Foundations of Practical Electronics
An Intuition-Driven Guide to Circuits and Systems

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Preface

Written as a personal technical reference and learning companion. Designed to allow rapid re-entry into circuit design after time away, and to serve as an intuitive introduction for motivated beginners.

This document does not at this time attempt to cover RF design, high-speed PCB layout, or integrated circuit design. These topics are intentionally excluded in favor of foundational circuit-level understanding. This document describes digital electronics concepts, unless analog behavior is specifically noted.

Familiarity with basic algebra is assumed. Calculus is not required. Prior exposure to Ohm's law, discrete mathematics, or basic logic gates may be beneficial, but all required concepts are introduced as needed.

Emphasis is placed on physical intuition, failure modes, and mental models rather than formal derivations. Mathematical rigor is introduced as optional material only where it directly supports understanding.

All circuits are assumed to operate at low voltages. Readers are responsible for safe practices when working with electricity.

This is an early, evolving technical manuscript.

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Thinking Discretely

We will begin by clarifying a common misconception. Discrete is defined as being separate, distinct, or individual, while discreet implies prudence and being careful.

Binary

In practical electronics work, electrical states are treated as discrete values. That is to say, its behavior is abstracted into separate states. Once a signal crosses a defined threshold the circuit is interpreted as being on, or off. Although voltages are continuous, Intermediate values are ignored, this abstraction is the basis of digital electronics. Operating on continuous values would describe analog behavior which is beyond the scope of this document.

As a simplified example, assume a threshold of 0v. All voltages above this level are considered to be logic high, while any voltage below zero is interpreted as logic low.

These HI/LO states are also represented as 1's and 0's. This forms the foundation of binary code, and describes the action of a digital signal.

Logic Gates

Logic gates operate on logical states, HI/LO, 1/0, not on voltages.

Each logic gate performs a specific Boolean operation which deterministically maps input states to an output state.

Output states are determined only by the current input state, past input values have no impact on output.

The output of one logic gate may be connected to the input of another, allowing for complex functions to be constructed.

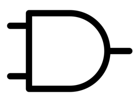
Every input must be satisfied, undefined inputs (not connected to anything) do not represent valid logical states.

Below, the three simplest logic gates and their behavior are listed.

AND

AND, also referred to as conjunction, is a logical operator which accepts at least two inputs, and outputs TRUE only when both inputs are TRUE.

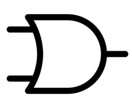
It can be represented graphically as follows.



OR

OR, also referred to as disjunction, is a logical operator which accepts at least two inputs, and outputs TRUE when at least one input is TRUE.

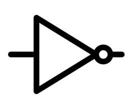
It can be represented graphically as follows.



NOT

NOT, also referred to as negation, is a logical operator which accepts at least one input, and outputs the opposite of the input.

It can be represented graphically as follows.



Truth Tables

The behavior of any given logic gate is defined by its truth table. Truth tables are logical tools which list every possible combination of input variables, and are used to determine their outputs. Truth tables value lay in their ability to determine the logical validity of a given logical argument.

The Truth tables for AND, OR, and NOT gates are given below

AND				OR				NOT	
INPUT		|OUTPUT		INPUT		|OUTPUT		INPUT|OUTPUT	
0	0	0		0	0	0		0	1
0	1	0		0	1	1		1	0
1	0	0		1	0	1			
1	1	1		1	1	1			

Boolean Algebra

Boolean Algebra is a branch of mathematics and the fundamental logical operators, AND, OR, and NOT can be written symbolically as $\wedge$, $\vee$, and, ¬ (or alternatively, ~)

These are used to create logical expressions which can be manipulated, and simplified by applying various laws, just as in traditional algebra.

Boolean expressions provide a symbolic, mathematical description of logical behavior.

This section will be expanded on in later versions of this document.

Reading and Thinking in Schematics

Electronic circuits are rarely simple enough to construct directly by placing components on perfboard without prior planning. As a result, circuits are often first modeled at higher levels of abstraction based on their intended logical behavior.

An important conceptual link to establish is that Boolean expressions describe the mathematical behavior of a given circuit, while schematics provide a graphical depiction of that same behavior.

In decreasing levels of abstraction, these diagram types are as follows.

Logic Diagrams (Abstract)

This section will be expanded on in later versions of this document.

Electronic Schematics (Physical reality)

This section will be expanded on in later versions of this document.

The Non-Negotiable Laws of Circuits

Ohm's Law

Ohm's law consists of three simple formulas which describe the fundamental relationships between voltage (V), current(I), and resistance(R) in a circuit.

V = I × R

I = V÷ R

R = V÷ I

The relationship between these three characteristics of electricity is somewhat analogous to water in a pipe. Voltage can be thought of as the water pressure, current as the flow rate, and resistance as the diameter of the pipe (resistance to flow).

Kirchhoff's Current Law (Nodes)

KCL, also known as the Junction Rule, states that the total current entering a junction, also called a node, must equal the total current leaving it. The key takeaway is that charge must be conserved, current is not simply lost at a connection point, it splits or combines.

Kirchhoff’s Voltage Law (Loops)

KVL states that if you start at a point in a circuit, travel around a closed loop and return to the starting point, the total change in voltage must be zero. By the time the entire circuit is traced there must be the same amount of energy. Energy can not appear nor disappear arbitrarily. Any rise or fall in voltage must be accounted for by an energy source or sink somewhere in the circuit.

Kirchhoff’s laws essentially affirm conservation of energy.

Fundamental Components

Resistors

Diodes

Transistors

MOSFETs

Power Distribution

This section will be expanded on in later versions of this document.

Signals, Time, and Noise

This section will be expanded on in later versions of this document.

Measurement and Debugging

Common Failure Modes and Lessons Learned

This section will be expanded on in later versions of this document.

Appendix

Image Attributions

AND Gate Symbol - Logic gates icon by *joalfa,*Flaticon

OR Gate Symbol - Logic gates icon by *joalfa,*Flaticon

NOT Gate Symbol - Logic gates icon by *joalfa,*Flaticon

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