Smart Lighting Controller
Smart lighting

- No need to spend energy lighting the room if
  - It’s already bright enough from natural light
  - There’s nobody in the room
- Idea is to detect these things, and turn off lights when not needed
- We’ll build a circuit to turn off the lights when the room is bright
What we’ll do

- We’ll learn how the circuit works
- We’ll learn to read a schematic
- We’ll build the circuit
- We’ll use an LED to represent the room lights
Block diagram

Battery -> Rail splitter -> Sensor -> Trans-impedance amplifier -> Comparator

Threshold set

Here’s the schematic
Rail splitter

- Also called voltage divider
- Ohm’s Law: \( V = IR \)
- Same current flows through both resistors

\[
\begin{align*}
V_{in} &= I(R_1 + R_2) \\
V_{out} &= IR_2 \\
\frac{V_{out}}{V_{in}} &= \frac{IR_2}{I(R_1 + R_2)} = \frac{R_2}{R_1 + R_2} \\
V_{out} &= \left( \frac{R_2}{R_1 + R_2} \right) V_{in}
\end{align*}
\]

If \( R_1 = R_2 \), then \( V_{out} \) will be half of \( V_{in} \).

We’ll use this as a reference for the next stage.
Light sensor

- We’ll use a phototransistor
- When light shines on it, current flows
- This will be the other input to the next stage
Next stage: uses an op amp
Operational Amplifier

- Very popular integrated circuit
  - No current can flow into inputs
  - With no feedback, difference between inputs is hugely amplified at output
  - With feedback, op amp forces inputs to be at same voltage
What’s it for?

- Just about everything!
- Depends on how you hook it up
- We’ll use two of them, in two different ways
- First way: transimpedance amplifier
  - Convert current to voltage
  - So does a resistor, hence “transimpedance”
This one has feedback

- There is a connection between the output and the input
- Therefore forces inputs to same voltage
How it works

- Both inputs at same voltage
  - 4.5 volts from rail splitter
- No current can flow into input
- Thus photocurrent must flow through feedback resistor
Current creates voltage across $V_r$

- Voltage at both inputs = $V_{ref}$
- Voltage at output = ??
Kirchhoff Voltage Law

- Sum of voltages around a loop equals zero
- Pick a direction (clockwise)
- If you find a + sign first, voltage is positive
Apply KVL

\[-V_{\text{ref}} - V_{\text{in}} + V_r + V_{\text{out}} = 0\]

But \(V_{\text{in}} = 0\), so

\[V_{\text{out}} = V_{\text{ref}} - V_r\]
But $V=IR$

$$V_{out} = V_{ref} - IR$$

Therefore, as light increases, the current increases, and the output voltage decreases.

*Use this as input to the next stage*
Use another op amp

This time it’s a comparator
This one does NOT have feedback

- No connection from output back to input
- This will amplify any difference in voltage between the inputs
  - One input comes from previous stage
  - It decreases as ambient light increases
  - Other input is a reference that we will adjust
Gain is about a zillion

- Suppose $V_{in}$ is greater than $V_{ref}$ (this would be when the room is dark)
- Comparator multiplies difference by a zillion, wants to go to a zillions volts
- But, battery is only 9 V, so that’s as high as it can go
- Similarly, can’t go lower than 0V
Operation:

- If input higher than ref, output goes to 9V
- If input lower than ref, output goes to 0 V
- Nothing in between
Adjusting the reference

- Use a variable resistor (potentiometer)
- As you turn the knob, the voltage changes
  » Remind you of the voltage divider rail splitter? Except now we adjust the voltage
Now, when light goes dim…

- We want the lights to come on!
- When light goes dim, photocurrent increases, input to comparator goes down
- When it goes below the reference (which we set), output goes to 0V
- Turn on an LED
LED: light-emitting diode

- Diode conducts current in only one direction
- When current flows, it lights up
OK, we’re ready to build!

- This is the breadboard
- Stick wires into the holes
- Green lines: busses
  » All holes connected together
- Blue lines: nodes
  » Five holes connected together
First make power connections

- Connect red lead (positive) from battery to one buss
- Connect black lead (negative) to another buss
- Useful to connect additional busses on other side
Check against schematic
Next, rail splitter

- Disconnect battery!
- Two resistors
  - 100K Ω: brown, black, yellow
  - Add a wire to connect to next stage
About the op amp

- Two op amps in one package
- Notice divot: tells you which end is up
- Diagram shows how pins are numbered

Internal Block Diagram

Vcc: code for “positive”

Divot or dot

GND: negative
Connect op amp power and ground

- Pin 8 to positive buss
- Pin 4 to negative buss
Light sensor and Transimpedance amp

- Sensor and first op amp
- Light sensor: long lead corresponds to arrow on sensor symbol
- Will connect to pin 2
- Other end connects to positive buss
And rest of first stage

- Output of rail splitter connects to pin 3
- Feedback resistor: $10 \, \text{K}\Omega = \text{brown, black, orange}$
  » Connects between pin 2 and pin 1
The potentiometer

- Pin 1: positive
- Pin 2: connect to pin 5 of op amp
- Pin 3: negative
Rest of stage 2

- Output of stage 1 (pin 1) connects to "-" input of stage 2 (pin 6)
LED circuit

- LED = light-emitting diode
- Diodes conduct current in one direction only
- When current flows, it lights up
- Long lead is the “anode” (positive)
LED Circuit, continued

- Resistor = 330Ω (orange, orange, brown)
- Long lead to positive buss
- Flat side to resistor
Now connect battery and try it

- Adjust pot until light just turns on or off
  - Then go to just barely off
- It’s a 25-turn pot
- Then cover sensor, see if light comes on
- Adjust
Troubleshooting

- LED never comes on?
  » Check polarity of LED
- LED never goes off?
  » Check polarity of light sensor
- Battery gets hot?
  » DISCONNECT IMMEDIATELY! Check wiring
- Chip gets hot?
  » DISCONNECT BATTERY IMMEDIATELY