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Introduction

Welcome to another course in the STEP 2000 series, **Siemens Technical Education Program**, designed to prepare our distributors to sell Siemens Energy & Automation products more effectively. This course covers **Load Centers** and related products.

Upon completion of **Load Centers** you should be able to:

- Explain the role of a load center in residential distribution
- Distinguish between the terms panelboard and load center
- Define a load center (panelboard) according to the *National Electrical Code*
- Explain the need for circuit protection
- Identify various components of a Siemens load center
- Distinguish between a main breaker and main lug only load center
- Identify various power supply systems used in residential applications
- Explain the use of load centers used as service-entrance equipment
- Describe the proper grounding techniques of service entrance and downstream panelboards
- Describe the proper use of GFCI circuit breakers in a load center
- Describe the proper use of the circuit breaker surge arrester in a load center
- Identify various ratings of Siemens load centers

This knowledge will help you better understand customer applications. In addition, you will be able to describe products to customers and determine important differences between products. You should complete **Basics of Electricity** and **Molded Case Circuit Breakers** before attempting **Load Centers**. An understanding of many of the concepts covered in **Basics of Electricity** and **Molded Case Circuit Breakers** is required for **Load Centers**.

If you are an employee of a Siemens Energy & Automation authorized distributor, fill out the final exam tear-out card and mail in the card. We will mail you a certificate of completion if you score a passing grade. Good luck with your efforts.

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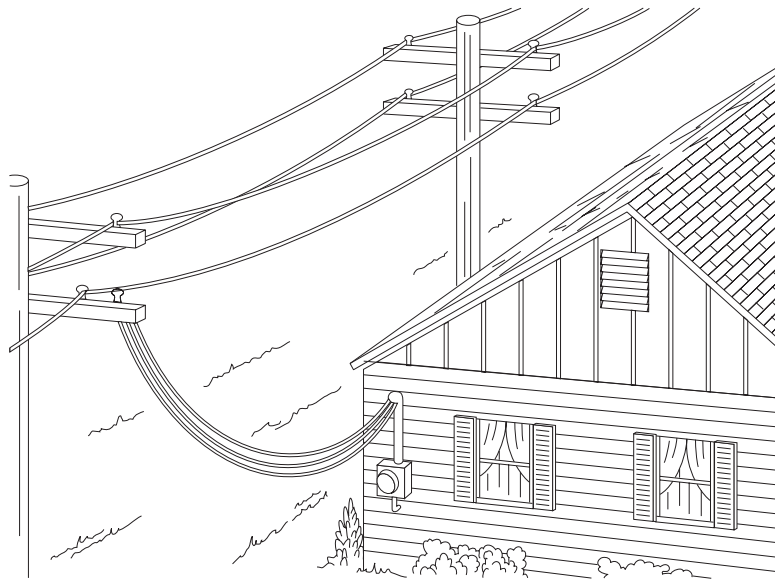
National Electrical Manufacturers Association is located at 2101 L. Street, N.W., Washington, D.C. 20037. The abbreviation "NEMA" is understood to mean National Electrical Manufacturers Association.

Residential Distribution

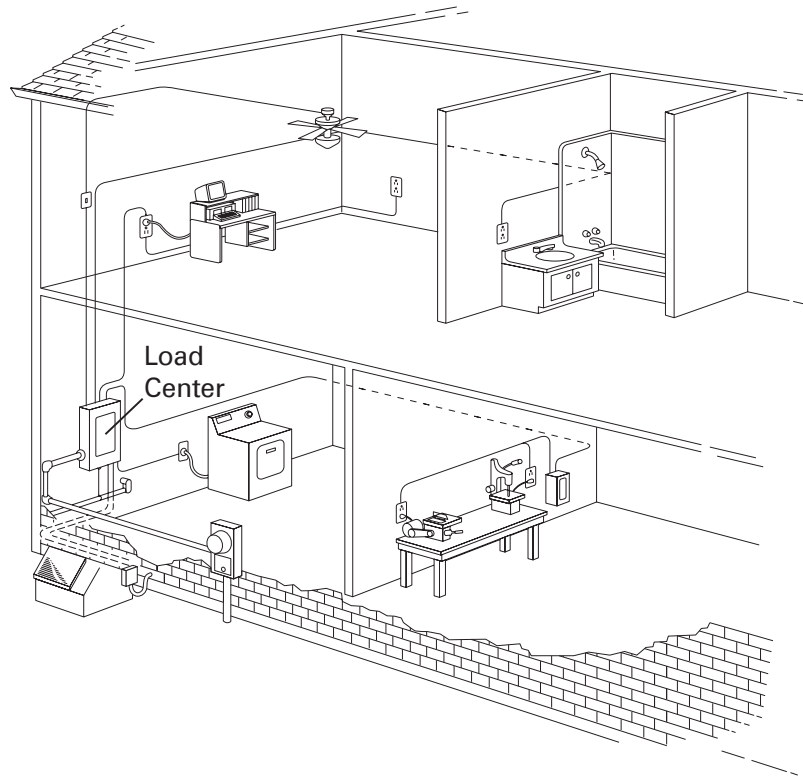
A distribution system is a system that distributes electrical power throughout a building. Distribution systems are used in every residential, commercial, and industrial building.

Residential distribution

Most of us are familiar with the distribution system found in the average home. Power, purchased from a utility company, enters the house through a metering device.

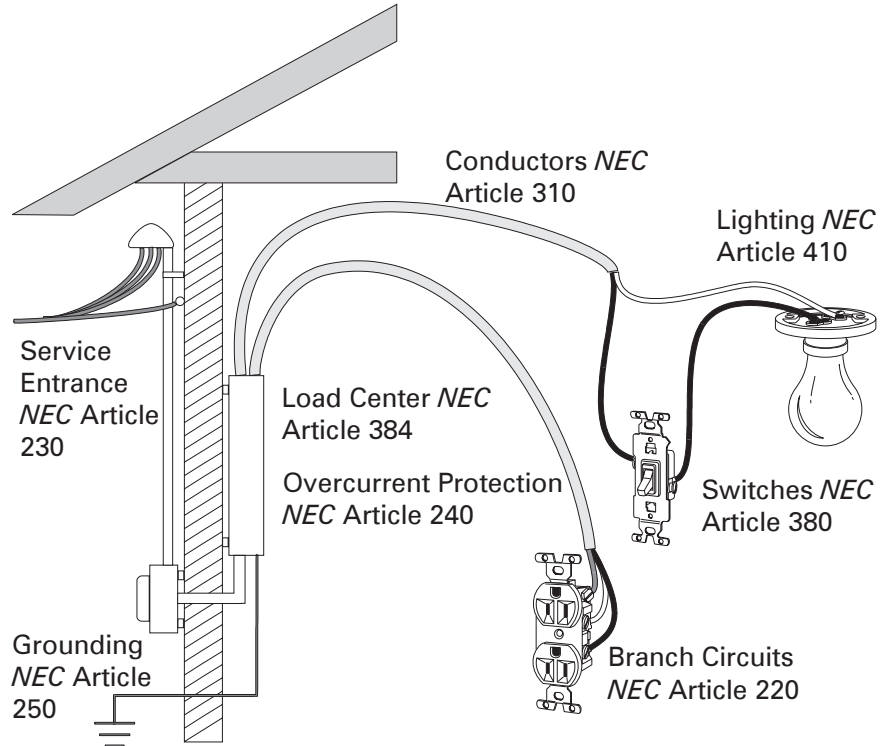


The incoming power then goes to a load center which provides circuit control and overcurrent protection. The power is distributed from the load center to various branch circuits for lighting, appliances and electrical outlets. Careful planning is required so that the distribution system safely and efficiently supplies adequate electric service for present and possible future needs.



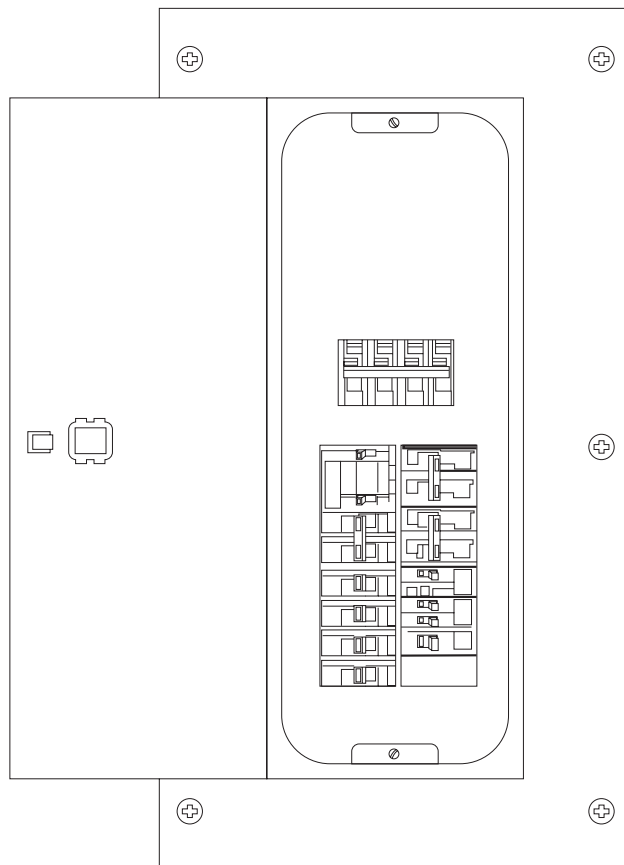
The National Electrical Code® (NEC®)

The *National Electrical Code* is used extensively in the electrical industry. Throughout this course various articles of the *NEC* will be referred to. For example, load centers (panelboards) are covered by Article 384 in the *NEC*. The basic requirements are given in *NEC* Sections 384-13 through 384-16. You are encouraged to become familiar with this material. You are also encouraged to become familiar with local building codes which are often more stringent than the *NEC*.



Load Centers

The term load center is an industry term used to identify a panelboard used in certain applications. Load centers are typically rated 225 Amps or less and 240 Volts maximum and are intended for use in residential applications. *NEC* and *UL*, however, make no distinction between a panelboard and a load center. Rules and definitions that apply to panelboards also apply to load centers.

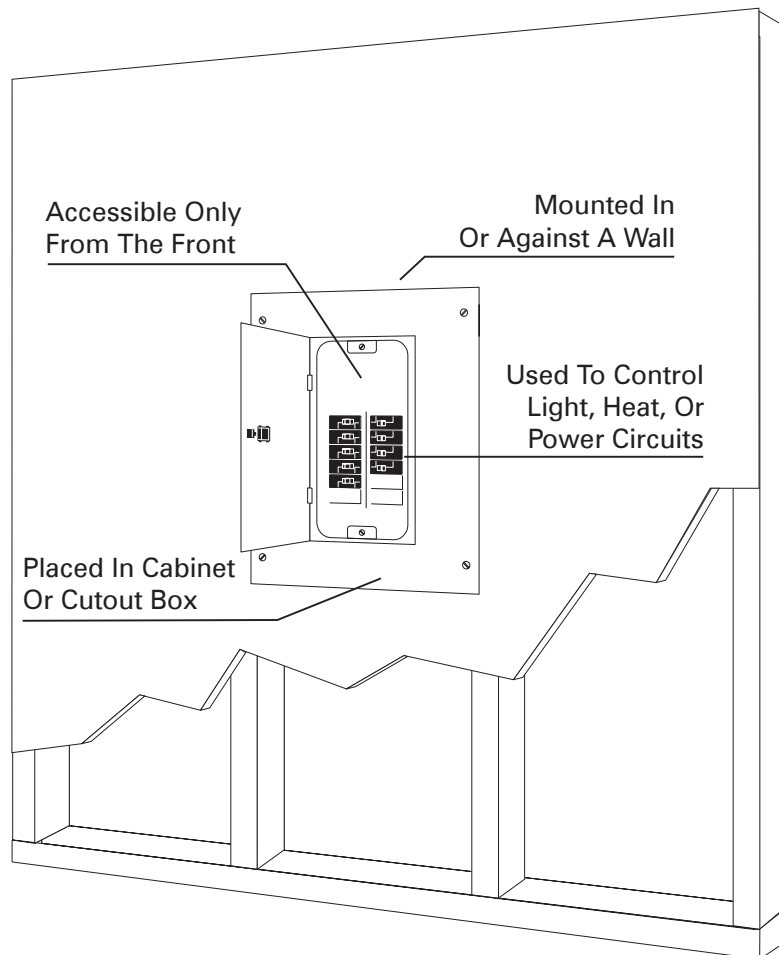


Panelboard definition

The *National Electrical Code* defines a panelboard as a *single panel or group of panel units designed for assembly in the form of a single panel; including buses, automatic overcurrent devices, and equipped with or without switches for the control of light, heat, or power circuits; designed to be placed in a cabinet or cutout box placed in or against a wall or partition and accessible only from the front* (Article 100-definitions).

According to the *NEC* definition, panelboards and load centers are:

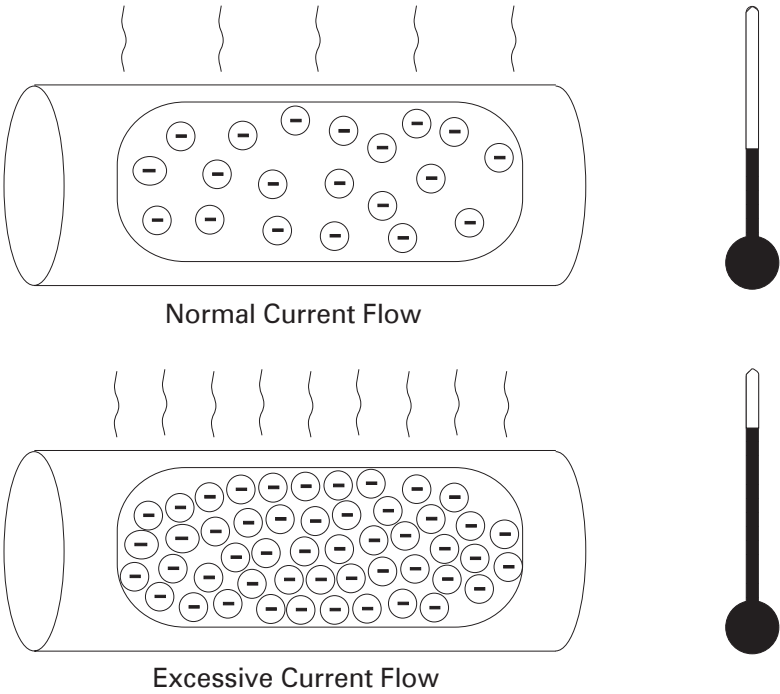
- Used to control light, heat, or power circuits
- Placed in a cabinet or cutout box
- Mounted in or against a wall
- Accessible only from the front



Overcurrent Protective Devices

Excessive current is referred to as overcurrent. The *National Electrical Code* defines overcurrent as *any current in excess of the rated current of equipment or the ampacity of a conductor. It may result from overload, short circuit, or ground fault* (Article 100-definitions).

Current flow in a conductor always generates heat. The greater the current flow, the hotter the conductor. Excess heat is damaging to electrical components. For that reason, conductors have a rated continuous current carrying capacity or ampacity. Overcurrent protection devices are used to protect conductors from excessive current flow. These protective devices are designed to keep the flow of current in a circuit at a safe level to prevent the circuit conductors from overheating.

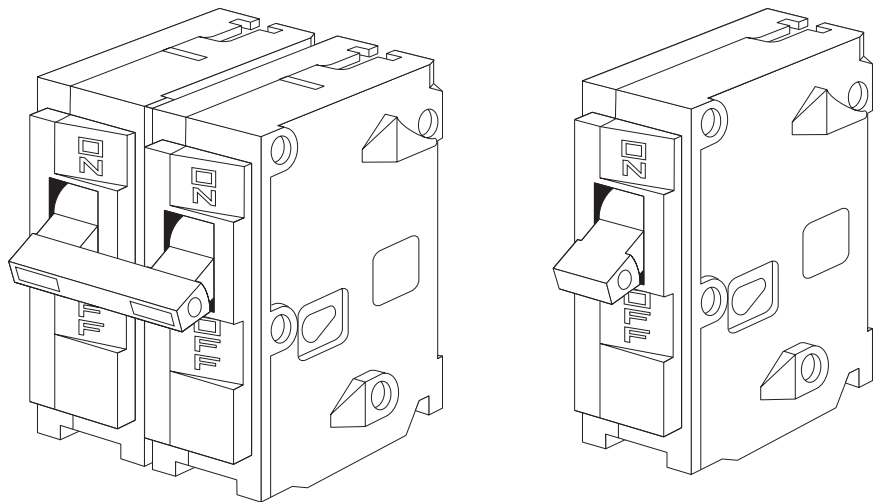


Circuit protection would be unnecessary if overloads and short circuits could be eliminated. Unfortunately, overloads and short circuits do occur. To protect a circuit against these currents, a protective device must determine when a fault condition develops and automatically disconnect the electrical equipment from the voltage source. Slight overcurrents can be allowed to continue for a short time, but as the current magnitude increases, the protection device must open faster. Short circuits must be interrupted instantly.

Circuit breaker

One type of device used for overcurrent protection is a circuit breaker. The *National Electrical Code* defines a circuit breaker as *a device designed to open and close a circuit by nonautomatic means, and to open the circuit automatically on a predetermined overcurrent without damage to itself when properly applied within its rating.*

Circuit breakers provide a manual means of energizing and deenergizing a circuit. In addition, circuit breakers provide automatic overcurrent protection of a circuit. A circuit breaker allows a circuit to be reactivated after a short circuit or overload is cleared. Unlike fuses which must be replaced when they open, a simple push of the handle to the "Off" then "On" position restores the circuit. If a circuit reopens upon reset to the "On" position, a qualified electrician should be consulted to determine the problem.



Ampere rating

Every circuit breaker has a specific ampere, voltage, and fault current interruption rating. The ampere rating defines the maximum current a circuit breaker can carry without tripping. Siemens residential circuit breakers are available with ratings from 15-125 Amps.

Voltage rating

Each circuit breaker is also rated for the maximum voltage it can handle. In residential applications, single-pole breakers protect 120 Volt branch circuits; two-pole breakers protect 240 Volt branch circuits. Siemens residential circuit breakers have a voltage rating of 120/240 Volts. The rating of a circuit breaker can be higher than the circuit voltage, but never lower.

**Short circuit
interrupting rating**

The circuit breaker's short circuit interrupting rating is the maximum available fault current which a breaker is designed to interrupt. Siemens residential circuit breakers have interrupting ratings from 10,000 Amps to 65,000 Amps. The available fault current is rarely above 10,000 Amps in single-family homes.

Review 1

1. Match the following subjects with the appropriate *NEC* Article.

NEC Article

Subject

250 _____

a. Service Entrance

240 _____

b. Grounding

220 _____

c. Load Centers (Panelboards)

380 _____

d. Overcurrent Protection

384 _____

e. Conductors

230 _____

f. Lighting

410 _____

g. Switches

310 _____

h. Branch Circuits

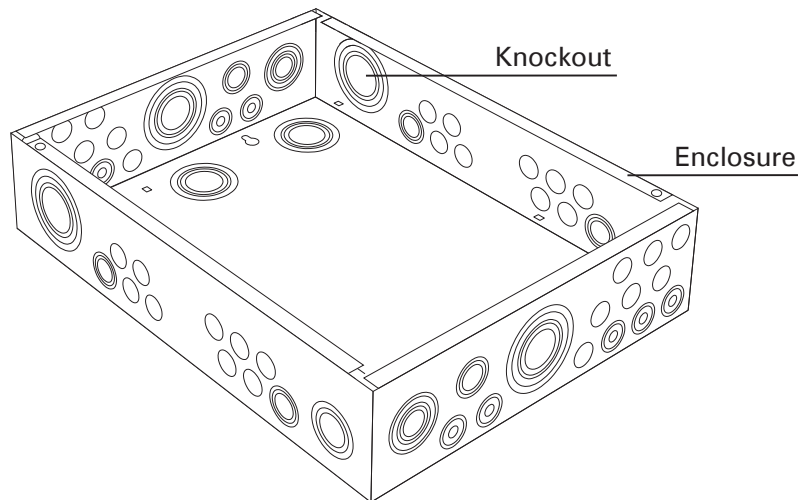
2. A _____ is an industry term used to define a panelboard used in residential applications.
3. Which of the following does not meet the *National Electrical Code* definition of a load center?
- a. Used to control light, heat or power circuits
 - b. Placed in a cabinet or cutout box
 - c. Mounted in or against a wall
 - d. Accessible from the front or back
4. The continuous current carrying capacity of a conductor is known as _____.
5. Circuit breakers are rated for _____, _____ and short circuit interrupting rating.

Load Center Construction

There are several components that make up a load center. Load centers consist of an enclosure, interior, and trim.

The enclosure

The enclosure is typically constructed of cold rolled (for indoor use) or galvanized steel (for outdoor use) and houses the other components. It is designed to provide component and personnel protection. Knockouts are provided to allow the user to install conduit or cabling as required. Approved cable clamps or conduit hubs are used in the holes to secure and protect the cable and conductors.

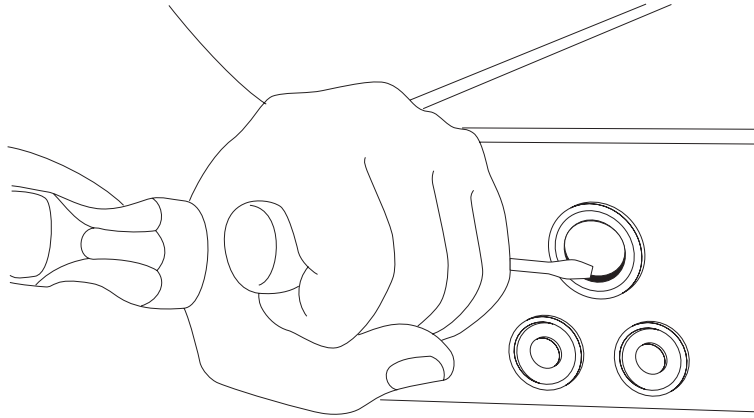


NEMA enclosures

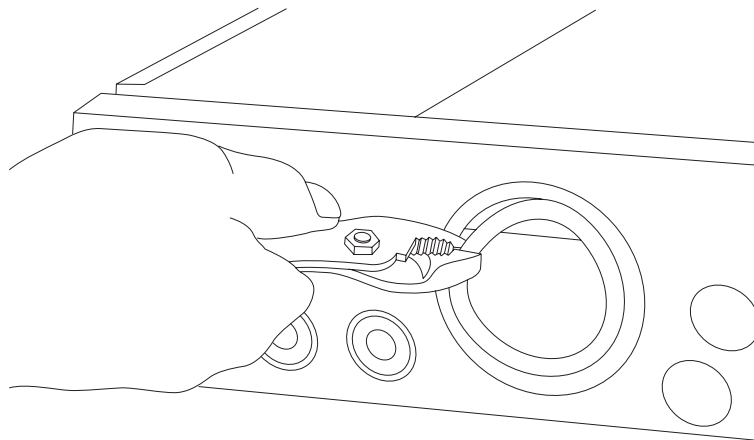
The National Electrical Manufacturers Association (NEMA) and UL have established guidelines for electrical equipment enclosures. NEMA Type 1 enclosures are intended for indoor use. NEMA Type 3R enclosures are intended for outdoor use primarily to provide a degree of protection against rain, sleet and damage from external ice formation.

Removing knockouts

Required knockouts may be removed prior to mounting the enclosure. On multiple ring knockouts remove the center section by striking at the point furthest from the tie. Bend the knockout back and forth to break the tie.

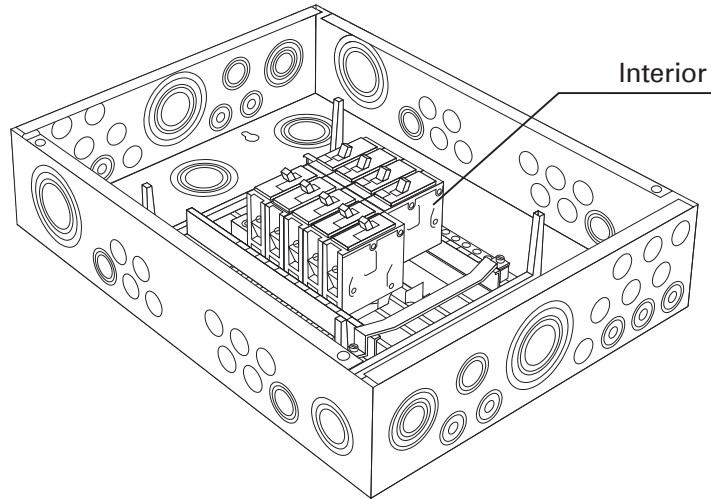


If a larger opening is required, remove each additional ring one at a time by prying with a screwdriver and bending back and forth with pliers as shown in the following figure.



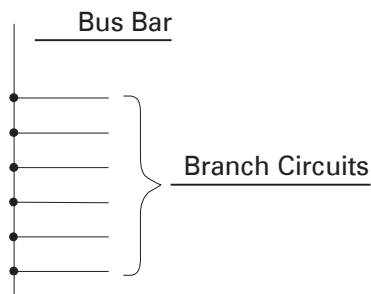
Interior

The interior consists of several components, including bus bars and insulated neutral bus bars. Branch circuit breakers are field added at the time of installation.



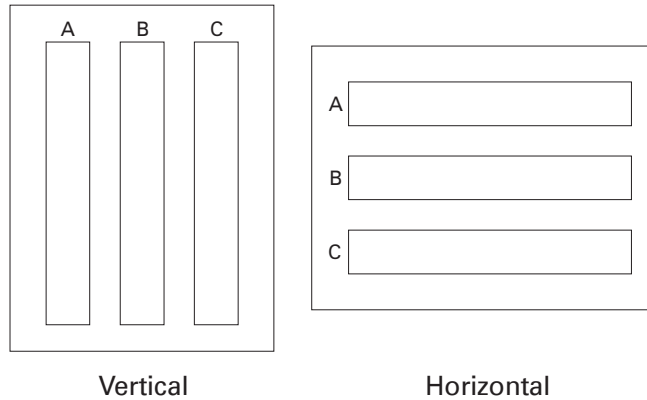
Bus bars

A bus bar serves as a common connection for two or more circuits. It is represented schematically by a straight line with a number of connections made to it. *NEC* article 384-3 states that bus bars *shall be located to be free from physical damage and shall be held firmly in place*. Siemens load center bus bars are made with tin plated aluminum or copper.



Circuit identification

Bus bars are required to have phases in sequence so that an installer can have the same fixed phase arrangement in each termination point in any panelboard or switchboard. This is established by NEMA and UL. It is assumed that bus bars are arranged according to NEMA and UL standards unless otherwise marked. The following diagram illustrates accepted NEMA and UL phase arrangements. Also see *NEC* Article 384.



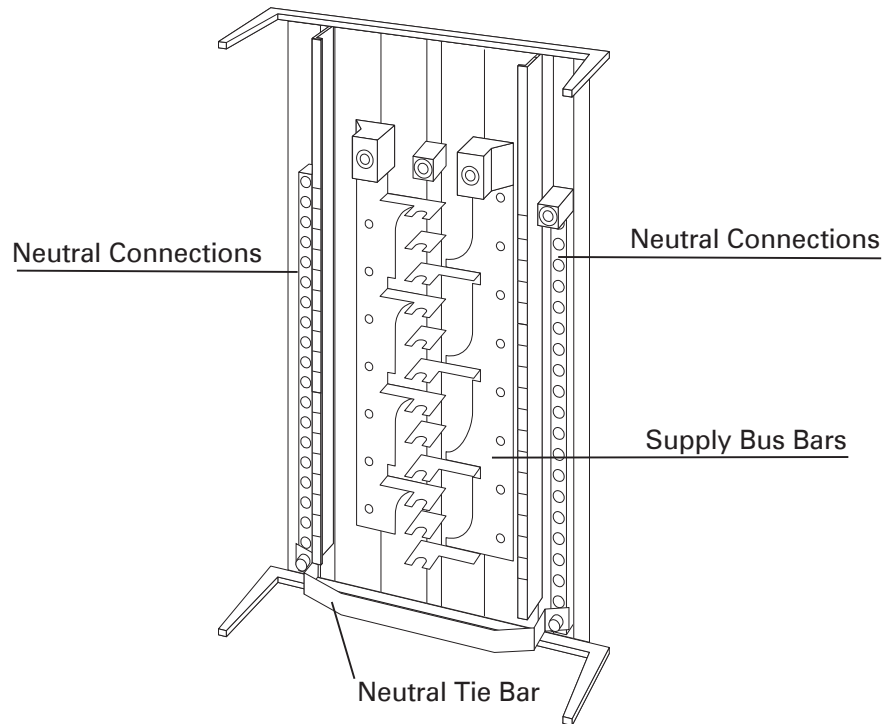
Neutral bus*

An insulated neutral bus (which may be grounded/bonded) is provided in the load center. The neutral is a current-carrying component that is connected to the third wire of a single-phase, three-wire system or the fourth wire of a three-phase, four-wire system. For example, the following illustration shows the secondary of a 240 Volt, single-phase transformer with a center tap. There are 240 Volts between phases and 120 Volts between phase A or B and neutral (N).

*Technically the "grounded circuit conductor."

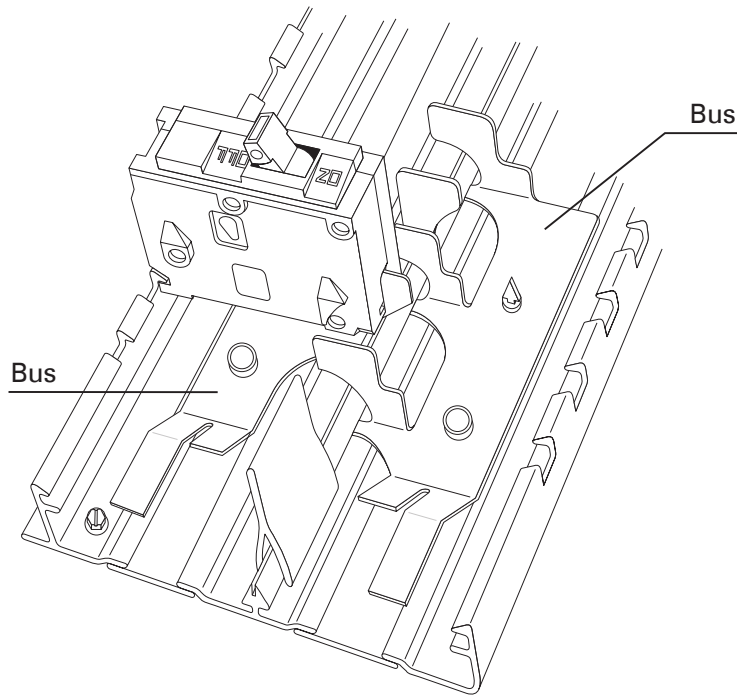
Split neutral

In most instances the neutral bus is a split neutral, meaning that neutral connections are available on both sides of the load center. Split neutrals are connected together through a neutral tie bar.



Circuit breakers

Circuit breakers mount directly to the bus bars. In the following illustration for example, a Type "QP" circuit breaker is mounted to the load center bus.



Label

The label identifies the load center's catalog number, enclosure type, Voltage rating, and ampacity. Additional information (not shown) on the label identifies circuit breaker types that can be used with the load center.

SIEMENS

Indoor Load Center C1094

Catalog Number G1212ML1125	Series .E	Enclosure Type 1
--------------------------------------	---------------------	----------------------------

Ratings:
125 Amps. Max.
See Main Breaker Rating if Used
120/240 Volts AC 1 Phase 3 Wire
208 Y/120 Volts AC 3 Phase 3 Wire
For grounded B Phase systems
use 240 VAC Breakers only.

Suitable For Use As Service Equipment

when used as service equipment all unused neutral branch terminals can be used as equipment grounding wire terminals.
General:
Remove twistouts from trim only where breaker will be installed. All openings must be filled with breakers or filler plates.
Circuit breaker overload trip indication is indicated by handle position midway between reset, move to trip position then turn

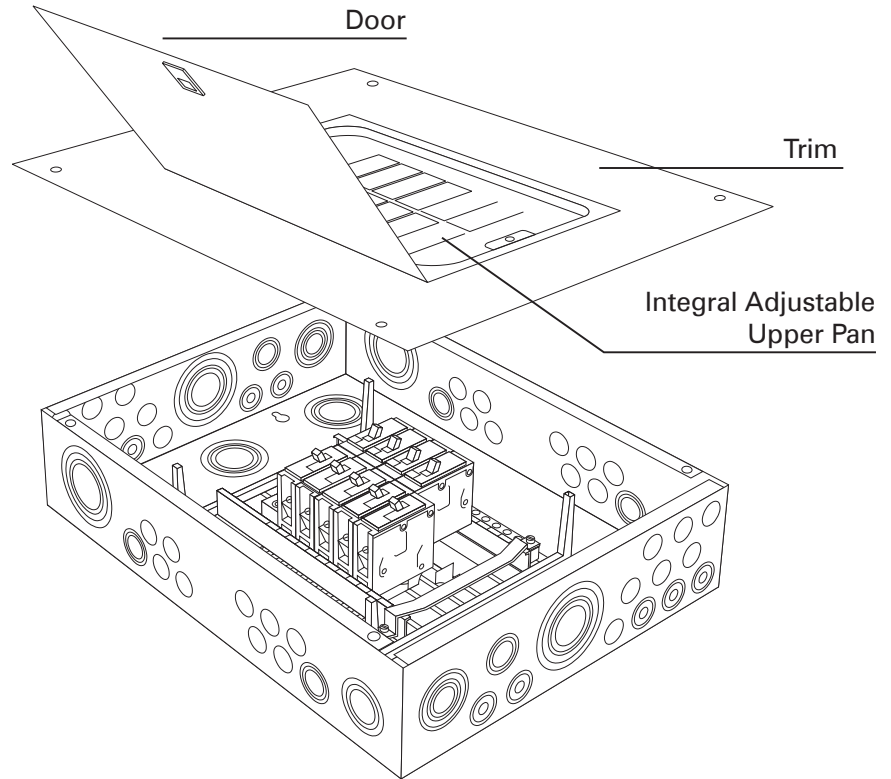
USE COPPER OR ALUMINUM 60°/75°C WIRE

Terminals	Wire	Torque
ABN	2/0-4 AWG	4-25 lb-in.
Neutral/Ground	14-10 AWG	
(Use Type GB Ground Bar Kits Accessory)	8 AWG	
Grid. Conductor		
LK1-2 (Access)		
LK2 (Access)		
LK3 (Access)		
LK4 (Access)		

Date Code

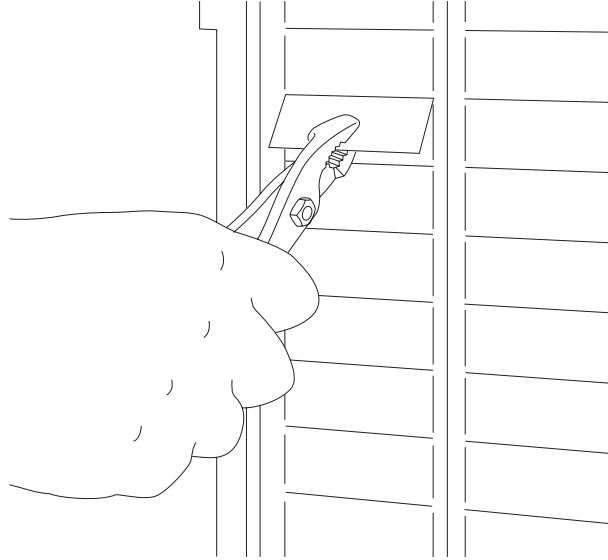
Trim assembly

The trim assembly is the front portion of the load center that covers the interior. The trim includes an access door and an adjustable upper pan. The trim/door provides access to the overcurrent devices while sealing off the bus bars and internal wiring from contact.



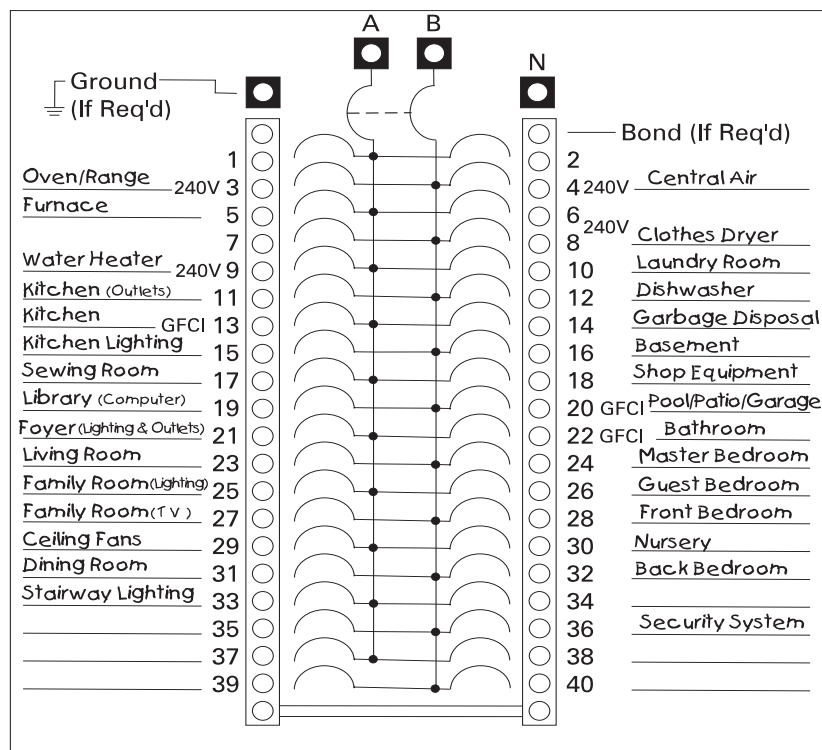
Twistouts

Part of the upper pan contains twistouts. These are used to cover any unused pole spaces not filled by a circuit breaker. Twistouts are removed by an up and down twisting motion with pliers. All unused openings in the upper pan must be filled with a QF3 filler plate.



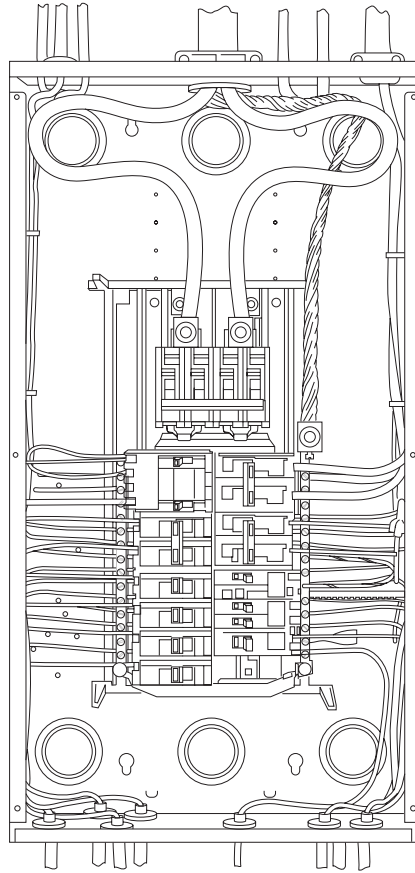
Circuit directory

A circuit directory (on the door), similar to one shown below, provides space for listing which breaker provides service for each room or large appliance.

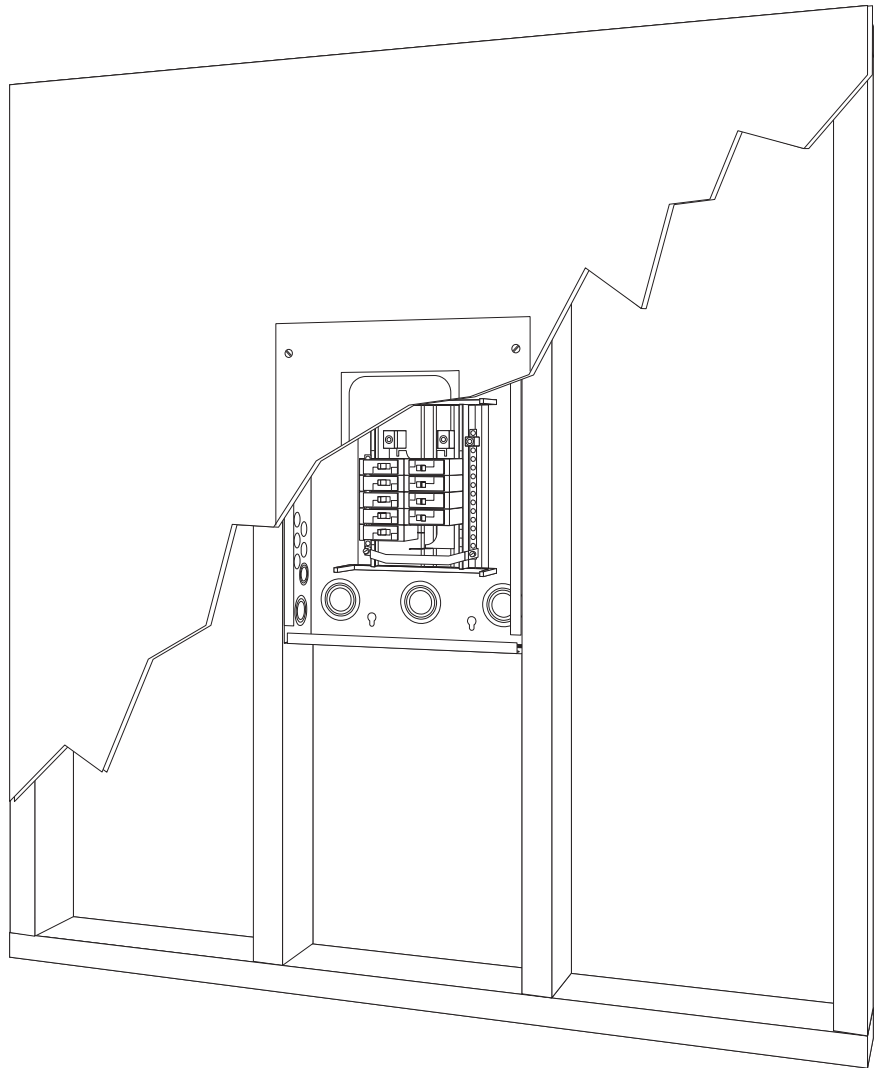


Panelboard installation

The enclosure, with the interior, is mounted to a wall. All incoming power wires and outgoing branch wires are connected to the load center. Exposed ends of aluminum wires must be wire-brushed and coated with an oxide-inhibiting compound.



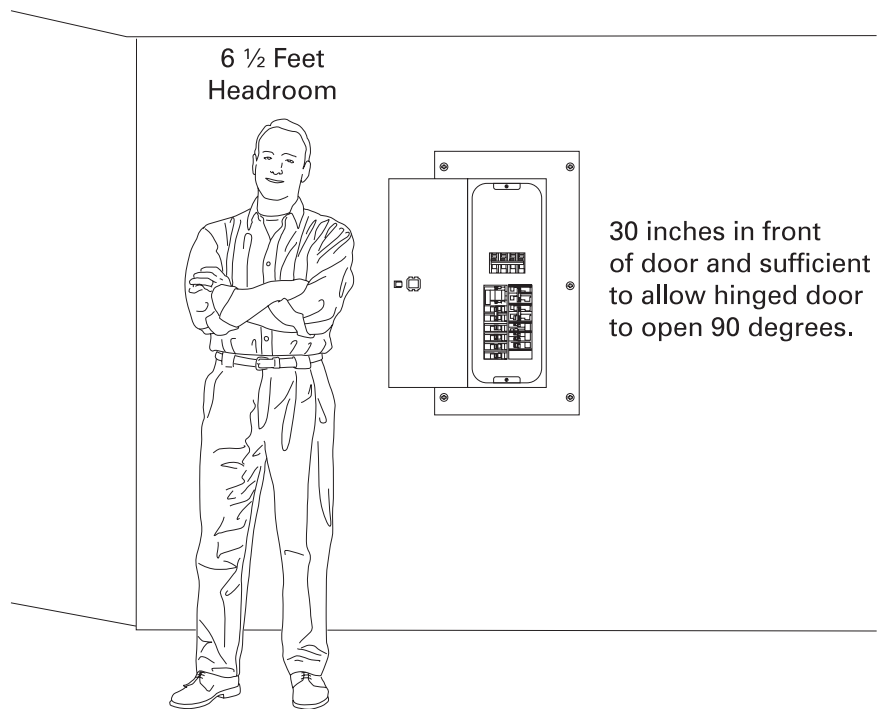
For flush mounted devices, the load center is positioned so that the front edge of the enclosure is flush with the finished wall. The trim assembly is installed after the wall is finished.



NEC Article 110-16

Article 110-16 of the *National Electrical Code* specifies clearances around load centers which will provide sufficient access and working space. There are three basic rules which we must be concerned with:

- Minimum distance from the load center to ground shall be 3 feet for 0-150 Volt systems.
- Space in front of the equipment shall be at least 30 inches wide and be sufficient to allow the hinged door to open 90 degrees.
- There shall be a minimum of 6 ½ feet of headroom.



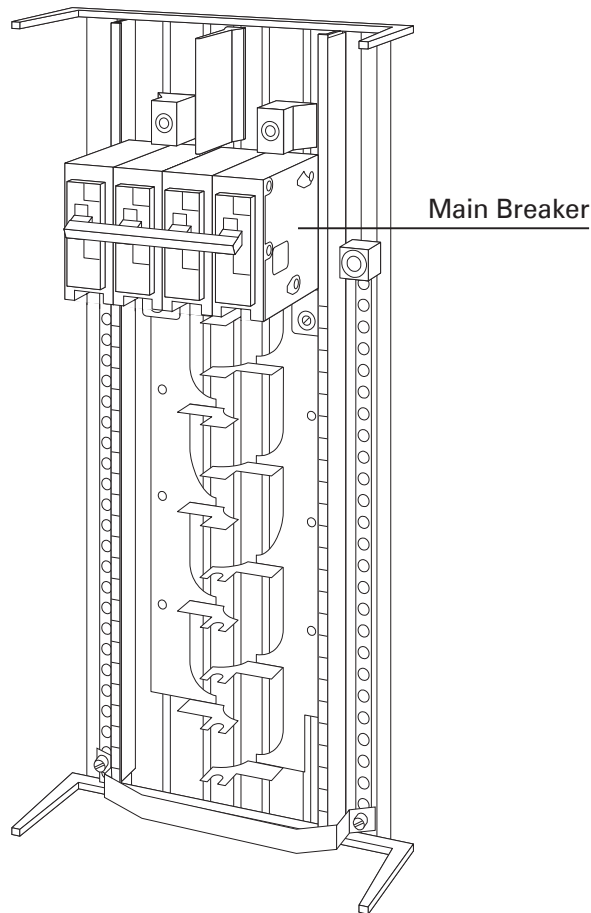
Review 2

1. The two types of NEMA enclosures available for Siemens load centers are NEMA Type _____ and NEMA Type _____ .
2. A _____ serves as a common connection for two or more circuits.
3. On a three-wire, single-phase, 240 Volt system there are _____ Volts between phase A and phase B and _____ Volts between any phase and neutral.
4. A _____ is a neutral connection that provides an equal number of neutral connections on either side of the load center.
5. The _____ assembly provides access to the overcurrent devices while sealing off the bus bars and internal wiring from contact.
6. Exposed aluminum wires in a load center must be wire-brushed and coated with an _____ - _____ compound.
7. According to *NEC* Article _____ there shall be a minimum of 6 ½ feet of headroom in the space a load center is mounted.

Types Of Load Centers

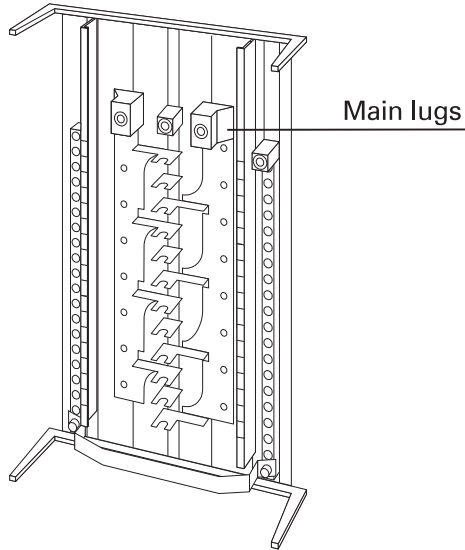
Main breaker type load center

There are two types of load centers, main breaker and main lug only. The incoming supply cables of a main breaker type load center are connected to the main breaker which in turn feeds power to the load center and its branch circuits. The main breaker disconnects power from the load center and provides overcurrent protection.

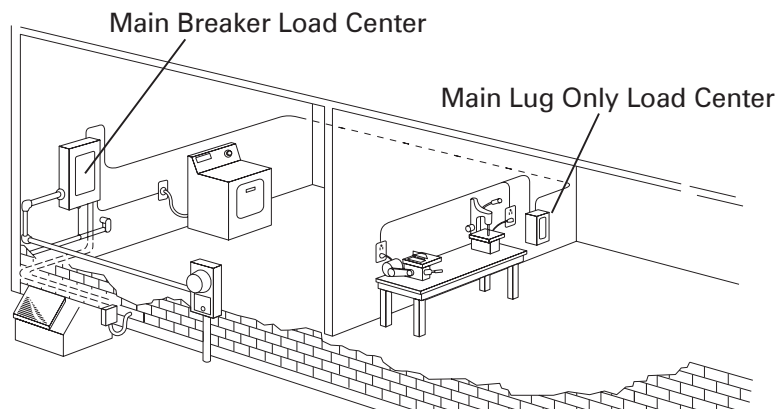


Main lug only type load center

The following illustration shows the interior of a main lug only load center. A main lug type load center does not have a main circuit breaker. The incoming supply cables are connected directly to the main lugs and bus bars. Primary overload protection for the load center is not provided as an integral part of the load center. Main lug units are primarily used as a distribution panel where there is a main breaker ahead of them in the circuit. There are situations where a backfed circuit breaker and a retainer clip (MBR1) are used to convert a main lug load center to a main breaker load center.

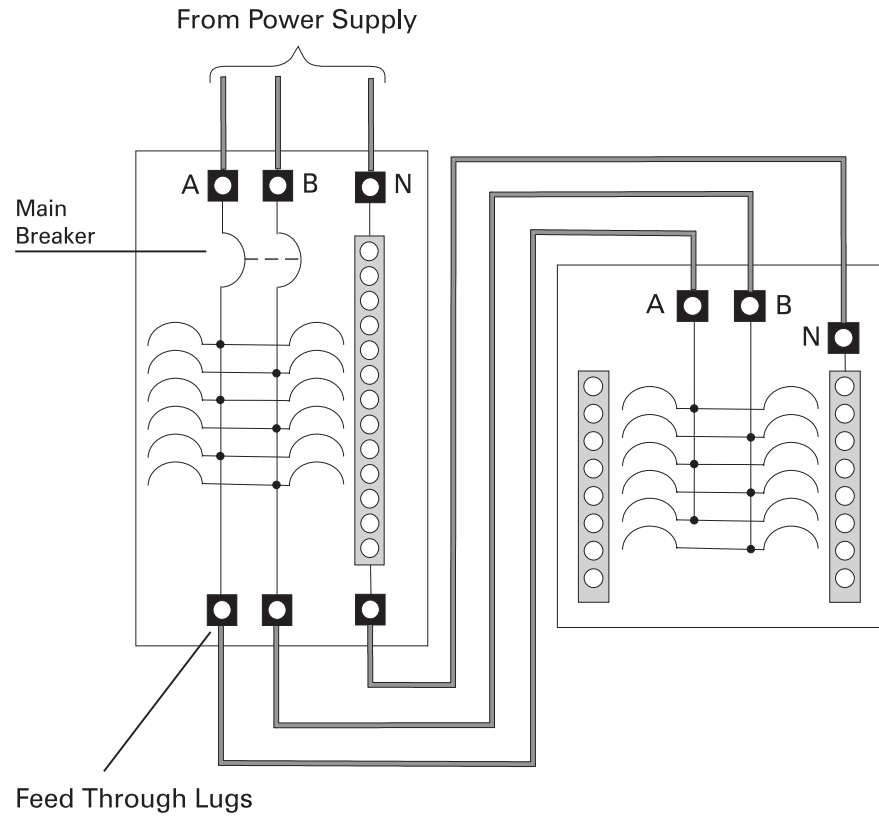


Main lug load centers are sometimes referred to as add-on, secondary or downstream panels. These panels are added when all circuit slots in the main breaker load center are full or when a remote panel is desired. For example, a main breaker load center might supply power to a main lug load center located in an area of the home used as a workshop. Main lug load centers are also fed from metering equipment when used in apartment installations.



Feed-thru lugs

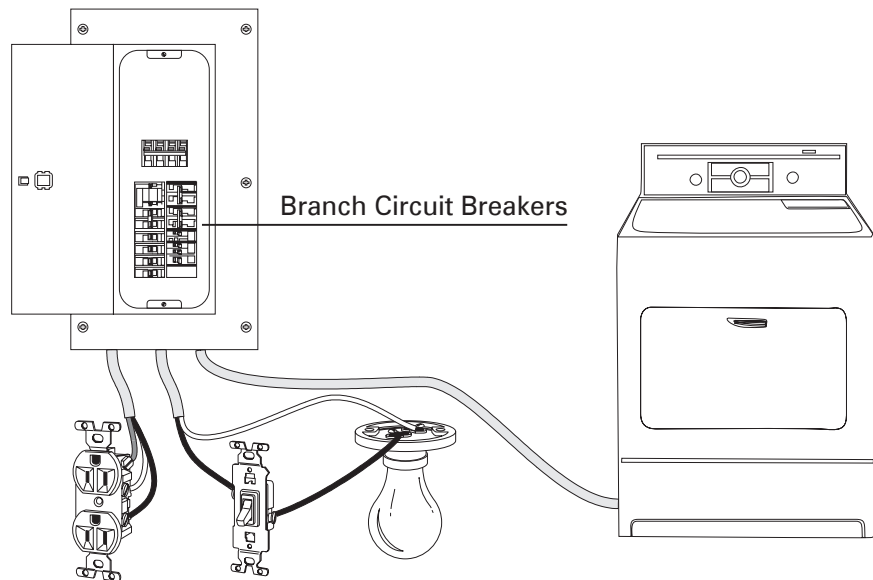
There are two ways to add on load centers. One way is to use a branch circuit breaker or a plug-on lug kit in the existing load center. Another way is to use a load center with feed-thru lugs. In the following illustration power is supplied to a main breaker load center. Power is taken from the feed-thru lugs and supplied to another load center downstream.



Branch circuit breakers

It is important to note the difference between a main breaker and branch circuit breakers. The main breaker of a main breaker type load center shuts off power to the entire load center and all circuits supplied by that load center. A main lug only load center does not have such a breaker. A main breaker load center and main lug only load center both have branch circuit breakers. Branch circuit breakers provide protection for each branch circuit conductor in the distribution system. Typical branch circuits:

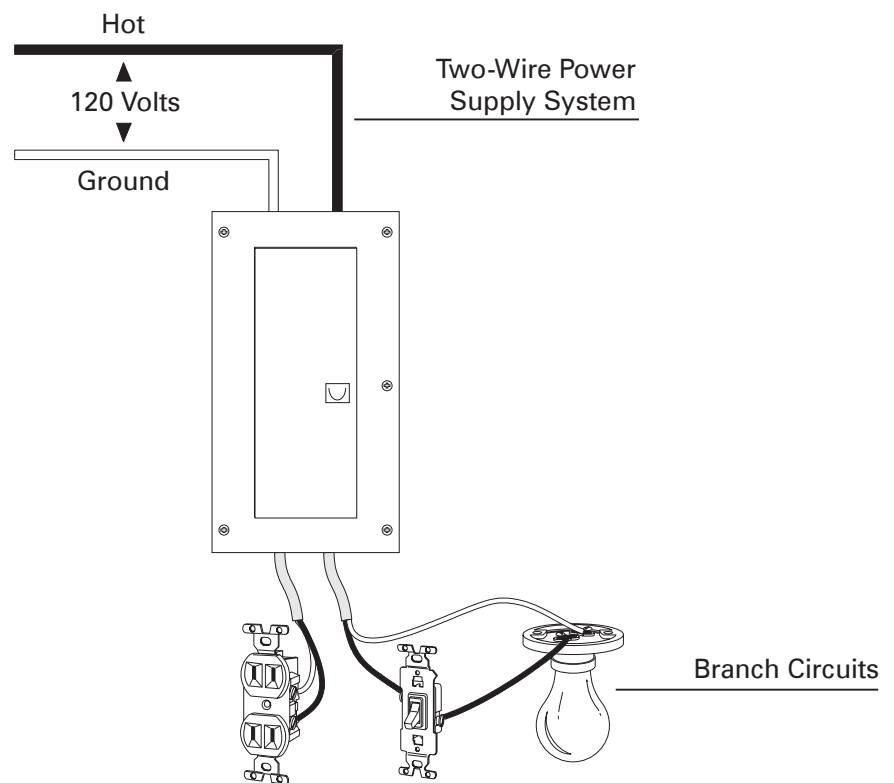
- 15 and 20 Ampere, 120 Volts supply power for lighting circuits and electrical outlets
- 20 Ampere, 120 Volts supply power for some kitchen and bath electrical outlets
- Appliances requiring larger amounts of power, such as clothes dryers, ranges, furnaces and air conditioners use separate branch circuit breakers rated for the appropriate voltage and current



Power Supply Systems

Two-wire system*

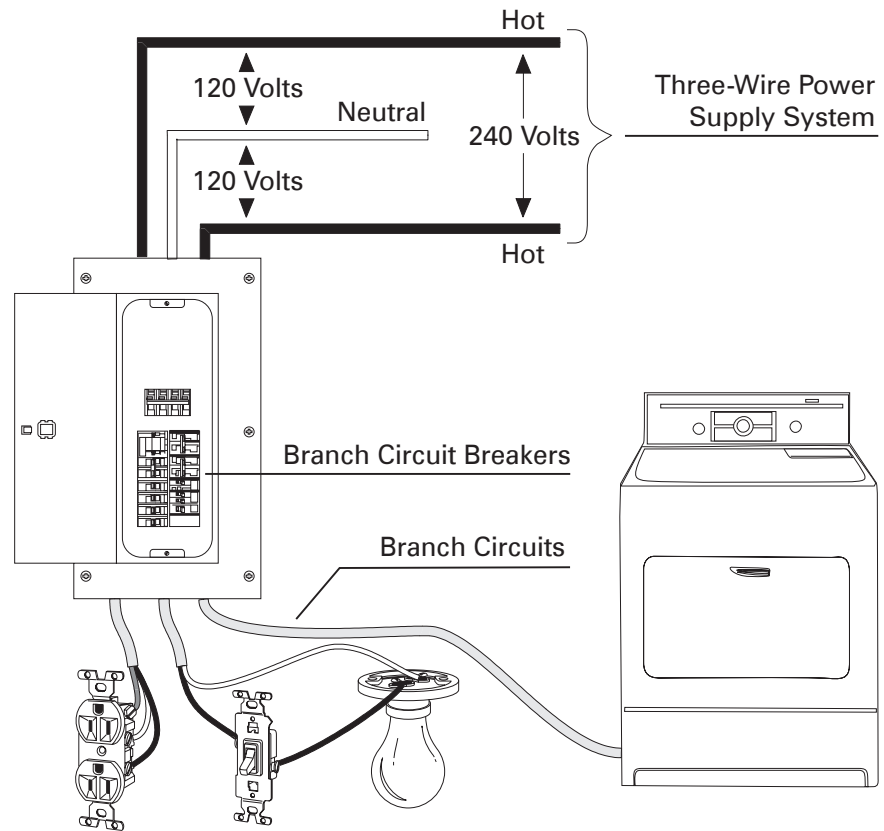
Homes built prior to 1936, especially in rural areas, used a two-wire supply system. This system provided 120 Volts between a hot conductor and a grounded conductor. A two-wire system is usually inadequate for today's residential electrical demands.



*Not allowed for new construction

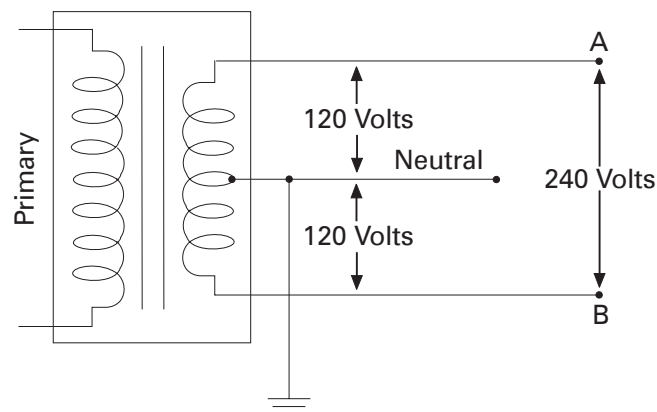
Three-wire system

The most common supply system used in residential applications today is a three-wire supply system. There are 120 Volts between any phase and neutral and 240 Volts between phases.



Three-wire, single-phase system

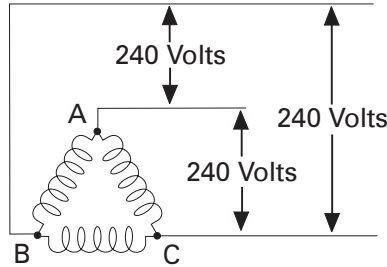
The following illustration shows a three-wire, single-phase 120/240 Volt system. 120 Volts can be obtained by connecting a load between phase A and neutral, or phase B and neutral. 240 Volts can be obtained by connecting a load between phase A and phase B.



Load centers can also be used in commercial applications. Electric power is brought into a building at one location and then is distributed through the building by means of separate circuits. Two distribution systems used in commercial applications that are suitable for Siemens load centers are three-wire, three-phase, 240 Volts; and four-wire, three-phase, 208Y/120 Volts.

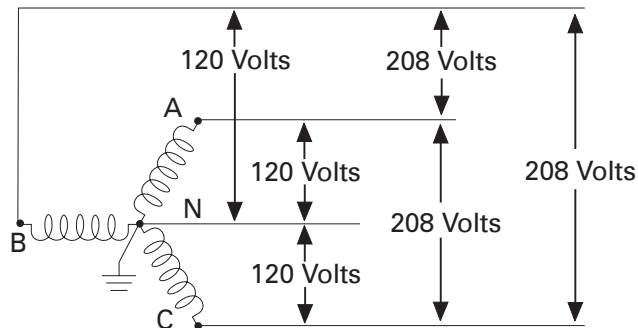
Three-wire, three-phase, 240 Volt system

The following illustration shows a three-wire, three-phase, 240 Volt system. There are 240 Volts available between any phase.



Four-wire, three-phase, 208Y/120 Volt system

The following illustration shows a four-wire, three-phase, 120/208 Volt system. There are 208 Volts between any two phases and 120 Volts available between any phase and neutral.

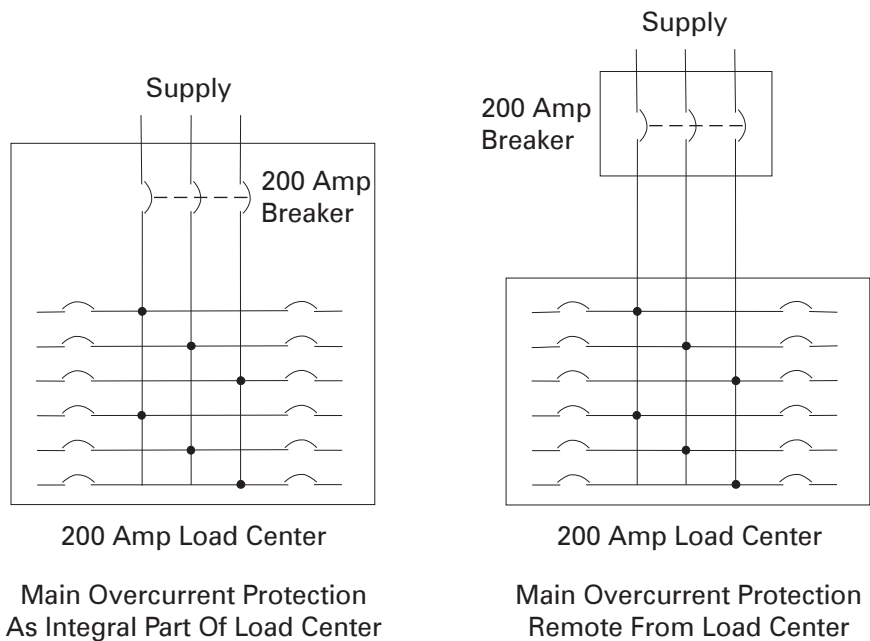


Individual Overcurrent Protection

The *National Electrical Code* requires load centers to be individually protected against overcurrent. Main overcurrent protection may be an integral part of a load center or located remote from the load center. *NEC Article 384-16 states that each lighting and appliance branch-circuit panelboard shall be individually protected on the supply side by not more than two main circuit breakers or two sets of fuses having a combined rating not greater than that of the panelboard.*

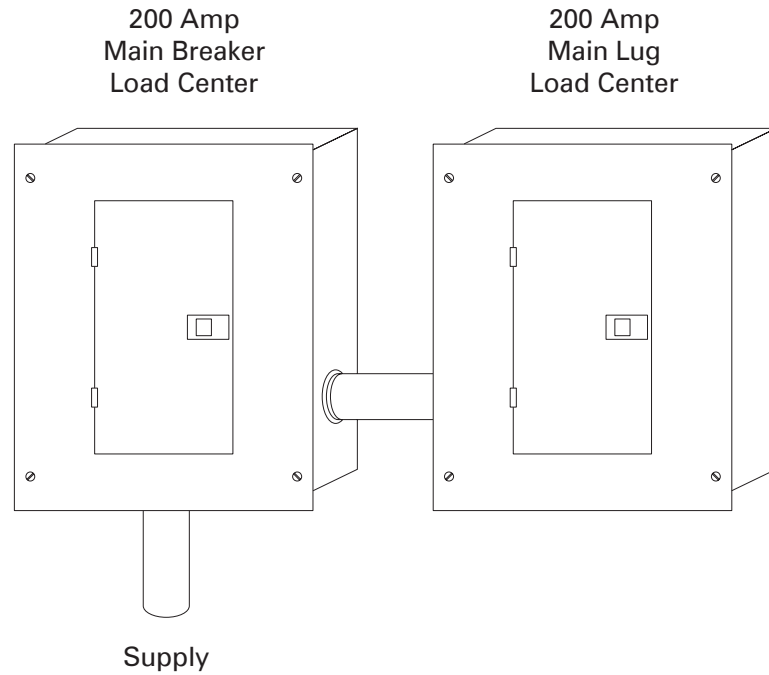
Individual protection

The following illustration shows two possible ways individual load center overcurrent can be accomplished. If a main circuit breaker is located as an integral part of the load center, it is a main breaker load center. If a main circuit breaker or main fusible is located remotely, then a main lug load center would be used. In this example the main breaker and load center are both rated for 200 Amps.



Exception to NEC 384-16

There is an exception to NEC Article 384-16. *Exception No. 1: Individual protection for a lighting and appliance panelboard shall not be required if the panelboard feeder has overcurrent protection not greater than the rating of the panelboard.* The following illustration shows two load centers protected by a single 200 Amp circuit breaker. Note that the circuit breaker provides overcurrent protection not greater than the rating of the load centers.

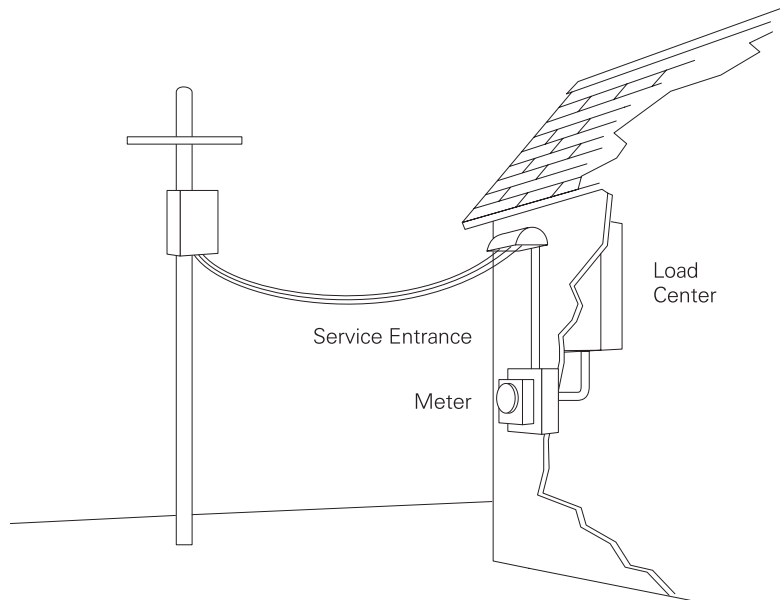


Review 3

1. The two types of load centers are main _____ and main _____ only.
2. Main lug only load centers are sometimes referred to as _____ - _____ , _____ , or _____ panels.
3. _____ - _____ lugs is one method used to supply power from one load center to another.
4. Homes built prior to 1936 used a _____ - _____ system.
5. The voltage between any phase and neutral is _____ Volts on a three-wire, single-phase, 240 Volt system.
6. The voltage between phases on a three-wire, three-phase, 240 Volt system is _____ Volts.
7. The *NEC* article that covers individual overcurrent protection for load centers is _____ .

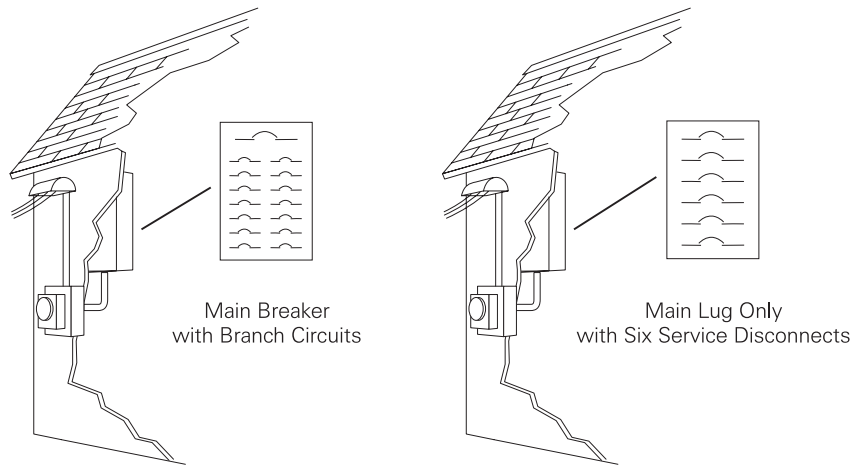
Service Entrance/Equipment Load Centers

Load centers are frequently used as service equipment for a building. This is the equipment located near where the power supply enters the building. The incoming power supply is connected to this equipment which provides a means to control and cut off the supply. The *National Electrical Code* discusses service entrance equipment in Article 230. Load centers used as service equipment must be listed and labeled as such. All Siemens EQ[®] main breaker load centers are factory labeled as suitable for use as service equipment.



Maximum number of disconnects for service entrance equipment

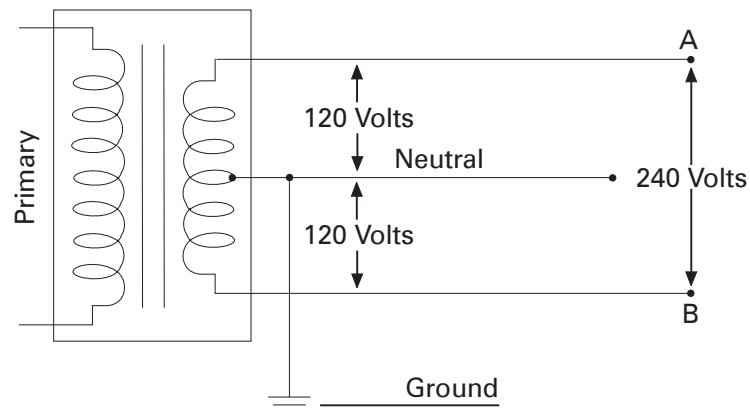
Service-entrance conductors must have a readily accessible means of being disconnected from the power supply. *NEC* Article 230-71a specifies that for each set of service entrance conductors no more than six switches or circuit breakers shall be used to disconnect and isolate the service from all other equipment. There are two ways load centers can be configured to meet this requirement. In one example, a main breaker load center is used. A single main circuit breaker will disconnect power to all equipment being supplied by the service. In another example, a main lug only load center is equipped with up to six circuit breakers (not lighting and appliance) to disconnect power to all equipment being supplied by the service. In any case, the circuit breaker must be clearly labeled for the load it supplies.



Load Center Grounding

Grounding is an important aspect of any electrical equipment and must be considered carefully. Article 250 of the *NEC* covers mandatory grounding requirements. The *National Electrical Code* defines ground as *a conducting connection, whether intentional or accidental, between an electrical circuit or equipment and the earth, or to some conducting body that serves in place of the earth.*

The following illustration, for example, shows the neutral (N) conductor of a secondary connected to ground.

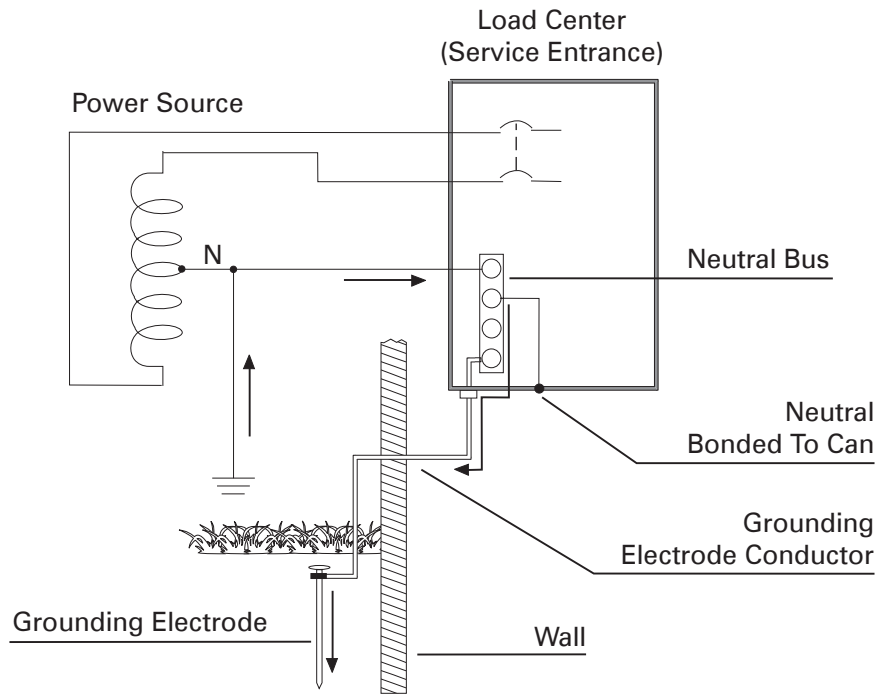


There are two objectives to the intentional grounding of electrical equipment:

- Keep voltage differentials between different parts of a system at a minimum which reduces shock hazard.
- Keep impedance of the ground path to a minimum. The lower the impedance the greater the current is in the event of a fault. The greater the current the faster an overcurrent device will open.

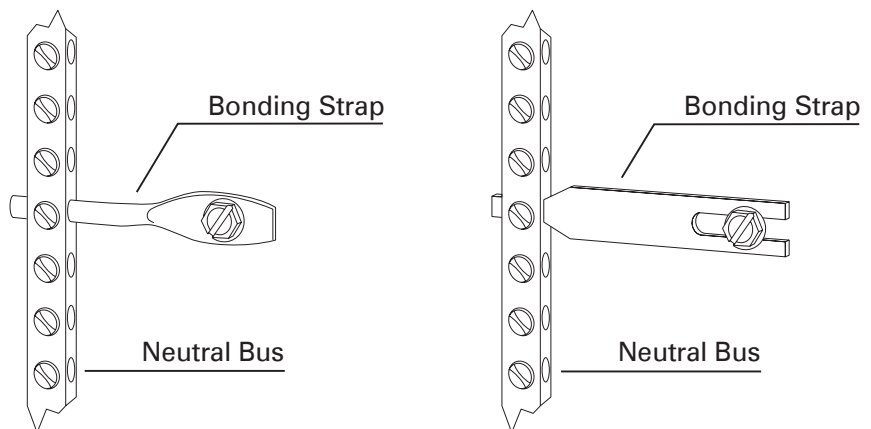
Service entrance grounding

The circuit is grounded only at the service entrance, never at any downstream equipment. In the following illustration the neutral is grounded at the service equipment by connecting a grounding electrode conductor from the neutral (grounded conductor) to a grounding electrode. The neutral and the panelboard enclosure are bonded together at the service equipment so that the enclosure is also connected to ground through the grounding electrode connector.



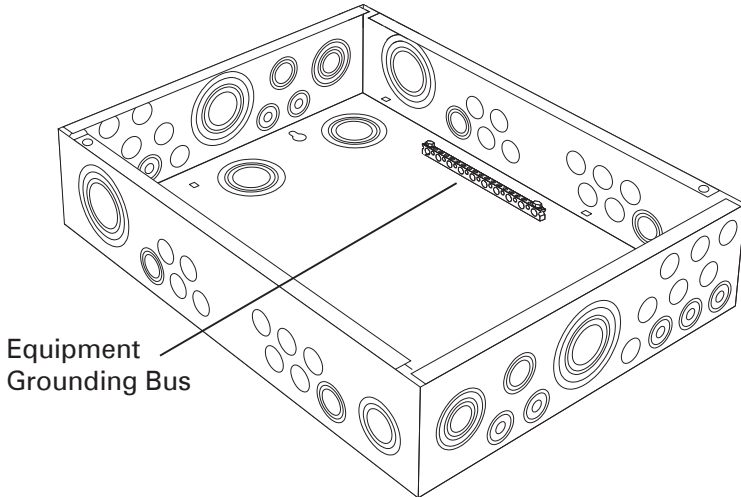
Bonding

Bonding (previous paragraph) is the permanent joining of metallic parts to form an electrically conductive path that will ensure electrical continuity. This is accomplished in Siemens load centers by attaching a metal strap between the neutral bus and the enclosure.



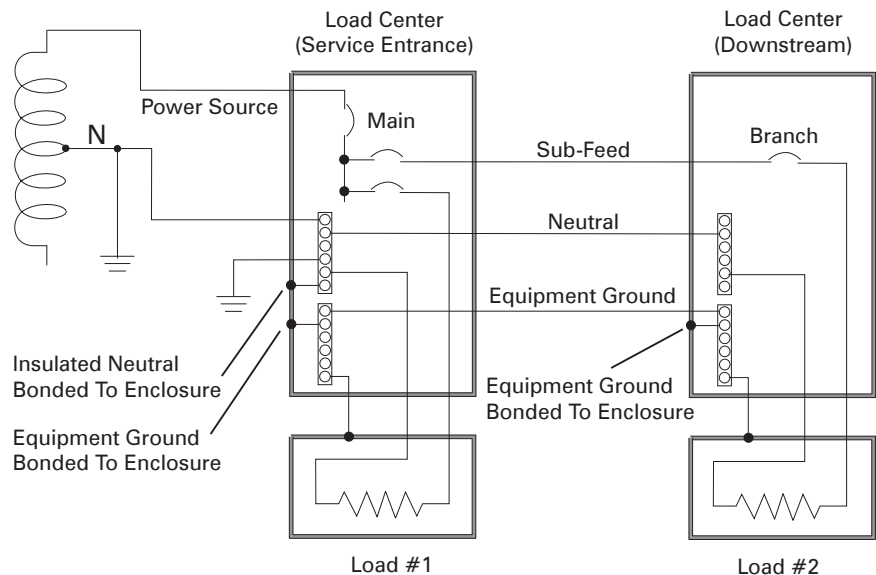
Equipment grounding bus

A load center also requires an equipment grounding bus which is connected directly to the enclosure. All feeder and branch circuit equipment that are connected to the equipment grounding bus are at the same potential as the load center enclosure. In service entrance applications the bonded/grounded neutral may serve as the connecting point for equipment grounding.



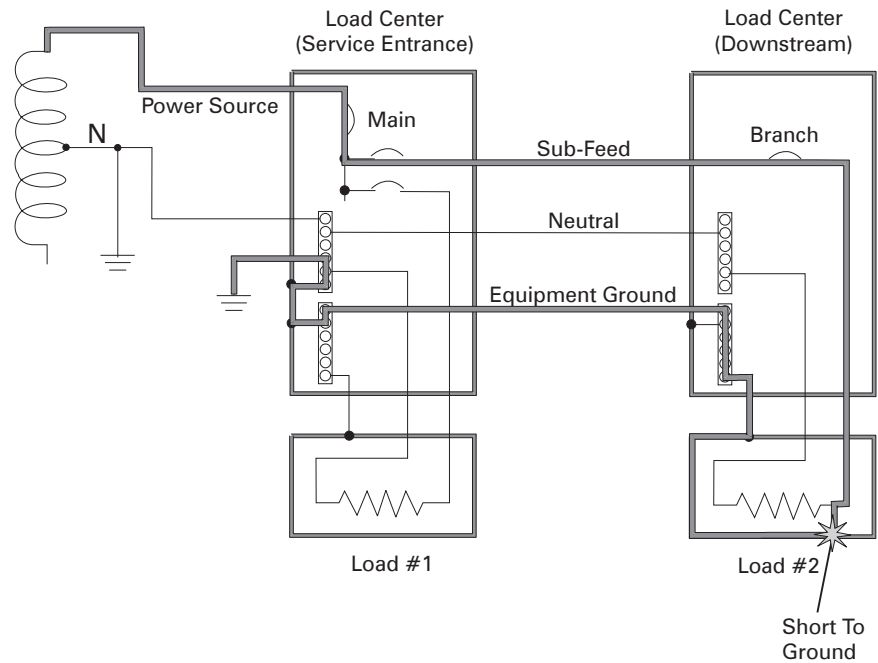
Grounding downstream load centers

The neutral (grounded conductor) is only connected to ground at the service entrance. Beyond the service equipment the neutral is always insulated and isolated. When a downstream panel is used the neutral is insulated and isolated in that panel. As shown in the following illustration the enclosure of the downstream panel is connected to ground through a grounding conductor back to the service equipment.



Using the neutral with service entrance and downstream panelboards

In the following illustration load #2 has become shorted to its metal enclosure. Fault current is returned to the source through the path indicated. With a properly coordinated system the branch circuit breaker in the downstream load center will open removing the load from the power source. For a discussion of circuit breaker coordination refer to the STEP 2000 course, **Molded Case Circuit Breakers**.



Load Center Ratings

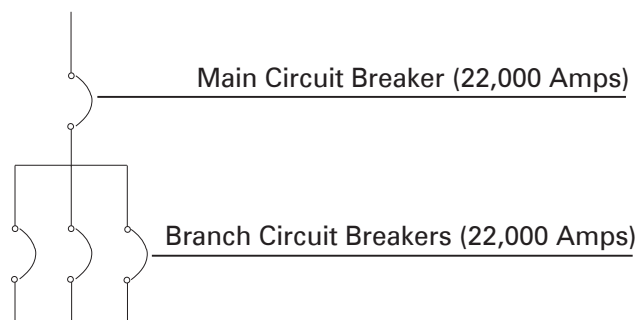
When selecting load centers and overcurrent protection devices, it is extremely important to know both the maximum continuous amperes and available fault current. *NEC* article 110-9 states:

Equipment intended to break current at fault levels shall have an interrupting rating sufficient for the system Voltage and the current which is available at the line terminals of the equipment.

Equipment intended to break current at other than fault levels shall have an interrupting rating at nominal circuit Voltage sufficient for the current that must be interrupted.

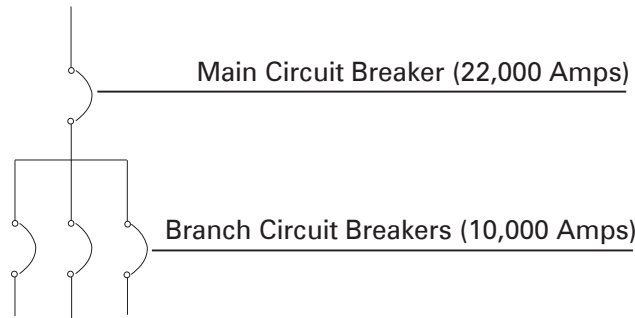
Full rating

There are two ways to meet this requirement. The full rating method is to select circuit protection devices with individual ratings equal to or greater than the available fault current. This means that, in the case of a building with 22,000 Amperes of fault current available at the service entrance, every circuit protection device must have an interrupting rating of at least 22,000 Amperes. In the following example, the main circuit breaker and each branch breaker is rated 22,000 AIC.



Series-rated

The series-rated method is that the main upstream circuit protection device must have an interrupting rating equal to or greater than the available fault current of the system, but subsequent downstream circuit protection devices connected in series can be rated at lower values. For example, a building with 22,000 Amperes of available fault current might have the breaker at the service entrance rated at 22,000 Amperes and additional downstream branch breakers rated at 10,000 Amperes.



In single family homes the available fault current normally does not exceed 10,000 Amperes. In this situation a load center with a main and branch circuit breakers with an interrupting rating of 10,000 Amperes will satisfy the requirement. In some instances the available fault current may exceed 10,000 Amperes, but rarely 22,000 Amperes. In these instances a load center with a main circuit breaker with an interrupting rating of 22,000 Amperes would be required. Using the full rating method the branch breakers would also have to be 22,000 Amperes. Using the series-rated method the branch breakers could be 10,000 Amperes. In larger installations, such as apartments, condominiums and commercial facilities, the available fault current will normally be greater than 10,000 Amperes. In these situations the series ratings become more important.

Series-rated breaker combinations must be tested in series in order to be UL recognized. The *NEC* requires the series ratings to be marked on the load center (240-83). Selected series-rated breakers are listed in the Speedfax catalog. Your Siemens sales engineer can provide more information on Siemens series-rated circuit breakers.

Review 4

1. The point at which the incoming power supply enters a building is known as the _____ .
2. According to *NEC* Article 230-71a, the maximum number of circuit breakers that can be used to disconnect and isolate the service from all other equipment is _____ .
3. One objective of intentional grounding is to keep _____ differentials between different parts of a system at a minimum which reduces shock hazard.
4. _____ is the permanent joining of metallic parts to form an electrically conductive path.
5. The _____ conductor is grounded only at the service entrance equipment, never at any downstream equipment.
6. Circuit breakers selection with individual ratings equal to or greater than the available fault current is referred to as the _____ method.
7. Circuit breaker selection with the main upstream circuit breaker equal to or greater than the available fault current, and downstream circuit breakers rated at lower values is referred to as the _____ method.

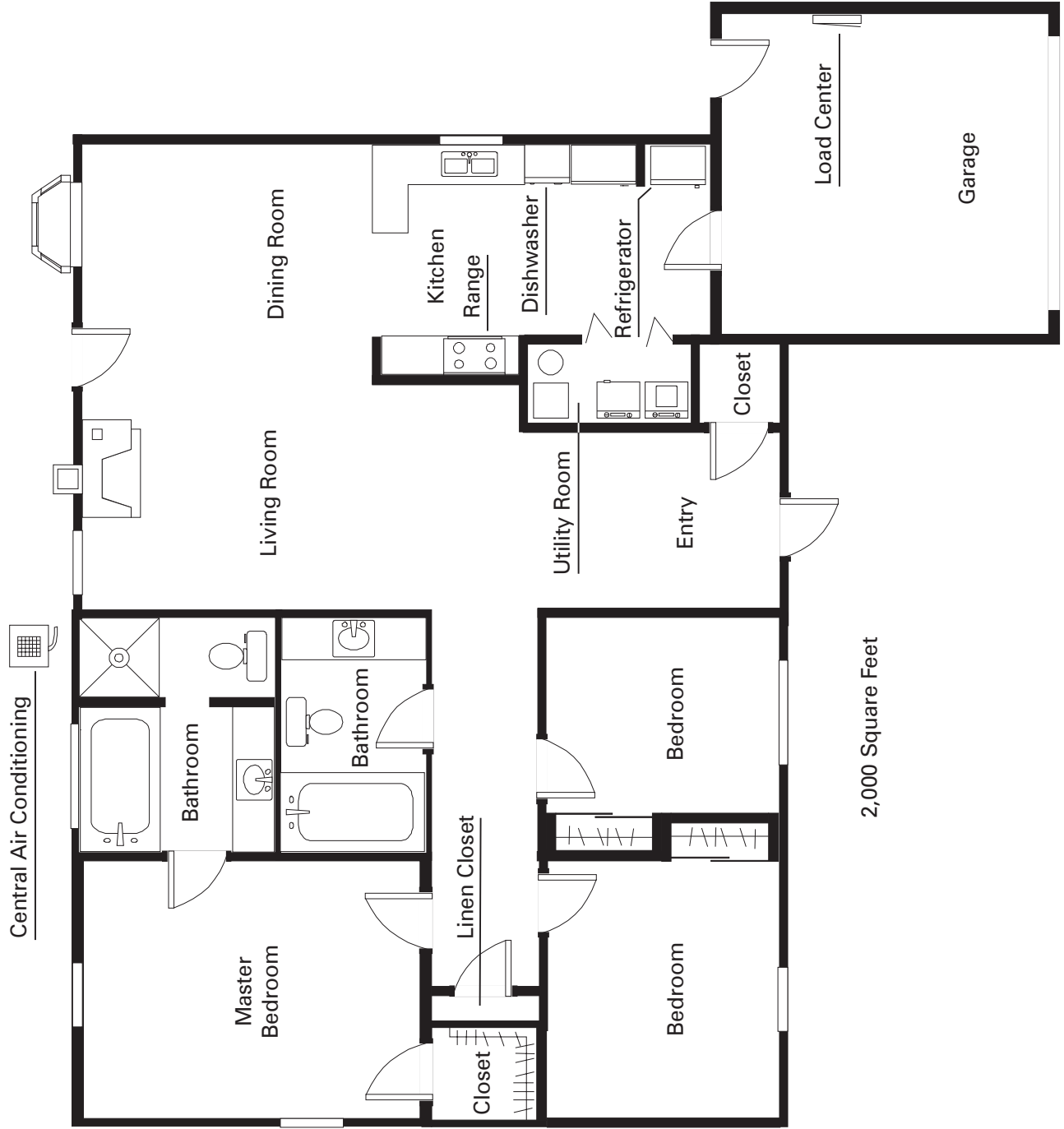
Sizing The Load Center

Planning is an important first step for all electrical projects. Careful engineering is required so that the distribution system safely and efficiently supplies adequate electric service to both present and possible future loads. A 40-circuit, 200 Amp load center is usually a good choice for most new homes over 1,500 square feet. To calculate the amperage demands more precisely the procedures in *NEC* Article 220 should be used. To correctly size the load center the following must be known:

- General lighting based on square footage of living space
- Small appliance load
- Laundry circuit
- Large appliance load
- Miscellaneous appliance load

Work

When a force causes motion, work is accomplished. In an electrical circuit, voltage applied to a conductor will cause electrons to flow. Voltage is the force and electron flow is the motion. Amps is a measurement of electrons flowing through a conductor. The rate at which work is done is called power. Watts and Volt-Amps are both terms describing power and sometimes thought to be interchangeable. Strictly speaking, they are not. Volt-Amps (VA) is apparent power and is obtained by multiplying voltage times current. Watts is a measurement of true power and is obtained by multiplying voltage times current, times the power factor. For a more complete explanation of true power and apparent power refer to the STEP 2000 course, **Basics of Electricity**. Electrical equipment, such as found in the home, may be rated in amps, watts or Volt-Amps. Volt-Amps (VA) will be used for the following examples.



2,000 Square Feet

Central Air Conditioning

A sample floor plan of a home is shown on the previous page. In the following example, a 2000 square foot home has a 9600 VA (240 Volts x 40 Amps) air conditioner, a 9600 VA (240 Volts x 40 Amps) electric range, 12,000 VA (240 Volts x 50 Amps) electric heat, 5000 VA (240 Volts x 20.8 Amps) clothes dryer, 1500 VA (120 Volts x 12.5 Amps) dishwasher, and a 1176 VA (120 Volts x 9.8 Amps) garbage disposal. Three small appliance circuits will be used in the kitchen area.

Note: A thorough knowledge of the *National Electrical Code* is required to properly size load centers and conductors. You are encouraged to become familiar with this material. The *National Electrical Code* publishes a handbook. In addition, several publishers have books available on residential wiring.

General lighting load

According to *NEC* Table 220-3b, the general lighting load for a dwelling is calculated at 3 VA per square foot of living space. This includes non-appliance receptacles for items such as table lights and television sets. The example has 2,000 square feet of living space. The calculated living space does not include carports, garages or unfinished spaces, such as basements, that are not adaptable for future use. The required general lighting load is 6000 VA.

$$3 \text{ VA} \times 2000 \text{ square feet} = 6000 \text{ VA}$$

Small appliance loads

According to *NEC* Article 220-4b at least two 120 Volt, 20 Amp small appliance circuits shall be provided. These are located in the kitchen area for small appliances such as toasters and coffee makers. *NEC* Article 220-15 also states that these circuits shall be rated at 1500 VA. In the example house there will be three small appliance circuits for a total rating of 4500 VA.

$$3 \times 1500 \text{ VA} = 4500 \text{ VA}$$

Laundry circuit

NEC Article 220-4c requires one 120 Volt, 20 Amp circuit (2400 VA) for the laundry area.

$$2400 \text{ VA}$$

Total general lighting and small appliance load

From the previous calculations the total general lighting and appliance load is:

General lighting	6000 VA
Small appliance load	4500 VA
Laundry circuit	2400 VA
Total	12,900 VA

Demand factors for general lighting and small appliance load

All residential electrical outlets are never used at one time. Knowing this the *NEC* allows for a demand factor in sizing electric services. Demand factors for general lighting are given in Table 220-11. The first 3000 VA is rated at 100%. The remaining 9900 VA (12,900 VA minus 3000 VA) may be rated at 35% which is the allowable demand factor.

First 3000 VA at 100%	3000 VA
Remaining 9900 VA at 35%	3465 VA

Net general lighting and small appliance load 6465 VA

Large appliance loads

Large appliance loads must be considered individually. The following large appliances are used in the example:

Air conditioner	9600 VA
Electric heat	12,000 VA
Electric clothes dryer	5000 VA
Electric range	9600 VA

The air conditioner and the electric heat will not be used at the same time. Only the larger of the heater load and air conditioner load is used. In this case the heater load (12,000 VA) is greater than the air conditioner load (9600 VA).

All other large appliance loads must be calculated at 100% except for the electric range. The *NEC* Table 220-19 allows a demand factor for electric ranges. Not all burners will normally be on high at the same time. According to Table 220-19, an electric range with a rating not greater than 12,000 VA can have a demand factor of 8000 VA. The range in this example is 9600 VA which is less than 12,000 VA; the 8000 VA demand factor rating can be used.

Electric heat	12,000 VA
Electric clothes dryer	5000 VA
Electric range	8000 VA

Net large appliance load 25,000 VA

Miscellaneous appliance loads

Miscellaneous appliance loads must also be taken into consideration. The example has the following miscellaneous appliance loads:

Dishwasher	1500 VA
Garbage disposal	1176 VA

Total miscellaneous appliance load	2676 VA
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The required service size is found by adding the calculated values together.

General lighting, laundry and small appliance load	6465 VA
--	---------

Net large appliance load	25,000 VA
--------------------------	-----------

Miscellaneous appliance load	2676 VA
------------------------------	---------

Total load	34,141 VA
-------------------	------------------

Required service size

The average power supply for residential use is 120/240 Volts. To determine the required load center rating divide the total load by 240 Volts (the highest Voltage used).

$$34,141 \text{ VA} \div 240 \text{ Volts} = 142 \text{ Amps}$$

A Siemens load center rated for 150 amps could be selected. Before a load center is selected, however, it is important to plan for electrical service expansion by providing space for at least two future branch circuits. Since the load for these future circuits is undetermined, add ten amperes per space. The amperage requirement is now 162 Amps.

$$142 \text{ Amps} + 20 \text{ Amps (expansion)} = 162 \text{ Amps}$$

Selecting a load center

Circuit breakers are affected by the temperature of the air surrounding them. For this reason an additional safety factor of 20% is added to the load center requirements.

$$162 \text{ Amps} + 32.4 (.20 \times 162) = 194.4 \text{ Amps}$$

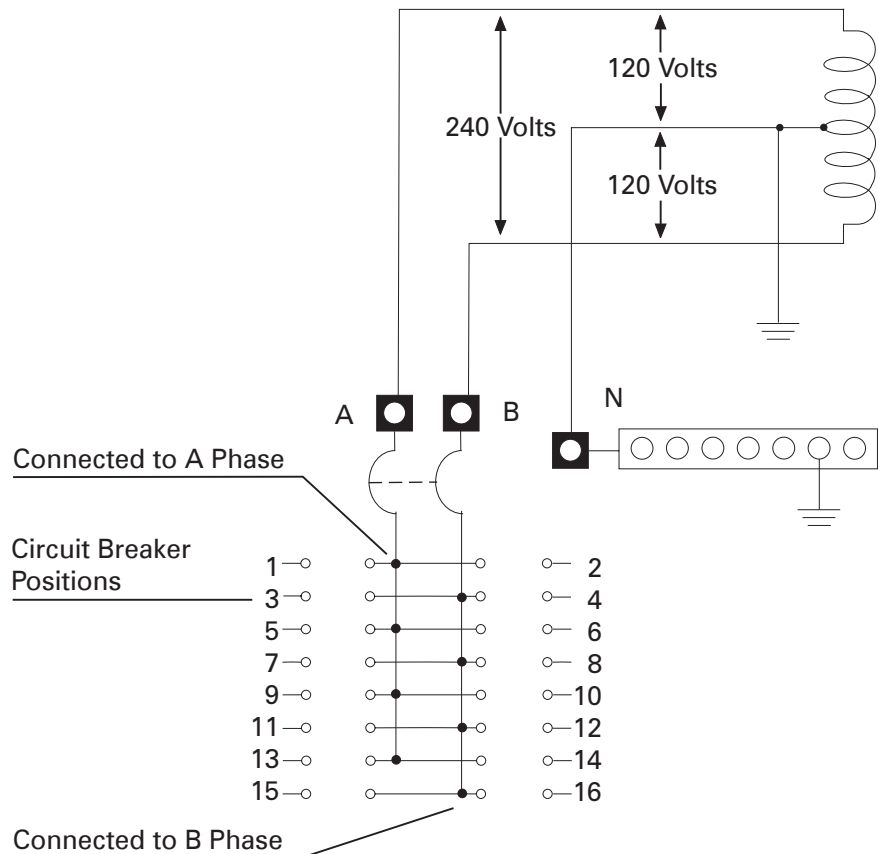
A 200 Amp load center would be a better choice.

Review 5

1. A 120 Volt, 10 Amps appliance would be rated at _____ Watts.
2. A 10,000 VA, 240 Volt appliance would require _____ Amps to operate.
3. The general lighting load of a 1390 square foot home is _____ VA.
4. The *National Electrical Code* requires a minimum of _____ 120 Volt, 20 Amp small appliance circuits for the kitchen area.
5. A home requiring 10,000 VA for general lighting, small appliances and the laundry circuit would have a net general lighting and appliance load of _____ VA after factoring in the allowable demand factor.
6. The minimum required service size of a load center in a home supplied by 120/240 Volt service with a connected load rated at 36,500 VA is _____ Amps.

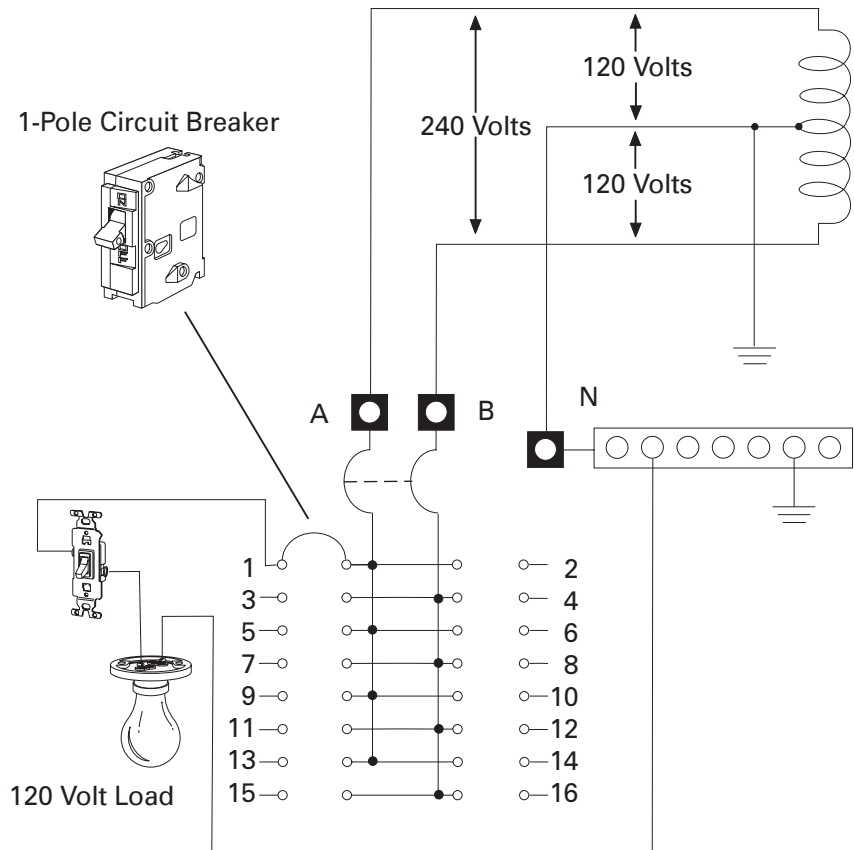
Determining The Number Of Circuits

To calculate the number of circuits required in a load center involves an understanding of how circuits are configured. In the following example a 120/240 Volt power supply is connected to a 16-space/circuit load center. The term A phase refers to the part of a single-phase system between one hot wire and neutral. The term B phase refers to the part of a single-phase system between the other hot wire and neutral. Half of the circuits are connected to A phase and half to B phase. For example, circuits 1 and 2 are connected to A phase; circuits 15 and 16 are connected to B phase. The number of usable circuits in this load center depends on how many 120 Volt and 240 Volt circuits need to be connected to it. Each 120 Volt circuit will use one of the circuit breaker positions. Each 240 Volt circuit will use two of the circuit breaker positions.



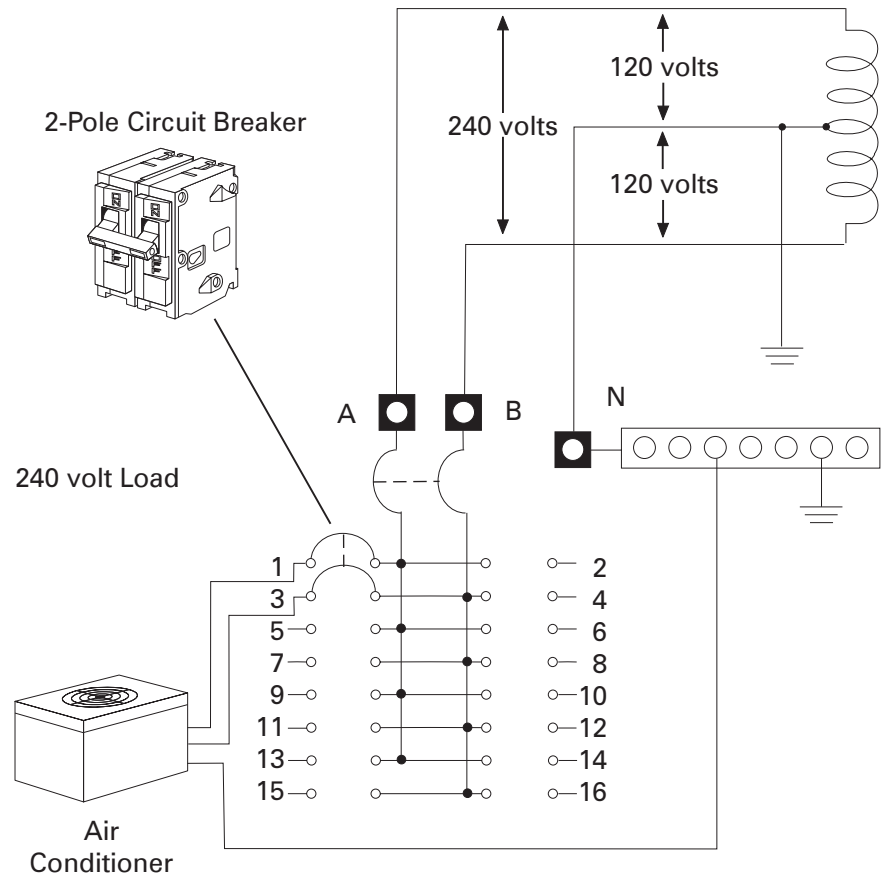
120 Volt circuit

A circuit requiring 120 Volts, such as general lighting and electrical receptacles, is connected through a 1-pole circuit breaker. In the following example a 1-pole circuit breaker has been installed in position 1. A lighting circuit receives 120 Volts from A phase, through the circuit breaker and returning to the neutral connection. Power to the light can be interrupted by the light switch. There are 15 circuit breaker positions left for additional circuits.



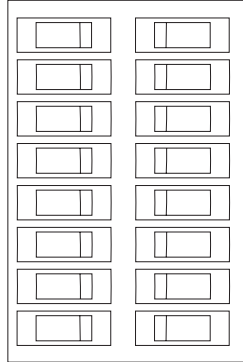
240 Volt circuit

A circuit requiring 240 Volts, such as an air conditioner or water heater, is connected through a 2-pole circuit breaker. In the following example a 2-pole circuit breaker has been installed in positions 1 and 3. An air conditioner receives 240 Volts from phase A, through the circuit breaker pole connected to position 1, and phase B, the pole of the circuit breaker connected to position 3. There are 14 circuit breaker positions left for additional circuits.

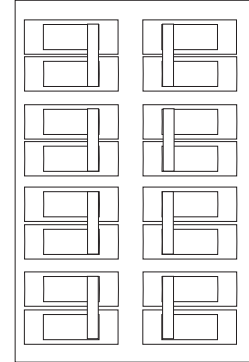


Full-size breakers

A full-size, 1-pole breaker requires one space (1") and a full-size, 2-pole breaker requires two spaces (2"). If a 16-space load center were selected, 16 full-size 1-pole breakers, 8 full-size 2-pole breakers, or a combination of 1- and 2-pole breakers in a combination that does not exceed 16 spaces can be used.



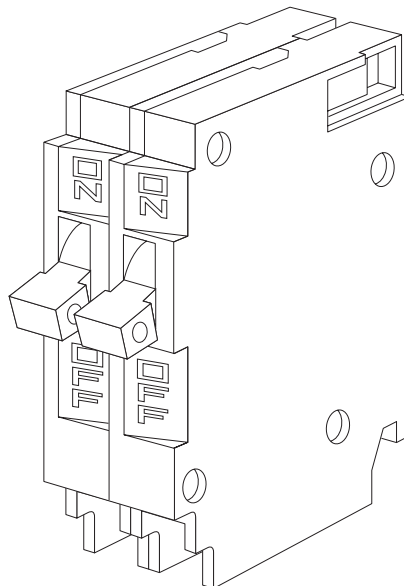
16 Full-Size Breakers
1-Pole Breakers
16 Spaces=16 Circuits



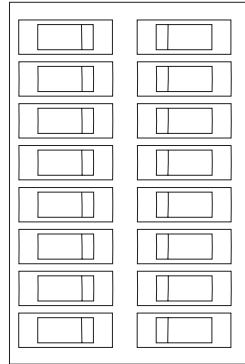
8 Full-Size
2-Pole Breakers
16 Spaces=8 Circuits

Dual breakers

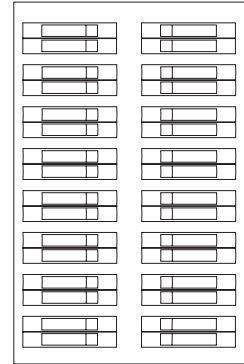
In most cases only full-size breakers are used. There are times, however, when extra branch circuits are needed but all spaces are used. Some Siemens load centers are designed to accept dual breakers. A dual breaker is two breakers in a housing that has the same dimensions of a full-size, 1-pole breaker. A quad 2-pole breaker (not shown) can be used in place of a full-size 2-pole breaker which will provide two, 2-pole circuits.



A full-size, 1-pole breaker requires one space and provides one 1-pole circuit. A dual 1-pole breaker requires one space and provides two 1-pole circuits. In a 16-space/32 circuit load center, 16 circuits are available if full-size 1-pole breakers are used, and 32 circuits are available if dual 1-pole breakers are used.



16 Full-Size Breakers
1-Pole Breakers
16 Spaces=16 Circuits



16 Dual Breakers
1-Pole Breakers
16 Spaces=32 Circuits

In the following example the number of circuits (spaces) required for a load center will be calculated using the example in the previous section, "Sizing The Load Center." Full-size circuit breakers will be used.

General lighting circuits

The minimum number of lighting circuits required for general lighting is calculated first. In the sample home the general lighting load was 6000 VA. To determine the amount of current used by a 6000 VA load, divide by the maximum Voltage. The maximum voltage for general lighting is 120 Volts.

$$6000 \text{ VA} \div 120 \text{ Volts} = 50 \text{ Amps}$$

Either 15 amp or 20 amp circuit breakers can be used. Typically 15 amp circuit breakers are used for general lighting. The number of minimum circuits is calculated by dividing current by breaker size. If 15 Amp circuit breakers were used four (4) circuits would be required. Depending on the layout of lighting and receptacles an electrician may specify more than the minimum number of circuits.

$$50 \text{ Amps} \div 15 \text{ Amps} = 4 \text{ circuits (3.33 rounded up to 4)}$$

Small appliance circuits

There are three 120 Volt, 20 Amp small appliance loads. Three 20 Amp circuit breakers are required.

Laundry circuit

There is one 120 Volt, 20 Amp laundry circuit. One 20 Amp circuit breaker is required.

Air conditioner circuit

Large appliances are considered individually. The air conditioner, heater, clothes dryer and range are all rated for 240 Volts. Each 240 Volt circuit will require a 2-pole circuit breaker which occupies two positions in the load center. The amperage is calculated by dividing VA rating by 240 Volts. The air conditioner, for example, is 9600 VA.

$$9600 \text{ VA} \div 240 \text{ Volts} = 40 \text{ Amps}$$

Generally the ampere rating of a circuit breaker is selected at 125% of the continuous load current. This usually corresponds to the conductor ampacity which is also selected at 125% of load current. The air conditioner is a 40 Amps load. A 50 Amp circuit breaker would be selected.

$$40 \text{ Amps} \times 1.25 (125\%) = 50 \text{ Amps}$$

Electric heater circuit

The electric heater is a 240 Volt, 50 Amp (12,000 VA \div 240 Volts) device.

$$50 \text{ Amps} \times 1.25 (125\%) = 65 \text{ Amps}$$

In this case, a non-standard rating (65 Amps) is required. It is not practical for manufacturers to have all ratings so the next available size, 70 Amps, would be selected.

Clothes dryer circuit

The clothes dryer is a 240 Volt, 21 Amp (5000 VA \div 240 Volts) device.

$$21 \text{ Amps} \times 1.25 = 26.25 \text{ Amps}$$

A 30 Amp circuit breaker would be selected.

Electric range circuit

The electric range is a 240 Volt, 40 Amp (9600 VA \div 240 Volts) device.

$$40 \text{ Amps} \times 1.25 = 50 \text{ Amps}$$

A 50 Amp circuit breaker would be selected.

Dishwasher circuit

The dishwasher and garbage disposal are 120 Volt loads. The dishwasher is a 120 Volt, 12.5 Amp (1500 VA ÷ 120 Volts) device.

$$12.5 \text{ Amps} \times 1.25 = 15.625 \text{ Amps}$$

A 20 Amp circuit breaker would be selected.

Garbage disposal circuit

The garbage disposal is a 120 Volt, 9.8 Amp (1176 VA ÷ 120 Volts) device.

$$9.8 \text{ Amps} \times 1.25 = 12.25 \text{ Amps}$$

A 15 Amp circuit breaker would be selected.

Number of load center spaces required

The total number of load center spaces (circuits) can now be calculated.

Circuit	Qty	Circuit Breaker	Voltage	Spaces Required
General Lighting	4	15 A	120 V	4
Small Appliance	3	20 A	120 V	3
Laundry	1	20 A	120 V	1
Air Conditioner	1	50 A	240 V	2
Electric Heater	1	70 A	240 V	2
Clothes Dryer	1	30 A	240 V	2
Electric Range	1	50 A	240 V	2
Dishwasher	1	20 A	120 V	1
Garbage Disposal	1	15 A	120 V	1
Total Spaces Required				18

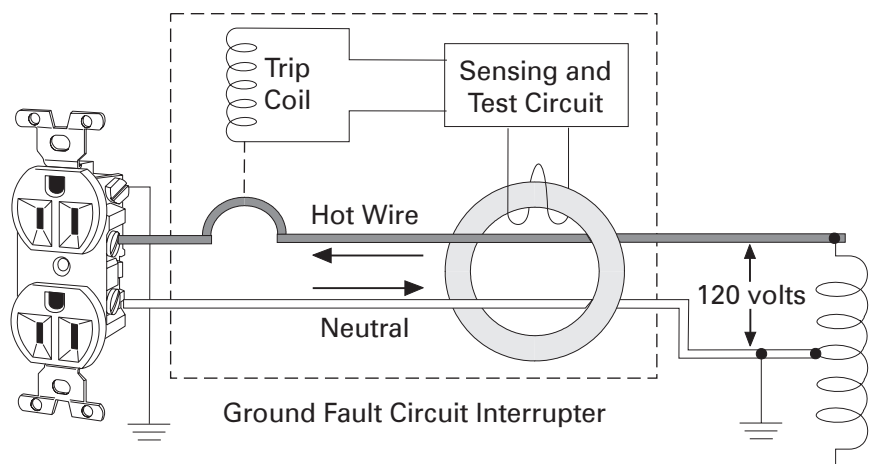
Selecting a load center

In the above example a load center with a minimum of 18 spaces would be needed. Since load centers are typically selected with spare circuit breaker spaces a 24-space load center would be a better choice.

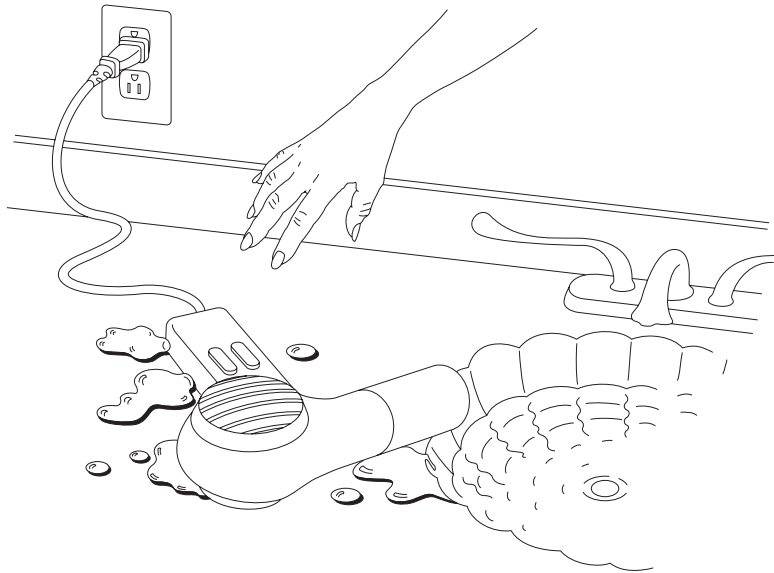
Ground Fault Protection

A ground fault occurs when a current-carrying conductor comes in contact with ground. A faulty appliance or the presence of water in contact with a conductor are two possible ways a ground fault can occur. One way ground fault protection is accomplished is by the use of GFCI receptacles. These are installed in place of a normal receptacle. Another way is with a GFCI circuit breaker such as the Siemens Type QPF GFCI circuit breakers. Any receptacle connected to the same circuit as the QPF GFCI circuit breaker is ground fault protected.

A ground fault circuit interrupter (GFCI) compares current on the hot wire with current returning on the neutral wire. Under normal circumstances the current is equal.



When a ground fault occurs some of the current will return to the source through ground. In the following illustration, for example, a ground fault has occurred in a common household appliance. Anyone coming in contact with the appliance will become part of the circuit. The sensing and test circuit will detect that the amount of current returning on the neutral is less than the current on the hot wire. The sensing and test circuit will cause the trip coil to automatically open the circuit breaker, removing power from the appliance. GFCI devices trip between 4 to 6 Milliamps. The amount of time it takes for a GFCI device to trip depends on the current. The higher the current the faster the device will trip.



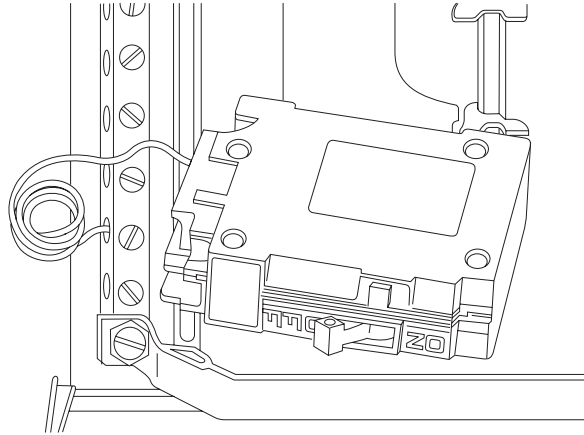
Areas requiring GFCI

Circuits providing power to certain areas of the home require ground fault circuit interrupters (GFCI). *NEC* Article 210-8 describes the requirements for location of GFCIs. Ground fault protection is required on the following circuits:

- Bathroom receptacles
- Residential garage receptacles
- Outdoor receptacles
- Receptacles in unfinished basements
- Receptacles in crawl spaces
- Receptacles within six feet of a kitchen or bar sink
- Pools

Installing a GFCI type circuit breaker

GFCI type circuit breakers have one white neutral lead which is connected to the neutral bus in the load center. The phase and load neutral are connected to lugs in the GFCI. They mount in the load center in the same way as a standard circuit breaker.



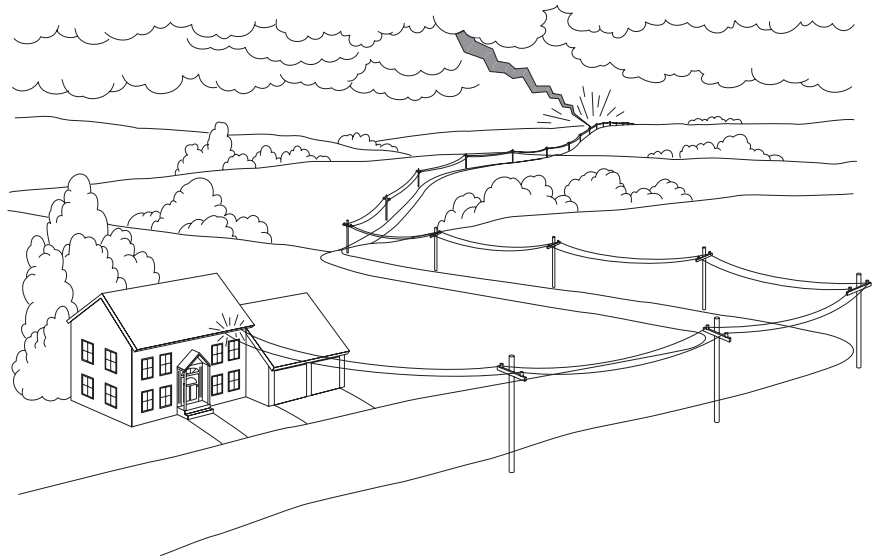
Review 6

1. The minimum number of 15 amp circuit breakers required for general lighting of a 1200 square foot house is _____ .
2. The laundry circuit requires one _____ Amp circuit breaker.
3. An air conditioner rated for 240 Volts, 40 Amps would require a 2-pole, _____ Amp breaker.
4. A _____ breaker can be used when an extra branch circuit is required but all of the load center spaces are already used.
5. A _____ _____ _____ _____ compares current on the hot wire with current returning on the neutral wire.
6. Which of the following areas does not require a GFCI device?
 - a. Bathroom receptacles
 - b. Outdoor receptacles
 - c. Living room receptacles
 - d. Receptacles within six feet of a kitchen sink

Surge Protection

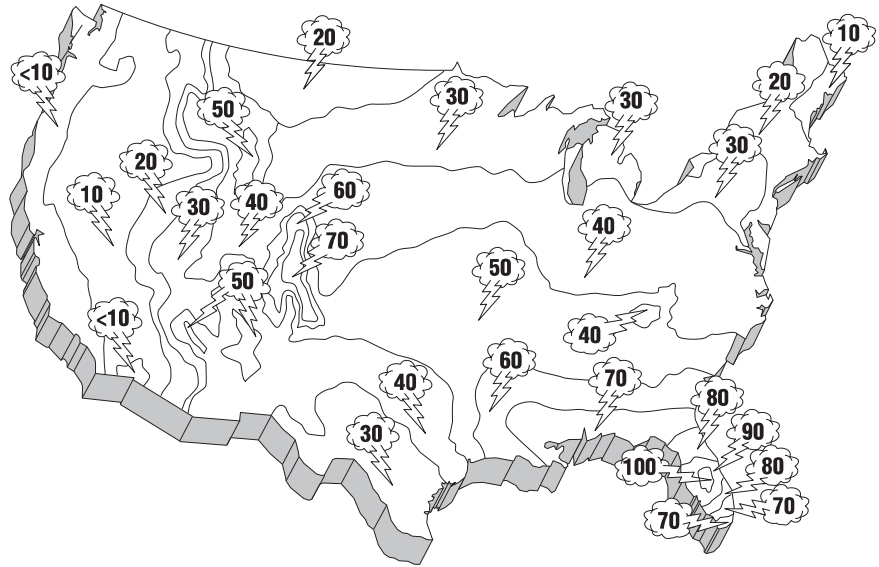
Need for surge protection

Today's homes have many semiconductor-based devices such as televisions, VCRs, stereos, computers and microwave ovens. These devices are highly susceptible to voltage spikes. Devices used in the home which generate voltage spikes include vacuum cleaners and other motor driven devices, and spark igniters on gas ranges, furnaces and water heaters. The most damaging voltage spikes are caused by lightning strikes. A lightning strike on a power line several miles away still has the potential to cause extensive electrical damage in a home. Lightning strikes on high voltage lines are generally dissipated by utility transmission and arresters. The average home, however, will experience eight to ten voltage surges of 1,000 to 10,000 Volts annually. Damage to expensive electrical equipment can be instantaneous or cumulative.



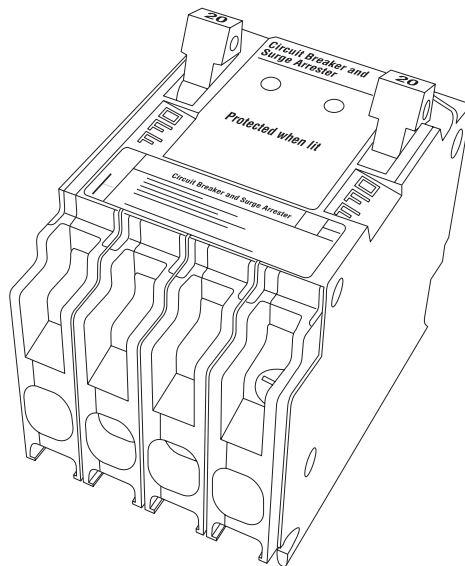
Number of thunderstorms

Worldwide there are 44,000 thunderstorms each day, 2000 thunderstorms at any given time, and 1000 lighting flashes per second. A typical lightning strike consists of 25,000 Amps at 30 million Volts. The following map shows the approximate mean annual number of days with thunderstorms in the United States.



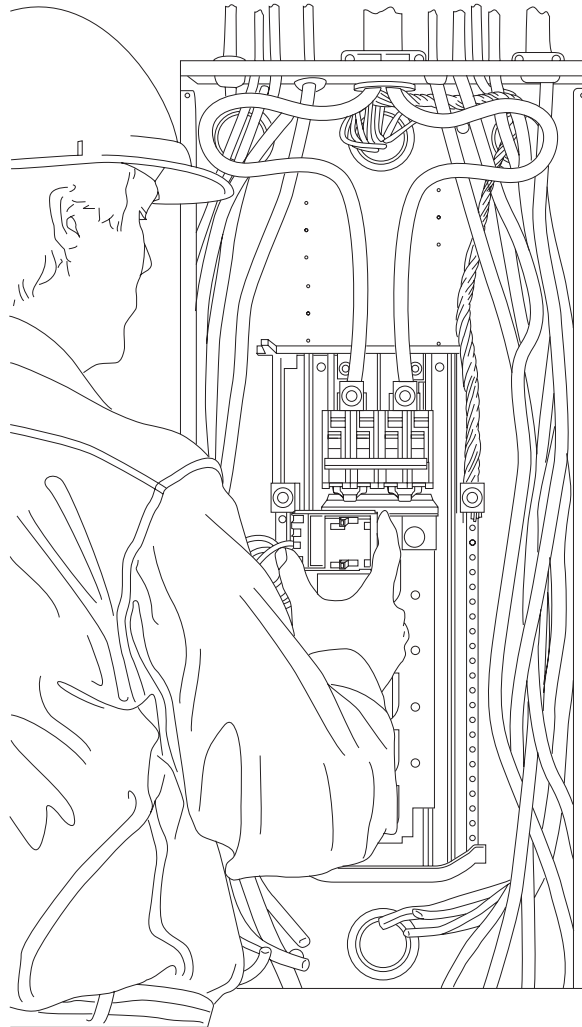
Siemens circuit breaker surge arrester

An electrical surge, whether it is caused by electrical equipment or lightning, always seeks ground. Any component between the source of the surge and ground can be damaged. Siemens circuit breaker surge arresters provide a preferred route to ground, bypassing expensive and sensitive equipment.



Installation

Installation is as simple as mounting a conventional circuit breaker in a Siemens load center. After power is switched off and the trim removed, the circuit breaker/surge arrester plugs into place. A lead wire is provided to connect the ground side of the module to the load center's neutral bus. One device provides protection for the electrical system. Two red LEDs indicate that the device is working. The device does not require a dedicated space and can be added on to existing Siemens load centers. The circuit breaker portion of the surge arrester can be used on noncritical lighting circuits to provide additional visual indication that the device is working. If the device trips due to a high voltage surge, it is reset like any other circuit breaker in the panel.



Clamping Voltage

Clamping voltage is the amount of voltage allowed across a surge suppression device when it is conducting a specific current created by a surge. The clamping voltage of the Siemens surge arrester is 600 Volts at 1500 Amps, and 800 Volts at 5000 Amps.

Peak current rating

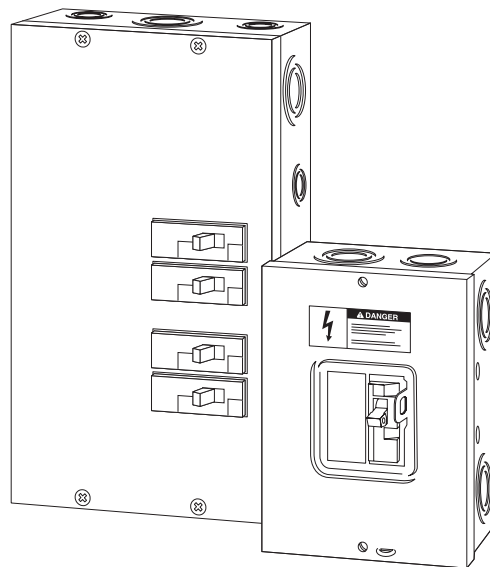
Peak current rating specifies the maximum energy that can be dissipated from a single surge without causing the protecting device to sacrifice itself. The Siemens surge arrester can withstand impulse currents as high as 40,000 Amps, and energy levels as high as 460 joules.

Siemens Small EQ[®] Load Centers

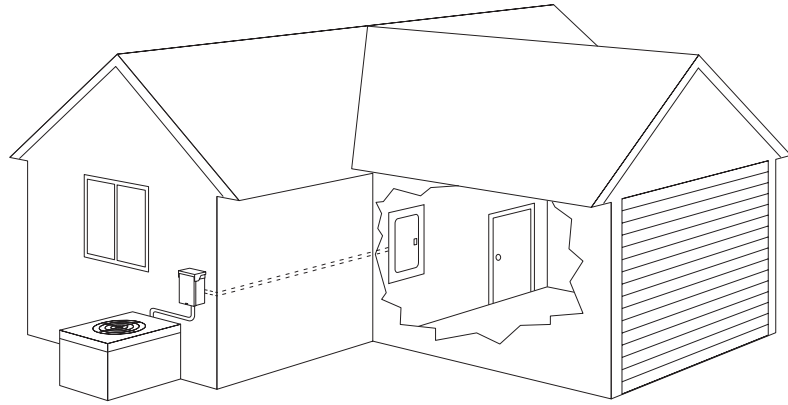
Siemens manufactures a variety of load centers. These can be categorized as small, medium and large EQ[®] load centers. The small EQ load centers are main lug only and range from 40 to 125 Amps with 2-8 spaces. These are for 1-phase, 3-wire, 120/240 Volt applications and are available with indoor (Type 1) and outdoor (Type 3R) enclosures.

Circuit breaker enclosures

Circuit breaker enclosures are available with indoor (Type 1) and outdoor (Type 3R) enclosures. Circuit breaker enclosures are available for 1-phase, 3-wire and 3-phase, 3- or 4-wire with 1-4 spaces. Circuit breaker enclosures are typically used as disconnects for machinery or service entrance applications.

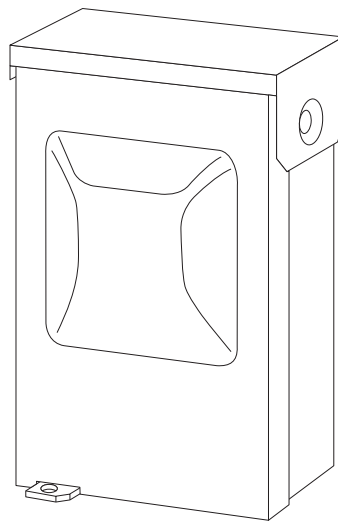


Circuit breaker enclosures are useful for supplying power to large pieces of equipment located downstream from a load center. This provides a means of disconnecting power within sight of the equipment. For example, a 50 Amp circuit breaker in a load center could supply another circuit breaker in an enclosure suitable for outdoor use located next to an air conditioner.

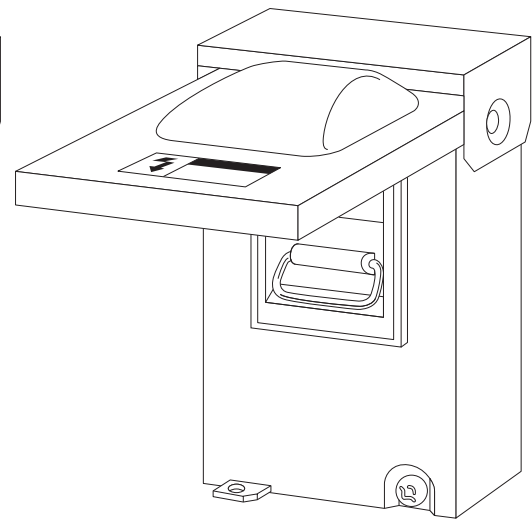


Fused, non-fused and molded case switch disconnects

Siemens also manufactures fused, non-fused and molded case switch disconnects. These are supplied in a NEMA Type 3R enclosure.

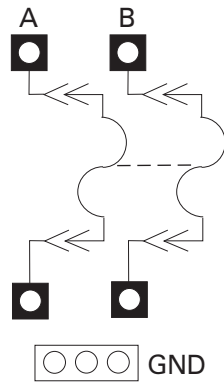


Disconnect Enclosure

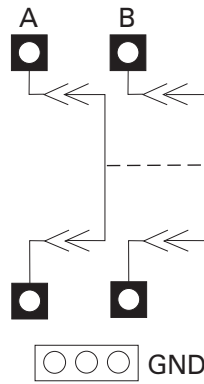


Fused Disconnect

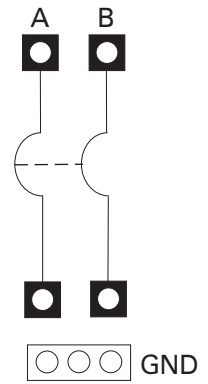
The fused pullouts are 240 Volt, 2-pole, 30 or 60 Amps. The non-fused pullouts are 240 Volt, 2-pole, 60 Amps. The molded case switch disconnects are 240 Volt, 2-pole, 50 or 60 Amps. Molded case switch disconnects are supplied with nonautomatic (QP molded case switch) circuit breakers.



Fused
Disconnect



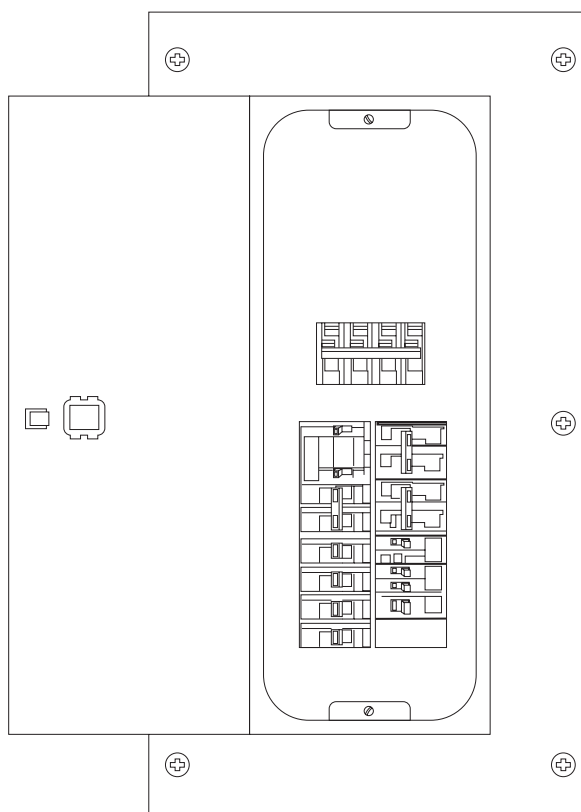
Non-Fused
Disconnect



Molded Case Switch
Disconnect

Siemens Medium EQ[®] Load Centers

Siemens medium EQ[®] load centers are available as main breaker or main lug only load centers. These load centers are available with indoor (Type 1) and outdoor (Type 3R) enclosures. Medium EQ load centers can be supplied with 12, 16, 20, 24, 30, 40 or 42 spaces. Main breaker load centers are rated for 100, 125, 150, 200 or 225 Amps. Main lug load centers are rated for 40, 60, 100, 125, 150, 200, or 225 Amps.



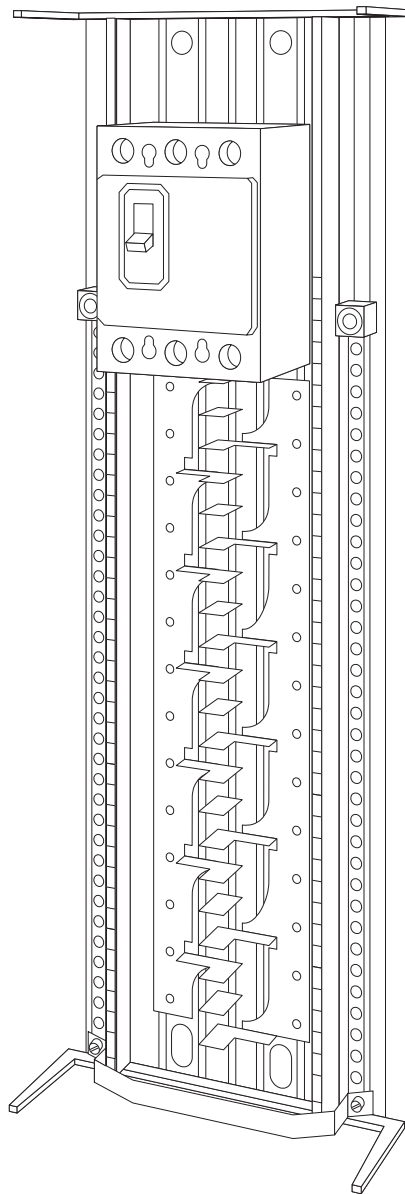
Medium EQ load centers are available for the following power supply systems:

1-phase, 3-wire, 120/240 Volts

3-phase, 3- or 4-wire, 120/240 or 208Y/120 Volts

Siemens Large EQ[®] Load Centers

Siemens large EQ[®] load centers are available as main breaker or main lug only load centers. These load centers are available with indoor (NEMA/UL Type 1) and outdoor (NEMA/UL Type 3R) enclosures.



Large EQ load centers have a maximum of 30 or 42 1-pole spaces and 14 or 20 2-pole spaces. Main breaker load centers are rated for 300, 400 or 600 Amps. Main lug only load centers are rated for 400 or 600 Amps.

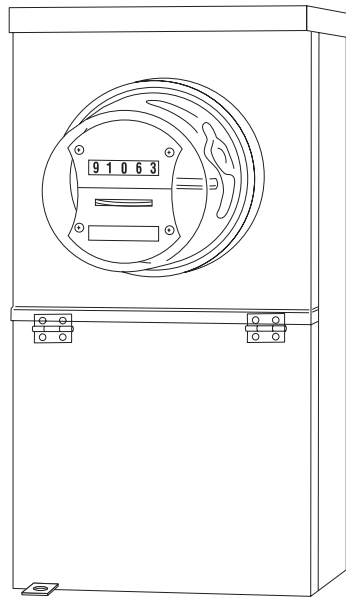
Large EQ load centers are available for the following power supply systems:

1-phase, 3-wire, 120/240 Volts

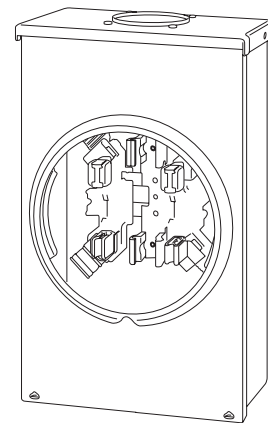
3-phase, 3- or 4-wire, 120/240 or 208Y/120 Volts

Single-Position Meter Sockets and Meter Combinations

Most of us are familiar with the watt-hour meter located outside of our homes. This equipment is used by the power company to determine how much electricity has been consumed for billing purposes. Siemens manufactures single-position meter sockets and meter mains, as shown below, as well as combination units.



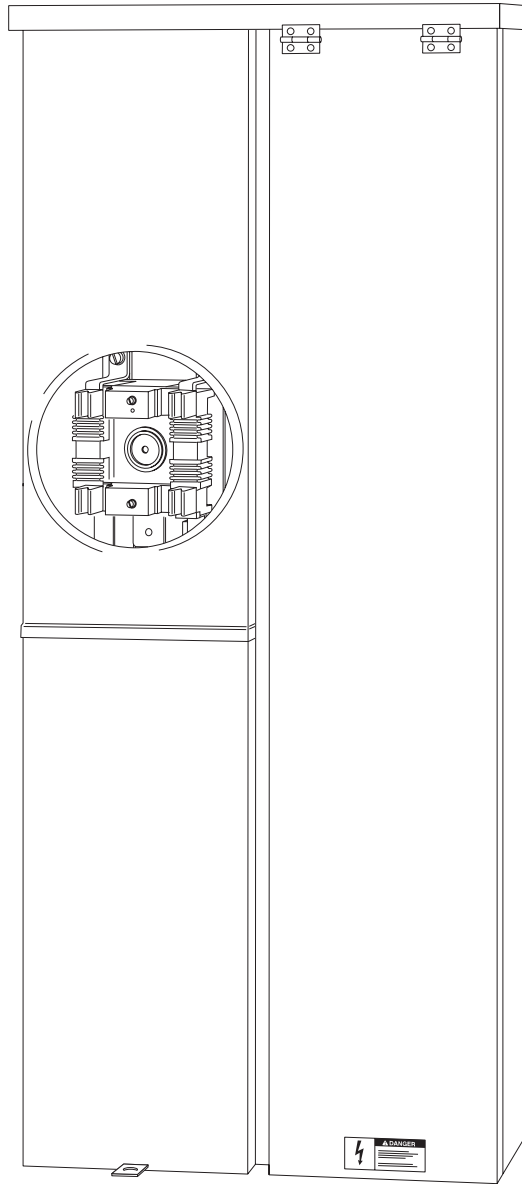
Meter Main



Single-Position Meter Socket

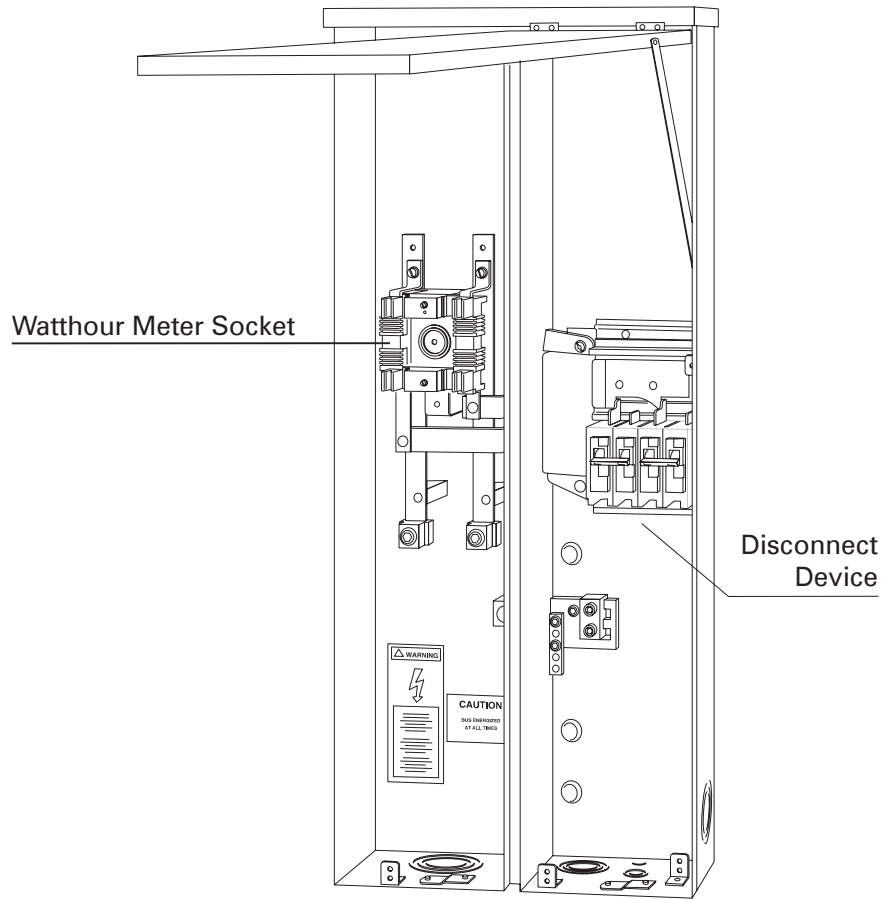
EQ meter combination

Siemens EQ® meter combinations are supplied in a NEMA Type 3R outdoor enclosure. Meter combinations are primarily found on the West Coast where they are mounted to the exterior of a house. Meter combinations are also becoming popular in other areas of the country.



Meter Load Center

This type of load center provides space for a watt-hour meter (supplied by the utility company) and some type of disconnect within the same enclosure. EQ meter combinations are rated for 100, 125, 150, 200 or 225 Amps with 2, 4, 8, 12, 20 or 40 spaces. A 400 Amp EQ meter combination comes with either 24 or 30 spaces and rated for 200 or 400 Amps.



Meter Main

Catalog Numbers

To help identify each type of load center a catalog number is assigned. The catalog number provides a description of the load center. There are nine parts to the standard EQ® load center. The following figure illustrates a typical catalog number.

1	2	3	4	5	6	7	8	9
G	12	24	MB	1	100	S	CU	22

Part 1

Part 1 identifies the type of enclosure or the component.

E	=	Indoor Type 1, 2-16 and 30-40 circuits
G	=	Indoor Type 1, 12-42 circuits
W	=	Outdoor Type 3R
T	=	Trim
I	=	Interior
R	=	Riser
MC	=	Meter Load Center
MM	=	Meter Main

Part 2

Part 2 identifies the number of spaces or poles. The number of spaces is the maximum number of Type QP, 1", 1-Pole circuit breakers that can be installed.

Part 3

Part 3 identifies the maximum number of circuits. The number of circuits will depend on how many 1-pole, 2-pole or dual circuit breakers types are installed.

Part 4

Part 4 identifies the type of load center.

ML	=	Main Lug Only
MB	=	Main Breaker
MC	=	Convertible

Part 5

Part 5 identifies the voltage and system.

1 = 1-Phase, 3-Wire

3 = 3-Phase, 3-Wire or 3-Phase, 4-Wire

Part 6

Part 6 identifies the main ampere rating.

Part 7

Part 7 identifies the type of trim and other characteristics.

Blank = Combination

GB = Ground Bar Installed

F = Flush

P = Pump Panel

S = Surface

T = Feed Through Lugs

Part 8

Part 8 identifies the type of bus bar.

Blank = Aluminum

C or CU = Copper

Part 9

Part 9 identifies the main breaker interrupting rating.

Blank = 22,000 AIR

22 = 22,000 AIR (3-phase load centers)

Review 7

1. The average home experiences _____ to _____ surges of _____ to _____ Volts annually.
2. Siemens circuit breaker surge arrestors provide protection against electrical Voltage surges by providing a _____ route to ground.
3. The Siemens circuit breaker surge arrestor has a peak current rating of _____ Amps.
4. Siemens disconnects are supplied in a NEMA Type _____ enclosure.
5. The maximum current rating of a Siemens medium sized load center is _____ Amps.
6. Meter combinations are primarily found on the _____, _____, however they are finding popularity in other areas of the country.
7. A "24" in part 3 of the load center catalog number indicates:
 - a. The load center is 24" high
 - b. The load center is rated for 24 Amps
 - c. The load center is rated for 240 Volts
 - d. The load center has a maximum of 24 circuits

Review Answers

- Review 1** 1) 250-b, 240-d, 220-h, 380-g, 384-c, 230-a, 410-f, 310-e.;
2) load center; 3) d; 4) ampacity; 5) ampere, voltage.
- Review 2** 1) 1, 3R; 2) bus bar; 3) 240, 120; 4) split neutral; 5) trim;
6) oxide-inhibiting; 7) 110-16.
- Review 3** 1) breaker, lug; 2) add-on, secondary, downstream; 3) feed-
thru; 4) two-wire; 5) 120; 6) 240; 7) 384-16.
- Review 4** 1) service entrance; 2) six; 3) voltage; 4) Bonding; 5) neutral;
6) full rating; 7) series-rated.
- Review 5** 1) 1200; 2) 41.6; 3) 4170; 4) 2; 5) 5450; 6) 152.
- Review 6** 1) 2; 2) 20; 3) 50; 4) dual; 5) ground fault circuit interrupter; 6)
c.
- Review 7** 1) eight to ten, 1,000 to 10,000; 2) preferred; 3) 40,000; 4) 3R;
5) 225 Amps; 6) West Coast; 7) d.

Final Exam

The final exam is intended to be a learning tool. The book may be used during the exam. A tear-out answer sheet is provided. After completing the test, mail the answer sheet in for grading. A grade of 70% or better is passing. Upon successful completion of the test a certificate will be issued. Those receiving a score of less than 70% will be provided a second test.

1. The basic requirements for load centers (panelboards) are given in *NEC* Article _____ .
 - a. 230
 - b. 384
 - c. 380
 - d. 410

2. Which of the following does not meet the *NEC* definition for a load center (panelboard)?
 - a. Used to control light, heat or power circuits
 - b. Placed in a cabinet or cutout box
 - c. Mounted in or against a wall
 - d. Accessible from either the front or back

3. A component used in a load center that serves as a common connection between two or more circuits is _____ .
 - a. the interior
 - b. a bonding strap
 - c. a bus bar
 - d. the enclosure

4. The required distance in front of a load center door and sufficient to allow the hinged door to open 90° is _____ .
 - a. 30 inches
 - b. 4 feet
 - c. 3 feet
 - d. 6 ½ feet

5. Two types of load centers are _____ .
- a. main breaker and back fed
 - b. main lug only and split neutral
 - c. main breaker and main lug only
 - d. main breaker and split neutral
6. The most common distribution used in residential applications is _____ .
- a. 2-wire, 120 Volts
 - b. 3-wire, 120/240 Volts
 - c. 3-wire, 480 Volts
 - d. 4-wire, 208Y/120 Volts
7. *NEC* Article 230-71(a) requires that no greater than _____ switches or circuit breakers can be used to disconnect and isolate the service from all other equipment on service-entrance equipment.
- a. 1
 - b. 2
 - c. 4
 - d. 6
8. The neutral conductor is _____ bonded/grounded at the service-entrance load center.
- a. always
 - b. never
 - c. rarely
 - d. often
9. The neutral conductor is _____ bonded/grounded at the load centers downstream from the service-entrance load center.
- a. always
 - b. never
 - c. rarely
 - d. often
10. The _____ method has the main upstream circuit breaker equal to or greater than the available fault current, and downstream circuit breakers rated at lower values.
- a. series-rated
 - b. withstand rating
 - c. full rating
 - d. interrupting rating

11. A 2400 square foot house would require a minimum of _____ 15 Amp circuit breakers for general lighting.
- a. 3
 - b. 4
 - c. 5
 - d. 6
12. According to *NEC* Article 220-4b at least _____ 120 Volt, 20 Amp small appliance circuits shall be provided for use in the kitchen area for small appliances such as toasters and coffee makers.
- a. 1
 - b. 2
 - c. 3
 - d. 4
13. Given a total general lighting and small appliance load of 15,000 VA, the net general lighting and small appliance load using the demand factor is _____ VA.
- a. 4200 VA
 - b. 12,000 VA
 - c. 7200 VA
 - d. 42,000 VA
14. A 240 Volt circuit requires _____ spaces in a load center supplied by a 3-wire, 120/240 Volt supply.
- a. 4
 - b. 3
 - c. 2
 - d. 1
15. A _____ breaker can be used when an extra branch circuit is required but all of the load center spaces are already used.
- a. full size
 - b. 2-pole
 - c. GFCI
 - d. dual
16. Ground fault protection is required in which of the following areas?
- a. bathroom receptacles
 - b. bedroom receptacles
 - c. living room receptacles
 - d. family room receptacles

17. Siemens surge arrestors can withstand impulse currents as high as _____ Amps.
- | | | | |
|----|--------|----|--------|
| a. | 10,000 | b. | 20,000 |
| c. | 30,000 | d. | 40,000 |
18. Siemens medium size load centers are available with a maximum current rating of _____ Amps.
- | | | | |
|----|-----|----|-----|
| a. | 100 | b. | 200 |
| c. | 225 | d. | 250 |
19. Siemens small EQ fused, non-fused, and molded case switch disconnects are supplied in a NEMA Type _____ enclosure.
- | | | | |
|----|---------|----|----|
| a. | 3R | b. | 1 |
| c. | 1 or 3R | d. | 12 |
20. A type of load center that provides space for a watt-hour meter and some type of disconnect within the same enclosure is a _____ .
- | | |
|----|---------------------------|
| a. | main breaker load center |
| b. | main lug only load center |
| c. | circuit breaker enclosure |
| d. | meter combination |