**Constructing your digital thermometer.**
A step-by-step approach

Safety hazards
Students must be trained for safety in the use of all manufacturing devices prior to creating this sensor. Students are to wear indirectly vented chemical-splash goggles at all times, especially during the scoring, cutting, and firing of the glass tube and during soldering of electronic joints. Only one student should be at the soldering station at a time. Hazardous fumes from silicone caulking and soldering are to be avoided by use of a fume hood or direct ventilating exhaust system. Make sure that students wash their hands with soap and water after using the solder—it contains lead, which is a poisonous metal. An ABC-class, portable fire extinguisher must be located in close proximity so that it can be immediately available should the need arise. Floor areas under and within 11 m [35 ft] of the soldering operation must be swept clean of combustible and flammable materials.

Materials checklist and costs
- integrated circuit (IC) sensor (LM35™):
  www.jameco.com/Jameco/Products/ProdDS/155740.pdf
- 1 m standard telephone cable (four internal wires)
- 8–12 cm of 0.5 cm ID glass tubing (fired with Bunsen burner on ends for safety)
- one 7.7 × 1 cm and two 5 × 0.33 cm shrink tubing
- 9V battery and battery lead
- soldering iron
- heat gun
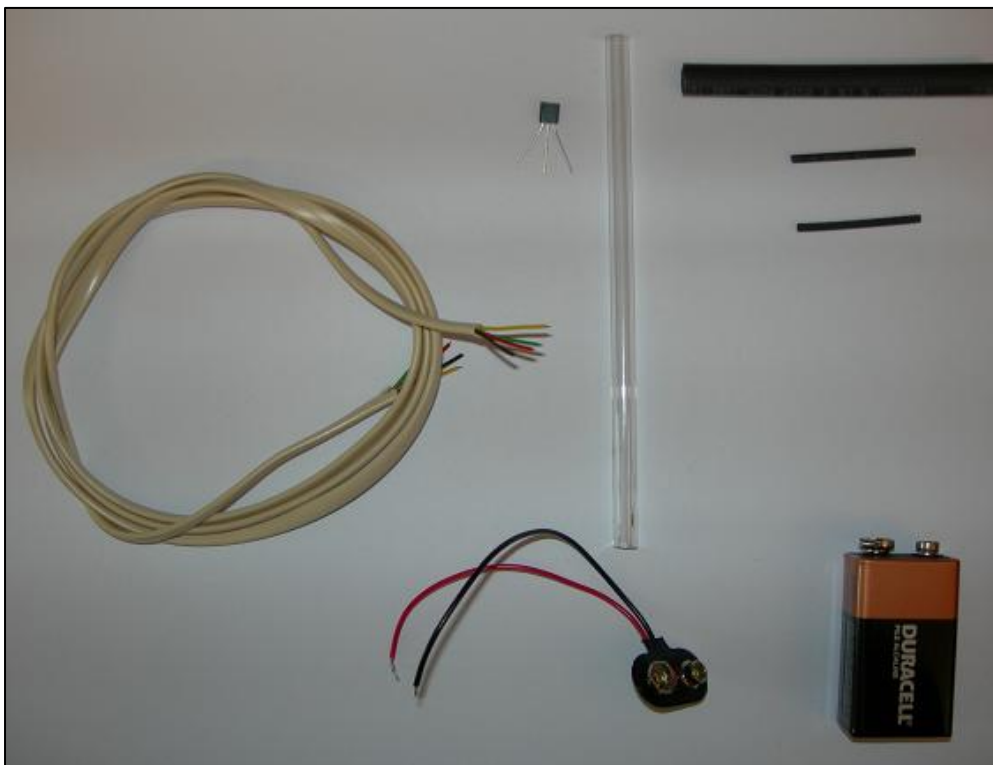
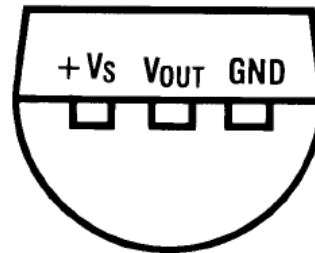| Materials	Cost
LM35DZ	$1.49/1 unit or $1.19/10 units
Silicone caulking, tubing, shrink wrap, and power chord	$5
Telephone wire	$2
9V battery and 9V battery lead	$1.20
	Total: $9.39–9.69 per digital thermometer

Procedure
Step 1
The IC sensor will have three leads and may either be metal or plastic, TO-46 or TO-92, respectively. (Pin-outs for both sensor packages are shown below.)
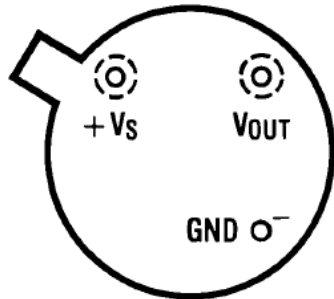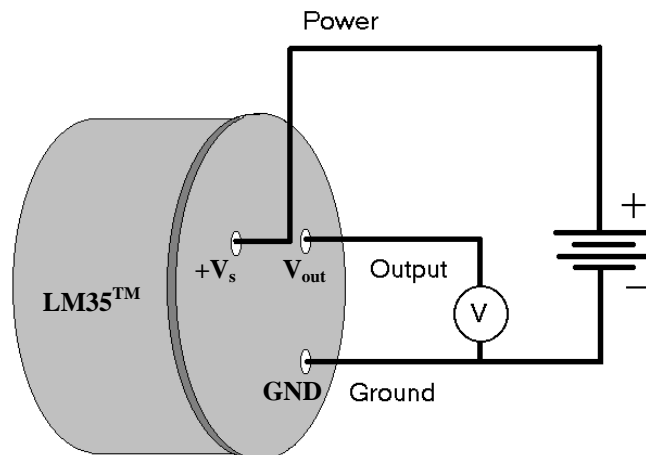

The circuit diagram below shows the orientation of an IC sensor with a battery, positive and negative poles, and the digital voltmeter (DVM). (From the diagrams above, +Vs directly corresponds to the positive pole of battery, V_{out} corresponds to sensor output, and GND corresponds to the negative pole of the battery.)

Step 2

Cut a 1 m telephone cable and solder the yellow, green, and red wires to the IC sensor. (You may choose from any of the four wires, as long as they are insulated.) Once the outer plastic shielding and fourth wire are trimmed back to the length of the glass tubing, slide the remaining three wires through the glass tube so that they may be soldered to the three IC sensor leads. Before soldering the three wires to the sensor leads, be sure to slide the two 5×0.33 cm shrink tubings over any two of the three wires. Make sure the tubings are at least 7 cm from the solder joint so they do not prematurely shrink. Finally, solder the yellow wire to the power supply, $+V_s$; the green wire to the ground, GND; and the red wire to the sensor output, V_{out}.
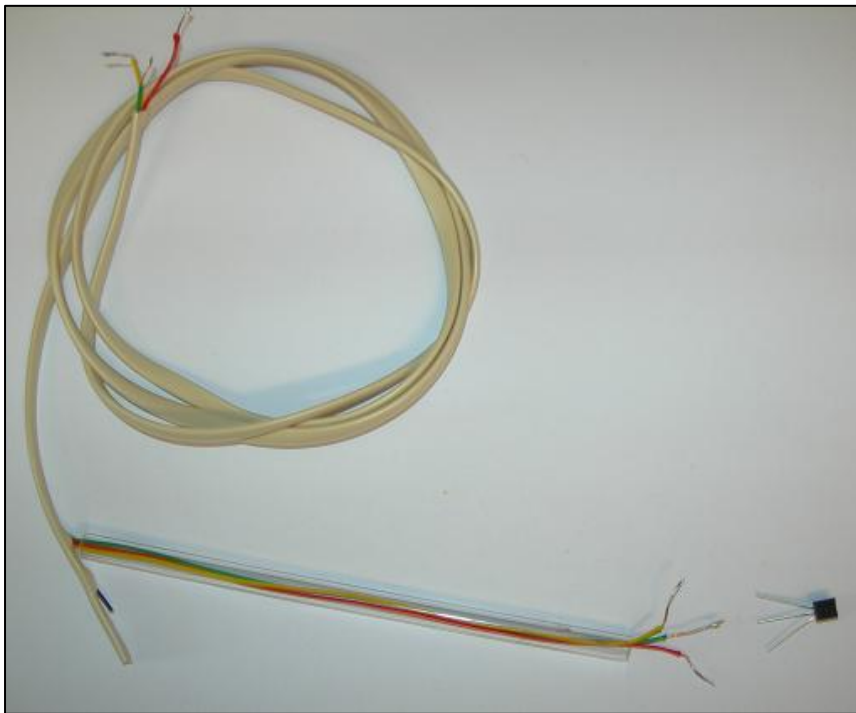

Step 3

Slide the two 5×0.33 cm shrink tubings over the wire-sensor solder junctions. Make sure they are snuggly behind the IC sensor and shrink them into place with the soldering iron.
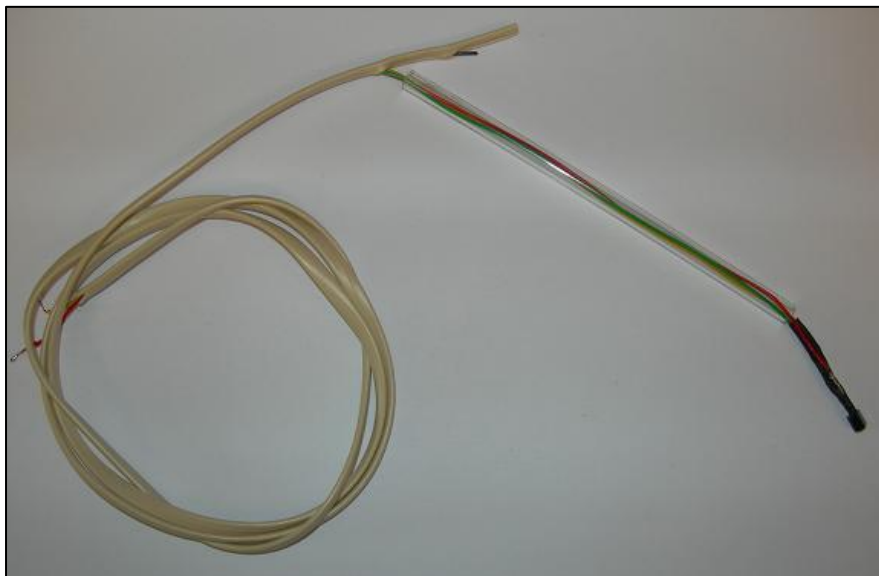
Step 4

Place approximately a 2 cm bead of caulking from the back of the IC sensor toward the glass tubing. Then, pull the loose wires from the opposite end of the tubing so that the wires and IC sensor fit snugly into the tip of the tube. You may use toothpicks and rubber gloves to ensure that there are no leaks between the head of the IC sensor and the wires located in the end of the tube. Wipe off any excess caulking and allow it to dry for at least 24 hours.
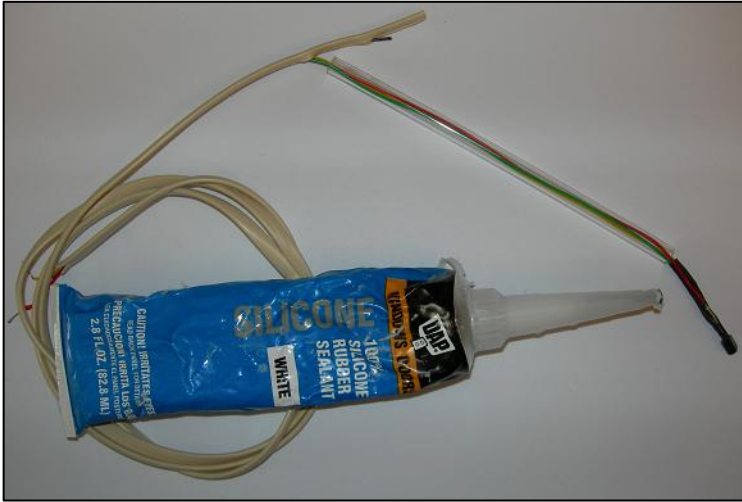
Step 5

After a day of drying, use a 7.7×1 cm piece of shrink tubing to enclose the connection from the glass tubing and telephone cable. Next, solder the GND wire to the negative pole or black lead of the 9V battery connector. Now, solder the V_s wire to the positive pole or red lead of the 9V battery connector.
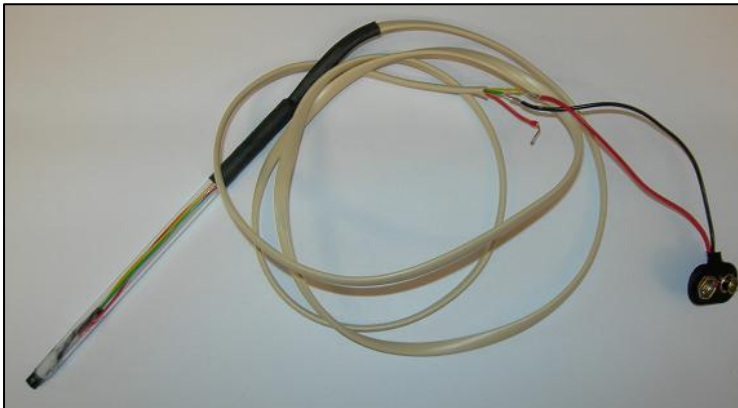
Turn on your DVM and configure it to read volts. Clip an alligator lead from the DVM's red test lead to the IC sensor's output, V_{out}. Finally, connect the DVM's common ground

lead to the negative pole of the 9V battery or GND. At this point, your homemade IC digital thermometer should be functioning!

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