Bucknell University
Electrical and Computer Engineering Department
Series on Technical Communication

Schematics

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As with all aspects of technical communication, schematic drawings should be correct and clear. This document briefly outlines some of the standards and conventions that engineers use when creating schematics.

General Organization

As a general rule, higher voltage power supply connections are located toward the top of the sheet, and progressively lower voltages are moved toward the bottom of the sheet. The usual exception is that a separate ground symbol should be placed near each element that needs the ground connection.

Input connectors and voltage sources should be placed on the left, with output signals on the right. The natural flow of signals should be from left to right.

Use implicit signal connections (i.e. air wires) sparingly. The usual exception to this rule is for power supply and ground connections.

Avoid "4-way" junctions, where two wires completely cross over each other **and** are connected together. Junction dots are often used to emphasize that these intersections are actually junctions, but the dot can be difficult to discern. Such connections should be split into two "T" intersections. If two signal lines cross over each other the safe assumption should be that they **are not** connected.

Don't allow parts of the drawing to overlap. In particular, nothing should be allowed to overlap text elements. Wires should not be drawn over component symbols.

Don’t depend on color to convey information. A significant fraction of people have some degree of color-blindness, and your documents will often be reproduced in black-and-white.

Add an appropriate drawing frame and fill in the title block.

Symbols

The symbols for components used in schematics have been standardized in the U.S. and Canada by the IEEE, in IEEE Std 315 and IEEE Std 91a. These documents describe the preferred symbols for schematic elements and provide examples of how they should be drawn. There are also international standards for schematic symbols that are defined by the International Electrotechnical Commission (IEC), and some of these are much different from the symbols you may be accustomed to. For example, Fig. 1 shows the symbols for a fixed resistor as suggested in IEEE Std 315. The top symbol is the conventional symbol used in the U.S. but the bottom symbol is common internationally. Note that the asterisk is not actually part of the symbol and should be replaced with the resistor's value.

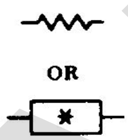

Figure 1: Symbols for Fixed Resistors

Be careful when using symbols that imply **polarity**, such as symbols for capacitors where one of the plates is drawn as a curved line. The curved line is assumed to be connected to the lower voltage. If the capacitor is polarized, such as an electrolytic capacitor, then an explicit plus sign should be added to the symbol to mark the capacitor terminal that must be connected to the more positive voltage.

Symbols for digital logic elements are provided in IEEE Std 91. The preferred symbols given in the standard are quite different from the symbols we usually see; the preferred symbols are simply rectangles with annotations and do not have a distinctive shape, as shown in Fig. 2. The standard notes that the common distinctive shape symbols are not preferred by the IEC.

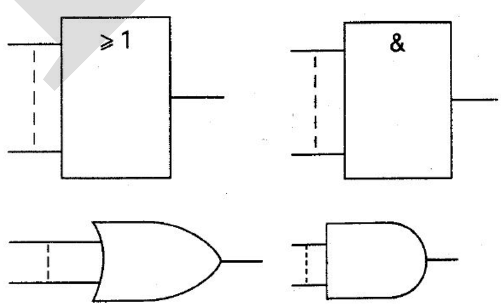

Figure 2: Standard symbols for OR and AND elements

Note that the XOR function is only defined unambiguously for exactly 2 inputs. The standard describes the exclusive-OR as a "one and only one" function, and recommends that a different symbol be used if what you intend is an odd-parity function.

Reference designations

Reference designations make it easier to talk about the components in a schematic. Instead of describing the voltage across the third resistor from the left, you can talk about the voltage across R17. IEEE Std 200 is the applicable standard for reference designations.

- Each type of component has a **class designation letter**, for example:
  - C for capacitors
  - J for jacks and receptacles
  - P for plugs
  - R for resistors and potentiometers

- A **reference designation** for a component is the class designation letter followed by an integer
  - For example, the first resistor drawn would be R1.
  - If a component is deleted its reference designation is not reused.
  - Unused and highest-used reference designations are often listed on the schematic.

Component Values

The values of components such as resistors and capacitors should be annotated on the schematic near their respective symbols. These values are often written exactly as you would write the SI value in a formal document using Greek letters, decimal points in numbers, and lower-case letters.

While such markings are technically correct, and alternative marking system known as **RKM code** has been standardized in IEC 60062. In the RKM style of indicating component values the SI symbol for the unit is omitted when it is clear from the context (see examples in Table 1). For example, capacitor values are always in farads so the 'F' is not needed. Decimal points are replaced by letters that also indicate the appropriate SI prefix for the value, and the letter 'u' is used instead of μ to indicate the *micro* prefix. When no prefix is needed the decimal point is replaced by a letter chosen specifically for the component type, such as `R` for resistors.

Table 1: RKM value code examples

SI style	RKM style
47 kΩ	47K
4.7 Ω	4R7
4.7 kΩ	4K7
0.47 Ω	R47

Example Schematic

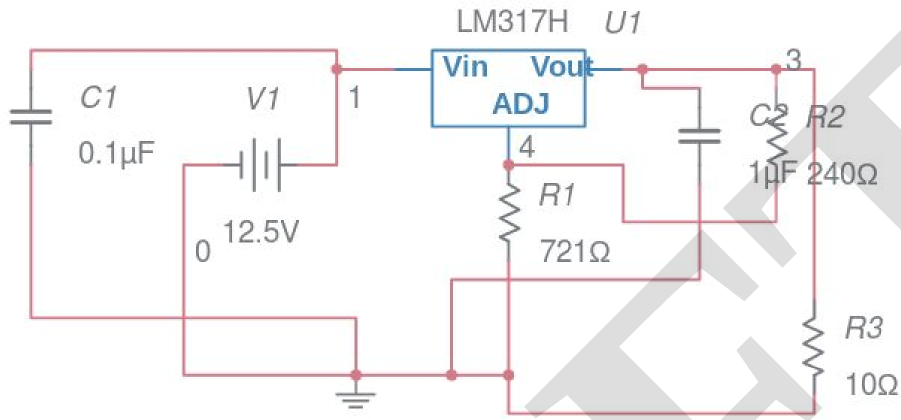

Figure 3: A really bad schematic

An example of a particularly bad schematic is shown in Fig. 3. This is a schematic for a simple power supply using the LM317 adjustable voltage regulator. The input comes from a 12.5V battery and the output is simulated as a 10 Ω resistor. Resistors R1 and R2 are used to set the output voltage. Capacitors C1 and C2 provide additional load regulation and may also be necessary to prevent oscillation. Unfortunately, the poor positioning of the "Vout" label on U1 is part of the LM317H symbol in the schematic drawing tool's library.

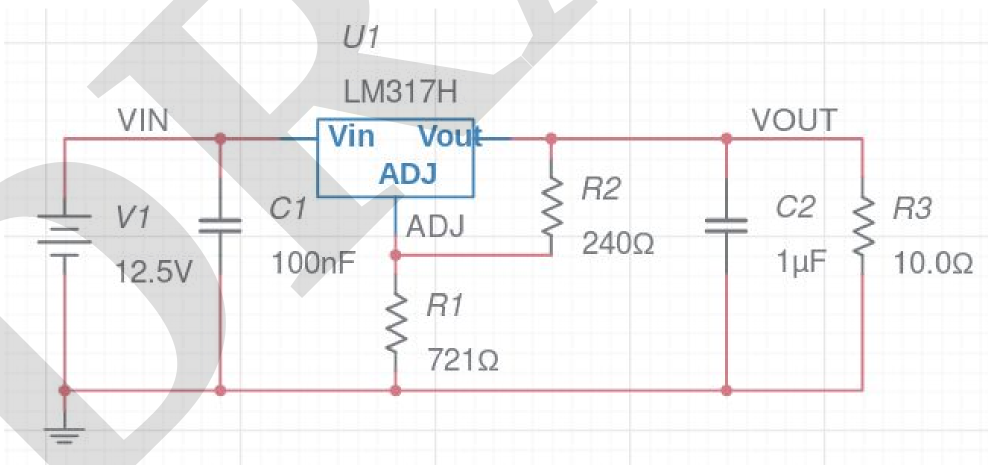

Figure 4: Improved schematic

The much improved version of this schematic is shown in Fig. 4. The components have been placed to avoid overlapping signal lines and 4-way junctions. The input voltage source is moved to the left and the load resistor is clearly the right-most element. Note that the correspondence between a particular element, its reference designator, and its value is much more clear. The reference designator and value could generally be moved closer to their related element symbol, but the schematic capture tool used to create these schematics did not allow them to be repositioned independently.

References

Electrical Engineering Stack Exchange: Rules and guidelines for drawing good schematics

Autodesk: The Top 10 Tips to Draw Your Next Schematic Design Like a Pro

EEVblog #1129 - Creating a Nice Readable Schematic

IEEE Std 200 Standard Reference Designations for Electrical and Electronic Parts and Equipments

IEEE Std 315 Graphic Symbols for Electrical and Electronics Diagrams (Including Reference Designation Letters)

IEEE Std 91 IEEE Standard Graphic Symbols for Logic Functions

IEEE Std 991 IEEE Standard for Logic Circuit Diagrams

American National Standard Drafting Practices (Electrical and Electronics Diagrams), Y14.15-1966 (R1973) and Supplements Y14.15a-1970 (R1973) and Y14.15b-1973

IEC 60062 Marking codes for resistors and capacitors

About this Guide

This guide is part of a series that has been established to provide a repository of information on technical communication for the students and faculty of the Bucknell University Electrical & Computer Engineering Department. Its primary goal is to foster consistent standards applied to the preparation of reports, presentations, and other forms of communication within the ECE curriculum. In effect, the guides in this series constitute official department policy on technical communication.

Although it is important to adhere to standards for graded class work, you should strive to maintain high standards as well in ungraded work and in day-to-day communications with your professors, other students, and professional contacts. You should view every instance of communication as an opportunity to practice your skills so that eventually they become second nature. Fair or not, your colleagues will form opinions of your professional competence based partly on how well you express yourself.