UNDERSTANDING ELECTRONIC SCHEMATICS

John D. Lenk

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JOHN D. LENK
Consulting Technical Writer

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To IRENE, the "Sandpiper Lady"
and to MR. LAMB, the "Magic Bunny"

Preface

The word schematic means to show the scheme of things, how things work. In electronics the word schematic is applied to diagrams that identify circuits and show how the circuits work, or how they interrelate to other circuits. To understand such diagrams, you must be able to identify the symbols used, relate these symbols to circuit parts, and then identify the electronic circuits formed by the parts (as represented by the symbols).

The obvious test of any book or course on schematic reading is how well you understand schematics after you have read the book. Throughout this book, and particularly in the last chapters, you are given a variety of schematics. These are both full and partial schematics, from the very simple to the complex. You are asked to "read" the schematics, to identify parts and circuits, describe how the circuits operate, and how the circuits relate to other circuits. If you have read and digested all of the material up to that point, you will be able to read each schematic as it is presented. If you have trouble, you can review the material since each question is related to previous paragraphs or sections.

This is not a math or theory book. Of course, math and theory are not completely ignored, since it is impossible to read schematics without any knowledge of electronics. However, math and theory are kept to an absolute minimum, and used only where necessary to help you read and understand schematics.

In Chapter 1, you are introduced to the electronic schematic. The chapter starts by describing the relationship of schematics to basic electronics, and then proceeds with a discussion of typical schematic symbols, and how symbols are arranged to represent circuits. Next, you are given some actual schematics for study. Although you are not expected to read the schematics at this point in the book, you are taken through the schematics, symbol by symbol, to show what information is available, for example, part values, waveforms, test points, and voltage distribution. The subjects of other electronic diagrams (including pictorial, practical wiring, block, and pinout diagrams) are then discussed, stressing their relationship to the schematic.

With basics out of the way, Chapter 2 launches directly into descriptions of common electronic symbols representing passive electronic devices. Many examples are given to show the variations in electronic symbols, as well as preferred and alternate symbol forms. The symbols covered in Chapter 2 include: conductors, wires, resistors, capacitors, inductors, coils, resonant circuits, a-c circuits, transformers, antennas, grounds, attenuators, pads, batteries, earphones, headsets, loudspeakers, microphones, pickups, circuit breakers, fuses, lamps, relays, switches, connectors, terminals, meters, motors, and generators. By the time you have completed Chapter 2, you should be able to look at a schematic and say "that symbol is a capacitor, and its function in a circuit is . . . ."

Chapter 3 provides the same type of coverage for electronic symbols representing active devices. The symbols covered in Chapter 3 include: vacuum tubes, diodes, transistors (two-junction, bipolar, field effect and unijunction), controlled rectifiers, thyristors, light activated devices (photocells), voltage variable capacitors, saturable reactors, magnetic amplifiers, and integrated circuits. By the time you have completed Chapter 3, you should be able to see a schematic symbol and say "that is a diode, and it functions to pass current in one direction, but not in the opposite direction."

Chapter 4 concentrates on reading the schematics of some very simple, but important, basic circuits. Such circuits are made up of the passive devices described in Chapter 2, and the active devices of Chapter 3. The circuits covered in Chapter 4 include: audio amplifiers, radio frequency amplifiers, oscillators, waveshaping circuits, operational amplifiers, power supplies, attenuators, filters, and control circuits. When you have completed Chapter 4, you should be able to see a circuit schematic and say "that is an oscillator, and it operates as follows . . . ."

Chapter 5 concentrates on reading the schematics of complete electronic equipments or sets. Such equipments are made up of the basic circuits discussed in Chapter 4. In Chapter 5 you are taken on a tour through the schematics of a CB set and a TV set, on a stage by stage, circuit by circuit basis. By the time you have finished Chapter 5, you should be able to look at a TV set schematic, point out every stage, and say "that is the sync separator, and it operates as follows . . . ."

A series of questions follows each chapter. The answers to all questions are given following Chapter 5. To get full benefit from this book, you should try to answer the questions before going on with the next chapter. This will test your skill, and make sure that you are ready for the next chapter.

Many professionals have contributed their talent and knowledge to the preparation of this book. The author willingly acknowledges that the tremendous effort to make this book comprehensive and relevant is impossible for one person, and wishes to thank all who have contributed directly and indirectly. The author wishes to give special thanks to Mr. Joseph A. Labok of Los Angeles Valley College.

JOHN D. LENK

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1

Getting Started with Schematics

You can learn to read music without becoming a musician. You can also learn to read electronic schematics without becoming an engineer, technician, or any other form of electronic wizard. Of course, if you are making a study of electronics, at any level, it is quite helpful if you learn to interpret schematics. In fact, it is impossible to go very far in any study of electronics without being able to interpret a schematic diagram. This is because electronics people use schematics as a means of communicating with each other. That is, the *symbols* found in schematics are used to show such vital information as: what *parts* (resistors, capacitors, transistors, etc.) are used, how the parts are connected to form *circuits* (amplifiers, oscillators, logic networks, etc.), and how the circuits are connected to form a piece of *equipment* (television set, citizen's band set, etc.) or a *system* (stereo system, radar, etc.).

1-1 SCHEMATICS AND BASIC ELECTRONICS

Just as it is impossible to learn electronics without being able to read schematics, it is equally impossible to learn the art of schematic reading without learning something about electronics. In practical terms, if you learn the schematic symbols, how the symbols are connected to represent circuits, and how the circuits are arranged to form a piece of equipment or a system, *you will be learning basic electronics.* Do not let this frighten you! Unlike most books and courses in basic electronics, this book does not dwell on the abstract theory of how a particular part performs its function, or discuss details of the math involved in the process. Instead, we show you the commonly used symbols and *state in simple terms* what function is performed by the part that the symbol represents. You must accept these statements! (If you cannot accept the statements, or if you insist on knowing the theory back of how a part performs its function, there are a number of well-written books on the subject. But theory and math are not vital to an understanding of electronic schematics.) Once we have given the symbol and an explanation of what the corresponding part does, we go on to talk about how this function is used in a circuit or piece of equipment.

1-2 A TYPICAL SYMBOL USED IN SCHEMATICS

Let us consider a typical example of this approach to understanding the electronic schematic. Figure 1-1 shows the symbol of a *solid-state diode.* These diodes are generally made of crystal or crystal-like material, such as silicon, germanium, or selenium. Actually, a diode is a *junction* of two materials. A typical book on theory will tell you (possibly in several paragraphs) that the materials are made up of atoms and that the atoms are made up of electrons. It will go on to say that when voltage is applied across a junction, the electrons in one material near the junction will pass to holes in the atoms of the other material on the other side of the junction. This creates holes in the atoms of the first material, causing more electrons to move, thus creating a flow of electrical current, and so on.

In this book, we bypass all of that and simply state that the symbol shown in Fig. 1-1 is that of a solid-state diode. The pointed (or arrow-like) part of the symbol represents the *anode;* the flat part represents the *cathode.* The junction is the point at which the anode touches the cathode. When the anode is made *more positive* than the cathode, from whatever source and for whatever reason,

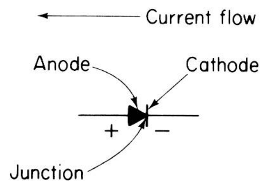

FIGURE 1-1 Basic solid-state diode symbol

current will flow through the diode from the cathode to the anode (against the arrow). When the anode is not more positive than the cathode, no current flows in either direction. You do not have to know how or why, but when you find a diode in a schematic, you must remember that the diode will pass current in *one direction only* and only under one condition (when the anode is more positive than the cathode).

1-3 A TYPICAL CIRCUIT USED IN SCHEMATICS

Now that you have learned one basic symbol and the corresponding function of the part represented by that symbol, let us see how the function can be used in an elementary circuit. Figure 1-2 shows the diode connected in a *rectifier* circuit. This very common circuit, usually found in *power supplies* and *detectors,* uses the basic diode function to convert alternating current (ac) into direct current (dc).

There are other symbols in Fig. 1-2. First, there is the circle (containing a sine wave), which represents an *a-c source.* This source could be any alternating current, including normal house power. We could have omitted this symbol and simply stated "a-c power" (as is done on some schematics), but that would have limited understanding to those who read English. Keep in mind that schematic symbols are international in nature (even though there are some

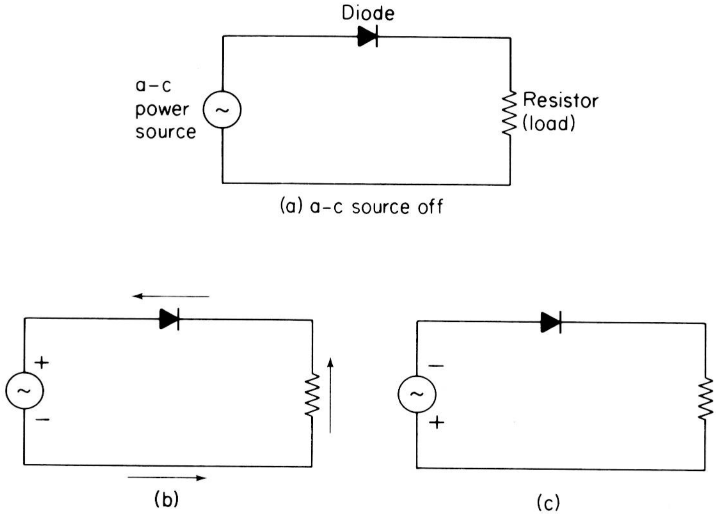

FIGURE 1-2 Basic diode connected as a half-wave rectifier

variations from country to country). A Russian technician, for example, will instantly recognize the a-c source symbol. Figure 1-2 also shows a *resistor* or resistance element symbol, as well as wires interconnecting the a-c source, diode, and resistor. (In a Russian schematic, the resistor symbol will be a narrow rectangular box instead of the zigzag line.)

Note that the a-c source is shown on the left, with the resistor (labeled the *load*) shown on the right. This is because schematics are normally *read from left to right.* That is, the *signal flow* or *function flow* is shown from left to right. For example, a properly drawn schematic of a stereo system will show the tape head, preamplifier, final amplifier, and loudspeaker in that order, from left to right.

Figure 1-2a shows the rectifier circuit when no power is applied (the a-c source is turned off). Figure 1-2b shows operation of the circuit when power is applied and the top line or terminal of the a-c source is positive (with the bottom terminal negative). As you go on with your study of electronics, you will learn that the polarity of alternating current switches regularly. Under the conditions of Fig. 1-2b, the anode of the diode is made positive and the cathode is made negative. Thus, the diode is "turned on" and current flows from the a-c source through the resistor (load) and diode back to the a-c source, as indicated by the arrows.

Figure 1-2c shows the mode of operation when the a-c source has reversed polarity. The anode is now negative, the cathode is positive, and the diode is "turned off." There is no current flow, even though the a-c power source is still available.

When you compare Fig. 1-2b and c, you will see that current flow through the resistor is always in one direction and only on every other polarity change of the source. The circuit of Fig. 1-2 has thus converted alternating current into direct current. As you will learn, one *complete change* of the a-c source polarity (from positive to negative and back to positive again) is called a *cycle* or *wave.* A change from one polarity to the other is called a *half-wave* or *half-cycle.* Thus, the circuit of Fig. 1-2 is generally referred to as a *half-wave rectifier.* We will discuss electronic terms in greater detail later. Here we concentrate on schematics and symbols.

1-4 SOME TYPICAL SCHEMATICS

Now let us take a giant leap from the very simple to the real thing—the schematics of actual electronic circuits and equipment. Figures 1-3 through 1-5 show three typical schematic diagrams. Although none

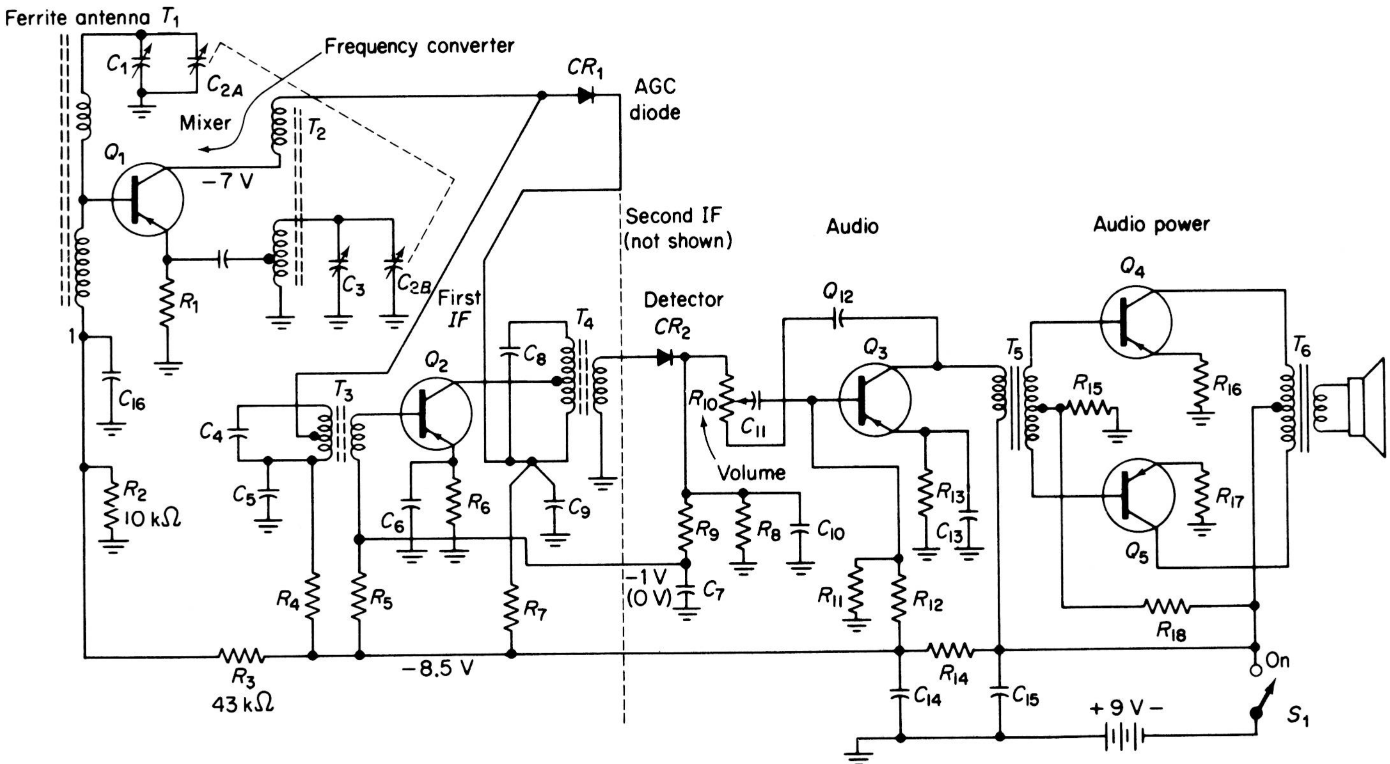

FIGURE 1-3 Schematic diagram of receiver

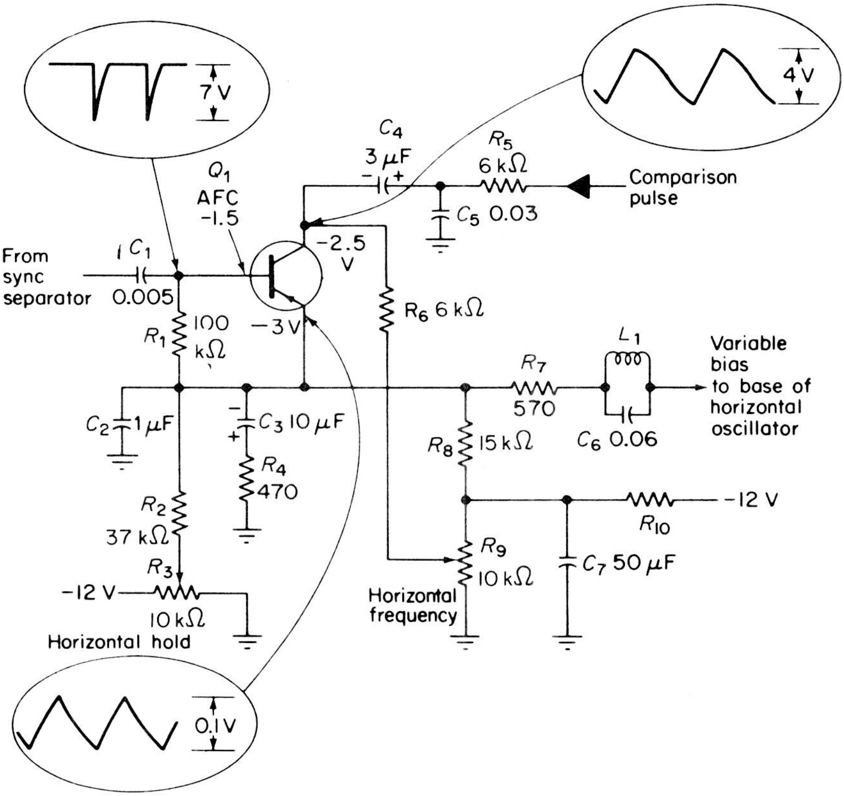

FIGURE 1-4 Examples of waveform and voltage information found in commercial service literature

of these are really very complex, they probably strike terror in the hearts of readers who are totally unfamiliar with electronics! To such readers, the diagrams are a jumble of symbols, wires, and strange notations. However, when you break down the overall schematic into circuits, and then break down the circuits into a group of symbols, they are not quite as formidable.

As an example, try placing a sheet of paper or your hand over the schematic of Fig. 1-3 so that the paper covers everything to the left of the symbol for transformer T5. [If you cannot find T5, start at the extreme right-hand side (at the loudspeaker symbol) and work your way back to the left.] When you have covered everything to the left of T5, the remaining part of the schematic is a circuit of an *audio power amplifier*, consisting of transistors Q4 and Q5; trans-

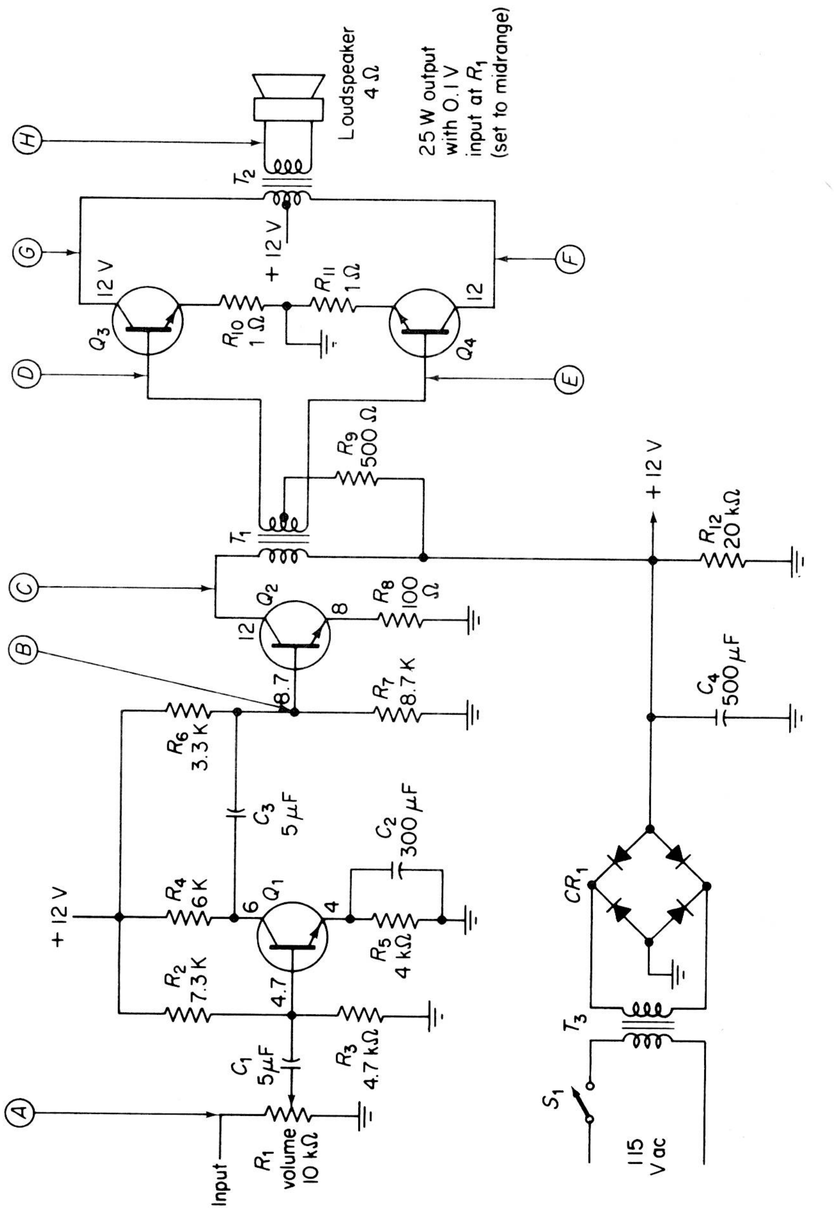

FIGURE 1-5 Schematic diagram of simple audio amplifier

formers T5 and T6; a loudspeaker; and assorted resistors, each represented by corresponding symbols.

The most complex schematic diagram can be broken down into a number of circuits. In turn, each circuit breaks down into a few parts (represented by corresponding symbols). By the time you have finished reading this book, you will be able to identify the most commonly used symbols and circuits and will understand their functions.

However, before we go on, note well that there are a number of special circuits to be found in electronics. Such circuits, which often result when an electronic designer attempts to solve a difficult problem, may break all the rules of conventional circuit design. Even experienced technicians and engineers may find it difficult even to identify the circuit function, much less to describe how the circuit works! That is why well-prepared service literature includes a "theory of operation" section, which describes all the circuit functions or at least those functions that are "odd." Therefore, do not feel inferior, or that all your time has been wasted, if you can not identify every circuit of a complex schematic or describe the circuit function. But, after reading this book, you should be able to recognize at least 90% of the circuits you encounter.

1-5 SCHEMATIC DATA

A well-prepared schematic will show much more than all the parts and circuits involved. Let us examine the schematic of Fig. 1-3. Each part (capacitor, resistor, etc.) is represented by a symbol. In turn, each symbol is identified by combinations of letters and numbers called *reference designations.* The letter is determined by the type of part (C for capacitors, Q for transistors, etc.). The numbers are arbitrarily assigned. In simple equipments, the numbers run from 1 through 100 (higher if necessary). In more complex devices, where there are several groups of circuits, each circuit group is assigned a separate set of reference-designation numbers. For example, in a communications set, the transmitter reference designations may be in the 100 range (C101, R103, T107), with 200s used for the receiver (R201, L201) and the 300s used for the modulator section (T301, Q301).

The letter portion of the reference designation is supposedly consistent on all schematics. In fact, there is a military specification covering reference designations. Unfortunately, not everyone uses