Making Circuits Work

When you first assemble a circuit on a breadboard, or even on the final printed circuit board, there is a good chance it won't work as intended. This document contains some suggestions for systematically finding and fixing the problems. Many of the methods can be generalized to debugging computer code and getting mechanical devices running.

A. Basic design

Review the circuit diagram to be sure your design does what you think it does. Then check the wiring to be sure you built the circuit you drew. This includes checking the component connections - even if you are very certain of the pin or lead identifications, consult the manufacturer's spec sheet to get them right. There are common configurations, but no standards.

B. Power

Power wiring is not always shown in textbook diagrams, so you may have to make the implied connections on your own.

Is the power supply turned on? Are the voltages correct? Check the actual voltage at a couple of points in the circuit to be sure. Check that supposedly grounded points are at zero potential.

Some analog circuits require a dual voltage, positive and negative, supply. This means that there are two different output terminals, one positive and one negative with respect to a common terminal.

Unlike oscilloscopes or function generators, the common terminal of power supplies is usually not connected to earth ground through the building wiring system. (The supply is said to "float" with respect to ground.) If you are using several supplies, perhaps +5V for a digital chip and ±15V for some op-amps, you must connect their common terminals together so they have the same reference potential.

C. Breadboarding foibles

The contact points in breadboards can be connected, internally and to an outboard, in various ways. Refer to available diagrams to understand how your breadboard is set up, or use an ohmmeter to trace the connections.
Breadboards can be abused, or just worn, so some contact points may not work well. Try jiggling components or pushing wires in a bit more. Voltage checks on the component leads can also be useful. If you find problems, avoid that area or try a different board.

Jumper wires that have been bent too often can break inside the insulation. This is very rare, but infuriating when it happens.

D. Checking signal flow

If the circuit passes all these checks but still doesn't work, the problems are likely to be more interesting. You now need to follow the signal from input to output, to check proper operation of each stage. After localizing the problem, you can logically or even physically subdivide the circuit and test each functional module separately. This is facilitated by using an oscilloscope and, for digital circuits, a logic-state indicator.

The basic procedure is to apply a known input to the circuit, and see if it produces the expected output at each stage. That is, see that the voltage at the output of each successive transistor, op-amp or logic gate is what you expect, given the inputs to that stage. If not, try to understand what sort of failure would cause the output you see, fix it, and check again.

The signal-tracking procedure can sometimes be completed on the intact circuit, but it may be necessary to isolate parts to detect some problems. For example, if a chip is damaged so that an input pin is internally shorted to ground, it may appear that whatever is driving that pin cannot produce a voltage. This would only be found by disconnecting the failed chip from the rest of the circuit.

For very large and complex projects, you may have to build individual parts of the circuit separately, test them, and then connect them together after you are sure they function properly. This is in fact standard practice for coding software.

E. Clean up

When you think you have fixed the problems, go back and check the operation of the whole circuit again. It's fairly easy to forget to put a wire back or install a chip. This is also the time to correct your circuit diagram, if you had to make changes, so you know what really worked.

Put obviously damaged or broken components, with melted cases or broken leads for example, in the trash. If you aren't sure the component works, put it aside for the instructor to check later. Don't put dubious parts back in the drawers to catch an innocent victim later.