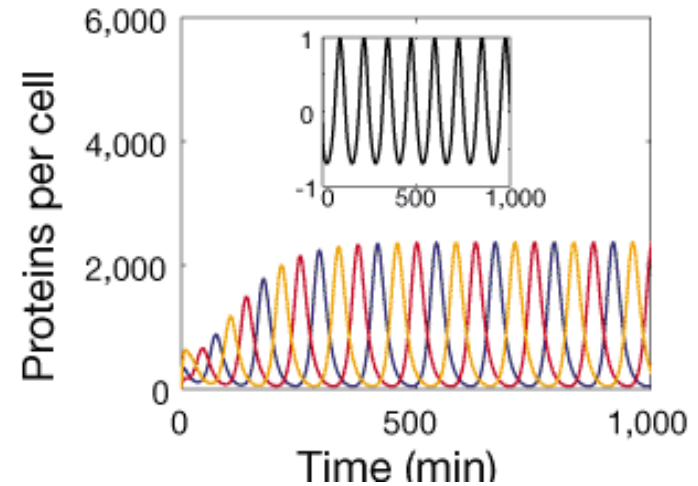
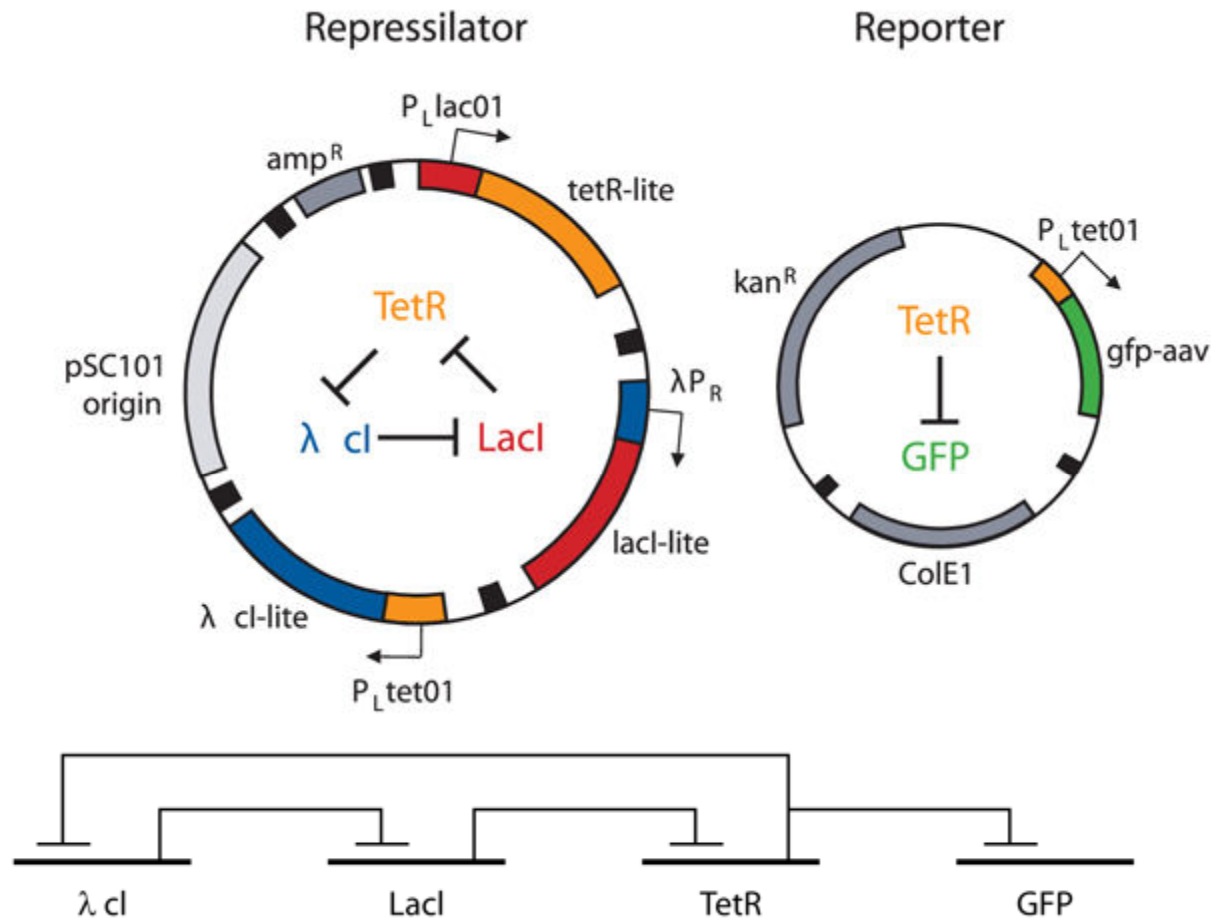


# Project: Repressilator



- Idea:
  - Use electronic circuits to understand the operation of a genetic oscillator.
  - Genetic oscillators must be involved in circadian rhythms and other periodic protein expression.
  - Similar math can be used to understand both electronics and gene circuits.
- Potential uses: Help with understanding feedback effects in biology.
- Components:
  - Timing circuits
  - Amplifiers
  - Light emitting diodes

# Gene Circuit



**From the following article:**

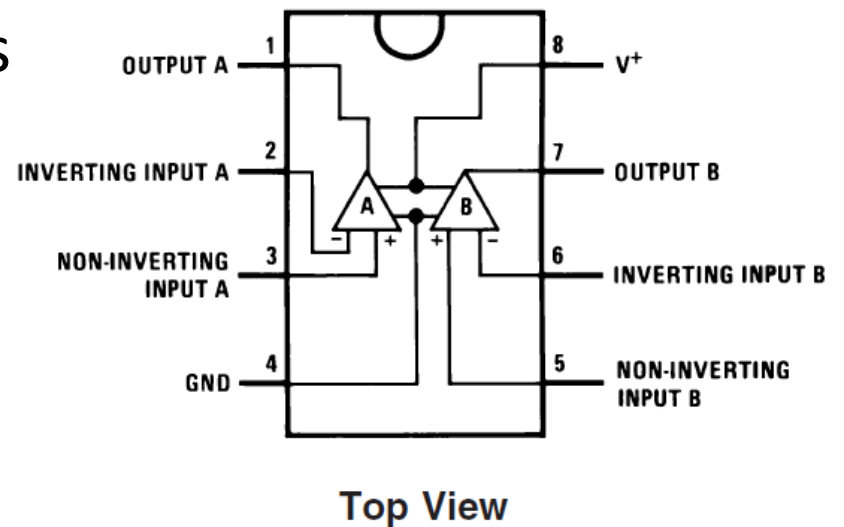
[A synthetic oscillatory network of transcriptional regulators](#)

Michael B. Elowitz and Stanislas Leibler

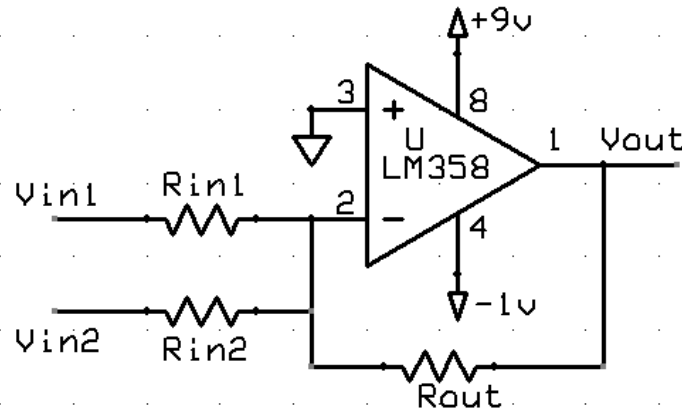
Nature 403, 335-338(20 January 2000)

# Operational Amplifier LM358

- Opamp is used in many circuits to compare voltages, amplify voltages, or to amplify currents.
- One physical DIP package contains two opamps. Each opamp has many transistors, but we can usually ignore the internal complexity.
- Opamps require power to run, in our case +9 volts on pin 8 and -1 volt on pin 4.

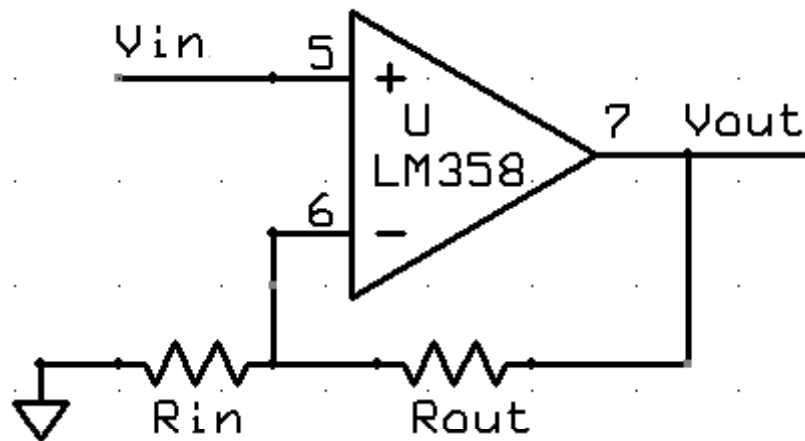


# LM358 as an inverting amplifier



- $V_{out} = -R_{out} * (V_{in1}/R_{in1} + V_{in2}/R_{in2})$
- If  $R_{in2} = \text{infinity}$ , which means you just leave it out then:  
 $V_{out} = -V_{in1} * R_{out}/R_{in1}$
- $V_{out}$  is limited to being no bigger than +9 volt and no smaller than -1 volt.

# LM358 as an non-inverting amplifier

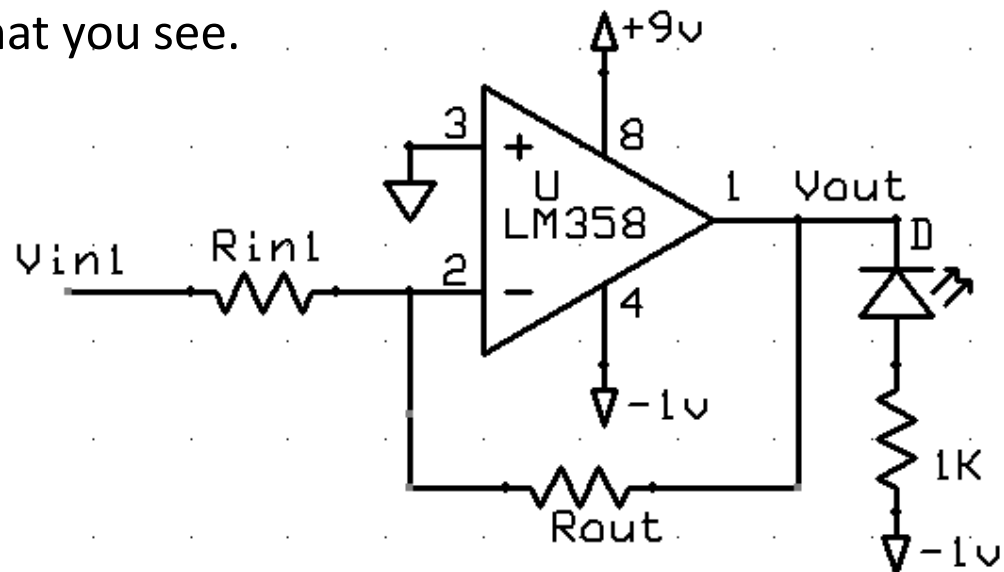


- $V_{out} = V_{in} * (1 + R_{out}/R_{in})$
- $V_{out}$  is limited to being no bigger than +9 volt and no smaller than -1 volt.
- Special case: if you leave out  $R_{in}$  and make  $R_{out} = \text{zero}$  (a wire) then  $V_{out} = V_{in}$ . Then why bother? LM358 acts a current amplifier with a gain of several million.

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

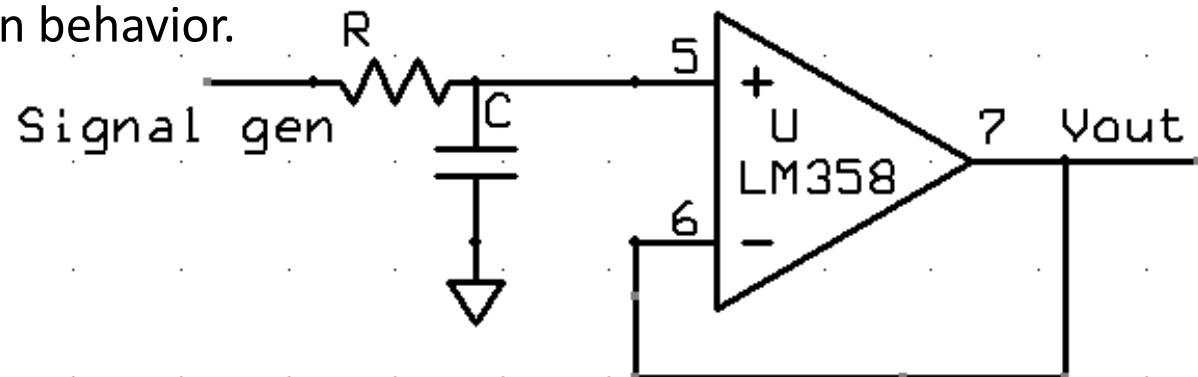
# LM358 testing part 1

- Testing:
  - Pick a couple of resistors between 1K and 100K and build an inverting amplifier with a gain of -2.
  - Test it by connecting the input to the waveform generator and the output to an LED as shown below. Vary the frequency. At what frequencies can you see the LED vary brightness?
  - Set up the waveform generator to produce a 0.1 volt amplitude sine wave, then hook one scope probe to the input, another to the output and explain what you see.



# LM358 testing part 2

- Testing:
  - Build a noninverting amplifier with a gain of 1.
  - Add a resistor and capacitor to the input. Start with  $R=1K$ , and  $C=1\mu f$ .
  - Test it by connecting the input to the waveform generator and the output to the scope as shown below.
  - Set up the waveform generator to produce a 0.1 volt amplitude square wave, then hook one scope probe to the input, another to the output and explain what you see as you vary the frequency.
  - Hook up the LED from part 1 to both pin 5 and pin 7 and explain the difference in behavior.



# Relationship of opamp to gene function

- The three genes of the repressilator are turned *off* quickly as protein concentration rises. This can be modeled by an inverting opamp with high gain. The opamp input is a voltage corresponding to protein concentration, the output is the gene activity. An LED on this opamp output shows gene activity.
- The protein concentration from an active gene accumulates slowly like the charge (and therefore voltage) on a capacitor connected through a resistor. The capacitor voltage is buffered by a unity gain amplifier and becomes the input to the next gene. An LED on this opamp output shows protein concentration.