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Diodes as Ionizing Radiation Detectors and Temperature Measurements

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Abstract – From the Shockley ideal diode equation it might appear that the voltage has a positive temperature coefficient (at a constant current), but usually the variation of thereverse saturation current term is more significant than the variation in the thermal voltage term. Most diodes therefore have a negative temperature coefficient, typically −2 mV/˚C for silicon diodes at room temperature. This is approximately linear for temperatures above about 20 kelvins. Some graphs are given for: 1N400x series, and CY7 cryogenic temperature sensor. In electronics, cosmic rays and other sources of ionizing radiation cause noise pulses and single and multiple bit errors. This effect is sometimes exploited by particle detectors to detect radiation. A single particle of radiation, with thousands or millions of electron volts of energy, generates many charge carrier pairs, as its energy is deposited in the semiconductor material. If the depletion layer is large enough to catch the whole shower or to stop a heavy particle, a fairly accurate measurement of the particle's energy can be made, simply by measuring the charge conducted and without the complexity of a magnetic spectrometer, etc. These semiconductor radiation detectors need efficient and uniform charge collection and low leakage current.

Key words: coefficient, linear, ionizing radiation, semiconductor, magnetic spectrometer

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CONTEXT

Voltage is associated with any two points in the circuit, and represents the difference in electrical potential between those points. Stated differently, voltage is the electric force that causes electrons to flow in a circuit. Voltage is defined as a relative quantity. In a typical digital circuit, the lowest possible voltage is called ground and is arbitrarily assigned 0 volts. In most existing digital circuits, the highest possible voltage value is defined not to exceed 5.5 volts (industry is starting to move toward a 3.3-volt power supply). In digital systems, we assign logic 1 to "high" voltages and 0 to "low" voltages, but these assignments are somewhat arbitrary. For TTL technology of the kinds described in this book, a voltage in the range of 0 to 0.4 volts is interpreted as logic 0, while 2.5 to 5.5 volts is interpreted as a logic 1. Voltages outside these ranges are not guaranteed to be interpreted as either a 0 or a 1.

The fundamental concepts of electricity can often be described by analogy with water. The greater the electrical potential, the larger the voltage, and the greater the force on the flow of the charge-carrying electrons. Think of a waterfall. A large voltage corresponds to a waterfall of great height. As a water molecule flows "downhill," a good deal of pressure is exerted on it by gravity and the force of water behind it. By analogy, water molecules correspond to electrons and electrical current corresponds to the speed of the water flow.

REVIEW OF LITERATURE:

Digital hardware systems can be viewed from many alternative perspectives, including Boolean logic, logic gates, and behavioral specifications. For most of this book, the most primitive abstraction we use is the logic gate. In this appendix, we peek beneath the sheets to get some idea of how logic gates are actually implemented by more primitive electrical components.

We begin by reviewing briefly the concepts of electricity that influence the fundamental operation of logic gates. Digital hardware systems can be viewed from many alternative perspectives, including Boolean logic, logic gates, and behavioral specifications. For most of this book, the most primitive abstraction we use is the logic gate. In this appendix, we peek beneath the sheets to get some idea of how logic gates are actually implemented by more primitive electrical components. We begin by reviewing briefly the concepts of electricity that influence the fundamental operation of logic gates. We will also examine the basic implementation technologies from which logic gates are constructed, such as diodes, capacitors, resistors, bipolar transistors, and MOS transistors.

MATERIAL AND METHOD:

In this section diodes were studied as, semiconductor diodes sensitive to more energetic radiation. In electronics, cosmic rays and other sources of ionizing radiation cause noise pulses and single and multiple bit errors. This effect is sometimes exploited by particle detectors to detect radiation. A single particle of radiation, with thousands or millions of electron volts of energy, generates many charge carrier pairs, as its energy is deposited in the semiconductor material. If the depletion layer is large enough to catch the whole shower or to stop a heavy particle, a fairly accurate measurement of the particle's energy can be made, simply by measuring the charge conducted and without the complexity of a magnetic spectrometer, etc. These semiconductor radiation detectors need efficient and uniform charge collection and low leakage current. They are often cooled by liquid nitrogen. For longer-range (about a centimetre) particles, they need a very large depletion depth and large area. For short-range particles, they need any contact or un-depleted semiconductor on at least one surface to be very thin. The back-bias voltages are near breakdown (around a thousand volts per centimetre). Germanium and silicon are common materials. Some of these detectors sense position as well as energy. They have a finite life, especially when detecting heavy particles, because of radiation damage. Silicon and germanium are quite different in their ability to convert gamma rays to electron showers. Semiconductor detectors for high-energy particles are used in large numbers. Because of energy loss fluctuations, accurate measurement of the energy deposited is of less use.

TEMPERATURE MEASUREMENTS

A diode can be used as a temperature measuring device, since the forward voltage drop across the diode depends on temperature, as in a silicon bandgap temperature sensor. From the Shockley ideal diode equation it might *appear* that the voltage has a *positive* temperature coefficient (at a constant current), but usually the variation of thereverse saturation current term is more significant than the variation in the thermal voltage term. Most diodes therefore have a *negative* temperature coefficient, typically −2 mV/˚C for silicon diodes at room temperature. This is approximately linear for temperatures above about 20 kelvins. Some graphs are given for: 1N400x series, and CY7 cryogenic temperature sensor.

CONCLUSION:

An electrical device that can switch between low resistance and very high resistance is called a transistor. A transistor is a three-terminal device that establishes a low-resistance path between two terminals when a high voltage is placed on the third terminal. When a low voltage is placed on this control terminal, the remaining two terminals are separated by a high resistance. If *R*2 is replaced by a transistor, it's easy to see that we obtain an inverter. When the input voltage is high, the output voltage is low. When it is low, the output voltage is high. But before we can examine transistors in more detail, we need to take a look at a simpler, two-terminal device: the diode. A diode is a two-terminal electrical device that allows current to flow in one direction but not the other. It is like a pipe with an internal valve that allows water to flow freely in one direction but shuts down if the water tries to flow backward.

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