

CHAPTER 17

Basic Roof Framing

Section 17.1

Planning a Roof

Section 17.2

Roof Framing with Common Rafters

Section 17.3

Ceiling Framing

Section 17.4

Roof Trusses

Chapter Objectives

After completing this chapter, you will be able to:

- **Identify** the basic roof styles.
- **Understand** the basic terms relating to roof-framing carpentry.
- **Explain** the layout of a common rafter, using at least one of the four basic methods.
- **Describe** the layout ceiling joists.
- **Name** the three basic parts of a roof truss.
- **Demonstrate** how to install roof trusses.



Discuss the Photo

Building a Roof Roofs are constructed in many different shapes. *What are some things to consider in determining the shape of a roof?*



Writing Activity: Research and Summarize

Contact a manufacturer of residential wood trusses. Find answers to the following questions. Then summarize your findings in a one-page report.

1. How long does it take to design a truss, and how far in advance should a builder order them?
2. How are computers used in the design of trusses?



Before You Read Preview

Roof framing is the last major framing activity in the construction of a house. Choose a content vocabulary and academic vocabulary word that is new to you. When you find it in the text, write down the definition.

Content Vocabulary

- rafter
- ridge board
- span
- total run
- unit run
- total rise
- unit rise
- slope
- pitch
- chord
- web

Academic Vocabulary

You will find these words in your reading and on your tests. Use the academic vocabulary glossary to look up their definitions if necessary.

- benefit
- distributed
- access
- specify

Graphic Organizer

As you read, use a two-column chart like the one shown to organize content vocabulary words and their definitions.

Content Vocabulary	Definition
rafter	A rafter is an inclined framing member that supports the roof.

Go to glencoe.com for this book's OLC for a downloadable version of this graphic organizer.

Academic Standards

Mathematics

Measurement: Apply appropriate techniques, tools, and formulas to determine measurements (NCTM)

Geometry: Use visualization, spatial reasoning, and geometric modeling to solve problems (NCTM)

Algebra: Understand patterns, relations, and functions (NCTM)

Geometry: Apply transformations and use symmetry to analyze mathematical situations (NCTM)

Geometry: Analyze characteristics of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships (NCTM)

English Language Arts

Use different writing process elements to communicate effectively (NCTE 5)

Science

Science and Technology: Abilities of technological design (NSES)

Science in Personal and Social Perspectives: Personal and community health (NSES)

Life Science: Behavior of organisms (NSES)

Industry Standards

Framing in Wood
Roof, Ceiling, and Wall Framing

NCTE National Council of Teachers of English

NCTM National Council of Teachers of Mathematics

NSES National Science Education Standards

Planning a Roof

Roof Styles

Which roof styles are most common where you live?

Roof framing is considered the most complicated frame carpentry in a house because of all the angles involved. It may also seem difficult to learn because of the many special terms. However, it is important to understand that even the most complex roofs are based on a few standard designs.

Roof framing begins after the house walls have been framed. In most cases, the walls have also been sheathed to increase their strength and stiffness. Nominal 2" lumber is generally used for roof framing but I-joists are increasingly common (see Chapter 13,

“Engineered Wood”). This and following chapters describe roof framing using conventional lumber. Using I-joists requires the same basic understanding of rafter layout and roof design. Truss roof framing is covered in Section 17.4.

The main purpose of a roof is to protect the house in all types of weather with a minimum of maintenance. The roof must be appropriate for the climate in which the house is being built. A roof must be strong to withstand snow and wind loads. A roof should provide a continuous downward slope to shed rain water and snow melt. The parts must be securely fastened to each other to prevent them from coming apart in high winds or collapsing under a heavy load of snow.

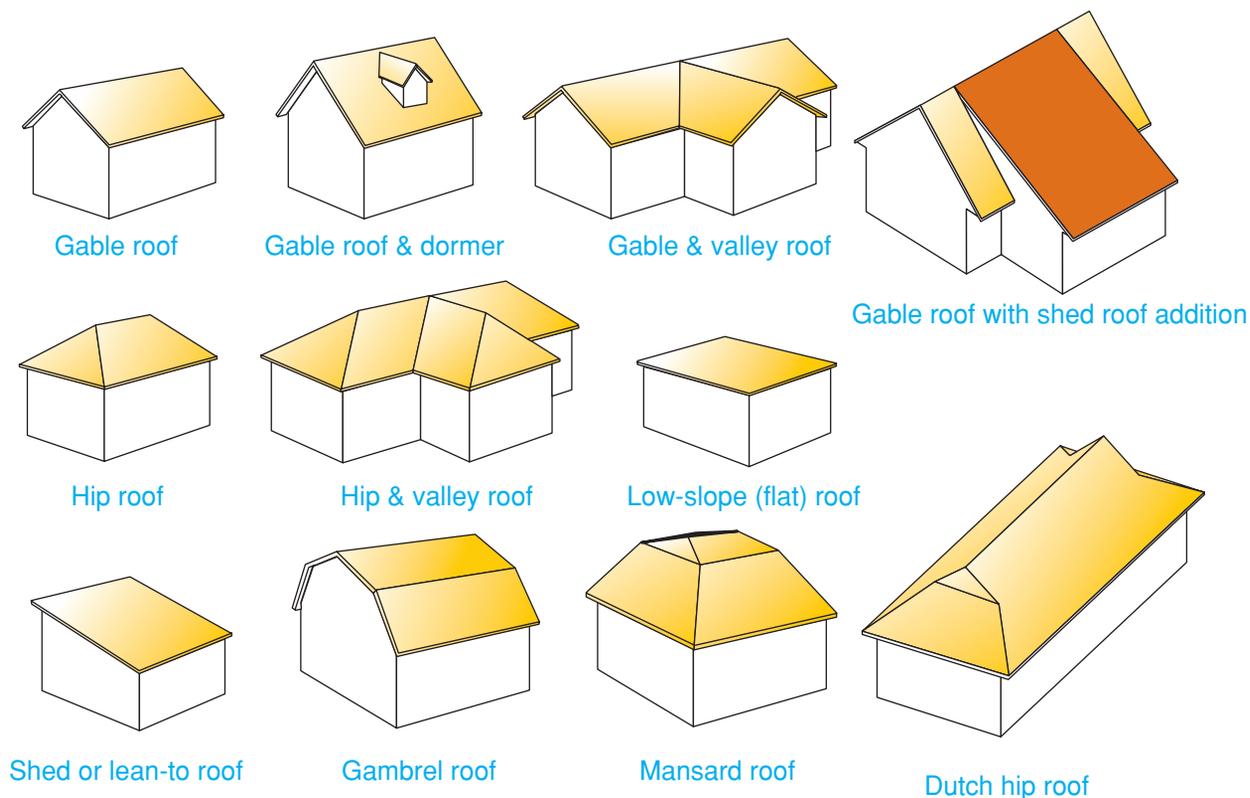


Figure 17-1 Common Roof Styles
Shape Determines Style Each style of roof has advantages and disadvantages.



Figure 17-2 Two Styles of Roof

Multiple Styles Gable roofs and hip roofs are common styles in homebuilding. *Which roof styles do you see on this house?*

A carpenter must understand and be able to frame roofs in different styles. The basic roof styles used for homes and small buildings are gable, hip, low-slope, and shed, as shown in **Figure 17-1**. Variations are associated with architectural styles of different regions or countries. Some of these include the gambrel roof, the mansard roof, and the Dutch hip roof.

A roof should also add to the attractiveness of the home. Roof styles are used to create different effects. A house may have more than one style of roof, as shown in **Figure 17-2**.

Gable Roof

The *gable roof* has two sloping sides that meet at the top to form a gable at each end. A *gable* is the triangular wall enclosed by the sloping ends of the roof. A gable roof may include *dormers* (upright window projections) that add light and ventilation to second-floor rooms or the attic. The gable roof is the most common type of roof.

Hip Roof

A *hip roof* slopes at the ends of the building as well as at the two sides. The slope on all sides results in an even overhang all around the building and gives a low appearance. Because there is no siding above the overhang, maintenance needs are



Mathematics: Geometry

Calculating Rafter Length Lawford Construction is building a house with a gabled roof that has a 24' span. The total rise of the roof is 9'. How long should the rafters be if the design calls for a 10" tail?

Starting Hint Use the Pythagorean Theorem to figure the length of the rafter from the ridge board to the top plate. Then add the length of the rafter tail.

reduced. The hip is also a very strong roof and is often found in regions where severe storms are common.

Low-Slope Roof

Sometimes called a *flat roof*, a *low-slope roof* is not perfectly flat. Instead, the rafters are laid at a slight angle to encourage water to drain. A **rafter** is an inclined framing member that supports the roof. Sheathing and roofing are applied to the top of the rafters. The ceiling material is applied to the underside of the rafters. Because a flat roof can be difficult to waterproof, it is found most often in dry climates.

Shed Roof

Sometimes called a *lean-to roof*, the *shed roof* slopes in one direction only. A shed roof is often used for an addition to an existing structure. In this case, the roof may be attached to the side of the structure or to the roof.

Gambrel Roof

The *gambrel roof* is a variation of the gable roof. It has a steep slope on two sides. A second slope begins partway up and continues to the top. It is commonly used on barns. A gambrel roof allows for more useable attic space than a typical gable or hip roof. This space can also be used as a second floor.

Mansard Roof

The *mansard roof* is a variation of the hip roof. It has steep slopes on all four sides. Partway up, a shallow second slope is developed and continues to the top where it meets

the slopes from the other sides. The mansard roof style was brought to North America by the French who settled in Quebec, Canada.

Dutch Hip Roof

A *Dutch hip roof* is related to both the gable roof and the hip roof. Basically, it is a hip roof with a small gable at each end near the top. Like a hip roof, it has an even overhang around the entire building. This protects the walls from rain. Like a gable roof, portions of a Dutch hip roof are formed by two slopes that meet at the top.

Roof Framing Basics

How does the slope of a roof relate to local weather patterns?

Mastering the special terms used in roof framing will make it easier for you to understand roofing concepts. Become familiar with the framing square, which you will be using. Its short leg is called the *tongue*. Its long leg is called the *blade*, or *body*.

Parts of a Roof

A basic, conventional roof consists of rafters, ceiling joists, and a ridge board, as shown in **Figure 17-3**. More complex roofs include other elements such as braces, valley rafters and jack rafters. (See Chapter 18, “Hip, Valley, and Jack Rafters.”)

A *rafter* is an inclined member of the roof framework. Rafters serve the same purpose in the roof as joists in the floor or studs in the wall. They are usually spaced 16" or 24" apart. Rafters vary in depth depending on their length, the distance they are spaced apart, their slope, and the kind of roof covering to be used. A *collar tie* is a horizontal tie that connects opposite pairs of rafters to help stiffen the roof. A **ridge board**, or *ridge*, is the horizontal piece that connects the upper ends of the rafters. It extends the full length of the house.

Rafters often extend beyond the exterior walls to form *eaves* (also called *overhangs*) that protect the sides of the house from sun and water damage. The *tail* is the portion of the rafter that extends beyond the wall of the building to form the eave. Unsupported eaves

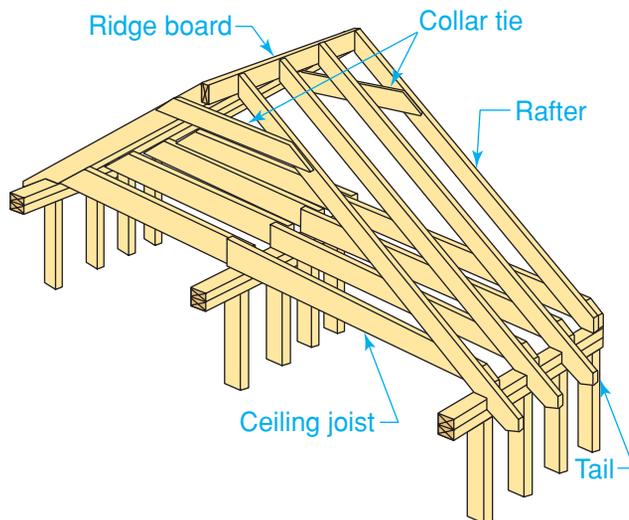


Figure 17-3 Conventional Roof Framing Basic Elements The basic parts of a roof frame.

commonly range from 6" to 24" in depth. Deeper eaves should be supported by posts.

The types of rafters shown in **Figure 17-4** can be used to frame various styles of roof. Not every type of rafter will be needed for each roof.

- *Common rafters* extend from the top plate to the ridge board at 90° to both.
- *Hip rafters* extend diagonally from the corners formed by the top plates to the ridge board.
- *Valley rafters* extend diagonally from the top plates to the ridge board along the lines where two roofs intersect.
- *Jack rafters*, also called *jacks*, never extend the full distance from the top plate to the ridge board. There are three kinds of jack rafters. *Hip jack rafters* extend from the top plate to a hip rafter. *Valley jack rafters* extend from the ridge board to a valley rafter. *Cripple jack rafters* extend between a hip rafter and a valley rafter or between two valley rafters.

Calculating Roof Slope

The slope of a roof must be calculated before construction can begin. It depends upon several factors, including the roof's span, run, and rise (see **Figure 17-5**).

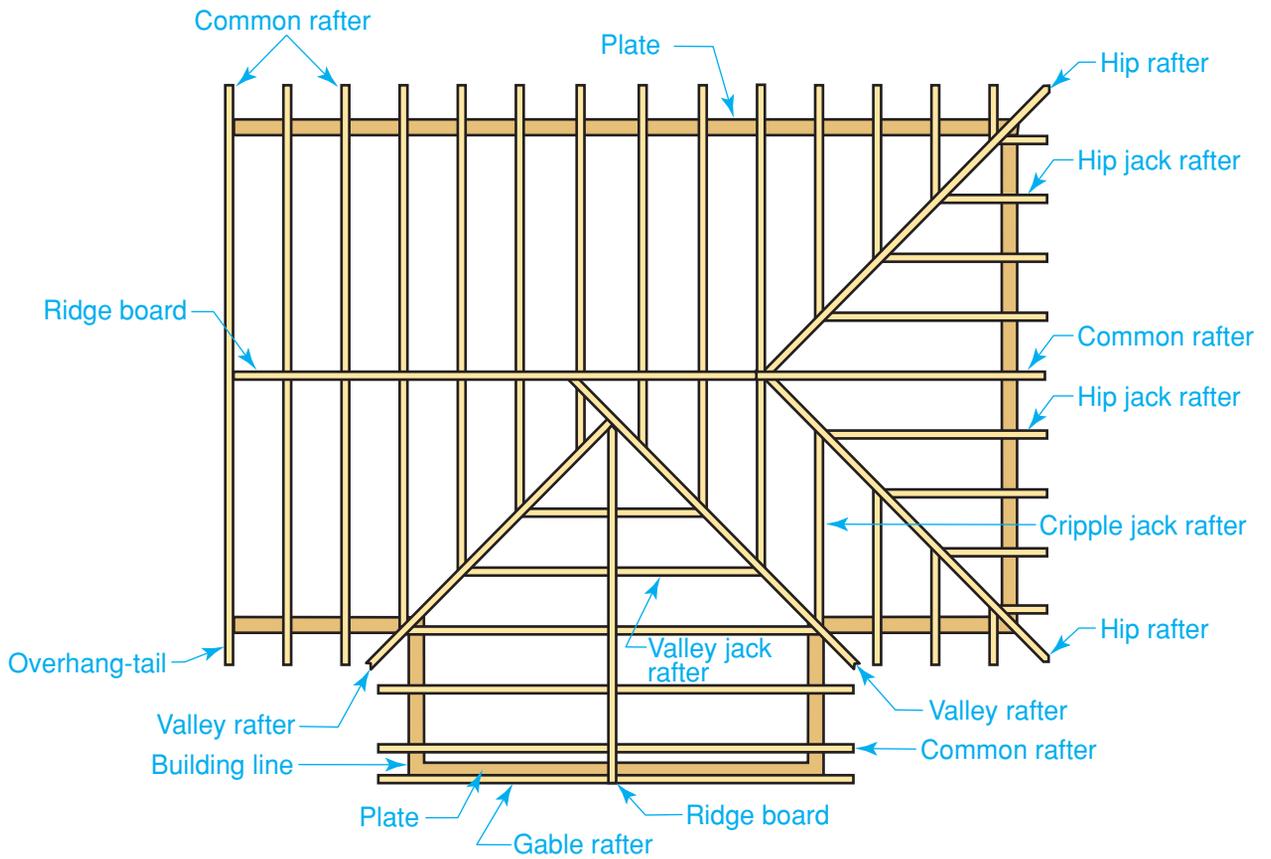


Figure 17-4 Types of Rafters
Plan View This is a plan view of a roof that contains various types of rafters.

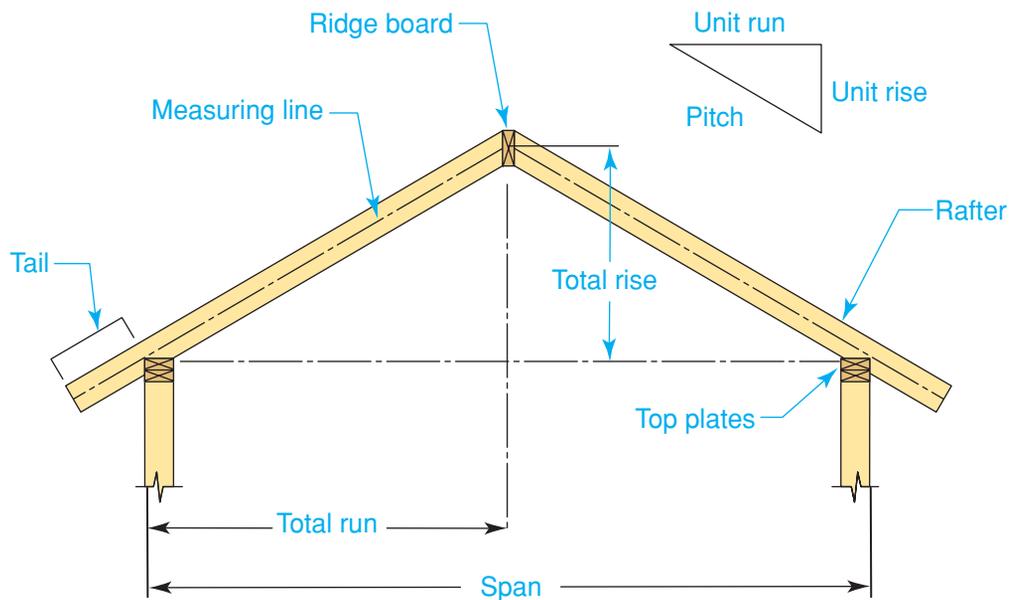


Figure 17-5 Terms Used in Roof Framing
Key Terms This drawing shows the basic elements a builder must be familiar with in order to frame a roof.

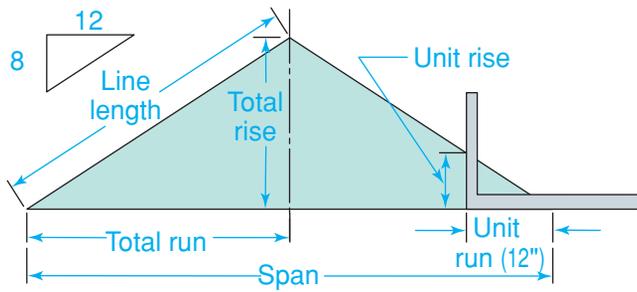


Figure 17-6 Unit Run and Unit Rise

Understanding Run The unit run of a common rafter is always 12". The rise in inches is variable, depending on the slope of the roof. In the example shown here, there are 8 inches of rise per unit of run.

The **span** is the distance between the outer edges of the top plates. It is measured at right angles to the ridge board. The **total run** is one-half the span (except when the slope of the roof is irregular). The **unit run**, or *unit of run*, is a set length that is used to figure the slope of rafters. The **unit run** for a rafter that is at a 90° angle to the ridge (a common rafter) is always 12". The unit run for a rafter that is at a 45° angle to the ridge is 17". The *measuring line* is an imaginary line running from the outside wall to the top of the ridge. The **total rise** is the vertical distance from the top of the top plate to the upper end of the measuring line. The **unit rise** is the number

of inches that a roof rises for every 12" of run (the unit run). As the unit rise varies, the slope of the roof changes, as shown in **Figure 17-6**.

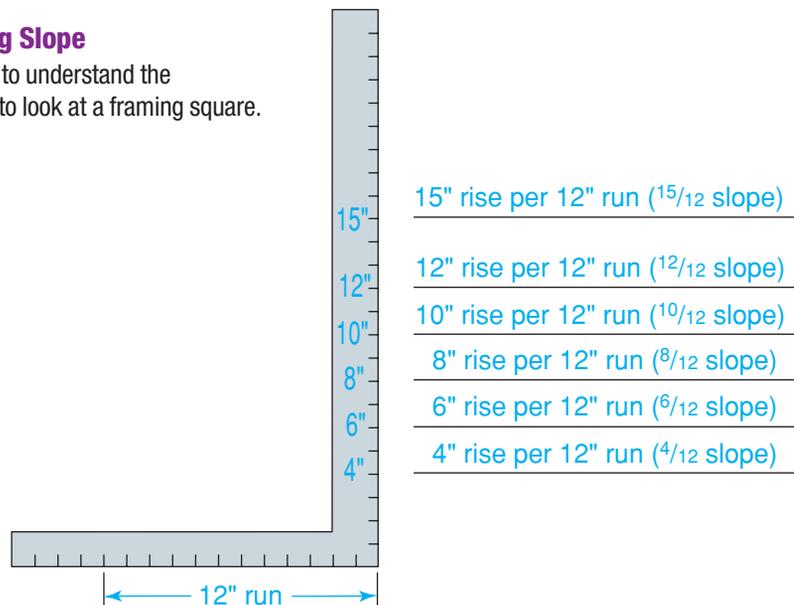
Many carpenters, and even some construction dictionaries, use the terms *slope* and *pitch* as if they are synonymous. However, they do not mean the same thing. **Slope** refers to a ratio of rise to run. **Pitch** refers to a ratio of rise to span. Either term can be used to describe the inclination (slant) of roofs and rafters, but slope is the term most suited to roof framing.

The triangular symbol above the roof in **Figure 17-6** shows the slope visually. When the slope is written out in words, the unit rise is separated from the unit run by a slash mark. For example, a roof may have a unit rise of 6" and a unit run of 12". The information would be written "6/12 slope" and pronounced "six twelve slope" or sometimes "six in twelve slope." See **Figure 17-7** for a visual description of this concept. The slope of a roof can also be given in degrees. For example, a roof with a 12/12 slope forms a 45° angle, as shown in **Figure 17-8**. However, referring to degrees is not a common practice.

Plumb lines and level lines refer to the direction of a line on a rafter, not to any particular rafter cut. Any line that is vertical when the rafter is in its proper position is called a

Figure 17-7 Describing Slope

By Rise and Run One way to understand the relationship of run to rise is to look at a framing square.



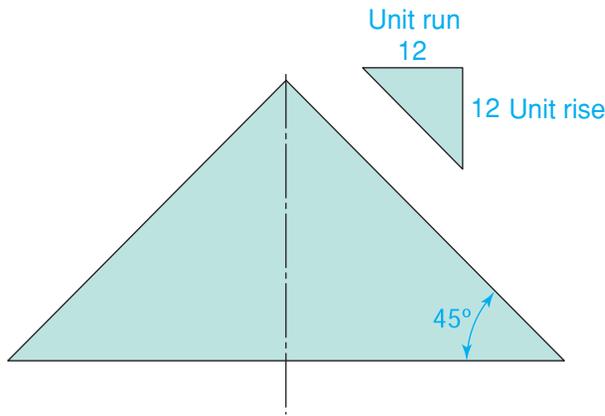


Figure 17-8 Another Way to Describe Slope By Degrees The slope of a roof can also be described by giving the angle formed by the roof.

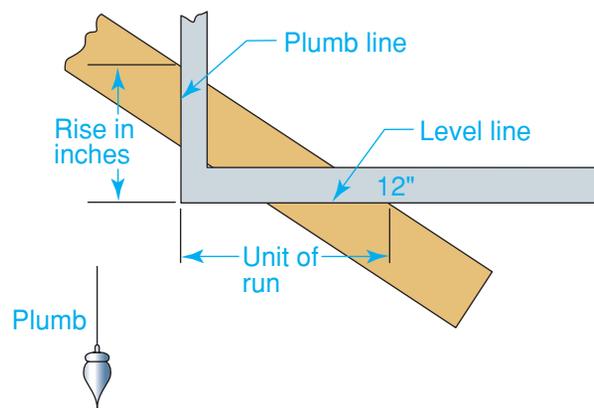


Figure 17-9 Plumb and Level Lines Using a Square A plumb line is drawn along the tongue of the square. A level line is drawn along the body, or blade.

plumb line. Any line that is horizontal when the rafter is in its proper position is called a *level line*. A framing square is used to lay out plumb and level lines on a rafter, as in **Figure 17-9**.



Recall State the purposes of the collar tie and the ridge.

Laying Out a Roof Framing Plan

Before cutting rafters, the carpenter must determine what kinds of rafters are needed to frame the roof. A roof framing plan may be included in the set of building plans to help in this regard. If it is not included, you must lay one out for yourself as shown in the following illustrations.

Gable Roof The gable roof framing plan is the simplest to develop, as shown in **Figure 17-10**.

1. Lay out the outline of the building (A).
2. Determine the direction in which the rafters will run.
3. Draw the centerline at right angles to this direction (B). The centerline determines the location of the ridge line (C). This corresponds to the location of the ridge board.
4. Determine the distance between the rafters and lay out the roof frame plan (D).

Gable and Valley Roof A gable and valley roof is simply two gable roofs that intersect. In the majority of cases, they intersect at a 90°

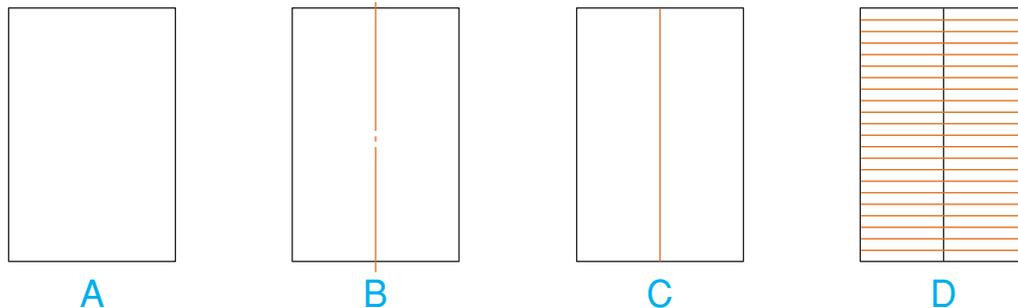


Figure 17-10 Framing Plan for a Gable Roof A Simple Plan The framing plan for a shed roof would be one-half of this.

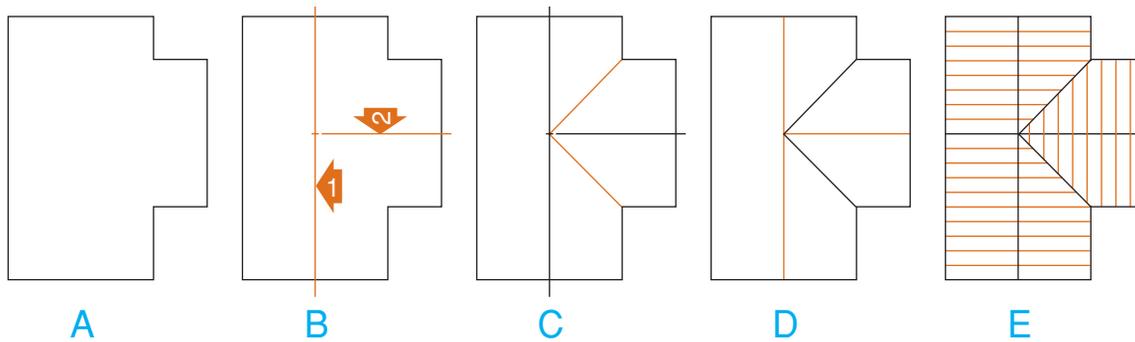


Figure 17-11 Framing Plan for a Gable and Valley Roof
T-Shaped Plan The rafters of an addition will be perpendicular to rafters of the main roof.

angle. The intersection creates two valleys as shown in **Figure 17-11**.

1. Lay out the outline of the building (A).
2. Draw the centerline of the larger rectangle (B, arrow 1).
3. Draw the centerline of the smaller rectangle (B, arrow 2).
4. Draw 45° lines from the interior corners of the building to where the centerlines intersect (C).
5. Draw the ridge lines (D).
6. Determine the distance between the rafters and lay them out on the roof framing plan (E).

Hip Roof The angle at which the hip extends from each corner is usually 45°, as shown in **Figure 17-12**. However, other angles are possible. A 45° angle will insure that each surface of the roof will have the same slope.

If the angle is something different than 45°, the slopes will not be the same.

1. Lay out the outline of the building (A).
2. Locate and draw a centerline (B).
3. Starting at each corner, draw a 45° line from the corner to the centerline (C). This establishes the location of the hip rafters.
4. Draw the ridge line between the intersecting points of the hip rafters (D).
5. Determine the distance between the rafters and lay them out on the roof framing plan (E).

Hip and Valley Roof A hip and valley roof can be quite complex. It is created when one or more hip roofs intersect at 90° angles, as shown in **Figure 17-13**.

1. Lay out the outline of the building (A).
2. Outline the largest rectangle inside the building outline (B).

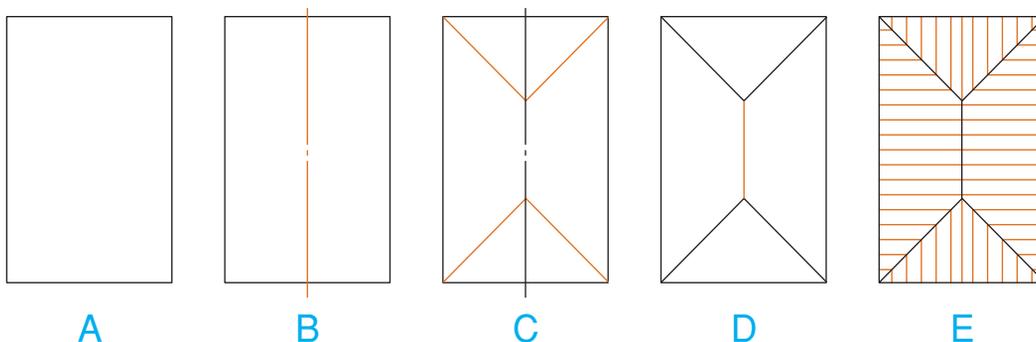


Figure 17-12 Framing Plan for a Hip Roof
Hip Roof Like a gable roof, the framing plan for a hip roof is symmetrical.

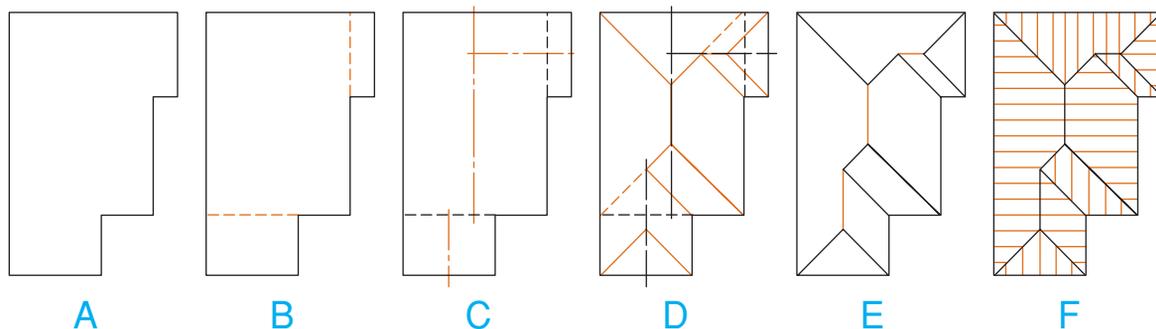


Figure 17-13 Framing Plan for a Hip and Valley Roof
Complex Plan Note how the roof is first divided into rectangular sections.

3. Draw centerlines for every rectangle formed inside the building outline (C).
4. Draw a 45° line from each inside and outside corner. Extend these lines to intersect with the centerlines (D). The lines indicate the location of the hip rafters on outside corners and valley rafters on inside corners.
5. The centerlines drawn in (C) connect the hip and valley rafters. Draw these as solid lines where the ridges will be located (E).
6. Figure the distance between the rafters and lay them out on the roof framing plan (F).



JOB SAFETY

LIFTING RAFTERS During the layout and assembly of a roof frame, a great volume of lumber is handled. Due to their size and length, rafters are much heavier than wall studs and far more unwieldy. Organize the work to minimize back strain. For example, have lumber delivered close to where it will be cut. Work with a helper to lift rafters into position.

Go to glencoe.com for this book's OLC for more on job safety.

Section 17.1 Assessment

After You Read: Self-Check

1. Name the four basic roof styles used for homes.
2. The gambrel roof is a variation of which basic roof style?
3. Explain the difference between a plumb line and a level line.
4. What is the purpose of a roof framing plan?

Academic Integration: Mathematics

5. **Slope and Pitch** The terms slope and pitch are often used synonymously. However, slope and pitch are two different calculations. What is the slope of a roof if the unit run is 12" and the pitch is $\frac{1}{3}$?

Math Concept Pitch is a ratio of total rise to span. Slope is a ratio of unit rise to unit run. To find the slope, multiply the pitch times 24. Then place the product over the unit run.

Go to glencoe.com for this book's OLC to check your answers.

Roof Framing with Common Rafters

Laying Out Common Rafters

What is a seat cut?

In conventional roof construction, carpenters assemble the roof from individual ceiling joists and rafters. The rafters should not be erected until the ceiling joists have been fastened in place (see Section 17.3). The ceiling joists act as a tie to prevent the rafters from pushing the exterior walls outward. The roof framing methods that follow are used for a gable roof. Variations apply to gambrel, shed, and flat roofs.

The rafters form the skeleton of the roof. They must be carefully made and fitted if they are to support the roof's weight. The top of the rafter rests against the ridge board, as shown in **Figure 17-14**. The cut made in the rafter so it fits against the ridge is called

a *plumb cut*. The bottom of the rafter rests on the plate. The cut made here is called a *level cut*, or *seat cut*.

- **Plumb cut** A line for the plumb cut can be drawn using a framing square as a guide, as shown in **Figure 17-15A**. The unit run (12" mark) on the blade of the square is aligned with the edge of the rafter. The unit rise on the tongue of the square will correspond to the pitch of the roof. The unit rise is aligned on the same edge of the rafter. The line for the plumb cut is then drawn along the edge of the tongue.
- **Seat cut** A line for the seat cut is drawn with the square in the same orientation on the rafter but with the square in a different location. The line is drawn along the body of the framing square as shown in **Figure 17-15B**.

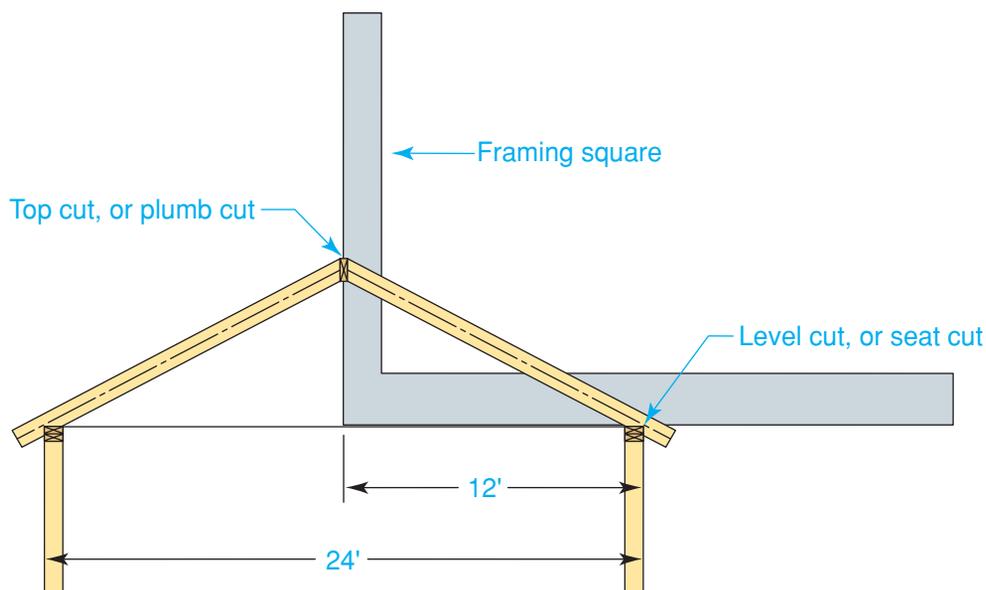


Figure 17-14 Visualizing Rafter Cuts

Plumb and Seat Cuts A framing square was enlarged to show its relationship to the roof and to the top and bottom cuts.

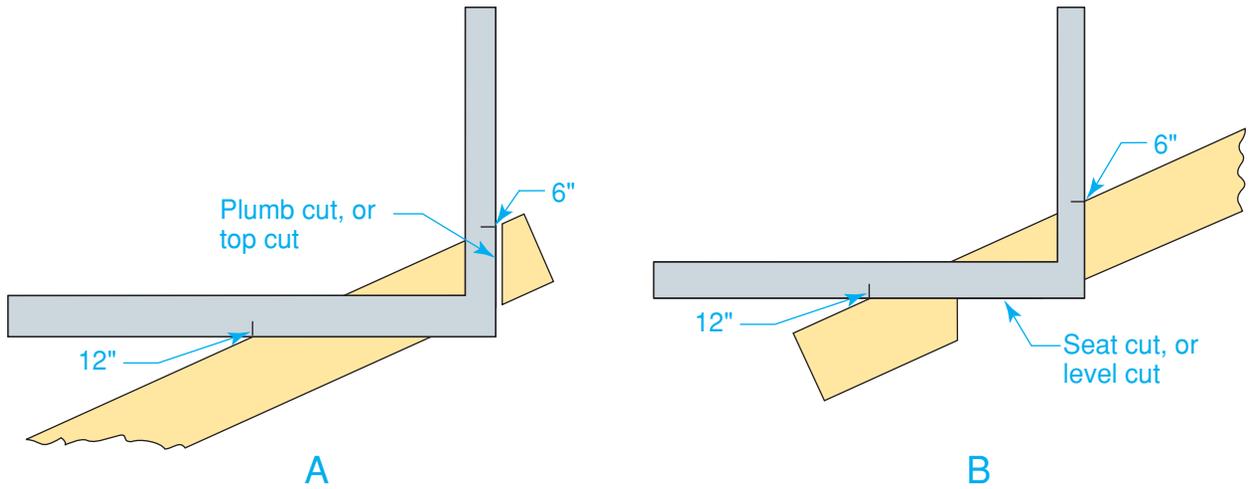


Figure 17-15 Making Plumb and Seat Cuts
The Square Shifts A. A plumb line has been drawn for the plumb cut on a roof with a 6" unit rise ($\frac{1}{4}$ pitch). B. A level line was drawn for the seat cut. This cut was made for a roof with a 6" unit rise.

Look at **Figure 17-16** and **Figure 17-17**. The *theoretical length* of a common rafter is the shortest distance between the outer edge of the plate (A) and a point where the measuring line of the rafter meets the ridge line (B). This length is found along the measuring line. It may be calculated in the following ways:

- By using the Pythagorean theorem.
- By using the unit length obtained from the rafter table on the framing square.

- By stepping off the length with the framing square.
- By entering the rise and run into a calculator designed for solving construction problems.

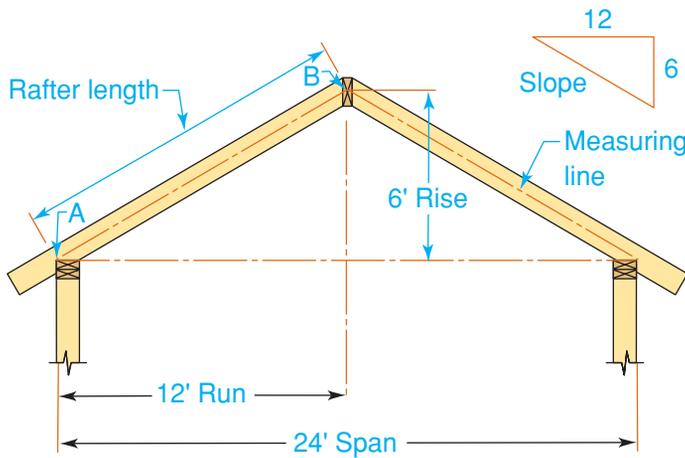


Figure 17-16 Theoretical Rafter Length
Layout The theoretical rafter length is measured from point A to point B.

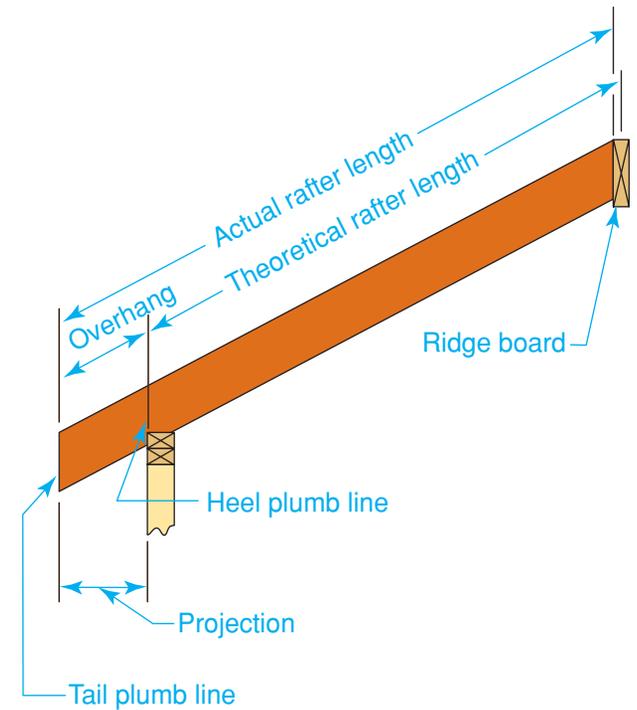


Figure 17-17 Actual Rafter Length Comparison The actual and theoretical length of a common rafter.

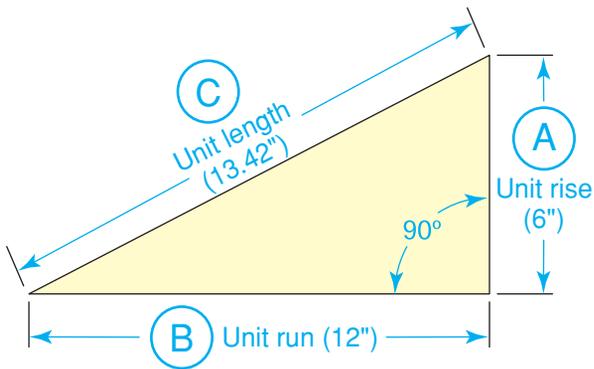
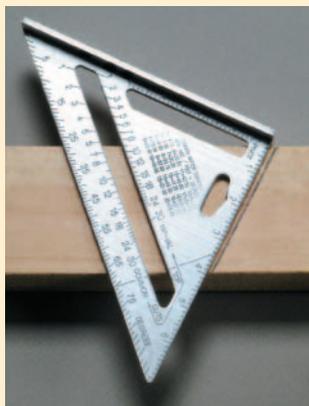


Figure 17-18 Unit Length Hypotenuse The unit length of the rafter is represented by the line C. The length of this line can be found in the rafter table on the framing square.

Builder's Tip

ANOTHER TYPE OF FRAMING SQUARE Some carpenters find a triangular framing square easier to use and more convenient to carry. Another advantage is that the thickened lip along one side allows it to be used to guide a circular saw when crosscutting lumber. One brand of triangular framing square is called a Speed Square™. To make a plumb cut with the triangular framing square (shown below), hold the square's pivot point against one edge of the rafter stock. Pivot the square until the appropriate rise number on the "common" scale of the square lines up with the same rafter edge. As shown here, the rise is 6-in-12. Mark the rafter from the pivot point along the top edge of the square. This is the plumb line.



Pythagorean Theorem Method

The Pythagorean theorem states that the square of the hypotenuse of a right triangle is equal to the sum of the squares of the other two sides (see **Figure 17-18**):

$$A^2 + B^2 = C^2$$

The length of the hypotenuse (C) will be the square root of the sum of the square of the other two sides.

$$C = \sqrt{A^2 + B^2}$$

The rise, the run, and the rafter of a roof form a right triangle. Therefore the hypotenuse can be used to represent the rafter. The length of the rafter (C) can thus be calculated from the rise (A) and the run (B).

Unit-Length Method

The unit-length method uses the rafter table on a framing square. *Unit length* is the length of a rafter per foot of run. It can be expressed as the hypotenuse of a right triangle. The unit run (12") is the base, and the unit rise (in inches per foot of run) is the altitude, as in **Figure 17-18**. Look at the rafter table on the framing square in **Figure 17-19**. The top line of the table reads: "Length Common Rafters per Foot Run." The inch markings along the top represent unit rise. For example, if you follow across the top line to the figure under 6 (for a unit rise of 6"), you will find the number 13.42. This is the unit length for a roof triangle with a unit run of 12" and a unit rise of 6".

Let us figure the total length of a rafter for a small building with a unit rise of 5", a span of 6', and a run of 3', as shown in **Figure 17-20**. Look at the rafter table to obtain the unit length. For a unit rise of 5", the unit length is 13" per unit run. The total length is the unit length times the total run. The total run of the building in this example is 3'. Therefore the total length of the common rafters is 39". Remember that the overhang must be added to the calculated rafter length, and half of the ridge width must be subtracted to determine the true total length.

23	22	21	20	19	18	17		
LENGTH	COMMON	RAFTERS	PER FOOT	RUN	21	63	20	81
"	HIP OR	VALLEY	"	"	24	74	24	02
DIFF	IN LENGTH	OF JACKS	16 INCHES	CENTERS	28	7/8	27	3/4
"	"	"	2 FEET	"	43	3/4	41	3/8
SIDE	CUT	OF	JACKS	USE	6	11/16	6	15/16
"	"	HIP OR	VALLEY	"	8	1/4	8	1/2
22	21	20	19	18	17	16		

23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1		
LENGTH	COMMON	RAFTERS	PER FOOT	RUN	21	63	20	81	19	57	18	54	17	51	16	48	15	45	14	42	13	39	12	36
"	HIP OR	VALLEY	"	"	24	74	24	02	22	66	21	63	20	60	19	57	18	54	17	51	16	48	15	45
DIFF	IN LENGTH	OF JACKS	16 INCHES	CENTERS	28	7/8	27	3/4	26	7/8	25	3/4	24	3/4	23	3/4	22	21	20	19	18	17	16	15
"	"	"	2 FEET	"	43	3/4	41	3/8	40	3/8	38	3/8	37	3/8	35	3/8	34	3/8	32	3/8	31	3/8	30	3/8
SIDE	CUT	OF	JACKS	USE	6	11/16	6	15/16	5	1/2	5	1/2	4	1/2	4	1/2	3	1/2	3	1/2	2	1/2	2	1/2
"	"	HIP OR	VALLEY	"	8	1/4	8	1/2	7	1/4	7	1/4	6	1/4	6	1/4	5	1/4	5	1/4	4	1/4	4	1/4

Figure 17-19 Finding the Unit Length

Using the Tables To find the unit length of common rafters, check the rafter table on the face of the framing square. An enlarged portion is shown here.

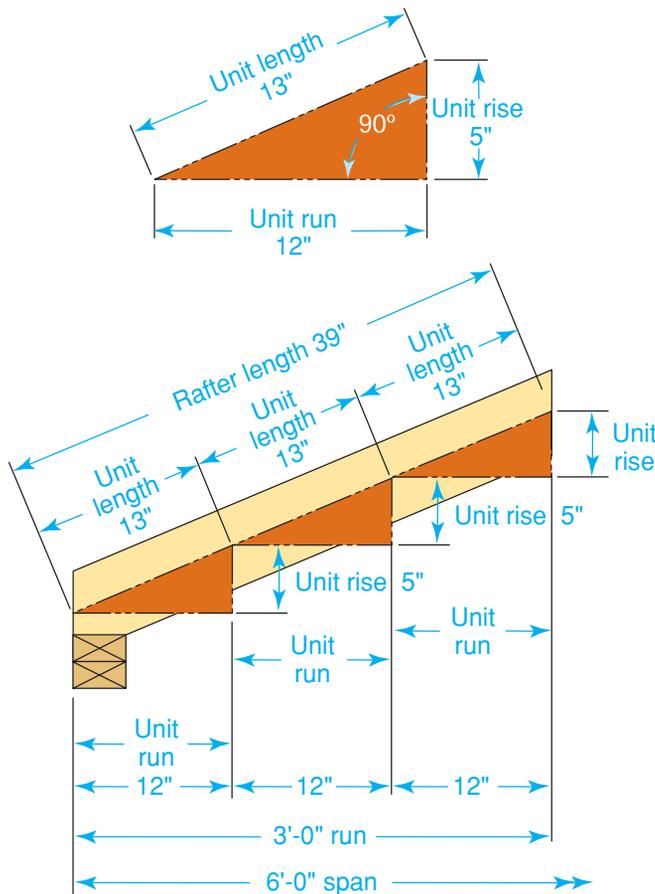


Figure 17-20 Sample Problem

Finding the Length The total theoretical length of a rafter is the total run times the unit length. In this example, the total run is 3' and the unit length is 13". Therefore, the length of the rafter is 39".

Step-Off Method

A third method for finding the theoretical rafter length is by using the framing square to “step off” the length, as shown in **Figure 17-21** on page 478. Place the square on the rafter with the tongue along the plumb cut. Step off the length of the unit run on the rafter stock as many times as there are feet in the total run. In this case, it would be three times.

Often the total run of a building will not come out in even feet. For example, the run might be 3'-4". To handle that, put the square at the first position, then draw a line along the edge of the tongue to represent the plumb cut at the ridge board, as in **Figure 17-22** on page 478. At the 4" mark on the blade, make a mark on the rafter along the level line—not along the edge. Then, starting at this mark, step off the unit run three times, for a total run of 3'-4". This is the theoretical length of the rafter.

Calculator Method

Small, easy-to-use construction calculators, such as the one in **Figure 17-23** on page 478, are common on job sites. Measurements can be entered into the calculator in feet and inches, including fractions. If you know the rise and the run, you can easily determine the length of a common rafter by entering these figures into the calculator. You can also use the tool to calculate cuts for hip rafters and valley rafters.

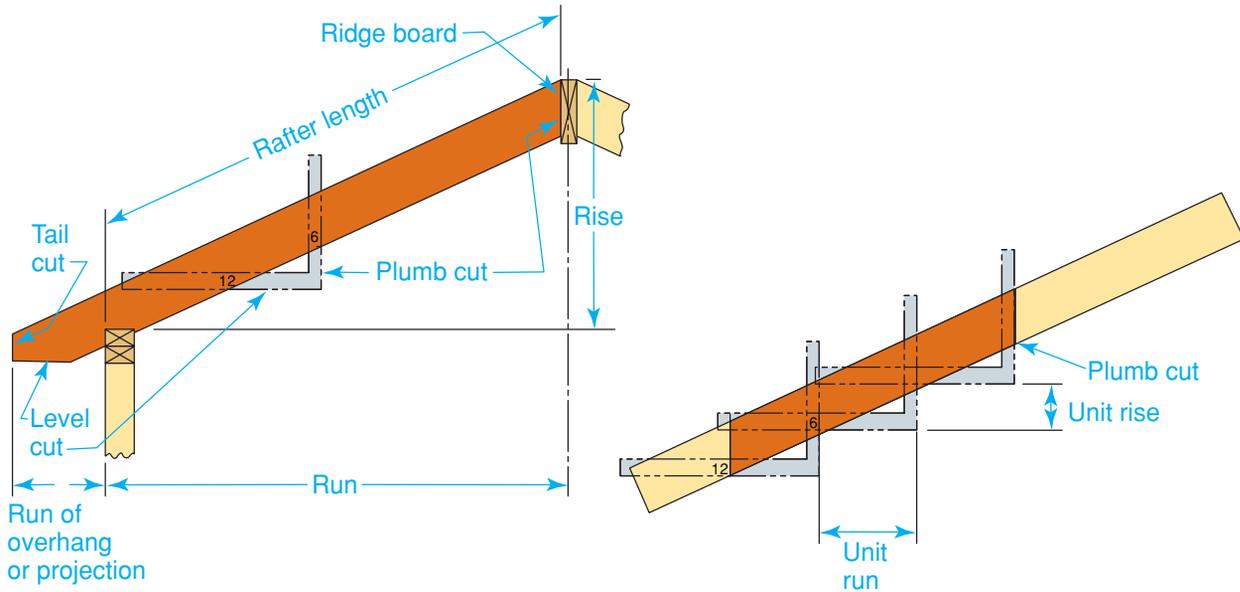


Figure 17-21 Stepping Off the Unit Length Using the Square This is another way to find the length of a common rafter.

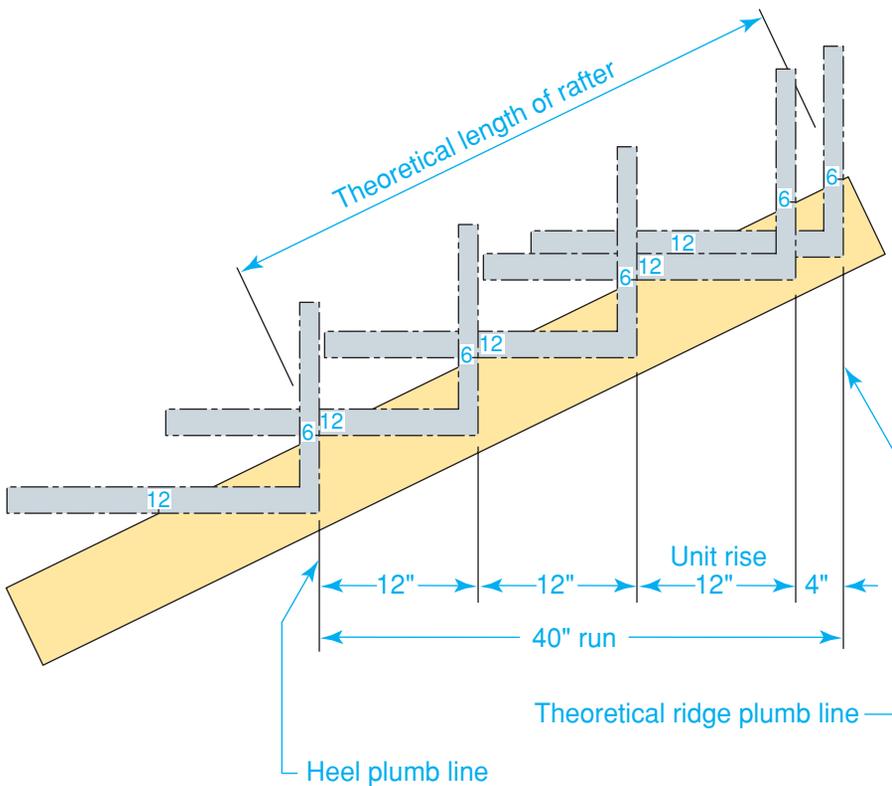


Figure 17-22 Uneven Runs Using the Square Stepping off the rafter when the total run is not an even number of feet.

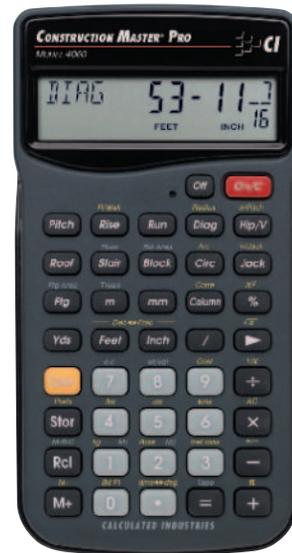


Figure 17-23 A Construction Calculator Time Saver A construction calculator is often used to solve roof framing problems.

Completing the Layout

What are some advantages of having a roof with an overhang?

After the basic rafter layout is complete, additional work is required. The ridge allowance, rafter overhang, and bird's mouth must be considered. (Layout of the ridge board itself will be discussed in Chapter 19, "Roof Assembly & Sheathing").

Common Rafter Ridge Allowance

The theoretical rafter length does not take into account the thickness of the ridge board or the length of the overhang, if there is one. To cut a rafter without an overhang to its actual length, you must deduct one-half the thickness of the ridge board from the ridge end, as shown in **Figure 17-24**. For example, if 2× stock is used for the ridge board, its actual thickness is 1½". One-half of this is ¾". The ¾" is indicated along the level line, and the line for the actual ridge plumb cut is drawn, as shown in **Figure 17-25**.

Common Rafter Overhang

A roof may or may not have an overhang, or eave. If not, the rafter must be cut so that its lower end is even with the outside of the

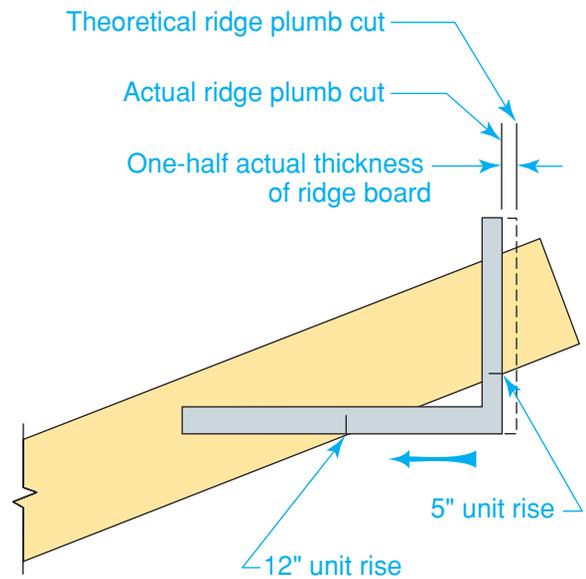


Figure 17-25 Marking the Ridge Allowance

Avoid the Edge Lay off one-half the thickness of the ridge board along the level line. Do not lay it off along the edge of the rafter.

exterior wall. If the end is cut parallel to the ridge plumb cut, it is said to have a *heel*, as shown in **Figure 17-26**. The portion of the rafter that rests on the plate is called the *seat*. To lay out the seat, place the tongue of the framing square on the heel plumb

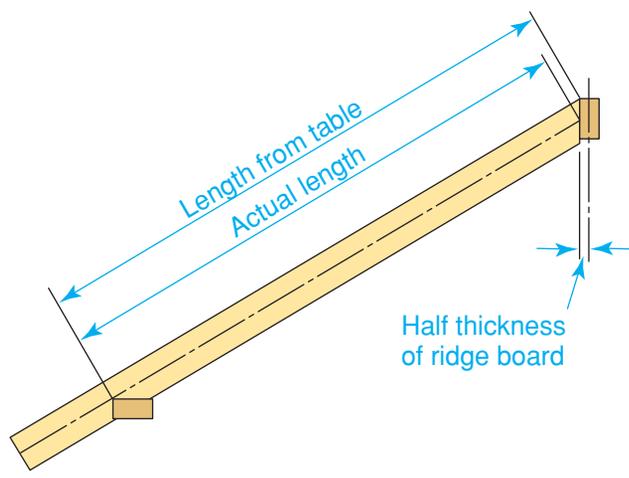


Figure 17-24 Understanding Ridge Allowance

Ridge Thickness Subtract one-half the *actual* thickness of the ridge board from the theoretical length of the rafter to obtain the rafter's actual length.

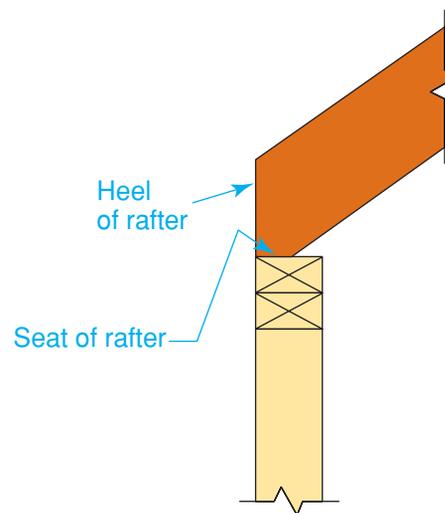


Figure 17-26 Rafter Heel

End of Rafter A rafter without an overhang rests on the exterior wall plate.

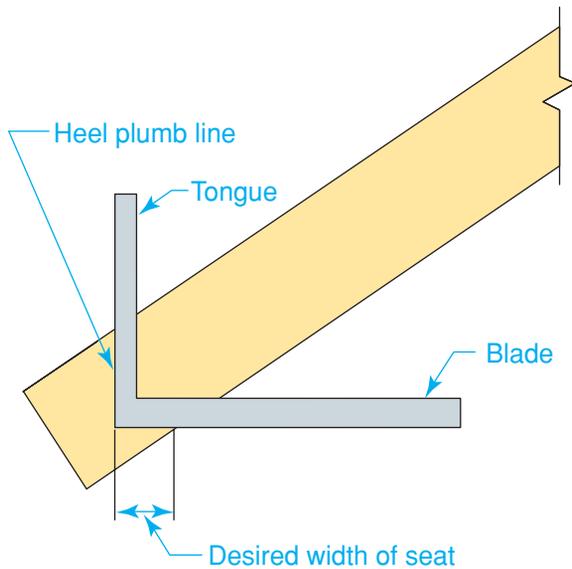


Figure 17-27 Rafter Seat
Horizontal Line Using the square to lay out the rafter seat.

line. The rafter edge will intersect the correct seat width on the blade, as shown in **Figure 17-27**. Indicate the seat by drawing a line from the heel plumb line along the blade.

A roof with wide overhangs provides protection for side walls and end walls. Though it adds slightly to the initial cost, this type of roof extension saves on maintenance later.

If the roof does have an overhang, the overhanging part of the rafter is called the tail. Its length must be added to the length of the rafter in order to find the total length of the rafter. The length of the tail may be calculated as if it were a separate short rafter. Any of the methods used for finding rafter length may be used to find the length of the tail. For example, suppose the run of the overhang is 24" and the unit rise of the roof is 8", as shown in **Figure 17-28**. Look at the rafter table on the framing square to find the unit length for a common rafter with a unit rise of 8". You will see the unit length is 14.42". Since the total run of the overhang is 24", the total length is 28.84", or $28\frac{27}{32}$ ":

$$14.42'' (\text{in. per unit run}) \times 2 (\text{units of run}) = 28.84''$$

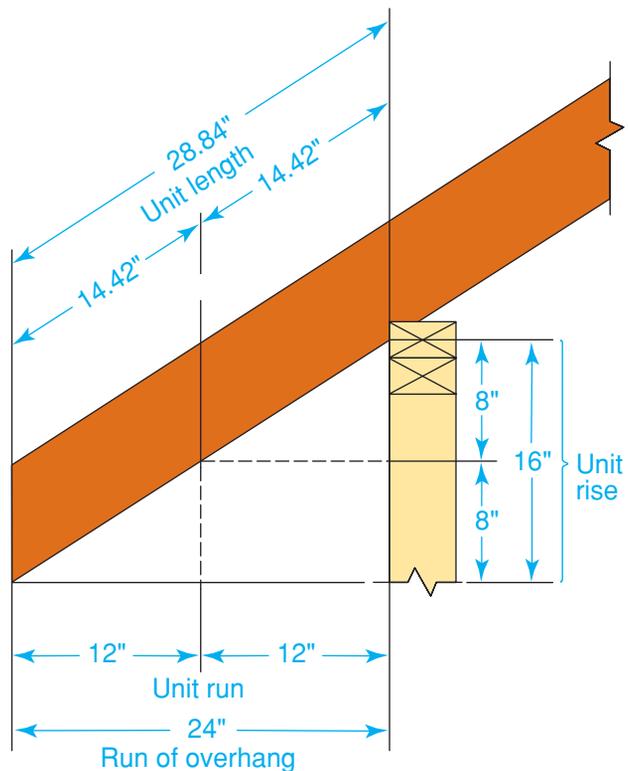


Figure 17-28 Calculating Overhang
Mini-Rafter The length of the rafter overhang may be found by using the rafter table on the framing square.

Another way to lay out the overhang is with the framing square. Suppose the run of the overhang is 10". Start the layout by placing the tongue of the square along the heel plumb line and setting the square to the pitch of the roof. In **Figure 17-29**, the square is set to a unit rise of 8" and a unit run of 12". Move the square in the direction of the arrow, as shown, until the 10" mark of the blade is on the heel plumb line. Draw a line along the tongue. This will mark the tail cut. If fascia or soffits are to be added later, be sure to allow for them in figuring the length of the rafter tail.

Many carpenters do not cut the tail to the finished length until after the rafters have been fastened in place. Instead, a sufficient amount of material is allowed for the overhang. After the rafters are fastened in place, a chalk line is snapped on the top edge of all the rafters. A tail plumb line is then drawn down from this chalk line on

each rafter and the tail is cut along the line. The **benefit** of this method is that it results in perfectly aligned rafter ends even if the house walls are not perfectly straight or if there is a slight bow in the ridge beam. The disadvantage is that the carpenter must make plumb cuts with a circular-saw while on the roof or on a ladder, which can be awkward.

In some cases, the end of a rafter does not require a plumb cut. It can be square cut instead. A square is placed on a chalk mark snapped across the top edge of the rafters so that a line can be drawn 90° across each rafter. This results in a square cut. This can only be done when there is no requirement for gutters on the house. A square cut makes gutters very difficult to mount.

Laying Out a Bird's Mouth

A *bird's mouth* is a notch made in a rafter with an overhang so that the rafter will fit against a plate, as shown in **Figure 17-30**. The plumb cut for the bird's mouth, which bears against the side of the plate, is called the *heel cut*. The level cut, which bears on the top of the plate, is called the *seat cut*.

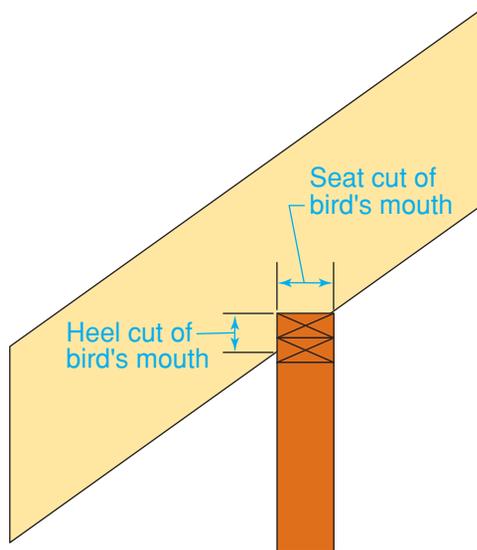


Figure 17-30 Bird's Mouth
A Notch for Bearing The bird's mouth on a rafter with an overhang.

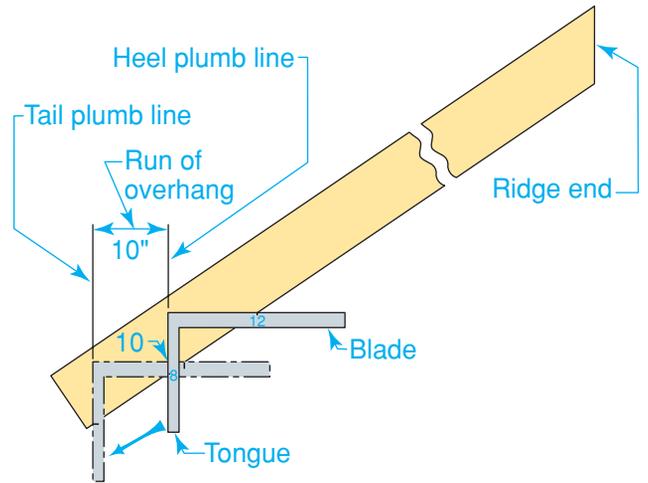


Figure 17-29 Overhang Using a Square
Step It Off Laying out the run of the overhang directly on the rafter using the framing square.

The size of the bird's mouth for a common rafter is usually stated in terms of the depth of the heel cut rather than the width of the seat cut. The bird's mouth is laid out much the same way as the seat cut for a rafter without an overhang. Measure off the depth of the heel on the heel plumb line, set the square, and draw the seat line along the blade as shown in **Figure 17-31**.

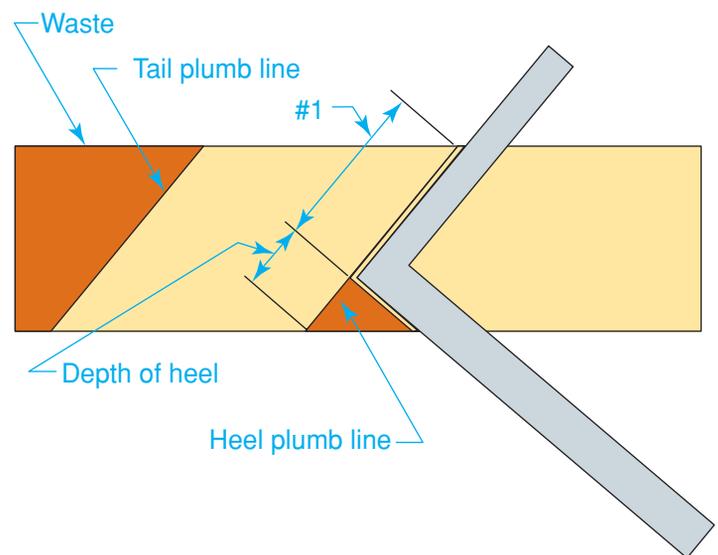


Figure 17-31 Bird's Mouth Layout
Layout of the Notch Using the square to lay out a bird's mouth. The line at arrow #1 is important when laying out the bird's mouth for a hip and valley rafter.

Cutting Rafters

When should a rafter have the ridge cut facing up?

To cut common rafters, the actual length of one rafter is laid out on a piece of stock. The crown of the rafter should be on the top edge. After the first rafter is cut, it is used as a pattern for cutting a second.

The two rafters are then tested on the building using the ridge board or a scrap piece of the same size material to see how the heel cut and the top cut fit. If they fit properly, one of these rafters can be used as a pattern to cut all the others needed.

Once cut, the rafters should be **distributed** to their locations along the building. The rafters are usually leaned against the building with the ridge cut up. The carpenters on the building can then pull them up as needed and fasten them in position.

In large developments, houses must be built quickly. Carpenters who use conventional roof framing methods instead of trusses, which are installed more quickly, must develop efficient work habits. One way in which they can speed their work without sacrificing quality is to gang-cut rafters. After the master rafter pattern has been established, many pieces of rafter stock are clamped together atop sawhorses. Lines are marked across the edges of the stock to indicate heel cuts, plumb cuts, and

bird's-mouth cuts. Then the cuts are made on a group of rafters at the same time, sometimes using special saws.

Gambrel, Shed, & Low-Slope Roof Framing

Why are gambrel roofs common on barns?

Other kinds of roofs can be framed using variations of the same basic techniques used to build a gable roof. These roofs include gambrel roofs, shed roofs, and flat, or low-slope, roofs.

Framing a Gambrel Roof

The framing for a gambrel roof combines primary and secondary rafters. The lower (primary) rafter has a steep pitch, and the upper (secondary) rafter has a low pitch. If the pitches are known, the rafters may be laid out in the same manner as any common rafter.

The roof may also be laid out full size on the subfloor, as shown in **Figure 17-32**. Use the run of the building (AB) as a radius and draw a semicircle. Draw a perpendicular line from point A to intersect the semicircle at E. This locates the ridge line. Find the height of the walls from the plans. Draw

Builder's Tip

CUTTING THE BIRD'S MOUTH Rafter cutting is usually done with a circular saw. It is important not to overcut when making the bird's mouth. This will weaken the rafter. It is best to stop the heel cut and the seat cut short of each intersecting layout line. In other words, make partial cuts. Then finish the cut with a handsaw or jigsaw.

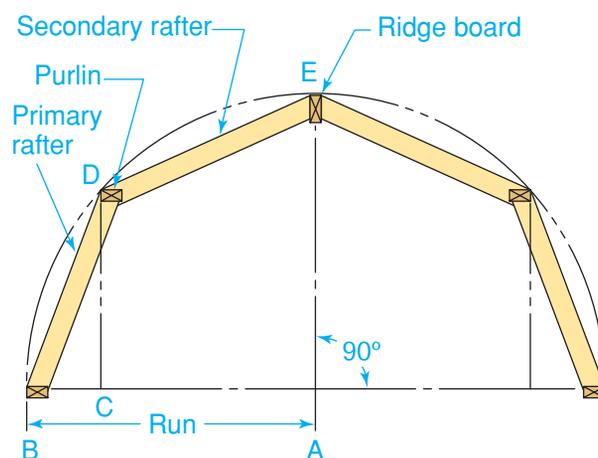


Figure 17-32 Gambrel Roof

Full-Size Layout The patterns for the rafters in the gambrel roof may be made by laying out the full-size roof on the subfloor.

a perpendicular line (CD) to this length between the plate and the semicircle. Connect points B and D and points D and E. This gives the location and pitch of primary rafter BD and secondary rafter DE. From this layout the rafter patterns can be made and cut for test fitting on the building.

Framing a Shed Roof

A shed roof is basically one-half of a gable roof. The full-length rafters in a shed roof are common rafters. The total rise is the difference in height between the walls on which the rafter will bear. The total run is equal to the span of the building minus the width of the top plate on the higher wall, as shown in **Figure 17-33**. The run of the overhang on the higher wall is measured from the inner edge of the top plate. With these exceptions, shed roof common rafters are laid out like gable roof common rafters. A shed roof common rafter has two bird's mouths. They are laid out just like the bird's mouth on a gable roof common rafter.



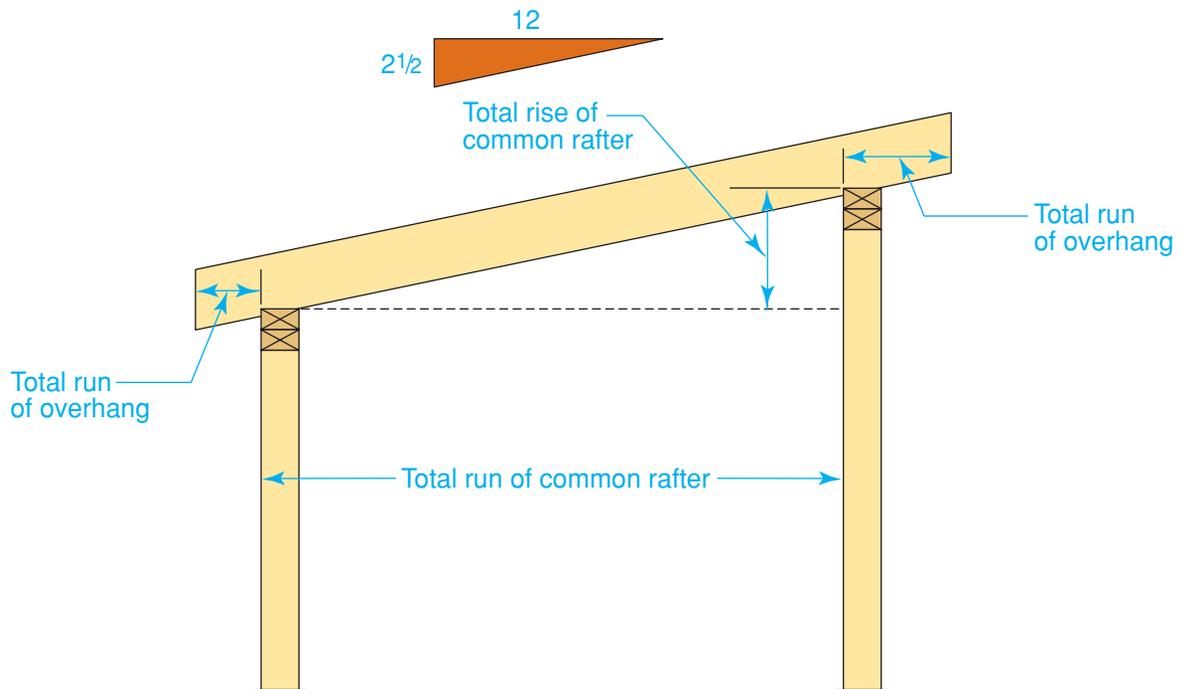
JOB SAFETY

NAILING SAFETY Nailing rafters into place is often done under conditions that increase the possibility of injury. Be sure you have solid footing when nailing. Keep your hands safely away from the action. This caution applies both to hand nailing and power nailing.

 Go to glencoe.com for this book's OLC for more on job safety.

Framing a Low-Slope Roof

A low-slope roof is any roof with a slope of $\frac{3}{12}$ or less. This includes flat roofs, which actually have a slight slope to encourage water to drain off. Low-slope roofs generally require larger rafters than roofs with steeper slopes, but the total amount of framing lumber is usually less because the rafters also serve as ceiling joists. Thus, their size is based on both



 **Figure 17-33 Shed Roof**
Single Slope A shed roof rafter is like a rafter on just one side of a gable roof, except that it has two bird's mouth cuts.

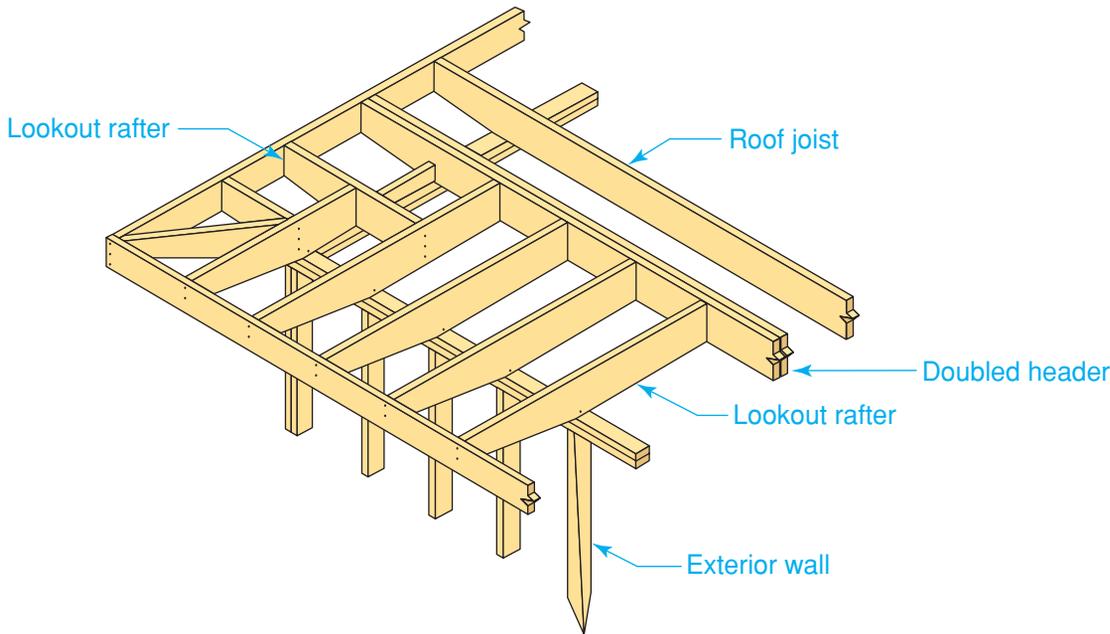


Figure 17-34 Low-Slope Roof
Almost Flat Construction of a low-pitched roof with an overhang.

roof and ceiling loads. The size is given on the plans or determined from rafter span tables.

When there is an overhang on all sides of the house, *lookout rafters* (sometimes called *outriggers*) are ordinarily used on two of the sides. Lookout rafters project beyond the walls of the house, usually at 90° to the common rafters, as shown in **Figure 17-34**. Where they run perpendicular to common rafters, they are nailed to a double header and toenailed to the wall plate. The distance from the double header to the wall line is usually twice the overhang. Rafter ends may be capped with a barge rafter, which will serve as a nailing surface for the fascia.

Using I-Joist Rafters

I-joists can be a good substitution for what?

Laminated-veneer lumber (LVL) can be used to build many portions of the house frame, including the roof. (For more on laminated-veneer lumber, see Chapter 13). It is also used in commercial wood framing. LVL I-joists can be used in place of lumber

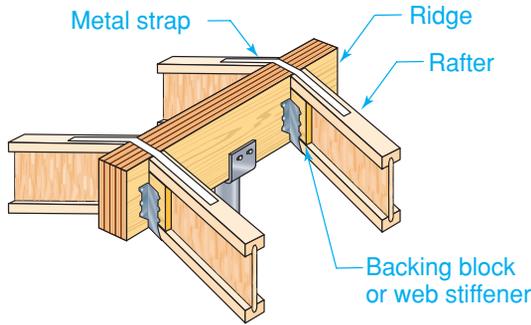
rafters. Various companies make I-joists and you must follow the manufacturer's instructions for the product you are using.

The details shown in **Figure 17-35** provide a general introduction to the subject of I-joist roof framing. Always follow manufacturer's installation instructions for installing these products. Be sure to check the building code for additional information.

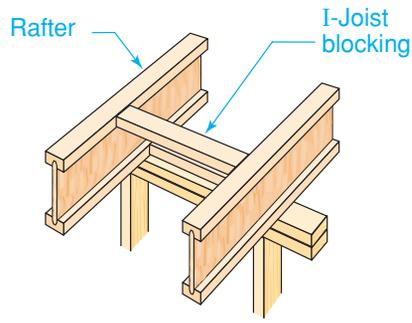
Builder's Tip

NAILING I-JOIST RAFTERS The flanges of I-joist rafters are made of LVL stock. Improperly nailing through this material seriously weakens it. The correct way to nail is shown here. The other methods will split the material.

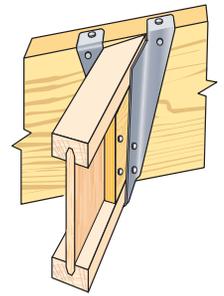
Correct



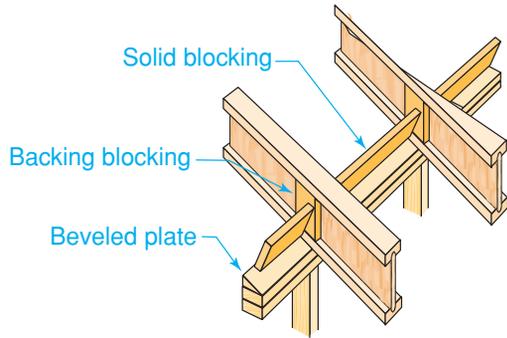
RAFTERS AT STRUCTURAL RIDGE BEAM



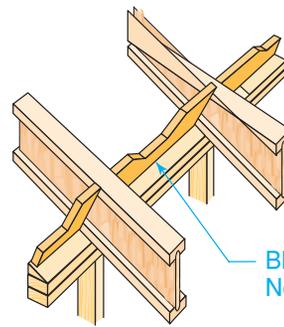
RAFTERS AT WALL PLATE



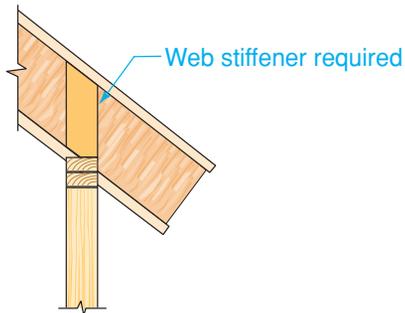
JACK RAFTER



BLOCKING

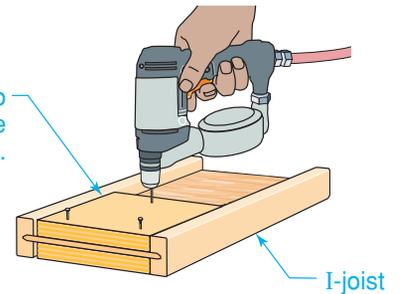


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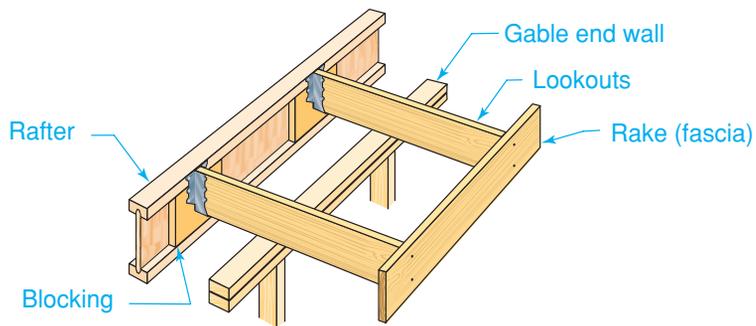


RAFTER OVERHANG

Stiffener: Attach to both sides with three 8d nails. Clinch points.



WEB STIFFENERS



RAKE

Figure 17-35 LVL Framing Details

Suggested Details These illustrations show various installation details for I-joist rafters. These are suggestions only. Always consult the manufacturer's instructions before installation.

 **After You Read: Self-Check**

1. What prevents rafters from spreading and pushing out on the exterior walls?
2. State the Pythagorean theorem.
3. Name the parts of a bird's mouth and tell where they bear.
4. When making cuts for a bird's mouth, what mistake should you avoid?

 **Academic Integration: English Language Arts**

5. **Writing Instructions** The theoretical length of a common rafter is the shortest distance between the outer edge of the plate and a point where the measuring line of the rafter meets the ridge line. There are four ways to find the theoretical length of a rafter: the Pythagorean theorem method, the unit-length method, the step-off method, or the calculator method. Write a set of instructions for an individual wishing to find the theoretical length of a rafter using the step-off method.

 Go to glencoe.com for this book's OLC to check your answers.

Section

17.3

Ceiling Framing

Ceiling Joists

How is the size of a ceiling joist determined?

Ceiling joists are the framing members that support ceiling loads. In the first story of a two-story house, the same framing serves as both ceiling and floor, as in **Figure 17-36**. In other words, if you stood downstairs and looked up, you would refer to it as the ceiling framing. However, if you stood upstairs and looked down, you'd call it the floor framing. The floor framing for the first story of a house is covered in Chapter 15, "Floor Framing."

The ceiling framing discussed in this chapter is directly related to the roof framing. It prevents walls from bowing outward by tying the lower ends of the rafters together. At the same time, it ties the walls of the house together and forms the floor of the attic.



Figure 17-36 Ceiling Framing

Two Roles Ceiling framing often supports a second floor.

Ceiling framing for the top level of a house usually proceeds at the same time as roof framing. While the rafters are being laid out and cut, other carpenters cut and install the ceiling joists. Like floor joists, ceiling joists may be supported by girders or by bearing walls.

Sizing Ceiling Joists

The size of the ceiling joists is determined by the distance they must span and the load they must carry, as shown in **Table 17-1**. The species and grade of wood must also be considered. The correct size for the joists will be found on the building plans. Spacing and span limitations must comply with local building codes.

Estimating

The methods for estimating the number of ceiling joists, as well as the material cost, are the same as for estimating floor joists. Refer to Chapter 15, "Floor Framing."

Layout

The layout for ceiling joists is determined as one lays out the rafters. Rafter spacing and placement are determined first. Ceiling joist spacing and placement are determined second.

Ceiling joists are usually placed across the width of the building and parallel to the rafters. The ends of the joists that rest on the exterior wall plates next to the rafters will usually project above the top edge of the rafter, as shown in **Figure 17-37**. If left untrimmed they would interfere with the installation of roof sheathing. These ends are

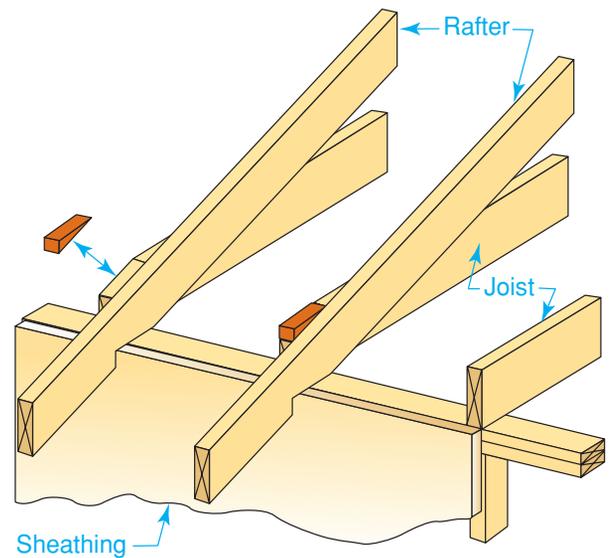


Figure 17-37 Trimming Joist Corners

Trim for Clearance The upper corners of the ceiling joists must be cut off at an angle to match the angle of the rafters.

cut off at an angle to match the angle of the rafters. The cuts should be about $\frac{1}{8}$ " below the rafter's top edge. This is best done before the joists are installed.



REGIONAL CONCERNS

Wind Uplift When houses are built in areas with high winds, extra precautions such as metal framing anchors should be taken to secure framing joints.

Go to glencoe.com for this book's OLC for more information about regional concerns.

Table 17-1: Allowable Spans for Ceiling Joists Using Non-Stress-Graded Lumber

Size of Ceiling Joists (inches)	Spacing of Ceiling Joists (inches)	Maximum Allowable Span (feet and inches)			
		Group I	Group II	Group III	Group IV
2×4	12	11-16	11-0	9-6	5-6
	16	10-6	10-0	8-6	5-0
2×6	12	18-0	16-6	15-6	12-6
	16	16-0	15-0	14-6	11-0
2×8	12	24-0	22-6	21-0	19-0
	16	21-6	20-6	19-0	16-6

Installation begins at one end of the house and continues to the other end. The spacing of the joists is usually 16" or 24" OC. Extra joists are placed, as needed, without altering the spacing. For example, a ceiling joist will be needed at the inside edge of the plate on an end wall. This provides an edge nailing surface for the ceiling finish as shown in **Figure 17-38**. An extra joist is sometimes located over the studs in a partition wall, as shown in Figure 15-30 on page 416. The distance between the first two joists at this location will then be less than the normal OC spacing but each succeeding joist is spaced 16" or 24" on center. The ends of all ceiling joists must have at least 1½" of bearing on a wood framed wall. They must have at least 3" of bearing on a masonry wall.

Lumber ceiling joists meet other ceiling joists at the center of the building. The joists are normally offset 1½" on the two outside walls so that they lap each other when they meet over the bearing partition wall, as shown in **Figure 17-39A**. Code requires that the joist lap be at least 3" long. This lap is

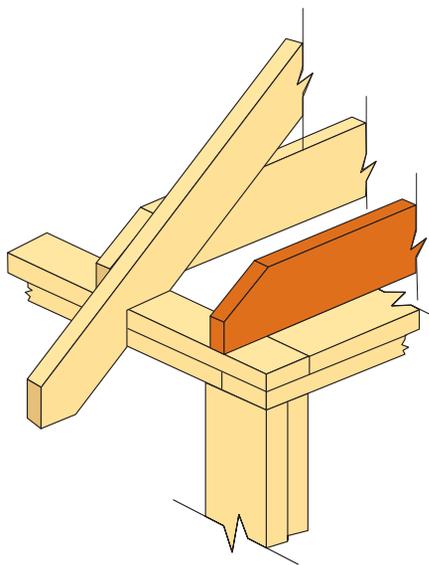


Figure 17-38 Adding a Ceiling Joist
Extra Joist A ceiling joist should be set on the inside edge of the end wall to permit nailing of the material for the ceiling surface.

face-nailed with three 10d nails. The joists are toenailed to the bearing wall plate with three 8d nails. In an alternate method, the end of the joists butt against each other over a bearing wall as shown in **Figure 17-39B**.

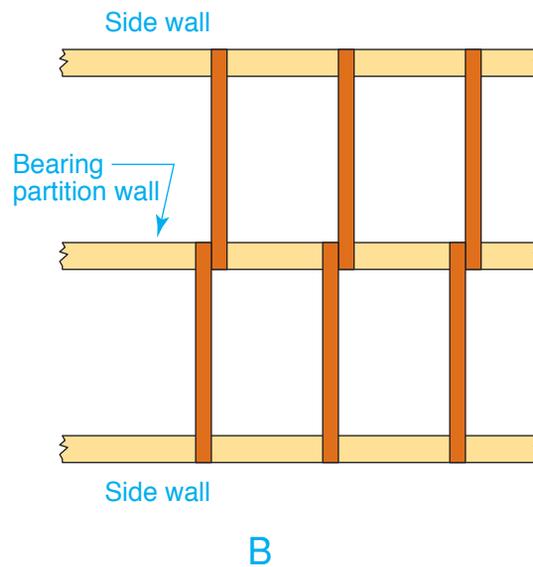
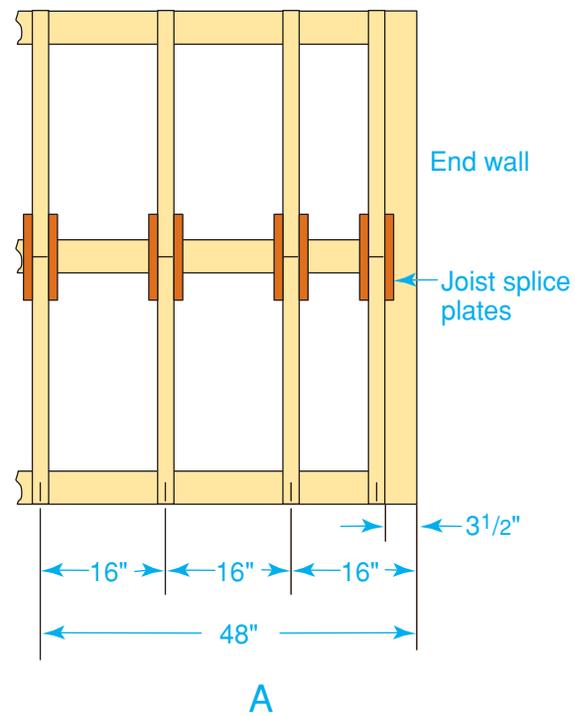


Figure 17-39 Ceiling Joist Spacing
Two Methods Ceiling joists are usually lapped at a bearing wall (**A**). However, it is also possible to have the joists meet in a butt joint as long as the joint is reinforced (**B**).

The ends that butt will have to be squared and cut off to length. Each joist end will be resting on just half of the wall plate. A wood or metal splice plate must be nailed securely to both sides of the joists to hold them together. Note that the distance between the first two pairs of joists is less than 16".

Nonbearing partitions that run parallel to the ceiling joists are nailed to blocks installed between the joists, as shown in **Figure 17-40**. Blocking or manufactured spacers can also be used in the middle of long spans to prevent the ceiling joists from twisting or bowing. Blocking can be removed if heating or air-conditioning ducts must run through the spaces between joists.

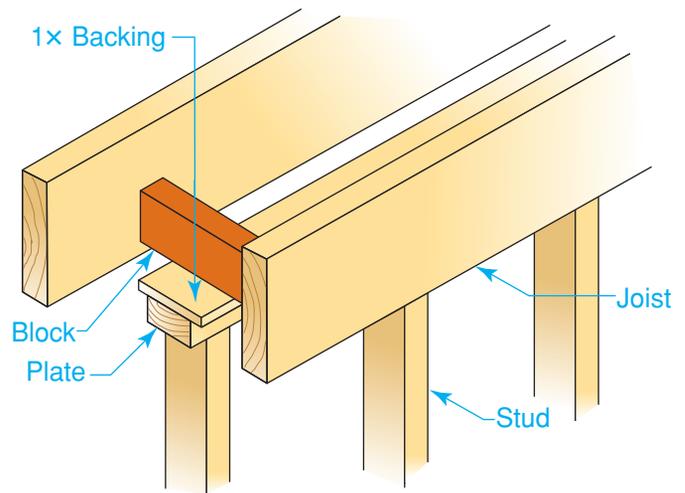
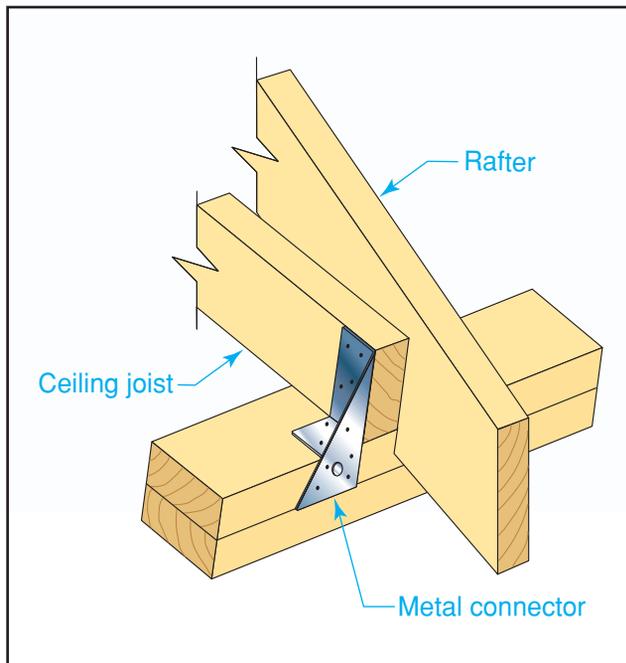


Figure 17-40 Blocking at a Nonbearing Wall
Important Details Notice the 1× backing that has been attached to the top of the wall for nailing the ceiling material.

Step-by-Step Application

Installing Ceiling Joists The locations for ceiling joists are laid out like the locations for floor joists (see Chapter 15, "Floor Framing," page 405). The spacing of the joists will be found on the building plans. Mark the plates for the correct spacing. Then install the joists as shown in the figure.



Step 1 Cut each joist to length. Sight down the edge of the joist to determine where the crown is. Trim off the corners that will extend above the rafters.

Step 2 Distribute the joists around the building so that they can be lifted into place.

Step 3 Place each joist with the crown up. Align the end of the ceiling joist with the outside edge of the exterior wall plate.

Step 4 At one end, toenail three 8d nails through the joist and into the plate or use a metal framing connector.

Step 5 Toenail the other end of the joist to a girder or bearing wall.

Step 6 Nail lapped joists to each other with three 10d nails.

Go to glencoe.com for this book's OLC for additional step-by-step procedures, applications, and certification practice.

Special Ceiling Framing

What does a flush girder do?

Ceiling framing must often accommodate interruptions in the regular spacing of joists. Before beginning layout and installation, the carpenter should check the plans to identify these special situations.

Hip Roofs

In the framing for a hip roof with a shallow slope, the first ceiling joist will interfere with the bottom edge of the rafters. *Stub joists* (short joists) installed at right angles to the regular joists will correct this situation, as shown in **Figure 17-41**. Space the stubs 16" OC for attaching the finished ceiling. Locate them so that the rafters, when installed, may be nailed directly to their sides.



Reading Check

Recall How are stub joists used in hip roofs?

Ceiling Openings

Openings in the ceiling may be required for a chimney or for **access** to the attic. These openings are often larger than the spacing between the joists and will require the cutting of one or more joists. Such joists must be supported and framed as described in the section titled Framing Large Openings in Chapter 15.

Building codes require that any framing, including ceiling framing, be kept at least 2" from the front and sides of masonry fireplaces, and at least 4" from the back.

Framing Flush Ceilings

In the past, homes usually had many small rooms. Today, however, homeowners often prefer larger and more open living spaces. A combined kitchen and family room is common, for example. To visually tie the rooms together, *flush ceilings* (the two

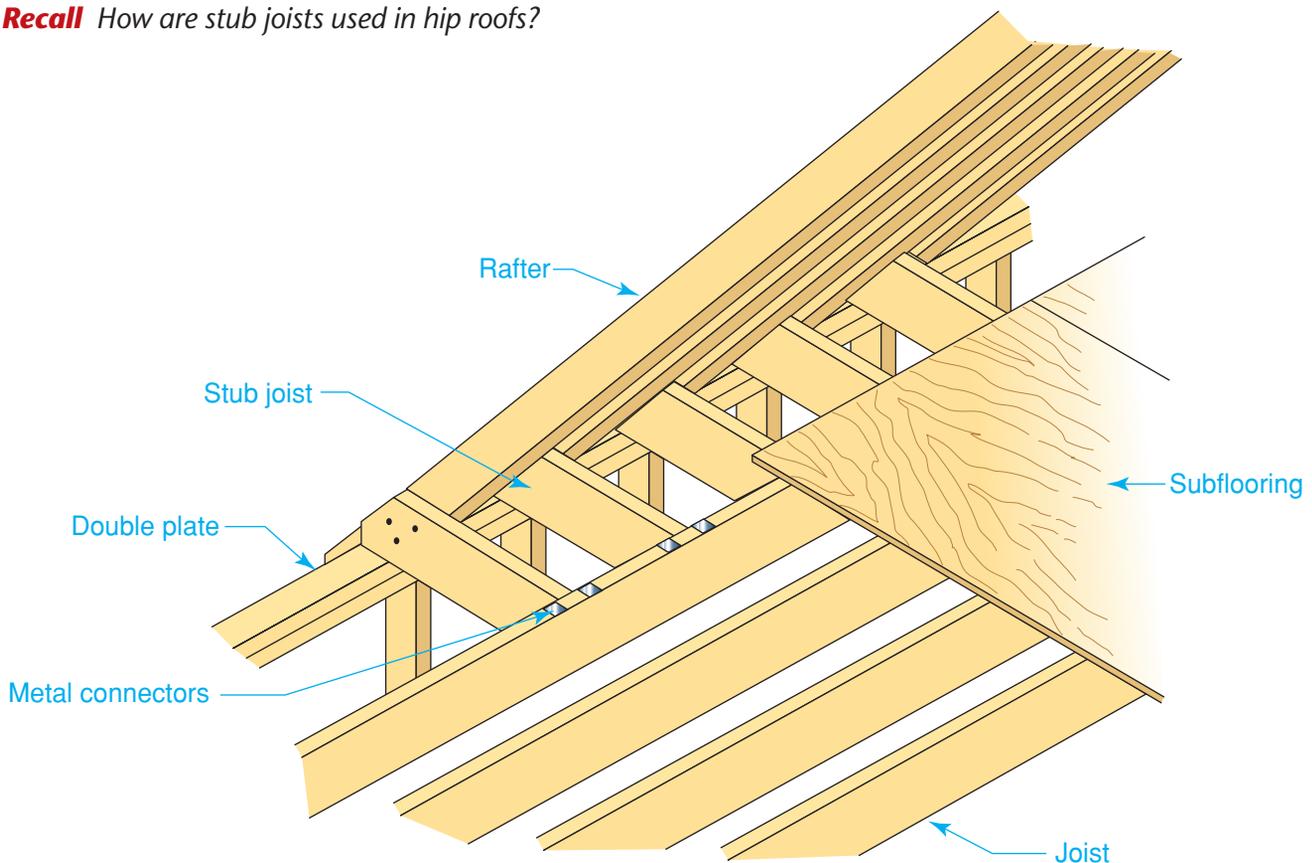


Figure 17-41 Stub Joists

Plan Ahead Stub joists are securely anchored to the regular joists with metal framing connectors.

ceilings flow together as one) are desirable. Because there is no partition, a girder is often needed to support the interior ends of the ceiling joists.

This support can be provided by a *flush girder*. A flush girder is usually built up from the same stock used to frame the rest of the ceiling. It can also be a glulam or LVL beam. Instead of resting on top of the girder, ceiling joists are fastened to the side with joist hangers as shown in **Figure 17-42**. Joist hangers are nailed to the girder with 10d or larger nails and to the joist with joist hanger nails. It is

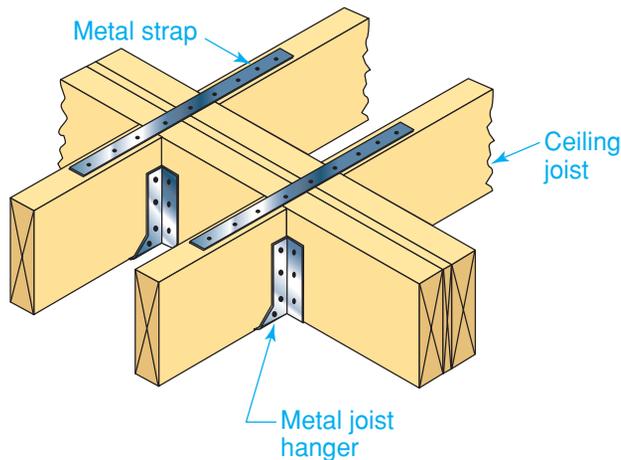


Figure 17-42 A Flush Girder
Flush Gains Headroom Ceiling joists are fastened to a flush girder with joist hangers. The joints can be reinforced with metal straps.

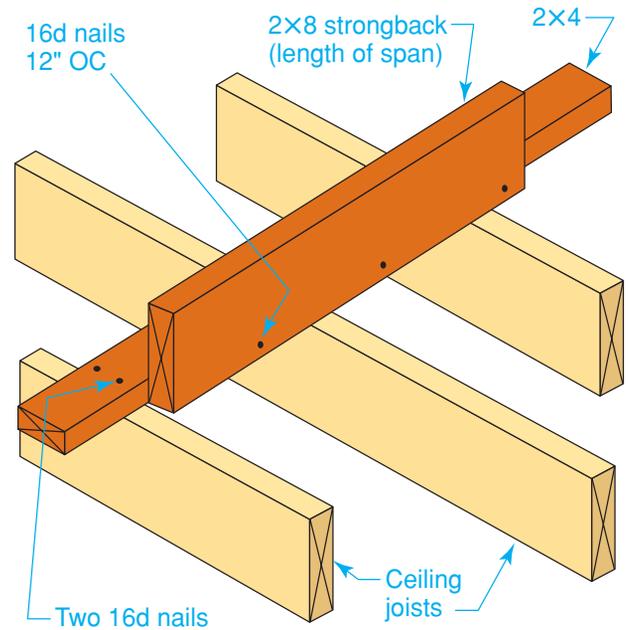


Figure 17-43 A Strongback
Hidden Strength A strongback is used to give long joists additional support.

often easiest to fasten the hangers to the ends of the joists before raising the joists into place.

Another approach that can sometimes be used with shorter spans is to stiffen the ceiling joists with a member called a *strongback*. A strongback, shown in **Figure 17-43**, should be nailed to the tops of the ceiling joists. However, this method will not eliminate the need for some kind of header.

Section 17.3 Assessment

After You Read: Self-Check

1. What factors determine the size of ceiling joists?
2. How are ceiling joists arranged in relation to the building and rafters?
3. How much space must be left between ceiling joists and the front and sides of a masonry chimney?
4. How are joists attached to a flush girder?

Academic Integration: English Language Arts

5. **Flush Ceilings** Flush ceilings are often used to visually tie two rooms in a home together. In this case, a girder is often needed to support the interior ends of the ceiling joists. Write a paragraph describing what a flush girder is constructed from and how it is installed.

Go to glencoe.com for this book's OLC to check your answers.

Roof Trusses

Roof Truss Basics

What are the chord and the web?

A roof truss is an assembly of members forming a rigid framework of triangular shapes. It can support loads over long spans. Many residential and commercial buildings are framed with roof trusses. Trusses are made in factories and delivered to the job site by truck. One advantage of using trusses is that they save money on materials and on-site labor. Materials may cost about 30 percent less than those used for traditional roof framing because they utilize smaller dimension lumber.

The basic parts of a roof truss are shown in **Figure 17-44**. A **chord** is the top or bottom outer member of the truss. The **web** is the framework between the chords. It creates a rigid assembly. Chords and webs are often connected at the joints by rectangular connector plates. A *connector plate* is a pre-punched metal plate with many teeth. It is pressed into the wood under hydraulic

pressure. Most trusses are built from 2×4 stock. They may also be built of other materials or combinations of materials, including metal and timber.

Trusses can be erected quickly. They are usually designed to span from one exterior wall to the other with lengths of 20' to 32' or more. They are usually concealed by interior finish materials but can be left exposed. Because no interior bearing walls are required, interior design can be more flexible. Partitions can be placed without regard to structural requirements.

Types of Roof Trusses

Though the overall shape of most common trusses is triangular, trusses come in a wide variety of shapes to solve nearly any problem. Span and load requirements (for snow, wind, etc.) govern the type of truss to be used. King-post, Fink, and scissors trusses are most commonly used for houses and are shown in **Figure 17-45**. These and similar trusses are most adaptable to

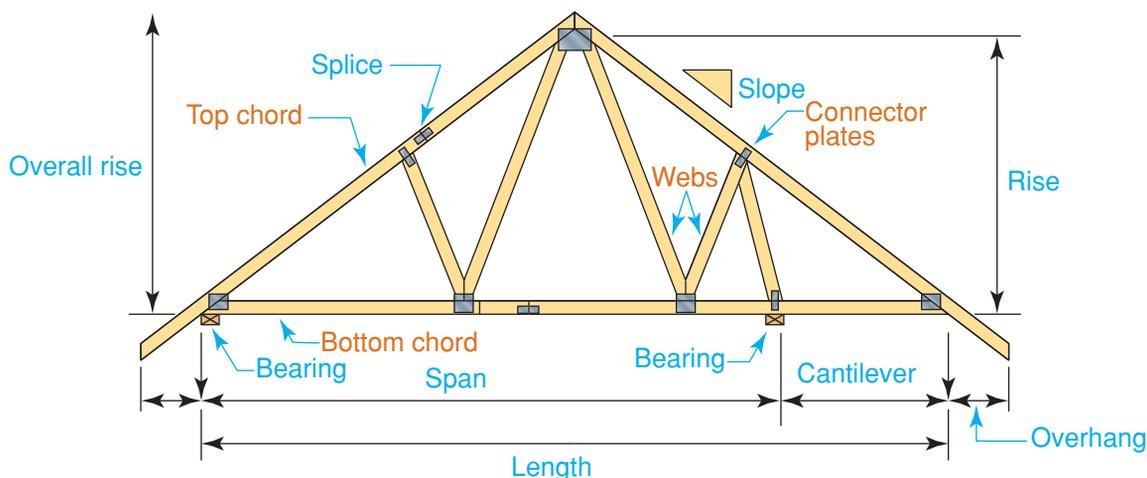


Figure 17-44 Parts of a Roof Truss

Three Elements The main parts of a truss are the chords, webs, and connector plates (also known as gusset plates).

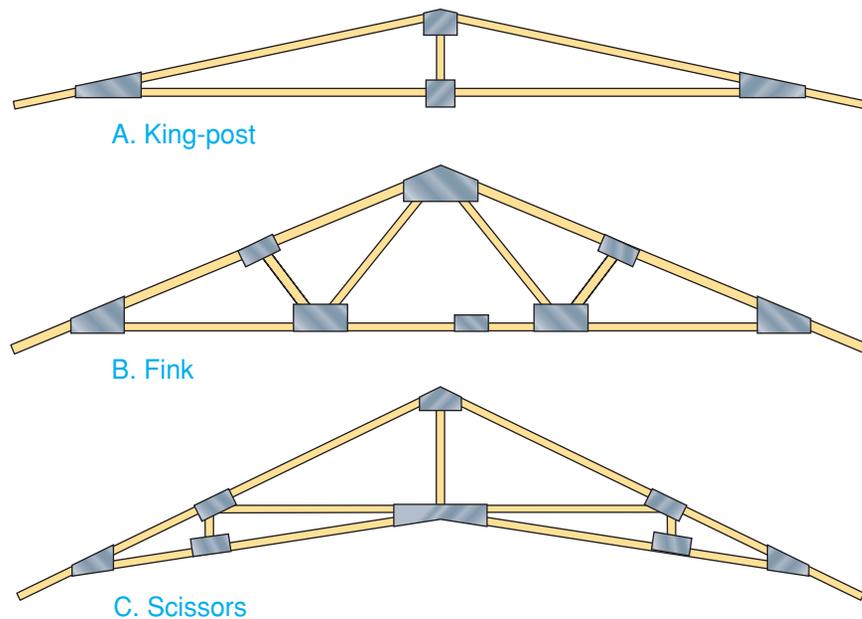


Figure 17-45 Three Basic Trusses
The Big Three These trusses are the ones most often used in residential roof framing.

rectangular houses because the uniform width requires only one type of truss. However, trusses can also be used for L-shaped houses. For hip roofs, hip trusses can be provided for each hip and valley area.

King-Post Truss The *king-post truss* has upper and bottom chords and a single vertical post in the center, as in Figure 17-45A. This vertical post is sometimes called a strut. It is the simplest form of truss used for houses. For short and medium spans, the king-post truss is probably more economical than other types. It has fewer pieces and can be fabricated faster. However, because so much of the upper chord is unsupported, allowable spans are somewhat shorter than for the Fink truss when the same size members are used.

Fink Truss The *Fink truss*, also called a *W-truss*, uses three more supporting members than the king-post truss. Distances between connections are shorter, as shown in Figure 17-45B. This usually allows the use of lower grade lumber and somewhat longer spans for the same member size. It is perhaps the most popular and most widely used of the light-wood trusses.

Scissors Truss The *scissors truss* features sloped top and bottom chords, as shown in Figure 17-45C. It is more complicated than the Fink truss. It is used for houses having cathedral ceilings, where it provides a savings in materials over conventional framing.

Truss Design

The design of a truss depends not only on the loads it must carry but also on the weight and slope of the roof itself. Generally, the flatter the slope, the greater the stresses. Therefore, flatter roofs require trusses with larger members and stronger connections.

Many lumber dealers can provide the builder with completed trusses ready for installation. Often, the builder orders trusses directly from a truss manufacturer. To order a series of trusses, the builder must supply a precise description of what is needed. Much of the information is on the set of building plans. Ordering information includes the following:

- **Nominal span** Generally, the nominal span is the length of the bottom chord.
- **Overhang length** The overhang length is the horizontal distance from the end of

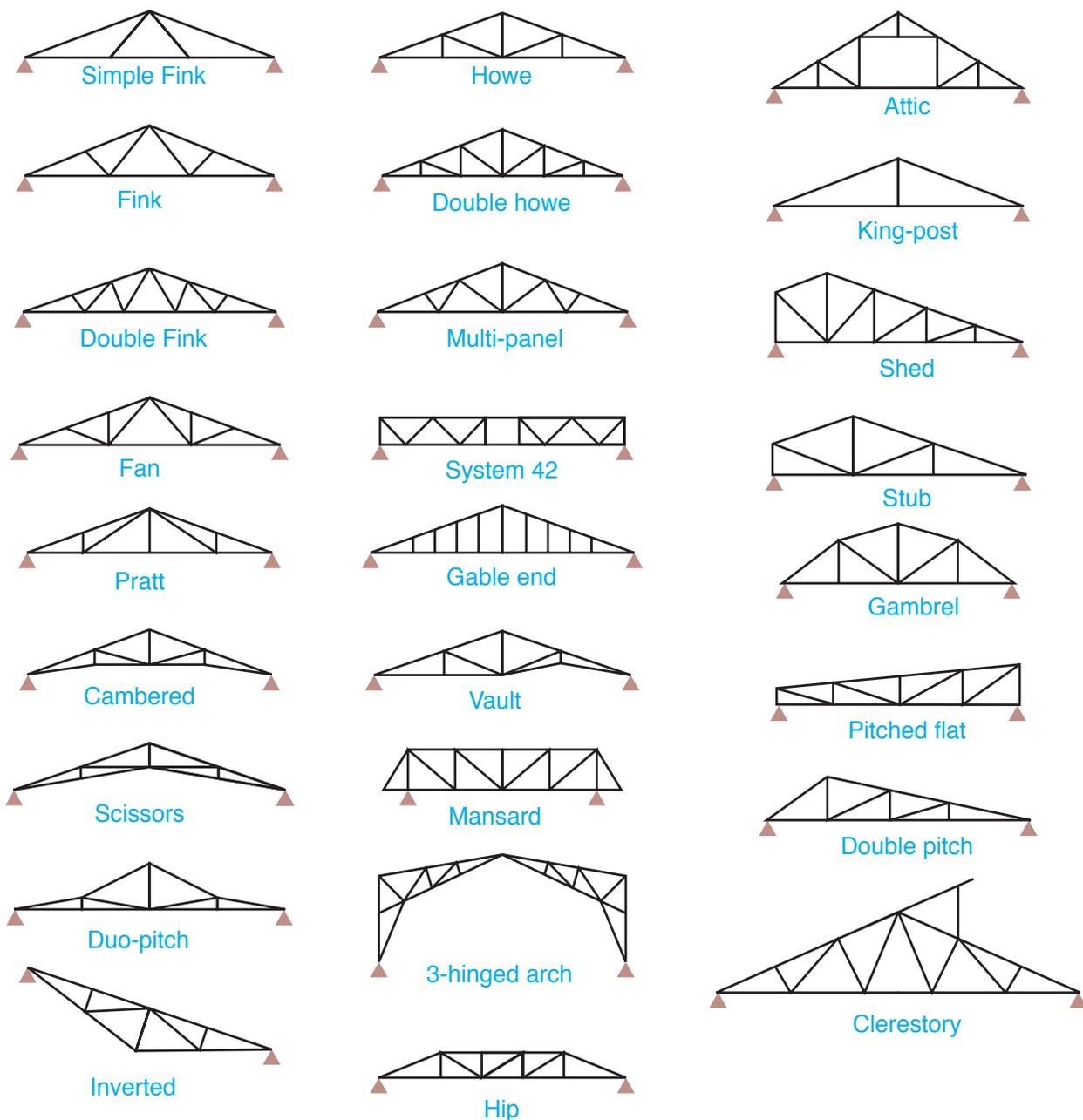


Figure 17-46 Types of Trusses

Many Shapes Some of the many types of roof trusses. The solid triangles indicate bearing points.

- the bottom chord to the bottom edge of the rafter (extension of the top chord).
- **End cut of rafter** Will the ends be plumb cut, square cut, or untrimmed?
- **Roof pitch** State the vertical unit rise per 12" of run. Strictly speaking, this is the roof's slope, but the term *pitch* is often used instead.
- **Type of truss** See Figure 17-46 for different types of trusses.
- **Quantity** The number of trusses required, including gable-end trusses, must be specified.
- **Design parameters** These would include information about the expected loads, particularly anything unusual, such as very heavy snow.



◀ **Figure 17-47 Roof Trusses**
An Open Floorplan Because these trusses would be exposed to the living space, the truss builder took extra care to make them visually appealing.

- **Special requirements** These include anything unusual about the use of the truss, such as the need for it to cantilever past a wall.

When the trusses have been designed, drawings made by the manufacturer must be approved by local building officials. These drawings are then made a part of the approved set of building plans.

Machine Stress-Rated Lumber *Stress-rated lumber* is structural lumber that has been graded electronically and stamped to indicate the specific load it will support. Because the grading is done with a machine, lumber rated in this way is called machine stress-rated lumber (MSR). When strength properties are critical, an architect or engineer may **specify** machine stress-rated lumber of a certain species and grade. Manufacturers of roof trusses often use MSR lumber since trusses are so important to the strength of the house.

Sheathing Requirements Trusses are commonly designed for 24" OC spacing. This spacing requires thicker interior and exterior

sheathing or finish material than is needed for conventional 16" OC rafter spacing. The interior trusses in **Figure 17-47** have been left exposed.

Costs A manufacturer delivers trusses to the job site and sets them on the rafter plate with a crane. They are then ready for workers to tip them into place for less than the cost of the material alone in conventional framing. To estimate exact costs, the truss fabricator reviews the building plans. When a bid is provided, the builder should know exactly what it covers. For example, is setting the trusses in place on the house included in the cost?

Installing Trusses

What weather conditions might make it unsafe to install trusses?

When handling and storing trusses, avoid placing unusual stresses on them. They are designed to carry roof loads in a vertical position. For this reason, they must be lifted and stored upright. However, it is important

to prevent them from tipping and possibly injuring nearby workers. If they must be handled or stored in a flat position, they should be supported along their length to lessen bending. Never support the trusses only at the center or only at each end when they are in a flat position.

If the trusses will be stored outdoors before being installed, they should be supported above the ground to protect them from dampness or water. A tarp should cover them to prevent rain damage. The bands around bundles of trusses should not be cut or removed until just before the trusses are ready to be erected. Because every part of the truss has been specifically designed for a particular job, a truss must never be cut or altered.

Raising Trusses

Completed trusses can be raised into place by hand or by crane. The truss fabricator may bring a truck-mounted crane when delivering the trusses. Because a large truss can be heavy and awkward to handle, a crane is the preferred method. However, take great care to secure the truss properly as the crane is lifting it. A guide rope must be attached so that a worker on the ground can keep the truss from swinging out of control. For more on rigging techniques, see the **Ready Reference Appendix**.

When cranes and other equipment are used to lift heavy loads such as trusses, the operator often relies on someone on the

ground to help place the load in the right spot. Because voices cannot be heard over loud engine sounds and other noises, hand signals are often used to communicate. For example, a raised thumb is the signal for raising the load, and a closed fist is the signal to stop. For more on hand signals, see the **Ready Reference Appendix**.

When raising small trusses by hand, care is needed to avoid damage to the trusses and accidental injury to workers. One by one, the trusses should be laid across the building and swung up into place by two or more workers. Another worker should be at the roof level to brace the trusses as soon as they are tipped into place.

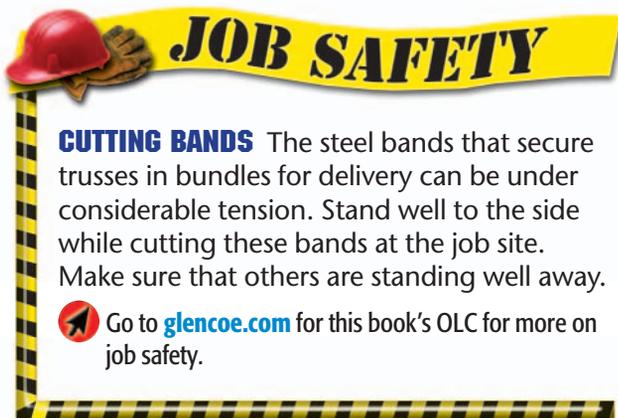
Bracing Trusses

Trusses must be braced temporarily as they are being installed. This helps to maintain precise spacing during installation. Bracing is also important for safety because it prevents trusses from tipping like dominoes. The manufacturer's drawings will accompany the trusses when they are delivered to the job site. These drawings should be studied for information about proper bracing.

Permanent bracing may also be required. This type of bracing stiffens the entire roof assembly and is meant to be left in place after the structure is complete.

Temporary Bracing The gable-end truss is the first truss on the building and the most important to brace. It should be braced with lumber standoffs anchored to stakes driven into the ground, as shown in **Figure 17-48**.

As each additional truss is put into place, it is braced temporarily to the adjacent trusses with a length of nominal 2" lumber. The lumber is secured diagonally to the top chord with two 16d nails at every intersection, as shown in **Figure 17-49**. Such diagonal bracing is sometimes called sway bracing or cross bracing. Lateral bracing may also be required. Finally, a second gable-end truss is placed at the other end of the building. Top-chord bracing can be removed as the roof sheathing is installed.



CUTTING BANDS The steel bands that secure trusses in bundles for delivery can be under considerable tension. Stand well to the side while cutting these bands at the job site. Make sure that others are standing well away.

Go to glencoe.com for this book's OLC for more on job safety.

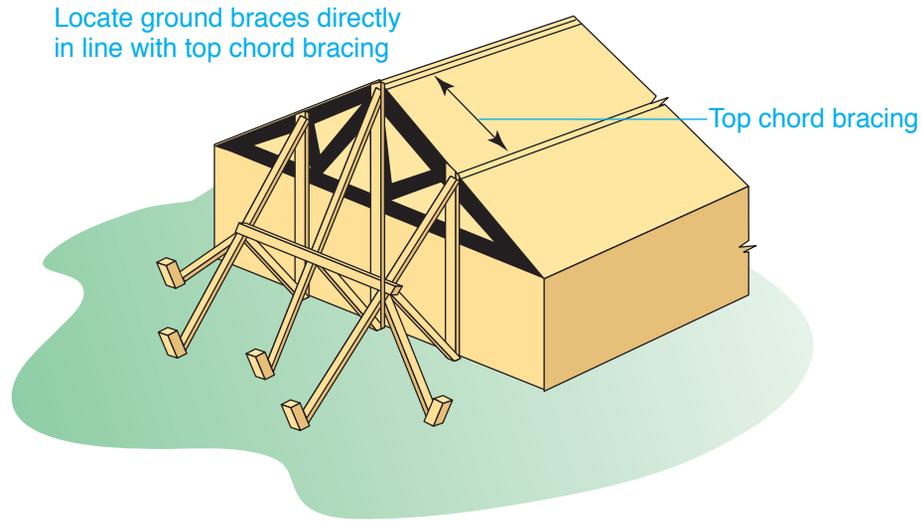


Figure 17-48 Ground Bracing

Bracing for Safety The gable-end truss should be securely braced. This method is sometimes called ground bracing.

Permanent Bracing There are several types of bracing that are designed to remain in place once installed. Permanent lateral metal bracing ties the individual trusses into a rigid structural system. It also ensures precise spacing. However, it does not eliminate the need for temporary gable-end and diagonal bracing with nominal 2" lumber. See **Figure 17-50** on page 498.

Permanent continuous lateral bracing consists of 2×4 or wider stock that is nailed to the web or to the bottom chord of each

truss. The exact location of the lateral bracing is usually specified in the truss design.

On trusses with long spans, permanent bracing prevents the bottom chords from moving as the ceiling finish is applied. Nominal 2" lumber is nailed to the top edge of the bottom chord and runs the length of the building. After the permanent bracing is in place, the roof should be sheathed as soon as possible. Roof sheathing prevent trusses from collapsing sideways and strengthens the entire roof system.

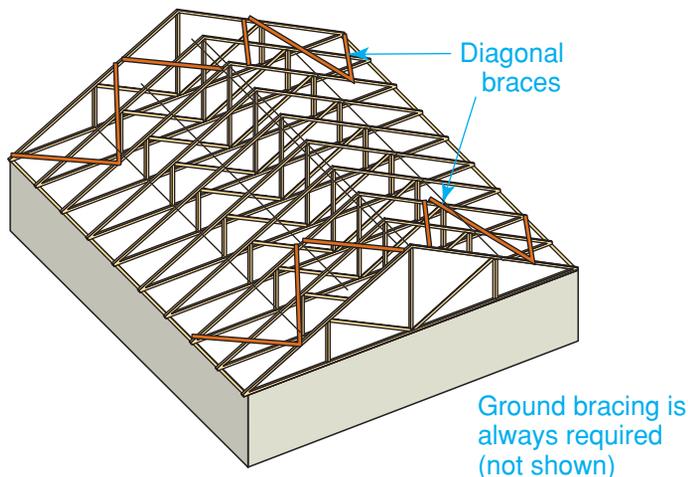


Figure 17-49 Diagonal Bracing

Diagonal Ties Diagonal bracing helps to prevent the trusses from shifting until the roof sheathing can be applied.



Figure 17-50 Truss Bracing
Double Duty Prefabricated metal spacers help to brace trusses and ensure exact spacing.

Fastening Trusses

Trusses are fastened to the outside walls with nails or metal framing anchors. Resistance to wind uplift stresses and thrust must be considered. A ring-shank nail provides a simple connection that resists modest uplift. Toenailing is also sometimes done, but this is not always satisfactory because metal truss plates are located at the wall plate and make toenailing difficult.

A better system uses a metal bracket, such as the one in **Figure 17-51**. These brackets are available commercially in a variety of shapes. They are nailed to the top and sides of the wall plate and to the bottom chord of the truss. They provide superior resistance against wind uplift and may be required by building codes.

Truss Layout The location of each roof truss is marked on the top plate, in the same way as standard rafters (see Section 19.2, Roof Assembly). Unlike rafter framing, however, there is no need to incorporate ceiling framing. This is because the bottom chord of the truss serves as the ceiling framing. As

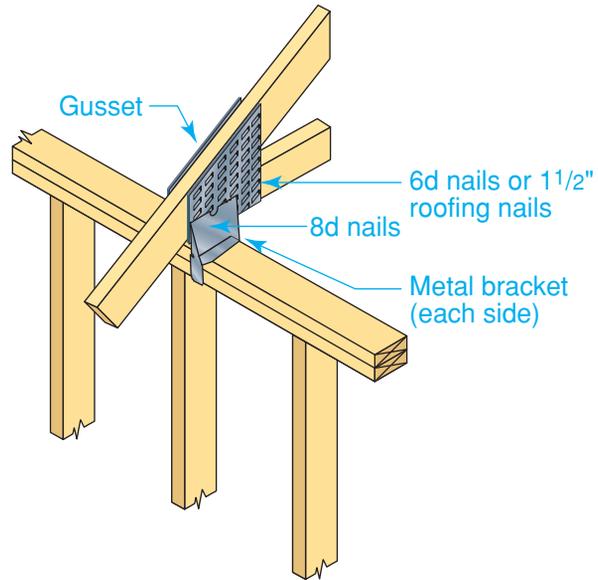


Figure 17-51 Securing a Truss
Secure Connection Fastening trusses to the wall plate using metal brackets.

you mark the plates, be sure to double check the overall layout as you work.

Interior Partitions

Sometimes partitions run parallel to and between the bottom truss chords. When these partitions are erected before the ceiling finish is applied, install 2×4 blocking between the bottom chords of the truss. This blocking should be spaced not more than 4' OC. To provide nailing for lath or drywall, nail a 1×6 or 2×6 continuous backer to the blocking.

When these partitions are erected after the ceiling finish is applied, 2×4 blocking is placed with its bottom edge level with the bottom of the truss chords. The blocking is fastened with two 16d nails in each end.

Metal brackets, called *clips*, should also be used to align and fasten the bottom chord of a truss where it passes over nonbearing partitions. These clips, shown in **Figure 17-52**, prevent the chords from moving from side to side. They also allow the bottom chord to flex upward slightly when the truss is loaded. This is important in order to prevent the walls from interfering with truss movement.

Problems with Framing

Unlike conventional framing, roof trusses are manufactured to precise tolerances before being delivered to the job site. For this reason, carpenters must take extra care when framing a house with a trussed roof. The trusses cannot be altered to make up for minor errors in framing.

If an interior partition wall is too high, it will prevent trusses from seating properly. A similar problem occurs when the top plate of one or more of the partition walls

is not level. These problems might also put dangerous stresses on the bottom chord of the truss, which could cause the truss to fail. The stresses could also cause interior wall finishes to crack later.

Wall framing problems are sometimes caused by errors in reading the plans, or by mistakes made in measuring or assembly. These problems are fairly easy to correct. However, problems caused by a poorly constructed foundation or an unlevel floor system are much more troublesome.

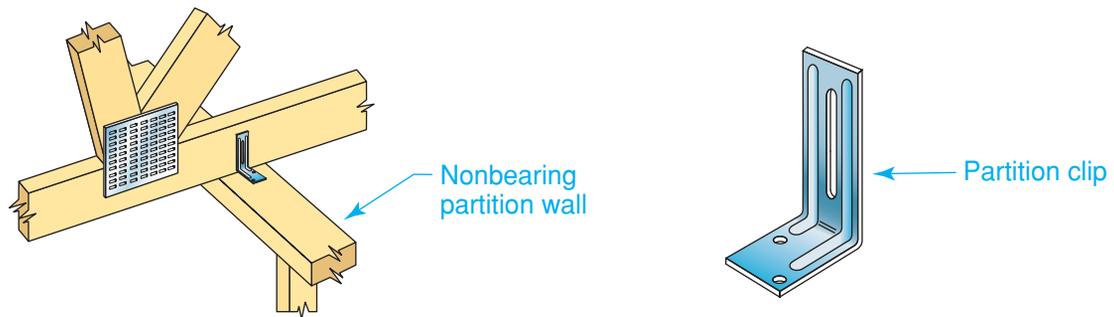


Figure 17-52 Partition Clip
Simple Stabilizer Leave a $\frac{1}{16}$ " gap between the nailheads and the clip to help prevent squeaking.

Section 17.4 Assessment

After You Read: Self-Check

1. What precautions should be taken when handling and storing roof trusses?
2. What two methods can be used to raise roof trusses into place, and which one is preferable?
3. What is the first thing that should be done when a truss has been raised into place?
4. What is the procedure for temporary bracing of roof trusses?

Academic Integration: Science

5. **Truss Safety** Trusses provide a strong and efficient way to frame a roof. However, many accidents have occurred due to improper installation and bracing. Review the latest safety guidelines provided by OSHA regarding roof truss installation. In addition, locate at least one manufacturer of metal truss braces for further safety guidance. Prepare a three-minute presentation in which you discuss common mistakes that lead to improper installation, how to avoid these mistakes, and how to work safely with trusses.

Go to glencoe.com for this book's OLC to check your answers.

Review and Assessment

Section

17.1

Chapter Summary

Planning a roof calls for an understanding of architectural styles as well as an understanding of how the individual pieces are assembled. A roof plan must be developed before any framing can begin.

Section

17.2

There are four basic methods for laying out the cuts required for a common rafter. They include the Pythagorean theorem method, the unit-length method, the step-off method, and the calculator method.

Section

17.3

Ceiling framing is much like floor framing. However, it is often considered to be a part of roof framing.

Section

17.4

Roof trusses are strong, efficient, and cost less than traditional framing. Common truss shapes include the king-post, the Fink (W-truss), and the scissors. The design of a truss depends on the loads it must carry and the weight and slope of the roof. Each truss should be solidly braced immediately after being lifted into place.

Review Content Vocabulary and Academic Vocabulary

- Use each of these content vocabulary and academic vocabulary words in a sentence or diagram.

Content Vocabulary

- rafter (p. 467)
- ridge board (p. 468)
- span (p. 470)
- total run (p. 470)
- unit run (p. 470)
- total rise (p. 470)
- unit rise (p. 470)
- slope (p. 470)

Academic Vocabulary

- benefit (p. 481)
- distributed (p. 482)
- access (p. 490)
- specify (p. 495)

Speak Like a Pro

Technical Terms

- Work with a classmate to define the following terms used in the chapter: *dormers* (p. 467), *low-slope roof* (p. 467), *lean-to roof* (p. 467), *collar tie* (p. 468), *eaves* (p. 468), *overhangs* (p. 468), *hip jack rafters* (p. 468), *valley jack rafters* (p. 468), *cripple jack rafters* (p. 468), *unit of run* (p. 470), *measuring line* (p. 470), *plumb line* (p. 471), *level line* (p. 471), *theoretical length* (p. 475), *bird's mouth* (p. 481), *outriggers* (p. 484), *stub joists* (p. 490), *flush girder* (p. 491), *strongback* (p. 491), *king-post truss* (p. 493), *fink truss* (p. 493), *W-truss* (p. 493), *scissors truss* (p. 493).

Review Key Concepts

- Name the four basic roof types.
- Recall common terms used in roof-framing carpentry.
- Use one of the four basic methods to lay out a common rafter.
- Explain how ceiling joists are laid out.
- Identify the three basic parts of a roof truss.
- Describe how roof trusses are installed.

Critical Thinking

9. **Compare** What is the difference between common rafters and hip rafters?

Academic and Workplace Applications

STEM Mathematics

10. **Fractions and Decimals** Small, easy-to-use construction calculators are now common on job sites. Measurements can be entered into the calculator in feet and inches, including fractions. Use a construction calculator to make the following calculation: Add $14'-6\frac{3}{8}"$ to $23'-9\frac{1}{16}"$.

Math Concept Fractional measurements have decimal equivalents. For example, $\frac{1}{16}" = 0.0625$; $\frac{1}{8}" = 0.125$; $\frac{3}{16}" = 0.1875$

Step 1: Input the following: 14 [feet] 6 [Inch] 3 [/] 8 [+] 23 [Feet] 9 [Inch] 11 [/] 16 [=]

Step 2: Use the correct keys to convert to decimal feet, then to decimal inches, then to fractional inches.

STEM Science

11. **Fungi** Certain precautions must be taken in order to prevent damage to lumber products such as trusses. If the trusses will be stored outdoors before being installed, they should be supported above the ground to protect them from dampness or water that can cause the wood to rot. Fungi are a direct cause of wood rot. Find out more about wood rot caused by fungi and summarize your findings in a one-page report. State what fungi are and how they interact with their environment to cause wood rot.

21st Century Skills

12. **Critical Thinking: Research Regional Styles** Find out more about roof styles such as gable, hip, flat, and shed roofing. List the purposes of each type and classify them according to the regions of the country for which they are appropriate. Observe

residential homes in your area and become expert at identifying roofing styles. Assess the neighborhood you live in and determine which roofing styles have been used. Write a paragraph stating which types you have observed and state why these types have been chosen for this region.

Standardized TEST Practice



Multiple Choice

Directions Choose the phrase that best completes the following statements.

13. The angle at which the hip extends from each corner is usually _____.
a. 30° b. 90° c. 45° d. 180°
14. To obtain the actual length of a rafter it is necessary to _____.
a. add one-half the actual thickness of the ridge board from the theoretical length
b. subtract one-half the actual thickness of the ridge board from the theoretical length
c. subtract one-quarter of the actual thickness of the ridge board from the theoretical length
d. add one-quarter of the actual thickness of the ridge board from the theoretical length
15. On trusses with long spans, _____ prevents the bottom chords from moving as the ceiling finish is applied.
a. temporary bracing
b. ceiling joists
c. permanent bracing
d. sheathing

TEST-TAKING TIP

When you first get a test, look at the total number of questions and sections before answering any questions. Once you have scanned the test, estimate what pace you should maintain in order to finish the test in the time allotted.

*These questions will help you practice for national certification assessment.