AIRCRAFT TECHNICAL BOOK COMPANY

B2

AVIATION MAINTENANCE TECHNICIAN CERTIFICATION SERIES

ELECTRONIC FUNDAMENTALS

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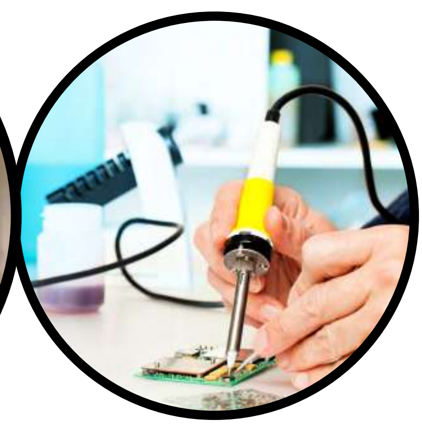

COMPLIANT WITH EASA European Aviation Safety Agency EASA PART 66/147

EASA 2023-989 COMPLIANT

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VERSION	EFFECTIVE DATE	DESCRIPTION OF REVISION(S)
001	2016.01	Module creation and release.
002	2019.10	Format updates.
002.1	2022.06	Clarified number of electrons in *Orbital Shells*. Submodule 1, page 1.4
002.2	2023.04	Minor appearance and format updates.
003	2024.08	Regulatory update for EASA 2023-989 Compliance.

Module was reorganized based upon the EASA 2023-989 subject criteria. Enhancements included in this version 003 are:

4.1.3 *Phase Inverted Amplifiers* - topic added.
4.3A *Proximity Switches* - topic added.
4.3A *Digital Tachometers and Encoders* - topic added.
4.3B *PID Controllers* - topic added.
4.3B *Servo Motor Faults* - topic added.
4.3B *Reversal of Synchro Leads* - topic added.
Additional *minor non*-regulatory adjustments throughout text and figures.

ELECTRONIC FUNDAMENTALS

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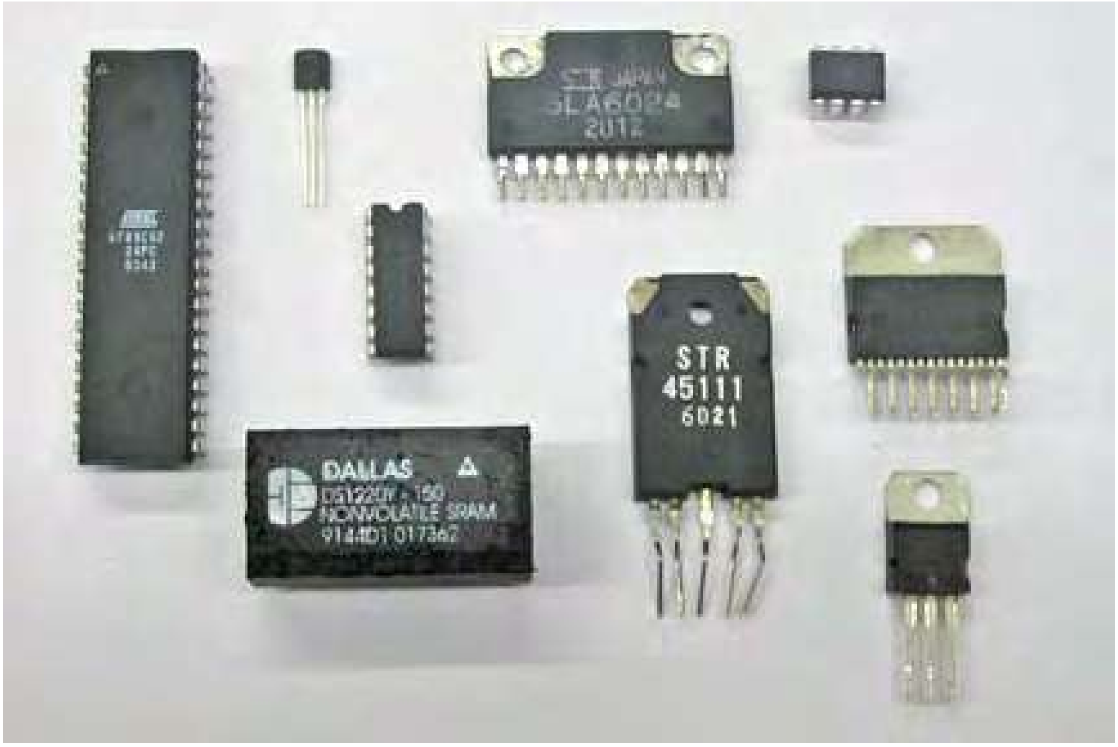


Figure 1-1. Solid-state semiconductor devices.

electrons flow; when the AC cycles, the diode becomes reverse biased and electrons do not flow. This sub module will go into further detail on diode parameters, symbols, identification and behavior. It will also detail the operation of various types of diodes, and show how they are used in power supplies and other common circuits.

DIODE SYMBOLS

Diode symbols used in circuit diagrams are shown in **Figure 1-2**. Different types of diodes have slightly altered symbols for identification. These will be shown as they are discussed.

Note that electron flow is typically discussed in this text. The conventional current flow concept where electricity is thought to flow from the positive terminal of the battery through a circuit to the negative terminal is sometimes used in the field. To differentiate between the two flows in diagrams, the arrows in **Figure 1-3** may be used.

DIODE IDENTIFICATION

There are many types of diodes varying in size from the size of a pinhead (used in subminiature circuitry) to large 250 ampere diodes (used in high power circuits). Because there are so many different types of diodes, some system of identification is needed to distinguish one diode from another. This is accomplished with the semiconductor identification system shown in **Figure 1-4**. This system is not only used for diodes, but for transistors and many other special semiconductor devices as well.

As illustrated in this **Figure 1-4**, the system uses numbers and letters to identify different types of semiconductor devices. The first number in the system indicates the number of junctions in the semiconductor device and is a number one less than the number of active elements. Thus 1 designates a diode; 2 designates a transistor (which may be considered as made up of two diodes); and 3 designates a tetrode (a four element transistor). The letter "N" following the first number indicates a semiconductor. The 2- or 3- digit number following the letter "N" is a serialized identification number. If needed, this number may contain a suffix letter after the last digit. For example, the suffix letter "M" may be used to describe matching pairs of separate semiconductor devices, or the letter "R" may be used to indicate reverse polarity. Other letters are used to indicate modified versions of the device which can be substituted for the basic numbered unit.

For example, a semiconductor diode designated as type 1N345A signifies a two element diode (1) of semiconductor material (N) that is an improved version (A) of type 345.

When working with these different types of diodes, it is also necessary to distinguish one end of the diode from the other (anode from cathode). For this reason, manufacturers generally

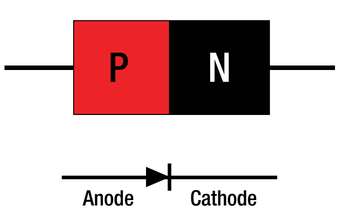


Figure 1-2. Semiconductor diode symbols.

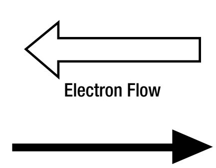


Figure 1-3. Current flow arrows used on diagrams.

code the cathode end of the diode with a "k," "+," "cath," a color dot or band, or by an unusual shape (raised edge or taper) as shown in **Figure 1-5**. In some cases, standard color code bands are placed on the cathode end of the diode. This serves two purposes: (1) it identifies the cathode end of the diode, and (2) it also serves to identify the diode by number.

The standard diode color code system is shown in **Figure 1-6**. Take, for example, a diode with brown, orange, and white bands at one terminal and figure out its identification number. With brown being a "1," orange a "3," and white "9," the device would be identified as a type 139 semiconductor diode, or specifically 1N139.

DIODE CHARACTERISTICS AND PROPERTIES

The key characteristics that have allowed solid state devices to replace vacuum tubes in most applications are their small size and weight, low operating voltages, lower power dissipation, higher reliability and extremely long life. In addition, there is no warm up period required since semiconductors are absent a cathode heater. However, Semiconductors typically do not perform as well as vacuum tubes for high power, high frequency operation, such as television broadcasting, and they are much more vulnerable to Electro Static Discharge (ESD) during handling and operation.

ESD is the transfer of electrostatic charges between bodies at different potentials caused by direct contact or induced by an electrostatic field. If a solid-state component that is charged is then suddenly grounded, the charge will dissipate to ground, but in the process, the component will be damaged due to excessive heat from breakdown of the dielectric material within the component. Care must be taken to discharge any static electricity from the person handling the component and the work station before touching sensitive semiconductor devices.

Semiconductor materials, such as silicon and germanium, exhibit unique properties whereby the conductivity of these materials can be varied and over wide ranges by subtle changes in temperature, light intensity, and impurity content. Semiconductors are manufactured both as single discrete devices, such as diodes and transistors, and as fully Integrated Circuits, which can consist of millions or billions of discrete components manufactured and interconnected on a single semiconductor substrate or wafer. Their long life, reliability, and resilience in harsh environments make them ideal for use in avionics.

The key to the function of solid state devices is in the electrical behavior of semiconductors. To understand semiconductors, the following sections will review what makes a material an insulator or a conductor, followed by an explanation for how materials of limited conductivity are constructed and some of their many uses.

DIODES IN SERIES AND IN PARALLEL

A diode offers a slight resistance to current flow in forward bias and, therefore, a voltage drop occurs as current flows through the diode. In a forward biased circuit, the voltage drop is approximately 0.7 volts for a silicon diode, and about 0.3 volts for a germanium diode. The remainder of the voltage is applied to any load in the circuit downstream of the diode.

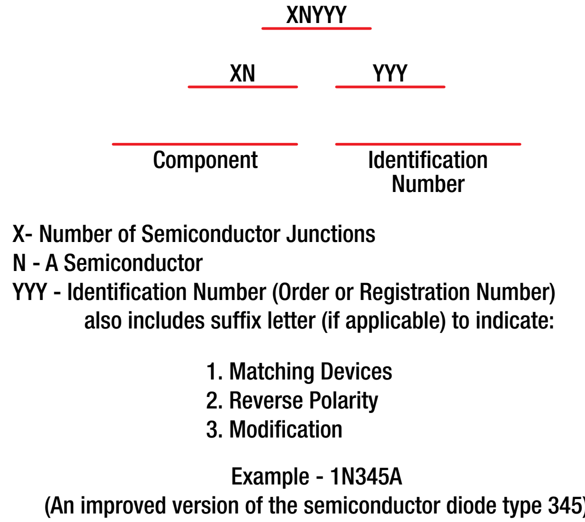


Figure 1-4. Semiconductor Identification Codes.

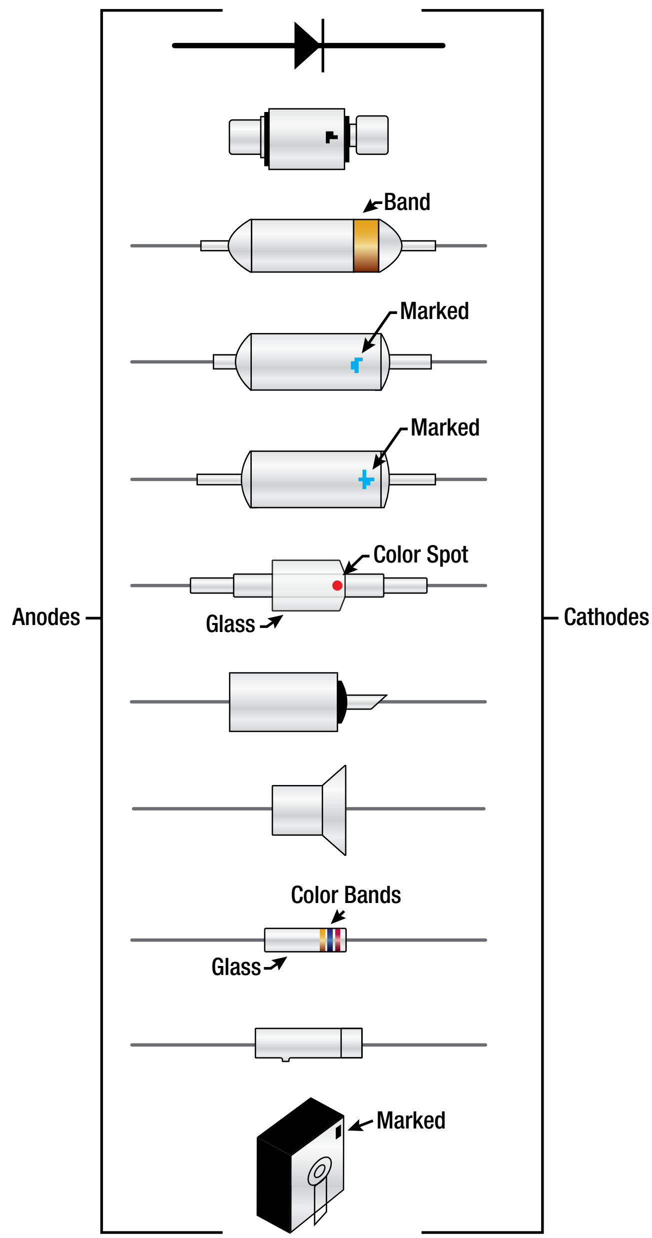


Figure 1-5. Semiconductor Diode Markings.

Diodes connected in series provide a constant DC voltage across the diode combination. The output voltage across the diodes remains constant in spite of changes to the load current or changes to the supply voltage. Thus, series combinations of diodes can be used to create voltage regulator circuits. As shown in **Figure 1-7**, the individual voltage drops across each diode are subtracted from the supply voltage to result in a predetermined voltage potential across the load resistor. By adding more diodes in series, the voltage is reduced further. The load resistor can also be placed in parallel with the diode stack providing a constant regulated voltage source, as such as shown on the right, where three silicon diodes in series each drop 0.7v which equals an output of 2.1v at RLOAD.

MATERIALS AND ELECTRON CONFIGURATION

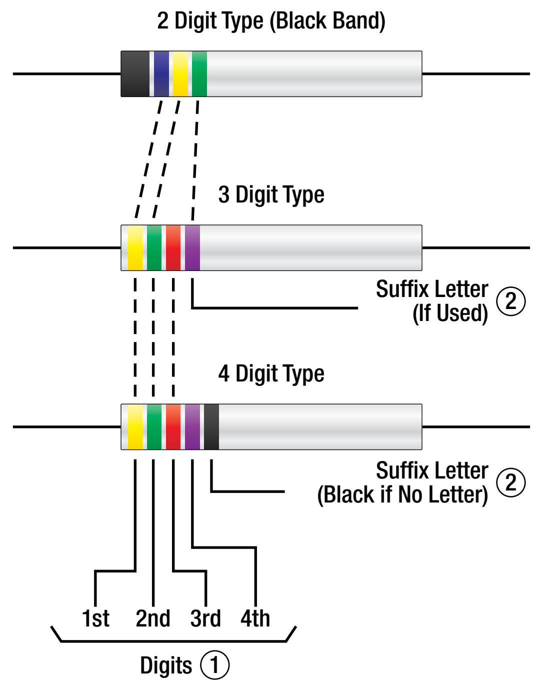
SEMICONDUCTOR MATERIALS

The periodic table, shown in **Figure 1-8**, is a tabular arrangement of the elements, organized on the basis of their atomic number (number of protons in the nucleus), electron configurations, and recurring chemical properties. Elements are presented in order of increasing atomic number, which is typically listed with the chemical symbol in each box.

Elemental semiconductors, known as metalloids on the periodic table, are made from a group of materials having electrical conductivities that lie between metal conductors and non-metal insulators. These group IV elements, such as Carbon (C), Silicon (Si), Germanium (Ge) etc., are known as elemental or single element semiconductors. Silicon is by far the most widely used material in semiconductor devices. Its combination of low raw material cost, relatively simple processing, and a useful temperature range make it ideal for use among many applications. Germanium was widely used early on; however, its thermal sensitivity makes it less useful than silicon. Germanium is often combined with silicon to make Silicon Germanium (SiGe) devices. In addition, Silicon is often combined with Carbon to form Silicon Carbide (SiC) devices for high power and high temperature applications.

Compound semiconductors do not appear in nature, but are synthesized using two or more elements from groups II through VI of the periodic table. Compound semiconductors that can be synthesized using elements from 3rd and 5th group of the periodic table include Gallium Arsenide (GaAs), Gallium Phosphide (GaP), Gallium Nitride (GaN), Gallium Aluminum Arsenide (GaAlAs), Indium Phosphorus (InP), and Indium Antimony (InSb). The color of light that emits from a Light Emitting Diode (LED) depends on which of these compounds are used.

Compound semiconductors that are synthesized using elements from 2nd and 6th group include Cadmium Selenium (CdSe), Cadmium Tellurium (CdTe), Cadmium Mercury Tellurium (CdHgTe), and Zinc Sulfer (ZnS). Light detectors, such as photocells, are typically made from InSb or CdSe compounds. Any combination of elements, such as zinc, cadmium, boron, aluminum, gallium, indium, carbon, silicon, germanium, tin, phosphorous, arsenic, antimony, sulfur, selenium, and tellurium, can be formed in to compound semiconductors with various properties.



Color	① Digit	② Diode Suffix Letter
Black	0	-
Brown	1	A
Red	2	B
Orange	3	C
Yellow	4	D
Green	5	E
Blue	6	F
Violet	7	G
Gray	8	H
White	9	J
Silver	-	-
Gold	-	-
None	-	-

Figure 1-6. Semiconductor diode color code system.

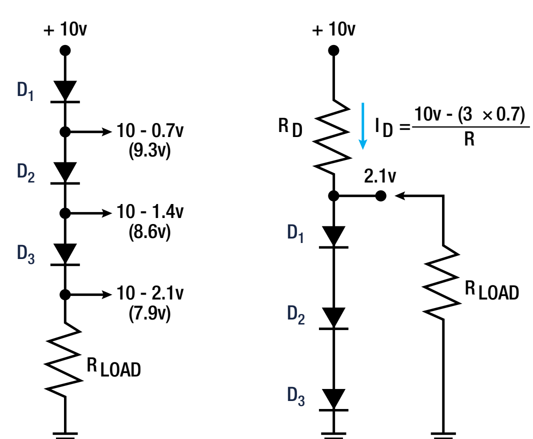


Figure 1-7. Diodes in series create a regulated voltage source.

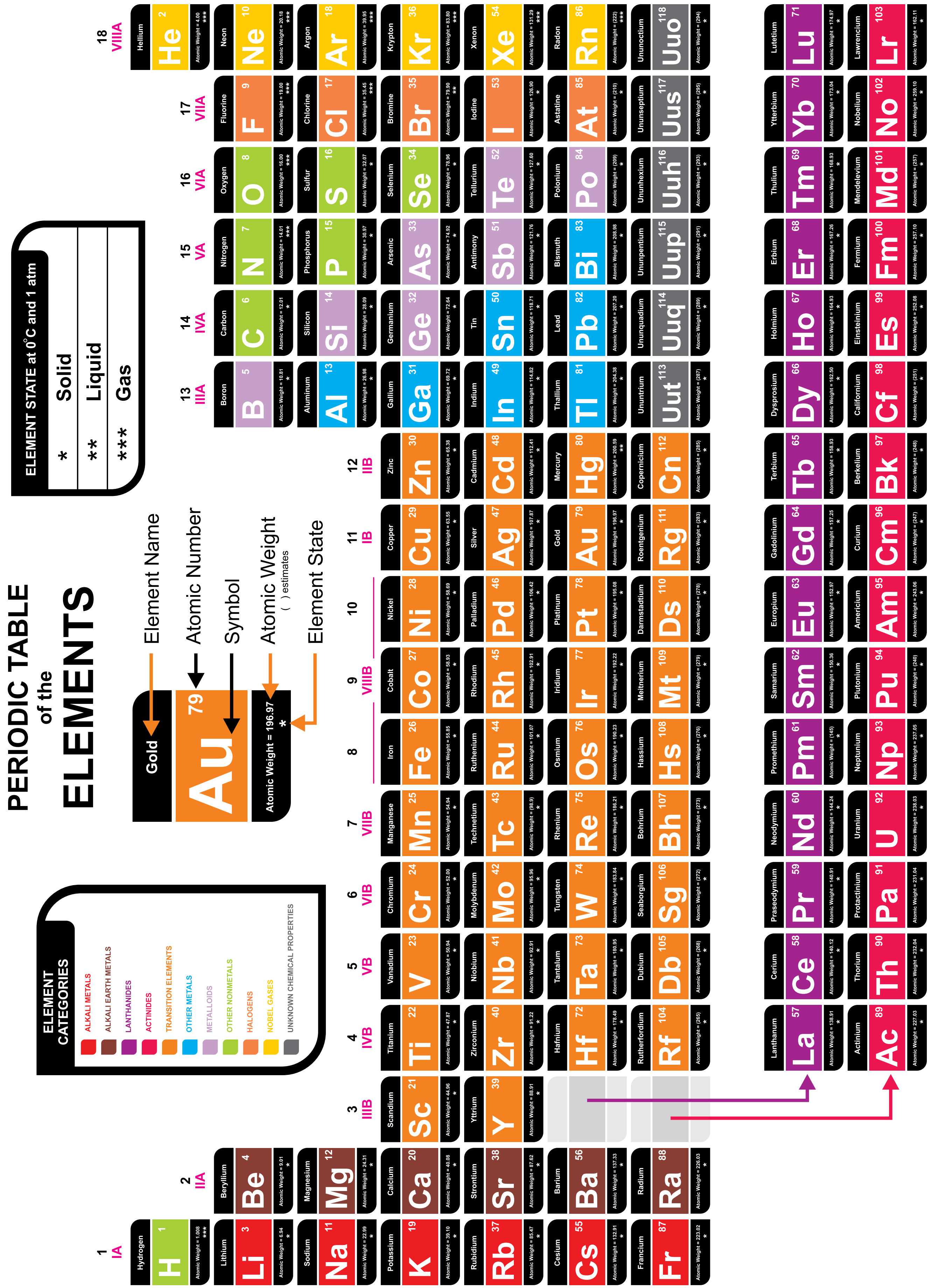


Figure 1-8. Periodic table of elements.