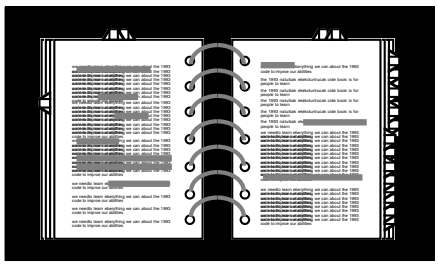
BRANCH CIRCUITS

By Tom Henry and Tim Henry



Based on the 2023
National Electrical Code®

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CODE ELECTRICAL
LEADER IN ELECTRICAL
EDUCATION WORLD WIDE

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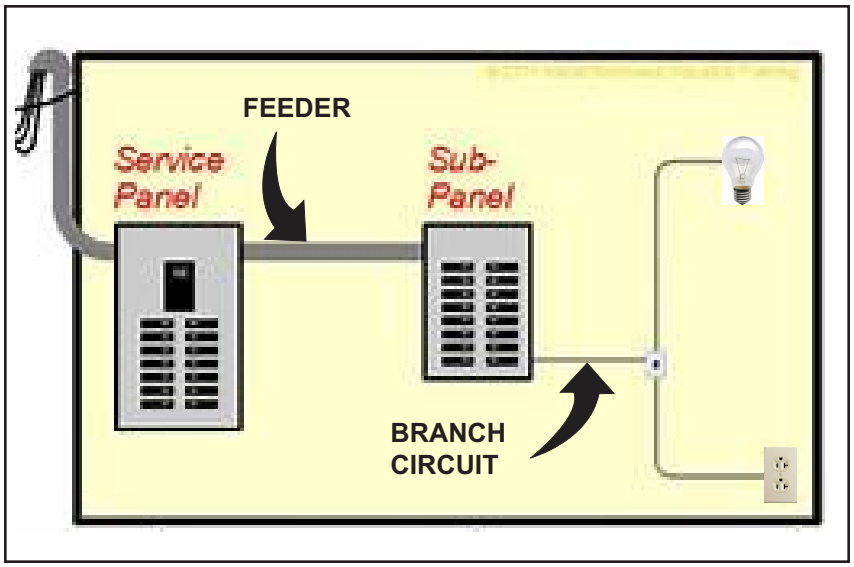
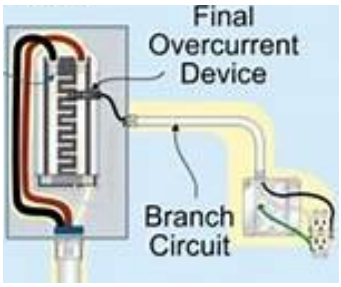
Chapter One
Branch Circuits



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*.

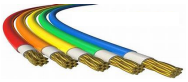
Utilization Equipment. Equipment that utilizes electric energy for electronic, electromechanical, chemical, heating, lighting, or similar purposes.

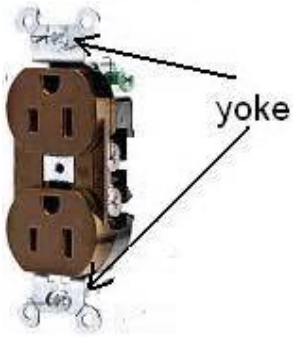
Receptacle Outlet. An *outlet* where one or more receptacles are installed.

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

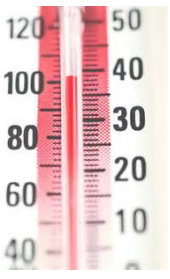
Materials for wiring interior electrical systems in buildings vary depending on:

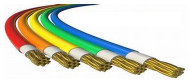
- Intended use and amount of power demand on the circuit
- Type of occupancy and size of the building
- National and local regulations
- Environment in which the wiring must operate.

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.

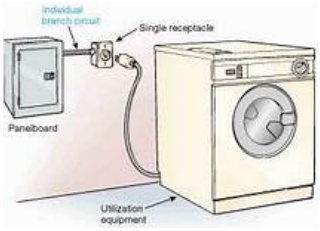
Individual branch circuit: A branch circuit that supplies a single load.

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.

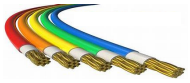


An individual branch circuit is an electric circuit designed specifically for powering a single, higher power electric device such as an oven, dryer or HVAC system.

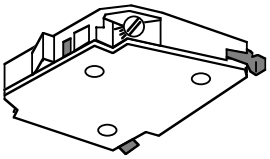
Branch Circuit Rating. The rating of any branch circuit will be the maximum permitted ampere rating or setting of the **overcurrent device** protecting this branch circuit.

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).



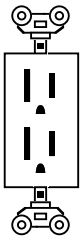
•**Author's note**: A **single** receptacle installed on an individual branch circuit shall have an ampere rating of not less than that of the branch circuit. An individual branch circuit supplies only one utilization equipment. Example: A **single** receptacle to a washer shall be 20 amp rated on the 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** 15amp 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).

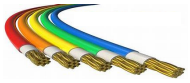


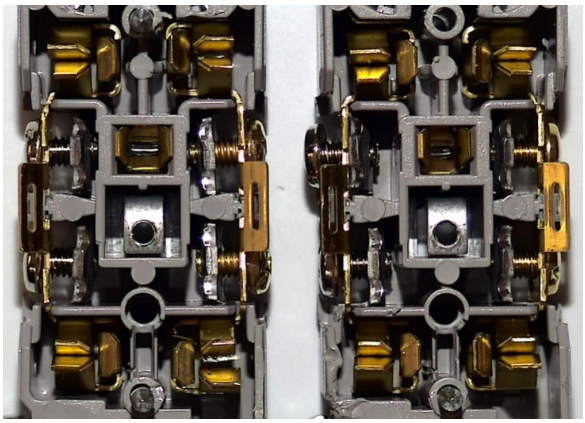
Table 210.21(B)(3) Receptacle Ratings for Various Size Circuits

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.

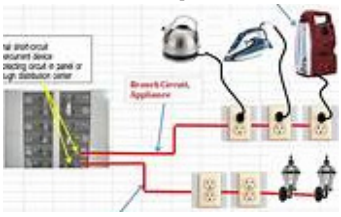


15 amp **20 amp**

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*.

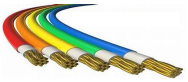
A 15 amp and 20 amp duplex receptacle of the **same grade are identical internally**. Both are rated for 20 amp feed-thru.



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.


15 amp CB
12 amps


20 amp CB
16 amps

210.23(B)(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.

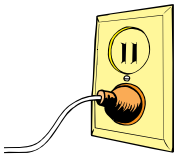


Table 210.21(B)(2) Maximum Cord-and-Plug-Connected Load to Receptacle

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 then 15 amp x 80% = 12 amps, 80% rule is 12 a x 120v = 1440 watts, the hair dryer, steam iron, vacuum cleaner, etc.

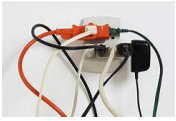

1875 watts
15.6 amps


1800 watts
15 amps


1440 watts
12 amps







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.

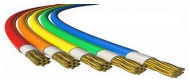
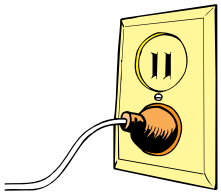


Table 210.24(1) Summary of Branch-Circuit Requirements Copper Conductors

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(B)**	See 210.23(B)	See 210.23(C)	**See 210.23(D)**

[1]These gauges are for copper conductors.
[2]**Branch circuits rated 10 amperes shall not supply receptacle outlets.**

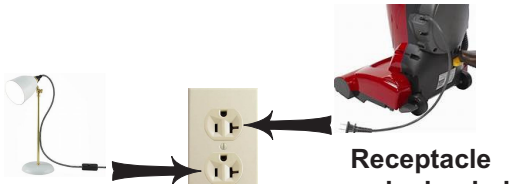


Cord and plug connected load

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).

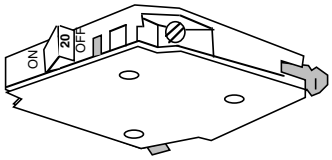
Example: A 20 amp rated **single receptacle** can be loaded to only 16 amps (**80% of 20a**) when supplying a plug and cord connected load, but the **branch circuit** can still be loaded to the rating of 20 amps.

Receptacle can be loaded 16 amps



This receptacle can be loaded 4 amps

Receptacle can be loaded 16 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.

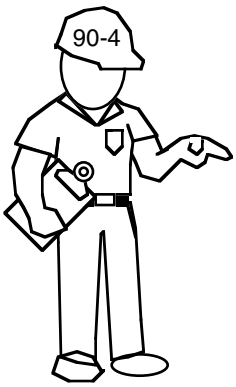
The majority of modern ceiling fans use less than an amp, averaging between 0.5 and 1 amp, depending on the model and the setting. One amp drawn by a ceiling fan is equivalent to about 120 watts. Low settings use less amperage while higher settings use more. For example, an average ceiling fan set on 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 Ouput	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

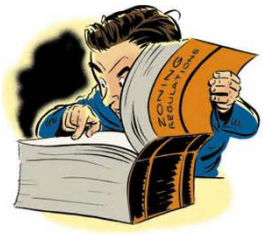
Chapter Two
The Small Appliance Branch Circuit



Understanding the Code

NEC 90.2 Purpose.
(B) Adequacy. This Code contains provisions that are considered for **safety**. Compliance therewith and proper maintenance result in an installation that is essentially free from hazard ***but not necessarily efficient,*** convenient, or adequate for good service **or future expansion of electrical use**.

Understanding Definitions



Article 100 contains only those definitions essential to the application of this Code. It is not intended to include commonly defined general terms or commonly defined technical terms from related codes and standards. An article number in parentheses following the definition indicates that the definition only applies to that article.

Appliance. Utilization equipment, generally other than industrial, that is fastened in place, stationary, or portable, is normally built in a standardized sizes or types and is installed or connected as a unit to perform one or more functions such as clothes washing, air-conditioning, food mixing, deep frying, and so forth.

Portable Equipment. Equipment with electrical components suitable to be moved by a single person without mechanical aids.

Appliance, Portable An appliance that is actually moved or can easily be moved from one place to another *in normal use*.

Appliance, Fixed An appliance that is fastened or otherwise secured at a specific location.

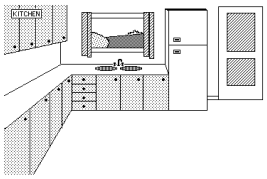
Fixed (as applied to equipment) Equipment that is fastened or otherwise secured at a specific location.

Stationary (as applied to equipment) Equipment that is not moved from one place to another in normal use.

Accessible (as applied to equipment). Admitting close approach; not guarded by locked doors, elevation, or other means.

Lighting Outlet. An outlet intended for direct connection of a lampholder or luminaire.
210.70(A)(1) Habitable Rooms. At least one wall switch-controlled lighting outlet shall be installed in every habitable room, **kitchen**, laundry, and bathroom.

Kitchen Appliance Branch Circuits



With the exception of the electrical cooking appliance such as the range, ovens and cooktops, the kitchen is the heaviest loaded 120 volt area in the household.

Today, we find our kitchens stocked with higher energy consuming appliances so this is why upgrading the wiring to today's requirements is a good practice to follow, besides it will increase your home value and make your kitchen equipped to serve you better.

Kitchen Counter Appliances - Plug-and-Cord Connected

8.3 amps

10 amps

10 amps

5.4 amps

10.8 amps

2.5 amps

12.5 amps

12.5 amps

3.75 amps

12.5 amps

12.5 amps

Total ampere with all counter appliances (2-slice toaster) on = 88.25 amps x 120v = 10,590 watts

Total ampere with all counter appliances (4-slice toaster) on = 90.75 amps x 120v = 10,890 watts

Under the Kitchen Counter Appliances, Refrigerator and Microwave

10 amps

Section 210.8(D) Kitchen Dishwasher Branch Circuit. GFCI protection shall be provided for the branch circuit or outlets that supply dishwashers installed in dwelling units.

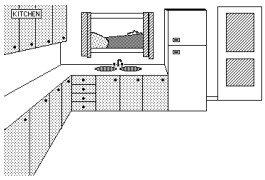
3.75 amps

Total ampere with all under counter appliances, refrigerator, and above the range microwave oven.
= 41.5amps x 120v = 4,980 watts

+

Total ampere with all counter top appliances.
(2-slice toaster) on = 88.25 amps x 120v = 10,590 watts

7 amps

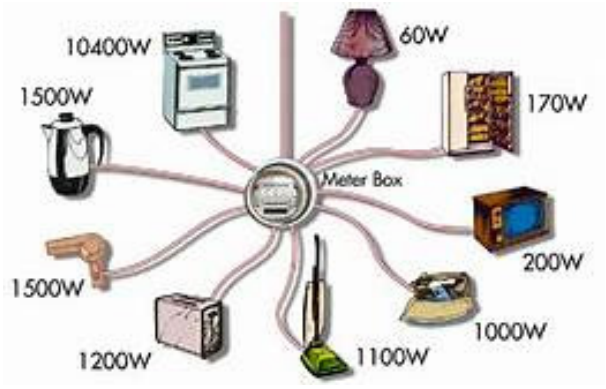


Kitchen total ampere with all appliances.
129.75 amps x 120v = 15,570 watts

14.5 amps

6.25 amps

Household Appliances



Small Appliance Branch Circuits

Appliance Load @ 120 volts

Dishwasher	1200 - 1500 watts	10 amps - 12.5 amps	(12 amps)
Microwave (over the range)		1700 watts	14.5 amps
Refrigerator/freezer		6.25 amps	
Waste disposal	450 watts	3.75 amps (1/2 hp @120v)	
Trash compactor		6-7 amps (running, more to start)	
Range hood		2.5 amps	
Toaster oven (portable)	1300 watts	10.8 amps	
Electric cooktop burner	1500 watts	12.5 amps	
Electric skillet	1500-1800 watts	12.5 - 15 amps	
Deep fryer	1500 watts	12.5 amps	
Coffee pot	800-1200 watts	10 amps	
Hand-stand mixer	650 watts	5.4 amps	
Food processor	450 watts	3.75 amps	
Smart stick blender	300 watts	2.5 amps	
Bread toaster 2-slice	1200 watts	10 amps	
Bread toaster 4-slice	1500 watts	12.5 amps	

















210.11(C) Dwelling Units. Small Appliance Branch Circuits. In addition to the number of branch circuits required by other parts of section 210.11, two or more 20 ampere small-appliance branch circuits shall be provided for all receptacle outlets specified by 210.52(B).

210.52(B) Small Appliances

(1) Receptacle Outlets Served. In the kitchen, pantry, breakfast room, dining room, or similar area of a dwelling unit, the two or more 20 ampere branch circuits required by 210.11(C)(1) shall serve all wall and floor receptacle outlets covered by 210.52(A), all countertop outlets covered by 210.52(C), and receptacle outlets for refrigeration equipment.

Exception #1: In addition to the required receptacles specified by 210.52, switched receptacles supplied from a general-purpose branch circuit as defined in 210.70(A)(1), Exception #1 shall be permitted.

Exception #2: In addition to the required receptacles specified by 210.52, a receptacle outlet to serve a *specific appliance* shall be permitted to be supplied from an individual branch circuit rated 15 amperes or greater.

Kitchen

Pantry

Breakfast Room

Dining Room

No room is quite as multifunctional as the kitchen. The hub of the home, this space has evolved from a strictly utilitarian unit into a versatile room to prepare food, entertain guests and share meals.

A pantry is a room where beverages, food, and sometimes dishes, household cleaning chemicals, linens, or provisions are stored. Food and beverage pantries serve in an ancillary capacity to the kitchen.

A breakfast room, also known as a breakfast nook, is designed to be in close proximity to the kitchen. Typically, a breakfast room features a smaller table than a dining room and is not designed to host a large number of guests.

One of the main differences between a dining room and a breakfast room is its size. Dining rooms may range from seating five to over 15 while breakfast rooms are more intimate, thus reducing the number of seats. The casual nature of a breakfast room is another defining difference.

Dining rooms are specifically designed as the official area of the home where food is consumed. The placement of this room is typically near or connected to the kitchen and features a large table, known as a dining table, and adequate lighting for guests to clearly see their meals.

210.52(B)(2). No Other Outlets. The two or more small appliance branch circuits specified in 210.52(B)(1) shall have no other outlets.

Exception #1: A receptacle installed solely for the supply to and support of an *electric clock* in any of these rooms specified in 210.52(B)(1).

Exception #2: Receptacles installed to provide power for supplemental equipment and lighting on gas-fired ranges, ovens, or counter-mounted cooking units.

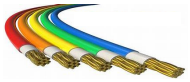
210.52(B)(3). Kitchen Receptacle Requirements. Receptacles installed in a kitchen to serve countertop surfaces shall be supplied by not fewer than two small-appliance branch circuits, either or both of which shall be permitted to supply receptacle outlets in the same kitchen and in other rooms specified in 210.52(B)(1). Additional small-appliance branch circuits shall be permitted to supply receptacle outlets in the same kitchen and in other rooms specified in 210.52(B)(1). No small-appliance branch circuit shall serve more than one kitchen.

An over the range microwave oven is designed to be mounted over a cooktop is equipped with a ventilation system to cope with the cooking odors, smoke and moisture that rise from the cooking surface. The ventilation system simply recirculates air back into the kitchen.

The fan motor is located at the top rear of the microwave and re-circulates into the room through the charcoal filter depending on the installation.

The range hood is competitive. It moves 300 cubic feet of hot and smoky air per minute, which can help keep smoke out of your kitchen while you're cooking.

One of the most convenient kitchen appliances found in almost every home is the popular *over the range* microwave oven, more commonly known as an OTR microwave oven.



Article 90, the Introduction to the Code starts with 90.2, The Purpose.

(A) Practical Safeguarding. The purpose of this Code is the **practical safeguarding** of persons and property from hazards arising from the use of electricity. This Code is not intended as a design specification or an instruction manual for untrained persons.

(B) Adequacy. This Code contains provisions that are considered necessary for **safety**. Compliance therewith and proper maintenance result in an installation that is essentially free from hazard but ***not*** *necessarily efficient, convenient, or adequate for good service or future expansion of electrical use*.

Informational Note: Hazards often occur because of overloading of wiring systems by methods or usage not in conformity with this Code. *This occurs because the initial wiring did not provide for increases in the use of electricity*. An initial adequate installation and reasonable provisions for system changes **provide for future increases in the use of electricity**.

Welcome to tomorrow!

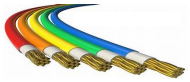
Very Interesting Predictions

Auto repair shops will go away. A gasoline engine has 20,000 individual parts. An electrical motor has 20. Electric cars are sold with lifetime guarantees and are only repaired by dealers. It takes only 10 minutes to remove and replace an electric motor. Faulty electric motors are not repaired in the dealership but are sent to a regional repair shop that repairs them with robots. Your electric motor malfunction light goes on, so you drive up to what looks like a Jiffy-auto wash, and your car is towed through while you have a cup of coffee and out comes your car with a new electric motor!

Gas stations will go away. Parking meters will be replaced by meters that dispense electricity. Companies will install electrical recharging stations; in fact, they've already started. You can find them at select Dunkin Donuts locations.

Most (the smart) major auto manufacturers have already designated money to start building new plants that only build electric cars.

Coal industries will go away. Gasoline/oil companies will go away. Drilling for oil will stop. So say goodbye to OPEC!



Homes will produce and store more electrical energy during the day and then they use and will sell it back to the grid. The grid stores it and dispenses it to industries that are high electricity users. Has anybody seen the Tesla roof?

A baby of today will only see personal cars in museums.

The FUTURE is approaching faster than most of us can handle.

In 1998, Kodak had 170,000 employees and sold 85% of all photo paper worldwide. Within just a few years, their business model disappeared and they went bankrupt. Who would have thought of that ever happening?

What happened to Kodak will happen in a lot of industries in the next 5-10 years and, most people don't see it coming.

Did you think in 1998 that 3 years later, you would never take pictures on film again? With today's smart phones, who even has a camera these days?

Yet digital cameras were invented in 1975. The first ones only had 10,000 pixels, but followed Moore's law. So as with all exponential technologies, it was a disappointment for a time, before it became way superior and became mainstream in only a few short years. It will now happen again (but much faster) with Artificial Intelligence, health, autonomous and electric cars, education, 3D printing, agriculture and jobs.

Forget the book, "Future Shock", welcome to the 4th Industrial Revolution.

Software has disrupted and will continue to disrupt most traditional industries in the next 5-10 years.

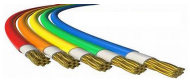
UBER is just a software tool, they don't own any cars, and are now the biggest taxi company in the world! Ask any taxi driver if they saw that coming.

Airbnb is now the biggest hotel company in the world, although they don't own any properties. Ask Hilton Hotels if they saw that coming. (Just a quick aside, go type Airbnb into a Google Search area and see what you find!)

Artificial Intelligence: Computers become exponentially better in understanding the world. This year, a computer beat the best Go-player in the world, 10 years earlier than expected.

In the USA, young lawyers already don't get jobs. Because of IBM's Watson, you can get legal advice (so far for right now, the basic stuff) within seconds, with 90% accuracy compared with 70% accuracy when done by humans. So, if you study law, stop immediately. There will be 90% fewer lawyers in the future, (what a thought!) only omniscient specialists will remain.

Watson already helps nurses diagnosing cancer, it's 4 times more accurate than human nurses.



Facebook now has a pattern recognition software that can recognize faces better than humans. In 2030, computers will become more intelligent than humans.

Autonomous cars: In 2018, the first self-driving cars are already here. In the next 2 years, the entire industry will start to be disrupted. You won't want to own a car anymore because you will call a car with your phone, it will show up at your location and drive you to your destination. You will not need to park it, you will only pay for the driven distance and you can be productive while driving. The very young children of today will never get a driver's license and will never own a car.

This will change our cities, because we will need 90-95% fewer cars. We can transform former parking spaces into parks.

1.2 million people die each year in car accidents worldwide including distracted or drunk driving. We now have one accident every 60,000 miles; with autonomous driving, that will drop to 1 accident in 6 million miles. That will save a million lives plus worldwide each year.

Most traditional car companies will doubtlessly become bankrupt. Traditional car companies will try the evolutionary approach and just build a better car, while tech companies (Tesla, Apple, Google) will do the revolutionary approach and build a computer on wheels.

Look at what Volvo is doing right now; no more internal combustion engines in their vehicles starting this year with the 2019 models, using all electric or hybrid only, with the intent of phasing out hybrid models.

Many engineers from Volkswagen and Audi; are completely terrified of Tesla and so they should be. Look at all the companies offering all electric vehicles. That was unheard of, only a few years ago.

Insurance companies will have massive trouble because, without accidents, the costs will become cheaper. Their car insurance business model will disappear.

Real estate will change. Because if you can work while you commute, people will move farther away to live in a more beautiful or affordable neighborhood.

Electric cars will become mainstream about 2030. Cities will be less noisy because all new cars will run on electricity.

Cities will have much cleaner air as well. (Can we start in Los Angeles, please?)

Electricity will become incredibly cheap and clean.

Solar production has been on an exponential curve for 30 years, but you can now see the burgeoning impact.

And it’s just getting ramped up.

Fossil energy companies are desperately trying to limit access to the grid to prevent competition from home solar installations, but that simply cannot continue - technology will take care of that strategy.

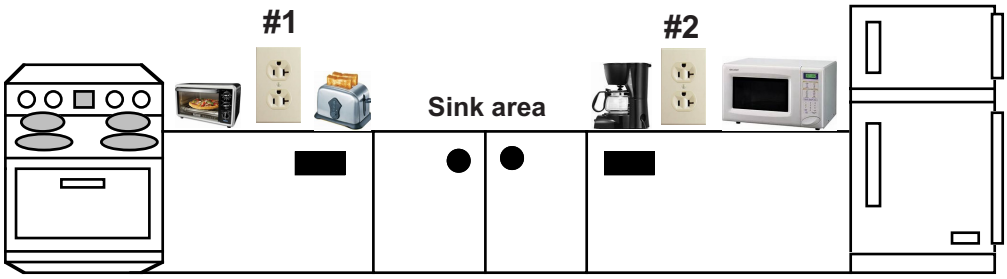
Health: The Tricorder X price will be announced this year. There are companies who will build a medical device (called the "Tricorder" from Star Trek) that works with your phone, which takes your retina scan, your blood sample and you breath into it. It then analyses 54 bio-markers that will identify nearly any disease. There are dozens of phone apps out there right now for health purposes.

WELCOME TO TOMORROW – it actually arrived a few years ago.

New electric appliances are coming onto the market each day now, we must install the wiring to supply these increased loads.

Branch Circuits Counter Top Small Appliances

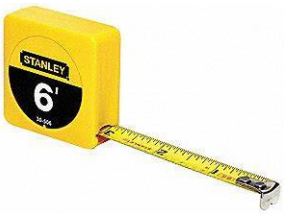
To lay out the 20 amp small appliance kitchen circuits, one must determine the counter space to be used by the appliances. This sketch shows a long counter top with cabinets and **a sink**. Two 20 amp duplex receptacles for two 20 amp small appliance circuits. Supplied by two 20 amp dual function ***combination AFCI/GFCI circuit breakers.***



GFCI

(A) Dwelling Units. All 125-volt, single-phase, 15 and 20 ampere receptacles installed in locations specified in **210.8(A)(1) through (12)** shall have **GFCI protection for personnel**.

210.8(A)(6) Kitchens - where the receptacles are installed to serve the countertop surfaces.



210.8(A)(7) Sinks - where receptacles are installed within 6 feet from the top inside edge of the bowl of the sink.

210.12 Arc-Fault Circuit-Interrupter Protection. AFCI protection shall be provided as required in 210.12(B), through (E). The AFCI shall be installed in a readily-accessible location.

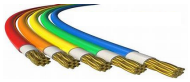
(B) Dwelling Units. ***All*** 120-volt, single-phase, 15 and 20 ampere **branch circuits** supplying **outlets** or ***devices*** in **dwelling unit kitchens**, family rooms, dining rooms, living rooms, parlors, libraries, dens, bedrooms, sunrooms, recreation rooms, closets, hallways, laundry areas, or similar rooms or areas shall be protected by any of the means described in 210.12(A)(1) through (6):

•**Note**: **210.8(A)(6) Kitchens** - where the receptacles are installed to serve the countertop surfaces are required to be GFCI.

210.12(B) Dwelling Units. All **kitchen** receptacles shall be protected by AFCI.

A 20 amp *dual function* ***combination breaker AFCI/GFCI*** could be installed.

Small Appliance Branch Circuits



The maximum power draw is **1,920 watts** (80% of 2400 watts) on a 20 amp, 120-volt circuit per section *210.23(B)(1)*.

Duplex receptacle #1. Top receptacle is for the 10.8 amp (1296 watt) toaster oven. The bottom receptacle is for the 10 amp (1200 watt) bread toaster. **Total for the two appliances is 2,496 watts. One 20 amp circuit could trip the circuit breaker of 2400 watts.**

Duplex receptacle #2. Top recptacles is for the 10 amp (1200 watt) coffee pot. The bottom receptacle is for the 8.33 amp (1000 watt) microwave oven. **Total for the two appliances is 2,200 watts. The 20 amp circuit would exceed the 80% of 1,920 watts.**

Try using the deep fryer or an electric skillet at the same time on the same 20 amp circuit without tripping the circuit breaker.

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. This allows the breaker to handle the temporary surge that happens when an appliance starts up.

When deciding how many receptacles to add to a 20-amp circuit, **consider what you are likely to plug into each one**. For safety, the total draw on the circuit shouldn't exceed 16 amps at any one time, which translates to a maximum power draw of **1,920 watts** on a conventional 120-volt circuit, even though the breaker won't trip until the power draw exceeds 2,400 watts. You should limit the number of receptacles on a circuit that will handle a power-hungry appliance. For example, most microwave ovens draw 1,000 watts, so a branch circuit that powers one, should have fewer other loads.

Be advised the two small appliance circuits that serve the counter tops is the Code required **minimum**, not a recommedation. Heavy loading and designing for tomorrow could *demand more than two small appliance circuits*.

The two small appliance circuits that serve the counter tops, they are **not** permitted to serve the under the counter top appliances such as the dishwasher, disposal, or trash compactor. The dishwasher, disposal, and trash compactor circuiting will depend on the manufacturer's installation guidelines.

Small Appliance Branch Circuits

Remember 90.2(B), **Adequacy.** This Code contains provisions that are considered necessary for **safety**. Compliance therewith and proper maintenance result in an installation that is essentially free from hazard but ***not*** *necessarily efficient, convenient, or adequate for good service or* ***future expansion of electrical use***.

To lay out the countertop receptacles, or any receptacle throughout the dwelling, you should consider future expansion and install the ***20 amp rated*** receptacles.

A 15 amp plug has two vertical blades, 20 amp plug has one vertical and one horizontal. The former places the neutral blade parallel to the hot blade while the latter places the neutral blade perpendicular to the hot blade. The different configurations are so you don't accidentally plug a piece of equipment that draws 20 amps into a 15 amp circuit.

20 amp

Today, most homeowners don't own a 20 amp appliance. But, there are some available and more to come in the future, for example; a Kitchen Aid mixer with a 1.3 hp motor, portable electric space heater, an electric jackhammer, a UPS, large refrigerators, etc.

15 amp

20 amp

You can't insert at 20 amp attachment plug into a 15 amp receptacle because a 20 amp attachment plug has one sideways prong.

15 amp receptacles are allowed on 20 amp branch circuits which are intended to have **multiple receptacles** on a single circuit.

20 amp

20 amp

It should be noted that a 20 amp branch circuit must have a 20 amp receptacle, because it is designed to provide the full 20 amps to an individual appliance.

20 amp

20 amp

210.21(B) Receptacles.
(1) Single receptacle on an Individual Branch Circuit. A single receptacle installed on an individual branch circuit shall have an ampere rating not less than that of the branch circuit.