Framing a Bay Window With Irregular Hips

How one carpenter calculates the tough cuts

by Don Dunkley

My crew and I frame houses in central California, near Sacramento, where designers compete with one another to see who can create the most complicated roofs. To stay in business, the local carpenters have to be adept at framing every type of roof—hip, gable, octagon, cone—sometimes all in the same building.

One modest and enduring feature that turns up in many of these homes is the bay window popout. The kind we build most frequently, and the subject of this article, consists of two 45° corners and a projection, or offset, of 2 ft. (floor plan, p. 80). It is 10 ft. wide at the wall line and 6 ft. wide at the front of the offset. The plate height of the bay and of the adjoining room are 8 ft. 1 in., and the roof pitch is 8-in-12.

A hip roof commonly tops this kind of a bay. But unlike many of the hip-roof bays that get built locally, we frame ours with two irregular hips (photo above right). More often than not I run across roof plans that leave out a second irregular hip. Without it, the plane of the roof has to be warped to intersect the valley (photo above left). Once you become aware of this refinement, chances are you'll spot many an example of incorrectly framed bays on a casual drive down a residential street. Adding the second irregular hip allows the roof planes to meet at crisp angles.

Building a roof with one pair of irregular hips is a challenge—add another pair and it's a task for a journeyman carpenter. When I first started out as a framing carpenter, I spent a lot of time laying out the rafter locations on the subfloor, then transferred them by way of plumb bobs and stringlines to temporary staging, where another session with stringlines and tape measures would follow as I puzzled out seat cuts and cheek cuts. No more. I've incorporated two tools into my roof-cutting procedures that do away with all the plodding.

The first is a Construction Master Dimensional Calculator (Calculated Industries, Inc., 22720 Savi Ranch Pkwy., Yorba Linda, Calif. 92686). This calculator works in decimal numbers and in feet and inches. It also has pitch, rise, run, diagonal and hip/valley functions, which eliminate some of the key strokes required to apply standard calculators to carpentry work. For instance, instead of using a square-root formula to find a diagonal, I enter 11 ft. as rise, 14 ft. as run, punch the diagonal button, and the calculator will read 17.8044. When I punch the convert-to-feet-and-inches button, it tells me 17 ft. 9⅝ in.

The second tool is a book called *Roof Framing,* by Marshall Gross (Craftsman Book Company, P. O. Box 6500, Carlsbad, Calif., 92008). Gross uses a technique to lay out roofs that he calls the "height above plate" method (HAP). Simply stated, the HAP system allows me to set the ridges first at their actual height. Then I bring the rafters to meet them. I've found this system to be unbeatable for assembling complex roofs. But before we dive into HAP and bay window/roof theory and calcs, let's look at layout and walls.

Leaving the second irregular hip out of a bay-window roof causes an awkward warp in the sheathing, which shows up in the shingling and the valley flashing (photo above left). The bay in the photo at the right was framed with both hips, and the valley runs straight and true.

Patterns and plates—We build bays like the one shown in the photograph (top photo, facing page) on either slab or wood-framed floors, and sometimes on cantilevered joists. In each case, laying out the bay begins after the subfloor is in place and I've snapped a chalkline marking the inside edge of the wall plates around the house.

To save time and ensure accuracy when I mark the position of the bay, I use a plywood pattern of a 2-ft. by 2-ft., 45° corner (floor plan, p. 80). By placing the pattern along the wall line at the beginning of the bay, I can quickly lay out a perfect 45° wall. The pattern has layout marks on both sides, so I can flip it to lay out the opposite corner.

I usually make square cuts on the ends of the diagonal wall plates. They abut outer wall plates that have two 45° cuts on their ends (floor plan detail, p. 80). I do this for two reasons: the angled stud on the outer wall plate gives me a good nailing surface to anchor the walls together, and it gives me a little more room to squeeze the window into the diagonal wall. Designers inevitably want lots of windows in these walls. That means I need from 26½ in. to 27½ in. for my header, depending on the width of the windows. As you can see from the photo below, this can get snug. To make the windows fit, I sometimes have to use 1x4 king studs instead of 2x4s next to the trimmers that carry the window headers.

After the walls have been framed and plumbed, it's time for the roof. If you're familiar with roof theory, I'll go straight to calculating the rafters for the bay. If you'd like to brush up on roof basics, please refer to the sidebar, "Regular and irregular hips," on page 83.

Locating the ridge—To find the ridge height using the HAP method, I add the distance the rafter sits above the plate at the seat cut to the theoretical rise, minus the reduction caused by the thickness of the ridge (elevation view, p. 81). For example, our seat cut (the horizontal portion of a bird's mouth) is 3½ in. on the level, giving a 4¼-in. rise above the plate for a 2x6 rafter. The run of the common rafter is 5 ft., and the rise is 40 in. (8-in. pitch by 5-ft. run). This gives us a theoretical rise of 44¼ in. If there were no ridge, the peak of the rafters would be this height, but the ridge comes between them and must be accounted for. This applies to both common rafters intersecting the ridge at a right angle or, as in this case, a common rafter in line with the ridge. I find the reduction the "new-fashioned" way, courtesy of Construction Master (detail 1, p. 81). Our ridge is 1½ in. thick. Using my Dimensional Calculator, I enter half the thickness of the ridge (¾ in.) as the run. Next I enter 8 in. as the pitch, and punch the rise button. My answer is ½ in. I subtract that from 44¼ in. to get the actual height of the ridge above the plate: 43¾ in.

To begin erecting the bay's roof, I set its ridge on temporary legs so that it sits precisely 43¾ in. above the plate. If I later cut all my rafters accurately, and my walls have been properly plumbed, lined and braced, all the parts will converge to lock the assembly together.

Because the offset of the bay is 2 ft., the ridge is approximately 2 ft. long. Actually, it's a little longer in order to compensate for the shortening allowance of the common rafter. More on this in a minute.

First, the valleys—Our floor plans show a 2-ft. offset and a 6-ft. long front to the bay window. The interior opening of the bay is 10 ft. wide. The roof plan shows two valley rafters, one common rafter and two sets of irregular hip rafters (roof plan, next page). The roof overhang is 2 ft.

At this stage of the roof framing I'm not concerned about the 45° wall of the bay. Instead, I'm thinking about the 10-ft. wide opening to the bay. Dividing it in half gives me a pair of 5-ft. squares in plan. The bay's ridge and common rafter form a line between the squares, and its regular valleys are the diagonals.

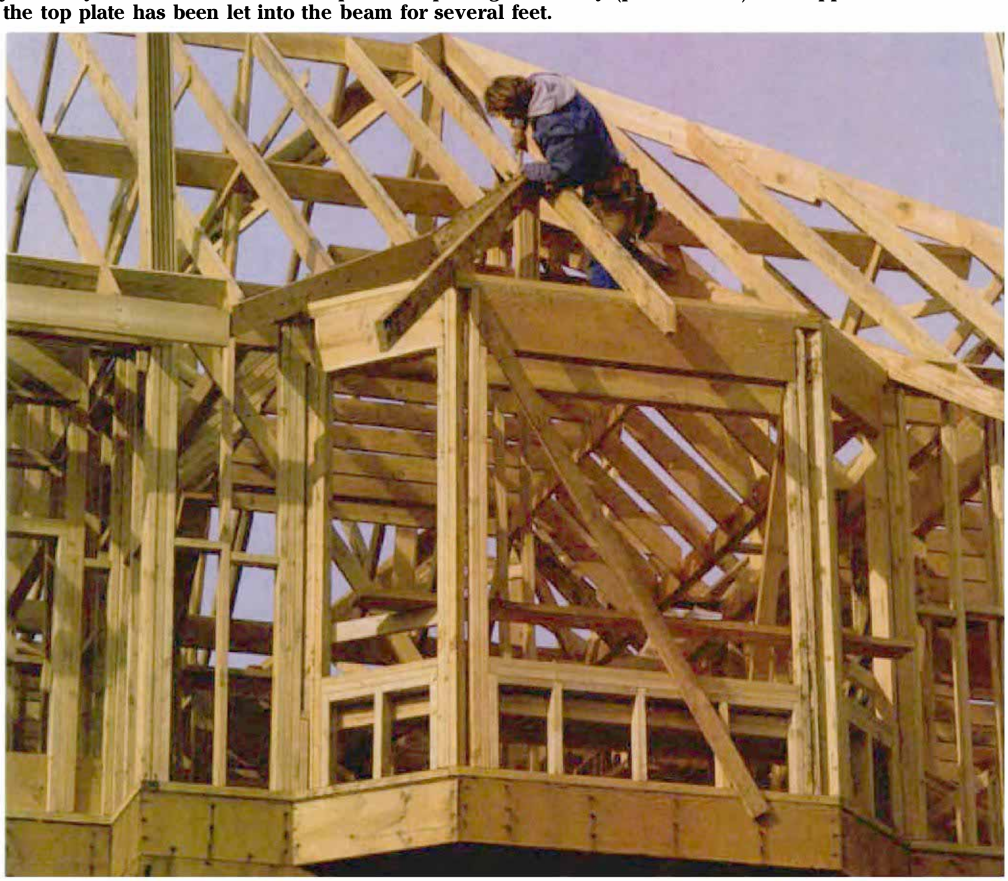
An 8-in-17 valley (see sidebar) on a 5-ft. run calculates to be 7 ft. 9¾ in. long. To get my 2-ft. overhang, I have to add 3 ft. 1½ in. from the seat cut to the tail cut. The vertical edge (heel cut or plumb cut) of the bird's mouth aligns with the exterior face of the wall framing.

The skinny little lines we see when we look at roof framing plans represent the center lines of rafters and beams. To transfer the ideal of a line with no width into a rafter that is typically 1½ in. thick, we have to take the shortening allowance (SA) into consideration. For a regular hip or valley, the SA is equal to half the thickness of the common rafter, cut on a 45° angle (detail 2, p. 81). That works out to 1$\frac{1}{16}$ in. for 2x framing lumber. Remember this is a level measurement, and has to be adjusted for the pitch of the roof. For our 8-in-17 pitch, the valley rafter has to be shortened by 1$\frac{3}{16}$ in. To find the adjusted SA with the Construction Master, enter the pitch as the decimal .47 (8-in. rise divided by 17-in. run). Then enter 1$\frac{1}{16}$ in. as the run, and punch the diagonal button to get the adjusted SA of 1$\frac{11}{64}$ in. Round it off to 1$\frac{3}{16}$ in.

I'm in the habit of cutting double cheek cuts on valley rafters. Often there are other rafters intersecting the same ridge, and the double cheek cut gives me a little extra room for adjustment. In addition, to save time at the cutting table I put double cheek plumb cuts on all my valley and hip stock at the same time, and then decide later which ones end up as hips or valleys. The photo on p. 82 shows how the valleys intersect the ridge.

Common rafter—In order for the common rafter to be at the same height as the valley rafter, it also must be calculated on the 10-ft. span, or 5-ft. run. An 8-in-12 common on a 5-ft. run calculates to be 6 ft. ⅛ in. long. Measured on the level, its SA is half the

The author nails down irregular hip rafter A on a cantilevered bay (photo below). Note the 1x4 king studs in the diagonal walls. They allow more room for the window. Opposing walls are joined by a tie beam across the top of the opening to the bay (photo above). The upper half of the top plate has been let into the beam for several feet.



Drawings: Michael Mandarano

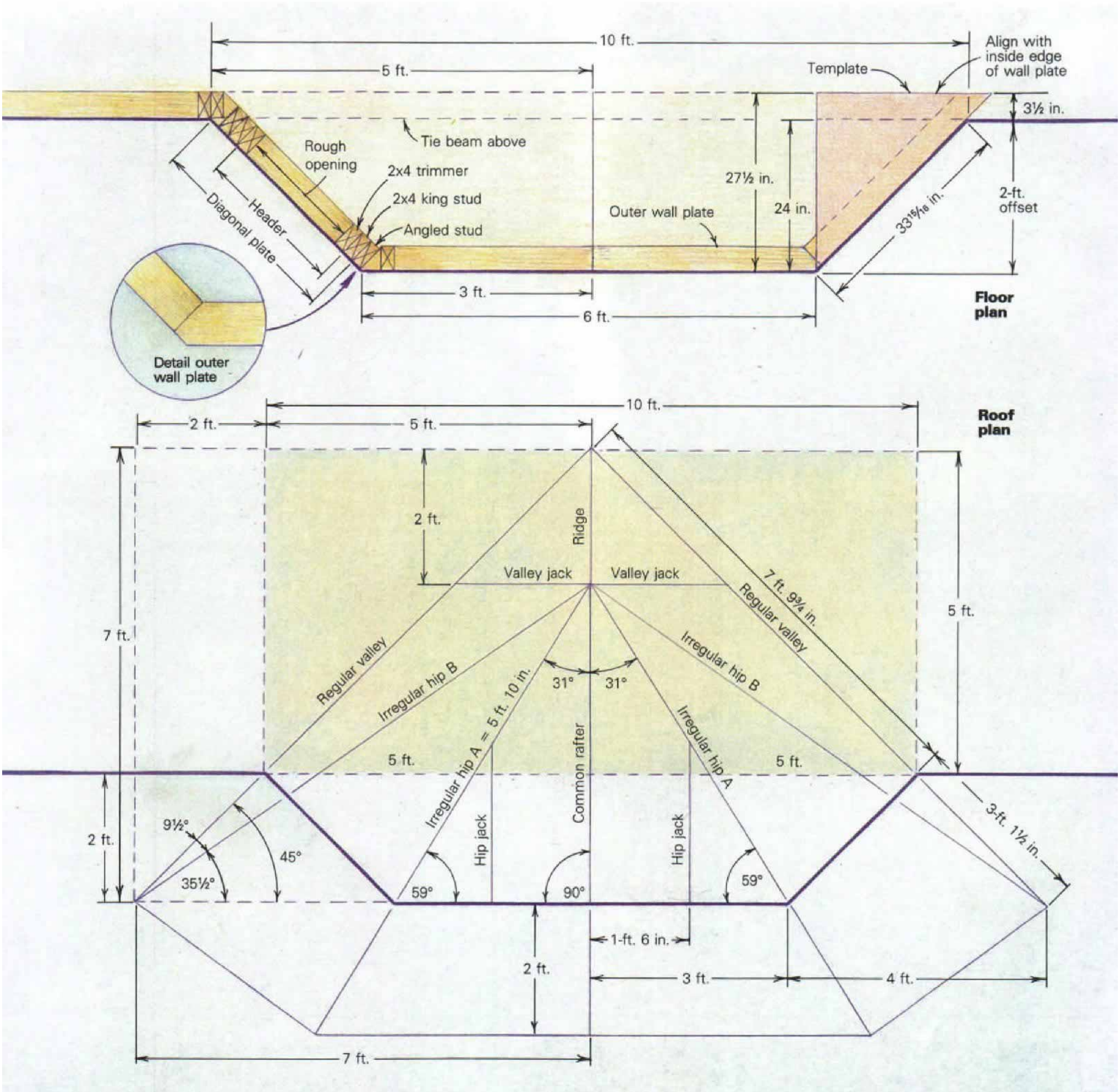
thickness of the ridge—in this case ¾ in. (detail 1, facing page).

Our next move is to calculate the lengths of the valley jacks. Since our run from the common rafter to the valley rafter is 2 ft., our valley jack will be cut on that run. The valley jack will have two SAs—one for half the thickness of the ridge and one for half the thickness of the valley measured across its top at a 45° angle.

Irregular hip A—Looking at the roof plan (bottom drawing) we see that the distance from the common rafter to irregular hip A is 3 ft. The run of the common rafter to the ridge is 5 ft. To find the run of hip A, I enter 3-ft. rise and 5-ft. run. When I punch the diagonal button, it reads 5 ft. 10 in. But that's measured on the level. To figure the length of hip A, we need its actual rise. By feeding our 40-in. rise and 5-ft. 10-in. run into the calculator, I get the full unadjusted length of the rafter from seat cut to ridge junction: 6 ft. 8⅝ in.

While we're working with these numbers, let's figure out the plumb cut for this hip by dividing our 40-in. rise by our 5-ft. 10-in. run to get tangent .571428. The trig tables say that's almost 30°. While the tangent number is still in the calculator's display screen, I punch the convert-to-inches button, which now reads 6⅞ in. That means the pitch (and the plumb cut) of this hip rafter is 6⅞-in-12.

Because we're dealing with an irregular hip here, we need to know the angles formed by its intersection with the plate and the common rafter. Without them we can't calculate the cheek cuts on the hip rafter at the ridge or the cheek cuts on the hip jack rafters. Using the tangent method and the trig tables, I find that the angle made by the hip



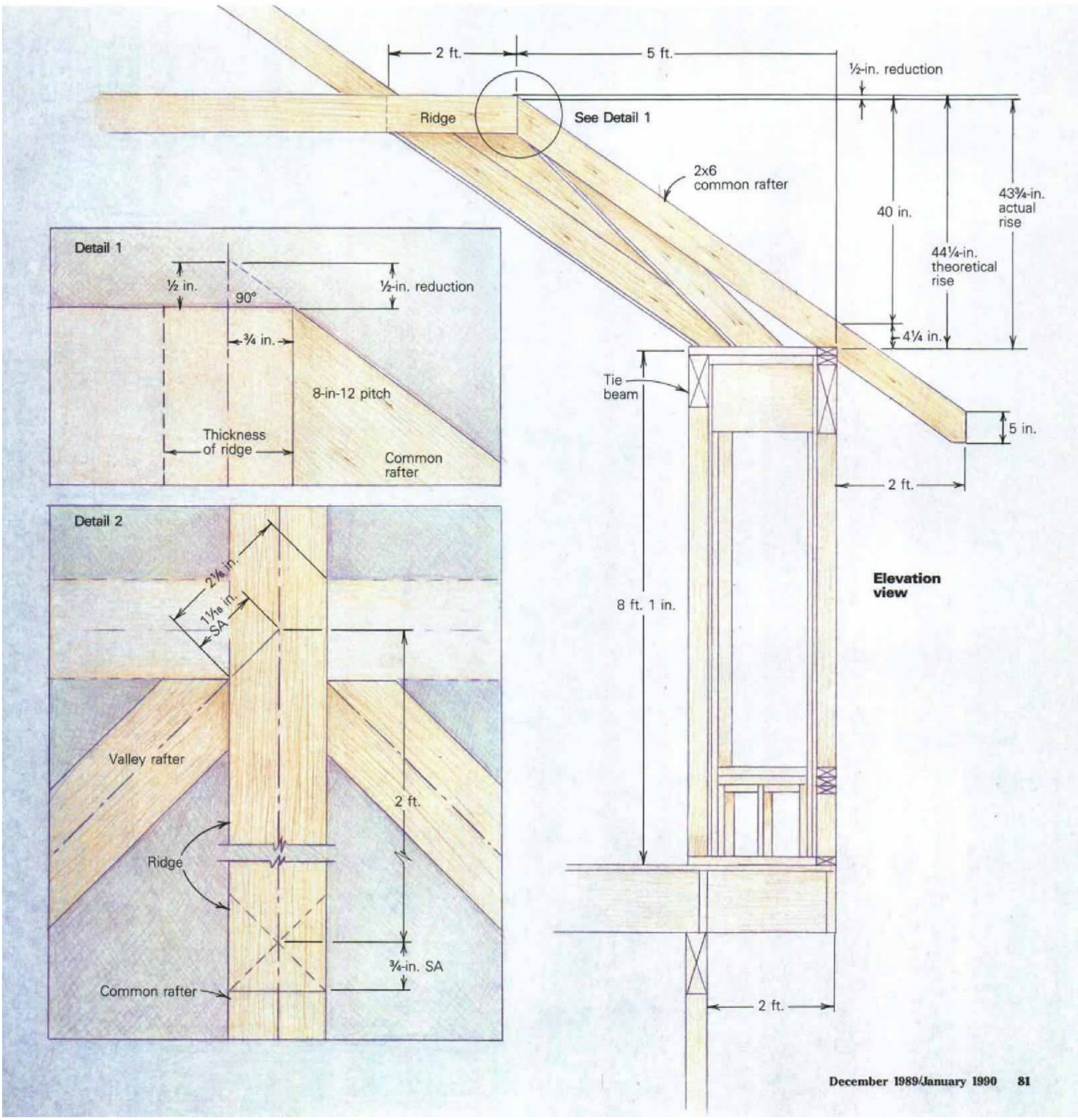
and the plate is 59°; therefore the complementary angle is 31°.

To be an irregular hip is to be off center at the intersection of all the other rafters (plan of rafter intersection, next page). Here's a way to calculate the SA and cheek-cut angles for this asymmetrical junction. In the triangle ABC, the rise of BC is half the thickness of the ridge, or ¾ in. The angle A is 31°, derived from the plan view of our roof. Thirty-one degrees is the same as a 7 3/16-in. roof pitch. Calculator in hand, I enter 7 3/16 in. as pitch and ¾ in. as rise, punch the diagonal button, and it reads 1 7/16 in. for the hypotenuse AB in triangle ABC. This is the SA, measured on the level. The adjusted SA for this 6⅞- and 12-pitch is 1⅝ in.

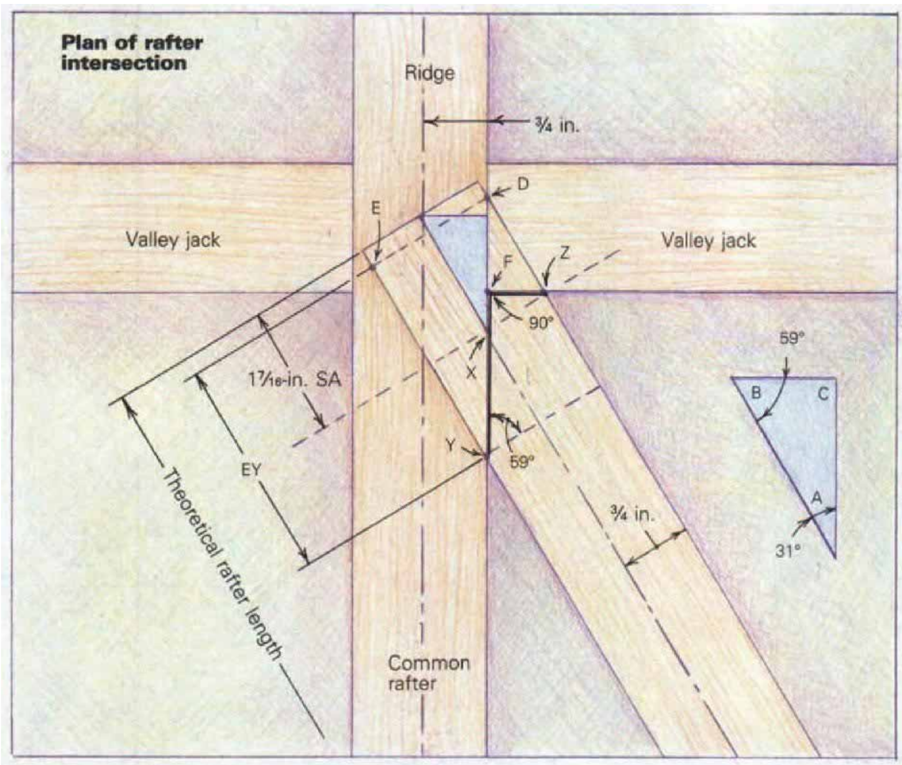
Let's take a look at the rafter intersection plan to see how the framing square is used to lay out this irregular-hip plumb cut. First, measure back from the full length of the rafter the adjusted SA, 1⅝ in., to mark point X on the rafter's centerline. By looking at the plan view we see that the hip needs two different cheek cuts. Let's make the longest side first. By laying the framing square on top of our rafter with the tongue set at 7 3/16 and the body set at 12, draw a line on the edge of the rafter that passes through point X (detail 3, next page). This line (YD) gives us the angle for the cheek cut on the side of the common rafter.

By studying our plan of our rafter intersection, we see that the two cheek cuts intersect off the centerline of the rafter at point F. To find this point, first square a line from the edge of the rafter to X to find point Z. A line perpendicular to YD that intersects point Z gives us the second cheek cut in plan.

Now we've got the cheek-cut angles for a horizontal rafter. Just to make this a chal-



Converging rafters meet at the end of the bay's ridge beam. In the lower left corner of the photo you can see where the valleys intersect the ridge. The "X" marks one end of the 2-ft. ridge.



lenging exercise, the angles change as the rafter's pitch increases–the greater the pitch, the greater the change. You can demonstrate this phenomenon by drawing an equilateral triangle on a slip of paper. Hold the drawing level, with its base toward you. Now slowly rotate the drawing to vertical to change its pitch. You can watch the angle change from an obvious 60° to a right angle and beyond.

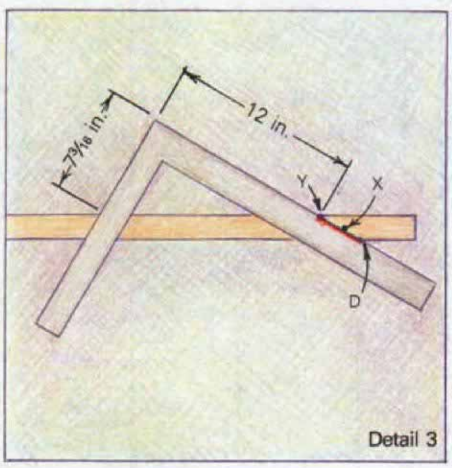
When you make compound cuts with a circular saw, such as the cheek cuts on a hip or jack rafter, the saw automatically compensates for the pitch of the rafter. But if you have to use a handsaw to cut an angle beyond the circular saw's 45° capability, you have to compensate for the angle change in your layout. The angle we need to cut here is 59°. Here's how to lay it out.

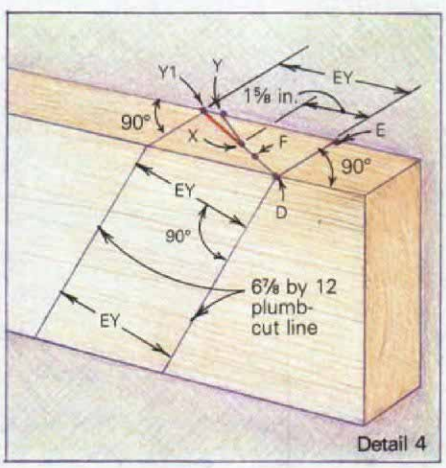
Recall that our hip plumb cut is 6⅞ and 12. Scribe a line at this pitch on the side of the rafter, beginning at point D (detail 4 below). Now mark from this line the distance EY on the side of the rafter, and scribe another line at 6⅞ pitch. Square this line across the top of the rafter to find point Y1. Connect point F and point Y1 to find the adjusted cheek cut. If you want to cut the other angle with a handsaw, repeat the process to find the adjusted cut for the other cheek. In plan, they look like detail 5 below. Now you're ready to make the double-cheeked plumb cut for irregular rafter A, and to take a break.

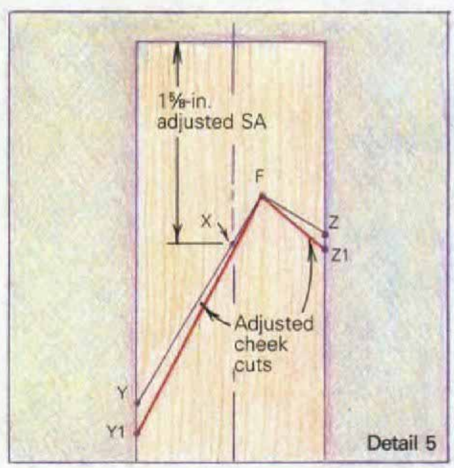
In practice, when the rough framing is going to be covered up by a ceiling, I generally trim this cut to fit. A perfect cut isn't necessary for structural integrity, and as always, time is of the essence. But a journeyman carpenter should know how to make this cut precisely if the rafters are going to be exposed to view.

I let the tails of these two rafters run wild past the wall. Once I've got the rest of the rafters in place, I use my level to determine the position of my tail cut. In this manner I can make sure that the fascia and gutters end up in the right place.

Irregular hip B–These hips can be calculated mathematically, but to tell the truth I







use stringlines to figure them out. I tack a nail in the top of the valley rafter to represent the centerline intersection of the valley and its neighboring hip. Then I run a string to the point at which the rafters are intersecting at the end of the ridge. I'll measure this distance to get the unadjusted length of the rafter, and while I'm at it I measure the distance from the Stringline to the wall plate to get the depth of the seat cut.

To lay out the radically tapered tail cut on hip B, I need to know the angle the rafter makes with the front of the bay. Using the tangent method, I find it to be 35½°. From the plan view we see that the 45° valley and 35½° hip come together to form a 9½° angle (45° minus 35½°). The complement of 9½° is 80½°. I use this angle on my Speed Square to mark the tail cut. Once I adjust the cheek cut for the pitch of the rafter, I make the cut with a sharp handsaw. The only rafters left to install are the hip jacks.

Because I have 3 ft. from corner to common rafter, I center the jack at 1 ft. 6 in. You should have enough information now to figure out their rise, run, pitch, length and cheek cuts. ❑

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Regular and irregular hips

Understanding complex roofs requires an understanding of the mathematics of a simple roof. Here are some basics.

The *pitch* of a roof is determined by the relationship of vertical *rise* to the horizontal ran. An 8-in-12 roof means that for every 12 in. of run the rafter will rise 8 in. To represent this relationship visually, a diagonal line connects the two, forming a triangle (detail C below). The diagonal represents the slope of the rafter. Because the rise and run are perpendicular to one another, the three lines form a right triangle. The mathematical formula to find the length of the diagonal of a right triangle is called the Pythagorean theorem: $\mathbf{a^2 + b^2 = c^2}$**.** Another way to figure it: c = the square root of a + b.

Fortunately, the carpenter can reach for a calculator to process these numbers. Another way to bypass tedious rafter calculations is with a rafter book, such as *Full Length Roof Framer* (A. F. Reichers, Box 405, Palo Alto, Calif. 94302). It lists the lengths for common, regular hip and valley rafters for roofs with 48 different pitches.

If you divide the rise by the run, you get the *tangent.* For an 8-in-12 roof, the tangent is .666667. What can you do with this information? By looking at a table of trigonometric functions you'll find that a tangent of .666667 is equal to approximately **33¾°.** Therefore an 8-in-12 roof rises at an angle of **33¾°.** All roof pitches have a corresponding tangent/degree.

Once we know two of the angles in a triangle, we can subtract their sum from 180° to get the third angle. In our example, **180° - (90° + 33¾) = 56¼°,** which is called the *complement of* the **33¾°** angle (complementary angles add up to 90°). When laid out with a Speed Square, this **56¼°** angle will give the *level* or *horizontal cut* of a rafter whereas the **33¾°** is the *plumb cut* (detail A).

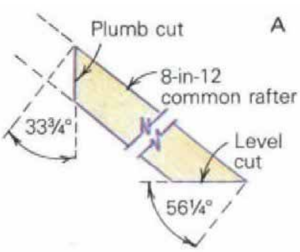
In plan, a *regular hip* rafter intersects common rafters at a 45° angle. To understand a hip, look at it from the plan, or top view (drawing below). The common rafters intersect the plates at 90°, while the hip is 45° to the plates. In order for the regular hip rafter to reach the same point as a common rafter, its run must be longer. For every 12 in. a common rafter needs for run, a regular hip rafter, regardless of pitch, needs 16.97 in. (for pitch designations, carpenters round the number off to 17 in.). This relationship holds true for *regular valley* rafters as well. Therefore, a regular hip or valley rafter on an 8-in-12 roof is cut to a 8-in-17 pitch. Divide 8 by 17 to get the tangent: .4705, which gives us the hip *plumb cut*—**25½°.**

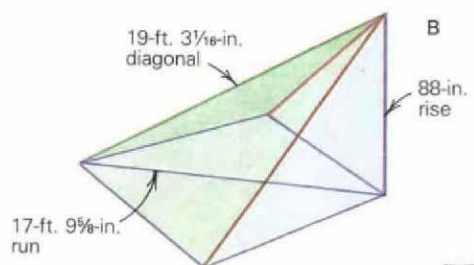
As shown in our plan, a regular-hip roof over a 22-ft. span reveals two 11-ft. squares. The run of the commons will be 11 ft. Find the run of the hips by multiplying the run of the common times the run of a regular hip: or, 11 x 16.97 in., which equals 15 ft. **$6\frac{11}{16}$** in.

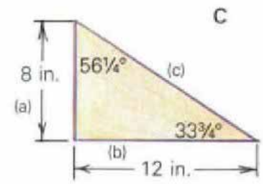
So what does this tell us about how to calculate irregular hips? To figure out an *irregular hip* the diagonal length of its run is needed. But because an irregular hip doesn't have a 45° angle in plan, the value of 16.97 can't be used. Back we go to the Pythagorean theorem.

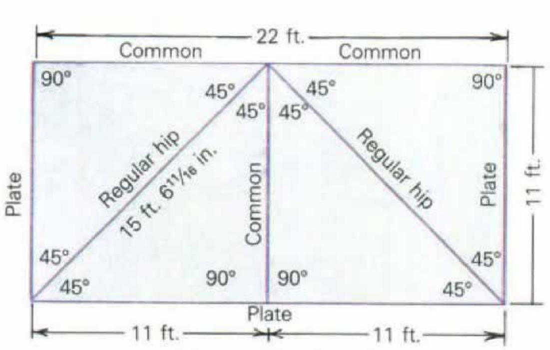
Let's say we have an 8-in-12 roof with commons that run 11 ft., but the commons are 14 ft. from the corner where the hip originates at the plates (drawing below and detail B). By using the Pythagorean theorem, we find that the diagonal in a triangle with 11 ft. and 14 ft. sides is 17 ft. **9⅝** in., which gives us the run of this irregular hip. To find the full length (also referred to as theoretical or unadjusted length) of the hip rafter, use the rise (88 in.) and the run to find the diagonal, which is 19 ft. **$3\frac{1}{16}$** in.

The hip jacks are another wrinkle—those intersecting an irregular-hip rafter have different angles on their cheek cuts. Using our tangent formula, we find that our Irregular hips divide the plan view of our roof into 38° and 52° angles. When the cheeks of opposing jack rafters are cut at these angles and adjusted for the pitch of the rafter as shown in the bottom drawing, p. 80, they'll fit snug against the irregular hip. *—D. D.*

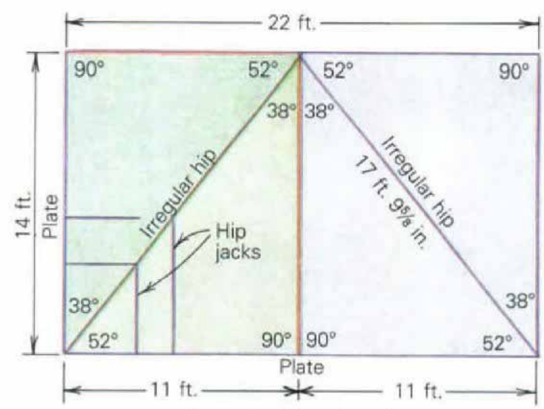








Regular-hip plan view



Irregular-hip plan view