<u>Circuit Grounds and Grounding Practices</u>

George Hunka

Undergraduate Laboratory, Dept. of EE

University of Pennsylvania

Contents

<u>List of Figures</u>

Figure

Circuit Grounds and Grounding Practices

I Introduction

This note attempts to clarify what is meant when the term "ground" is used in speaking of electrical circuits. Specifically the term refers to a current return path through the earth. Unfortunately, it has been loosely used to represent any type of current return path to an energy source.

One of the first electrical symbols that students of electricity are introduced to is the symbol for "ground", shown in Figure 1.

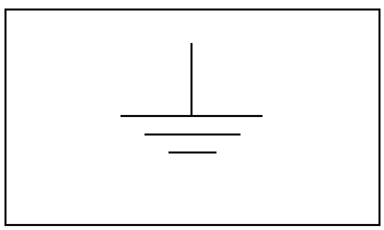


Figure 1 The Symbol for Earth Ground

This symbol represents a current return path through the earth to the low potential (voltage) side of an energy source. Frequently, however, it is used in electronic schematic drawings to indicate a current return such as a wire. In many cases it is used interchangeably with other symbols which, as we will see, are available to indicate specific returns. In any event, this use of the ground symbol can cause some confusion to the beginning student since many instruments provide an earth ground terminal.

II The Concept of "Earth" Ground

Early developers of electrical systems theorized that the earth was an electrically neutral body, i.e. an equal number of negative and positive charges are distributed throughout the earth at any given time. Being electrically neutral, earth is considered to be at zero potential and establishes a convenient reference frame for voltage measurements. Noting that voltmeters read only the difference in potential between two points, absolute measurements can be made by using earth as a reference.

A true earth ground, as defined by the National Electrical Code, physically consists of a conductive pipe or rod driven into the earth to a minimum depth of 8 feet.

Figure 2 shows this concept, where the earth is used as the conductive current return path to the lowest potential point of the generating system.

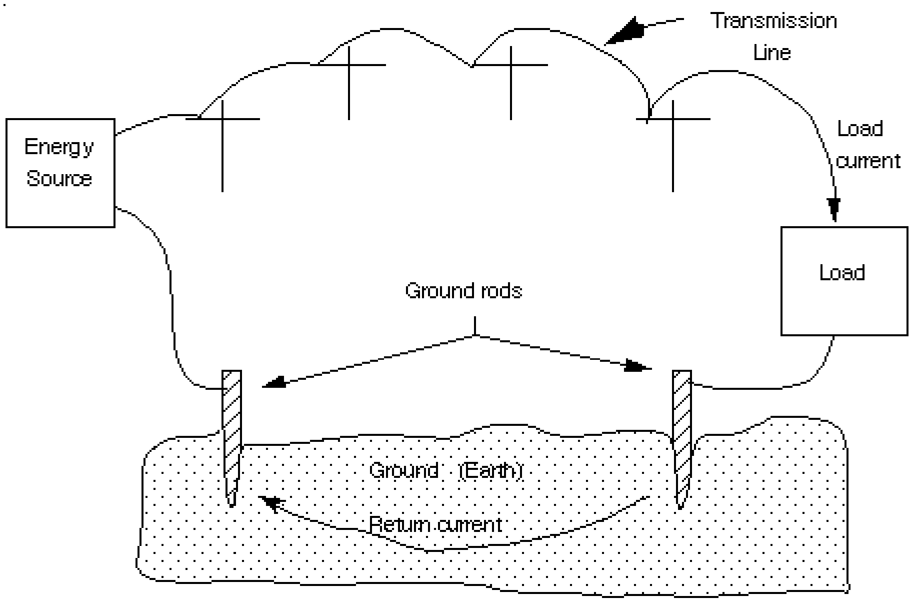


Figure 2 A Transmission System Using Ground as a Current Return Path

III <u>An Illustration of a Typical Power Supply Grounding Error</u>

As previously pointed out, the ground symbol, in many cases, has been taken as a generic symbol in electronic circuit diagrams to represent the current return path, even though no physical earth ground is used. This can cause some confusion to the novice engineering student when using instruments having an earth ground terminal. As an example, Figure 3 shows the front panel of a typical power supply. The supply is represented as a variable voltage battery. Note that three terminals are shown: a positive, a negative, and a ground terminal. The ground terminal of the supply is tied to the case of the instrument, which in turn is wired to a true earth ground such as a water pipe.

Let's look at the load connection in Figure 3. <u>Using the positive terminal of the battery and the ground terminal does not complete a current return path to the energy source (battery), so no current will flow from the source, i.e.</u>

$I_{load} = 0$.

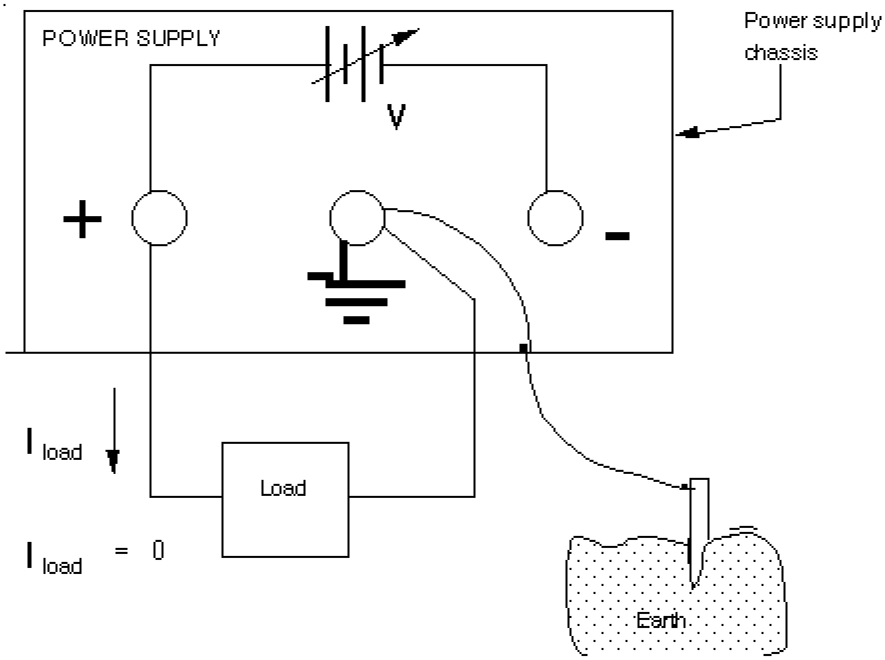
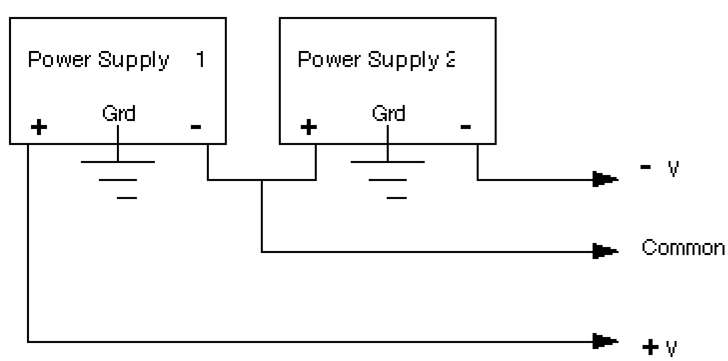


Figure 3 A Common Power Supply Grounding Error

The positive and negative terminals must be used to have a return path exist. Use of the ground terminal will be discussed in a following section.

Many circuits require both positive and negative voltages. A power supply must be used to provide each polarity. The supply for positive voltage will have the negative terminal as a return, and the negative supply will have the positive terminal as the return. These two terminals are connected together, forming a common return path for load current. Figure 4 shows

the proper connections for these supplies to provide positive and negative



voltages.

Figure 4 Power Supply Configuration for Dual Polarity Voltages

Although it may be shown as a ground in the circuit diagram, the connection between the negative and positive terminals of the supplies results in a common, or floating, return. If students feel that they must faithfully adhere to the circuit diagram, the floating common may be connected to the earth ground terminal of the supply. Generally, it will neither help nor hinder circuit performance.

IV Some Examples of Current Return Path Symbols

A current return path to an energy source is not necessarily, and frequently isn't, earth ground. It can be a simple wire or a metal chassis or enclosure on which the circuit is mounted. Because the return is the point of lowest potential for all these cases, it is a convenient reference for circuit voltage measurements.

Figures 5a, 5b, and 5c illustrate the symbols commonly used to represent the power supply common (a direct wire connection to the negative supply terminal) or floating return, the chassis ground, and earth ground returns, respectively. When more that one ground is required, the schematic circuit diagram will generally define the meaning of each symbol.

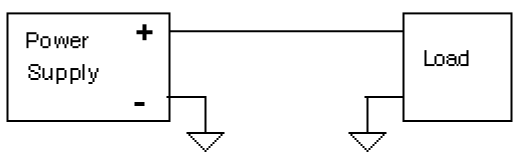


Figure 5a Common (Floating) Return

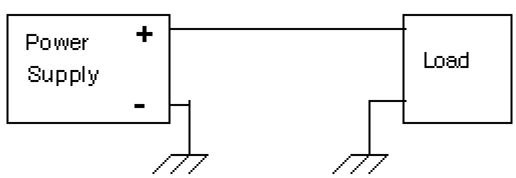


Figure 5b Chassis Return

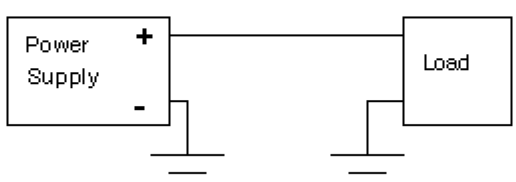


Figure 5c Ground Return

V Shock Hazard Protection Using Earth Ground

In instances where high voltages are required and chassis grounds or metal frames are used as return paths, hazardous conditions can be created if earth grounds are neglected. When the load circuit uses a metal enclosure as a chassis ground, resistive leakage or "sneak" paths can exist which result in high voltages between the enclosure and earth ground. (Leakage is any unsuspected, unwanted resistive path between two points.) If, inadvertently, a earth-grounded object, such as a water pipe, and the enclosure are simultaneously touched, a serious shock will result. Such a condition is illustrated in Figure 6.

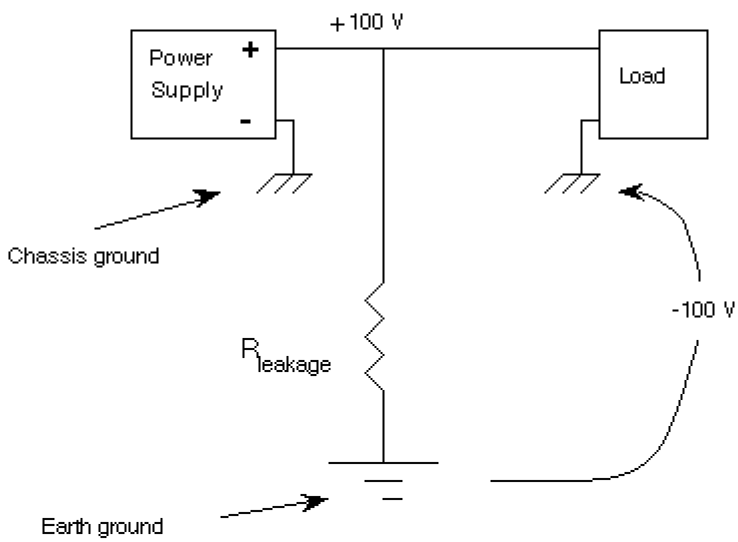


Figure 6 A Shock Hazard Created by a Leakage Path

In Figure 7, the earth ground is connected to the load enclosure, placing the water pipe and the enclosure at the same potential, eliminating the shock hazard. Similar hazardous conditions can develop in the installation of household appliances. This is the reason that electrical codes require that appliance frames such as washers and dryers be connected to earth ground.

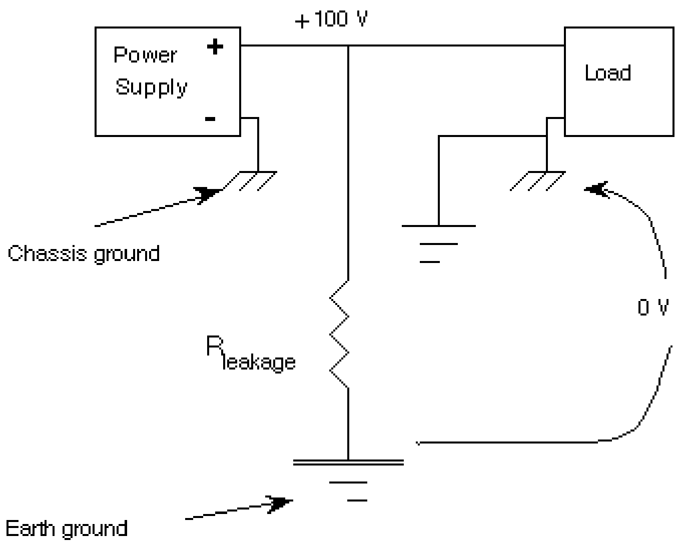


Figure 7 Using Earth Ground to Eliminate a Shock Hazard

VI **<u>Grounding Considerations</u>**

The most common noise problem encountered in large scale electronic systems stems from a lack of good grounding practice. Grounding is a major concern to practicing design and systems engineers. An extensive body of literature has been published on these subjects. While it is beyond the scope of this note to go into great depth, we will mention some basic practices to avoid grounding problems in your circuits.

If several points are used for ground connections, differences in potential between the points can cause troublesome "ground loops" which will cause errors in voltage readings. This is illustrated in Figure 8, where two separated chassis grounds are used. Vg represents a voltage existing between signal ground and the load ground. If voltage measurements are made between the load ground and the input signal, Vs,

an erroneous voltage, (Vs + Vg) will be indicated.

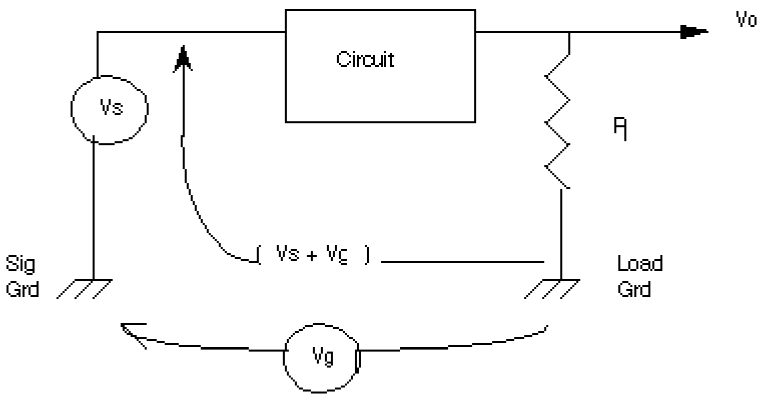


Figure 8 Generation of Ground Loops

A common sign that a ground loop(s) exists, or that a ground is missing, is the presence of induced power line (60 Hz) noise in the circuit.

Finding and eliminating troublesome ground loops in complex electronic systems can be a difficult and frustrating task; it requires an expertise gained largely through experience. This is why grounding, in many cases, is referred to as a " black magic art ".

VII Basic Grounding Practices

a. Circuit Grounding

The ideal " single point ground " concept insures that no ground loops are created. As the name implies, all circuit grounds are returned to a common point. This concept is shown in Figure 9.

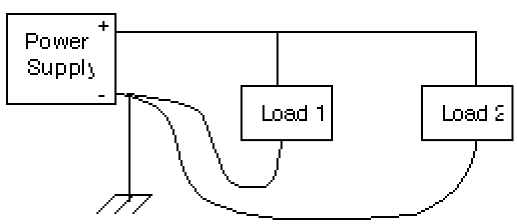


Figure 9 The Concept of " Single Point Ground "

While this approach looks good on paper, it is usually not practical. Even the simplest circuits can have 10 or more grounds, and connecting them at a common point becomes a physical challenge. The next best thing is a ground bus.

b. Ground Bus

Bus bars are available or can be constructed to serve as an adequate substitute for single point ground. The bus bar is simply a heavy wire or copper bar of low resistance which can carry the maximum sum total of the load current back to the power supply. The bus can be extended along the length of the circuitry so that convenient connections can be made at various points. The use of a ground bus is shown in Figure 10.

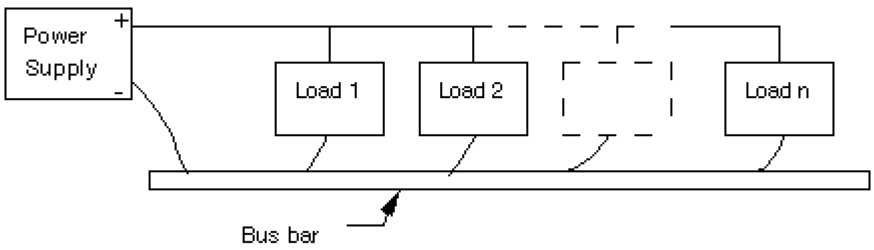


Figure 10 Bus Bar Return

c. Grounding Practice for Protoboards

Most protoboards provide 2 or 3 lines of connected terminals extending along the length of the board. One of these continuous strips should be dedicated as a circuit ground bus. All circuit grounds should be tied directly to this bus. A word of caution - with use, terminal contacts on the board can spread apart to the extent that intermittent contact may be made with an inserted wire. This could appear as noise in the circuit. Care should be taken that a good contact is made to the ground bus.

d. Analog/Digital Grounds

In general, analog and digital grounds should be kept separated and connected together only at one single point.