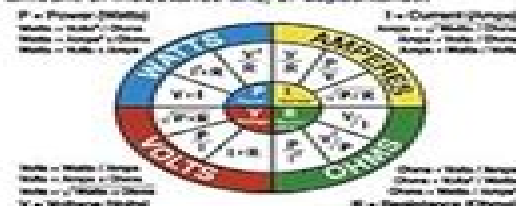


### NEUTRAL & GROUNDED CONDUCTORS (NEC Article 90; Article 200; Article 300)

#### OHM'S LAW & POWER FORMULAS

Ohm's law and the power formula are limited to circuits in which electrical resistance is the only significant opposition to current flow, including all DC circuits and AC circuits that do not contain a significant amount of inductance and/or capacitance.



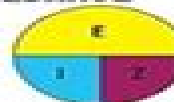
#### OHM'S LAW DIAGRAM & FORMULAS

**Voltage** = Current x Resistance  
 $E = I \times R$   
**Current** = Voltage ÷ Resistance  
 $I = E \div R$   
**Resistance** = Voltage ÷ Current  
 $R = E \div I$



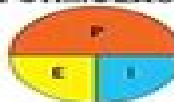
#### OHM'S LAW & IMPEDANCE

**Voltage** = Current x Impedance  
 $E = I \times Z$   
**Current** = Voltage ÷ Impedance  
 $I = E \div Z$   
**Impedance** = Voltage ÷ Current  
 $Z = E \div I$   
 $E$  = Voltage (in volts)  $I$  = Current (in amperes)  
 $Z$  = Impedance (in Ohms)



#### POWER DIAGRAM & FORMULAS

**Power** = Current x Voltage  
 $P = I \times E$   
**Voltage** = Power ÷ Current  
 $E = P \div I$   
**Current** = Power ÷ Voltage  
 $I = P \div E$



#### NUMBER OF CONDUCTORS — BOX FILL CALCULATIONS (Based on 314.16)

- Boxes and conduit bodies must be of an approved size to provide free space for all enclosed conductors.
- In no case must the volume of the box, as calculated in 314.16(A), be less than the fill calculation.
- Each conductor that originates outside the box and terminates or is spliced within the box must be counted once.
- Each conductor that passes through the box without splice or termination must be counted as one.
- Each loop or coil of unbroken conductor not less than twice the minimum length required for free conductors in 300.34 must be counted as twice.

#### NEUTRAL CONDUCTORS (Based on 200.4(A)(3)(2))

- Neutral conductors must be installed in accordance to:
- Neutral conductors must not be used for more than one branch circuit, for more than one multiwire branch circuit, or for more than one set of ungrounded feeder conductors.
- Where more than one neutral conductor associated with different circuits is in an enclosure, grounded circuit conductors of each circuit must be identified or grouped to correspond with the ungrounded circuit conductor(s) by wire markers, cable ties or similar means in at least one location within the enclosure.

#### GROUNDED CONDUCTOR IDENTIFICATION (Based on 200.6(A)-(3))

Grounded Conductors Size 6 AWG or Smaller must be identified by their insulation through one of the following means:

- A continuous white outer finish
- A continuous gray outer finish
- 3 continuous white or gray stripes along its whole length on other than green insulation.
- Insulated conductors with their outer covering showing a white or gray color but with colored tracer threads in the braid to identify the source are acceptable for identification.
- The grounded conductor of a mineral insulated, metal-sheathed cable (Type MI) must be identified at the time of installation by distinctive marking at its terminations.
- A single-conductor, sunlight-resistant, outdoor rated cable used as a grounded conductor in photovoltaic power systems, identified as indicated above at all terminations.
- Fixture wire must comply with the requirements for grounded conductor identification as specified in 402.8.
- For aerial cable, the identification must be as above, or by means of a ridge located on the exterior of the cable so as to identify it.

Grounded Conductors Size 4 AWG or Larger must be identified in one of the following ways:

- A continuous white outer finish
- A continuous gray outer finish
- 3 continuous white or gray stripes along the entire length of the conductor on any but green insulation
- At installation, by a distinctive white or gray marking at its terminations. Marking must encircle the conductor or insulation.



Continuous White or Gray Finish



Three White or Gray Stripes on Anything but Green



Outer Coloring White or Gray With Colored Threads in Braid

200 AMP Service Entrance - From Utility Pole to Energy Meter

150 AMP Service Entrance & Feeder Wire - to Panel Box

100 AMP Service Entrance & Feeder Wire - to Panel Box

55 AMP Feeder & Large Appliance Wire

40 AMP Feeder & Large Appliance Wire

30 AMP Appliances such as Dryer, Air Conditioning, Water Heater

20 AMP Appliances such as Laundry, Bathroom & Kitchen Circuits

15 AMP General Lighting, Fans & Outlet / Receptacle Circuits

#### VOLUME ALLOWANCE REQUIRED PER CONDUCTOR (Based on NEC Table 314.16(B)(1))

SIZE OF CONDUCTOR (AWG)	FREE SPACE WITHIN BOX FOR EACH CONDUCTOR	
	cm <sup>3</sup>	in. <sup>3</sup>
18	24.6	1.50
16	28.7	1.75
14	32.8	2.00
12	36.9	2.25
10	41.0	2.50
8	49.2	3.00
6	81.9	5.00

#### TERMINAL IDENTIFICATION (Based on 200.10(B)(3))

Receptacles, polarized attachment plugs, and cord connectors for plugs and polarized plugs must have the terminal intended for connection to the grounded conductor identified as:

- Identification must be by a metal or metal coating that is substantially white or silver in color or by the word white or the letter W located adjacent to the identified terminal.
- If the terminal is not visible, the conductor entrance hole for the connection shall be colored white or marked with the word white or the letter W.

#### SINGLE-PHASE DWELLING SERVICES & FEEDERS (Based on 210.10)

- For a service rated 100 through 400 amperes, the service conductors supplying the entire load associated with a one-family dwelling, or the service conductors supplying the entire load associated with an individual dwelling unit in a two-family or multifamily dwelling, must be permitted to have an ampacity not less than 83% of the service rating. **Note:** This also applies to feeders.
- In no case must a feeder for an individual dwelling unit be required to have an ampacity greater than that specified above.
- Grounded conductors must be permitted to be sized smaller than the ungrounded conductors, if the requirements of 220.61 and 220.42 for service conductors or the requirements of 215.2 and 220.61 for feeder conductors are met.

#### GROUNDED CONDUCTORS OF DIFFERENT SYSTEMS — IDENTIFICATION (Based on 200.6(D))

- Where grounded conductors of different nominal voltage systems are installed in the same raceway, cable, box or auxiliary gutter or other type of enclosure, each grounded conductor must be identified by nominal voltage system.
- Identification that distinguishes each system grounded conductor must be permitted by one of the following means:
  - One nominal voltage system grounded conductor must have an outer covering conforming to 200.6 (A) or (B).
  - The grounded conductor of other systems must have different outer coverings conforming to 200.6 (A) or 200.6 (B) or by an outer covering of white or gray with a readily distinguishable colored stripe other than green running along the insulation.

#### ALTERNATING-CURRENT SYSTEMS (Based on NEC 250.26)

TYPE OF SYSTEM	CONDUCTOR TO BE GROUNDED
Single Phase, 2 Wire	one conductor
Single Phase, 3 Wire	the neutral conductor
Multiphase systems having a common wire to all phases	the neutral conductor
Multiphase system where one phase is grounded	that phase conductor
Multiphase systems in which one phase is used as a single phase, 3-wire	the neutral conductor

# Electrical Systems Based On The 2005 Nec National Electrical Code

**H. Brooke Stauffer**



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**Engineer's Guide to the National Electrical Code** H. Brooke Stauffer, 2008 This informative introduction to the NEC provides electrical engineers both professionals and students with invaluable insight to customary building codes Written by the Executive Director of Standards and Safety of the NECA H Brooke Stauffer offers a comprehensive description of the NEC and commonly encountered building codes when designing a building's electrical subsystems The Engineer's Guide to the National Electrical Code steers beginning electrical engineers through the complex regulations of the NEC in a clear and accessible way

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**Electrical Systems Based on the 2011 NEC National**

**Electrical Code** Michael I. Callanan, Bill Wusinich, 2011 *Electrical Systems* is designed for use by journeyman and master electricians, inspectors, contractors, and others in the electrical trade. This authoritative textbook is recognized in the industry for providing a comprehensive overview of the National Electrical Code. Concise text and descriptive illustrations cover the Code and its application to wiring methods and materials, conductors, and overcurrent protection devices, branch circuits, and feeders, grounding, transformers, services, special locations, calculations, and more. Important changes in the 2011 NEC are covered throughout. Trade knowledge gained in the field is conveyed in concise text and full color illustrations for quick understanding.

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**Industrial Power Systems** Shoaib Khan, Sheeba Khan, Ghariani Ahmed, 2018-10-03 The modernization of industrial power systems has been stifled by industry's acceptance of extremely outdated practices. Industry is hesitant to depart from power system design practices influenced by the economic concerns and technology of the post World War II period. In order to break free of outdated techniques and ensure product quality and continuity of operations, engineers must apply novel techniques to plan, design, and implement electrical power systems. Based on the author's 40 years of experience in industry, *Industrial Power Systems* illustrates the importance of reliable power systems and provides engineers the tools to plan, design, and implement one. Using materials from IEEE courses developed for practicing engineers, the book covers relevant engineering features and modern design procedures, including power system studies, grounding, instrument transformers, and medium voltage motors. The author provides a number of practical tables, including IEEE and European standards and design principles for industrial applications. Long overdue, *Industrial Power Systems* provides power engineers with a blueprint for designing electrical systems that will provide continuously available electric power at the quality and quantity needed to maintain operations and standards of production.

*National Association of Broadcasters Engineering Handbook* Graham A. Jones, David H. Layer, Thomas G. Osenkowsky, 2013-04-26 The NAB Engineering Handbook provides detailed information on virtually every aspect of the broadcast chain, from news gathering, program production, and postproduction through master control and distribution links to transmission, antennas, RF propagation, cable, and satellite. Hot topics covered include HD Radio, HDTV, 2 GHz broadcast, auxiliary services, EAS workflow, metadata, digital asset management, advanced video, and audio compression, audio and video over IP, and Internet broadcasting. A wide range of related topics that engineers and managers need to understand are also covered, including broadcast administration, FCC practices, technical

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*Photovoltaic Systems Engineering, Third Edition* Roger A. Messenger, Amir Abtahi, 2010-02-26 The U S Department of Energy now estimates a factor of 14 increase in grid connected systems between 2009 and 2017 depending upon various factors such as incentives for renewables and availability and price of conventional fuels With this fact in mind Photovoltaic Systems Engineering Third Edition presents a comprehensive engineering basis for photovoltaic PV system design so engineers can understand the what why and how associated with the electrical mechanical economic and aesthetic aspects of PV system design Building on the popularity of the first two editions esteemed authors Roger Messenger and Jerry Ventre explore the significant growth and new ideas in the PV industry They integrate their experience in system design and installation gained since publication of the last edition Intellectual tools to help engineers and students to understand new technologies and ideas in this rapidly evolving field The book educates about the design of PV systems so that when engineering judgment is needed the engineer can make intelligent decisions based on a clear understanding of the parameters involved This goal differentiates this textbook from the many design and installation manuals that train the reader how to make design decisions but not why The authors explain why a PV design is executed a certain way and how the design process is actually implemented In exploring these ideas this cutting edge book presents An updated background of energy production and consumption Mathematical background for understanding energy supply and demand A summary of the solar spectrum how to locate the sun and how to optimize the capture of its energy Analysis of the components used in PV systems Also useful for students the text is full of additional practical considerations added to the theoretical background associated with mechanical and structural design A modified top down approach organizes the material to quickly cover the building blocks of the PV system The focus is on adjusting the parameters of PV systems to optimize performance The last two chapters present the physical basis of PV cell operation and optimization Presenting new problems based upon contemporary technology this book covers a wide range of topics including chemistry circuit analysis electronics solid state device theory and economics this book will become a relied upon addition to any engineer s library

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reference for professionals      **Energy-Efficient Electrical Systems for Buildings** Moncef Krarti, 2017-03-03 Energy Efficient Electrical Systems for Buildings offers a systematic and practical analysis and design approaches for electrical distribution and utilization systems in buildings In addition to meeting the minimal safety requirements set by the National Electrical Code NEC the design approach consider the life cycle cost analysis of designing energy efficient electrical distribution systems as well as integrating renewable energy technologies into both residential and commercial buildings The book first provides a general overview of basic power systems commonly available in buildings Then detailed discussions of various components of typical building electrical distribution system are outlined through several chapters including transformers protection devices conductors and conduits power and lighting panels and motor control centers The book includes several illustrations and numerous examples and analysis exercises are included along with detailed design examples      *Transmission, Distribution, and Renewable Energy Generation Power Equipment* Bella H. Chudnovsky, 2017-03-07 The revised edition presents extends and updates a thorough analysis of the factors that cause and accelerate the aging of conductive and insulating materials of which transmission and distribution electrical apparatus is made New sections in the second edition summarize the issues of the aging reliability and safety of electrical apparatus as well as supporting equipment in the field of generating renewable energy solar wind tide and wave power When exposed to atmospheric corrosive gases and fluids contaminants high and low temperatures vibrations and other internal and external impacts these systems deteriorate eventually the ability of the apparatus to function properly is destroyed In the modern world of green energy the equipment providing clean electrical energy needs to be properly maintained in order to prevent premature failure The book s purpose is to help find the proper ways to slow down the aging of electrical apparatus improve its performance and extend the life of power generation transmission and distribution equipment      **Contractor's Guide to the Building Code** Jack M. Hageman, 2008 Don t let your jobs be held up by failing code inspections Smooth sign off by the inspector is the goal but to make this ideal happen on your job site you need to understand the requirements of latest editions of the International Building Code and the International Residential Code Understanding what the codes require can be a real challenge This new completely revised Contractor s Guide to the Building Code cuts through the legalese of the code books It explains the important requirements for residential and light commercial structures in plain simple English so you can get it right the first time      NEC® 2008 Need to Know Kimberley Keller, 2008-07-01 Get Quick Access to the NEC Essentials Turn to NEC 2008 Need to Know for quick access to vital National Electrical Code NEC information that you need This expert resource explains and interprets key material from the first four chapters of the NEC including general installation requirements branch circuits feeders services overcurrent protection grounding conductors conduits cables fixture wiring switches receptacles lighting motors a c and refrigeration and generators plus critical tables from Chapter 9 Packed with on target illustrations this essential compliance tool contains calculations and formulas commonly used to

determine conduit and conductor sizes required ampacities adjustment multipliers and electrical loads This guide also presents a listing of specialty topics such as Emergency Systems Communications and Special Occupancy as well as a cross reference table with types of installations and where to find applicable Code Designed to save time and money reduce errors and increase safety NEC 2008 Need To Know features Clear explanations and interpretations of in demand NEC information Commonly used calculations and formulas A listing of specialty topics keyed to applicable Code A handy cross reference table for quick access to crucial material Inside This On the Job Guide to Vital NEC Information General Requirements for Electrical Installations Branch Circuits and Feeders Branch Circuit Feeders Service Calculations and Electric Services Overcurrent Protection and Transformers Grounding and Bonding Wiring Methods Conductors Boxes and Cablebus Lighting Requirements Motors Refrigeration and A C Generators Understanding and Applying NEC Chapter 9 Tables Code Locations and References for Additional Codes Appendixes

*2005 National Electrical Estimator* Edward J. Tyler, 2004-11 If you need to estimate the cost of electrical systems in buildings this book will be your most reliable guide to selecting the right material figuring the labor time required for installation and totaling the installation cost and material price Ed Tyler was named National Estimator of the Year by the American Society of Professional Estimators His depth and breadth of knowledge make him one of the nation s foremost authorities on electrical estimating Book jacket



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