Roof Calculations Simplified

The Construction Master calculator takes some of the head scratching out of cutting a hip roof

by Don Dunkley

When I started out as a framing contractor, I was often faced with complex roof structures that dwarfed my knowledge and experience. To weave through that seemingly impenetrable forest of rafters, I wished for a gray-bearded master carpenter to float over my job and plop down the brass ring of roof framing. He never showed up, so I had to read a few books and cut a lot of lumber. Eventually I got a fairly good feel for putting roofs together.

Back then, I used the tried-and-true *Full Length Roof Framer* by A.F.J. Reichers to figure out my rafters. Short on text (12 pages) but long on span tables, generations of carpenters have used this little book to make their calculations.

Things changed in the late 1980s when I came across the Construction Master calculator. I used it through one whole job — from layout to roof framing — and I've never looked back since. Now I use the Construction Master to work out a rafter cut list the night before framing begins. This saves me so much time that I get to bed at a reasonable hour.

Over the years, using the Construction Master has helped me develop a quick and precise system for figuring out the rafters. Not only did it help me shave time off calculations, but it also increased my understanding and ability to do more complex structures.

The Calculator

Before the Construction Master, carpenters who wanted to use a calculator had to rely on a scientific model that dealt in trigonometric functions and decimals. Converting decimals to feet and inches is a pain, and dealing with secant, tangent, and cosine functions is guaranteed to cause most carpenters' eyes to glaze over. Since the Construction Master deals in feet and inches and uses the more common terms of rise, run, and diagonal, it's the ideal calculator for the job site.

The first step to calculating any rafter is a simple matter of entering the known Run (in feet, inches, and any fraction of an inch) and entering the known Pitch. For a basic gable rafter, punching the Diag key displays the resulting rafter length. To display the full height of the rafter off the plate, press the Rise key.

Hip Roof Framing Plan

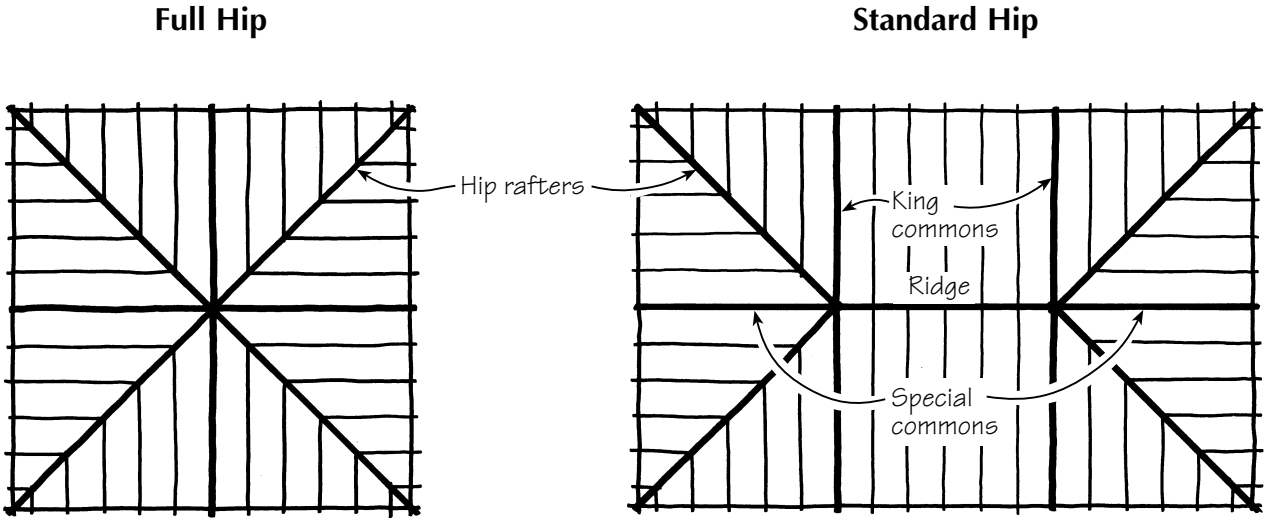

Figure 1. In plan view, hip rafters cross the diagonal of four squares on the end of the building. When the hips meet at the center, the roof is called a *full hip*. Hips separated by a ridge make a *standard hip roof*.

For a hip or valley rafter, press the Hip/V key (instead of Diag) for the length. To get the jacks for a hip or valley, you punch the Jack key to display the longest jack; keep pushing the Jack key to display successive jacks (the calculator has a default setting of 16 inches on-center, but any spacing can be entered). From a single Run and Pitch input, you get all those various rafter lengths. (Try that with a rafter table book!) If needed, you can use the conversion key (Conv) to find irregular hips and valleys and irregular jack rafters.

Hip Roof Principles

To explain how the Construction Master works, I'll work through the calculations I make for framing a hip roof on a building that's 22 feet wide and 57 feet long. The rafter stock will be standard two-by material — 2x6 for the commons and jacks, and 2x8 for the hips and ridge board.

Now, you can't expect to punch a few buttons and know how to cut a roof. It's just not that simple. But by understanding a few basic principles, you can learn to build just about any roof.

Hip terms. When four hips come together in the center of a building, they make four squares (see Figure 1). This is called a *full hip roof*. Separate the hips with a ridge board, attach commons, and you have the footprint of a *standard hip roof*. The standard hip corner is made up of three common rafters. Two are referred to as *king commons*, and the third, which is centered on the end wall, is the *special common*. Next to the king commons sit the jack rafters that fill in the hip.

Span. The first step is to measure the width of the building, or the *span*. In this case, the span is 22 feet. On the job site, I always measure the framed structure instead of relying on the plans. Even a slight variation between the plans and the actual length can throw the roof off enough to make a difference. I prefer to measure from the top plates to ensure accuracy.

Pitch. Divide the 22-foot span in half to determine the *run*. The run is the horizontal distance a rafter must cover to end in the center of the building. The *rise* is the vertical distance the rafter must travel from the top plate to the ridge. The ratio between rise and run is known as the roof slope, or *pitch,* which is expressed as the *unit rise* over the *unit run*. The unit run on common rafters is always 12 inches. The unit rise is also expressed in inches. The roof in this example has an 8/12 pitch — that is, 8 inches of rise for every 12 inches of run. The distance measured along the rafter from the outside wall to the top of the roof is the common rafter length. On a triangle this is called the hypotenuse, and on the Construction Master it's called the *diagonal* (Diag on the keypad).

Layout. When I sit down to make my cut list, I work through the layout in my head. The actual layout, of course, won't be done till the next day at the job site, but for the purposes of clearly explaining the calculations here, I'll walk through the steps as if I were on the job.

To prepare for the hip roof, the squares on the end of the building must be marked out to make sure the diagonally running hip rafters on each corner are of equal length. If the structure is out of square even slightly, the hips will not fit properly.

On the 22-foot-wide end wall, I measure in 11 feet from the outside plate. This marks both the center of the building and the center of the special common rafter. Using a Speed Square, I mark a square centerline and draw a "C" through it. On both sides of the center-

line I measure 3/4 inch (half the thickness of the rafter) and make two more square lines. I've now marked the centerline of the building and the outside edges of the special common.

I lay out the king commons on the 57-foot-long wall the same way, measuring in from the outside corner and marking a "centerline" at 11 feet, then adding lines for the rafter edges. Once I've marked both long walls, there should be 35 feet (57 - 22) between the centerline marks of the king common rafters.

At this point, I measure the distance between the outsides of both king commons. This measurement will give me the full length of the ridge board — 35 feet 1 1/2 inches. I could build this roof with an uncut, or "wild," ridge, assemble most of the roof, then pull up the special common rafters to scribe and cut the ridge. However, I find it best to precut all ridge boards to length to ensure accuracy when dealing with complex roofs. Many times there will be no kings or common rafters to help establish a ridge board.

After I lay out the king commons and take the ridge length, I lay out the hip location. I use my Speed Square to draw a 45-degree line through the center of the outside corner of the wall. Because the rafter stock is two-by, I measure 3/4 inch on each side of the line to mark the outside edges of the hip. I do this at all four corners.

In plan view, a hip rafter makes a 45-degree horizontal line through the 11-foot square from corner to ridge. This diagonal distance is the run of the hip. Since a square has equal sides, its diagonal is always 45 degrees, and this diagonal is always 1.414 times longer than the length of each side (by the Pythagorean theorem). Since the common rafter unit run is 12 inches, the unit run of the hip rafter is 1.414 times longer, or 16.97 inches (commonly rounded to 17). Therefore, the hip in this example has an 8/17 pitch. It has to travel 17 inches of run to match the rise of a common rafter that travels 12 inches of run. In this case, the hip will have to cover a total run of 15 feet 6 11/16 inches to meet the king commons that have 11 feet of run.

Calculating Common Rafters

Rafter length:

1 1 Feet Run 8 Inch Pitch Diag **13-2 5/8**

Shortening allowance:

3 / 4 Inch Run 8 Inch Pitch Diag **7/8**

Shortened rafter length:

1 3 Feet 2 Inch 5 / 8 − 7 / 8 = **13-1 3/4**

Note: With earlier Construction Master models, the pitch has to be entered with each calculation, as shown here. The Construction Master IV holds the pitch in memory and uses it repeatedly until changed.

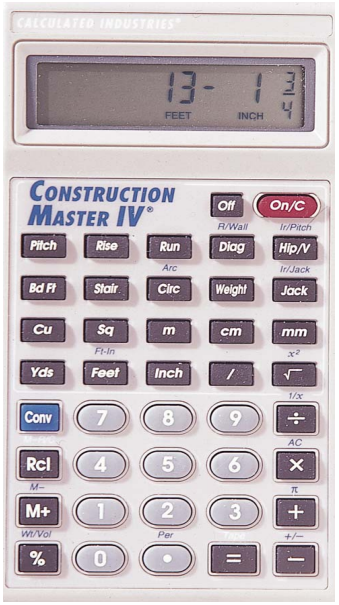

Figure 2. On the Construction Master, all rafter calculations begin with the entry of dimensions for the run and pitch of the roof. Hitting the Diag key gives the length of a common rafter.

Calculating Rafter Lengths

Once I lay out the building and confirm measurements, it's easy to compute the rafters using the Construction Master.

Common lengths. To compute the length of the king common rafter, I enter 11 Feet into the calculator, and push the Run key. Next, I enter 8 Inch, and push the Pitch key. (Note: With the Construction Master IV, once you enter the pitch, the value remains in the calculator as a constant — even after you turn it off. From then on, you don't have to enter the pitch when you do a calculation — it's always working in the background. With earlier versions of the Construction Master, you have to reenter the pitch with each calculation, as I've done above.)

To get the rafter length, I push the Diag key and the calculator displays 13 feet 2 5/8 inches. But this is not yet the correct dimension. Rafters and ridge boards are not just lines on paper — they occupy space. So I have to adjust to compensate for the thickness of the stock. With this full-length common rafter, I have to take into account the thickness of the two-by ridge. This is called the *shortening allowance*, and it is based on half the thickness of the ridge — in this case, 3/4 inch.

To find the shortening allowance for 3/4 inch, I enter 3/4 Inch, hit Run, enter 8 Inch, hit Pitch, then push Diag. The calculator will display 7/8 inch. I deduct this amount from the result of the first calculation to get a final rafter length of 13 feet 1 3/4 inches (Figure 2).

Hip lengths. I next calculate the hip: Enter 11 Feet, Run, 8 Inch, Pitch, then punch the Hip/V key to get 17 feet

Hip Rafter Shortcut

Shortening shortcut:
(when king common is 1 1/2 inches thick)

1 1 Feet – 3 / 4 = Run 8 Inch Pitch Hip/V **17-1 3/16**

Subtract to shorten Run — Calculate length of hip

(when king common is 3 1/2 inches thick)

1 1 Feet – 1 Inch 3 / 4 = Run 8 Inch Pitch Hip/V **16-11 5/8**

Subtract to shorten Run — Calculate length of hip

Note: The Construction Master IV automatically recognizes fractions as parts of an inch, so you don't need to hit the Inch key after entering a fraction like 3/4. When entering 1 3/4 inches, however, you need to hit the Inch key after entering the 1 — otherwise, the calculator will display 13/4 inches.

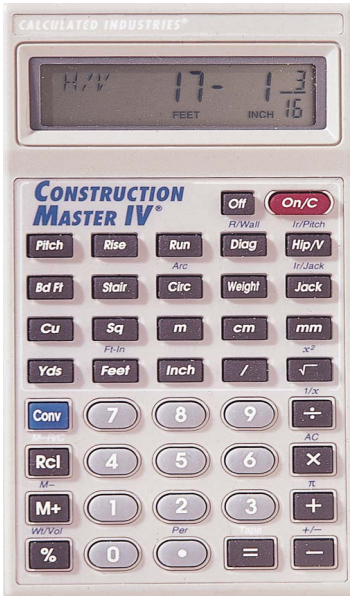

Figure 3. Instead of subtracting the shortening allowance after finding the rafter length, the author adjusts the run of the hip rafter before calculating the rafter length. With standard two-by king commons, this shortens the run by 3/4 inch (half the thickness of the commons). With wider 3 1/2-inch commons, the run is shortened by 1 3/4 inches.

2 3/8 inches on the display. I also need to make a shortening allowance for the hip connection at the ridge. Unlike the deduction for the ridge on a common, the hip shortening allowance is half the 45-degree thickness of the common rafter. To calculate this, I enter 3/4 Inch, Run, 8 Inch, Pitch, then push Hip/V. The calculator displays 1 3/16 inches. I deduct this from the first hip length to get a final hip length of 17 feet 1 3/16 inches.

Allowing for stock variations. In most conventional roof framing, the rafter and ridge stock are the same thickness. But when there is a difference in thickness, it affects the shortening allowance.

For example, the shortening allowance for the special common is based on half the thickness of the king commons — not the ridge. If the king commons are 3 1/2 inches thick, the ridge will grow by 1 3/4 inches rather than 3/4 inch. The centerline at 11 feet remains the same, but because of the thicker rafter stock, the ridge will extend out farther to flush out at the edge of the king common. In this case, the special common will be shortened by half the thickness of the king commons — 1 3/4 inches — by whatever the pitch is. In this case, the length of a special common on an 8/12 pitch would be shortened by 2 1/8 inches. This same principle applies to the hip, and therefore the shortening allowance is based on the king commons thickness rather than the ridge.

Shortcut. Once you become familiar with the basic principles behind hip framing, you can use a shortcut to make the calculations a little quicker. To avoid having to make the various shortening allowances, you can deduct the ridge and common thickness right off the span. Take for example the 22-foot-span building with a two-by ridge and rafters. I'll deduct 1 1/2 inches, representing the ridge, from the main span, leaving 21 feet 10 1/2 inches. I then divide this adjusted span by two to get an *adjusted run* of 10 feet 11 1/4 inches.

To find the lengths of the special and king commons on the calculator, I enter 10 Feet 11 1/4 Inch, Run, 8 Inch, Pitch. Then I push Diag to display 13 feet 1 3/4 inches. I then push Hip/V to find the hip length of 17 feet 1 3/16 inches.

Another way to make the same calculations is to subtract half the thickness of the ridge (for commons) or commons (for the hips) from the run. For example, to find the hip, I would subtract half the thickness of the king common (3/4 inch) from the run of 11 feet, then key in 8 Inch, Pitch, Hip/V to find the length of 17 feet 1 3/16 inches (Figure 3). If the king commons were 3 1/2 inches thick, I'd subtract 1 3/4 inches from 11 feet, hit Run, 8 Inch, Pitch, Hip/V for a hip length of 16 feet 11 5/8 inches.

Calculating Jack Lengths

The next rafters to be figured for a hip roof are the jacks. The jack rafters attach to the hip and get proportionally shorter as they follow the on-center layout on the plate from the king common toward the corner. This proportion is referred to as the *common difference*. To ensure a match on both sides of the hip, jacks are cut in pairs, making a right-hand and a left-hand jack. Our roof has eight jacks of each length, or four right- and left-hand sets. Since it's an equal-pitch hip roof, the plumb cut on all of the jacks is made on a 45-degree bevel.

The Construction Master has a Jack key that calculates the first, or longest jack, down to the last, or shortest, jack. Repeatedly pressing the key displays each successive jack length, deducting the common difference automatically.

Adjusted Run for Jacks

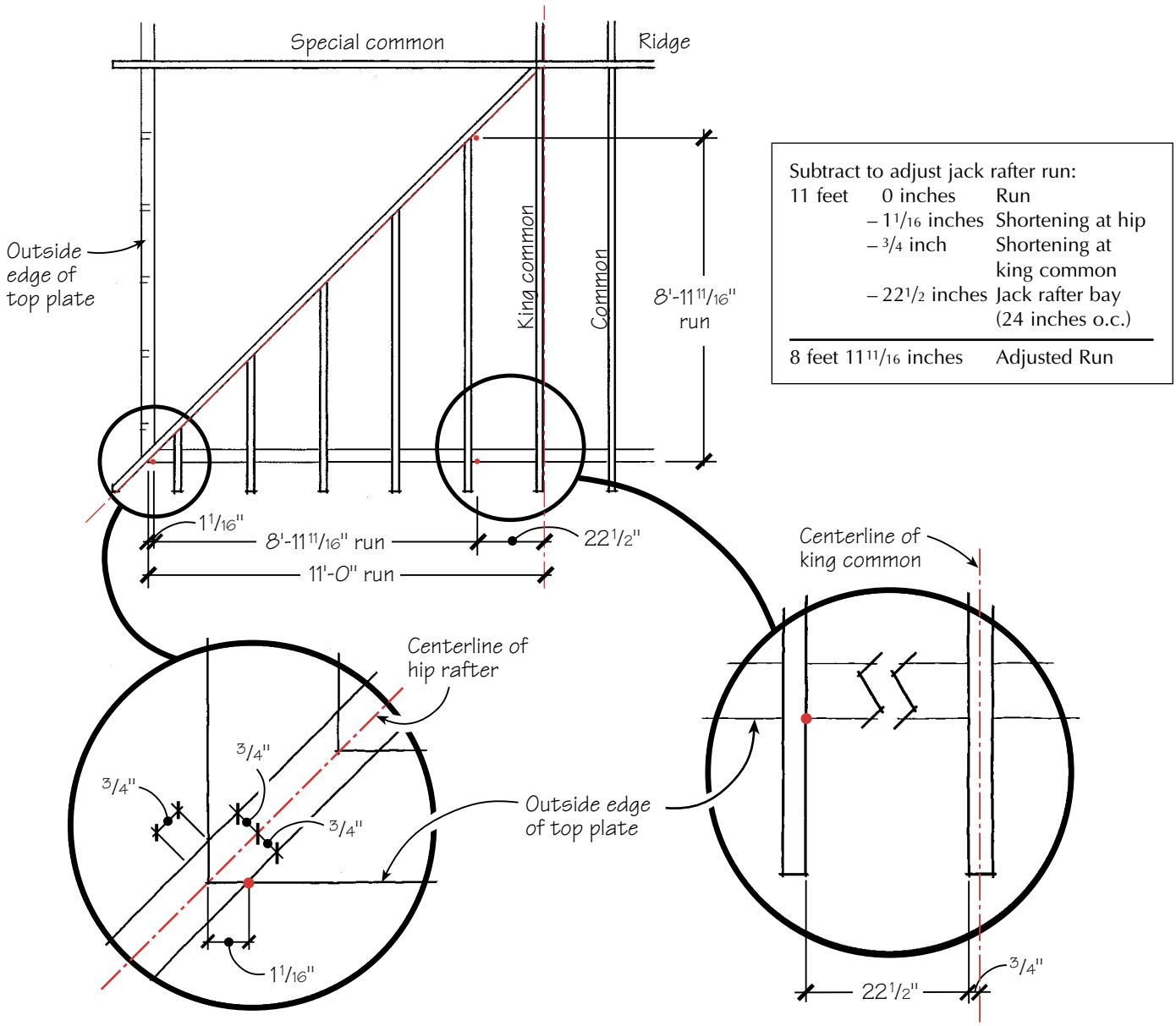

Figure 4. It's easier to lay out a jack rafter when you can measure to the long point of the bevel cut instead of the centerline. One way to do this is to use the run of the longest jack, which can be measured or calculated from the rafter layout marks on the wall plate. In this example, from the run of 11 feet, first subtract the hip shortening allowance (1 1/16 inch) — which is the same as the distance measured along the wall where the hip rafter overhangs the plate. Next subtract half the thickness of the king common (3/4 inch), then subtract the width of the last rafter bay (22 1/2 inches).

The Construction Master is programmed with a default setting for a 16-inch on-center jack spacing, but you can change it to whatever rafter spacing you are using. To do this on the Construction Master IV, clear the calculator, enter the on-center spacing, then press the Jack key. (On earlier versions, press the Jack key first, then enter the on-center spacing.) Then enter the run, the pitch, and press Jack again.

Now you're ready to calculate the length of the jack rafters. For example, to find the jacks for 2-foot on-center spacing, press Jack, and enter 2 Feet. Then enter 11 Feet, Run, 8 Inch, Pitch. Again, press Jack, and the calculator displays 10 feet 9 13/16 inches. Push Jack again and 8 feet 4 15/16 inches is displayed. Each jack is 2 feet 4 7/8 inches shorter than the previous one — the common difference for 24-inch on-center rafter spacing.

The jack rafters I calculated also need shortening to compensate for the thickness of the hip rafter. This shortening is based on the run of half the 45-degree

Shortcut for Jacks

Length of Jack from plate to long point:
(using Adjusted Run)

8 Feet 1 1 Inch 1 1 / 1 6 Run 8 Inch Pitch Diag	10-9 7/16
Jack	8-4 9/16
Jack	5-11 3/4
Jack	3-6 7/8
Jack	1-2 1/16
Jack	0-0

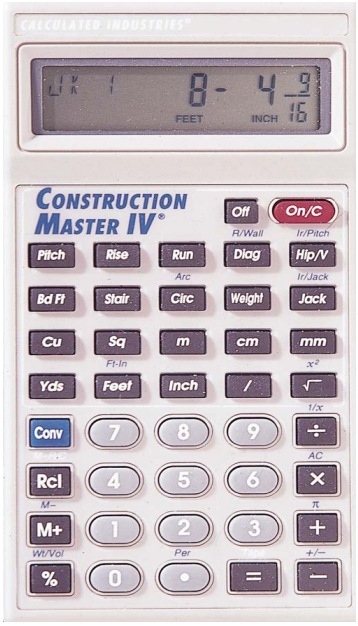

Figure 5. Using the Adjusted Run, hit the Diag key to get the length of the longest jack (from plate to long point). Repeatedly hitting the Jack key gives the length of each proportionately shorter jack rafter.

thickness of the hip. The 45-degree length of the 1 1/2-inch-thick hip is 2 1/8 inches. Half of that is 1 1/16 inches. To find the shortening allowance, enter 1 1/16 Inch, Run, 8 Inch, Pitch. Then enter Diag, and the display reads 1 1/4 inches. The jack length is cut short by that amount.

Shortcut for Jacks

The shortening allowance for jacks must be measured down the center top of the jack, since the lengths are calculated from center point to center point. This is quite inconvenient, especially when cutting large sets of jacks. To get around this, I use a shortcut that gives me the jack length from the long point of the bevel cut at the face of the hip to the outside of the plate. This allows for the tape to be hooked over the long point for easier measuring and accurate jack rafter spacing — important when the roof is sheathed in plywood.

To do this, I need to know the run from the face of the hip to the outside edge or long point of the first jack. To help visualize this distance, think about how the 1 1/2-inch-thick hip rafter sits at 45 degrees on the outside corner of the walls (Figure 4). One half of its thickness (3/4 inch) projects past the side of the outside edge of the plate. Measured along the outside of the wall, this overhang is 1 1/16 inches long. The run measurement I want starts from this point — the face of the hip — and goes to the long point of the first jack. If I were on site, I could use the rafter layout marks to measure between these two points along the wall plate. But I can also work backwards from the 11-foot run, first subtracting half the thickness of the king common (3/4 inch) then the width of the bay between the king common and the longest jack (22 1/2 inches), and finally, the 45-degree thickness of the hip (1 1/16). The result is a run of 8 feet 11 11/16 inches — the total distance from the face of the hip to the long point of the longest jack rafter.

To find the jack length on the calculator, I enter 8 Feet, 11 11/16 Inch, Run, 8 Inch, Pitch. Then I punch the Diag key to get the first jack length of 10 feet 9 7/16 inches (Figure 5).

When calculating this way, the Diag key must be pushed to get the first jack, although this key is usually used to figure the common. (If you entered the Jack key, the first jack would be skipped, since the calculator thinks that it's using the common rafter run). Now press the Jack key to get the next jack length — 8 feet 4 9/16 inches. Hit the Jack key again to get 5 feet 11 3/4 inches, and so on, until the last, or smallest jack, is displayed.

Further shortcut. I used this example to explain how you can make the calculator figure to the framing face and not the centerline. Once you understand how to figure the jacks this way, you can use another shortcut. To the original run of 11 feet, add 3/4 inch. This gives the length of the run to the outside of the king common. Deduct 1 1/16 inches for the space taken by the hip at the corner. This gives a distance of 10 feet 11 11/16 inches from the inside face of the hip to the outside of the king common. On the calculator, enter 10 Feet 11 11/16 Inch, Run, 8 Inch, Pitch. Now bypass the Diag key, and press the Jack key. The display will read 10 feet 9 7/16 inches. Again, this is the long point of the first, or longest, jack. Keep pressing the Jack key to get the lengths of the remaining jacks.

The Cut List

When I put together the rafter cut list, I put all the lengths down on a yellow legal pad. Knowing all the lengths enables me to accurately judge the lumber lengths I'll need to use on site. I organize my list carefully, labeling the various spans for easy identification, breaking down each section into its components, and then comparing it with the plans for any omissions or errors. Now it's time to make some sawdust.

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