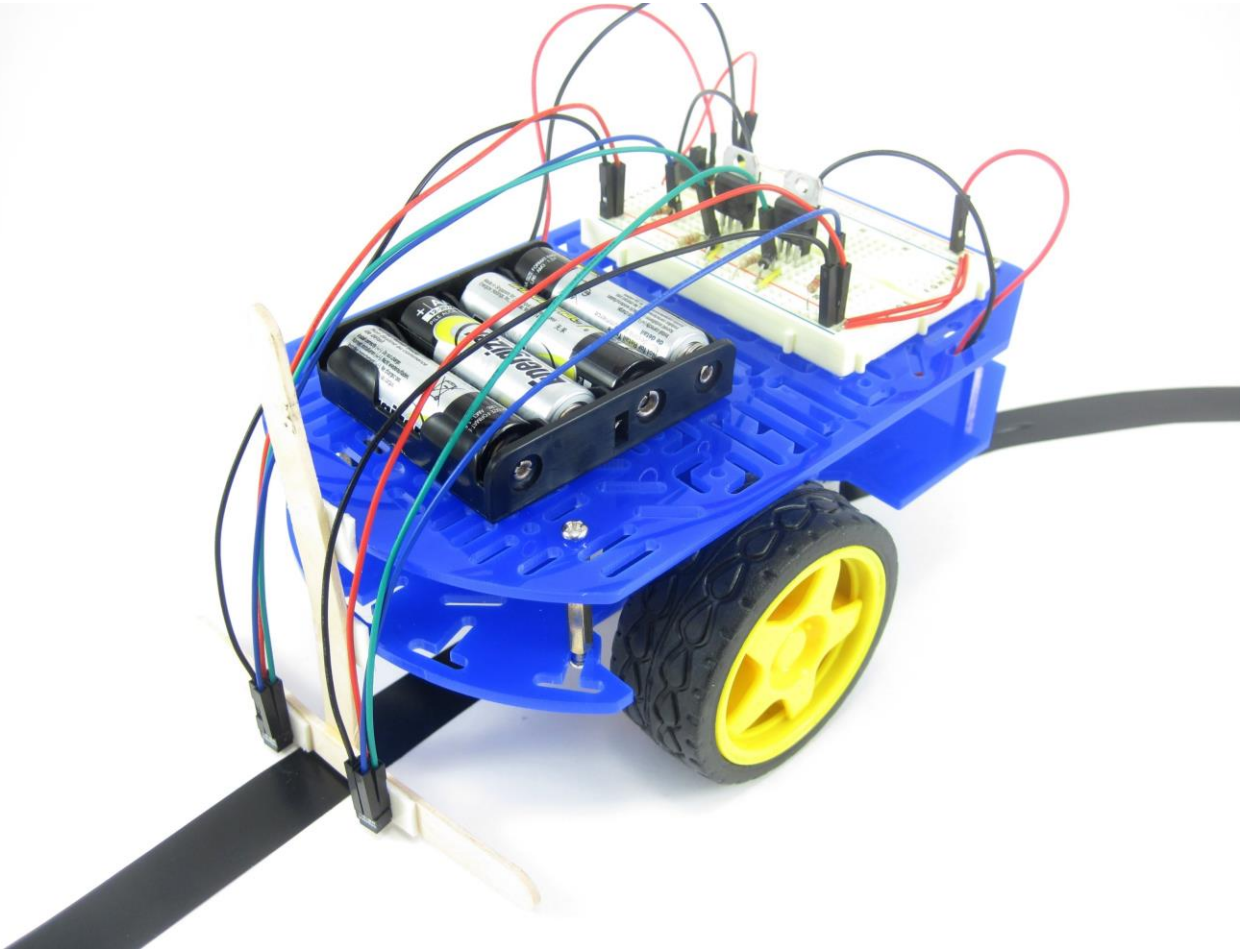
# Line Following Robot



www.sciencebuddies.org

SCIENCE BUDDIES

# How does the robot work?

- Introduction video: https://youtu.be/-cilOho6l3Q
- Infrared (IR) light sensors detect the line
- Infrared light is part of the electromagnetic spectrum
- Humans cannot see infrared light!
- Infrared light is **absorbed** by some surfaces and **reflected** by others

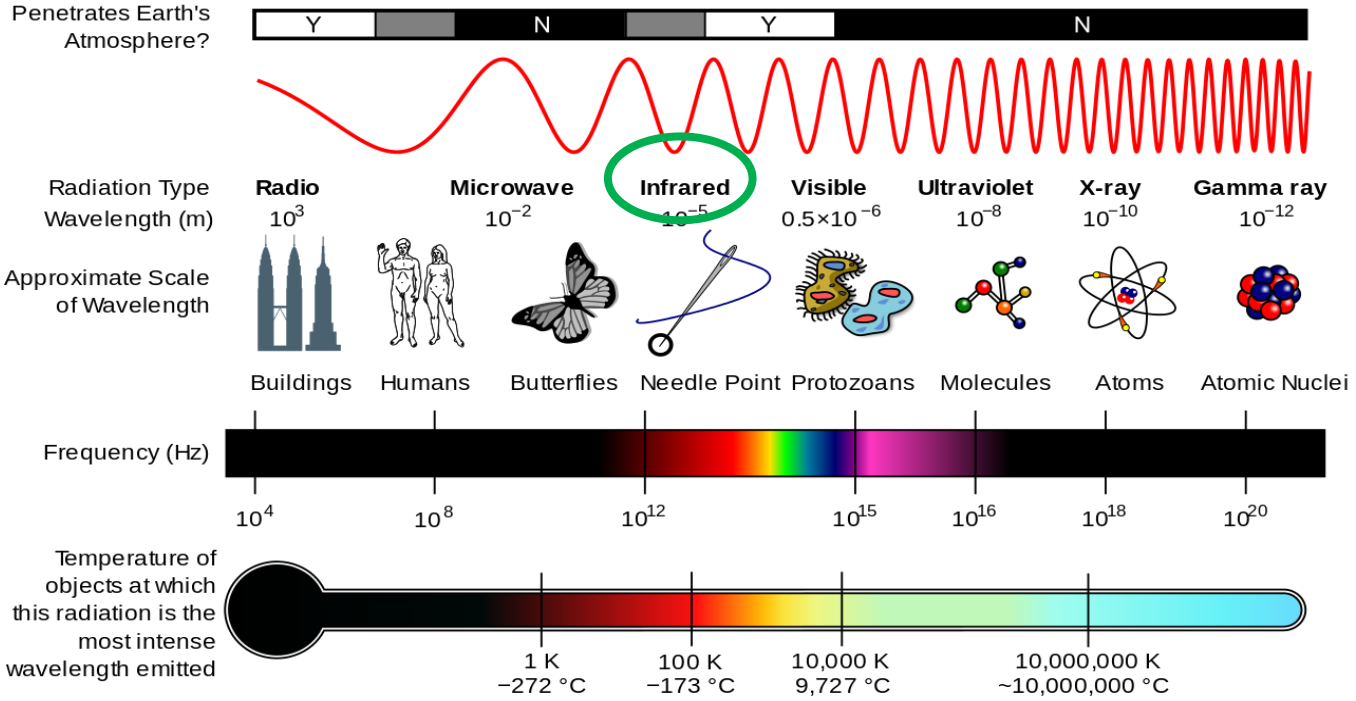
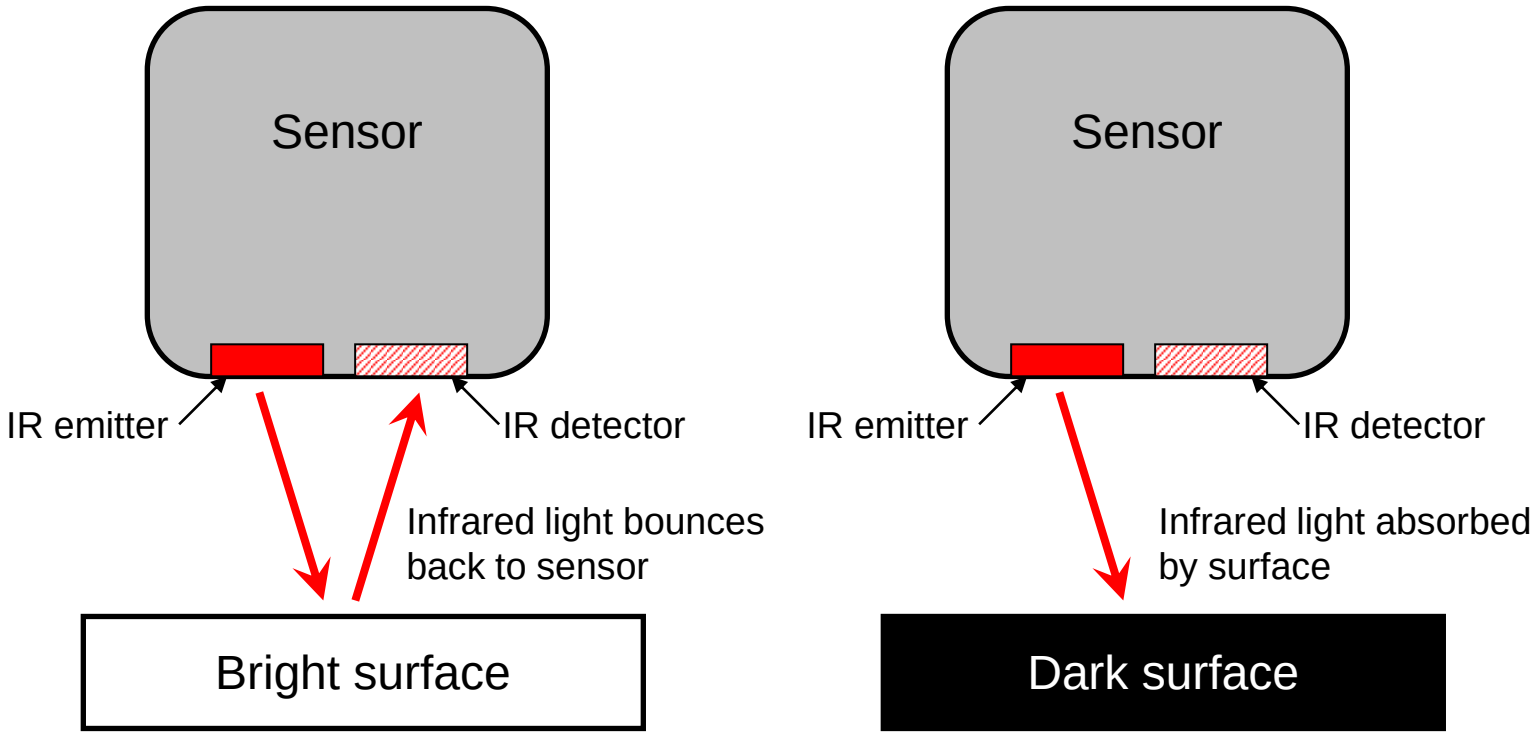



Image credit: Wikimedia Commons user Dizzyzane, https://commons.wikimedia.org/wiki/File:EM_Spectrum_Properties_edit.svg

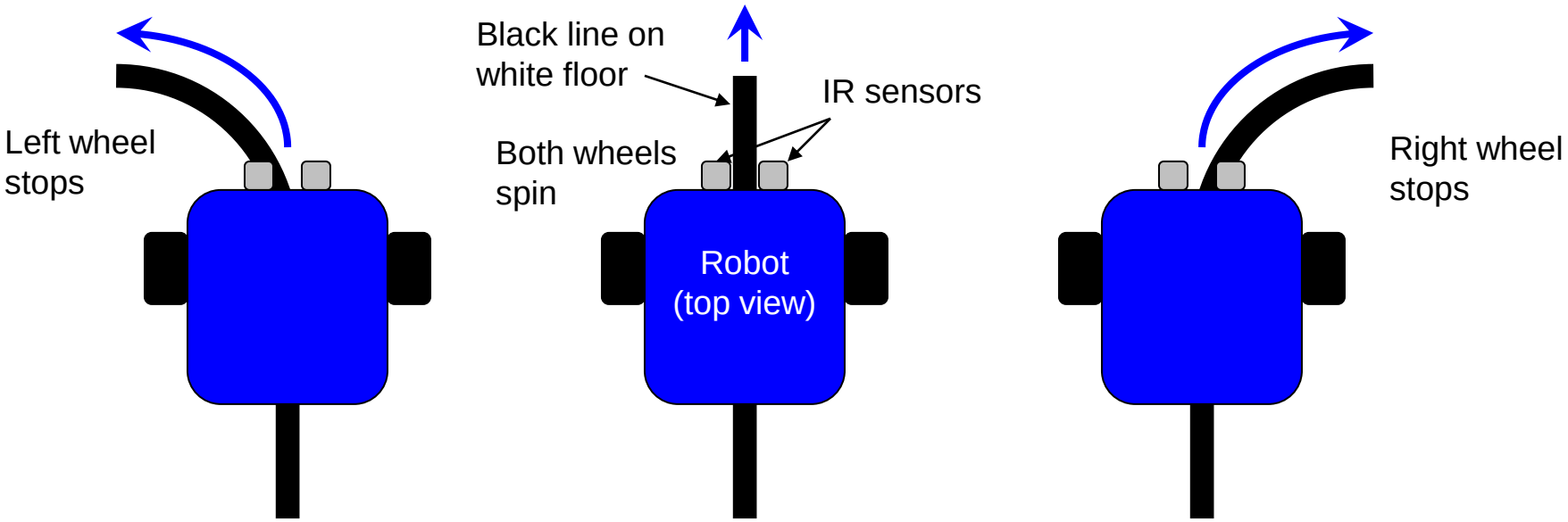
# How do the sensors work?

- Each sensor consists of an infrared emitter, which sends out IR light, and an infrared detector, which measures if IR light is reflected back
- Measurement range is very short (a few millimeters)



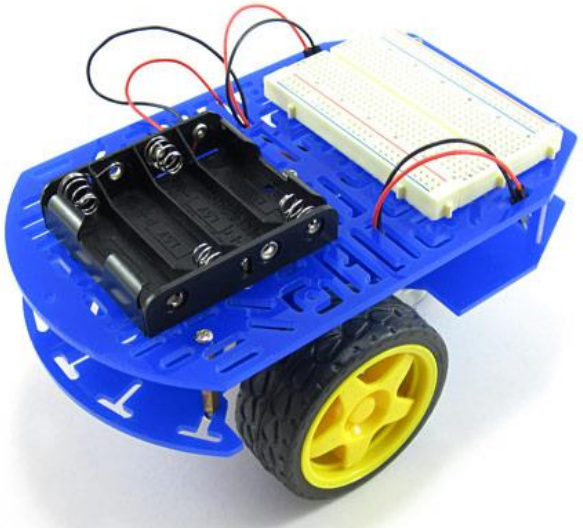
# How does the robot steer?

- The robot has two wheels, each controlled by a separate motor. This is called **differential steering**.
- When both wheels spin, the robot drives straight
- When only one wheel spins, the robot turns
- When a sensor “sees” black (no IR light is reflected back to the sensor), it stops the wheel on that side
- *How could you use this robot to determine which materials reflect infrared light and which absorb it?*



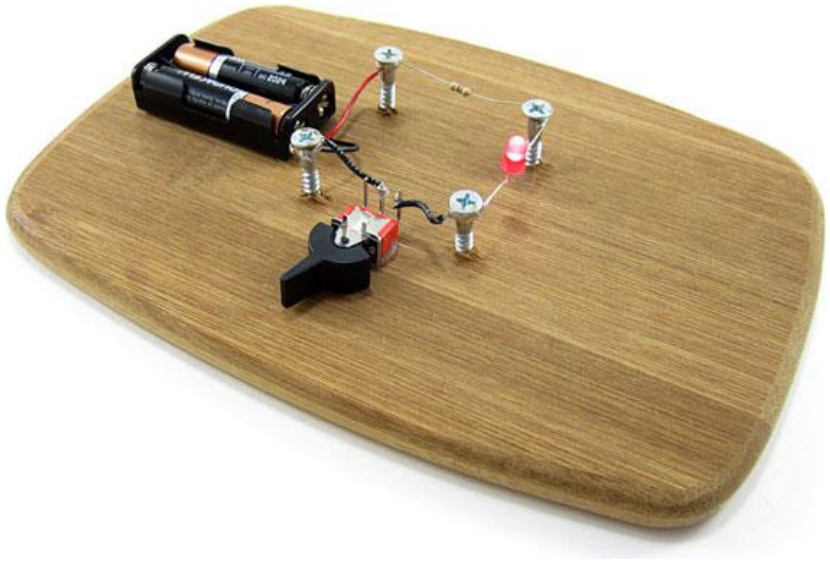
# Building the robot

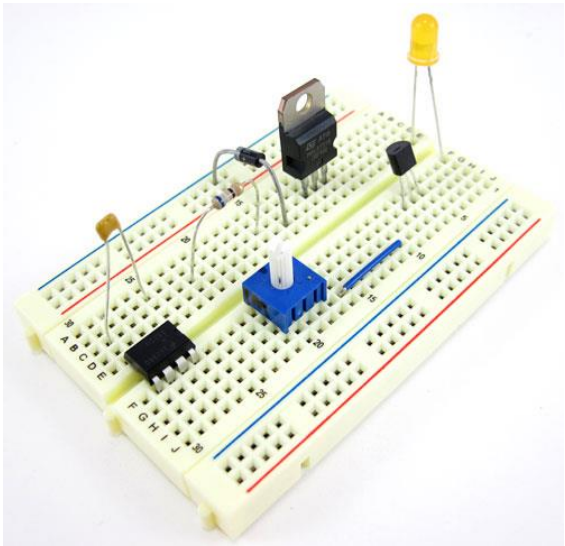
- The chassis (pronounced “chass-ee”) is the robot’s body
- You need a small Phillips head screwdriver to put it together
- The printed instructions can be hard to follow. Watch this video instead: https://youtu.be/SBeGl_IgWwY
- Tape the battery pack to the top plate so the batteries are easier to access, do not screw it to the bottom plate like in the printed instructions



# Using a breadboard

- To build the circuit you need to learn how to use a **breadboard**
- A breadboard lets you easily build electronic circuits
- It's called a breadboard because people used to use wooden breadboards with screws or nails in them to make electrical connections
- Modern breadboards are made from plastic





# Using a breadboard

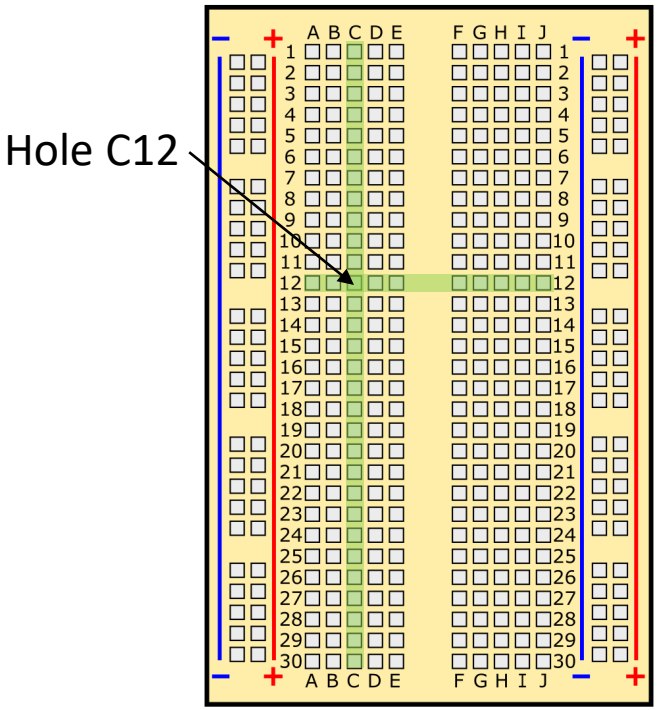
- A breadboard has metal clips inside it that pinch the pins of electronic parts in place
- If you peel the backing off a breadboard, you can see rows of these metal clips

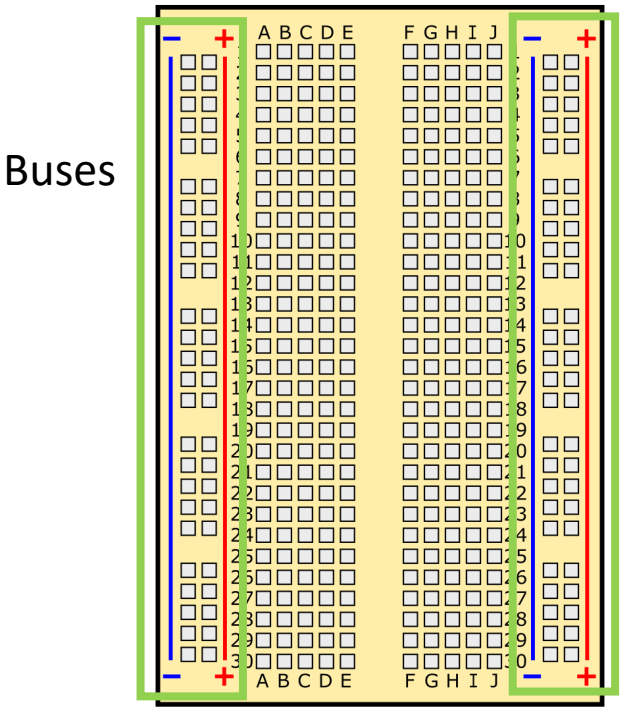




# Using a breadboard

- Holes are labeled with a grid system – numbers for rows, letters for columns
- The long vertical strips on the sides are called **buses**. Red for positive (+) bus, blue for negative (-) bus

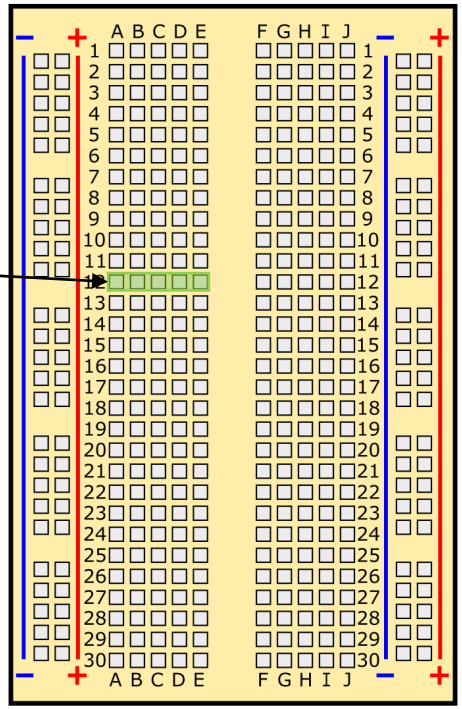


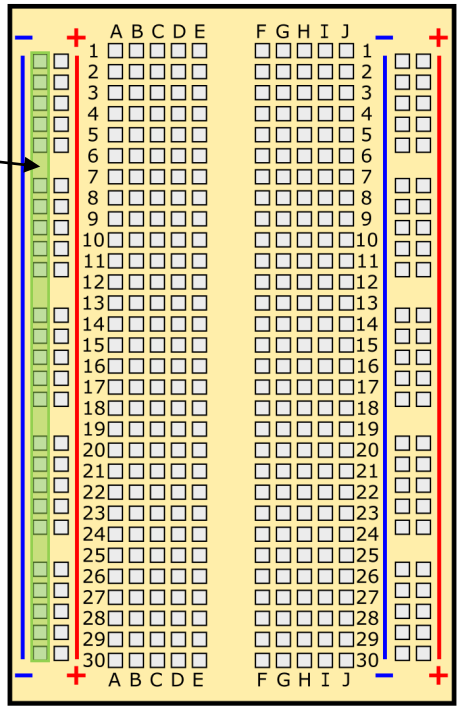
# Using a breadboard

- The holes in each **half row** are electrically connected by the metal pins inside
- The holes in each **individual bus** are electrically connected
- Very important not to put things in the wrong row or the wrong bus!

These 5 holes are connected

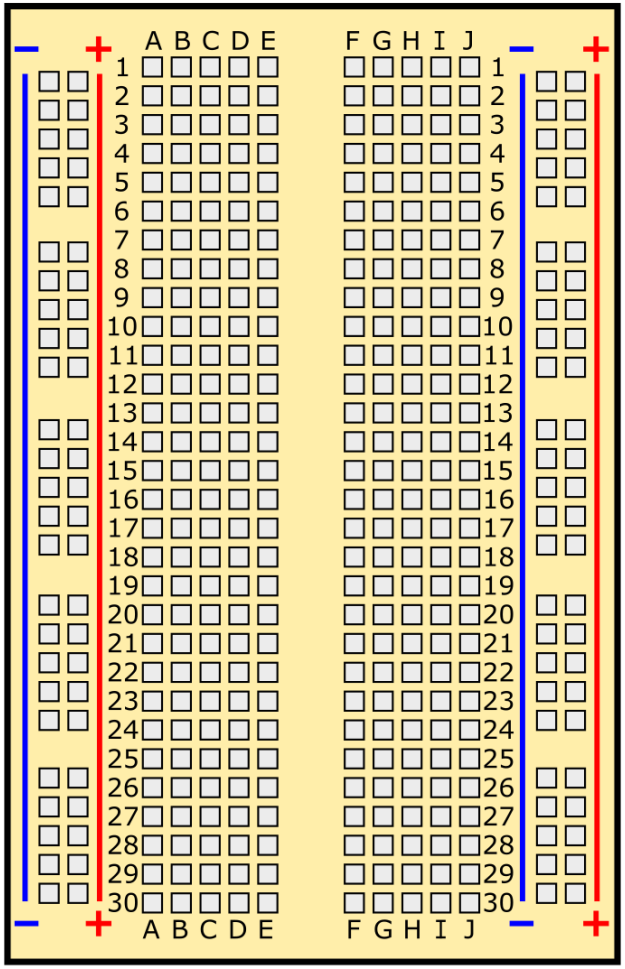



All holes in this bus are connected



# Building the circuit

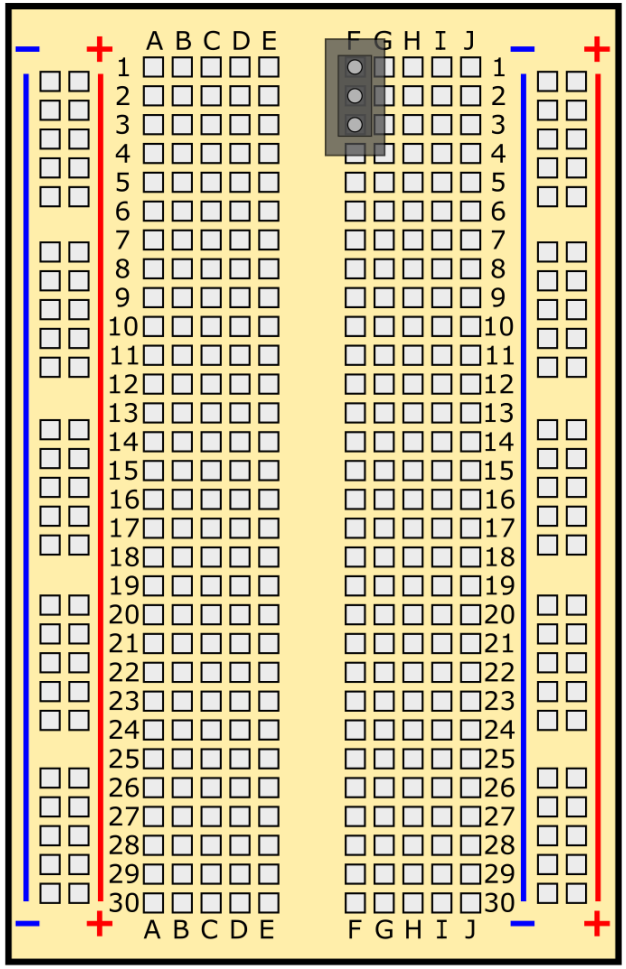
- Follow these step-by-step diagrams
- Always **carefully** check to make sure you put things in the right breadboard holes!
- Just one misplaced part can stop the whole circuit from working
- Push parts into the breadboard gently but firmly. Be careful not to bend or break their pins.



# Power switch



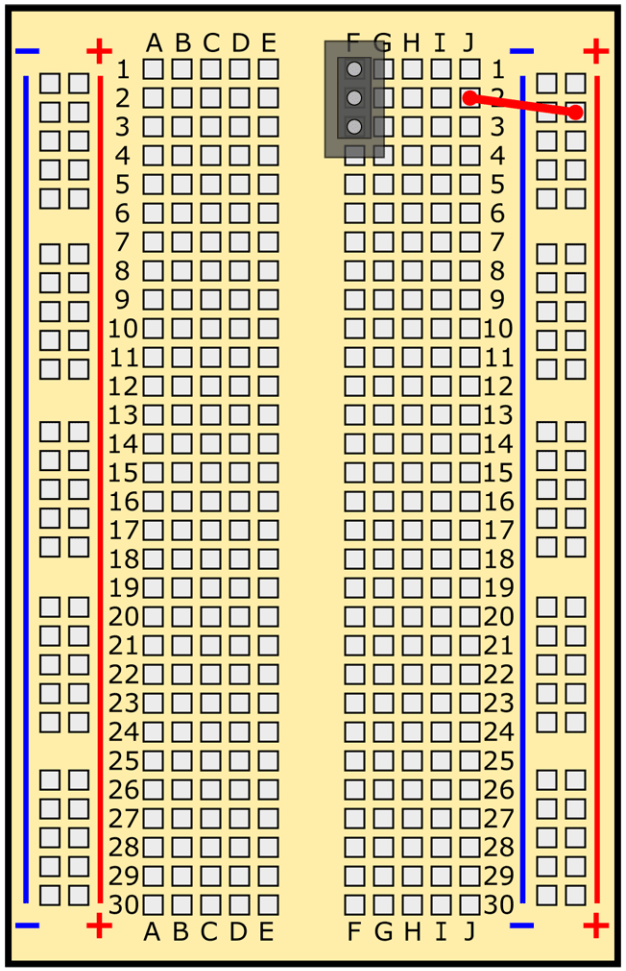
- Holes F1, F2, F3
- Used to turn the whole circuit on and off
- Slide the switch down (towards row 3), this is the “off” position



# Jumper wire #1



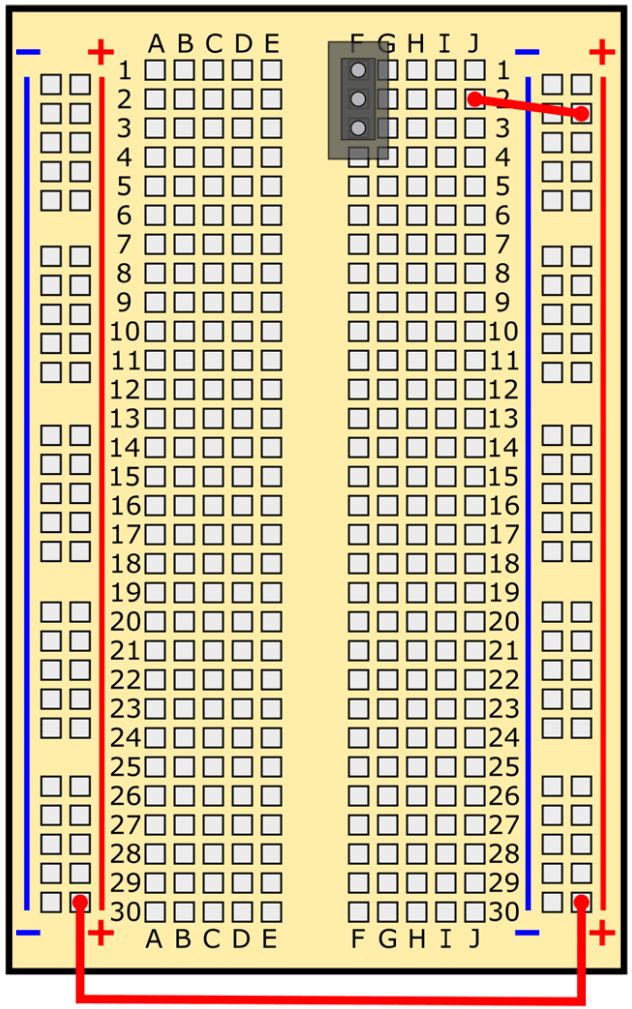
- Hole J2 to (+) bus
- Used to make electrical connections between two different points on breadboard
- Color does not matter, pick a wire with an appropriate length



# Jumper wire #2

- Left side (+) bus to right side (+) bus
- Color does not matter, pick a wire with an appropriate length

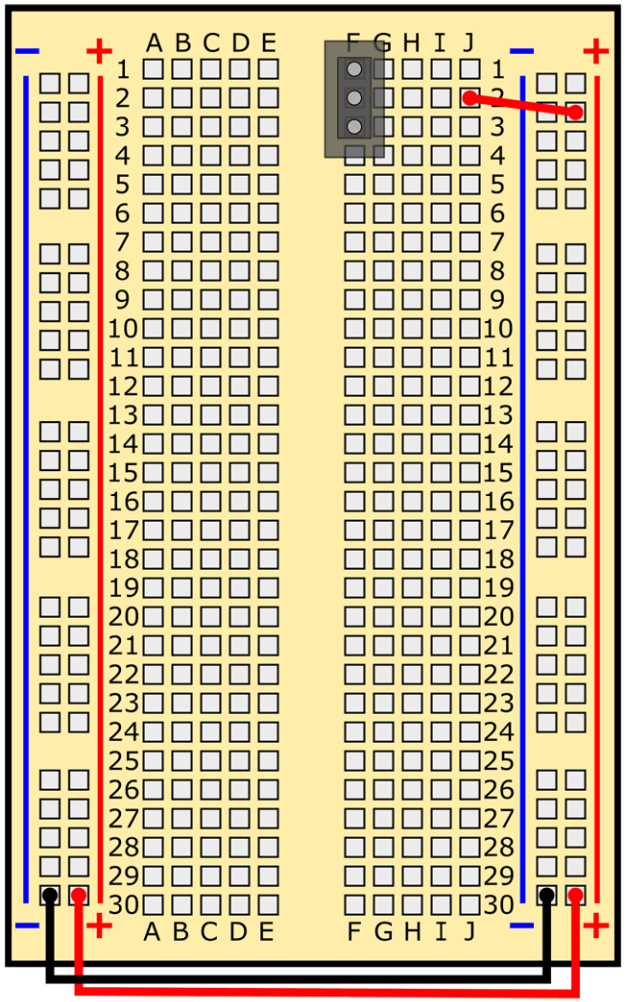




# Jumper wire #3

- Left side (-) bus to right side (-) bus
- Color does not matter, pick a wire with an appropriate length

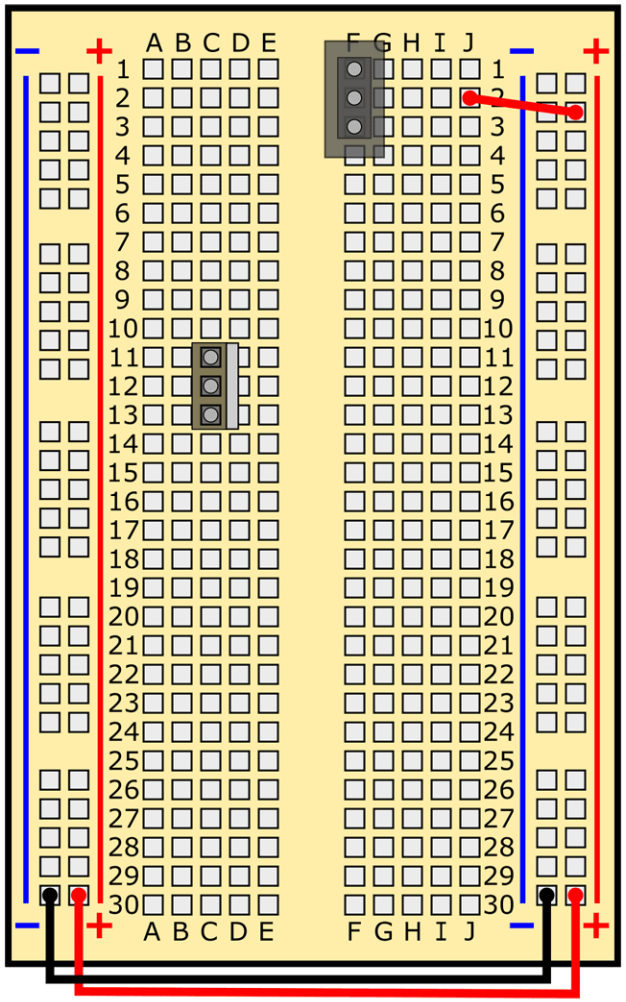




# Transistor #1



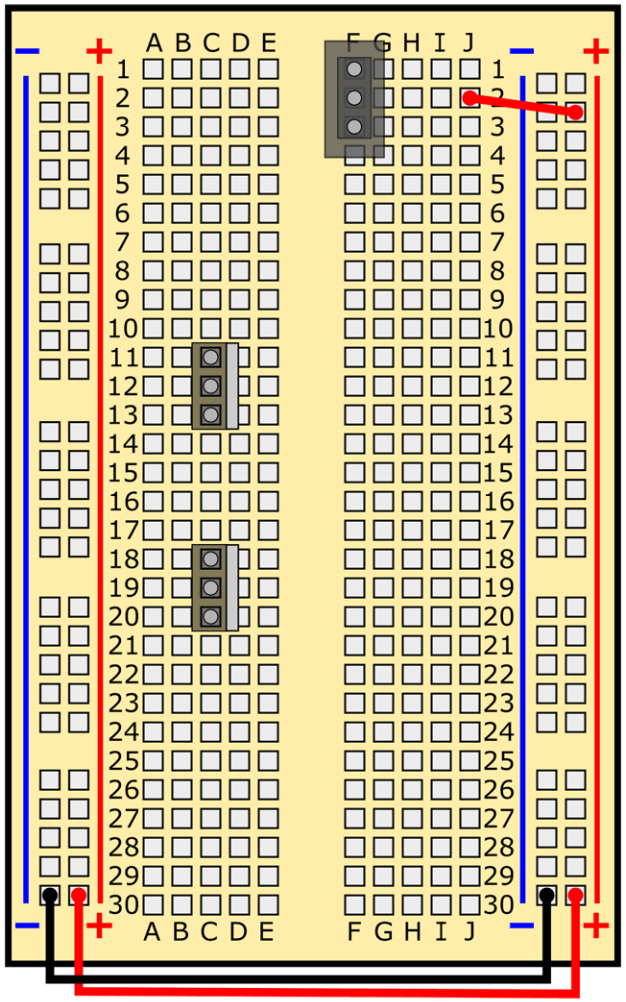
- Holes C11, C12, C13
- Like a valve that controls flow of electricity to the motor
- **Important:** writing on front must face to the left



# Transistor #2



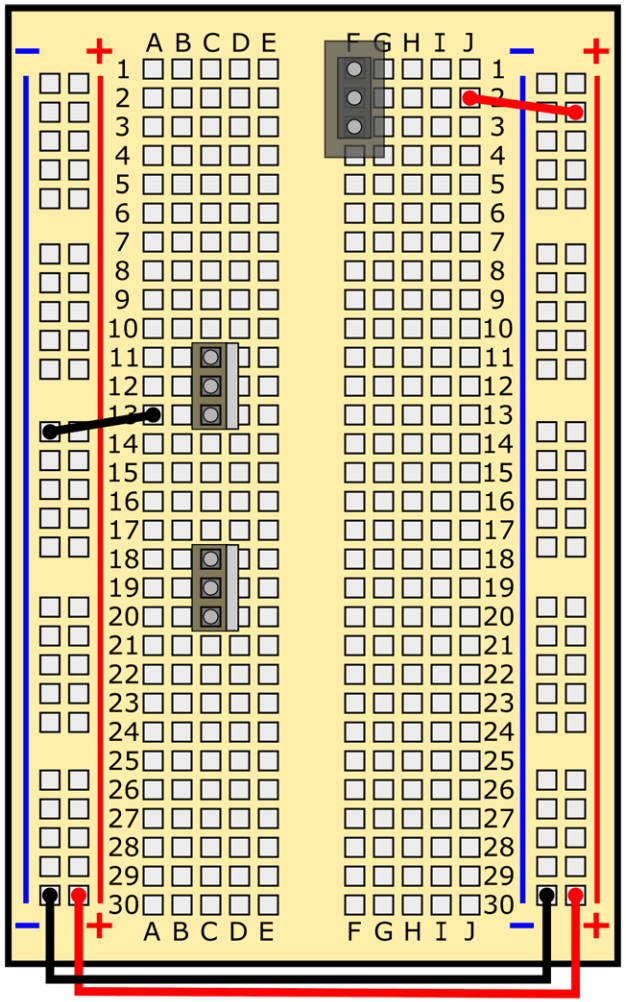
- Holes C18, C19, C20
- Like a valve that controls flow of electricity to the motor
- **Important:** writing on front must face to the left



# Jumper wire #4

- Hole A13 to (-) bus
- Color does not matter, pick a wire with an appropriate length

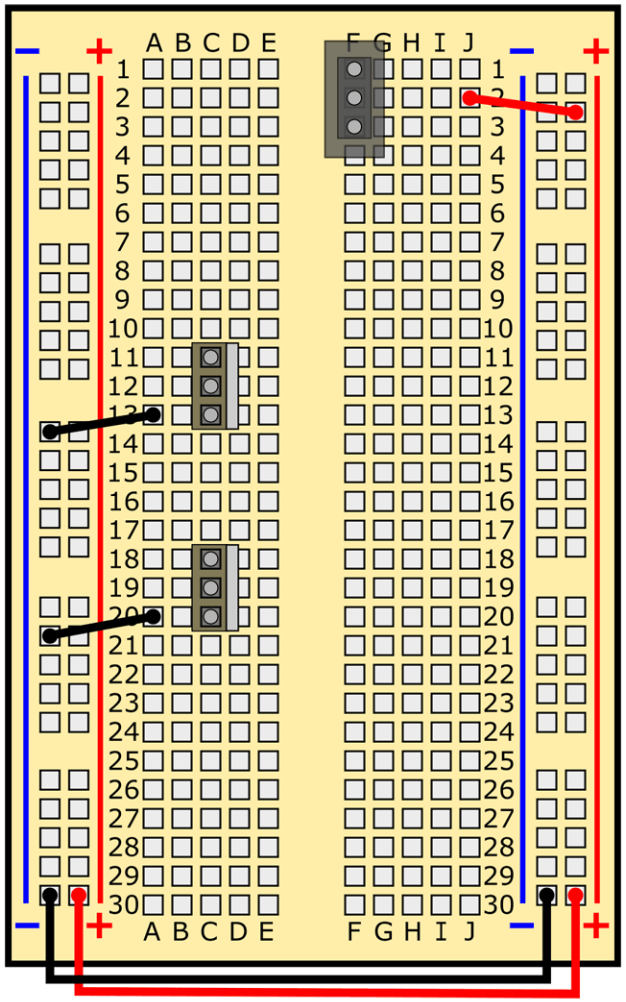




# Jumper wire #5

- Hole A20 to (-) bus
- Color does not matter, pick a wire with an appropriate length (yellow should work well)

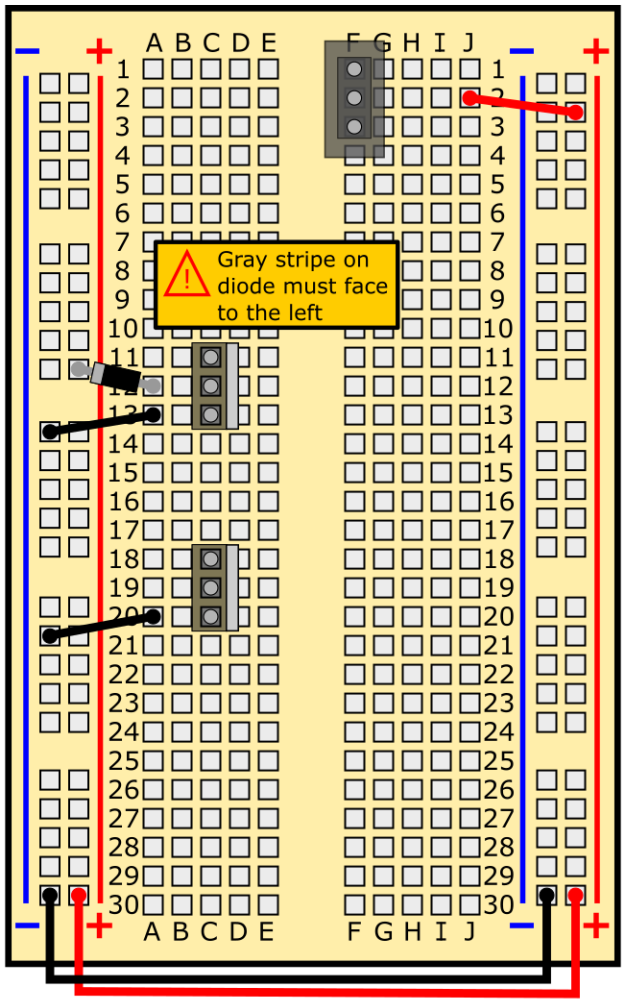




# Diode #1

- Hole A12 to (+) bus
- Protects the transistor from electrical damage when the motor stops suddenly
- **Important:** gray stripe must face to the left

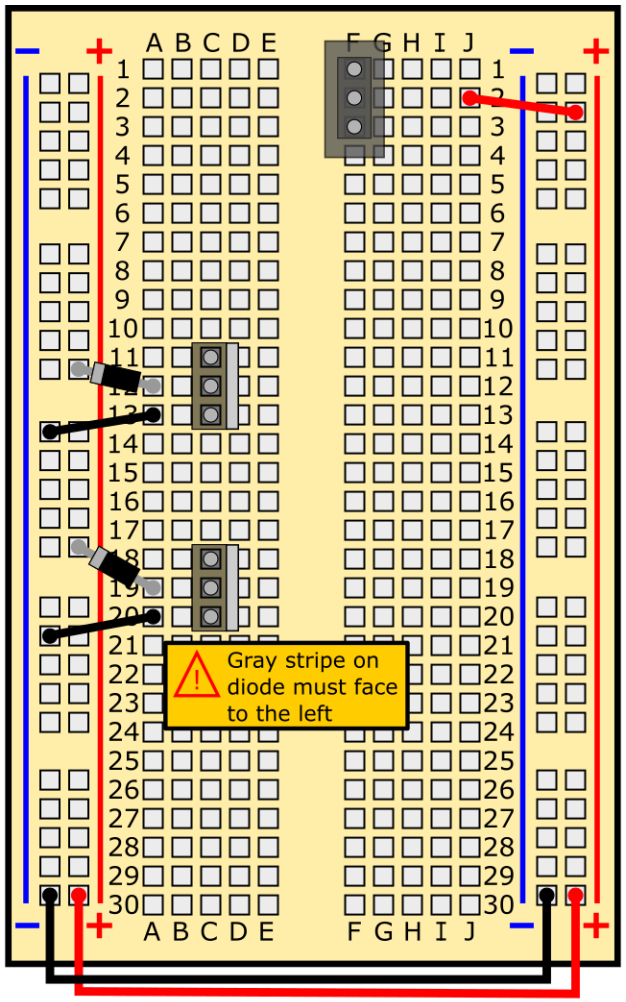




# Diode #2

- Hole A19 to (+) bus
- Protects the transistor from electrical damage when the motor stops suddenly
- **Important:** gray stripe must face to the left

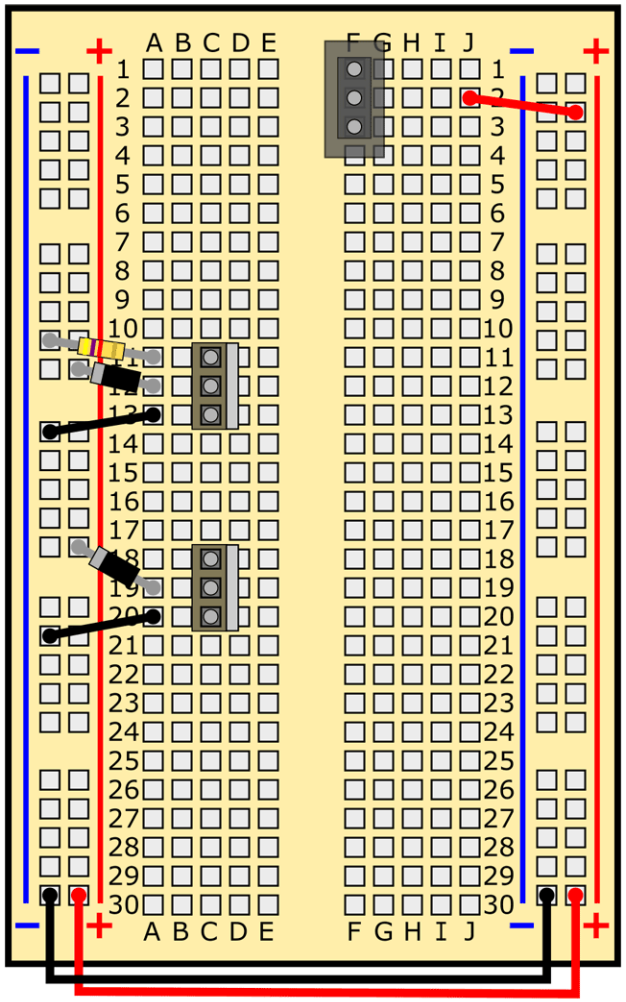




# 4.7kΩ resistor #1



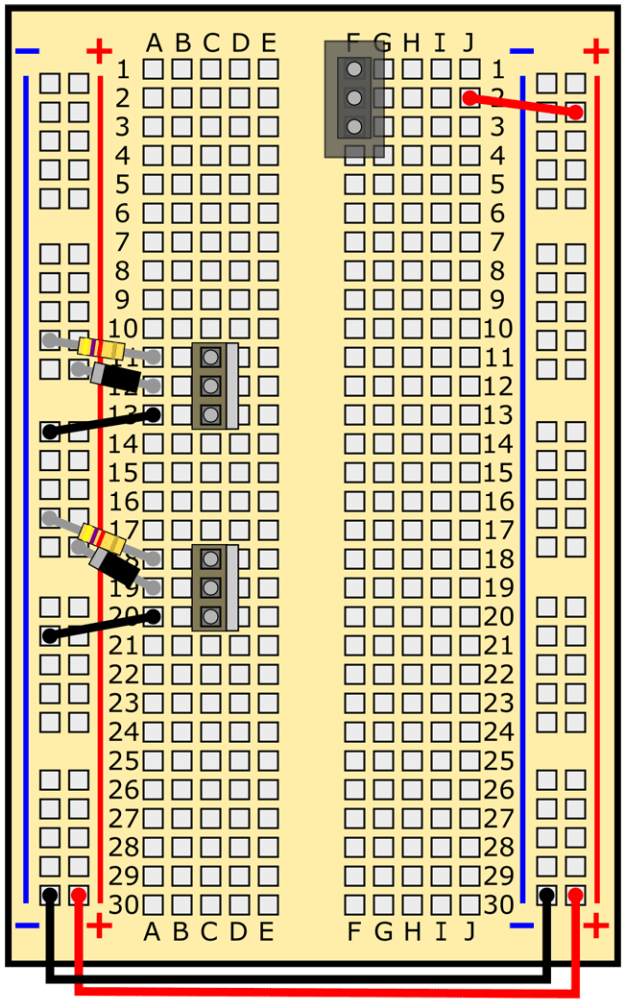
- Hole A11 to (-) bus
- Makes sure the transistor is off by default so the motors don't spin unnecessarily
- **Important:** pay attention to the colored stripes! Yellow, purple, red, gold
- Resistors have different values (Ω, the Greek letter Omega, stands for **ohms**, the unit of measurement for resistance)
- Your kit comes with several different resistor values – make sure you get the right one!



# 4.7kΩ resistor #2



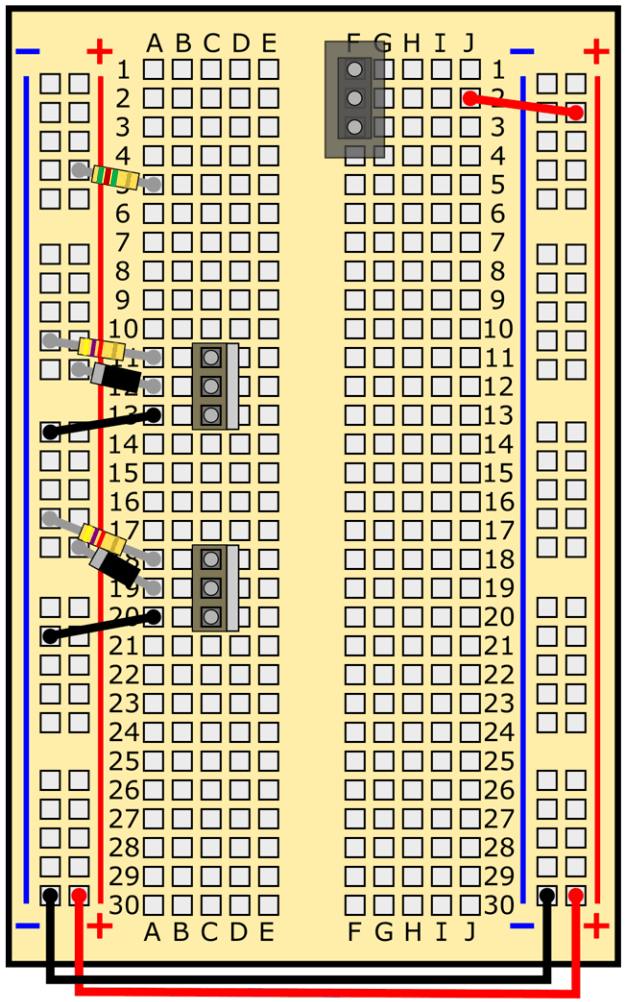
- Hole A18 to (-) bus
- Makes sure the transistor is off by default so the motors don't spin unnecessarily
- **Important:** pay attention to the colored stripes! Yellow, purple, red, gold
- Resistors have different values (Ω, the Greek letter Omega, stands for **ohms**, the unit of measurement for resistance)
- Your kit comes with several different resistor values – make sure you get the right one!



# 150Ω resistor #1



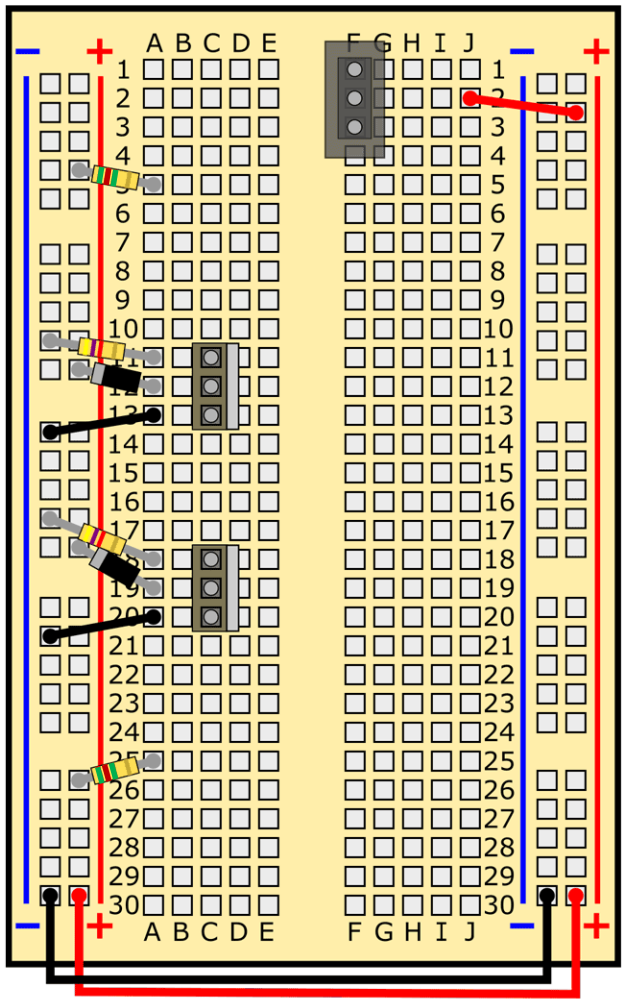
- Hole A5 to (+) bus
- Limits the flow of electrical current to the IR sensor to prevent it from burning out
- **Important:** pay attention to the colored stripes! Brown, green, brown, gold
- Resistors have different values (Ω, the Greek letter Omega, stands for **ohms**, the unit of measurement for resistance)
- Your kit comes with several different resistor values – make sure you get the right one!



# 150Ω resistor #2



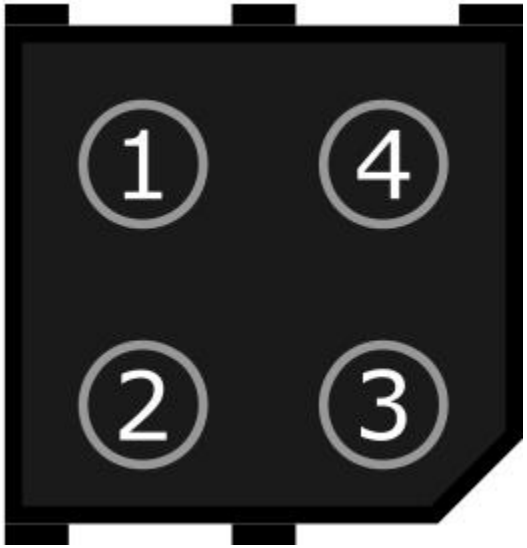
- Hole A25 to (+) bus
- Limits the flow of electrical current to the IR sensor to prevent it from burning out
- **Important:** pay attention to the colored stripes! Brown, green, brown, gold
- Resistors have different values (Ω, the Greek letter Omega, stands for **ohms**, the unit of measurement for resistance)
- Your kit comes with several different resistor values – make sure you get the right one!



# IR sensors

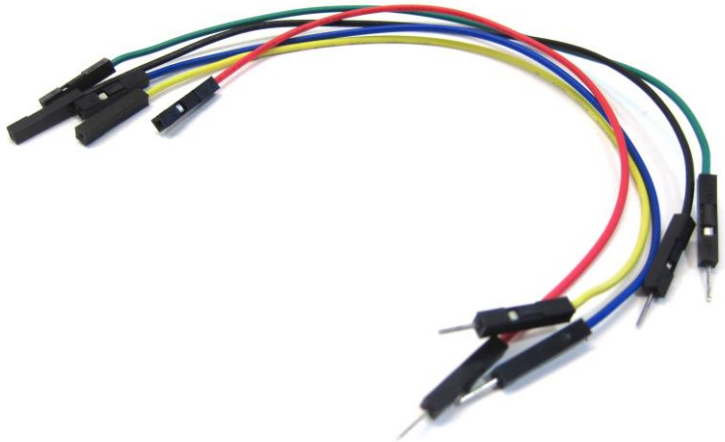
- Turn the sensor so the pins are facing you
- Look closely – there is a small diagonal notch in one corner
- Rotate the sensor so the notch is in the lower right right
- The pins are numbered counter-clockwise starting from the top left

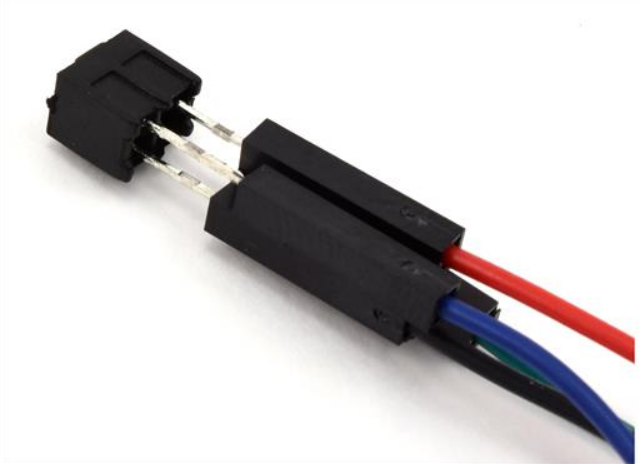


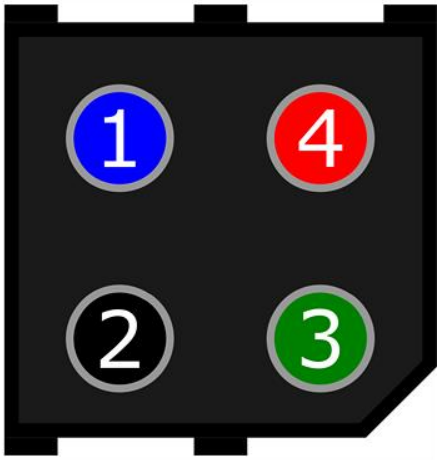


# IR sensors

- Use male-female (M-F) jumper wires to connect the sensors to the breadboard
- Color-coding will help you keep track of the pins
- Pin 1: blue
- Pin 2: black
- Pin 3: green
- Pin 4: red



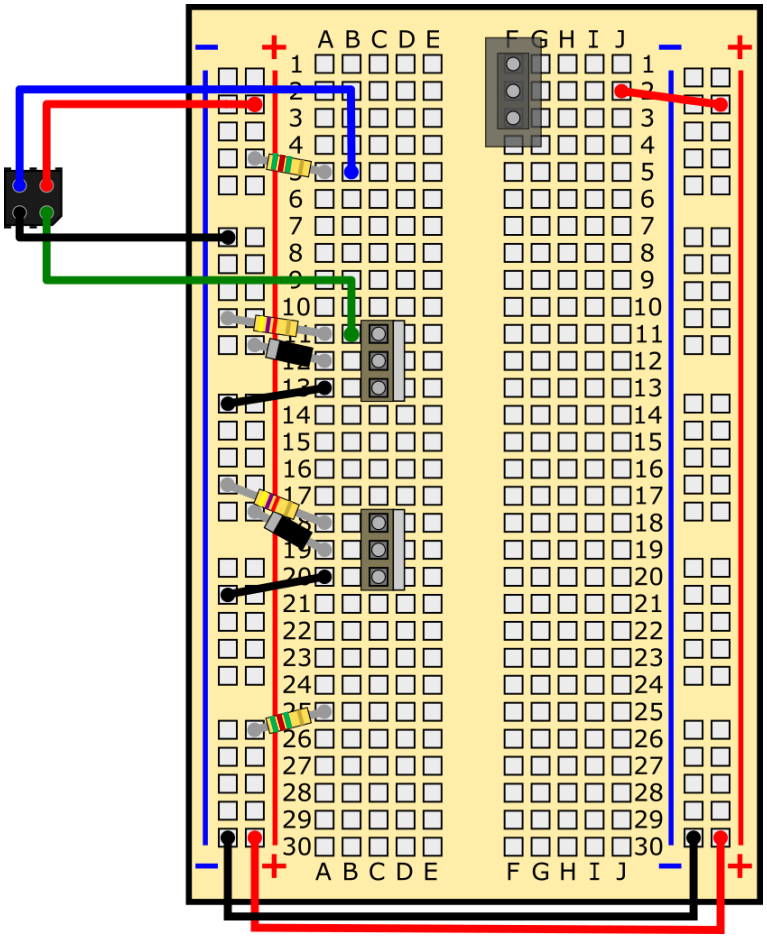




# IR sensor #1



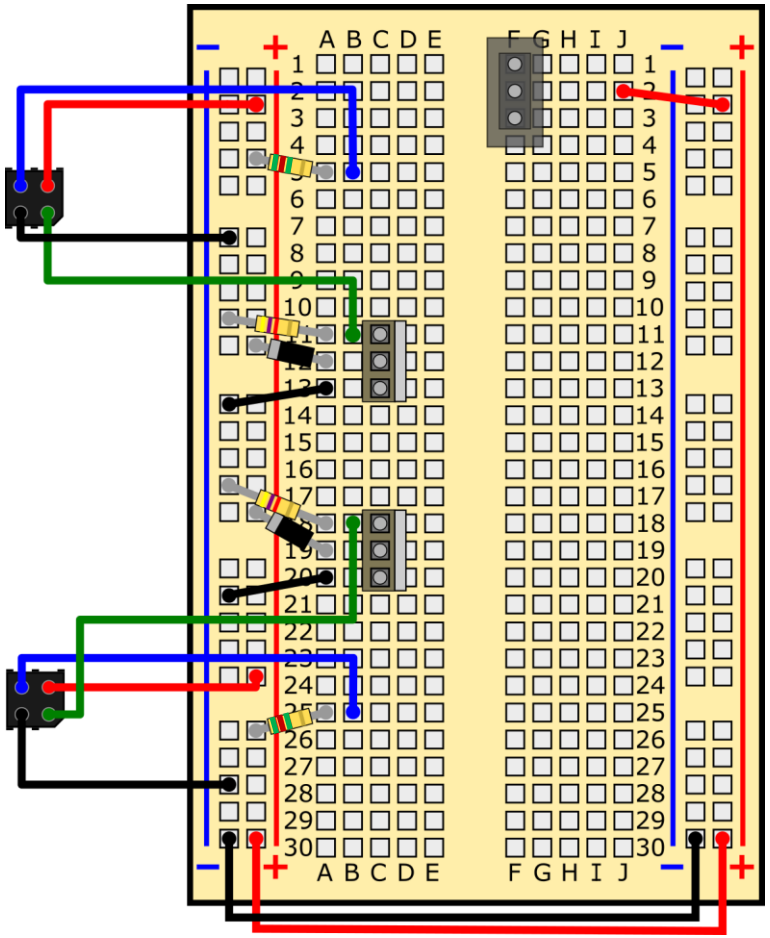
- Red wire to (+) bus
- Green wire to B11
- Blue wire to B5
- Black wire to (-) bus
- The sensor controls the transistor, which then controls the motor



# IR sensor #2



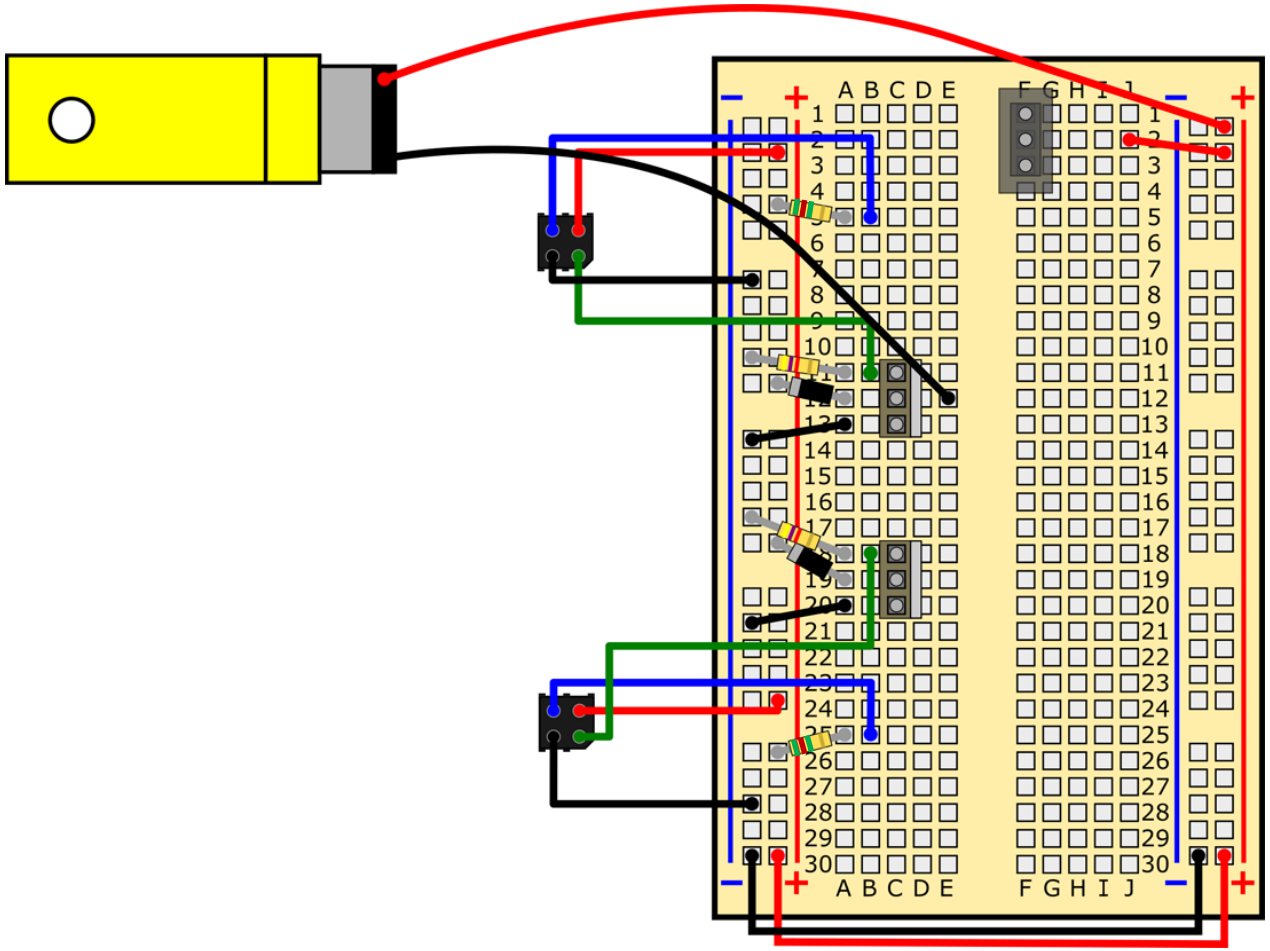
- Red wire to (+) bus
- Green wire to B18
- Blue wire to B25
- Black wire to (-) bus
- The sensor controls the transistor, which then controls the motor



# Motor #1



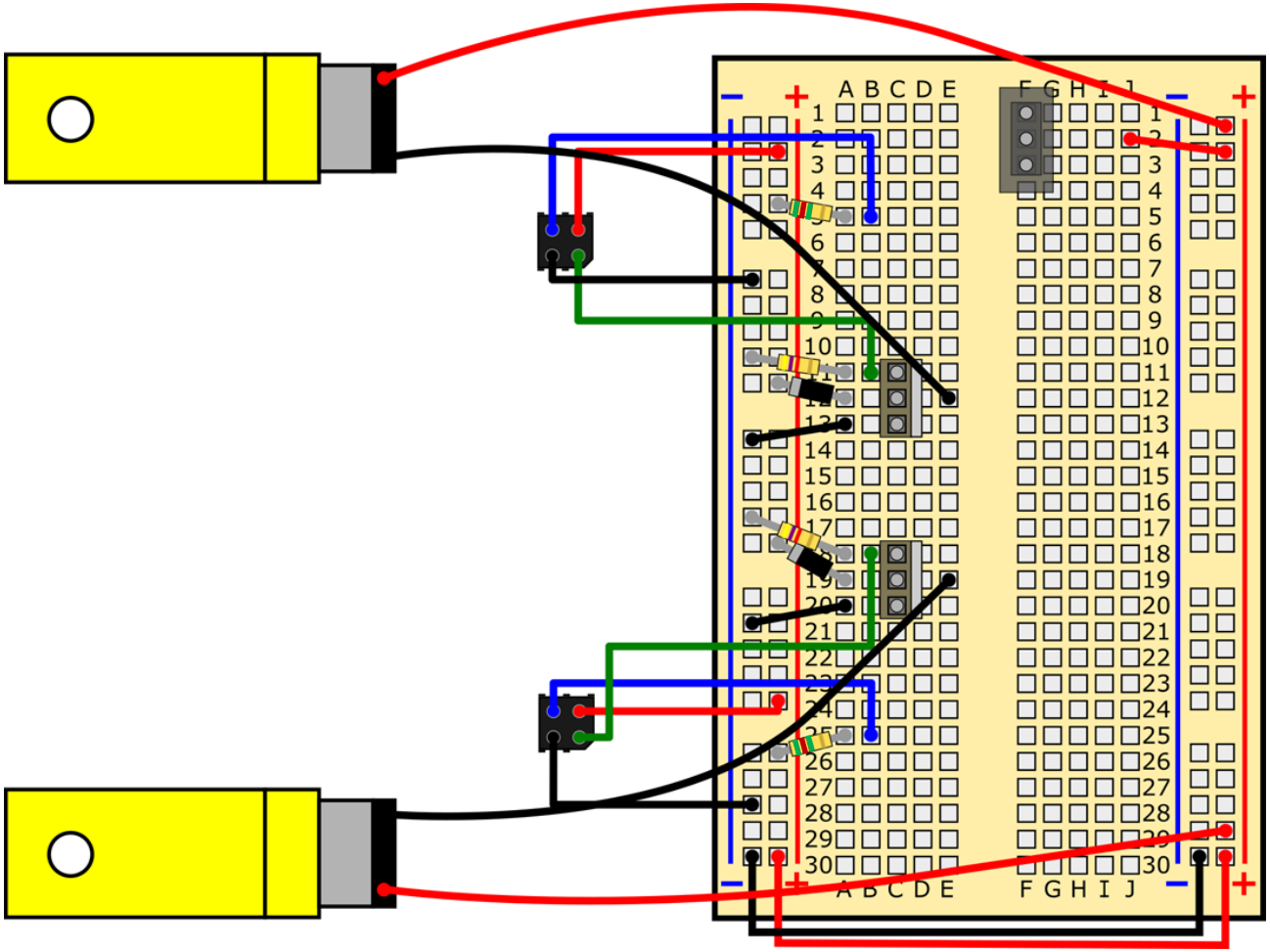
- Red wire to (+) bus
- Black wire to E12



# Motor #2



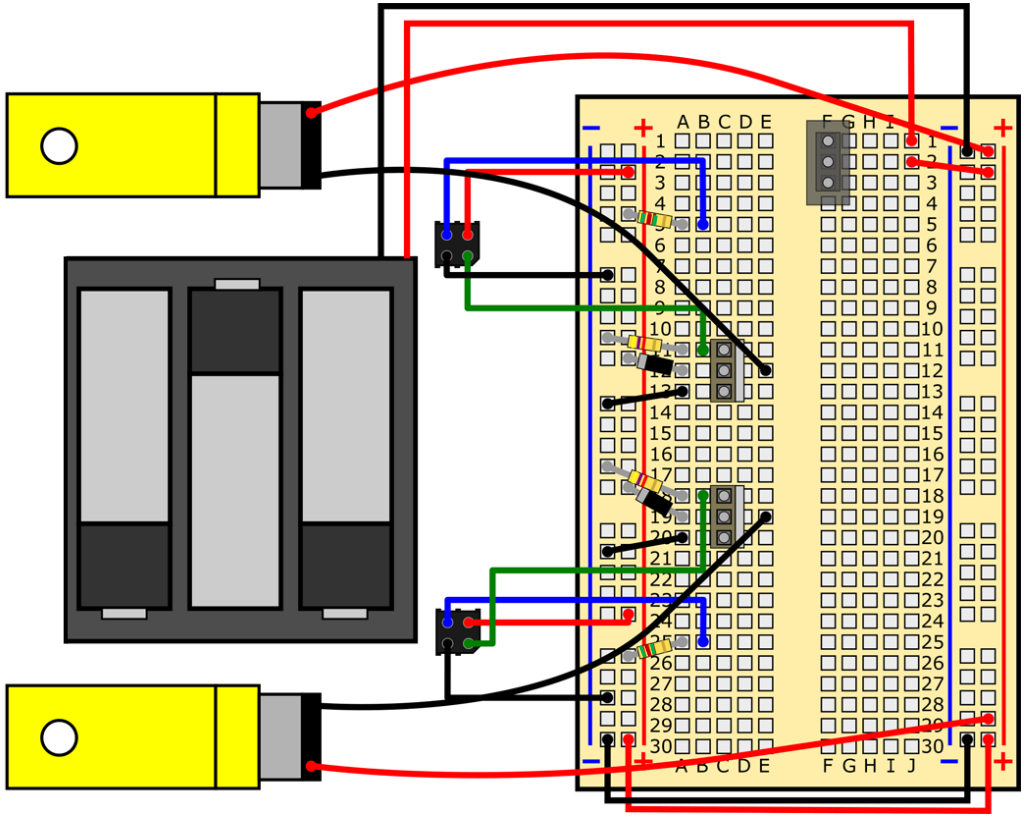
- Red wire to (+) bus
- Black wire to E19



# Battery pack

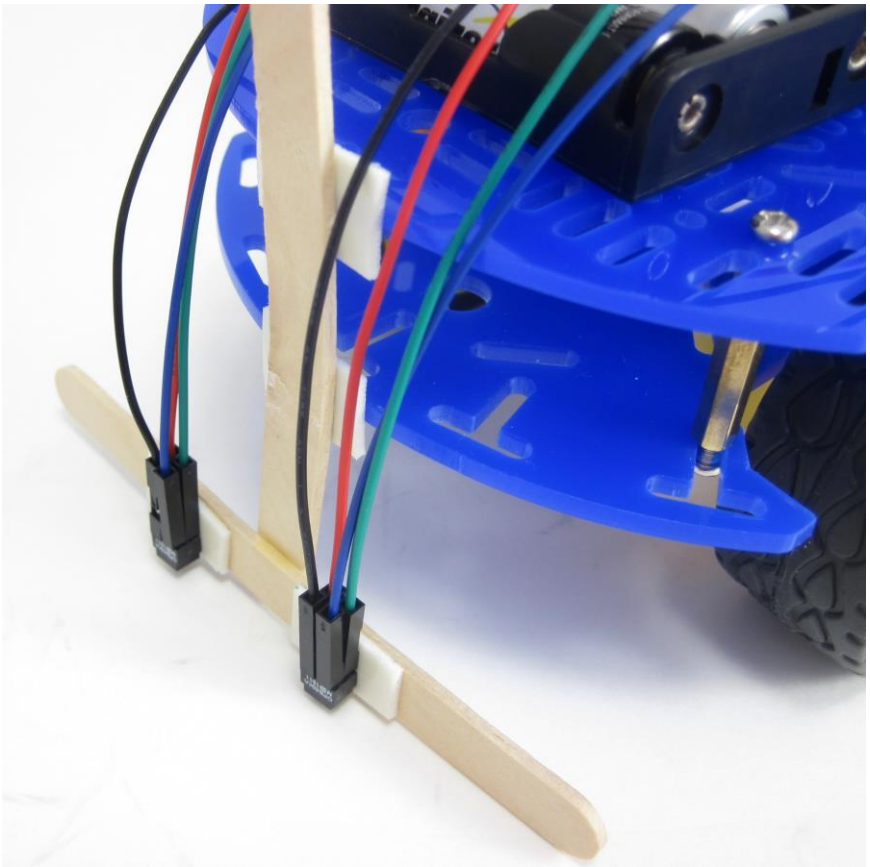



- Red wire to J1
- Black wire to (-) bus
- Insert 3 AA batteries
- Pay attention to + signs on batteries, they should line up with + signs in the battery pack
- **If you see or smell smoke, or your circuit feels hot, immediately disconnect the battery pack – you have a short circuit and something is connected wrong!**



# Mount the sensors

- Use tape and popsicle sticks (or building toys like LEGOs or K'nex) to mount the sensors to the front of the robot
- Do not permanently glue them in place, you will need to adjust them later
- Face of sensor should be a couple millimeters off the ground



# Test the robot

- Hold the robot so the wheels are off the ground
- Turn power switch on (slide it up towards row 1 of the breadboard)
- If you see or smell smoke, or the circuit feels hot, immediately turn the switch off – you have a short circuit and need to double-check your wiring
- Hold a piece of white paper up close to the IR sensors – the wheels should spin. *Why does this happen?*
- Try placing the robot down on a piece of white posterboard. It should drive forward (if not – don't worry, troubleshooting info is coming up!)

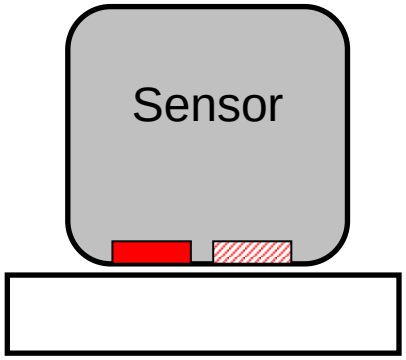
# Help! My robot doesn't work!

- Double-check all your wiring! Don't worry, it can be hard to get everything right on the first try if this is your first time using a breadboard.
  - Are your diodes backwards?
  - Are your transistors backwards?
  - Are all your parts in the right rows?
- Avoid short circuits – make sure parts with long skinny legs (like the resistors and diodes) do not bump into each other. Short circuits can also happen from putting a part in the wrong row or bus.
- If a wheel is spinning backwards, reverse the red and black wires for that motor. This depends on which way you mounted the motors to the chassis, nothing is wrong with your circuit.
- If the robot works when you hold paper up to the sensors, but not when you put it down on posterboard, you may need to adjust the sensors. See next slide.

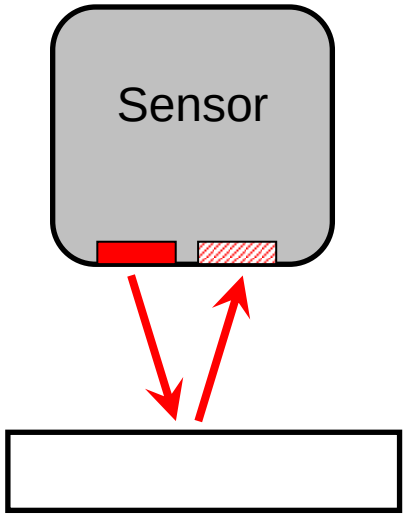
# Experiment

- *How can you use your robot to determine which materials reflect infrared light and which materials absorb it?*
- *What about colors other than black and white, or different materials of the same color?*
- Remember:
  - Each wheel is controlled independently by one of the sensors
  - The wheel will spin only when infrared light is reflected back to the sensor
  - The sensors have a very short range (a few millimeters), they will not work properly if they are too close or too far away from a surface

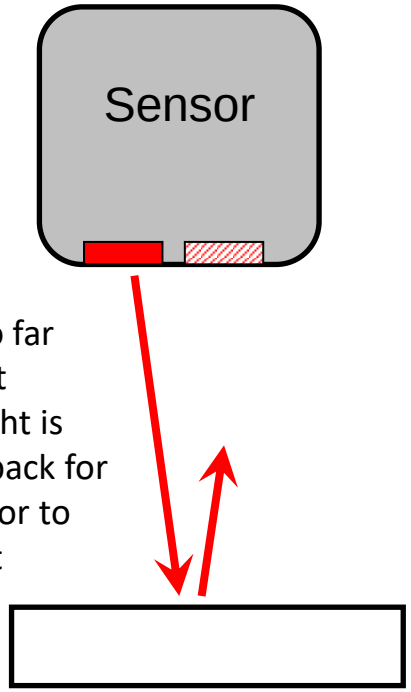
Sensor too close to surface, the detector is blocked and will not work properly even if the surface reflects IR light




Sensor an appropriate distance from surface

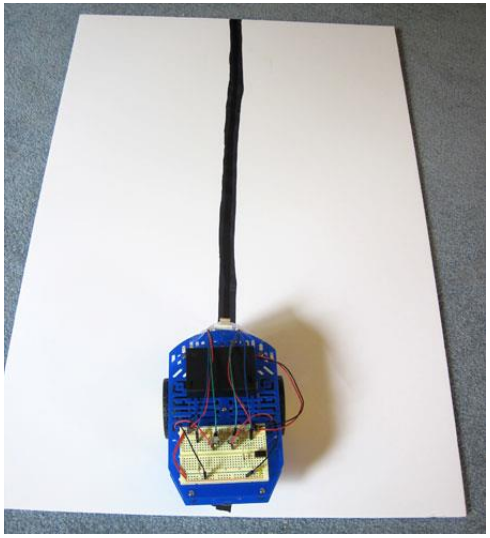


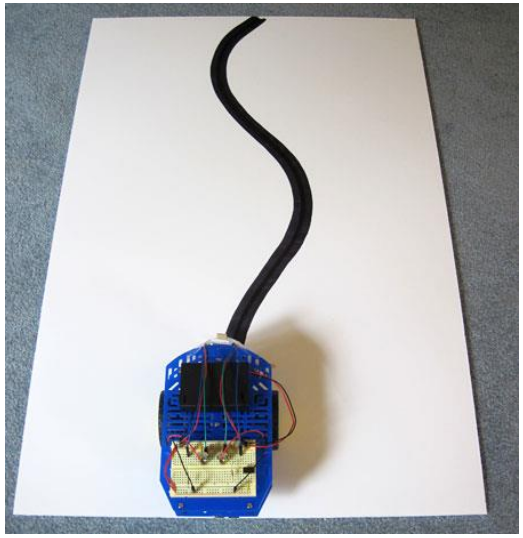

Sensor too far away – not enough light is reflected back for the detector to measure it

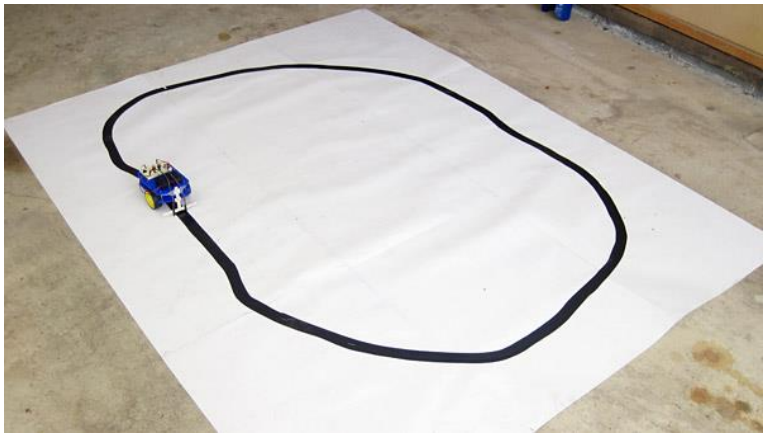


# Following a line

- Once you have figured out which materials reflect and absorb infrared light, try to get your robot to follow a line
- Start with a straight line, work your way up to gradual curves and eventually a full loop
- The robot will have trouble with very sharp curves or 90-degree turns
- If you have trouble, try adjusting the thickness of the line and the spacing of your sensors. *What happens if you make the line thicker or thinner? What happens if you move the sensors closer together or farther apart?*







# Troubleshooting

- **The robot always overshoots curves:** try more gradual curves or a thicker line. If the robot is going too fast, it might drive one sensor over the line before the motor comes to a complete stop. Then the sensor will “see” white again and the robot will just keep going. A thicker line and more gradual curves give the motor more time to stop, allowing the robot to turn.
- **The robot gets stuck or stops for no reason:** make sure your race course is completely flat, especially if you are using flexible posterboard or butcher paper. Since the IR sensors have a very short range and are only a couple millimeters off the ground, small bumps or bubbles in the surface can cause them to get physically stuck, or get too close to the surface so the detector is blocked (see slide 35).