

HOW TO DRAW SCHEMATIC DIAGRAMS

APPENDIX B

A well-drawn schematic makes it easy to understand how a circuit works, and it aids greatly in troubleshooting. A poor schematic only creates confusion. By keeping a few rules and suggestions in mind, you can draw a good schematic in no more time than it takes to draw a poor one. In this appendix we dispense advice of three varieties: general principles, rules, and hints. We have also drawn some real knee-slappers to illustrate habits to avoid.

B.1 General principles

- Schematics should be unambiguous. Therefore pin numbers, parts values, reference designators, polarities, etc., should be clearly labeled to avoid confusion.
- A good schematic makes circuit functions clear. Therefore keep functional areas distinct; don't be afraid to leave blank areas on the page, and don't try to fill the page. There are conventional ways to draw functional subunits; for instance, don't draw a differential amplifier as in Figure B.1, because the function won't be easily recognized. Likewise, flip-flops are usually drawn with clock and inputs on the left, set and clear on top and bottom, and outputs on the right.

B.2 Rules

- Wires connecting are indicated by heavy black dots; wires crossing, but not connecting, have no dot (don't use a little half-circular "jog"; it went out in the 1950s).
- Four wires must not connect at a point; i.e., wires must not cross *and* connect. You sometimes see this rule violated, but it's poor practice (because a missing or undersized dot is a different circuit).
- Always use the same symbol for the same device; e.g., don't draw flip-flops in two different ways (exception: assertion-level logic symbols show each gate in two possible ways).
- Wires and components are aligned horizontally or vertically, unless there's a good reason to do otherwise.

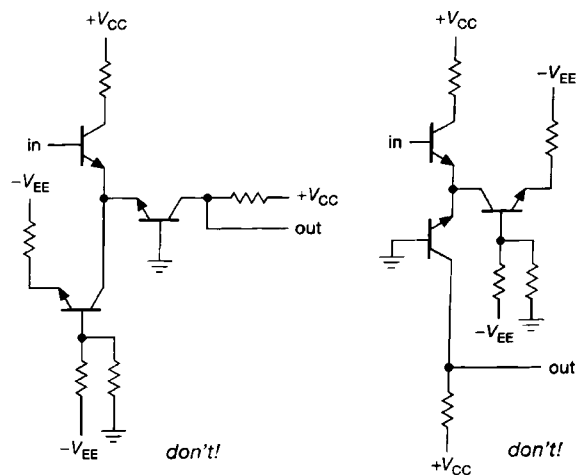


Figure B.1. Arrange components so that the function (here a differential amplifier) is clear. Don't corrupt the presentation to save space.

- Label pin numbers on the outside of a symbol, signal names on the inside.
- All parts should have values or types indicated; it's best to give all parts a label ("refdes"), too, e.g., R_7 or U_3 .

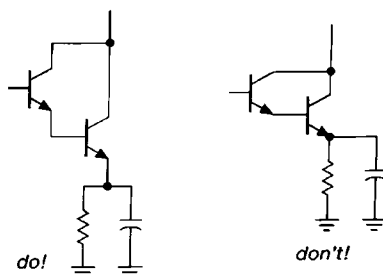


Figure B.2. Bring leads away from component symbols before connecting or jogging.

B.3 Hints

- Identify parts immediately adjacent to the symbol, forming a distinct group giving symbol, label, and type or value.
- In general, signals go from left to right; don't be dogmatic about this, though, if clarity is sacrificed.
- Put positive supply voltages at the top of the page, negative at the bottom. Thus *npn* transistors will usually have their emitter at the bottom, whereas *pnp*s will have their emitter topmost.
- Don't attempt to bring all wires around to the supply rails, or to a common ground wire. Instead, use the ground symbol(s) and labels like $+V_{CC}$ to indicate those voltages where needed.
- It is helpful to label signals and functional blocks and show waveforms; in logic diagrams it is especially important to label signal lines, e.g., RESET' or CLK.
- It is helpful to bring leads¹ away from components a short distance before making connections or jogs. For example, draw transistors as in Figure B.2.
- Leave some space around circuit symbols; e.g., don't draw components or wires too close to an op-amp symbol. This keeps the drawing uncluttered and leaves room for labels, pin numbers, etc.
- Label all boxes that aren't obvious: comparator versus op-amp, shift register versus counter, etc. Don't be afraid to invent a new symbol.
- Use small rectangles, ovals, or circles to indicate card-edge connections, connector pins, etc. Be consistent.

¹ Leads? Yeah, sure. ... I'll just check with the boys down at the crime lab. They got four more detectives working on the case. They got us working in shifts. Hahahaha. ... LEADS!

- The signal path through switches should be clear. Don't force the reader to follow wires all over the page to find out how a signal is switched.
- Power-supply connections are normally assumed for op-amps and logic devices. However, show any unusual connections (e.g., an op-amp run from a single supply, where $V_- = \text{ground}$), and the disposition of unused inputs.
- It is very helpful to include a small table of integrated circuit (IC) numbers, types, and power-supply connections (pin numbers for V_{CC} and ground, for instance).
- Include a title area near the bottom of the page, with name of circuit, name of instrument, by whom drawn, by whom designed or checked, date, and assembly number. Also include a revision area, with columns for revision number, date, and subject.
- We recommend drawing schematics freehand on coarse graph paper (pale gridlines, five per inch, for example National[®] Brand "Engineer's Computation Pad" in "Eye-Ease"[®] green), or on plain paper on top of graph paper. This is fast, and it gives very pleasing results. Use dark pencil (we like HB hardness, 0.5 mm diameter) or ink; avoid ballpoint or felt-tip pen.

B.4 A humble example

As an illustration, we've drawn a humble example (Figure B.3) showing "awful" and "good" schematics of the same circuit; the former violates nearly every rule and is almost impossible to understand. See how many bad habits you can find illustrated. We've seen all of them in professionally drawn schematics! (We drew the "bad" schematic in an airport while waiting for a flight. It was an occasion of great hilarity; we laughed ourselves silly.)