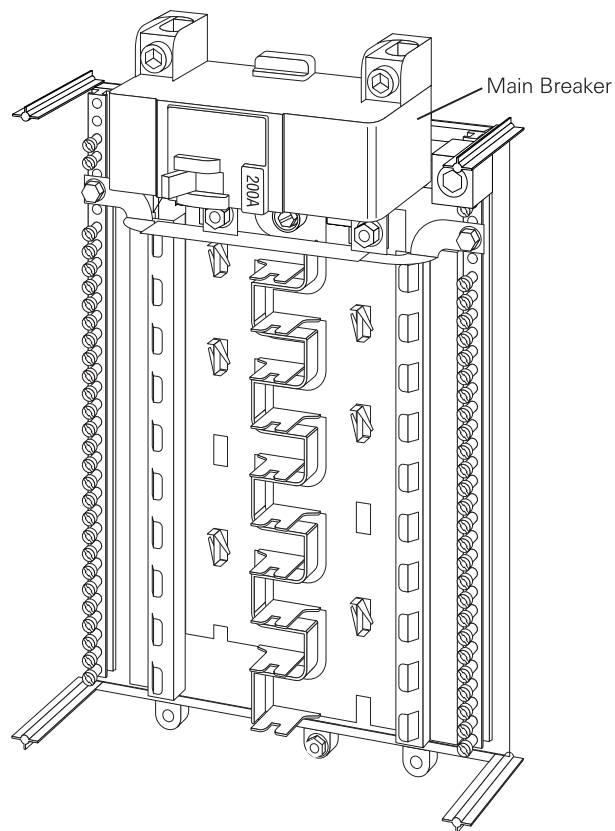


Types Of Load Centers

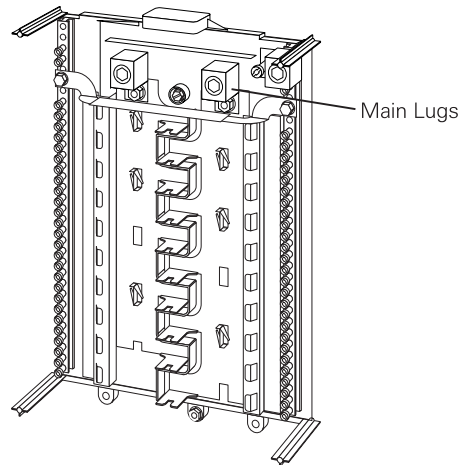
Main Breaker

There are two types of load centers, main breaker and main lug only. Main breaker load centers are suitable for use in service entrance applications. 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.

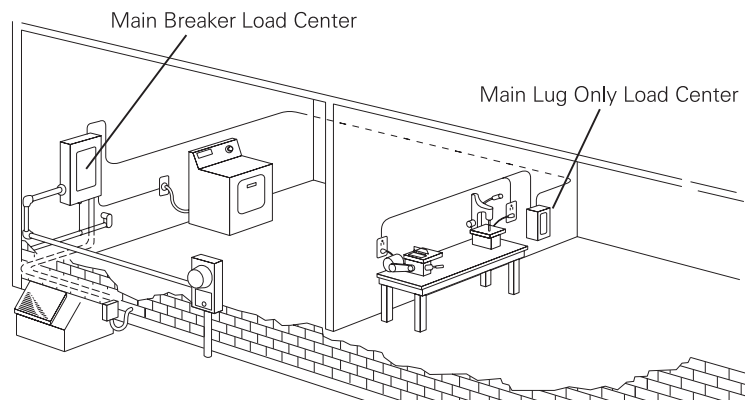


Main Lug Only

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 upstream in the system. There are situations where a back fed circuit breaker and a retainer clip (required by *NEC*[®]) are used to convert a main lug load center to a main breaker load center.



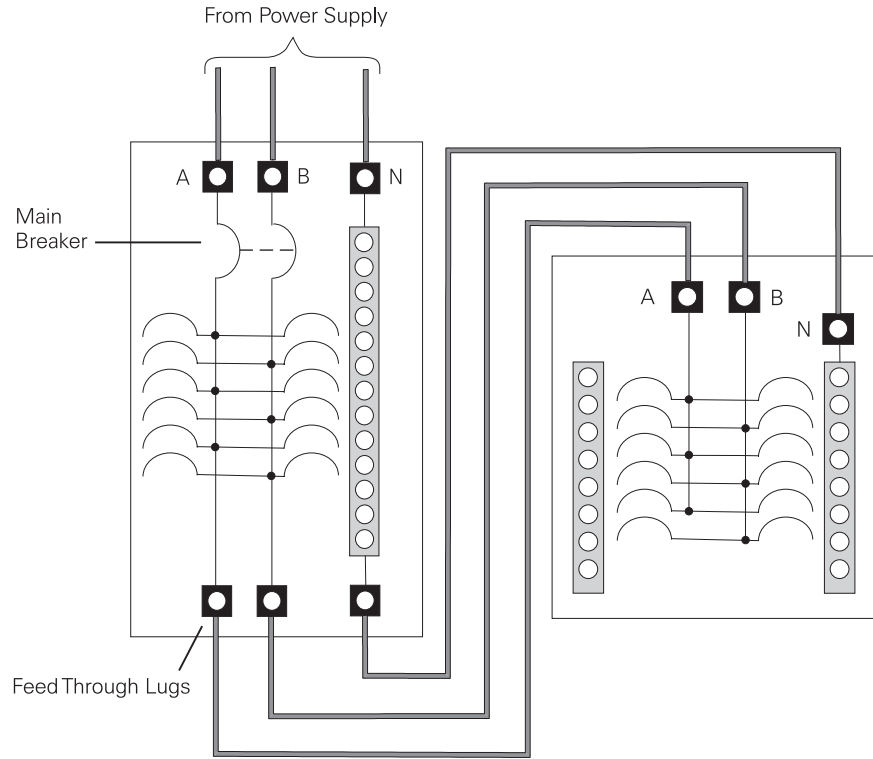
Main lug load centers are sometimes referred to as add-on, secondary or downstream panels. These panels are added when all circuit slots in the main breaker load center are full or when a remote panel is desired. For example, a main breaker load center might supply power to a main lug load center located 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.



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Feed-Thru Lugs

There are two ways to sub feed power to a secondary load center. 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 utility power is supplied to a main breaker load center. Power is taken from the feed-thru lugs and supplied to another load center downstream.



Load Center Ratings

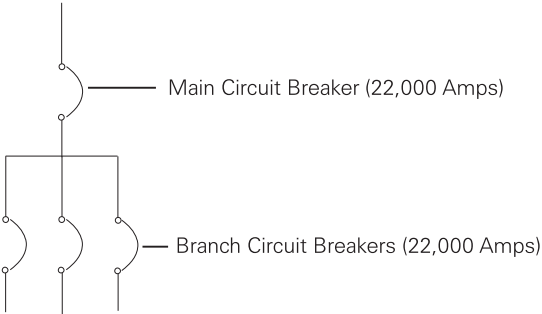
When selecting load centers and overcurrent protection devices, it is extremely important to know both the maximum continuous amperes and available fault current. *NEC*[®] article 110.9 states:

Equipment intended to interrupt current at fault levels shall have an interrupting rating sufficient for the nominal circuit voltage and the current that is available at the line terminals of the equipment.

Equipment intended to interrupt 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

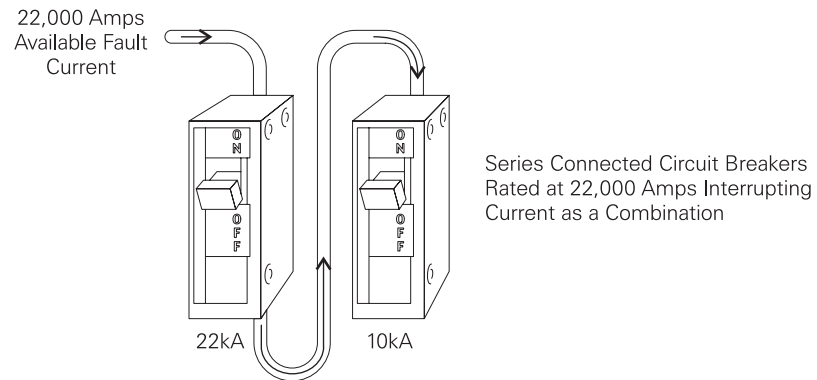
There are two ways to meet this requirement. The full rating method is to select circuit protection devices with individual ratings equal to or greater than the available fault current. This means that, in the case of a building with 22,000 amperes of fault current available at the service entrance, 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.



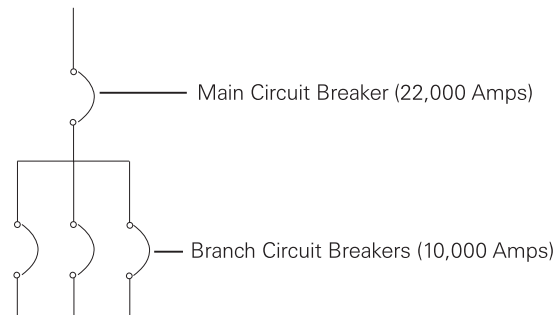
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Series Rated

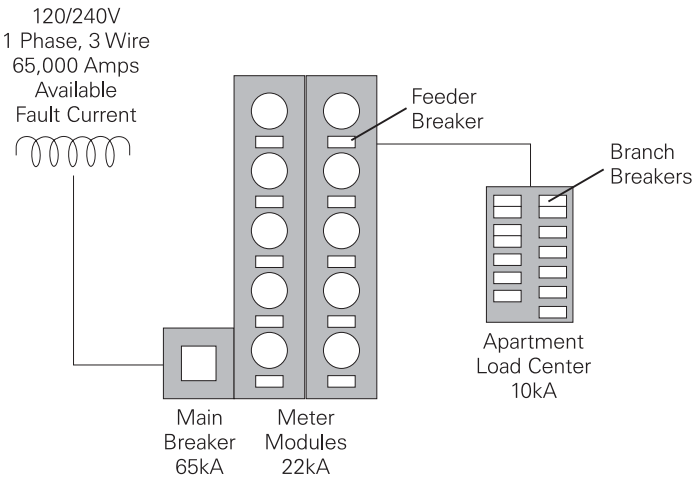
The series rated method is that the main upstream circuit protection device must have an interrupting rating equal to or greater than the available fault current of the system, but subsequent downstream circuit protection devices connected in series can be rated at lower values. For example, a building 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 it is not uncommon to see three breaker series combinations. The main power of an apartment complex, for example, might have 65,000 amperes available fault current. The main disconnect must be capable of interrupting this fault current. The feeder disconnects, however, may only have to be rated for 22,000 amperes of fault current, and individual apartments rated for 10,000 amperes of fault current.



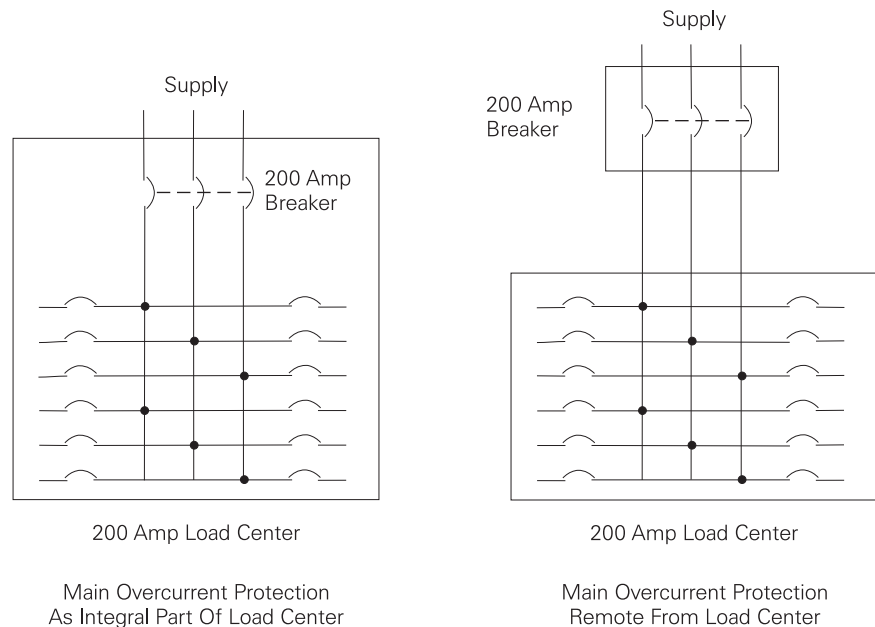
Series-rated breaker combinations must be tested in series in order to be UL recognized. The *NEC*[®] requires the series ratings to be marked on the load center (240.86). Selected series rated breakers are listed in the Speedfax catalog. Your Siemens sales engineer can provide more information on Siemens series-rated circuit breakers.

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 408.16(A) 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.*

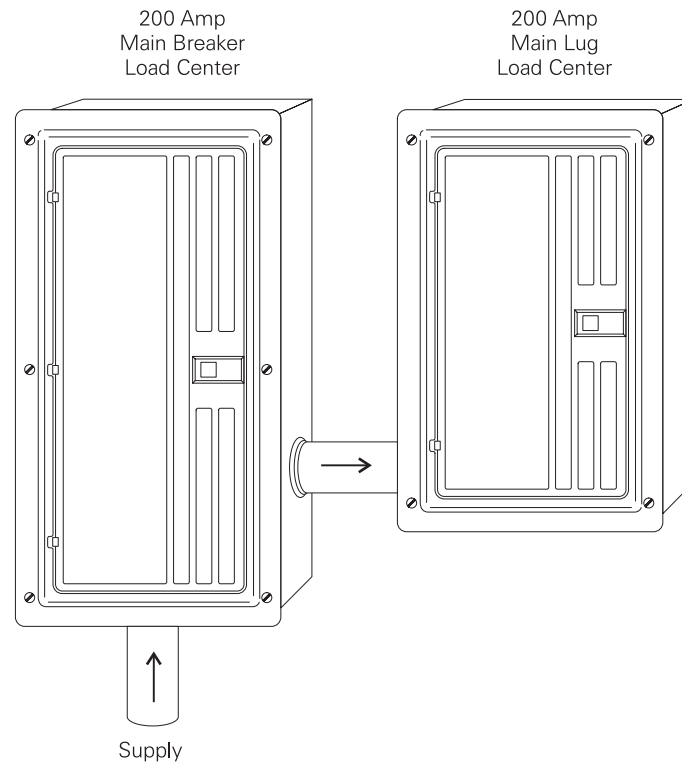
Individual Protection

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 could be used. In this example the main breaker and load center are both rated for 200 amps.



Exception to *NEC*[®] 408.16

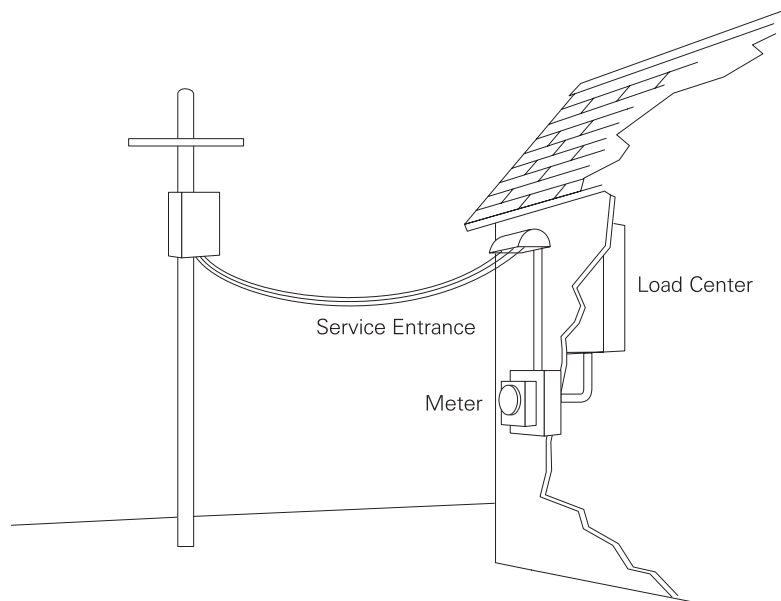
There is an exception to *NEC*[®] Article 408.16(A). *Exception No. 1: Individual protection for a lighting and appliance panelboard shall not be required if the panelboard feeder has overcurrent protection not greater than the rating of the panelboard.* The following illustration shows two load centers 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.



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Service Entrance/Equipment Load Centers

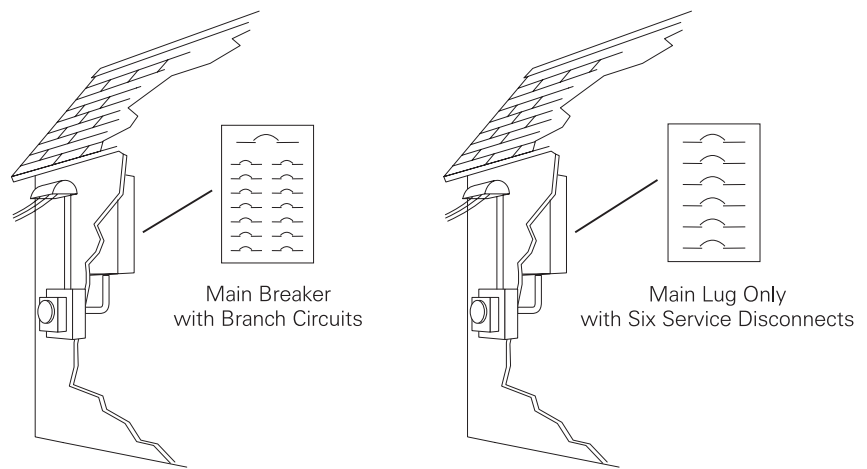
Load centers are frequently used as service equipment for a building. This is the equipment located near where the power supply enters the building. The incoming power supply is connected to this equipment which provides a means to control and cut off the supply. The *National Electrical Code*® discusses 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.



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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 230.71(A) 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.



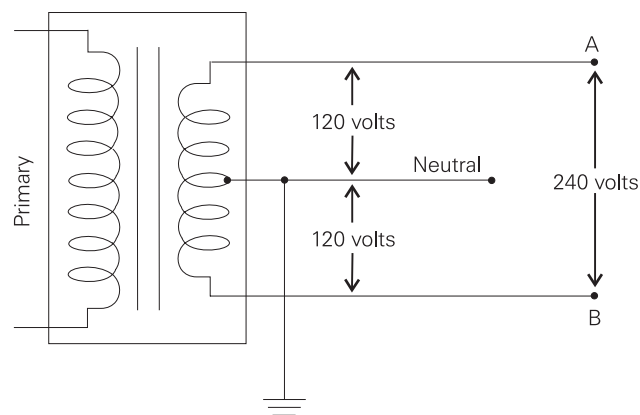
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1. The two types of load centers are main _____ and main _____ only.
2. Main lug only load centers are sometimes referred to as _____ - _____ , _____ , or _____ panels.
3. _____ - _____ lugs is one method used to supply power from one load center to another.
4. The _____ rating method is to select circuit protection devices with individual ratings equal to or greater than the available fault current.
5. The _____ rated method is that the main upstream circuit protection device must have an interrupting rating equal to or greater than the available fault current, but subsequent downstream circuit protection devices connected in series can be rated at lower values.
6. *NEC*[®] specifies that a maximum of _____ switches or circuit breakers used to disconnect the service and isolate the service from other equipment.

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.



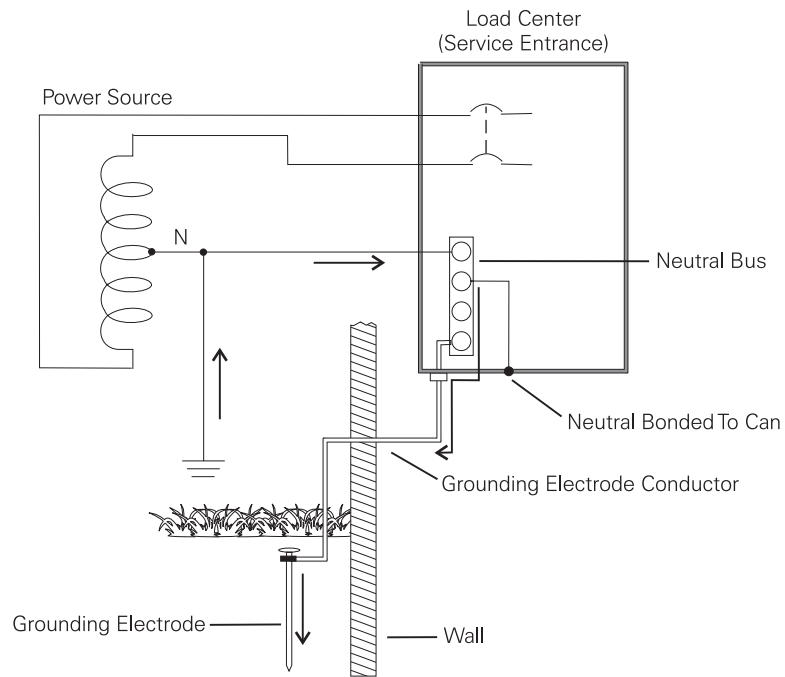
There are two objectives to the intentional grounding of electrical equipment:

- 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.

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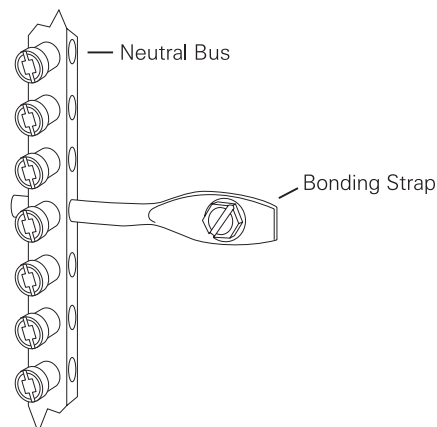
Service Entrance Grounding

The neutral 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.



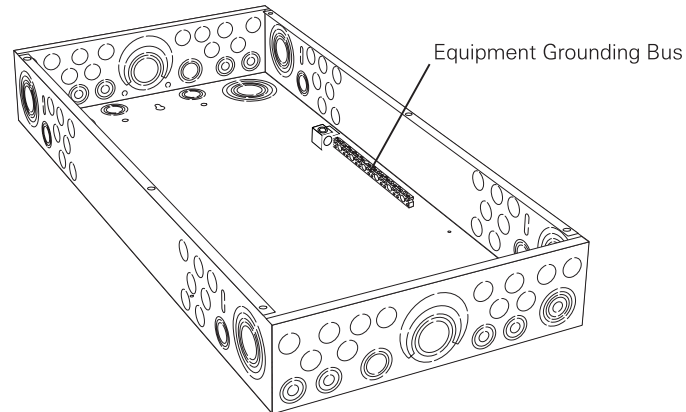
Bonding

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.



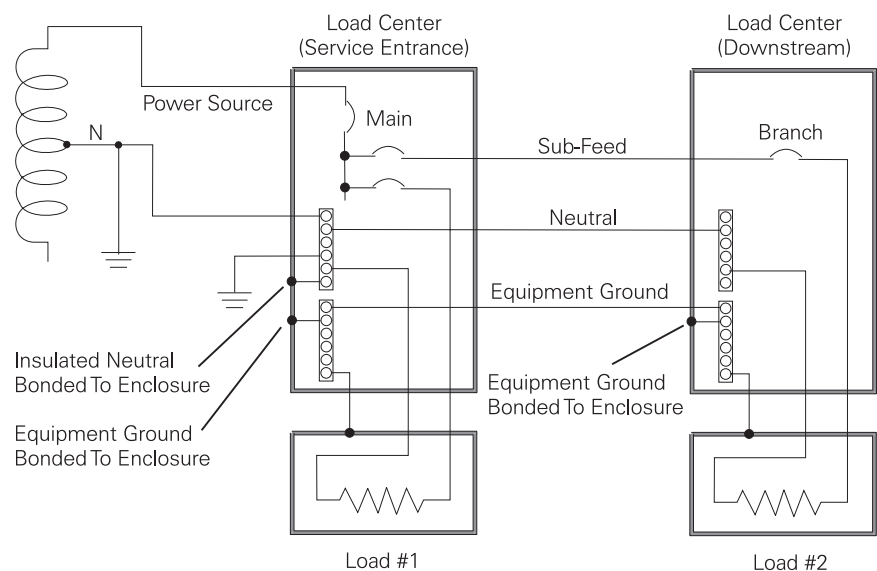
Equipment Grounding Bus

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.



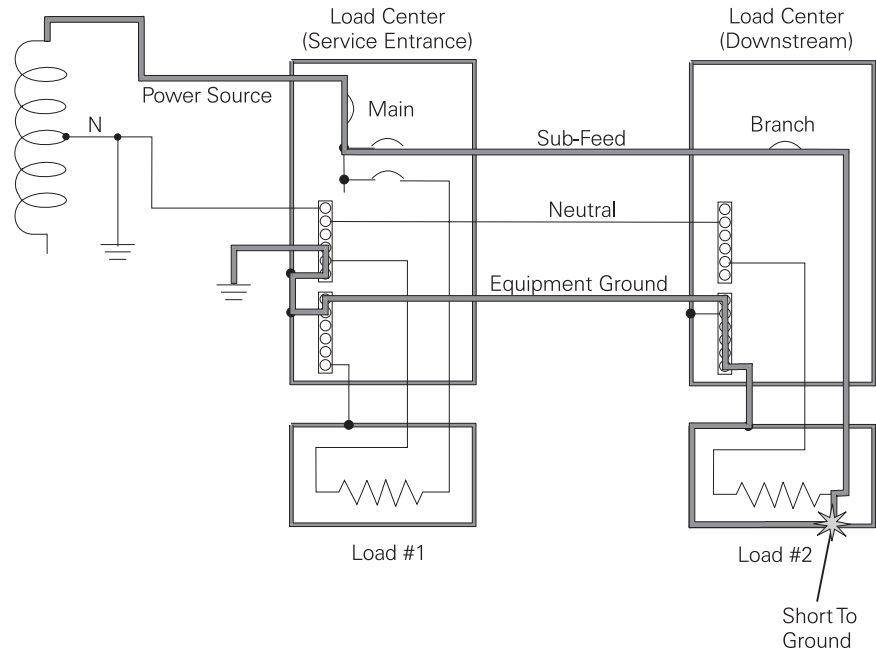
Grounding Downstream Load Centers

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

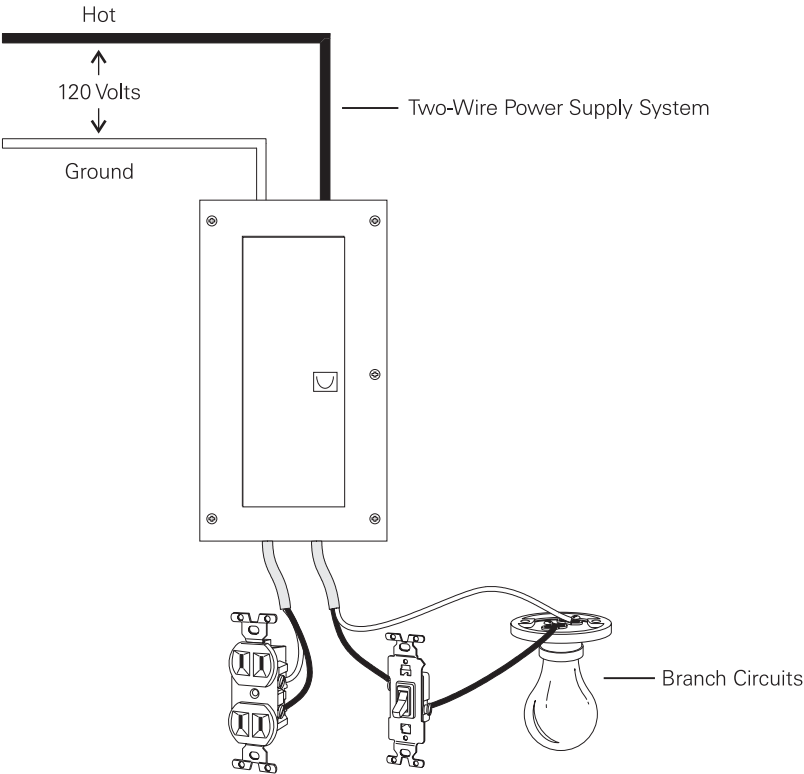
In the following illustration load #2 has become shorted to its metal enclosure. Fault current is returned to the source through the path indicated. With a properly coordinated system the branch circuit breaker in the downstream load center will open removing the load from the power source. For a discussion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



Power Supply Systems

Two-Wire System*

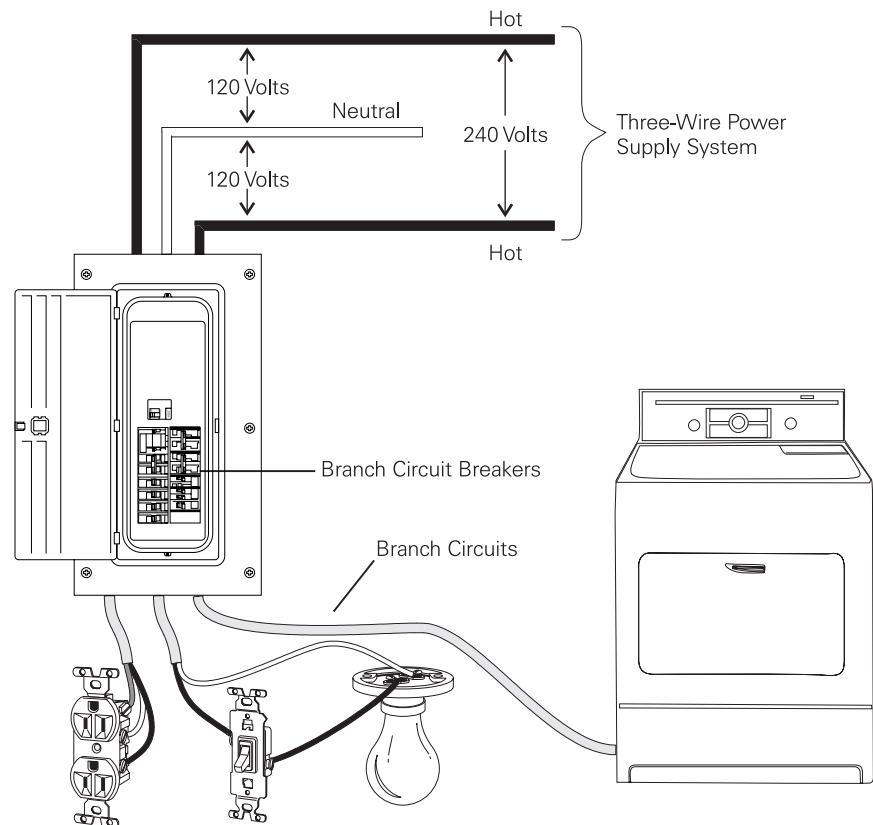
Homes built prior to 1936, especially in rural areas, used a two-wire supply system. This system provided 120 volts between a hot conductor and a grounded conductor. A two-wire system is usually inadequate for today's residential electrical demands.



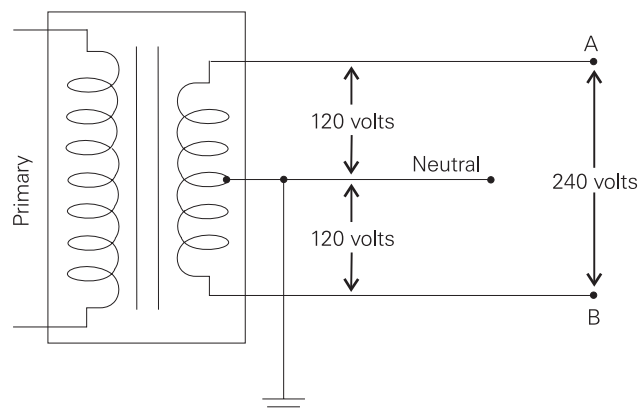
*Not allowed for new construction

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.



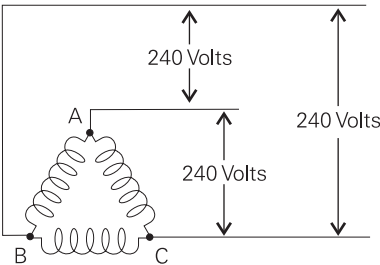
The following illustration shows a three-wire, single-phase 120/240 volt system. 120 volts can be obtained by connecting a load between phase A and neutral, or phase B and neutral. 240 volts can be obtained by connecting a load between phase A and phase B.



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.

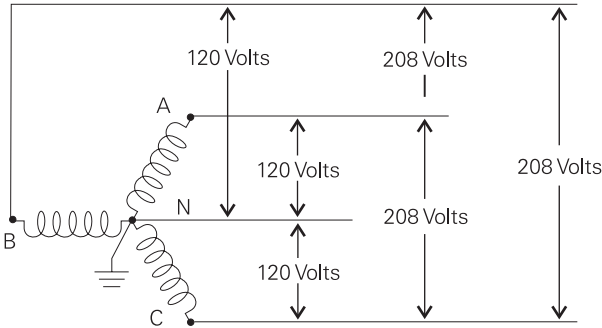
3-Wire, 3-Phase, 240 Volt

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



4-Wire, 3-Phase, 208Y/120V

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.

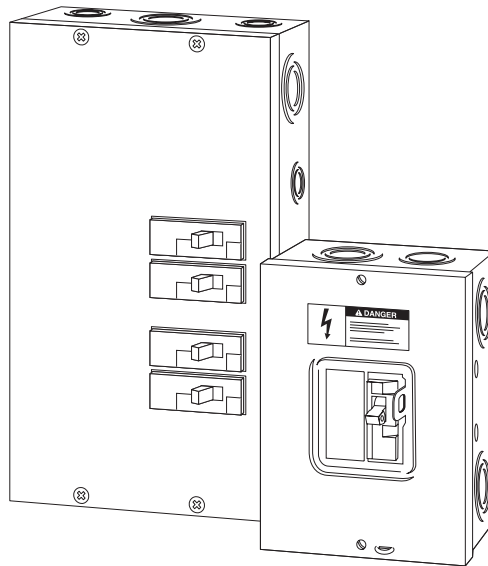


Siemens Small EQ Load Centers

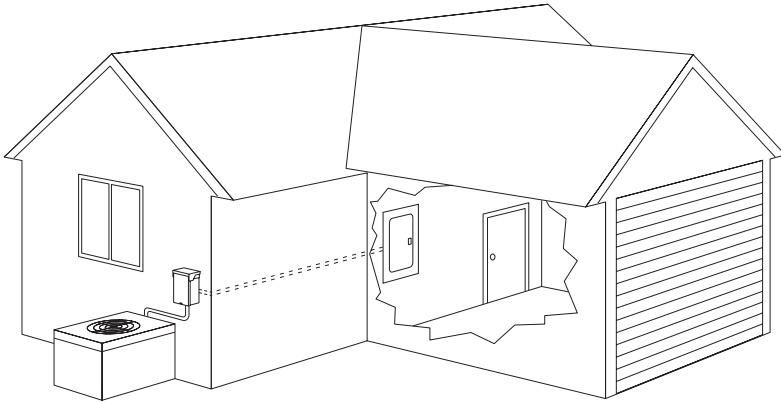
Siemens manufactures a variety of load centers. These can be categorized as small, medium and large EQ[®] load centers. The small EQ load centers range from 60 to 200 amps with 2-8 spaces. These are for 1-phase, 3-wire, 120/240 volt applications and are available with indoor (Type 1) and outdoor (Type 3R) enclosures.

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.

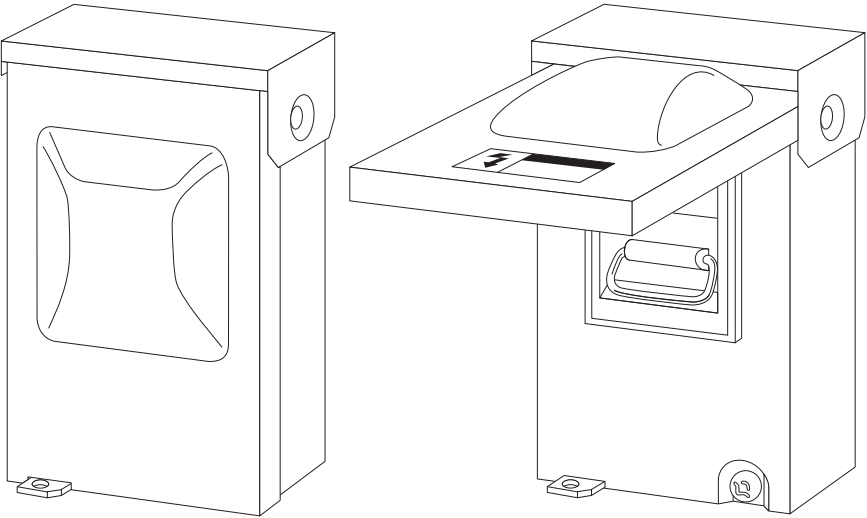


Circuit breaker enclosures are useful for supplying power to large pieces of equipment located downstream from a load center. This provides a means of disconnecting power within sight of the equipment. For example, a 50 amp circuit breaker in a load center could supply another circuit breaker in an enclosure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



Fused, Non-Fused, and Molded Case Switch Disconnects

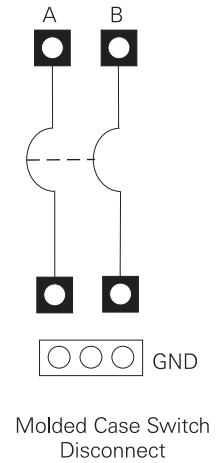
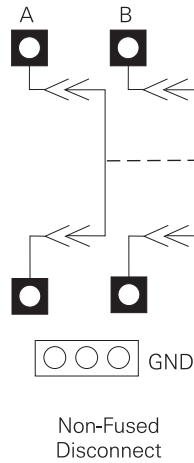
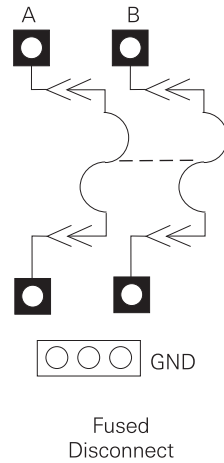
Siemens also manufactures fused, non-fused and molded case switch disconnects. These are supplied in a NEMA Type 3R enclosure.



Disconnect Enclosure

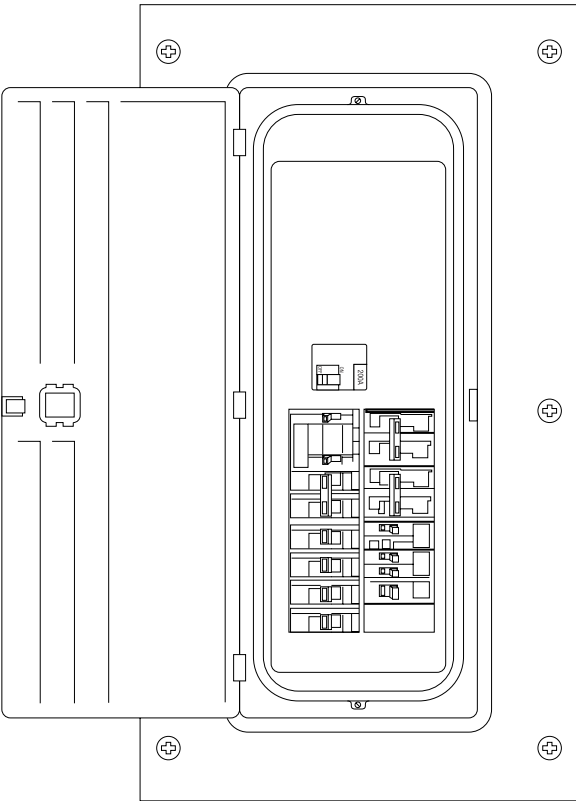
Fused Disconnect

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.



Siemens Ultimate Load Centers

Siemens Ultimate load centers are commonly used in single-family homes. They 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. Siemens Ultimate 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.



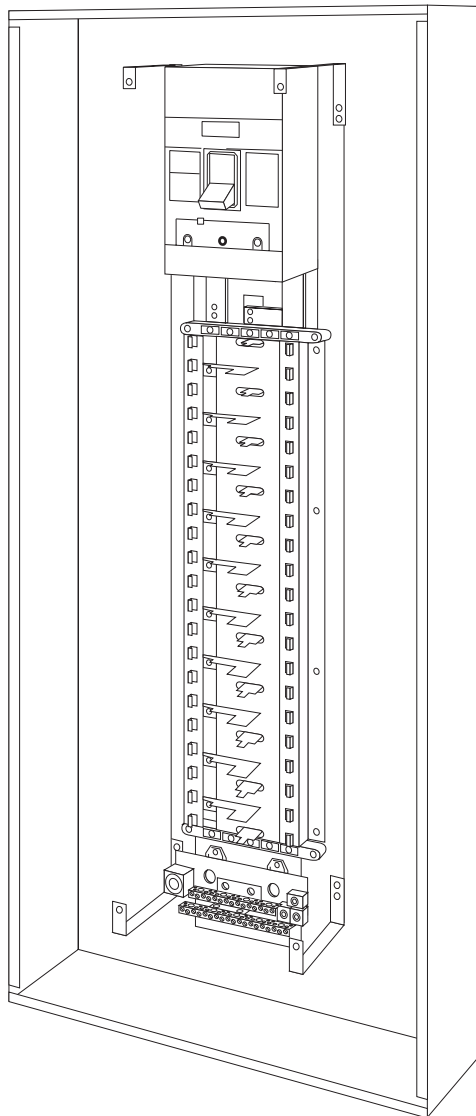
Medium EQ load centers are available for the following power supply systems:

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 or 400 amps. Main lug only load centers are rated for 400 amps.

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

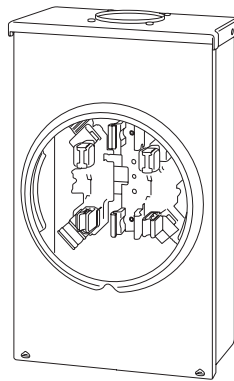
1-phase, 3-wire, 120/240 volts

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

Meter Sockets, Meter Mains, and Meter Combinations

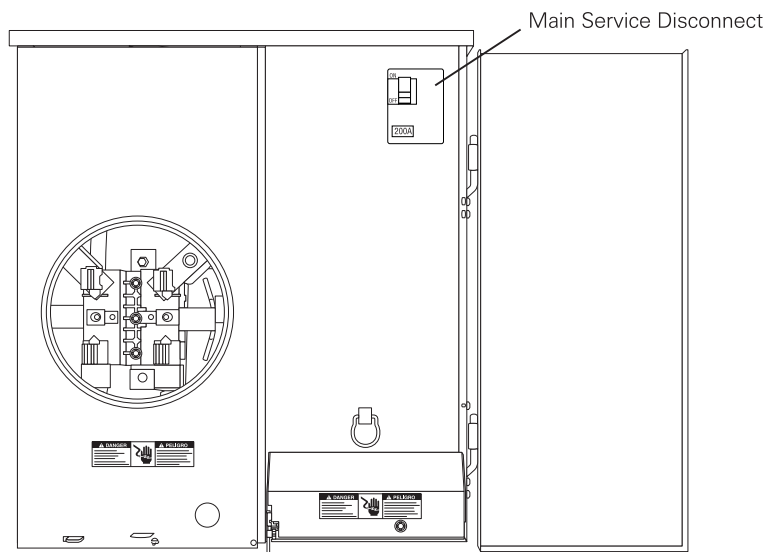
Meter Sockets

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 for residential use.

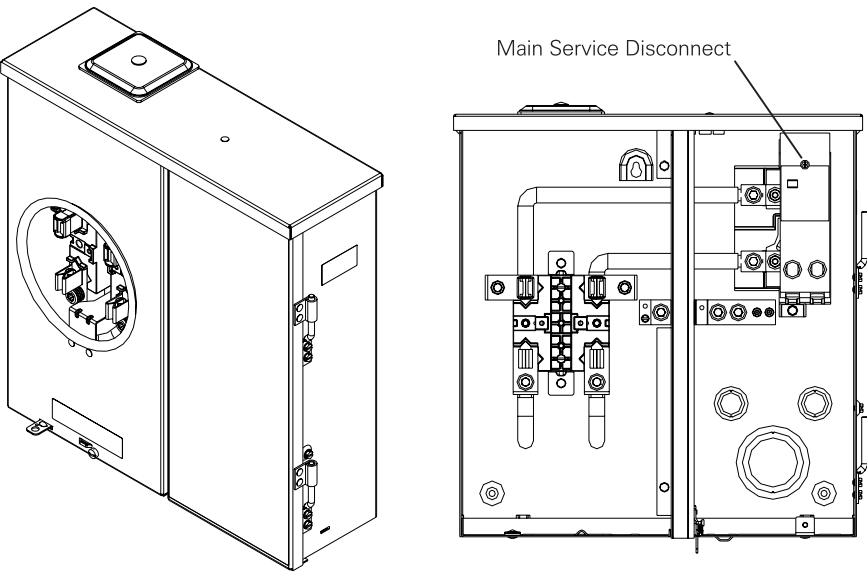


Meter Mains

Meter mains incorporates space for a watt-hour meter (supplied by the utility company) and a main service disconnect within the same enclosure.

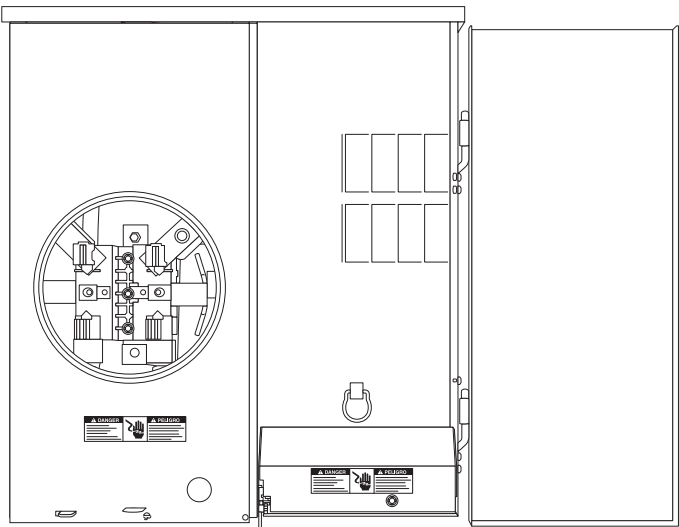


Siemens meter mains are rated for 125, 150, or 200 amps. They are available with 2 spaces (2 circuits) or 4 spaces (6 circuits). Siemens meter mains can be used with overhead or underground service.



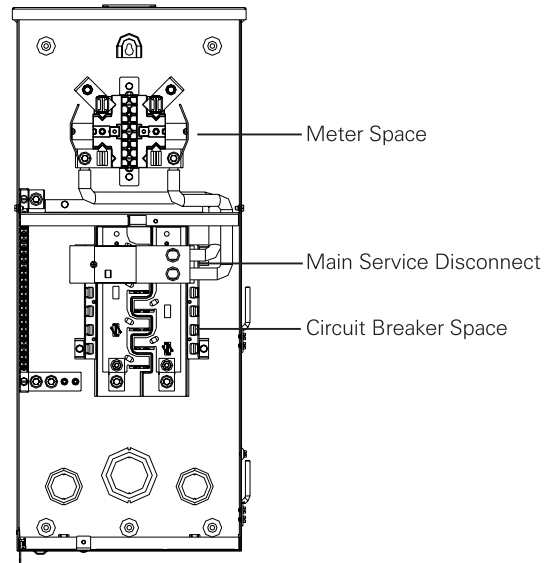
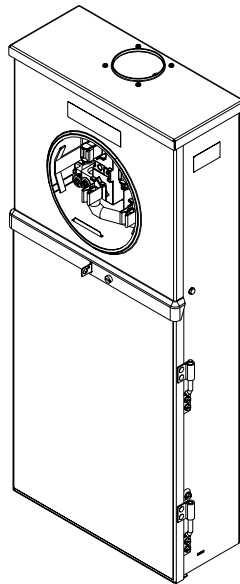
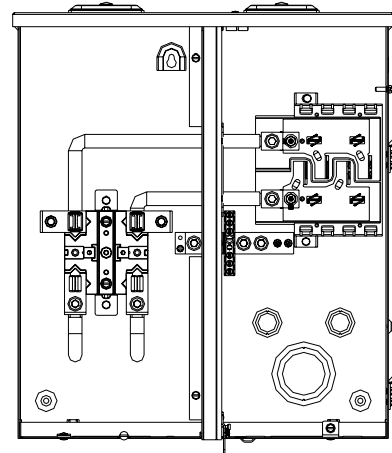
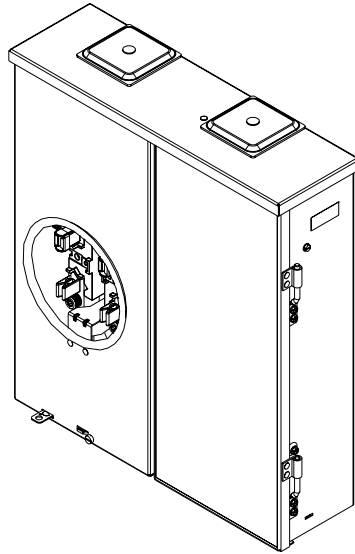
Meter Combinations and Trailer Service Panels

These types of load centers are primarily found on the West Coast where they are mounted to the exterior of a house. They are also becoming popular in other areas of the country. Meter combinations are also used as trailer service panels.



Watt-Hour Meter Space Circuit Breaker Space

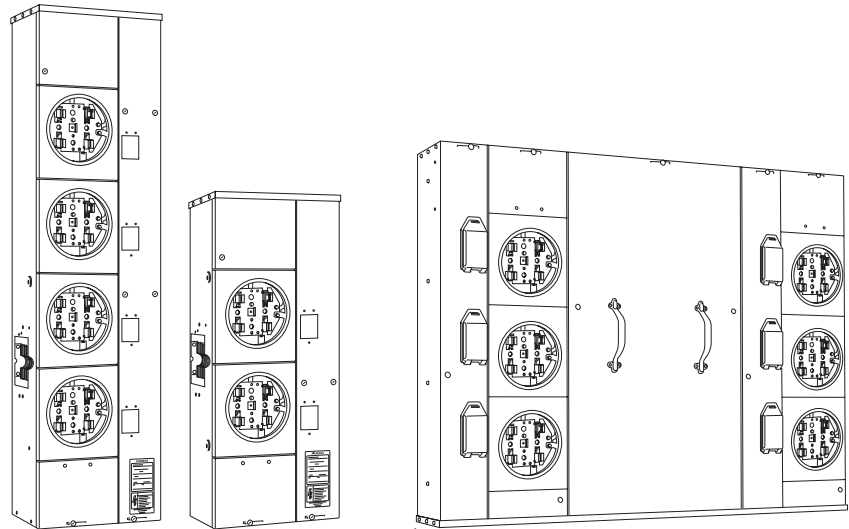
Meter combinations and trailer service panels are available with 8 spaces and can handle 16 circuits. Siemens meter mains can be used with overhead service.



Modular Meter Centers Metering Systems

Modular meter centers are used for multi-family dwellings such as duplexes or apartment buildings. These are used in conjunction with Siemens load centers. Modular meter centers are available with two to six meter compartments.

Metering systems are another option for multi-family dwellings. These are self-contained systems with two to six meter compartments. Individual branch circuit breakers for each tenant are located in a separate compartment adjacent to each meter socket.

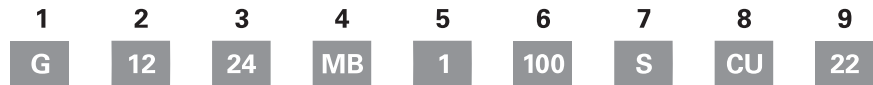


Modular Meter Centers

Metering System

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. The following figure illustrates a typical catalog number.



Part 1

Part 1 identifies the type of enclosure or the component.

E	=	Indoor Type 1, 2-16 and 30-42 circuits 300-400 Amp
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
B	=	Main Breaker/Convertible
L	=	Main Lug 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. For example,
100 = 100 amps.

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

B = Bottom Feed

G or GB = Ground Bar Factory Installed

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)

42 = 42,000 AIR (3-phase load centers)

Review 6

1. One objective of intentional grounding is to keep _____ differentials between different parts of a system at a minimum which reduces shock hazard.
2. _____ is the permanent joining of metallic parts to form an electrically conductive path.
3. The _____ is grounded only at the service entrance equipment, never at any downstream equipment.
4. The voltage between any phase and neutral is _____ volts on a three-wire, single-phase, 240 volt system.
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 _____ incorporates space for a watt-hour meter and a main service disconnect.
8. A "24" in part 3 of the load center catalog number indicates the load center:
 - a. is 24" high
 - b. is rated for 24 amps
 - c. is rated for 240 volts
 - d. has a maximum of 24 circuits

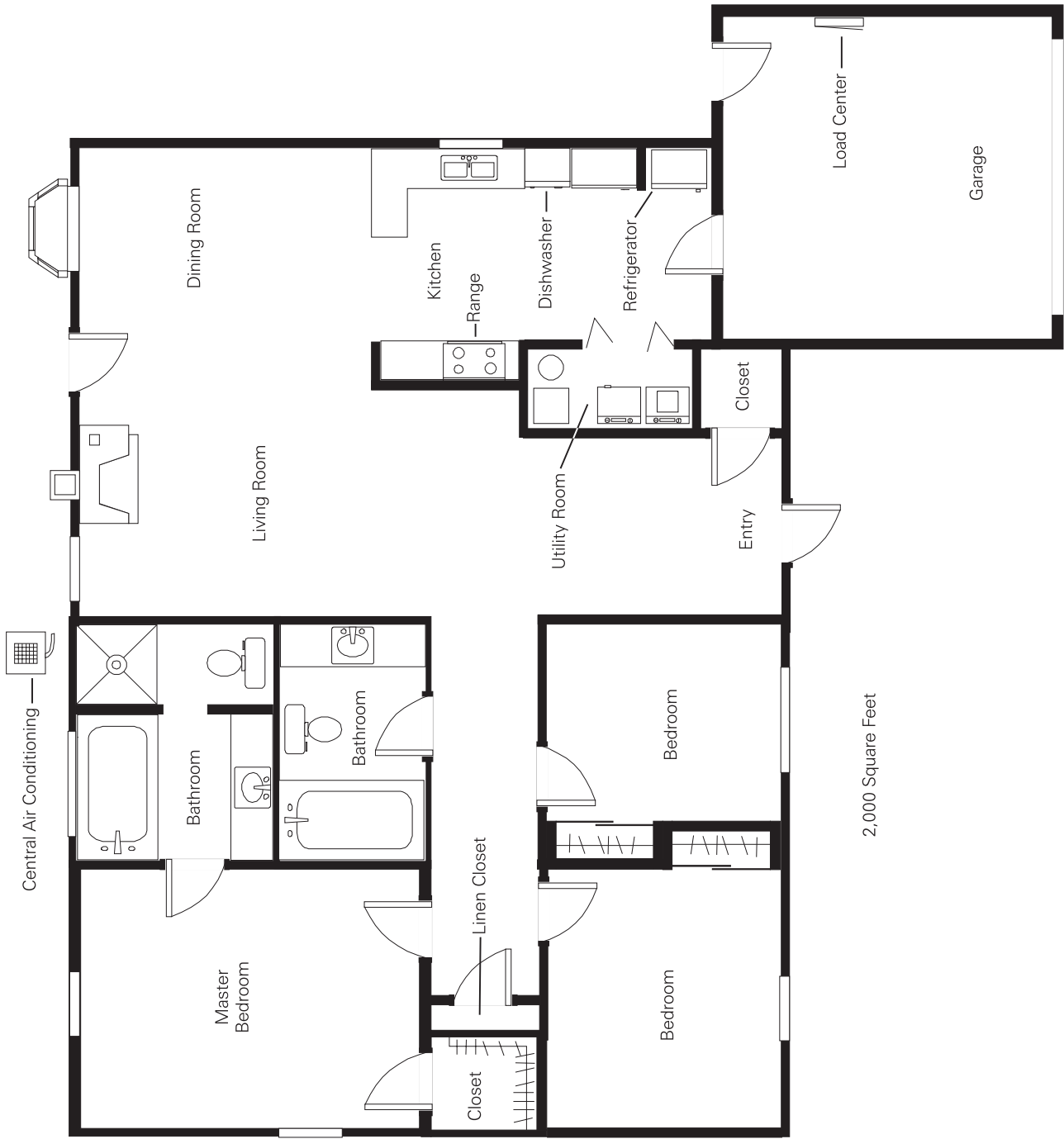
Sizing The Load Center

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 *National Electrical Code*® 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

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 220.3(A), 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 210.11(C)(1) 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 220.16(A) 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 210.11(C)(2) requires one 120 volt, 20 amp circuit for the laundry area. Article 220-16 (B) states that this circuit shall not be less than 1500 VA.

$$1500 \text{ VA}$$

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	1500 VA

Total **12,000 VA**

Demand Factors

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 9000 VA (12,000 VA minus 3000 VA) may be rated at 35% which is the allowable demand factor.

First 3000 VA at 100%	3000 VA
Remaining 9000 VA at 35%	3150 VA

Net general lighting and small appliance load **6150 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

Air conditioner and electric heat will not be used at the same time. Only the larger of the heater load and air conditioner load is used (*NEC*[®] Article 220.30(C)). 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. *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 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
---	----------------

Required Service

The required service size is found by adding the calculated values together.

General lighting, laundry and small appliance load	6000 VA
--	---------

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

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

Total load	33,676 VA
-------------------	------------------

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).

$$33,676 \text{ VA} \div 240 \text{ volts} = 140.5 \text{ amps}$$

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 160.5 amps.

$$140.5 \text{ amps} + 20 \text{ amps (expansion)} = 160.5 \text{ amps}$$

Safety Factor

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.

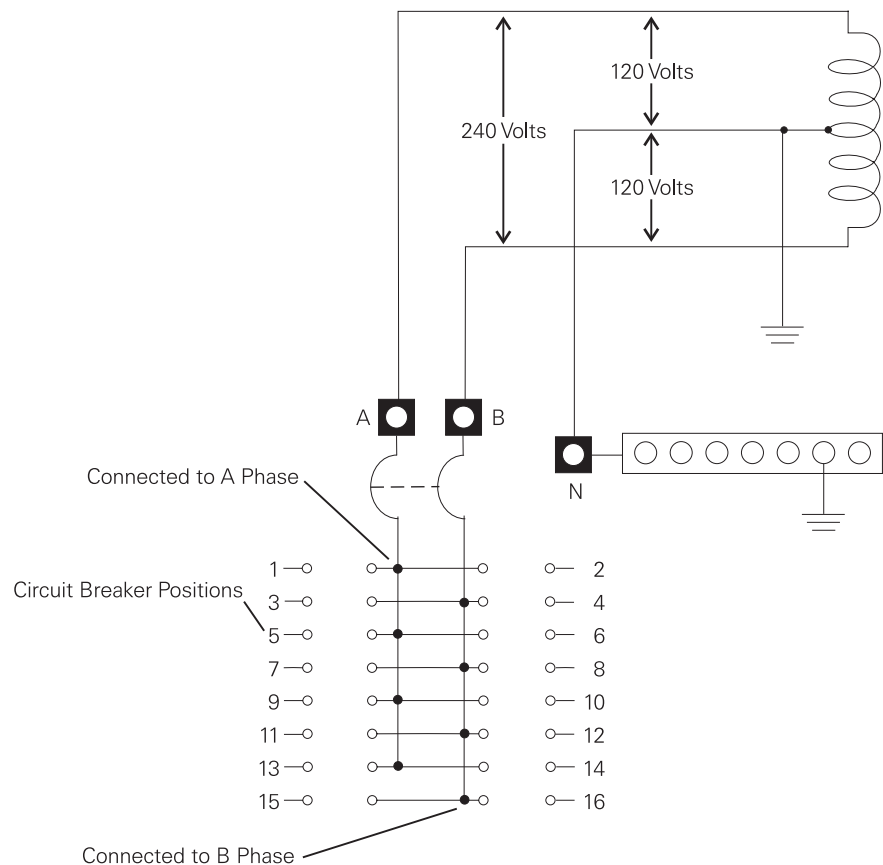
$$160.5 \text{ amps} + 32.1 (.20 \times 160.5) = 192.6 \text{ amps}$$

Load Center Selection

A 200 amp load center would be a better choice.

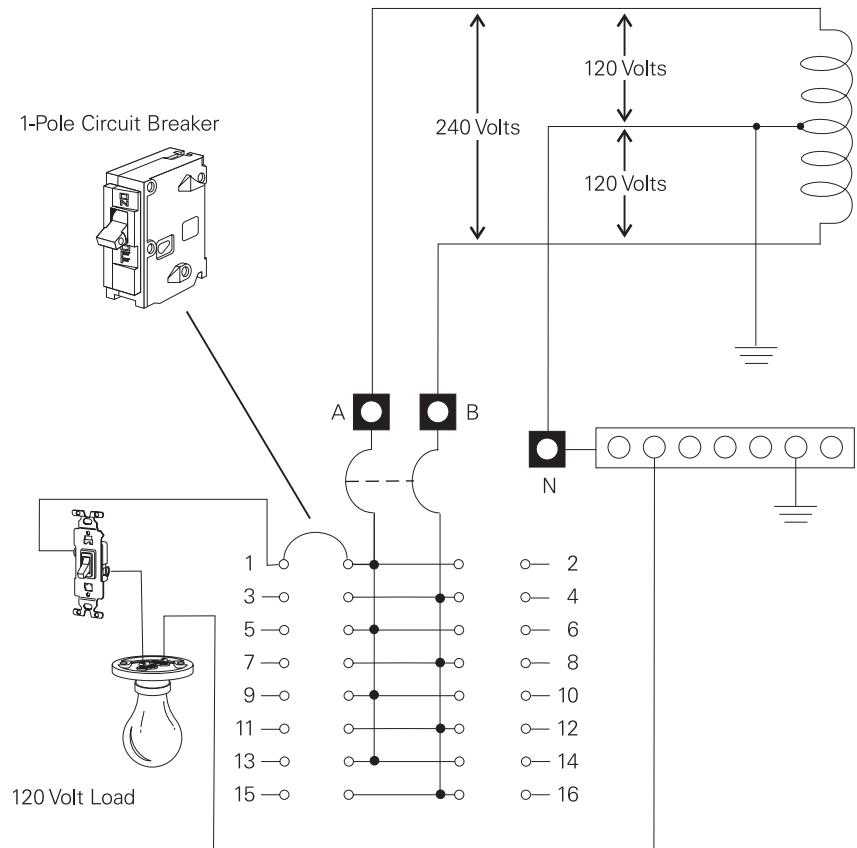
Determining The Number Of Circuits

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.



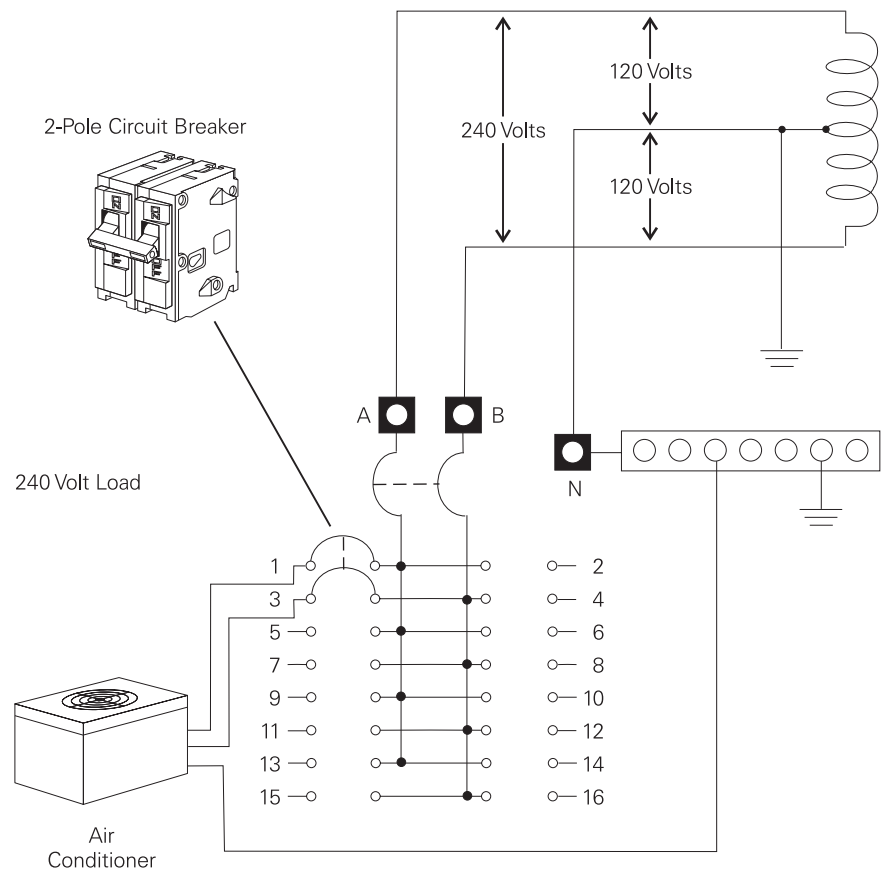
120 Volt Circuit

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.



Determining the Number of 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 amp load. A 50 amp circuit breaker would be selected.

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

Electric Heater Circuit

The electric heater is a 240 volt, 50 amp (12,000 VA ÷ 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 ÷ 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 ÷ 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.

Total Number of Spaces

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

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

Review 7

1. A minimum of _____ 120 volt, 20 amp, small appliance circuits are required by *NEC*[®].
2. The general lighting load for a dwelling is calculated at _____ VA per square foot of living space.
3. A 2400 square foot home would have a general lighting load of _____ VA.
4. A demand factor is allowed for general lighting. The first _____ VA is rated at 100%.
5. Each 240 volt circuit will use _____ position(s) in a load center.
6. A home with a general lighting load of 8000 VA would require _____ 15 amp circuits.
7. An air conditioner rated for 240 volts, 40 amps would require a 2-pole, _____ amp breaker.

Review Answers

Review 1

1) distribution; 2) 408; 3) 240; 4) a; 5) c.

Review 2

1) 1, 3R; 2) bus bar; 3) Branch; 4) split neutral;
5) INSTA-WIRE™; 6) trim; 7) circuit directory.

Review 3

1) heat; 2) isolated; 3) main; 4) duplex; 5) circuit limiting;
6) 2.

Review 4

1) ground; 2) b; 3) ground; 4) bedroom; 5) 25,000; 6) first;
7) 40,000.

Review 5

1) breaker, lug; 2) add-on, secondary, downstream; 3) Feed-thru;
4) full; 5) series; 6) 6.

Review 6

1) voltage; 2) Bonding; 3) neutral; 4) 120; 5) 225; 6) west coast;
7) meter main; 8) d

Review 7

1) 2; 2) 3; 3) 7200; 4) 3000; 5) 2; 6) 5; 7) 50.

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. 408
 - c. 310
 - 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. Load center installation requirements can be found in *NEC*[®] Article _____ .
 - a. 110.26
 - b. 250
 - c. 210
 - d. 310.1

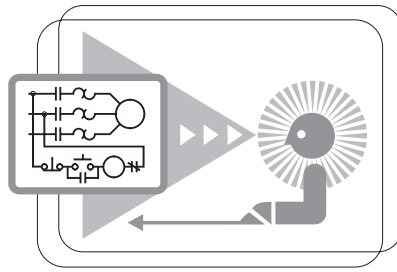
NEC[®] and *National Electrical Code*[®] are registered trademarks of the National Fire Protection Association.

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 volt
 - b. 3-wire, 120/240 volt
 - c. 3-wire, 480 volt
 - d. 4-wire, 208Y/120 volt
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 210.11(C)(1) 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?
- bathroom receptacles
 - bedroom receptacles
 - living room receptacles
 - 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 Ultimate 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 a main service disconnect within the same enclosure is a _____ .
- a. main breaker load center
 - b. main lug only load center
 - c. circuit breaker enclosure
 - d. meter main

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