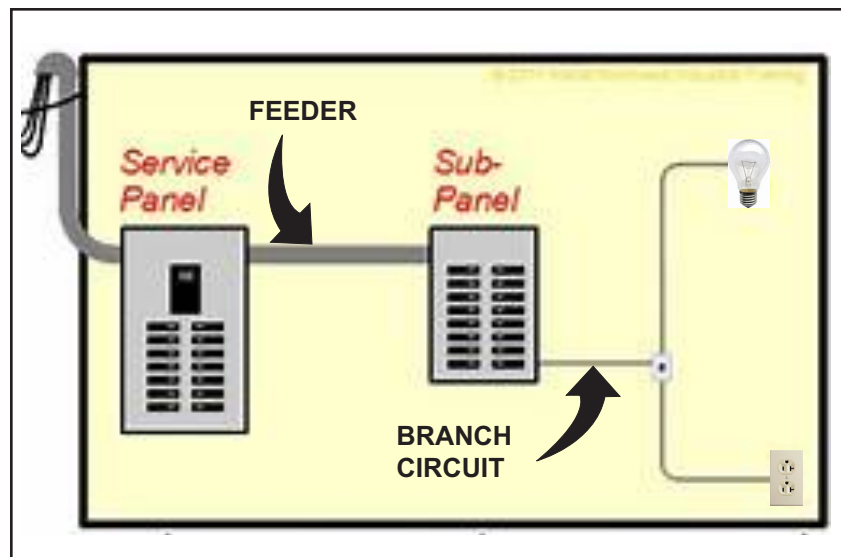

CONTENTS

	<u>PAGE</u>
Chapter One - The Branch Circuit _____	1
Chapter Two - Small Appliance Branch Circuit _____	11
Chapter Three - Multiwire Branch Circuit _____	31
Chapter Four - Switches and Receptacles _____	50
Chapter Five - Motor Branch Circuit _____	89
Chapter Six - Voltage Drop _____	97
Chapter Seven - The Human Generator _____	110
Chapter Eight - The GFCI _____	117
Chapter Nine - The AFCI _____	129
Chapter Ten - 240 Volt Branch Circuits _____	151
Chapter Eleven - Electric Vehicles _____	156
Chapter Twelve - Other Branch Circuits _____	164
Exams _____	179
Answers _____	231



Chapter One

Branch Circuits



Definition: Branch Circuit. The circuit conductors between the final overcurrent device protecting the circuit and the outlet(s).

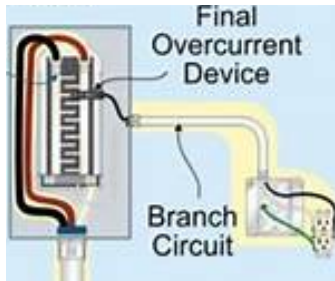
“Knowledge has to be improved, challenged, and increased constantly, or it vanishes.”



The Branch Circuit

A branch circuit is typically a loop of wire that runs from the service panelboard, out to receptacles. *Generally, a dwelling has no feeder conductor.* Branch circuits are classified as either general purpose, appliance, or individual circuits *depending on their function.*

There are over 30 types of branch circuits.



Understanding the Words



Outlet. A point on the wiring system at which current is taken to supply *utilization equipment.*

Utilization Equipment. Equipment that utilizes electric energy for electronic, electromechanical, chemical, heating, lighting, or similar purposes.



Receptacle Outlet. An *outlet* where one or more receptacles are installed.



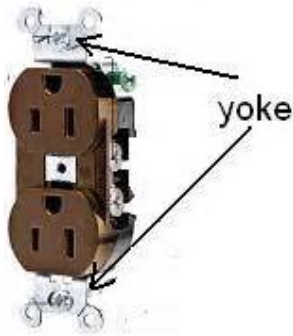
Receptacle. A contact *device* installed at the outlet for the connection of an *attachment plug*, or for the direct connection of electrical utilization equipment designed to mate with the corresponding contact device. A single receptacle is a single contact device with no other contact device on the same *yoke*. A multiple receptacle is two or more contact devices on the same yoke.



Device. A unit of the electrical system, other than a conductor, that carries or controls electric energy as its principal function.



Attachment Plug (Plug Cap) (plug). A device that, by insertion in a receptacle, establishes a connection between the conductor of the attached flexible cord and the conductors connected permanently to the receptacle.



Yoke. The "strap" which is part of devices (receptacle outlets, switches, etc.) and which extends out with a top and bottom with holes, and sometimes "ears" which allows the device to be secured to the box in which the device is installed. A duplex receptacle outlet is actually two receptacle outlets on one "yoke" (on one "strap").

Wiring methods



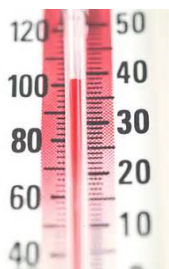
Materials for wiring interior electrical systems in buildings vary depending on:

- Intended use and amount of power demand on the circuit
- Type of occupancy and size of the building
- National and local regulations
- Environment in which the wiring must operate.

Wiring systems in a single family home or duplex, for example, are simple, with relatively low power requirements, infrequent changes to the building structure and layout, usually with dry, moderate temperature and non-corrosive environmental conditions. In a light commercial environment, more frequent wiring changes can be expected, large apparatus may be installed and special conditions of heat or moisture may apply. Heavy industries have more demanding wiring requirements, such as very large currents and higher voltages, frequent changes of equipment layout, corrosive, or wet or explosive atmospheres. In facilities that handle flammable gases or liquids, special rules may govern the installation and wiring of electrical equipment in *hazardous areas*.

Electrical wiring is an electrical installation of cabling and associated devices such as switches, distribution boards, sockets and light fittings in a structure.

Wiring is subject to safety standards for design and installation. Allowable wire and cable types and sizes are specified according to the circuit operating voltage and electric current capability, with further restrictions on the environmental conditions, such as ambient temperature range, moisture levels, and exposure to sunlight and chemicals.





Several Types of Branch Circuits



Appliances
 Small appliance
 General Purpose
 Individual
 Motor
 Multiwire
 Bathroom
 Common Area
 Air conditioner
 Busways
 Critical branch
 Electric vehicle
 Emergency system
 Energy management
 Fire alarm systems
 Fixed electric space heating
 Health care facilities
 Industrial process heating
 Irrigation machines
 Isolated power systems
 Low voltage suspended ceiling
 Mobile homes
 Modular data centers
 Multiple branch circuits
 Multiple outlet
 Outside branch circuits
 Park trailers
 Patient bed
 Recreational vehicles
 Selection current (air conditioner)
 Stage or Set
 Tap
 Through luminaires
 Voltage drop
 Voltage limitations
 X-ray equipment

- **Individual branch circuit:** A branch circuit that supplies a single load. If this load is an appliance, it will be called Appliance branch circuit.

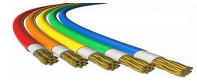
- The small-appliance branch circuits, laundry branch circuits, and bathroom branch circuits required in a dwelling unit(s) by 210.11(C)(1), (C)(2), and (C)(3) shall supply only the receptacle outlets specified in that section.

- **General Lighting Branch Circuits** shall be computed on a three va per square foot basis. You may wire up to 600 square feet of living area on a 15 ampere branch circuit or up to 800 square feet on a 20-ampere circuit.

- The limitations when grouping motors on a single overcurrent device include the method of motor *overload* protection, short circuit protection for the **motor branch circuit** conductors, controllers and motors, size of the tap conductors, and the length of the tap conductors.

- Multiwire branch circuits can offer fewer conductors, reduce the raceway size and reduce voltage drop. What are the possible electrical hazards? Improper wiring or mishandling of multiwire circuits can cause overloading of the grounded (neutral) conductor and/or destruction of equipment.

- A 40-50 ampere branch circuit shall be permitted to supply cooking appliances that are fastened in place in any occupancy. In other than dwelling units, such circuits shall be permitted to supply fixed lighting units with heavy-duty lamp holders, infrared heating units, or other utilization equipment.



Individual branch circuit: A branch circuit that supplies a single load.

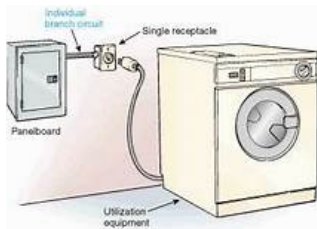


Branch Circuit, Individual: A branch circuit that supplies only one utilization equipment via a single receptacle.

An individual branch circuit supplies only one single receptacle for the connection of a **single attachment plug**.

An individual branch circuit installed in permanent locations such as an electric range, a clothes dryer, or an air conditioner. These circuits usually lead directly from the distribution panel to the appliance and do not serve any other electrical devices.

A branch circuit supplying both halves of a duplex receptacle is **not** an individual branch circuit in most cases, because each half of the duplex is classified as a separate device.



An individual branch circuit is an electric circuit designed specifically for powering a single, higher power electric device such as an oven, dryer or HVAC system.



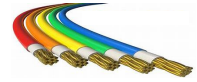
Branch Circuit Rating. The rating of any branch circuit will be the maximum permitted ampere rating or setting of the **overcurrent device** protecting this branch circuit.

Branch circuits serving **only one device** can have **any rating**. The rating for **other** than individual branch circuits shall be 15, 20, 30, 40 and 50 amperes.

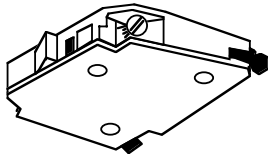


A single receptacle installed on an individual branch circuit shall have an ampere rating not less than that of the branch circuit. For example, a **single receptacle** on a 20-ampere individual branch circuit must be rated at 20 amperes per 210.21(B)(1).

Chapter One Branch Circuits



•**Author’s note:** A **single** receptacle installed on an individual branch circuit shall have an ampere rating of not less than that of the branch circuit. An individual branch circuit supplies only one utilization equipment. Example: A **single** receptacle to a washer shall be 20 amp rated on the required 20 amp branch circuit. *A 15 amp rated receptacle can be used on a 20 amp rated circuit when you have more than a **single** receptacle, a **duplex** receptacle can be rated 15 amps on a 20 amp circuit.*

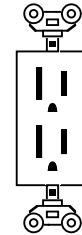


20 amp rated circuit



Single
receptacle

Shall be 20 amp rated



Duplex
receptacle

Can be 15a or 20a rated

The question: “Can you have only a single 15 amp receptacle on a 20 amp circuit breaker?” You are permitted to have a single 15 amp **duplex** receptacle on a 20 amp circuit, but in reality, it’s two receptacles on the circuit, and the Code allows for **multiple** 15 amp receptacles on a single 20 amp circuit:



If you’re talking about a single 15 amp receptacle like below then no, that’s not permitted be on a 20 amp circuit by itself — it must be on a 15 amp circuit. However, you are permitted to have multiple single or duplex receptacles, in 15 amp or 20 amp, or any mixture thereof, on a 20 amp circuit.



If you want a single receptacle on a 20 amp circuit, you are required to install a 20 amp receptacle:



Notice that it is designed to accept a standard 15 amp plug as an alternative to a 20 amp plug.

Note also that you are not permitted to install a 20 amp receptacle on a 15 amp circuit, period.

Reference: National Electrical Code (NFPA 70), section 210.21(B).





Table 210.21(B)(3) Receptacle Ratings for Various Size Circuits

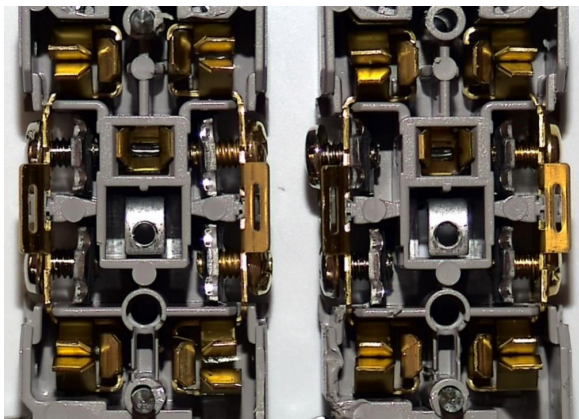


Circuit Rating (Amperes)	Receptacle Rating (Amperes)
15	Not over 15
20	15 or 20
30	30
40	40 or 50
50	50

The National Electrical Code, in section 210.21 (B) 1, 2, and 3, describes the requirements of single and multiple receptacles on a circuit.

The use of multiple 15 amp receptacles on a 20 amp circuit is permitted. A duplex receptacle is considered as multiple receptacles and is therefore permissible to use as the single, or one of several, multiple type receptacles on the circuit.

Receptacles rated higher than the circuit rating may **not** be used, so 20 amp receptacles are not permitted on a 15 amp circuit.



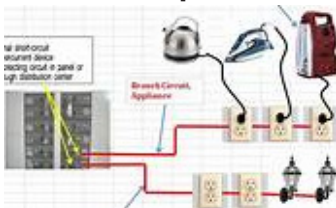
15 amp

20 amp

Part of the UL listing for the 15 amp receptacles is that they are capable of feeding through the 20 amp circuit, the primary difference between 15 and 20 amp receptacles being the faceplate configuration.

Underwriter's Laboratories requires that all 15 amp (on their face) receptacles have, *internally, circuit paths which are rated for 20 amps.*

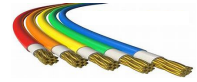
A 15 amp and 20 amp duplex receptacle of the **same grade are identical internally.** Both are rated for 20 amp feed-thru.



Branch Circuit, General-Purpose. A branch circuit that supplies two or more receptacles or outlets for lighting and appliances.

General purpose branch circuits are 120 volts circuits used for supplying lighting fixtures and receptacle outlets for most *small portable* appliances. There are usually a number of general purpose branch circuits supplying lights and outlets in different rooms around a residence or commercial or industrial building.

General purpose is the most common branch circuit. Typically, include lighting outlets and receptacles. Two common sizes: 15 amp, using #14 wire. 20 amp, using #12 wire. 20 amp general purpose circuits are recommended.



Branch Circuit, Appliance. A branch circuit that supplies energy to one or more outlets to which appliances are to be connected and that *no permanently connected luminaires* that are not part of an appliance.

The National Electrical Code doesn't limit the number of receptacles you can place on a 20-amp circuit, but you'll overload the breaker if you run appliances that draw more current than the breaker can handle. The NEC does specify that a circuit breaker shouldn't handle more than **80 percent** of the load for which it is rated unless the breaker is labeled otherwise. By this standard, the total current draw on a 20-amp circuit shouldn't exceed 16 amps. A 15-amp circuit should not exceed 12 amps.



210.23(A)(1). Cord-and-Plug-Connected Equipment. Not Fastened in Place. The rating of any *one cord-and-plug-connected* utilization equipment not fastened in place shall not exceed **80%** of the branch-circuit rating.

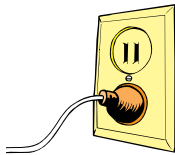

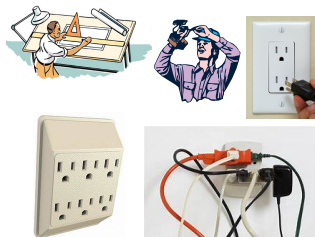


Table 210.21(B)(2) Maximum Cord-and-Plug-Connected Load to Receptacle

	Circuit Rating (Amperes)	Receptacle Rating (Amperes)	Maximum Load (Amperes)
	→ 15 or 20	→ 15	12
	→ 20	→ 20	16
	→ 30	→ 30	24

Today, you will find more appliances with a 15 amp plug that draws more than 15 amp x 80% = 12 amps, 80% rule is 12 a x 120v = 1440 watts, the hair dryer, steam iron, vacuum cleaner, etc.



But, how can the 80% be controlled? The electrical designer can design the branch circuit, the electrician can install the branch circuit in compliance with the Code rules.

Then who is going to inform the home owner to stop buying adapters, extensions, etc. to overload the branch circuit.

Now they are *assuming* the circuit breaker should trip, thus protecting the branch circuit wiring.

Chapter One Branch Circuits

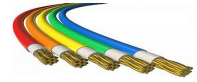
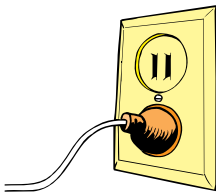


Table 210.24 Summary of Branch-Circuit Requirements

Circuit Rating	15 A	20 A	30 A	40 A	50 A
Conductors (min. size):					
Circuit wires ¹	14	12	10	8	6
Taps	14	14	14	12	12
Fixture wires and cords — see 240.5					
Overcurrent Protection	15 A	20 A	30 A	40 A	50 A
Outlet devices:					
Lampholders permitted	Any type	Any type	Heavy duty	Heavy duty	Heavy duty
Receptacle rating ²	15 max. A	15 or 20 A	30 A	40 or 50 A	50 A
Maximum Load	15 A	20 A	30 A	40 A	50 A
Permissible load	See 210.23(A)	See 210.23(A)	See 210.23(B)	See 210.23(C)	See 210.23(C)

¹These gauges are for copper conductors.

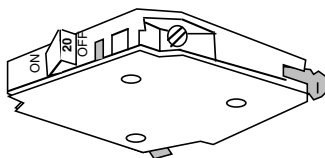
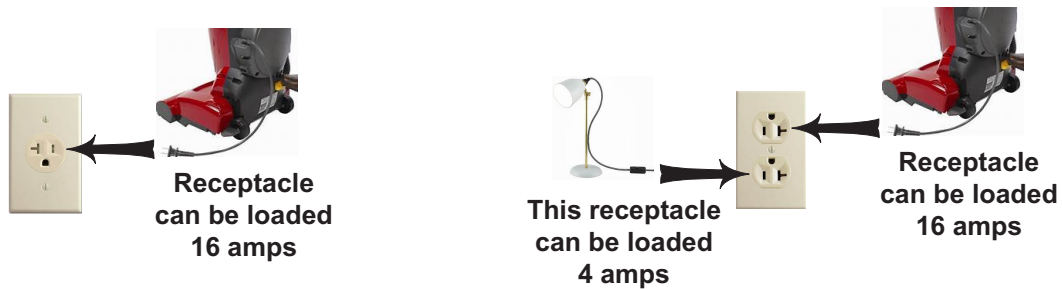
²For receptacle rating of cord-connected electric-discharge luminaires, see 410.62(C).



Cord and plug connected load

A **branch circuit** supplying two or more receptacles, a **receptacle** (not branch circuit) shall not supply a total **cord and plug connected load** in excess of the maximum shown in Table 210.21(B)(2).

Example: A 20 amp rated **single receptacle** can be loaded to only 16 amps (**80% of 20a**) when supplying a plug and cord connected load, but the **branch circuit** can still be loaded to the rating of 20 amps.



**20 amp rated circuit
can be loaded 20 amps**



Lighting Branch Circuits

Definition:

General lighting outlets are those outlets intended for general use for fixed-in-place luminaires (lighting fixtures). They are only used for lighting for the normal use of the occupants and its intensity should be adequate for any type of work performed in the area.



The location of lighting outlets is determined by the amount and type of illumination required to provide the desired lighting effects. The bathroom requires good lighting in the mirror area.






Luminaire manufacturers publish catalogs that provide information regarding recommendations for residential lighting.

The majority of modern ceiling fans use less than an amp, averaging between 0.5 and 1 amp, depending on the model and the setting. One amp drawn by a ceiling fan is equivalent to about 120 watts. Low settings use less amperage while higher settings use more. For example, an average ceiling fan set on low speed uses about 0.25 amp, on medium speed about 0.4 amp, and on high speed about 0.6 amp. The amps listed for the model by the manufacturer normally reflect only the use of the fan motor and do **not** include electricity used by an attached lighting fixture.



The difference is that incandescent bulbs require many more watts than LED bulbs for the same degree of brightness.

Light Output	LEDs	Incandescent	Compact Fluorescents
			
Lumens	Watts	Watts	Watts
450	4 - 5	40	9 - 13
800	6 - 8	60	13 - 15
1,100	9 - 13	75	18 - 25
1,600	16 - 20	100	23 - 30
2,600	25 - 28	150	30 - 55