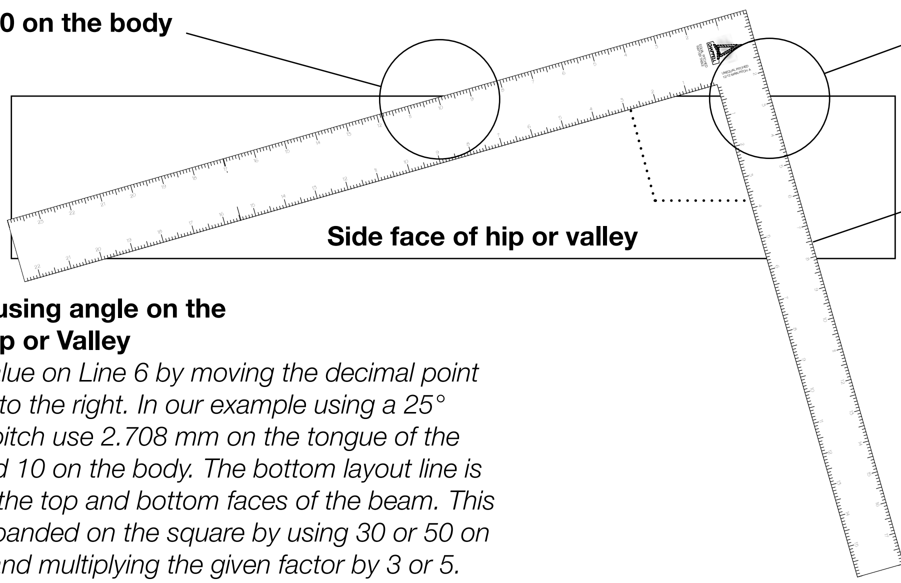
Chappell Universal Framing Square

Bringing the Framing Square into the 21st century

Instruction booklet for
Model 4560M Metric Master Framer &
Model 3050M Metric Traveler Framing Squares

The Chappell Universal Square™ Puts a Wealth of Building Knowledge Right in the Palm of your Hand...

Unlock the mystery of unequal pitch Compound roof framing with the Chappell Universal Square™

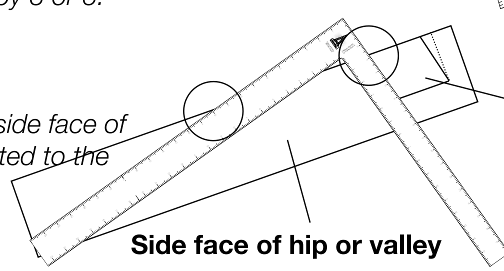


Purlin housing angle on the side of Hip or Valley

Use the value on Line 6 by moving the decimal point one place to the right. In our example using a 25° common pitch use 2.708 mm on the tongue of the square and 10 on the body. The bottom layout line is parallel to the top and bottom faces of the beam. This can be expanded on the square by using 30 or 50 on the body and multiplying the given factor by 3 or 5.

Side face layout for hip or valley to purlin header

This angle is also the layout angle for the side face of a hip or valley rafter joining to a purlin rotated to the common roof plane (square to the top of common rafter).



Rebuilding America One Square at a Time!

You now have the power to create!

Chappell Universal Framing Square™

Unequal pitched joined timber frame valley system built using the *Chappell Universal Square* system. Main pitch 15/12, secondary pitch 9/12.

"It would be part of my scheme of physical education that every youth in the state should learn to do something finely and thoroughly with his hand, so as to let him know what touch meant...

Let him once learn to take a straight shaving off a plank, or draw a fine curve without faltering, or lay a brick level in its mortar; and he has learned a multitude of other matters..."

—John Ruskin

This cupola atop the Palicio Nazaries in the Alhambra in Granada, Spain, was built in the 12th century by the Nasrid Emirs during the reign of the Moors in Spain. The star shaped footprint is developed from an octagonal base, and is rather unique in that it is an octagon that has both hip and valley rafters—something very rarely seen. One might question how the carpenters for the Emirs were capable of determining the rather complex math involved without the Chappell Universal Square™*.*

Though their system may have been lost to time, the Chappell Universal Square™ *contains all of the information one would need to replicate this roof system, and many others that may twist the rational mind.*

Contents

Octagon with both equal and unequal pitched dormers using the values and factors now available on the Chappell Universal Square*. This joined timber frame was crafted by students as a course project, using mortise & tenon pegged joinery, with no nails. Determining angles to create compound mortise & tenon joinery is quite complex, requiring strong math and visual skills. The* Chappell Universal Square *now puts this information right in the palm of your hand.*

Rebuilding The World One Square at a Time!

Chappell Universal Square

Overview

The *Chappell Universal Metric Framing Square* incorporates a broad number of new and unique roof framing applications, some of which have never before been available to carpenters before now. Applying these comprehensive tables to the framing square marks the first truly unique improvement to the framing square in over 110 years, bringing the carpenter's square into the 21st century.

The rafter tables on the standard framing square were developed at the turn of the last century and provide values to determine only 5 basic pieces of information: 1) length of common rafters, 2) length of hip and valley rafters, 3) the side cuts for the hip or valley and jacks rafters, 4) the difference in length for jack rafters for 2 spacings, 16 and 24 inches, and 5) the side cut of hip or valley. The *Chappell Universal Metric Square provides all of this information—and more—on the first line of the Equal Pitch rafter table alone*.

A) Expanded Hip & Valley Rafter Tables

The *Chappell Universal Metric Square* incorporates an expanded rafter table that gives 17 key values that include: 1) Common rafter length per 1 mm of run, 2) Difference in lengths of jack rafters per 1 mm of spacing, 3) Top cut of jack rafters, 4) Length of Hip & Valley rafters per mm of common run, 5) Difference in length of jack purlins per mm of spacing, 6) Top cut of jack purlins, 7) Sheathing angle offset per 1 mm, 8) Depth of backing & bevel angles per mm of hip or valley width, 9) Housing angle of purlin to hip or valley, 10) Hip & Valley side layout angle to purlin header, 11) Housing angle of hip or valley to principal (common rafter) and horizontal plate, 12) Working plane top of hip or valley, 13) Purlin Side cut angle, 14) Mitered fascia face layout angles, 15) Hip & Valley backing angles, 16) Jack rafter and purlin top cut saw angle, 17) Fascia miter saw cut angles.

This is only on the first level. There are multiple levels to the values, which can be unfolded to determine joinery design and layout for compound mortise and tenon joinery and more.

B) Unequal Pitched Rafter Tables

For the first time the history of the framing square, the *Chappell Universal Metric Square* provides comprehensive unequal pitched rafter tables that include: 1) Hip and Valley pitch in millimeters of rise per 1 mm of run, 2) Hip and Valley pitches in degrees, 3) Difference in length of runs side A to side B, 4) Length of Hip or Valley per mm of common run, 5) Difference in length of jack purlins per mm of spacing, 6) Top Cut of purlin, 7) Difference in length of jack rafters per mm of spacing, 8) Top Cut angle of jack rafters, 9) Backing and bevel angles in degrees, 10) Top Cut saw angles for jack rafters and purlins, 11) Purlin side face layout angle, 12) Fascia miter face layout angle, 13) Housing angle of purlins to hip or valley, 14) Side layout angle hip & valley to purlin header, 15) Fascia miter saw cut angle for rafter tails cut at 90°.

This is also only the first level. There are multiple levels to the values, which can be unfolded to determine joinery design and layout for compound mortise and tenon joinery.

C) 6 & 8 Sided Polygon Rafter Tables

Again, the *Chappell Universal Square* includes a comprehensive polygon rafter table that is available for the first time in any format. The tables include values for 6 & 8 sided polygons with common pitches from 2:12 to 18:12, to include: 1) Hip & Valley rafter pitch in rise over 1 mm of run, 2) Length of common rafters per 1 mm of side length, 3) Top cut layout for jack rafters & jack purlins, 4) Difference in length of jack rafters per mm of spacing, 5) Length of Hip/Valley per 1 mm of side length, 6) Difference in length of jack purlins per 1 mm of spacing, 7) Sheathing angle offset per mm of board or plywood width, 8) Backing & bevel angles in degrees, 9) Jack rafter & purlin top cut saw angle, 10) Jack purlin side cut angle, 11) Mitered fascia face layout angle, 12) Jack purlin housing angle to hip, 13) Hip & valley side layout angle to purlin header, 14) Depth of bevel & backing angles per mm of hip width, and 15) Fascia miter saw cut angle for rafter tails cut at 90°.

These are also only the first level. There are multiple levels to the values, which can be unfolded to determine joinery design and layout for compound mortise and tenon joinery

A Brief History of the Framing Square

Alongside a hammer and a stone chisel, a fixed and ridged square is perhaps one of the oldest tools in the history of building. The Egyptians used ridged squares made of wood in the construction of their dwellings—and even the pyramids—to set 'square corners' more than 6000 years ago. There is evidence that they even had digit markings to mark short distances. The builder's square went through numerous evolutions over the centuries, with most incarnations made of wood until the modern steel industry began to emerge in the late 16th century in Europe.

The first steel squares were seen as an improvement to increase the accuracy of the squares square. This, of course, is the primary importance of the square—to make and check square angles. The next natural evolution of the square was to mark the legs with scales to double as a rule. If we consider that the first steel squares were made for timber framers, one can see the benefit of having even a simple rule on the square to facilitate the layout of mortises and tenons in a parallel line along the length of the timber. The body and tongue width evolved as well to correspond to the standard mortise and tenon widths of 1-1/2 and 2 inches. This evolution took place prior to the advent of the metric system.

Soon after the introduction of accurate scales on the square, it became apparent that these could be used to designate the ratio of the rise to the run of rafters, and that by drawing a line connecting any two points on the two opposing legs of the square represented the hypotenuse of a right triangle. With this revelation, the builder's square soon began to be recognized for it's benefits in roof framing and began to be known as a carpenters' rafter square. The English began to use 1 foot as their base unit, with the rise in inches on the opposite tongue.

Evolution

The rafter square we are familiar with today began to be standardized in England in the 18th century with scales in inches. Carpenters during this period were trained to use the steel square to compute rafter lengths and angles by using the body to represent the run of the rafter using the standard base run of 1 foot, or 12 inches. The corresponding rise could be specified on the opposing tongue as inches of rise per foot of run.

By laying the square on the side of a beam and aligning the body on the 12 inch mark on the beams top face and the tongue on the number representing the ratio of the rise to the span (inches of rise per foot of run), the accurate level seat cut and vertical plumb cut could be made by marking lines along the body and tongue respectively. Perhaps the most valuable piece of information gained was that by measuring the distance from point A to B, being the hypotenuse of the right triangle, represented the length of the rafter per foot of run for any given pitch. These points could be measured with a rule and multiplied by the run in feet or inches, or stepped off along the beam using the square itself, or dividers, to accurately mark the full length of the rafter. In effect, the rafter square was the first usable calculator that could be used in the field by the common carpenter.

Once the square became recognized for it's geometrical properties representing a right triangle, the builders most experienced in geometry began to develop new and novel ways to use the square to arrive at measures and angles not easily achieved in the field and on-the-fly prior to this time. The mark of a good carpenter was judged in large part by his knowledge and competency in using the steel square, with the most competent carpenters capable of using the square to lay out compound hip and valley roof systems. Carpenters closely guarded this knowledge, as geometry and mathematics was still considered sacred even into the early 20th century. This may have been in part what prompted my father, a carpenter and cabinetmaker of over 40 years, to council me as I began to enter the trade to, "never tell anybody everything you know."

The Modern Square

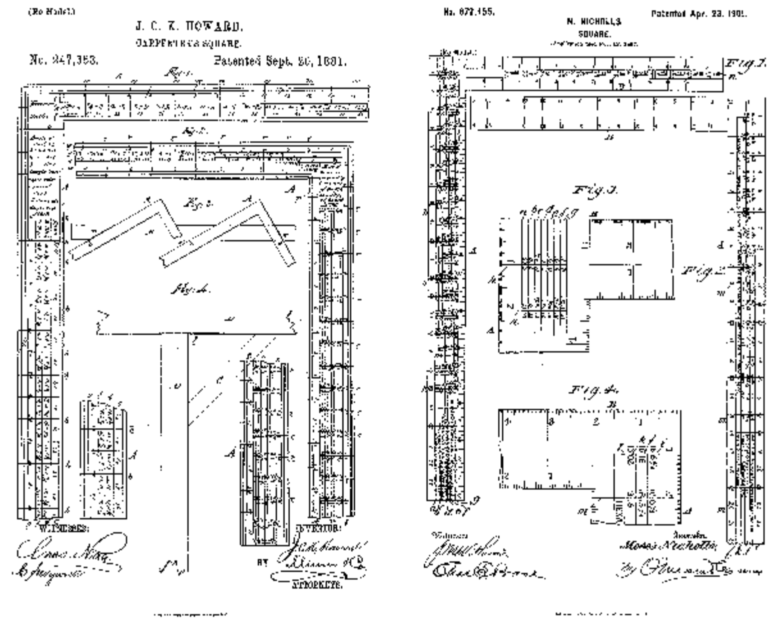
During the Industrial Revolution in the U.S., versions of the framing square began to appear with various tables imprinted on the blades. The earliest versions contained rudimentary tables to determine rafter lengths, board feet and diagonal brace lengths. The first U.S. patent for a framing square to include truly usable rafter tables was granted to Jeremiah C. K. Howard on September 20, 1881.

The Howard square resembled the common square as we know it today by incorporating a useful rafter table to compute common rafter lengths. This table, printed on the front side of the square, provided rafter lengths for the standard roof pitches of one-fourth, one-third and one-half, based on the building span. While the rafter table was at its time revolutionary, it was limited to only three common pitches and contained no information for determining hips and valleys. Though the Howard square provided information for only three common pitches, it paved the way for others to expand the possibilities of the square and to create more detailed and elaborate rafter tables.

While there were a few patented evolutions of the framing square in the years following Howard's patent in 1881, they were essentially elaborations of Howard's pitch and span table, limited only to standard common pitches.

The next truly unique evolution in the framing square was that patented by Moses Nichols, on April 23, 1901. The Nichols Square was the first to incorporate a rafter table that included computations for determining common rafter lengths from 2 to 18/12 and perhaps more ingeniously, it included tables for determining hip and valley rafter lengths. The Nichols square truly was revolutionary at its time, and proved to be the standard for framing squares. While there have been several patents granted for improved rafter squares in the years following Nichols' patent (and remarkably, none since 1929), none of these actually improved on Nichols' rafter table, but merely provided novel ways to perform essentially the same functions.

The modern framing square we find in hardware stores around the world to this day are essentially the same as the square invented and patented by Moses Nichols, back in 1901. The rafter table, which made the Nichols Square unique, remains unchanged today nearly 110 years later. That is, until now.



The Howard square, patented in 1881, was the first to have a comprehensive rafter table. The Nichols square, patented in 1901, was the first square to include compound hip & valley tables, and has remained the standard table imprinted on framing squares to this day, nearly 110 years later.

Chappell Universal Metric Square

The *Chappell Universal Metric Square* represents the first unique improvement in the framing square in over 110 years in general, and is truly revolutionary when it comes to the metric square. It is the first square (imperial or metric) to include rafter tables for both Unequal Pitched Roof Systems and 6 and 8 Sided Polygons. Its expanded, comprehensive hip and valley rafter tables provide a complete array of rotational angles to include backing/bevel angles and housing angles, which are available to the carpenter for the first time on the framing square.

The standard imperial carpenters square is based on the measure unit of 12, with the pitch given as the rise in inches over one foot of run. While attempts have been made to adapt rafter tables to the metric square in the past, the archaic and convoluted systems used made these tables impractical and cumbersome to use for the average carpenter. The *Chappell Universal Metric Square* is the first square to include rafter tables that can be readily applied to any roof system using metric units—and with roof pitches given in degrees.

Carpenters currently working in the metric system will readily adapt to the *Chappell Universal Metric Square*, as the metric scale is based on the unit of 10. The tables, however, are not limited strictly to the metric scale, but rather, are truly cross-platform, and can be applied to any unit of measure you desire. By using the factors given in any of the various rafter tables you will arrive at precise decimal angular and dimensional measures for that unit of measure. No conversions are necessary.

For the metric user there is, of course, no conversion required. However, the carpenter accustomed to imperial units and the rise over run convention may find the tables on the metric square (which are based on the degree of roof pitch) quite useful indeed. These tables work universally across all platform conventions, and can therefore be used with any unit of measure—centimeters, millimeters, inches or feet—resulting in decimal ratios and factors accurate for that unit of measure.

While this easy-to-use cross-platform decimal system is a recognizably advantageous feature, it is only a small part of the remarkable features embodied in the patented *Chappell Universal Square* rafter tables. These tables not only include complete angular and dimensional information for Equal Pitched hip and valley systems, but also for the first time in history, the *Chappell Universal Square* includes comprehensive tables for Unequal Pitched and 6 & 8 Sided Polygon roof systems—available to the carpenter for the first time in an easy-to-use format. The later truly are unique, as all previous versions of the framing square were limited only to the most basic information for equal pitched roof systems. Overall, the *Chappell Universal Metric Square* provides the first truly functional roof framing system available to the metric user since the framing square was first developed back in the days of the pharaohs.

The *Chappell Universal Metric Square* puts a wealth of knowledge right in the palm of your hand.

Features

The body (blade) of the *Chappell Universal 4560 Metric Square* has a width of 50 mm by 610 mm, and a tongue of 40 mm by 460 mm. The additional 50 mm in the length of the tongue over standard squares makes it more convenient when laying out steep pitched hip and valley rafters (as in steeples) by using the base constant of 424.26 mm on the tongue of the square as well as the body. Both the body and the tongue have this point highlighted, making it easy to layout hips and valley angles when using 300 mm as the base for the common runs.

The body and tongue on each side of the square are imprinted with comprehensive rafter tables to include polygon and both equal and unequal pitched roof systems for a broad variety of pitch and design conditions.

Description of Equal Pitch Rafter Table

The following is a line-by-line description of the equal pitched rafter table on the front side body.

Line Number 1
COMMON RAFTER RISE PER 1MM OF RUN

The front side body is imprinted with an equal pitched rafter table that gives comprehensive dimensional and angular information for both common rafter and hip & valley roof systems for pitches ranging from 15 to 60 degrees. Common Roof Pitches are specified in degrees along the body of the square. A base constant of 300 mm is commonly used by carpenters in the field as the run of the rafter, with the variable being the millimeters of rise over this constant run. This variable for any degree of pitch can easily be determined by using the factors along the first line of the Equal Pitched Table corresponding to the given degree of pitch.

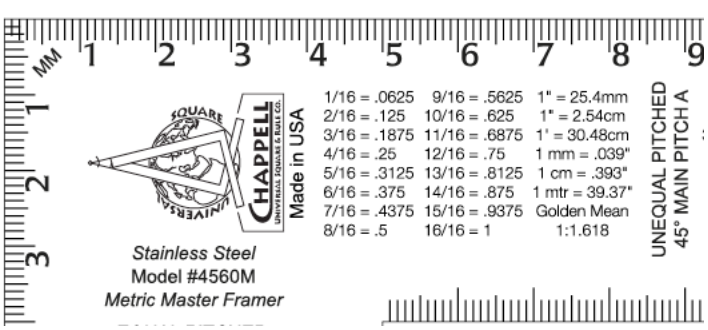
As an example, along the first line of numbers under 40° we find the value .8391. This is the ratio of the rise of the common rafter to every one unit of run. This may be 1 mm, 1 cm or 1 meter. For general roof layout we will be working most commonly with millimeters, so let's use millimeters throughout this discussion. This factor actually has significance for more than one aspect of the roof system, which will be discussed later, but in its primary aspect, this is the ratio of the common rafter rise per 1 mm of common rafter run.

To find the rise of the common rafter for a specific run, say 1630 mm, simply multiply the run times the given factor of .8391: 1630 x .8391 = 1367.733
We will most likely be using a pocket calculator to calculate a myriad of other aspects of the roof system, so it is best to work out all the calculations using the full decimal units. Rounding off to 2 or 3 decimal places can be done at the very end.

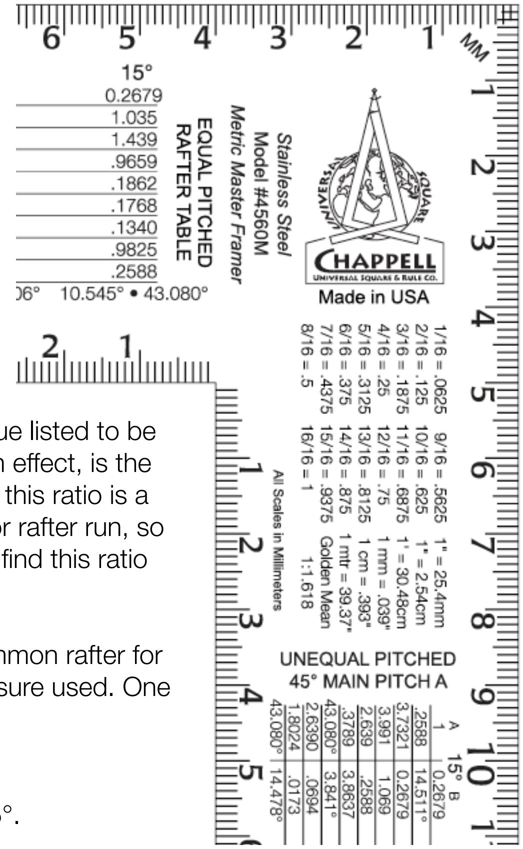
Angular Layout. If we are using 300 mm as our standard base run to facilitate the rafter layout, we can use the same factor on Line 1 to determine the number to use on the tongue of the square, that when opposing 300 mm on the body, will give us an accurate angular rafter layout for both the plumb and level cuts. In this case using 300 as the base we have:

300 x .8391 = 251.73

In this example we would use 300 mm on the body and 251.73 mm on the tongue to lay out the plumb and level cuts on the rafter. While 300 is a good standard to use, you could actually choose any point along the square body as the base run, and determine the opposing point on the tongue by simply multiplying by the given factor designated for the given degree of pitch.



The Chappell Universal Metric Square has a handy conversion chart on the front side tongue that allows quick conversions from decimal and fractional measure to the metric scale.



Line Number 2
LENGTH OF COMMON RAFTER PER 1MM OF RUN
• DIFF IN LENGTH JACK RAFTS PER 1 UNIT OF SPACING
• TOP CUT JACK RAFTER OVER 1

The data on Line 2 has significance and can be applied to the roof system in more than one way. Determining the COMMON RAFTER RISE PER 1MM OF RUN on **Line Number 1** was covered on the previous page. Let's begin here by defining the **Line Number 2**:

LENGTH OF COMMON RAFT PER 1MM OF RUN

The factors listed on this line in the columns below any of the degree markings from 15° to 60° give the ratio of the length of the common rafter per 1 millimeter of common run for a roof pitch corresponding to the degree. As an example, in the column under 55° we find the value listed to be 1.743. The degree corresponds to a roof pitch. The value in this row, in effect, is the ratio of the rafter run to the rafter length. In the example of a 55° pitch, this ratio is a constant of 1:1.743. This ratio remains true for any conceivable span or rafter run, so long as the common rafter pitch is 55°. As we move along the row we find this ratio changes depending on the given degree of roof pitch.

Multiplying the given rafter run by 1.743 results in the length of the common rafter for this example. This ratio remains constant regardless of the unit of measure used. One unit can be 1mm, 1cm, 1meter, 1 mile, 1 inch, 1 foot or 1 yard.

Example:
Assume we have a rafter run of 2700mm and the given roof pitch is 55°.

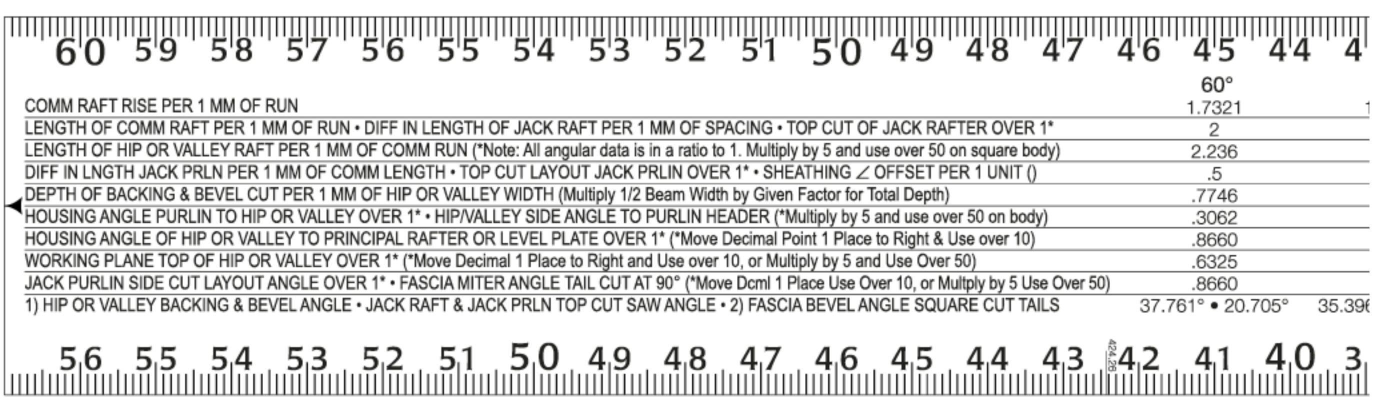
Rafter Length = 2700 x 1.743 = 4706.1

If we move down the row to the column under 30°, we find the value to be 1.156. The length of a rafter of the same run, 2700mm, with a pitch of 30° would be:

Rafter Length = 2700 x 1.156 = 3121.2

It is best to convert the measure to the smallest working scale with which you will be working (centimeters to millimeters, etc…) at the outset so as to prevent multiple conversions, which can lead to inadvertent errors.

Front Side Body
Equal Pitch
Rafter Table from
15° to 60°



DIFFERENCE IN LENGTH JACK RAFTERS PER 1MM OF SPACING

The second aspect of Line 2 relates to the difference in length of the jack rafters per 1 unit of spacing along the plate. In conventional construction rafter spacing is generally given as standards of 40, 60 or 120 centimeters on center.

Again, by using the base factor of 1 (1 millimeter, 1 centimeter, 1 inch or 1 foot), the *Universal Metric Square* allows one to readily understand the overall relationship of jack rafters to hip rafters to common rafters, as well as the relationships of the intersecting planes. It also makes it a simple step to calculate (and to understand the reason for) the difference in length of the jack rafters for any given spacing, at any roof pitch from 15° to 60°, in any unit of measure.

In any equal pitched hip or valley roof system with a corner angle of 90 degrees, the bisected footprint angle (angle of hip/valley to side walls in plan view) is 45 degrees. Therefore, every millimeter of spacing along one sidewall corresponds to an equal millimeter of spacing along the adjoining wall. Likewise, this spacing on one side corresponds directly to the run of the common rafter of the opposing side. Therefore, the difference in jack length per millimeter (1 unit) of spacing on equal pitched roof systems is equal to the length of the common rafter per millimeter (1 unit) of run.

Example:
Let's say we have a common pitch of 40° and a rafter spacing of 600 mm on center beginning from the corner of the building (zero point) so that the first jack rafter is spaced at 600 mm from point zero, and the second at 1200 mm from zero. The value in the column under 40° is 1.305. The length of the two jacks would be as follows:

Jack #1: 600 x 1.305 = 783mm

Jack #2: 1200 x 1.305 = 1566mm.

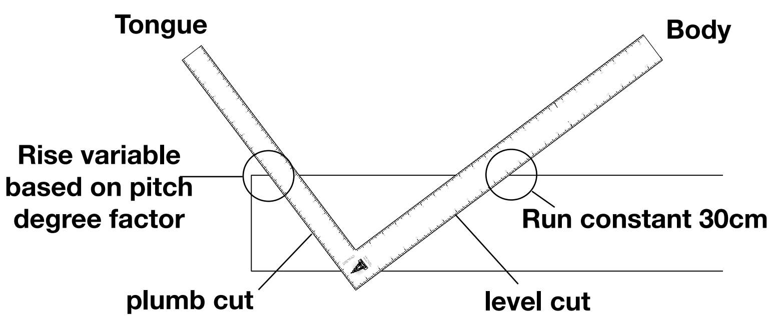
The first jack is exactly half the length of the second, therefore the difference in length of the jacks at 600mm spacing for a 40° common pitch is 783mm. Accurate results can be obtained for any conceivable spacing by using this ratio.

TOP CUT JACK RAFTER OVER 1

A jack rafter is a rafter in the common pitch that intersects the hip or valley rafter short of its full length. This may be from the plate to the hip or valley, or from the hip or valley to the ridge. The angle of intersection is in accordance with the angle of the common rafter to the hip or valley rafter.

The top cut of the jack rafter (and jack purlin) is therefore in direct relationship to the included roof angles (angles in the roof plane), which are determined by the right triangle created by the common rafter, hip or valley rafter and the top plate.

Using the Square to Lay Out Common Rafters



To lay out common rafters use 300 mm on the body side and the results calculated for the rise per unit of run on the tongue side. In our example for a 40° roof pitch:
300 x .8391 = 251.73

Marking along the body will lay out the horizontal level cut and marking along the tongue will lay out the vertical plumb cut.

The values given in the second line of the equal pitched rafter tables on the front body of the *Universal Square* specify the angular ratio of this angle to 1. We find that the second value in the column under 50° is: 1.506. The angle is therefore in the ratio of 1:1.506.

To mark the layout angle of the jack rafter (and also its complimentary angle for jack purlins), using the *Universal Square* simply move the decimal point over one place to the right and use this opposite 10cm on the tongue of the square.

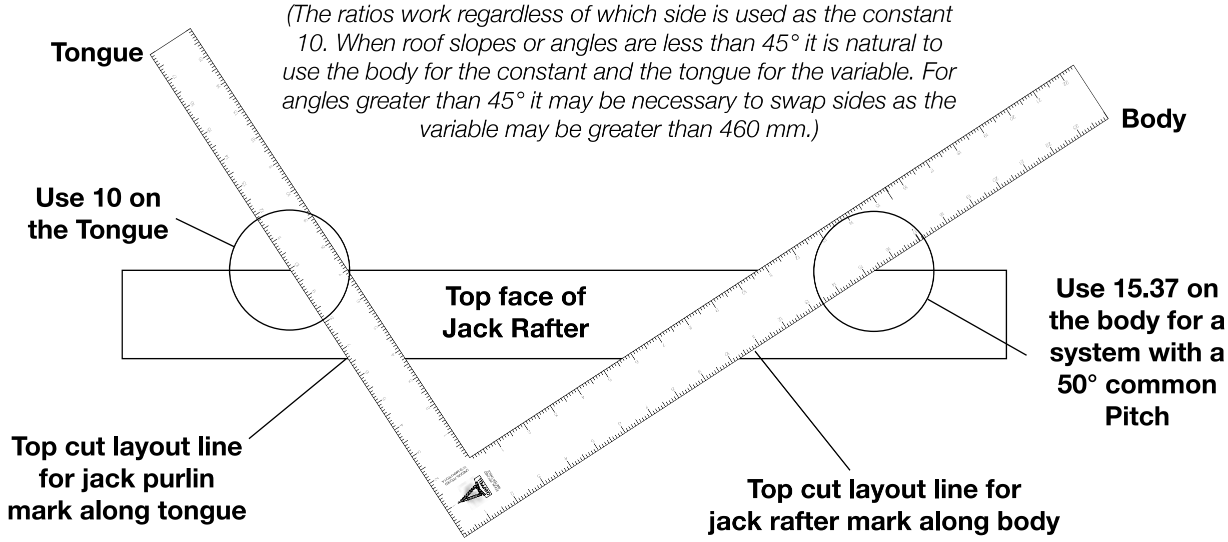
Example using the value at 50° = 1.506. Moving the decimal one place to the right becomes 15.06.

Therefore, the jack rafter top cut angle can be marked on the timber by using 15.06cm on the body, and 10cm on the tongue, and marking along the body of the square. This can be expanded to use a greater portion of the square by simply multiplying the factor by 30 or 50, and using the results over 30 or 50 centimeters on the body and tongue of the square: 30 x 1.506 = 45.18; 50 x 1.506 = 75.3

Top Cut Layout for Jack Rafters

Use the value on Line 2 by moving the decimal point one place to the right. In our example using a 50° common pitch use 15.06 mm on the body and 10 on the tongue. This can be expanded to use 30 or 50 cm as described above.

(The ratios work regardless of which side is used as the constant 10. When roof slopes or angles are less than 45° it is natural to use the body for the constant and the tongue for the variable. For angles greater than 45° it may be necessary to swap sides as the variable may be greater than 460 mm.)



Note: *The values given in the rafter tables of the* Chappell Universal Square *are expressed in a format that is intended to be easily used in-the-field by carpenters to lay out complex roof systems on-the-fly with nothing more than the* Universal Square *and a pencil. Even those with minimal math skills should be able to use the* Universal Square *effectively. However, there are multiple levels inherent to each value given. The description above, as well as those used throughout this booklet, give only the first level. As one uses the* Universal Square *some of these other levels will begin to unfold naturally, but in order to fully understand and use these advanced levels, one needs to first develop the ability to think three dimensionally and become conversant in trigonometry and the use of the scientific calculator.*

Just to give you a slight insight into these multiple levels, the single value given on line 2, as described here, can also be used to determine all of the values given in the totality of the rafter tables on the standard framing square. This includes the three aspects as described above, *i.e. 1) length of the common rafter, 2) difference in length of jack rafters, and 3) top cut of jack rafters. This, however, is only on the first level. Additional levels go beyond to include: 4) top cut jack purlin, 5) difference in length of jack purlins, 6) sheathing angle, 7) sheathing angle offset, 8) length of hip rafter per millimeter (or 1 unit) of common length, 9) working plane top of hip or valley (valley side cut), and 10) side cuts of jack rafters and purlins, etc... just to name a few.*

Line Number 3

LENGTH OF HIP OR VALLEY RAFT PER 1MM OF COMMON RUN

The values on Line 3 represent the ratio of the length of the hip or valley rafter to 1mm of common rafter run. Using this ratio readily gives the unit length of any hip or valley rafter corresponding to the common roof pitch degrees specified on the body of the Universal Square. This can be applied to any common run variable.

We find the value on line 3 in the column below 50° to be 1.849. This specifies that for each millimeter (or unit of 1) of common run the hip or valley length will be 1.849 millimeters. To determine the full-length simply multiply the total run by this given value. Example:

If the run is 4,500 mm and the common pitch is 50°, the equation would be as follows:

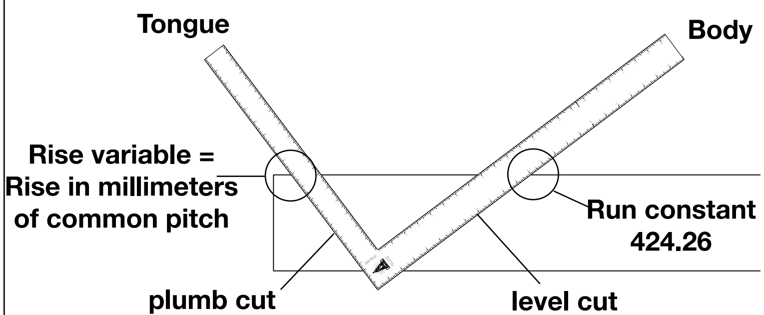
Factor ratio = 1.849

Common run of 4500

Hip/Valley length = 4500 x 1.849 = 8320.5

In this example the hip or valley rafter would be 8,320.5 mm.

Using the square to lay out Hip & Valley Rafters for Equal Pitched Roof Systems



The Chappell Universal Square has a special mark on the body of the square that designates 426.26 millimeters to assure accuracy in laying out hip and valley rafters.

To lay out hip & valley rafters use 424.26 on the body side and the common pitch rise in millimeters on the tongue side. If the common pitch is 40°, use 251.73 mm on the tongue and 424.26 on the body to lay out the hip or valley.

Marking along the body will lay out the horizontal level cut and marking along the tongue will lay out the vertical plumb cut.

Line Number 4

DIFFERENCE IN LENGTH JACK PURLINS PER 1 MM OF COMMON RAFTER LENGTH
• TOP CUT LAYOUT JACK PURLIN OVER 1 • SHEATHING ANGLE OFFSET PER 1 UNIT

DIFFERENCE IN LENGTH OF JACK PURLINS PER 1 MM OF COMMON RAFTER LENGTH

The values specified in row number 4 are in direct relation to the included roof angles in the roof plane and gives us the ratio as to the difference in length of the purlin per millimeter of common rafter length. Purlins are members that run parallel to the plate and ridge and perpendicular to the common rafters. Jack purlins are those that intersect with a hip or a valley. Because purlins run perpendicular to the common rafters the spacing is specified from eaves to ridge along the common rafter length. The value given under the corresponding roof pitch is based on the difference (reduction or increase) per millimeter, or unit, of common rafter length.

Using the example of a 50° pitch, we find the value given to be .6428.

This is to say that for every millimeter (or unit of 1) along the common rafter length, the jack purlin length changes .6428 mm. As an example, if we apply this factor to a purlin spacing of 1200 mm, we have:

1200 x .6428 = 771.36

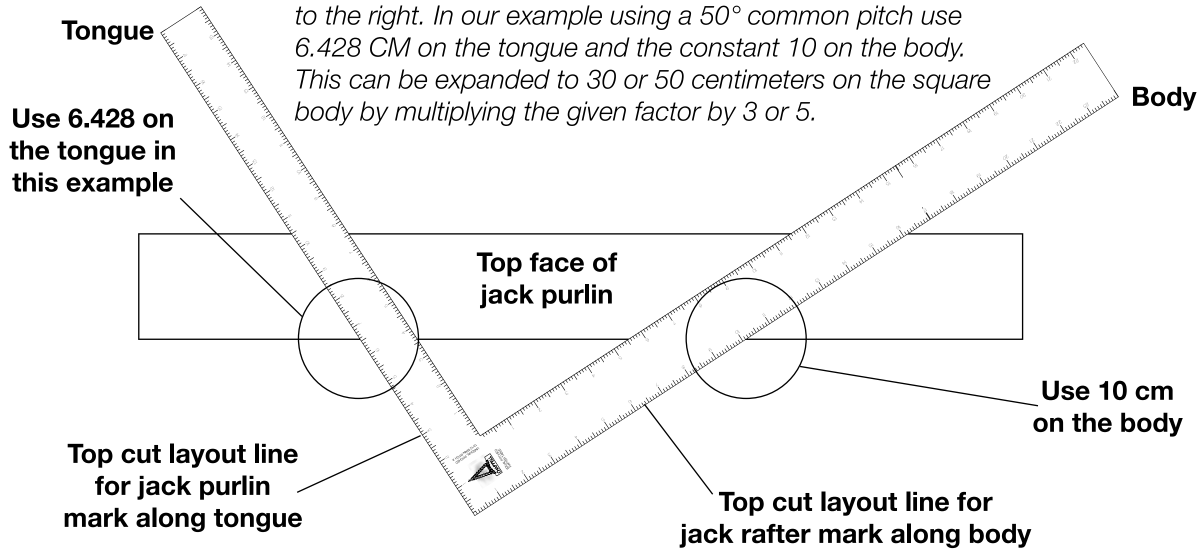
The difference in length of each jack purlin spaced at 1200 mm will be 771.36 millimeters.

TOP CUT JACK PURLIN OVER 1 MM

In addition to determining the jack purlin lengths, we can also use this value to determine the angle for the top cut layout of the purlin. This angle is often referred to as the sheathing angle in conventional construction as it is used to cut the angle of the sheathing into a hip or valley. In this case, we are using the value as an angular ratio to be applied to the square. To use this value to lay out the top cut of the purlin simply move the decimal point to the right one place, and use this over 10.

Top Cut Layout for Jack Purlins

Use the value on Line 4 by moving the decimal point one place to the right. In our example using a 50° common pitch use 6.428 CM on the tongue and the constant 10 on the body. This can be expanded to 30 or 50 centimeters on the square body by multiplying the given factor by 3 or 5.



Using the example of a 50° pitch, we find the value on line 4 to be .6428

Moving the decimal one place to the right becomes 6.428

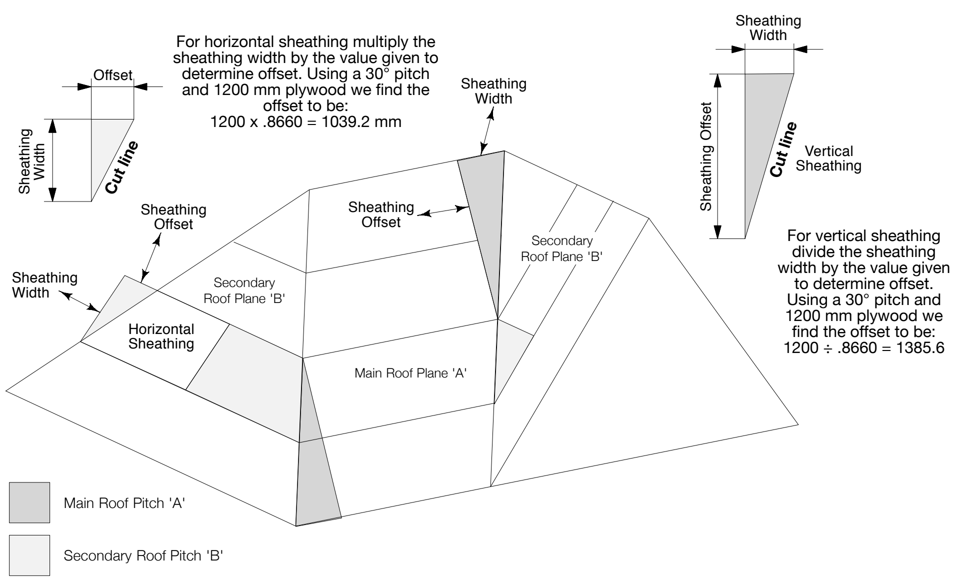
The jack purlin top cut angle can be marked on the timber by using 6.508 cm on the tongue, opposite 10 cm on the body, and marking along the tongue of the square. You will note by experimenting that this is a complementary angle to that used to determine the top cut of the jack rafter. In fact, these are similar triangles. As before, this can be expanded on the square to use 30 or 50 centimeters by multiplying the given factor by 3 or 5.

SHEATHING ANGLE OFFSET PER 1 MM OF SHEATHING WIDTH

Cutting boards or plywood to fit accurately into a hip or valley is more often than not accomplished by guesswork in the field. The value given on line 4 of the Universal Square puts this information right in the palm of your hand, taking away any guesswork.

The value given is the ratio of the offset angle per millimeter (or 1 unit length) of sheathing width. When running boards or plywood that run perpendicular to the common rafters into the hip or valley, simply multiply the width of the board or plywood by the given factor in the column under the appropriate roof pitch.

Using a 30° pitch as an example, we find the value of .8660 on line 4 in the column under 30°.



For a 200 mm board we find the offset measurement to be: 200 x .8660 = 173.2 mm

For 1200 mm plywood: 1200 x .8660 = 1039.2 mm

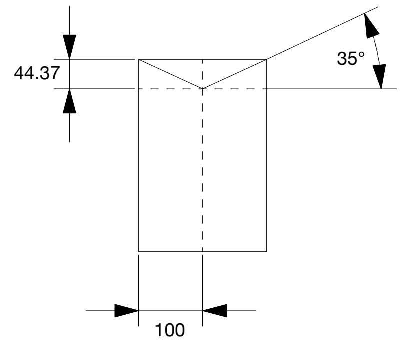
When the sheathing runs vertical from eaves to ridge, the sheathing offset measurement can be determined by dividing the sheathing width by the value given in the appropriate column corresponding to the roof pitch. As an example using an 200 mm board the equation would be: 200 ÷ .8660 = 230.946 mm

Line Number 5
DEPTH OF BACKING & BEVEL CUT PER 1MM OF HIP OR VALLEY WIDTH

The backing/bevel angle is the angle at which the two opposing roof planes intersect at the apex of the hip, or trough of a valley rafter, at a line along a vertical plane that passes through the longitudinal center of the hip or valley rafter. The depth of the backing/bevel angle, as measured perpendicular to the top face of the hip or valley, is a rotation of the angle in plane so that we can easily measure and mark the depth of cut on the side face of the actual hip or valley rafter.

The backing/bevel angle has many other implications in a compound roof system, especially concerning mortises and tenons projected from or into timber surfaces (in timber framing).

The values given in this table considers all rotations for any common pitch from 15° to 60° and provides the depth of the angle as measured perpendicular to the top face of the hip or valley. The value given for the depth of the backing or bevel angle is based on the ratio of depth to 1mm of beam width (or any unit of 1). Because the angles on a hip or valley rafter always generate from the center of the timber and slope toward the side faces, to determine the side face depth one must use this value over half the width of the beam.



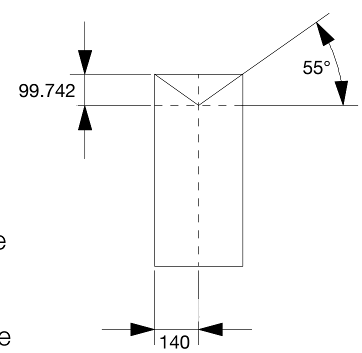
Example #1
100 x .4437 = 44.37

To make the correct calculation using these values, use the half-width of the beam as the base factor. If, for example, the common pitch was 35°, the value in the column on line 5 is listed as .4437, and using a 200 mm wide beam would make the half-width 100 mm we have:

100 x .4437 = 44.37

The backing/bevel depth in this example is 44.37mm.

In some cases you will need to make a bevel (angle) across the full width of the timber (as in cases where you have a hip roof plane passing into a valley gable plane (believe me, this happens). In this case, you will use the full beam width as the factor.



Example #2
140 x .7106 = 99.742

Multiply half the width of the hip or valley rafter by the value on line 5 to determine the depth of the backing angle

On Line 5, in the column under 55° on the body of the square, we find the value of .7106. This is the ratio of the depth of the backing/bevel angle to 1 for an equal pitched hip or valley system with a common pitch of 55°. Again, it makes no difference if the ‘1’ represents inches or centimeters, or any other unit of measure, the ratio is absolute.

If the unit of measure were 1 mm, then the depth of the backing/bevel cut would be .7106 mm for each 1 mm in width, from the center line of the beam to its side face for a roof system with a common pitch of 55°.

If a hip rafter has a width of 140 mm and a common pitch of 55°, use the following equation:

Determine ½ beam width: 140 ÷ 2 = 70

Multiply by given value: 70 x .7106 = 49.742

The backing/bevel depth would be 49.742 mm

If a timber needs to have a bevel or backing angle cut across the whole width of the plank or beam, the equation using the previous example for an 55° pitch would be:

140 x .7106 = 99.484 mm

Line Number 6
HOUSING ANGLE PURLIN TO HIP OR VALLEY OVER 1
• HIP/VALLEY SIDE ANGLE TO PURLIN HEADER

This is a very complicated and little understood element of compound roof framing and formulas to determine this angle have not existed through any means other than those used to determine the angles used on the Universal Framing Square.

When a purlin (a beam parallel to the plate) joins to a hip or valley there is a slight rotation that occurs due to the rotation of the bevel or backing angle that rotates the side face of the purlin incrementally from 90 degrees perpendicular to the top of the hip or valley rafter along it’s side face.

The values given in Line 6 of the rafter table represent the ratio of the purlin housing angle to 1, on the side face, off a line drawn perpendicular to the top face of the hip or valley. As in all other values used on the *Universal Square* relating to angular dimension, this is the ratio of the value given to 1.

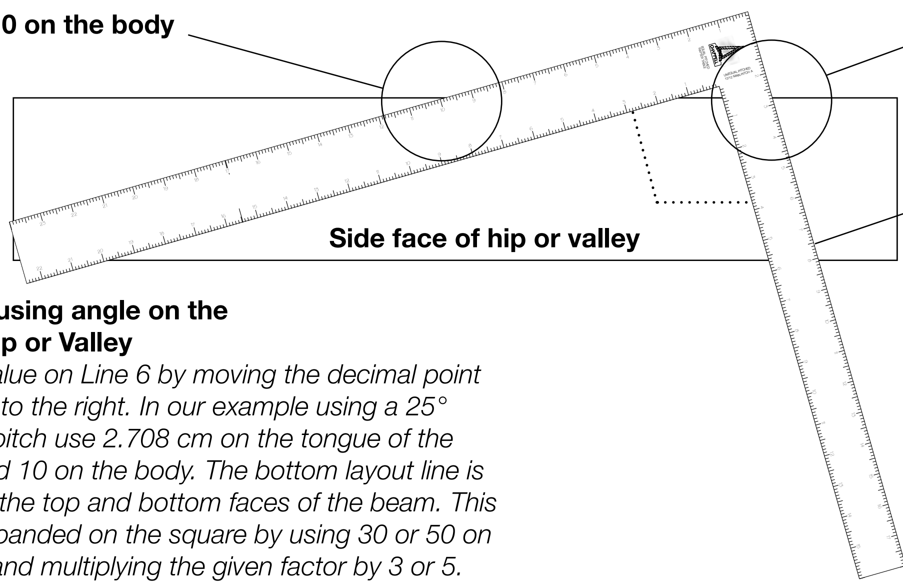
Using the example for a 25° pitch, we find that the value for the housing angle is .2708, giving a ratio of .2708:1

As this is an angular ratio, we can use it to lay out the angle along the side face of the hip or valley by using the same method as used previously by moving the decimal point one place to the right and using 10 on the opposing leg of the square. Moving the decimal from .2708 to the right gives 2.708.

Using this measurement on the tongue of the square and 10 on the body of the square (off the top face of the hip or valley) and marking along the tongue of the square will mark the accurate angle of the purlin housing angle. As before, we can use 30 or 50 on the body of the square by multiplying the factor by 3 or 5.

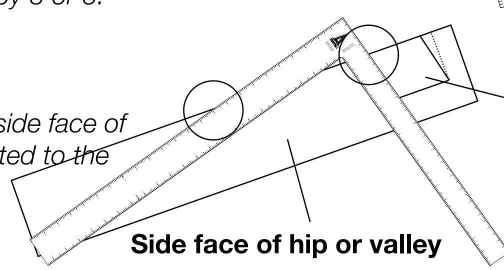
HIP/VALLEY SIDE ANGLE TO PURLIN HEADER

This is also the same angle that you would use for the side face layout of a hip or valley rafter that joined to the lower side face of a purlin header. A purlin header is one that has the top face in the same plane as the common roof plane.



Purlin housing angle on the side of Hip or Valley
Use the value on Line 6 by moving the decimal point one place to the right. In our example using a 25° common pitch use 2.708 cm on the tongue of the square and 10 on the body. The bottom layout line is parallel to the top and bottom faces of the beam. This can be expanded on the square by using 30 or 50 on the body and multiplying the given factor by 3 or 5.

Side face layout for hip or valley to purlin header
This angle is also the layout angle for the side face of a hip or valley rafter joining to a purlin rotated to the common roof plane (square to the top of common rafter).



Line Number 7
HOUSING ANGLE OF HIP OR VALLEY TO PRINCIPAL RAFTER OR LEVEL PLATE OVER 1

When a hip or valley rafter joins to the side face of a principal (common) rafter or a level horizontal plate, the sides of the hip or valley join to the common along a plumb line. The bottom face of the hip or valley however, joins to the common at a rotated angle relative to a level line. In many conventional situations this angle is often ignored, as it will be simply cut flush, nailed and covered. In timber framing, or when working with beams which will be exposed in a cathedral roof system, it is necessary to know this angle to make a fully recessed housing or to extend tenons on the valley and mortises on the principal rafter or horizontal plate. The value on Line 7 gives the factor to readily determine this angle.

Just as in the previous example, this is an angular rotation. Moving the decimal point one place to the right, and using this opposite 10 on the body of the *Universal Square* can perform the layout.

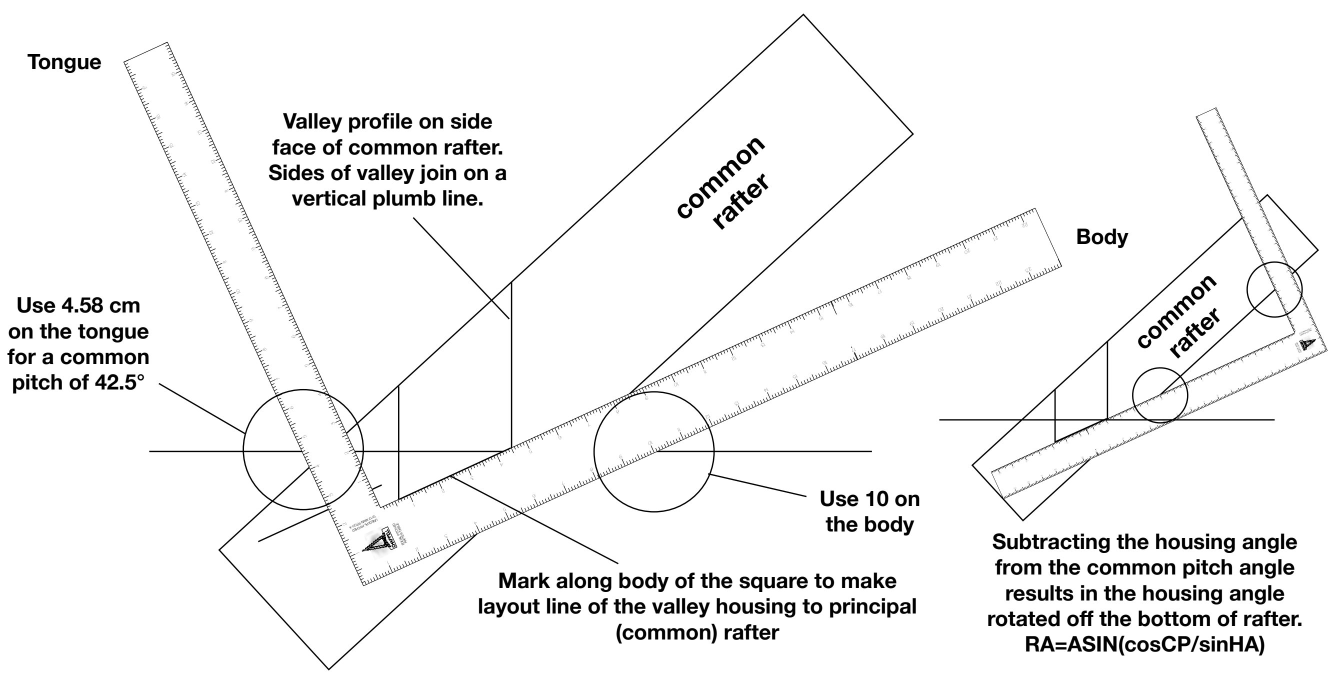
As an example, let's use the value we find in the column under 42.5°. The factor listed, .4582, is the ratio of the housing angle for a valley rafter in a roof system with a common pitch of 42.5°. The angle therefore, has a ratio of .4582:1

Moving the decimal point one place to the right we have 4.58, which will be used opposite 10. First, draw a level line across the face of the hip or valley rafter in the location of the joint. By then placing the square on this level line using 4.58 on the tongue of the square and 10 on the body, a line drawn along the body of the square will mark the accurate angle of the hip or valley rafter housing for the bottom of the rafter. The side faces join along a vertical plumb line.

The value given is the tangent of the housing angle. With a scientific calculator we can readily find the angle in degrees by using the inverse of the tangent. In this example for a 42.5° pitch, the housing angle is 25.882°. Subtracting this angle from the common roof pitch results in the housing angle from the bottom face of the common rafter: Common pitch 42.5° = 42.5° - 25.882° = 16.617°.

Housing angle bottom of hip or valley to principal rafter

Use the value on Line 7 by moving the decimal point one place to the right. In our example using a 42.5° common pitch we use 4.58 on the tongue and 10 on the body of the square along a level line across the face of the common rafter.



Line Number 8
WORKING PLANE TOP OF HIP OR VALLEY OVER 1

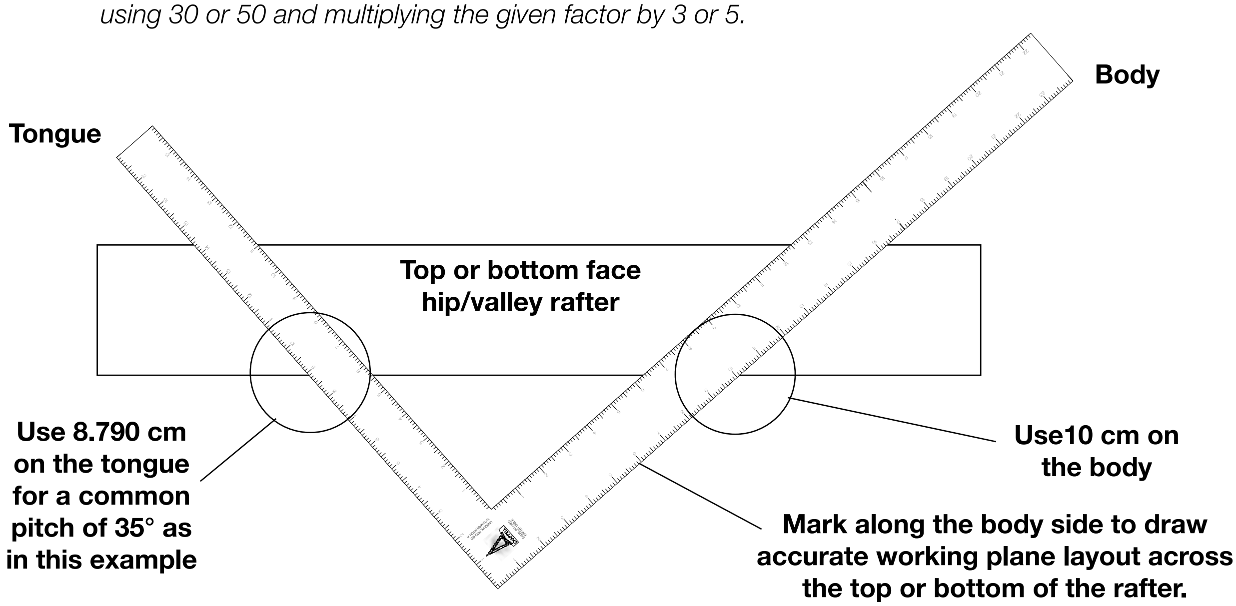
Generally, the last step in the process is to cut the actual backing or bevel cuts on the hip or valley. Prior to cutting the backing angle, the top face of the hip or valley is considered the working plane of the rafter. It will not become in true-plane until the backing/bevel angles are actually cut. In conventional construction, when using nominally dimensioned 2 by material for hips and valleys, it is often not even necessary to actually cut the backing or bevel angle on the beam. However, all of the layout must be transferred on and across this working surface prior to actually cutting the bevels and exposing the actual roof plane surfaces. For this reason, it is extremely helpful to know this rotated working plane so that accurate layout can be performed.

The value given on Line 8 of the *Universal Metric Square* gives the ratio of this rotated angle to 1 for all hip and valley roof systems from 15° to 60°. The process to determine this on the square is the same as the previous example.

Assume we are building an equal pitched compound roof system with a 35° pitch, and need to transfer the layout lines from one side of the hip/valley rafter to the opposite side. The process begins by first laying out a plumb line (or lines) on one side face, and then transferring across the top and bottom faces to the opposite side face. The value given on line 8 in the column under 35° is .8790. Just as in the previous example, this is an angular rotation in the ratio of .8790:1.

By moving the decimal point one place to the right, and using 10 as the opposite side, we can readily mark the angle across the top face of the hip or valley rafter by using 8.790 on the tongue of the square and 10 on the body and marking a line along the body to the opposite side of the beam. Plumb lines can then be drawn down the opposite face. Repeat the same step across the bottom face of the hip or valley rafter.

Laying out the working plane angle across the top face of hip or valley rafter
Use the value on Line 8 by moving the decimal point one place to the right. In our example using a 35° common pitch we use 8.790 on the tongue and 10 on the body. Mark along the body of the square to draw angle. This can be extended on the square by using 30 or 50 and multiplying the given factor by 3 or 5.



Line Number 9
JACK PURLIN SIDE CUT LAYOUT ANGLE OVER 1
• FASCIA MITRE ANGLE WITH TAIL CUT AT 90°

The purlin side cut angle, just as the purlin-housing angle, is a result of a rather complicated rotation relating to the valley pitch and the backing angles. To determine this angle through math alone requires not only strong geometry and trigonometry skills, but also a strong working experience and understanding of compound roof systems—all wedded with a talent to imagine and envision 3 dimensional structures in your mind.

Lacking this, no need to worry. Line 9 on the front side body of the *Chappell Universal Metric Square* gives the ratios of the purlin side cut angle for any equal pitched compound roof system from 15° to 60°.

Again, this is an angular ratio and to use it we will repeat the basic process as the previous example.

In this example, let's assume we are constructing a compound roof system that uses a 25° common roof pitch. On line 9 in the column under 25°, we find the value of .4226.

This is the angular rotation of the side cut angle in a ratio of .4226:1.

To apply the angle to the purlin, we must move the decimal one place to the right and use this over 10.

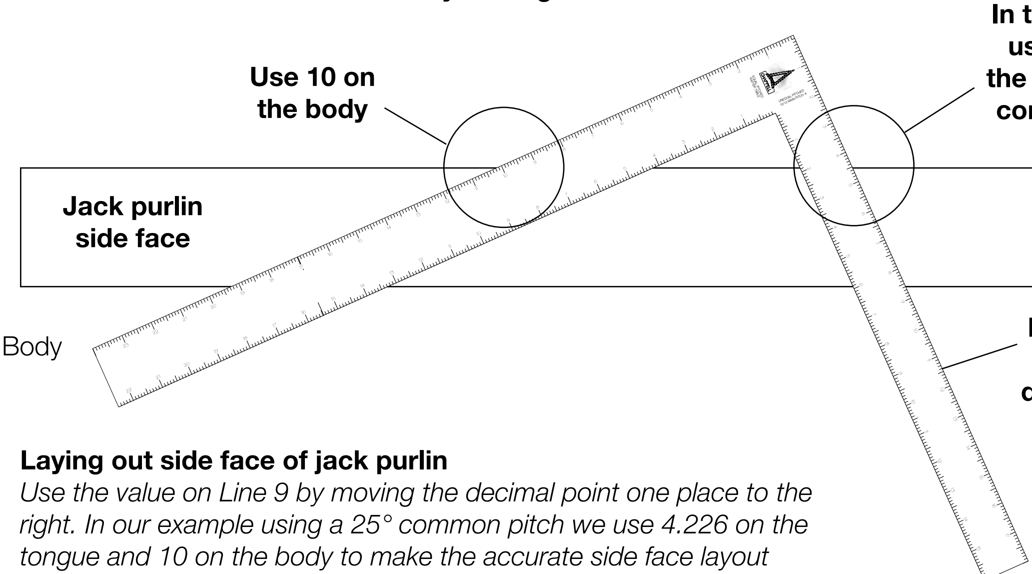
In this example, 4.226:10.

To lay out the purlin place the square on the side face with 4.226 on the tongue and 10 on the body. Drawing a line along the tongue of the square will mark the accurate purlin side cut angle.

FASCIA MITRE ANGLE WITH TAIL CUT AT 90°

This same angle (as described above) is used to lay out the face of a mitered facia board joining to a hip or valley when the tails of the common rafters are cut at 90 degrees (square cut) to the top of the rafter.

The saw set angle used to cut along this layout line to make the mitered saw cut is given as the first item on line 10 of the Equal Pitch Rafter Table on the front side body of the Universal Metric Square.

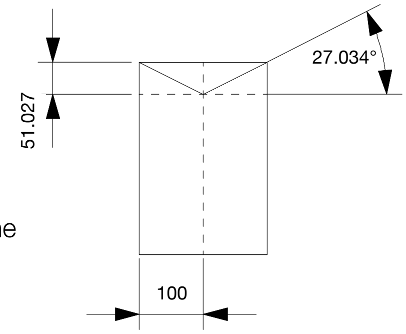


Laying out side face of jack purlin
Use the value on Line 9 by moving the decimal point one place to the right. In our example using a 25° common pitch we use 4.226 on the tongue and 10 on the body to make the accurate side face layout across the side face of the purlin. Mark along the tongue of the square. This can be extended on the square to use 30 or 50 by multiplying the given factor by 3 or 5, and using this on the tongue of the square.

Line Number 10
1) HIP OR VALLEY BACKING & BEVEL ANGLE • JACK RAFTER AND PURLIN TOP CUT SAW ANGLE
2) FASCIA BEVEL ANGLE SQUARE CUT TAILS

1) HIP OR VALLEY BACKING/BEVEL ANGLE

The key to successful compound roof framing is to know and to understand the significance of the backing and or bevel angle (backing for valleys and bevel for hips). While there are a few shortcuts to determining this angle, the normal approach requires calculations in multiple rotations that require both strong math and visualization skills. For this reason, the backing angle has remained a little understood aspect of compound roof framing and a sort of mystery throughout building history. In timber framing, the backing angle becomes one of the most important elements to understand, as it is a key to understanding the design, layout and execution of compound mortises and tenons.

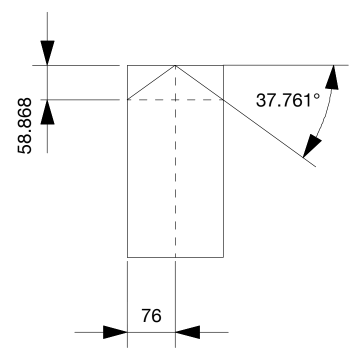


Backing angle on a valley rafter for a roof system with a 40° common roof pitch

The *Chappell Universal Metric Square* essentially takes the mystery out of the backing angle and puts it at hand and ready to use for any compound roof system with a pitch from 15° to 60°.

The 10th and bottom line on the front side body of the square gives the backing angle directly in degrees. We find in the column under 60° that the backing angle for a 60° equal pitched compound roof system is 37.761°. Under 40° it is 27.034°, and 45° it is 30°. It is as simple as that.

This angle will be used in a number of different applications in the roof system in various forms, but in its fundamental form it will be used as the saw set to cut the backing or bevel angles on the hip or valley. The depth of the backing angle, which is used to mark the line along the length of the hip or valley, can be found on the *Universal Metric Square* as well, and was covered under the heading for Line 5 in this section.



Bevel angle on a hip rafter for a roof system with an 60° common roof pitch

JACK RAFTER AND PURLIN TOP CUT SAW ANGLE

The backing angle is also used as the top saw cut angle on the top of the jack rafters and purlins. This is most commonly applied to the jack purlin more than to the jack rafters, though this angle applies to both equally.

Jack rafters are commonly laid out and cut along a plumb line on their side face because the angle of rotation (bisected footprint angle) in equal-pitched compound roof systems is always 45°. For this reason, sawing on the side face along a common pitch plumb line with the saw set to a 45 degree angle is the most direct and easiest approach. For larger timbers it may be necessary to lay out on all 4 faces and saw around the timber. In this case, the top cut saw angle of the jack rafter would be set to the backing angle and the top layout line would be in accordance with the previous description under the heading of Line Number 2.

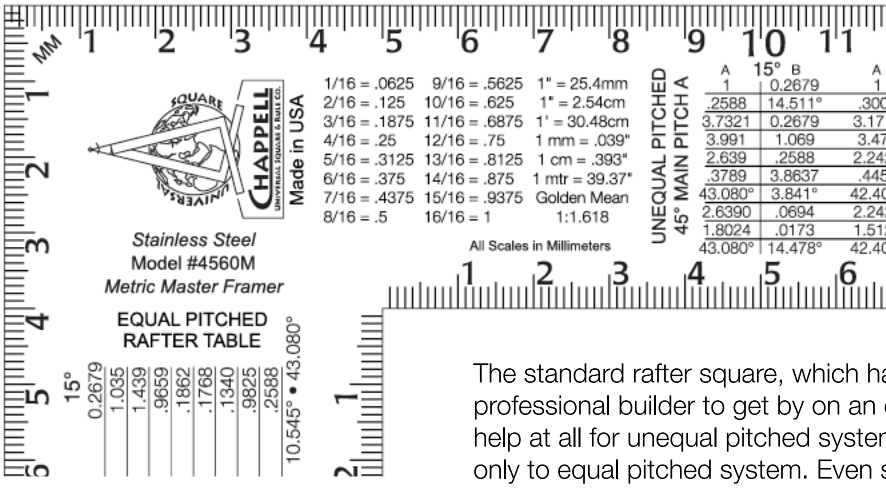
2) FASCIA MITER SAW CUT ANGLE TAILS AT 90 DEGREES

The third value given on line 10 of the Equal Pitched Rafter Table is the fascia miter saw cut angle used to cut the miter angle on fascias along the layout line as described on line 9. This is the second value given on line 10, and its value is given as the degree of the cut directly. This holds true for all roof systems when the common rafter tails are cut at 90 degrees to the top face of the rafters (perpendicular to the roof plane).

Using the example for a 30° roof pitch we find on line 10 in the column under 30°, two values. The first is 20.705°. This is the degree of the backing angle as described above. The second value is 37.761°. This is the degree of the saw cut angle for the fascia mitre cut when the tails of the common rafters are cut at 90 degrees to the roof plane. The first step is to lay out the fascia face as described on the previous page for the value on line 9, and then set your saw to the angle given on line 10. The result will be a perfect mitered cut.

When the rafter tails are cut plumb, the miter angle for fascias are equal to the bisected footprint angle.

UNEQUAL PITCHED HIP & VALLEY RAFTER TABLE



Front Side Tongue
Unequal Pitch Rafter Table
45°Main Pitch
with Secondary Pitches
listed from
15° to 60°

Unequal pitched hip and valley roof systems have always been a great challenge to all but the truly seasoned and experienced builder. Unequal pitched roof systems are often called ‘bastard roofs’, and for good reason. There seemed to be no rules or standard approach that could be applied to get even the most experienced carpenter by.

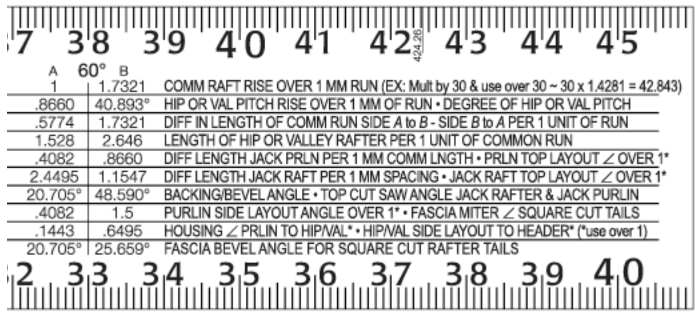
The standard rafter square, which has just enough information for a professional builder to get by on an equal pitched roof system, proved no help at all for unequal pitched system, in that the values in the tables apply only to equal pitched system. Even still, this system was never available in a truly usable metric square.

The *Chappell Universal Metric Square* for the first time unravels the mystery of the bastard roof by providing practical and easy-to-use Unequal Pitch Rafter Tables that unfold all of the necessary angles, dimensional ratios and member lengths necessary to build a bastard roof system. This is the first time since man started to build using a rafter square more than a millennia ago that this information has been made available, and absolutely the first time to be available on a framing square.

The main problem with unequal pitched roof systems regarding a concise and logistical table is that there are an innumerable number of combinations possible. For every possible main roof pitch there is an equal number, and unique, set of angular rotations on the opposing or secondary roof based on the combination of the principal and secondary roof pitches. This necessitates a different table for each main roof pitch.

If the main pitch is a 45°, it is possible to have a secondary pitch of anywhere from 10° to 70° or more. More commonly this may range from a 15° to 60°. If the main roof pitch changes to 40°, then a completely new set of secondary roof angles and ratios must be developed. With only so much room on the framing square, the *Chappell Universal Metric Square* has included two tables (one on each tongue), each with a different principal or main roof pitch. The table on the front side tongue has a table reflecting a 45° main roof with secondary pitches from 15° to 60°. The table on the backside tongue is for a main roof pitch of 30° with secondary roof pitches of from 15° to 60°. While the tables specify main roof pitches of 30° and 45°, the secondary pitch can be considered the main roof pitch in all examples with the same accurate results. This provides up to 46 specific options for the most common combination of roof pitches.

Front Side Unequal Pitch Rafter Table
The front side tongue of the *Chappell Universal Metric Square* has an Unequal Pitch Rafter Table that uses a base or Main Pitch of 45°, with secondary roof pitches from 15° to 60°. There are 2 columns in each row below the degree markings. These are marked A and B from left to right above the columns.



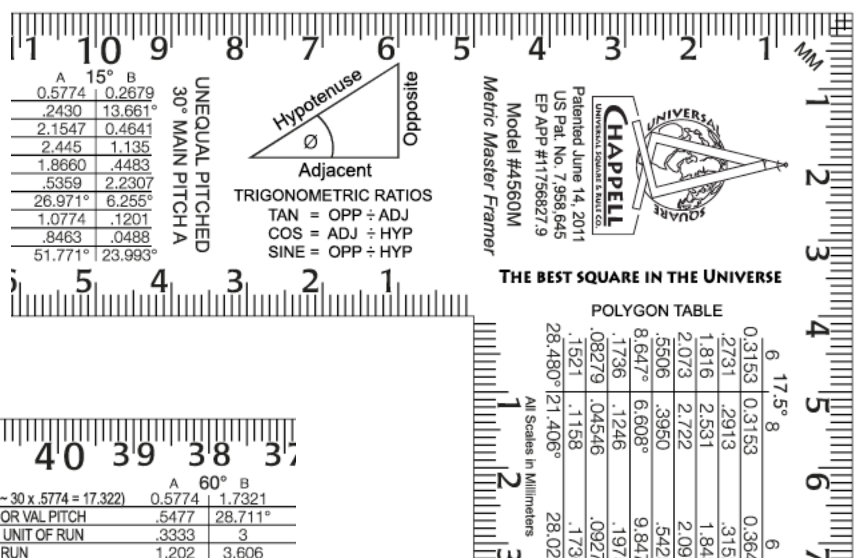
Front side unequal pitch table 45° Main Pitch

The column marked A gives the pertinent values as they relate to the Main Roof Pitch, which in this table is a 45° pitch. The 45° pitch is a constant in this table. The variable is the pitch of the Secondary Roof Pitch.

The column marked B gives the pertinent values for the secondary roof pitch, in accordance with the degree marking above the columns. For instance, the values in column B under the 35° would be relative to an unequal pitched roof system with a main pitch, A, of 45°, and a secondary pitch, B, of 35°. The values only hold true for a pitch combination of 45° and 35°, just as the values under the 50° hold true only for a pitch combination of 45° and 50°. You may flip this juxtaposition and consider 50° to be the main pitch and 45° the secondary pitch with equal accuracy—so long as you maintain the A to B orientation pertaining to the values given. In other words, the values under column A will remain relative to a 45° pitch in any situation.

Back Side Unequal Pitch Table
The backside tongue of the *Universal Square* has a similar scale. The only difference being that the base or Main Roof Pitch (values for A) are based on a 30° pitch. All of the value factors and ratio/dimensional rules, row-by-row and column-by-column used in this table are the same as those used on the front-side tongue scale.

Back Side Tongue Unequal Pitch Rafter Table 30° Main Pitch with Secondary Pitches listed from 15° to 60°



The chart showing the Trigonometric Ratios on the Back Side Heel is a handy reminder of the relationships of the Sine, Cosine & Tangent in a Right Triangle.

Line 1
COMMON RAFTER RISE OVER 1 MM of RUN

The common rafter rise in a bastard roof system is most easily determined by first calculating the rise of the Main Roof Pitch. The Secondary Roof Pitch will share this same rise, though the run will be different. Using the factors on Line Number 1 of the Unequal Pitched Rafter Table, one can quickly find the numerating factor stated as the millimeters of rise per millimeter of run for both roof pitches in a bastard system.

To determine the common rafter layout angle for the main pitch, simply multiply the standard run, 300 mm, by the factor given on Line 1. In a 45° roof system the rise is always equal to the run. Therefore, under column A on the front side tongue with a table for a 45° Main Pitch, we find the numerator to be 1 for all roof pitch combinations. Column B specifies the rise per millimeter of run for the secondary roof pitch for this roof pitch combination. These same relationships apply to the table on the backside tongue of the square, which is developed based on a 30° Maine Roof Pitch. Examples of how to apply these factors follows:

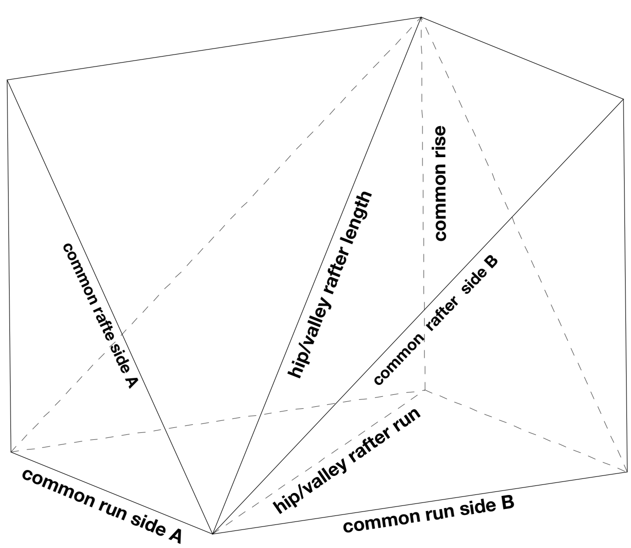
Common Pitch A = 45° = 300 x 1 = 300. Use 300 on the body and 300 on the tongue for the layout angle.
Common Pitch B = 25° = 300 x .4663 = 139.89. Use 300 on the body and 139.63 on the tongue for layout.

Line 2
HIP OR VALLEY PITCH RISE OVER 1 MM of RUN
• DEGREE OF HIP OR VALLEY PITCH

HIP OR VALLEY PITCH RISE OVER 1 MM of RUN

When working with equal pitched roof systems determining the angle of the hip or valley pitch is a simple step. Simply use the millimeters of rise per 300 millimeters of run over 424.26 mm instead of 300, and you have the valley level and plumb cuts. The tangent of this angle can also easily be determined by dividing the millimeters of rise by 424.26. Knowing the tangent, one can quickly determine the pitch angle in degrees with a pocket scientific calculator. Ready to move forward in a few moments.

Working with unequal pitches however is a completely different process and many a carpenter have a bald spot above their right ear from scratching their head in wonder just how to calculate this pitch. The *Universal Metric Square* for the first time solves this perplexing problem and within moments virtually anyone with only rudimentary math and or building skills can begin to layout an unequal pitched roof system with the *Chappell Universal Metric Square*.



Determining Unequal Hip & Valley Pitches

The drawing to the left provides one of the best views to help visualize and understand the relationships of the various angles and intersecting planes in a hip or valley roof system. In any compound roof system, the relative angles are identical regardless if it is a hip or a valley system. The only difference is that the angles are inverted between hip to valley systems. In this drawing, the dashed lines illustrate the relationship of the hip/ valley center line as it relates to a hip roof system. The solid lines illustrate the same to a valley roof system. One can see however, that it is all one cogent system.

The second line of the Chappell Universal Square *provides the hip or valley pitch directly in degrees and as a ratio to the rise per millimeter of run for a broad array of unequal pitch roof combinations.*

Line 2 of the Unequal Pitch Rafter Table relates only to the hip or valley rafter pitch. The hip or valley pitch, along with the common pitch rise, are the only aspects of a compound roof system that is shared by both roof pitches. The value in column A specifies the ratio of the hip or valley pitch rise per millimeter of run. As stated, both common pitches and the hip or valley pitch always share the same rise. The value in column B is the hip or valley pitch angle in degrees.

As an example, in the column A under 35° on the front side tongue, we find a value of .5736. This is the ratio of the hip or valley rise, per one millimeter (or unit) of run. To apply this value to the framing square, once again, move the decimal place to the right one place (5.736) and use this on the tongue over 10 on the square body. Marking along the body of the square will designate the level line and marking along the tongue will designate the plumb line. You can expand this ratio on the square by simply multiplying this factor by 2, 3, 4 or 5 and using the results on the tongue over 20, 30, 40, or 50 centimeters on the square body. In practice, use a number that best suits your needs.

Let's take another example. In column 'A' under 40°, we find the value .6088. This specifies that for every millimeter (or any unit of one) of the hip or valley rafter run, the vertical rise is .6088 millimeters. Moving the decimal one place to the right we have 6.08 centimeters. By using 6.08 cm on the tongue and 10 cm on the body, we can readily layout the hip or valley level and plumb cuts on the rafter. This would hold true for any unequal pitch roof with a combination of 40° and 45° pitches, regardless of which pitch was considered the Main Pitch.

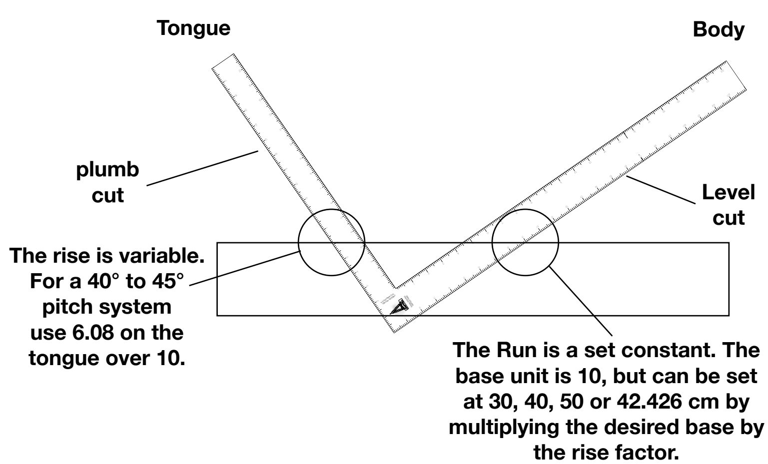
It is usually necessary to extend these numbers on the square so as to cover the full cross section of the timber. This can easily be accomplished by multiply the given factors by any rational number within the parameters of the scale of the square so as to maximize the use of the full body and tongue. It is common to use 300 mm as the standard base run for common pitches, and 424.26 mm as a standard for hip and valley pitches. There is a special mark on the *Chappell Metric Square* at 424.26.

DEGREE OF HIP OR VALLEY PITCH

The values on Line 2 under column B specify the hip or valley rafter pitch in degrees. This value is correct based on the combination of the Main Roof Pitch and the Secondary Roof Pitch as specified under the specific degree column. As an example:

In column B under 25° we find the value of 22.910°. This is the angle of the hip or valley rafter for an unequal compound roof system with combined common roof pitches of 25° and 45°. These angles hold true regardless of the buildings footprint dimensions, width, depth or rafter run or span.

Using the Universal Square to lay out Hip & Valley Rafters for Unequal Pitched Roof Systems



To lay out unequal pitched hip & valley rafters using the Universal Square use 10 on the body as the constant and the value given on Line 1 of the Unequal Pitch Rafter Table on the tongue by moving the decimal point one place to the right. Under the 40° on the front side the value given is .6088. In this case you would use 6.08 on the tongue of the square and 10 on the body to mark the hip or valley pitch angle.

Marking along the body will lay out the horizontal level cut and marking along the tongue will lay out the vertical plumb cut.

Line 3
DIFFERENCE IN LENGTH OF RUN
SIDE A TO SIDE B—SIDE B TO SIDE A—PER 1 UNIT OF RUN

The values given on Line 3 of the Unequal Pitch Rafter Table give the difference in the runs of common *A* to common *B*, and vise versa. In many Unequal Pitched compound roof designs only one of the common runs is given and the other run needs to be determined. Using the value given in the 3rd line of the ***Universal Metric Square*** will give the ratio factor to determine the opposing common run from either side *A* or side *B*, depending on which is the given side.

The value under column *A* gives the ratio of the common run of side *A* to Side *B*. If side *A* is known, simply multiply the given run by the value shown under *A* to find the run of common *B*. If the run of side *B* is the given, multiply this by the value under *B* to find the run of side *A*.

Using as an example a roof system with a Side *B* secondary common pitch of 40° and a Main Pitch *A* common run of 5000 millimeters, we find that:

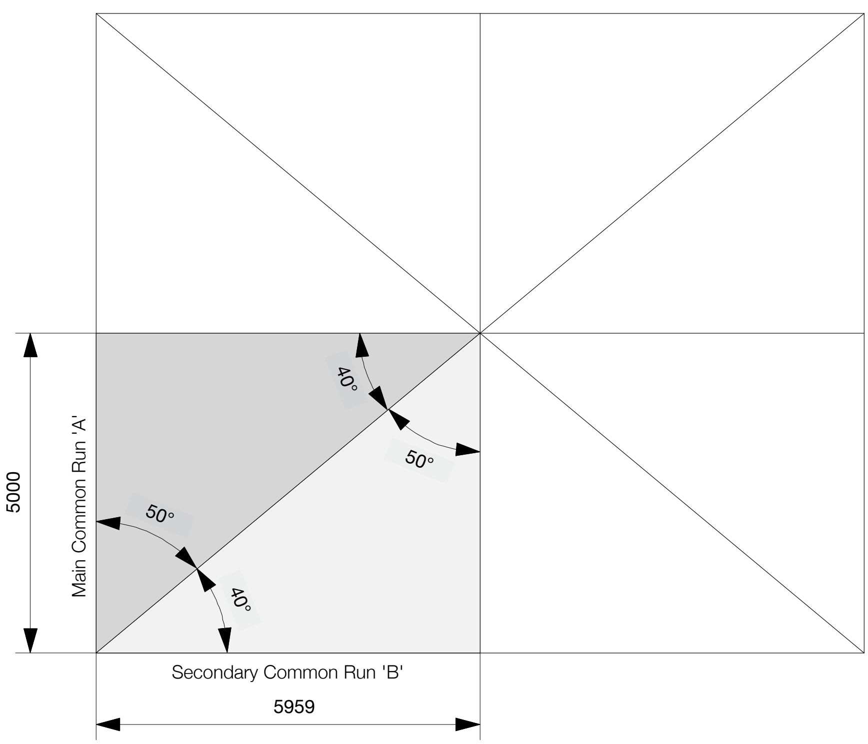
Side A factor = 1.1918; Side B factor = .8391

Side A run = 5000 x 1.1918 = 5959 Side B run = 5959 millimeters

If we reverse the equation and multiply the length for side *A* by the value under *B* we have:

5959 x .8391 = 5000 millimeters

The calculations can be made in any unit of measure with complete accuracy.



The values on line 2 give the ratio of the lengths of the common rafter runs for sides A & B

Bisected Footprint Angles for Unequal Pitched Roof Systems
Equal pitched roof systems have a bisected footprint angle of 45° because the common pitches share the same rise per foot of run. The bisected footprint angle for unequal pitched systems are based on the ratio of the lengths of the sides. This is dictated by the variance in the degree of common rafter pitch and the run.

Line 4
LENGTH OF HIP OR VALLEY PER 1 UNIT OF COMMON RUN

The values given on Line 4 of the Unequal Pitch Rafter Table give the length of the hip or the valley rafter per unit measure (any unit of 1) of common rafter run for both sides A and B.

As an example, if the secondary pitch were 25°, the ratio of the common run A, to the length of the valley would be 1:2.569. For side B, it would be 1:1.198.

Lets say that we have a roof system with the Main Pitch A of 45° (the base standard for this table) and the secondary pitch of 35°. Assume also that the given run of the Main Pitch, A, is 3800 millimeters.

In the column under 35° we find the value of 2.010 for side A, and 1.407 for side B. With this information, we can find the length of the valley from either side using the following equations:

Run of Main Pitch A = 3800 millimeters

Length of valley from common A = 3800 x 2.010 = 7638 millimeters

We can confirm that the value given under B is correct as well by going back to the values found on Line 3 previously described to find the common run of side B.

We find that the factor in column A in **Line 3** is 1.4281. This states that the length of common run B, with a given secondary roof pitch of 35° is 1.4281 times longer than that of run A.

Run of Secondary Pitch B = 1.4281 x 3800 = 5426.78

The run of side B is 5426.78 millimeters.

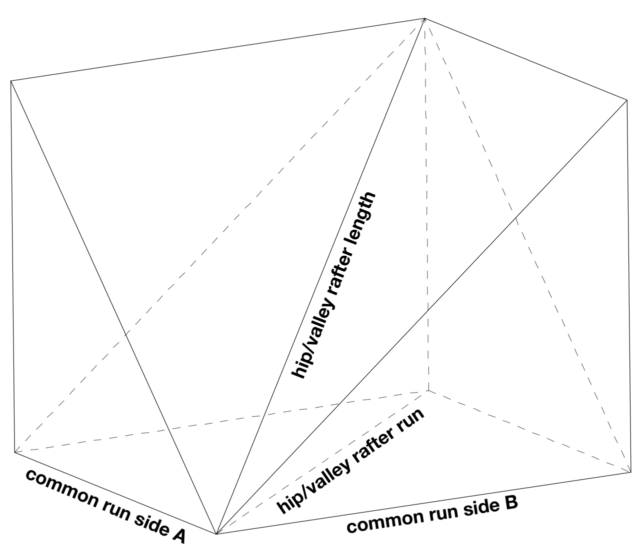
Multiplying this by the factor given on Line 4 for side B, 1.407, we find:

5426.78 x 1.407 = 7638

The results are the same.

Length of Hip or Valley Per MM of Common Run

The values on line 4 under column ‘A’ give the ratio of the length of the hip or valley rafter per 1 unit of common run from side A.



The values on line 4 under column ‘B’ give the ratio of the length of the hip or valley rafter per 1 unit of common run from side B.

Line 5
DIFFERENCE IN LENGTH OF JACK PURLIN PER 1 MM OF COMMON LENGTH
• PURLIN TOP LAYOUT ANGLE OVER 1

DIFFERENCE IN LENGTH OF JACK PURLIN PER 1 MM OF COMMON LENGTH

The values on Line 5 give the ratio of the length of the jack purlins per millimeter (or 1 unit length) of common rafter length. Since purlins run perpendicular the common rafter, their spacing is measured from the plate or ridge along the common rafter. The following is an example of how to use these factors to determine the difference in length based on the spacing and the overall purlin length.

On Line 5 on the front side tongue in the column under 30°—which specifies that the *Secondary Pitch B* is 30°, and the *Main Pitch A* is 45°—we find the factor relative to the *Main Pitch A* to be 1.2247. The factor relative to *Secondary Pitch B* in this column is .5. This simply states that the difference in the length of the purlin in the roof plane relative to *Pitch A* is 1.2247 millimeters for every millimeter of spacing along the common rafter; and .5 mm for every millimeter of spacing for purlins in the roof plane relative to *Pitch B*.

If we were to have purlin spacings of 800 mm on center on both sides *A* and *B*, The difference in length between each purlin would be as follows:

Pitch A = 1.2247 x 800 = 979.76 mm; Pitch B = .5 x 800 = 400 mm

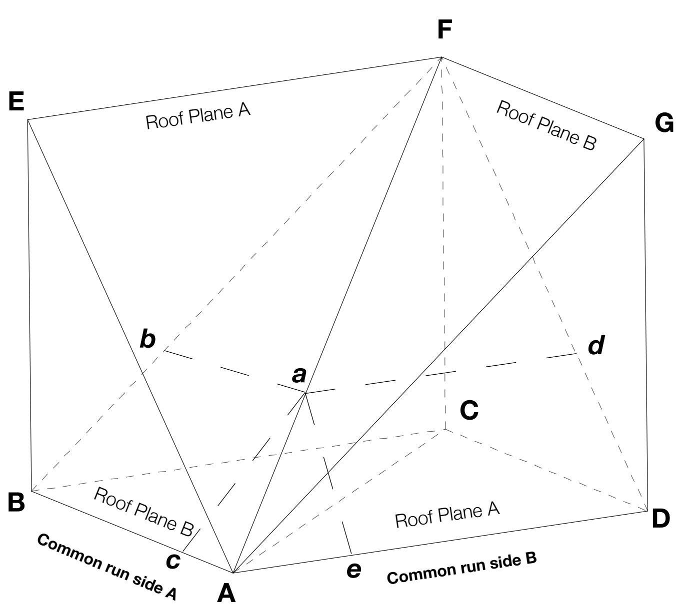
This example represents the difference in length for each purlin at a spacing of 800 mm, but any spacing unit can be used with the same accurate results. To see how this applies to a purlin placed in a hip system at a specific point on the common rafter, we can use the following example.

Let's say we needed to place a purlin (specified as line *ad* in the drawing below) from a common rafter to a hip rafter at a point 900 millimeters from the plate as measured along the length of the common rafter (line *Dd*). Using the *Main Pitch A* as 45°, and the *Secondary Pitch B* as 30°, and a distance of 3000 mm from the center line of the hip at the corner of the building (point *A*) to the center line of the common rafter (point *D*). To find the length of the purlin (line *ad*), use the following process:

Distance from point *A* to point *D* = 3000; The value factor given on the Universal Square for *Pitch A* = 1.2247

Difference in purlin length = 900 x 1.2247 = 1102.23 mm

Purlin length (*line ad)* = 3000 – 1102.23 = 1897.77 mm



Determining Jack Purlin Lengths

In the drawing to the left, lines AE and DF represent the common rafter length in the main roof plane A, and Lines AG and BF represent the common rafter length in the secondary roof plane B. Lines BF and DF represent their relationship to a hip in a hip roof system, and lines AE and AG represent their relationship to a valley rafter in a valley system.

Line 5 of the Universal Metric Square gives the ratio of jack purlin length per 1 unit (mm) of common rafter length. By attributing a unit length of 900 mm to line Dd & Bb we can determine the difference in jack purlin lengths (lines Ae & Ac) for both sides A and B. The purlin lengths are represented by lines ad and ab. The difference in length per spacing unit is represented by lines Ae and Ac. Example using a 40° secondary pitch:

Relative to Main Pitch A: Ae = 900 x .8427 = 758.43
Relative to Sec. Pitch B: Ac = 900 x .6428 = 578.52

The length of the purlin from the center line of the common rafter to the center line of the hip rafter would be 1897.77 millimeters at a point 900 mm from the plate or eaves line (specified as *line ad* in the drawing).

If we were to reverse the sides and put the header relative to the roof plane for *Pitch B*, assuming now that *line AB* is 3000 mm, we would have: Reduction factor for purlin in *Main Pitch B* = .5

Difference in purlin length: 900 x .5 = 450
Purlin length: 3000 - 450 = 2550

PURLIN TOP LAYOUT OVER 1

The values found on line 5 can also be applied to determine the top cut of the purlin. This is an angular ratio of the value given to 1. The angle can be determined readily by moving the decimal point of the given value one place to the right and using this on the tongue side of the square and 10 on the body of the square. Marking along the tongue of the square will accurately mark the top cut angle across the top of the purlin.

As an example, if the secondary roof *Pitch B*, has a given pitch of 40°, we have the following:

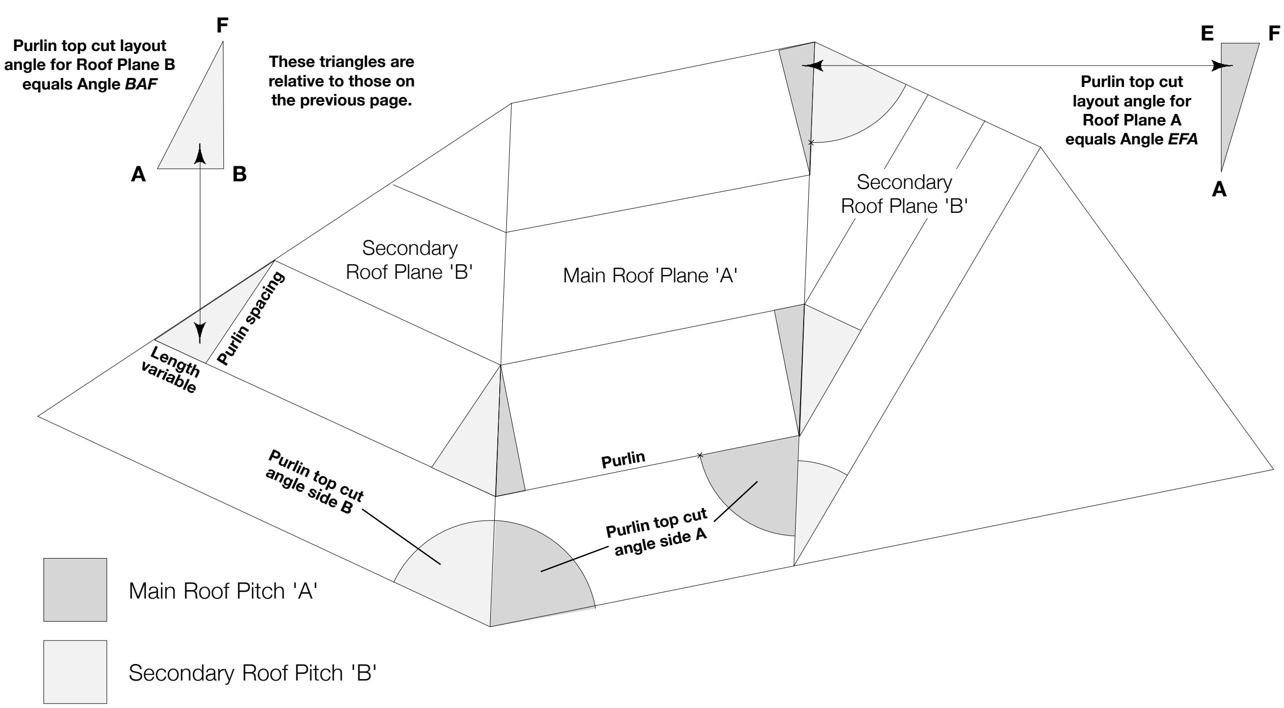
Factor for roof plane relative to Pitch A = .8427 Factor for roof plane relative to Pitch B = .6428

For *Pitch A*, moving the decimal place to the right makes it 8.427. Use this on the tongue, and 10 on the body, marking on the tongue side to make an accurate layout on top of the purlin relative to *Pitch A*.
For *Pitch B*, moving the decimal point to the right 1 place makes it 6.428. Use this on the tongue and 10 on the body and mark the tongue side to make an accurate layout on the top of the purlin relative to *Pitch B*.
As we have seen before, you can extend this layout on the square by multiplying the given factors to oppose any point on the square body.

It must be noted that a valley system is the inverse of a hip system. Hence, there is a mirror image flip required when applying the top cut angles, or determining the difference in lengths per spacing for both jack purlins, and jack rafters. Just remember that the pitch of the common rafter to which the purlin joins dictates the relative pitch, A or B, in relation to the hip or valley.

The purlin top cut angle is also the sheathing cut angle.

Relationships of Jack Purlins in Unequal Pitch Hip & Valley Roof Systems



Line 6
DIFFERENCE IN LENGTH OF JACK RAFTER PER 1 MM OF SPACING
• JACK RAFTER TOP LAYOUT ANGLE OVER 1

DIFFERENCE IN LENGTH OF JACK RAFTER PER 1 MM OF SPACING

The values on Line 6 give the ratio of the difference in the length of the jack rafters per inch of spacing along the plate or ridge beam. Since jack rafters run perpendicular to the plates and ridge, their spacing is measured along the plate or ridge. The following is an example of how to use these factors to determine the difference in the length of the jack rafters for any spacing distance.

On the front side tongue in the column below 50°—which specifies the *Secondary Pitch B* is 50°, and the *Main Pitch A*, is 45°—we find the factor relative to the *Main Pitch A* to be, 1.6854, and the *Secondary Pitch B* to be, 1.3054. This simply states that the difference in the length of the jack rafters relative to *Pitch A* is 1.6854 for every millimeter of spacing along the plate; and 1.3054 for every millimeter of spacing along the plate in reference to jacks in the roof plane relative to *Pitch B*.

If we were to have a common rafter spacing of 800 mm on center in both roof pitches, slopes A and B, The difference in length between each jack rafter would be as follows:

Main Pitch A = 1.6854 x 800 = 1348.32 mm; Secondary Pitch B = 1.3054 x 800 = 1044.32 mm

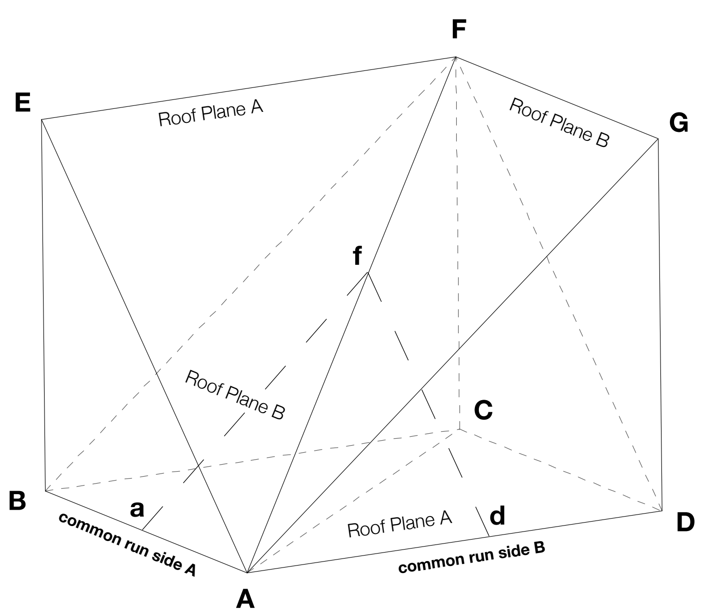
This example represents the difference in length for each jack rafter at a spacing of 800 millimeters, but any spacing unit can be used with the same accurate results.

Using an example of a hip roof structure with a Main Pitch of 45° and a Secondary Pitch of 37.5°, how long would the jack rafter (specified as line *df* below) be if it were spaced 1900 mm (distance from point *A* to point *d* below) from the corner of the building? In this case the corner of the building (*A*) is the zero point (where the center line of the hip and the corner of the building intersect). The distance from *A* to *d* is 1900 mm. To find the length of the jack rafter (line *df*) use the factor given for the *Main Pitch A*, 1.0852:

1900 x 1.0852 = 2061.88 Line *df* = 2061.88 mm

If we were to place the jack rafter on the opposite roof plane *B* (specified as line *af*), and now considered line *Aa* to be 1900 mm, we would use the factor given under column *B*, 1.6427:

1900 x 1.6427 = 3121.13 Line *af* = 3121.13 millimeters



Determining Jack Rafter Lengths

In the drawing to the left, lines AE and DF represent the common rafter length in the main roof plane A, and Lines AG and BF the common rafter length in the secondary roof plane B. Lines BF and DF represent their relationship to a hip in a hip roof system, and lines AE and AG represent their relationship to a valley rafter in a valley system. Their angular ratios remain the same even though they are inverted.

The Universal Metric Square gives the ratio of the jack rafter length per millimeter (or unit of 1) of spacing along the plates (AB, AD), and or, ridge (FE, FG). Attributing a spacing length of 800 mm on center along the ridge lines FE and FG, we can determine the difference in jack rafter lengths for both sides A and B. If we consider the lengths in relation to a valley system, the lengths are represented by lines AE and AG respectively.

Example using a 37.5° secondary pitch:

Relative to Main Pitch A: AE = 800 x 1.0852 = 868.16

Relative to Pitch B: AG = 800 x 1.6427 = 1314.16

JACK RAFTER TOP LAYOUT ANGLE OVER 1

The values found on line 6 can also be applied to determine the top cut of the jack rafter. This is an angular ratio of the given value to 1. The angle can be determined readily by moving the decimal point of the given value one place to the right and using this on the tongue side of the square and 10 on the body of the square. Marking along the tongue of the square will accurately mark the top cut angle across the top of the jack rafter.

As an example, if the *Secondary Pitch B* has a given pitch of 27.5°, we have the following:

Factor for roof plane relative to *Pitch A* = .7362

Factor for roof plane relative to *Pitch B* = 2.1657

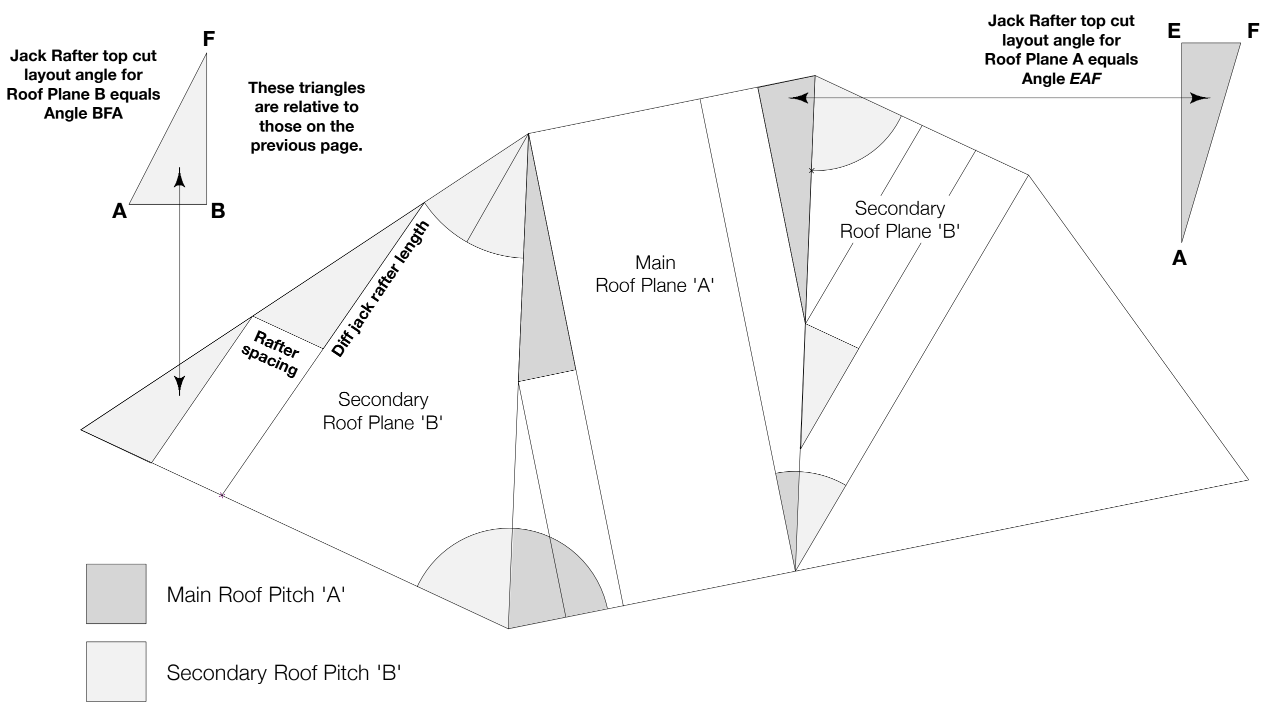
For *Pitch A*, moving the decimal place to the right makes it 7.362. Use this on the tongue and 10 on the body and mark on the tongue side to make accurate layout on top of the jack rafter relative to *Pitch A*.

For *Pitch B*, moving the decimal point to the right 1 place makes it 21.657. Use this on the tongue and 10 on the body. Mark the tongue side to make accurate layout on the top face of the jack rafter relative to *Pitch B*.

It must be noted again that a valley system is the inverse of a hip system. Hence, there is a mirror image flip required when applying the top cut angles or determining the difference in lengths per spacing for both jack purlins, and jack rafters. Just remember that the pitch of the common rafter to which a purlin joins dictates the relative side in relation to the jack purlin. For a jack rafter it is relative to the pitch of the jack rafter itself.

The jack purlin and rafter top cut angles are also the sheathing cut angles.

Relationship of Jack Rafters in Unequal Pitched Hip & Valley Roof Systems



Line 7
BACKING OR BEVEL ANGLE
• TOP CUT SAW ANGLE FOR JACK RAFTERS AND JACK PURLINS

As stated previously, the backing or bevel angle has been one of the more mysterious angles to understand in compound roof framing. This mystery is compounded tremendously when working with unequal pitched roof systems. Until now, determining the backing angles for bastard roofs required a long drawn-out process requiring a solid understanding of geometry and trigonometry, coupled with the ability to visualize 3 dimensional space. No simple task, even for the seasoned builder.

The *Universal Metric Square* turns this mystery into an easy-to-understand process by directly defining the backing angles for both intersecting roof planes.

On Line 7, the backing angles are given directly in degrees for both *Main Pitch A* and *Secondary Pitch B*. By quickly reviewing line 7 in the table we find in the column under 42.5°, the backing angles for a roof system with a combination 45° *Main Pitch* and a 42.5° *Secondary Pitch* are as follows:

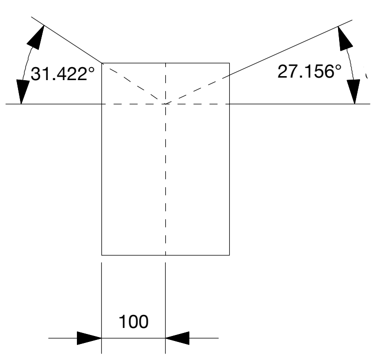
Main Pitch A = 31.422°

Secondary Pitch B = 27.156°

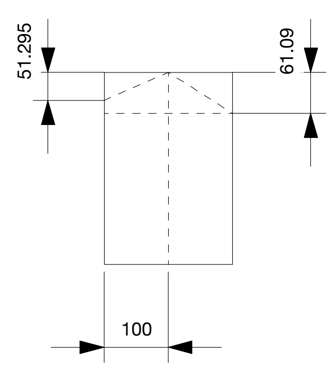
These angles are the angles at which the saw will be set to rip the angles along the hip or valley rafter.

The backing and bevel angles always generate from a vertical center line of the timber and slope outward toward the side faces. You will notice that two lines of different sloping angles when generated from a point on a cross-sectional center line in the vertical plane of a timber will intersect the side faces at different elevations. In *equal pitched roof systems*, both angles will intersect at the same elevation because the angles are equal. In *unequal pitched systems* the angle or bevel lines will intersect the side face of the timber at different elevations because the angles are different.

The total depth of the backing angle for any valley rafter is equal to the depth of the greater angle. The shallower angle will generate from this point on the center line to intersect with the outside face of the beam at some point lower than the corner. From this point a line parallel to the top of the beam will be drawn along the length of the rafter. This is the actual cut line along the side face of the rafter. This will be cut with the saw set to the designated backing angle.



Backing angle on an unequal pitch valley rafter with a 45° main pitch and a 42.5° secondary pitch.



Bevel angle on an unequal pitch hip rafter with a 45° main pitch and a 42.5 secondary pitch.

The depth of the backing or bevel angle is a ratio of the beam width times the tangent of the angle. The find the depth using trigonometry, multiply half the width of the timber by the tangent of the steeper backing angle. This will give the depth in whatever unit of measure you choose to use.

Using the example of 32.5° as the secondary roof pitch, we see that the angle relative to *Main Pitch A* is the steeper pitch at 36.61°.

The tangent of 36.61° = 0.74293

If the hip or valley rafter had a width of 200 millimeters the equation to find the total backing or bevel angle depth would be: 200 ÷ 2 = 100 x .74293 = 74.293

Depth of backing angle = 100 x .74293 = 74.293 mm

The same process can be used to find the shallower pitch. By subtracting the results for the shallower angle from the results of the greater angle, we arrive at the distance from the top edge that the angle will intersect the outside face. This is the cut line on the side face of the hip or valley rafter. Using the same example, we find the following:

Backing angle Pitch B = 16.78°

Tangent 16.78° = 0.30153

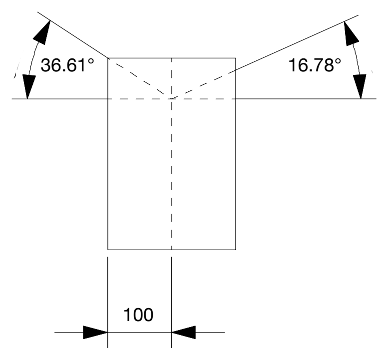
100 x .30153 = 30.153 mm

By subtracting side B from A we have: 74.293 – 30.153 = 44.14 mm

The cut line of side B is located 44.14 millimeters down from the top of the valley rafter.

This can easily be mapped onto the timber directly by drawing a vertical center line on the end cross section of the timber (or on paper to scale) as follows:

First, draw a line from the top edge of the timber using a bevel square set to 36.61° to intersect a center line drawn vertically along the end of the timber. Next, using a bevel square set to the adjoining backing angle, 16.78° in this example, generate a line from this center line point of intersection out to the opposing side face of the valley. The point where it intersects the side face is the location of the top of the bevel. Draw a line along the length of the rafter parallel to its top face and cut to this line using the specified backing angle. In our example, this would be 16.78°



TOP CUT SAW ANGLE OF JACK RAFTERS AND JACK PURLINS

The jack rafter and jack purlin top cut angles are equal to the Backing Angles. To make the top cuts of the jack purlins or rafters, cut along the top face layout line previously described in reference to the factors on lines 5 and 6, with the saw set to the appropriate backing angle as specified in accordance with the degree of angles listed under the appropriate roof pitch angles for the particular roof system.

In the examples above, the top cut for a jack rafter or purlin joining to the side face of the hip or valley rafter relative to the *Main Pitch A* would be set to 36.61°. For Secondary Pitch B the saw would be set to 16.78°.

Line 8
PURLIN SIDE FACE LAYOUT ANGLE OVER 1
• FASCIA MITER FACE LAYOUT ANGLE WITH TAILS AT 90°

The values listed on line 8 are angular ratios that compensate for rotations to give the side face layout angle for jack purlins to hip or valley rafters.

The values listed for sides A and B are in the ratio to 1. To use these ratios on the framing square to lay out the jack purlin side faces move the decimal point to the right one place and use opposite 10 on the square. The following is an example.

If we have a secondary rafter with a pitch of 50°, the values for sides A and B are:

Side A = .5933   Side B = .9129

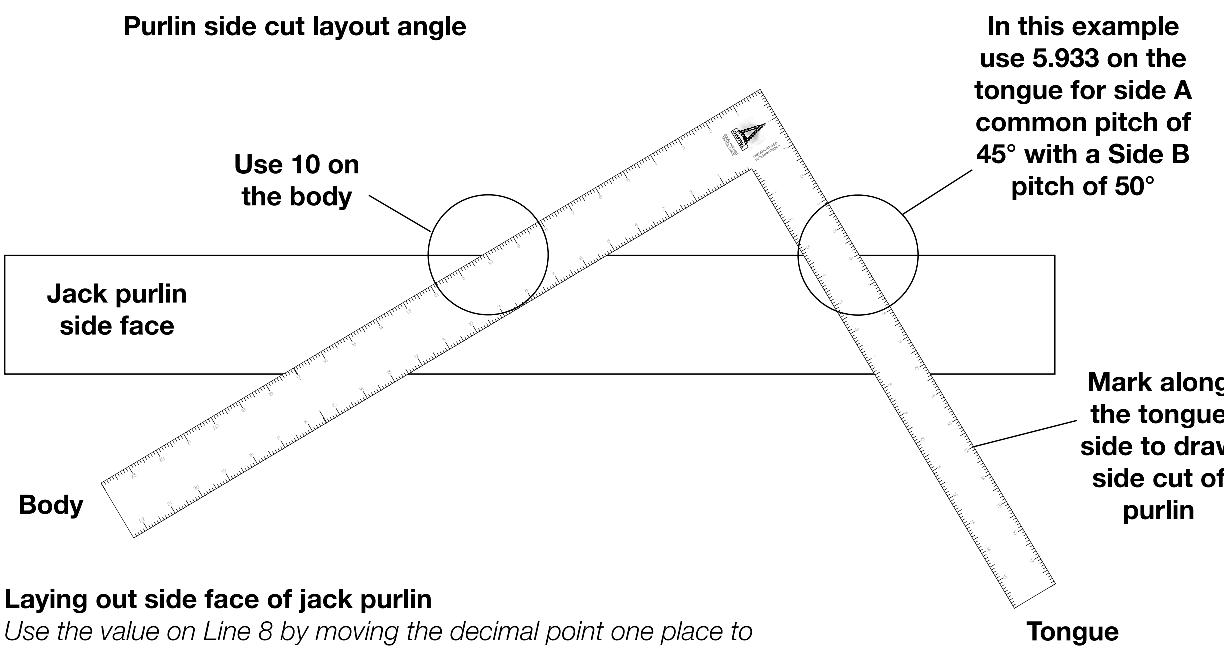
To lay out the side face of the purlin for side A, move the decimal to the right one place and use 5.933 on the tongue side, and 10 on the body side. Mark a line along the tongue side of the square to make an accurate layout line for the purlin side cut.

To layout the purlin for side B, repeat the same process, using 9.129 over 10. Mark along the tongue side to make the accurate side layout. These can be extended to other points on the square legs as described previously.

MITERED FASCIA FACE LAYOUT ANGLE WITH TAIL AT 90°

This same angle (as described above) is used to lay out the face of a mitered facia board joining to a hip or valley when the tails of the common rafters are cut at 90 degrees to the top of the rafter.

The saw set angle used to cut along this layout line to make the mitered saw cut is given on line 9 of the Unequal Pitch Rafter Tables on the front and backside tongue of the Universal Square.



Laying out side face of jack purlin

Use the value on Line 8 by moving the decimal point one place to the right. In our example using a 45° main common pitch and a 50° secondary pitch we use 5.933 on the tongue for side A and 9.129 for side B, and 10 on the body to make the accurate layout across the side face of the purlin. Mark along the tongue of the square. Multiply the factor by 2, 3, or 4 and use on 20, 30 or 40 on the body and use the resultant factor on the tongue. Example: 4 x 5.933 = 23.732. Use over 40

Line 9
HOUSING ANGLE PURLIN TO HIP OR VALLEY OVER 1
• HIP OR VALLEY SIDE FACE LAYOUT TO PURLIN HEADER

The housing angle values listed on Line 9, like the side cut angles, are angular ratios that will give the angle of the purlin housing on the side face of the hip or valley rafter. This angle will be as scaled off a line drawn perpendicular to the top face of the hip or valley.

In the column under 50° we find that the values given are: .2697 for side A and .4495 for side B. Using the same approach we used previously of moving the decimal one place to the right and using opposite 10 we have the following ratios:

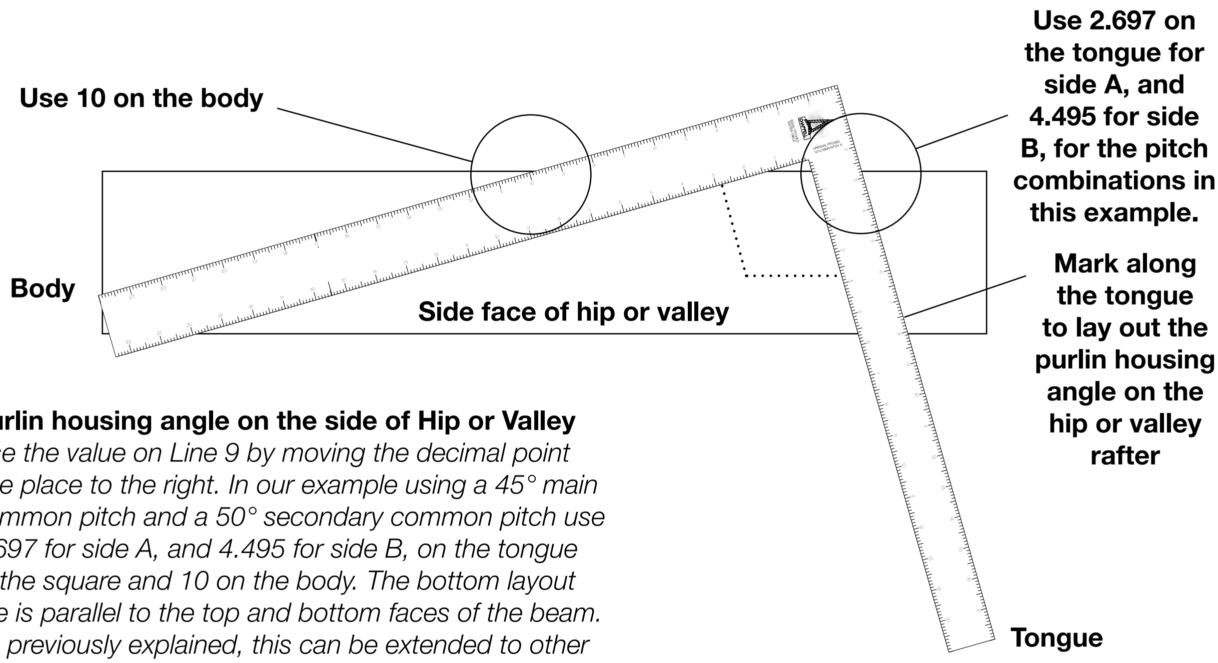
Side A = 2.697:10

Side B = 4.495:10

In both cases use 10 on the body and the value factor given for side A and B on the tongue. Holding the square so as to align these two points on the square along the top edge of the rafter mark the layout line on the tongue of the square. This will draw an accurate layout line corresponding to the purlin-housing angle.

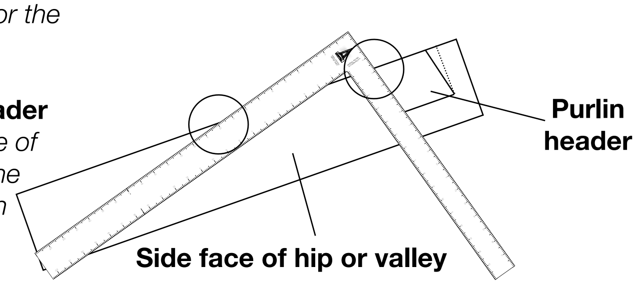
HIP/VALLEY SIDE ANGLE TO PURLIN HEADER

This is also the same angle that you would use for the side face layout of a hip or valley rafter that joined to the lower side face of a purlin header. A purlin header is one that has the top face in the same plane as the common roof plane. Use the angle relative to the pitch on the outside face of the hip or valley.



Purlin housing angle on the side of Hip or Valley
Use the value on Line 9 by moving the decimal point one place to the right. In our example using a 45° main common pitch and a 50° secondary common pitch use 2.697 for side A, and 4.495 for side B, on the tongue of the square and 10 on the body. The bottom layout line is parallel to the top and bottom faces of the beam. As previously explained, this can be extended to other points on the square by multiplying the given factor the 2, 3 or 4.

Side face layout for hip or valley to purlin header
This angle is also the layout angle for the side face of a hip or valley rafter joining to a purlin rotated to the common roof plane (square to the top of common rafter).



Line 10
FASCIA MITER SAW SET ANGLE FOR RAFTER TAILS CUT AT 90°

FASCIA BEVEL ANGLE FOR SQUARE CUT RAFTER TAILS

The values given on line 10 of the Unequal Pitched Rafter Table are the mitered fascia saw cut angles. These are the angles used to cut the miter bevel angle on fascias along the fascia face layout line as described on line 8 of the Unequal Pitch Table in this section. The values are given as the degree of the cut directly relative to each of the two roof pitches *A* and *B*. These angles hold true for all combinations of unequal pitch roof systems as specified in the table when the common rafter tails are cut at 90 degrees to the top face of the rafters (perpendicular to the roof plane). These are commonly called square cut tails.

As an example, if we were to use a common pitch of 30° for the Main Pitch A and a 25° roof pitch for Secondary Pitch *B*, we find on the bottom line in the column under 25° on the backside tongue, the two values for Pitch *A* and Pitch *B*.

The value for Pitch *A* is 42.355°. This is the degree of the fascia miter saw cut angle relative to pitch *A*.

The second value under the column for Pitch *B* is 34.712°. This is the degree of the fascia miter saw cut angle relative to pitch *B*.

The first step is to lay out the fascia face as described using the values found on line 8 of this section. Once the face layout is complete, simply set your saw to the appropriate angle given on line 10 (relative to pitch *A* or *B* as required) and saw along the layout line. The result will be a perfect mitered cut.

Bisecting the Miter Cut

As described above, the two joining fascias will be cut at two different angles. This will result in a variance in the length of the angle cut on each fascia, and may require a back cut on one of the fascias to flush them up at the bottom. When the variance in roof pitches is minor, this is the normal approach. However, if the variance in roof pitches is great you may wish to bisect the miter cut so as to arrive at the same miter saw cut angle, and hence, the same length for each of the angle cuts. This is easily accomplished using the values given in the Unequal Pitch Roof Tables as described below.

It is quite simple really. Just add the two values for the degree of the two angles given for *Pitch A* and *Pitch B* together and divide them by two. This will give you the bisected miter saw cut angle. As an example, let's say we had a roof system with a 45° *Main Pitch A*, and an 25° Secondary *Pitch B*. The values on line 10 under columns *A* and *B*, under 25° are as follows:

Pitch A = 39.856° Pitch B = 22.521°

The equation to find the bisected angle is as follows: $A + B \div 2$ = Bisected miter angle

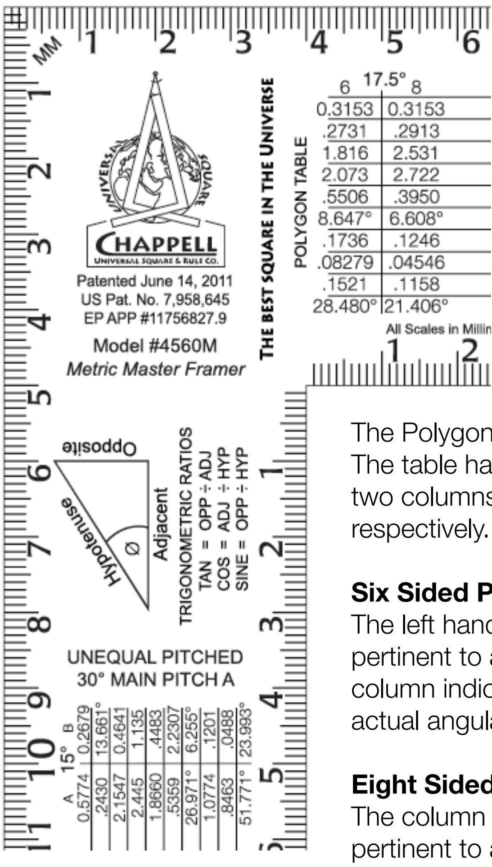
$$39.856 + 22.521 = 62.377 \div 2 = 31.1885$$

The bisected miter cut for this example would be 31.1885°.

Plumb Cut Rafter Tails

When the rafter tails are cut plumb, the miter angle for fascias is equal to the bisected footprint angles. In this case, the fascia face layout is marked at 90°, or square to the fascia board.

Polygon Rafter Table

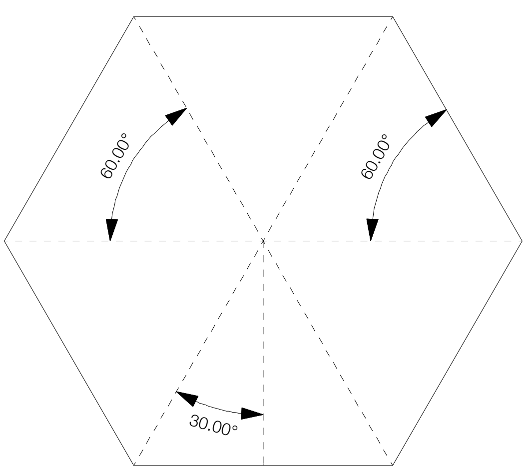


The *Chappell Universal Metric Square*—for the first time in the history of the framing square—includes a complete rafter table for two of the most common polygons; hexagons and octagons. While previous squares have included values to determine the miter angle or sidewall angles for polygons, the *Chappell Universal Metric Square* has a complete rafter table for polygons of 6 and 8 sides with common roof pitches from 17.5° to 60° in 2.5° increments. The table includes the ratios of all member lengths, and easy to apply values for all angles including bevel cuts, housing angles, side and top cuts for jacks, all in an easy to use table all based on ratios to a unit measure of 1.

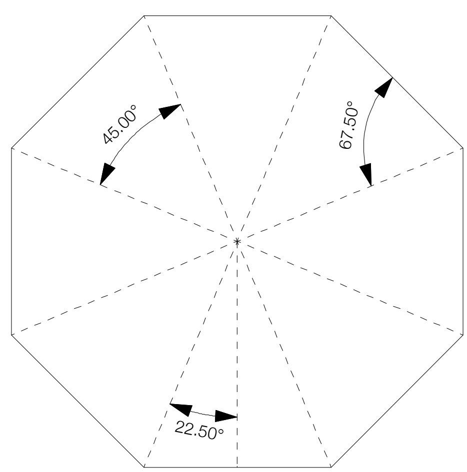
The Polygon Rafter Table is on the backside body of the *Universal Square*. The table has two columns under the degree markings from 17.5° to 60°. The two columns listed below each number are headed with the number 6 and 8 respectively.

Six Sided Polygons—Hexagon
The left hand column, marked 6, gives all the information in the roof system pertinent to a 6 sided polygon, or hexagon. The degree specified above the column indicates the given common roof pitch in degrees. This will dictate the actual angular and dimensional criteria for that specific pitch in the column.

Eight Sided Polygons—Octagon
The column on the right, marked 8, gives all the information in the roof system pertinent to an 8 sided polygon, or octagon. The degree marking above the column indicates the given common roof pitch in degrees. This will dictate the actual angular and dimensional criteria for that specific pitch in the column.



Hexagon Footprint



Octagon Footprint

Line 1
POLYGONS 6 & 8 SIDES COMMON PITCH GIVEN
• SIDE WALL ANGLES = 360 ÷ NUMBER OF SIDES

The first line designates the column headings for 6 and 8 sided polygons. The left column pertains to hexagons and the right column to octagons. The values below these column headings are relative to the number of sides and the given common roof pitch which corresponds to the degree specified above the two columns.

In this table the values and factors are based on the common rafter roof pitch as the given roof pitch. This will dictate the hip rafter pitch based on its rotation in accordance with the polygonal bisected footprint angle, and the common roof pitch. The bisected footprint angle is a ratio of the number of sides to the 360 degrees of a circle.

To find the sidewall angles and resulting bisected foot print angles, simply divide 360 (the number of degrees in a circle) by the number of sides of the polygon. This gives the angles radiating from a center point of the footprint.

Hexagon	Octagon
360 ÷ 6 = 60°	360 ÷ 8 = 45°

This gives us the angle between any two rays radiating from a center point of the footprint passing through the corner points of the polygon.

We know that every triangle has a total of 180 degrees, so we can find the two opposite angles by subtracting this radiating angle from 180 and dividing the remainder by 2:

$$180 - 60 = 120 \div 2 = 60$$

We see in the case of a 6 sided polygon that the angles of the base triangle are all equal to 60 degrees. This is considered an equiangular (equal angles) and equilateral (equal sides) triangle. These are the footprint angles.

To determine the bisected footprint angle we must bisect the triangle by drawing a line from the center point to bisect the sidewall at its midpoint. This line is perpendicular to the side, and therefore creates two right triangles with angles of 30, 60 and 90 degrees. In this example, 30° is the bisected footprint angle, and the line bisecting the base triangle and intersecting the side at 90° is considered the run of the common rafter. The hypotenuse of this triangle, the line from the center point to the corner point, is considered the hip rafter run. In the Polygon Rafter Table on the ***Universal Metric Square***, the given pitch is based on the common roof pitch, which is the ratio of the common run (from the center point to the mid point of the side) and the total rise based on the degree of the roof pitch.

If we follow the example of an 8 sided polygon, we find the base triangle to be 45, 67.5 and 67.5 degrees. The bisected footprint angle are 22.5, 67.5, and 90 degrees.

6	60° 8	POLYGONS 6 & 8 SIDES COMMON PITCH GIVEN • BISECTED FOOTPRINT ANGLES = 360 ÷ NUMBER OF SIDES
1.7321	1.7321	COMM RAFTER PITCH ~ RISE PER 1 MM OF RUN* (All Ratios are to a Factor of 1. Move Decimal 1 Place Right & Use Over 10 on Square Body)
1.5000	1.6002	HIP RAFTER PITCH ~ RISE PER 1 MM OF RUN* (Mltply Given Factor by Any # on SQ Body & Use on Tongue. Ex: 35° Octgn ~.6469 x 50 = 32.345)
3.464	4.828	LENGTH OF COMM RAFT PER 1 MM OF SIDE LENGTH (Max = Side / 2) • SHEATHING ANGLE OFFSET PER 1 MM ALONG PLATE
3.606	4.931	LENGTH OF HIP PER 1 MM OF SIDE LENGTH (Maximum Hip or Valley Length = Given Factor x Side Length ÷ 2)
.2887	.2071	DIFF IN LENGTH OF JACK PURLINS PER 1 MM SPACING ALONG COMM RAFT • TOP CUT LAYOUT JACK RAFT & PRLN OVER 1*
25.659°	19.355°	BACKING & BEVEL ANGLE IN DEGREES • JACK RAFTER & JACK PURLIN TOP CUT SAW ANGLE
.5000	.3587	JACK PURLIN SIDE CUT LAYOUT ANGLE • FASCIA MITER ANGLE FOR 90° TAILS (Move Decimal Point 1 Place & Use Over 10)
.12500	.06864	JACK PURLIN HOUSING ANGLE* • HIP OR VAL SIDE ANGLE TO PURLIN HEADER* (*Move Decimal 1 Place & Use Over 10)
.4804	.3513	DEPTH OF BACKING & BEVEL ANGLE PER 1 MM OF HIP WIDTH (Multiply 1/2 Beam Width by Given Factor for Total Depth)
14.478°	11.031°	FASCIA BEVEL ANGLE FOR SQUARE CUT RAFTER TAILS (*Note: All angular data is in a ratio to 1. Multiply x 10 & use over 10)

Line 2
COMMON RAFTER PITCH - RISE PER 1 MM OF RUN

The values on line 2 give the ratio of the common pitch rise per millimeter (or any unit of 1) of common run. This specifies the common rafter pitch as a ratio of rise over the base run of 1. This is an angular ratio.

As an example, let's use an 6 sided polygon with a 55° common pitch. Under 55° we find the first value in the right hand column under the heading 8 (octagon) to be: 1.4281. This signifies that for every 1 mm of common rafter run, the rise equals 1.4281 millimeters.

To apply the value, we repeat the same steps as previously described by moving the decimal point one place to the right and using this opposite 10 on the body of the square. Or, you can choose any number on the square body, say 300 mm, and multiply by that to arrive at the rise in millimeters for the specific run. In this example we have:

$$300 \times 1.4281 = 428.43$$

In this example the square set would be 300 mm on the body and 428.43 mm on the tongue.

Line 3
HIP RAFTER PITCH - RISE PER 1 MM OF RUN

The values on line 3 gives the hip rafter rise as a ratio of rise over the base run of 1 unit. This is an angular ratio, and 1 unit can be millimeters, centimeters, inches or feet.

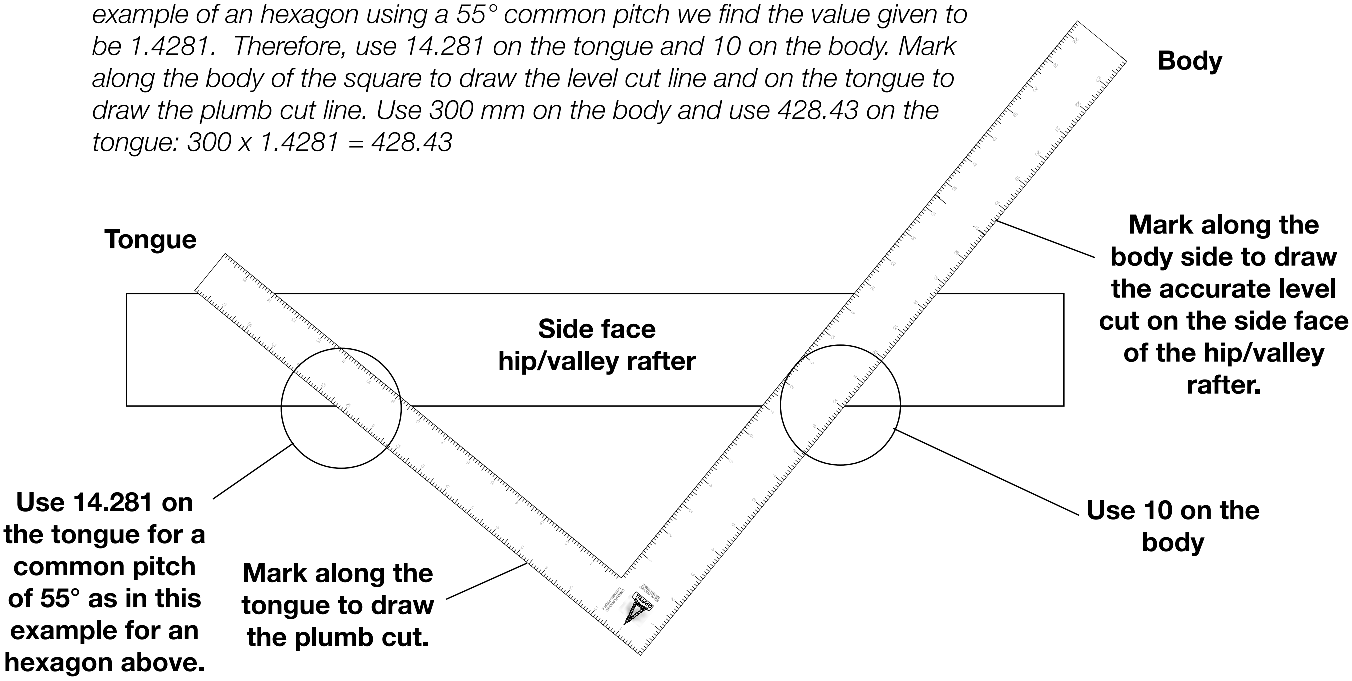
As an example, let's use an 8 sided polygon with a 40° common pitch. In the column under 40° we find the first value in the right hand column under the heading 8 (octagon) to be: 0.8391. This signifies that for every 1 unit of hip rafter run, the rise equals 0.8391 millimeters.

To apply the value, we repeat the same steps as previously described by moving the decimal point one place to the right and using this opposite 10 on the body of the square. For our example, 0.8391, use 8.391 on the tongue of the square and 10 on the body. Or if 300 mm were used: 300 x .8391 = 251.73

Marking a line along the body of the square designates the horizontal run, or level line of the hip rafter. A line marked along the tongue represents the vertical rise, or plumb line of the hip rafter.

Laying out the pitch on the side face of a common, hip or valley rafter

The values on lines 2 and 3 are used in the same way. The values are used by moving the decimal point one place to the right and applying over 10. In the example of an hexagon using a 55° common pitch we find the value given to be 1.4281. Therefore, use 14.281 on the tongue and 10 on the body. Mark along the body of the square to draw the level cut line and on the tongue to draw the plumb cut line. Use 300 mm on the body and use 428.43 on the tongue: 300 x 1.4281 = 428.43



Line 4
LENGTH OF COMMON RAFTER PER 1 MM OF SIDE LENGTH • SHEATHING ANGLE OFFSET PER 1 MM ALONG PLATE

LENGTH OF COMMON RAFTER PER 1 MM OF SIDE LENGTH (MAX = SIDE ÷ 2)

The standard dimensions given when building polygons is to attribute; 1) the lengths of the sides, and, 2) the common roof pitch. Because the plan view angular ratios and geometry of any given polygon is the same regardless of its size (the footprint triangles are all similar triangles), we can use the side wall length, in conjunction with the common roof pitch, to determine all other aspects of the roof system.

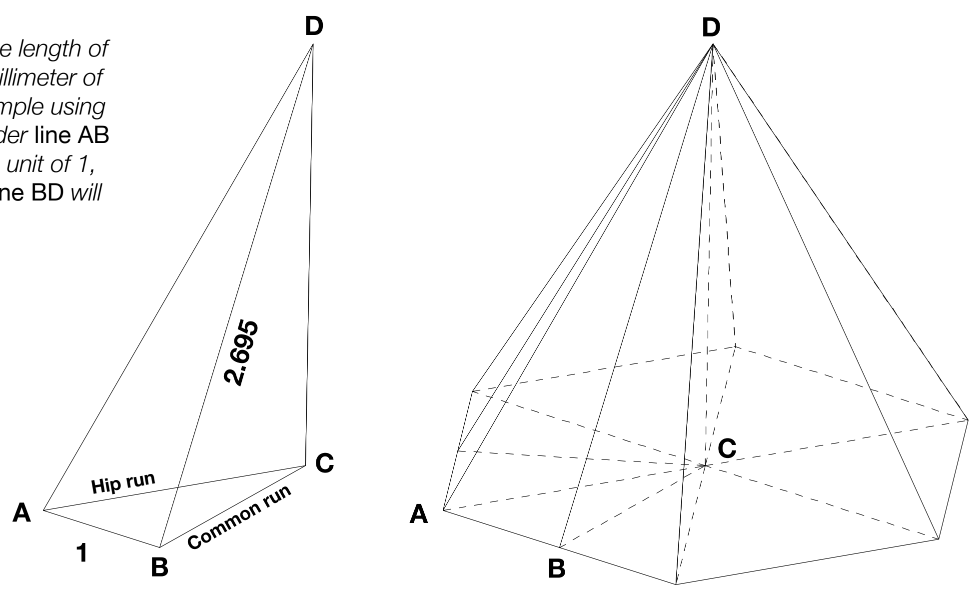
In a polygon the common rafters run perpendicular to the side walls with the maximum run of the common extending perpendicular from the center point of each side, where they all intersect at a center point of the polygon (side length ÷ 2). To allow the rapid calculation of common rafter lengths, the *Universal Metric Square* uses a factor based on the ratio of the rafter length to 1 unit of side length. Due to the geometric relationships of polygons, the maximum length of any common rafter would generate from the exact center point of the sides. Therefore, when working with the values specified in line 4, the maximum will always be no greater than the side length divided by 2.

The value found on line 4 of the Polygon Table gives the dimensional ratio of the common rafter length per 1 unit or 1 millimeter of side length. As an example, let's assume we have a 6 sided polygon with a given common pitch of 50°. The value in the left column (6) under 50° on line 4 is given as, 2.695.

That is, for every millimeter of side length the common rafter length for a 6 sided polygon with a common roof pitch of 50° would be 2.695 millimeters, or a ratio of 1:2.695. This can be applied to any similar hexagon regardless of side length. The ratio holds true, as well, for any unit of measure.

Length of common rafter per MM of side length
The values on line 4 give the length of the common rafter per 1 millimeter of side wall length. In our example using a 50° hexagon, if we consider line AB *to be the side length with a unit of 1, then the common length,* line BD *will have a length of 2.695*

Line AB = Side length
Line BC = Common run
Line AC = Hip/Val run
Line BD = Common length
Line AD = Hip/Val length
Line CD = Hip & Common rise
Angle ABD = 90°
Angle ABC = 90°



Relationship of Common Rafter Pitch to Hip Rafter Pitch in Polygons

Let's say we have a hexagon with a side length of 3650 millimeters, with a common pitch of 40°, and the common rafters are spaced at 500 mm on center, starting from the center of the side wall. What is the length of the central common rafter at the center point of the side wall and the difference in length for each jack rafter?

Common length ratio for a 40° pitch hexagon = 2.183

The relative wall length for the central common rafter = 3650 ÷ 2 = 1825

Length of central common rafter = 1825 x 2.183 = 3983.975 mm

Difference in length of jack rafters at 500 mm on center = 500 x 2.183 = 1091.5 mm

SHEATHING ANGLE OFFSET PER 1 MM OF SHEATHING WIDTH

Cutting boards or plywood to fit accurately into a hip or valley has caused the head scratching of many a carpenter, and even more so when building polygon structures. The value given on line 4 of the Polygon Tables on the Universal Metric Square puts this information right in the palm of your hand, no guesswork involved.

The values given in each of the columns for both 6 and 8 sided polygons are the ratio of the offset angle per one unit of sheathing width. When running boards or plywood that run perpendicular to the common rafters into the hip, simply divide the width of the board or plywood by the given factor in the column under the appropriate roof pitch and column.

Using a hexagon with a 50° pitch, we find the value in the sub column 6 to be 2.695.
For an 200 mm board the offset measurement to be: 200 ÷ .2.695 = 74.211
For 1200 mm plywood: 1200 ÷ 2.695 = 445.269

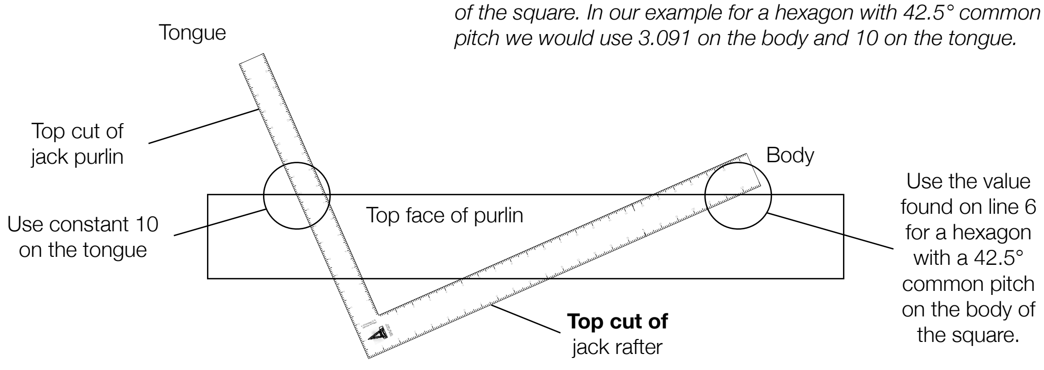
If we were to use the same pitch for an octagon, we would use the value of 3.756 as the offset factor.

When the sheathing runs vertical from eaves to ridge, the sheathing offset measurement can be determined by multiplying the sheathing width by the value given in the appropriate column corresponding to the roof pitch. As an example using the hexagon above and an 200 mm board, the equation would be:

200 x 2.695 = 539 mm

Top cut of Jack Rafters & Jack Purlins

The values on line 6 also give the angular ratio of the jack rafter and jack purlin top cut. Use the value by moving the decimal point one place to the right and use opposite 10 cm on the body (or tongue) of the square. In our example for a hexagon with 42.5° common pitch we would use 3.091 on the body and 10 on the tongue.



Line 5
LENGTH OF HIP RAFTER PER 1 MM OF SIDE LENGTH (MAX = SIDE ÷ 2)

Using the same process as in the previous example, we can readily find the length of the hip rafter by using the values given on line 5 of the Polygon Rafter Table.

The value found on line 5 of the Polygon Table gives the dimensional ratio of the hip rafter length per 1 unit of side length based on the given common rafter pitch. As an example, let's assume we have a 6 sided polygon with a given common pitch of 55°. The value in the left column (6) in the column under 55° on line 5 is given as: 3.181.

That is, for every millimeter (or unit of 1) of side length the hip rafter length for a 6 sided polygon with a common roof pitch of 155° would be 3.181 mm, or a ratio of 1:3.181. This can be applied to any similar hexagon regardless of side length. The ratio holds true, as well, for any unit of measure.

Let's say we have a hexagon with a side wall length of 4875 mm, with a common a pitch as stated above, 55°. The hip rafter length would be as follows:.

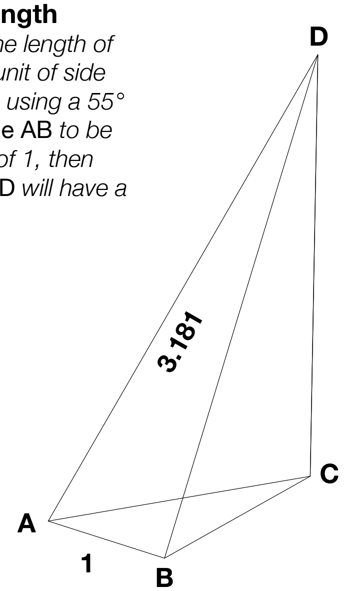
Hip rafter length ratio 55° hexagon = 3.181

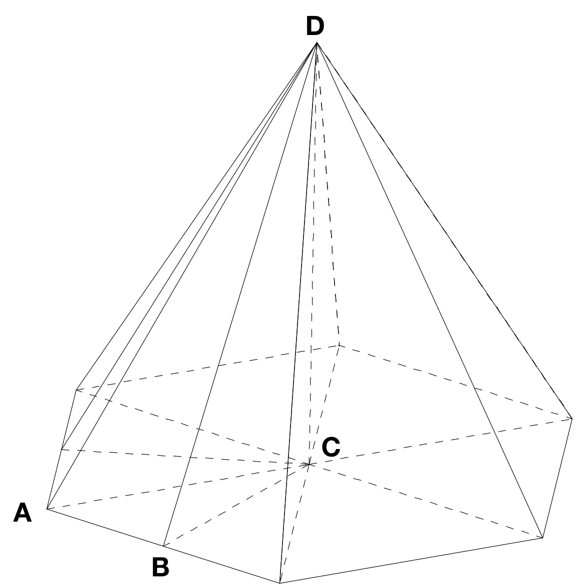
The relative wall length for the central common rafter = 4875 ÷ 2 = 2437.5

Length of hip rafter = 2437.5 x 3.181 = 7753.687 mm

Length of hip/valley rafter per one unit of side length
The values on line 5 give the length of the hip or valley rafter per unit of side wall length. In our example using a 55° hexagon, if we consider line AB *to be the side length with a unit of 1, then the hip rafter length,* line AD *will have a length of 3.181*

Line AB = Side length
Line BC = Common run
Line AC = Hip/Val run
Line BD = Common length
Line AD = Hip/Val length
Line CD = Hip & Common rise
Angle ABD = 90°
Angle ABC = 90°
Angle BAC = 60°





Relationship of Hip Rafter Pitch to Common Rafter Pitch in Polygons

Line 6
DIFFERENCE IN LENGTH OF JACK PURLINS PER 1 MM OF SPACING ALONG COMMON RAFTER LENGTH • TOP CUT LAYOUT OF JACK RAFTER & JACK PURLIN OVER 1

DIFFERENCE IN LENGTH OF JACK PURLINS PER 1 MM OF SPACING

The value given on line 6 is a dimensional ratio that gives the difference in length of the jack purlin for each unit of 1 as it moves along the length of the common rafter.

Using an example for a hexagon with a 42.5° pitch, we find the given value to be: .4257.

This specifies that for 6 sided polygons of this given common roof pitch, the difference in the length of a jack purlin will be .4257 for each unit of 1 as measured along the length of the common rafter.

If purlins were spaced at every 900 millimeters from the eaves plate, then the difference in length for each purlin from the center point of each side plate would be as follows:

900 x .4257 = 383.13 mm

If the purlin joins directly to both hip rafters, then this length would be doubled.

TOP CUT LAYOUT OF JACK RAFTER & JACK PURLIN OVER 1

The value on line 6 also provides the angular ratio of the jack purlin and jack rafter top cuts to 1.

The value given in line 6 is the tangent of the included roof angle (plate to hip angle). Used in this way, it is an angular ratio that can be applied directly to the framing square.

To lay out the top cut of either the jack rafter or purlin, use the value given on line 6 as follows:

Using the same 42.5° hexagon as an example, we find that the value of the included roof angle ratio is .3901. By moving the decimal point one place to the right and using 10 cm on the opposite leg, we can readily mark the correct top cut angles for both, jack purlins or jack rafters.

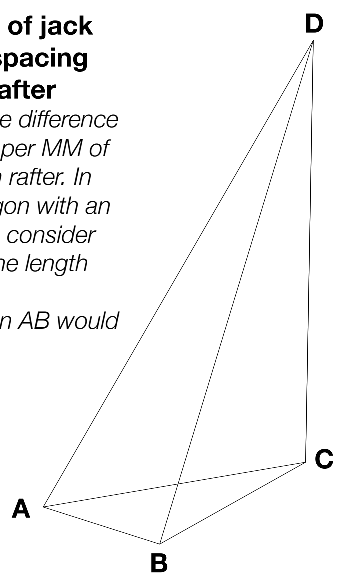
For jack rafters:
Use 3.901 on the body of the square and 10 on the tongue and mark along the *body* side to accurately lay out the top cut layout angle of the jack rafter. This can be extended on the square as previously discussed.

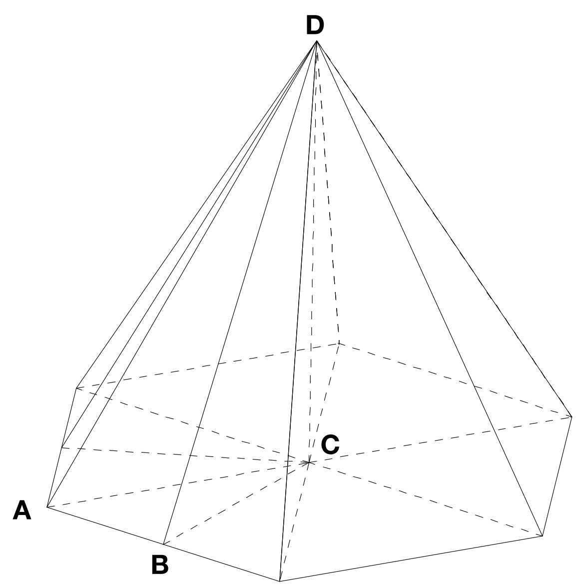
For jack purlins:
Use 3.901 on the body of the square and 10 on the tongue and mark along the *tongue* side to accurately lay out the top cut layout angle of the jack purlin. This can be extended on the square as previously discussed.

Difference in length of jack purlins per MM of spacing along common rafter

The values on line 6 give the difference in length of the jack purlins per MM of spacing along the common rafter. In our example (using a hexagon with an 42.5° common pitch), if we consider line BD to be 1 mm, then the length AB would be .4257 mm.
If BD equaled 900 mm, then AB would equal 383.13 mm.

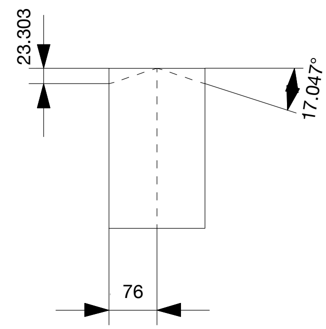
Line AB = Side length
Line BC = Common run
Line AC = Hip/Val run
Line BD = Common length
Line AD = Hip/Val length
Line CD = Hip & Common rise
Angle ABD = 90°
Angle ABC = 90°
Angle BAC = 60°





LINE 7
BACKING & BEVEL ANGLE IN DEGREES • JACK RAFTER & JACK PURLIN TOP SAW CUT ANGLE

The values on line 7 give the bevel/backing angles in degrees for any 6 or 8 sided polygon with common roof pitches of from 17.5° to 60°. The drawing to the right depicts the bevel angle of 17.047° for an octagon with a 50° common pitch, which is listed on the appropriate column on line 7. This angle would be used for the saw cut angle set to rip the bevel along the hip rafters length. In all cases, the bevel generates from a center line along the length of the hip (or valley) rafter to bisect the side face.



JACK RAFTER & JACK PURLIN TOP SAW CUT ANGLE

These angles are also the top cut angle for both jack rafters and purlins. To use this value, simply set the saw to the specified angle appropriate to the number of sides and the common roof pitch and cut along the top cut layout angle as described previously under the heading of Line 6.

LINE 8
JACK PURLIN SIDE CUT LAY OUT ANGLE OVER 1 • FASCIA MITER ANGLE FOR 90° TAILS

The values on line 8 gives the angular ratio of the purlin side cut layout angle. This ratio is applied to the framing square as the previous angular ratios—by moving the decimal point one place to the right and using opposite 10 on the framing square. This can be extended on the square as discussed earlier.

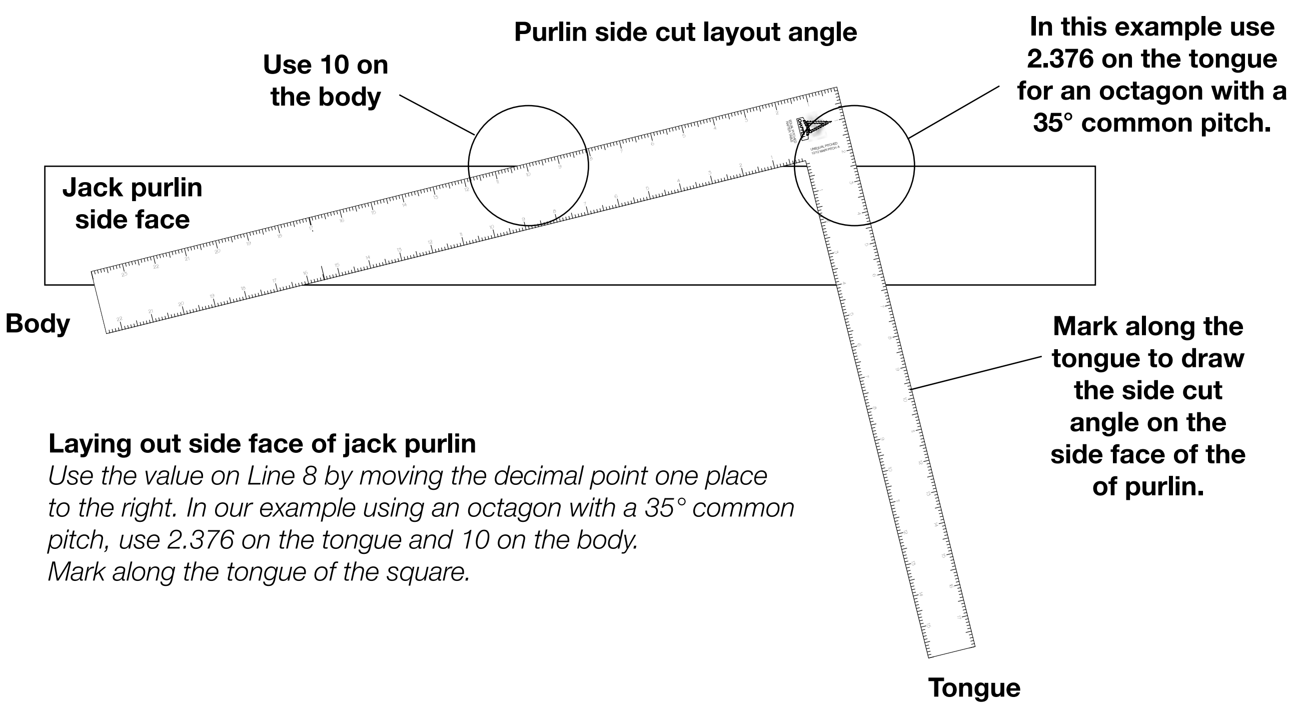
If we were cutting the roof system for an 8 sided polygon that had a common roof pitch of 35°, we find that the value given on line 8 is .2376.

To apply this to the framing square to lay out the side face of the purlin, move the decimal point one place to the right (2.376) and use this on the tongue side of the square and 10 on the body side. Draw along the tongue side to mark the accurate layout for the purlin side cut. To use 400 mm on the body, multiply the value by 400 and use over 95.04. 400 x .2376 = 95.04 mm

FASCIA MITER ANGLE FOR 90° TAILS

This same angle (as described above) is used to layout the face of a facia board joining to a hip or valley when the tails of the common rafter are cut at 90 degrees to the top of the common rafter.

The saw set angle used to cut along this layout line to make the mitered saw cut is given in line 11 of the Polygon Table on the backside body of the Universal Metric Square.



Laying out side face of jack purlin
Use the value on Line 8 by moving the decimal point one place to the right. In our example using an octagon with a 35° common pitch, use 2.376 on the tongue and 10 on the body.
Mark along the tongue of the square.

LINE 9
JACK PURLIN HOUSING ANGLE TO HIP OVER 1
• HIP/VALLEY SIDE FACE ANGLE TO PURLIN HEADER

The value in line 9 gives the angular ratio of the purlin housing angle on the hip rafter. This ratio is applied to the framing square as the previous angular ratios—by moving the decimal point one place to the right and using opposite 10 on the framing square. This can also be extended on the square are previously discussed.

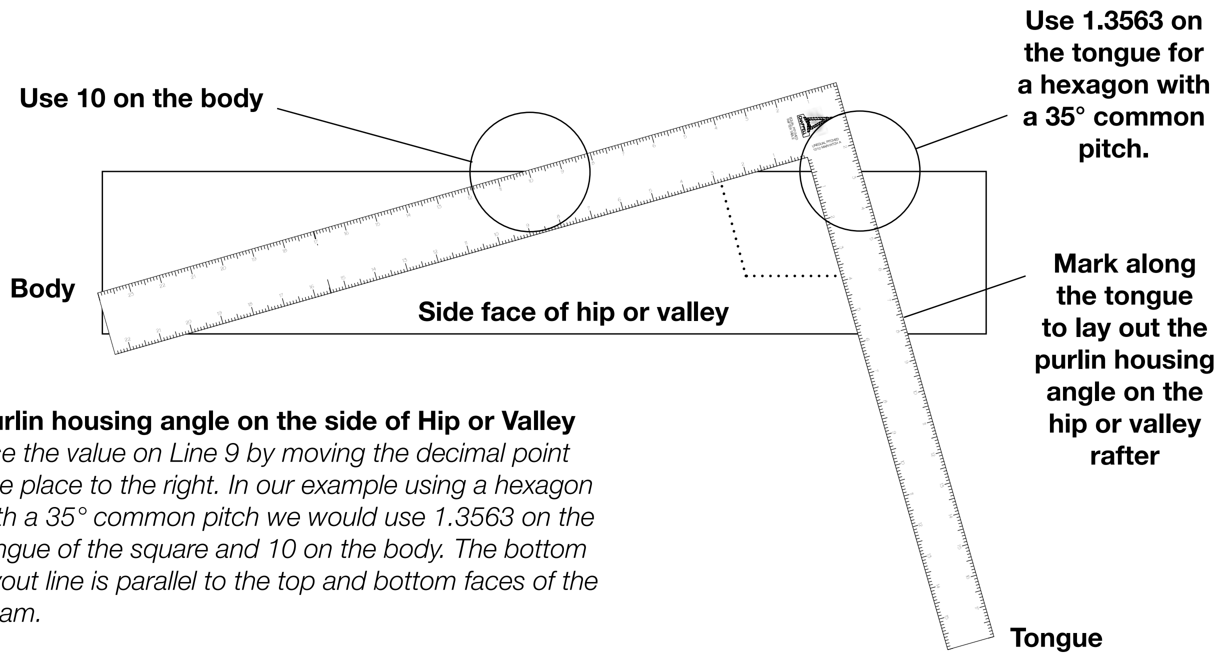
If we were cutting the roof system for an 6 sided polygon that had a common roof pitch of 35° we find that the value given on line 9 is: .13563.

To apply this to the framing square move the decimal point one place to the right and use the value 1.3563 on the tongue side of the square and use 10 on the body of the square. Laying the square on the side face of the hip rafter, align these two points of the square along the top of the beam and draw along the tongue side to mark the accurate layout for the purlin housing angle. To extend this on the square to cover more area, simply multiply the root value by the number on the body desired. As an example, if you chose to use 500 mm on the body proceed as follows: 500 x .13563 = 67.815

Use 500 mm on the body and 67.815 mm on the tongue.

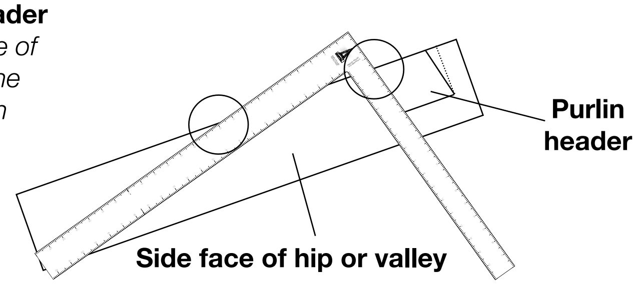
HIP/VALLEY SIDE ANGLE TO PURLIN HEADER

This is also the same angle that you would use for the side face layout of a hip or valley rafter that joined to the lower side face of a purlin header. A purlin header is one that has the top face in the same plane as the common roof plane.



Purlin housing angle on the side of Hip or Valley
Use the value on Line 9 by moving the decimal point one place to the right. In our example using a hexagon with a 35° common pitch we would use 1.3563 on the tongue of the square and 10 on the body. The bottom layout line is parallel to the top and bottom faces of the beam.

Side face layout for hip or valley to purlin header
This angle is also the layout angle for the side face of a hip or valley rafter joining to a purlin rotated to the common roof plane (square to the top of common rafter).



LINE 10
DEPTH OF BACKING OR BEVEL ANGLE PER MILLIMETER OF HIP WIDTH.

The values on line 10 of the Polygon Table gives the ratio of the depth of the backing or bevel angle for both 6 and 8 sided polygons with common roof pitches as specified from 17.5° to 60°.

The backing/bevel angle is the angle at which the two opposing roof planes intersect and meet at the apex of the hip or trough of a valley rafter and meet at the vertical plane that passes through the longitudinal center of the hip or valley rafter. The depth of the backing/bevel angle as measured perpendicular to the top face of the hip or valley rafter is a rotation of the angle in plane so that we may easily measure and mark the depth of cut along the length of the actual hip or valley.

The backing/bevel angle has many other implications in a compound roof system, especially concerning mortises and tenons projected into or from the timber surfaces (in timber framing).

The values given in this table considers all rotations for common pitches ranging from 17.5° to 60° for both 6 and 8 sided polygons, and provides the depth of the angle as measured perpendicular to the top face of the hip or valley rafter. The value given for the depth of the backing or bevel angle is based on the ratio of depth to 1 millimeter of beam width (or any unit of 1). Because the angles on a hip or valley rafter always generate from the center of the timber and slope toward the side faces, to determine the side face depth one must use this value over one half the width of the beam.

In some cases you will need to make a bevel (angle) across the full width of the timber (as in cases where you have a hip roof plane passing into a valley gable plane (believe me, this happens)). In this case, you will use the full beam width as the factor.

Example:
As an example, let’s say we are to build an 8 sided polygon with a common roof pitch of 55°. The value under 55° and the column marked 8, we find the value to be: .3301

This is the ratio of the depth of the bevel cut to 1, for an 8 sided polygon with an 55° common roof pitch of any conceivable sidewall length. Again, it makes no difference if the ‘1’ represents inches or centimeters, or any other unit of measure, the ratio is absolute.

Using millimeters as the unit of measure, then the depth of the bevel cut would be .3301 mm for each millimeter of the beam width in this example. Because the bevel angle generates from the beams vertical center line to its side faces, we must divide the beam width in half, and use this half-width as the base factor.

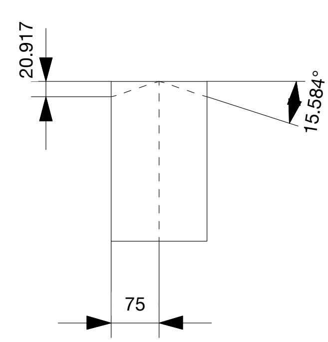
If the hip rafter has a width of 150 mm, the equation to determine the depth of the bevel cut would be based on 75 mm (150 ÷ 2) as the beam width factor:

75 x .3301 = 24.757 The depth would be: 24.757 mm.

For a 6 sided polygon with a common pitch 32.5° the factor would be .2789.

This equation would be:

150 ÷ 2 = 75 75 x .2789 = 20.9175 mm.



Line 10
FASCIA BEVEL ANGLE FOR SQUARE CUT RAFTER TAILS

The values on line 11 of the Polygon Rafter Table give the mitered fascia saw cut angles for both 6 and 8 sided polygon roof systems with common roof pitches ranging from 17.5° to 60°. These are the angles used to cut the miter angle on fascias along the fascia face layout line as described on line 8 of the Polygon Table in this section. The values are given as the degree of the miter cut directly relative to the number of sides (6 or 8). These angles hold true for all roof systems as specified in the table when the common rafter tails are cut at 90 degrees to the top face of the rafters (perpendicular or square to the roof plane).

As an example, if we were to build a hexagon with a common roof pitch of 60°, we find on the bottom line in the column under the number 60° (and further under the sub column 6), the degree of the fascia miter angle directly. In this example the miter angle is 14.478°

If we were building an octagon with the same common roof pitch, the miter angle will be 11.032°.

The first step is to lay out the fascia face angle as described on page 44 for line 8 under the sub-heading for the FASCIA MITER ANGLE FOR 90° TAILS. Once the face layout is complete, simply set your saw to the appropriate angle as given on line 11 (relative to a 6 or 8 sided polygon as your design dictates) and saw along the layout line. The result will be a perfect mitered cut.

Plumb Cut Rafter Tails

When the common rafter tails are cut plumb, the miter angle for fascias are equal to the polygon bisected footprint angles divided by two. In this case, the fascia face layout is marked at 90°, or square to the fascia board.

Determining the bisected footprint angle is discussed on the first page of this section. The equation can also be found on the first line of the Polygon Table. The equation for polygons being:

Bisected footprint angle = 360 ÷ Number of sides of polygon

To apply this to the fascia, we have to bisect this angle once more.

For a hexagon we have:

$360 \div 6 = 60 \div 2 = 30.$ The fascia miter angle is 30°

For an octagon we have:

$360 \div 8 = 45 \div 2 = 22.5$ The fascia miter angle is 22.5°

Left: Cleaning up the valley backing cut on a valley rafter.

Right: Valley rafter and common dormer rafter joining to a hip rafter.

All of these angles were determined using the Chappell Universal Square rafter tables.

Using the Chappell Universal Metric Square in Imperial Units

All of the angular and dimensional values on the *Chappell Universal Metric Square* are based on ratios relative to the unit of 1 (or 10), and therefore work interchangeably using either Metric or Imperial units of measure. One can use inches with the same accurate results as centimeters. The only consideration is in the way one designates the originating roof pitch.

In the U.S. the standard system used to designate roof pitch (angle of inclination) is based on the relationship of rise (in inches) to the run (based on the constant of 1 foot or 12 inches). Therefore, the roof pitch would be expressed as 9/12, 10/12, 12/12, etc. This would be 9 inches, 10 inches or 12 inches, of rise for every foot (12 inches) of run. The run of 1 foot is a constant and the variable is always the rise. The degree of the roof pitch can then be determined through trigonometry.

The most common method for specifying roof pitch in countries using the metric system is to give the angle of inclination directly in degrees. This is usually given as whole numbers such 25°, 30°, 35°, etc. In order to apply this to the timber to lay out the angle one must use an angle gauge or protractor, or convert it to a rise to run ratio to use on the framing square. As an example, a 30° angle would translate to a 6.92/12 pitch. The beauty of the traditional framing square is its compactness and ease of use in the field to lay out angles rapidly and accurately. Those wishing to use imperial units can do so by adapting at the outset the degree of roof pitch on the *Chappell Universal Metric Square* to a rise to run ratio. All subsequent calculations can be carried out in the decimal inch system with absolute accuracy.

The following is a list of roof pitches expressed in ratios of rise to run in inches, and degrees, with the closest degree equivalent most commonly used for roof pitches in metric based systems.

Rise to Run Ratio Actual Degree	Common Metric Degree Equivalent	Rise to Run Ratio Actual Degree	Common Metric Degree Equivalent	Rise to Run Ratio Actual Degree	Common Metric Degree Equivalent
2/12 = 9.46°	10°	8/12 = 33.69°	32.5°	14/12 = 49.4°	50°
3/12 = 14.03°	15°	9/12 = 36.86°	35°	15/12 = 51.34°	51.5°
4/12 = 18.43°	20°	10/12 = 39.80°	40°	16/12 = 53.13°	52.5°
5/12 = 22.61°	22.5°	11/12 = 42.51°	42.5°	17/12 = 54.78°	55°
6/12 = 26.56°	25°	12/12 = 45°	45°	18/12 = 56.3°	57.5°
7/12 = 30.25°	30°	13/12 = 47.29°	47.5°		

Roof pitches in countries using the metric system are usually expressed directly as the degree of the angle of inclination, i.e., 25°, 30°, 35°, etc. The table above shows the common metric degree equivalents for the rise and run ratios as specified on the Chappell Universal Metric Square*.*

All of the values on the *Chappell Universal Metric Square* are based on the degree of roof pitch, and subsequently to the rise to run ratios as described herein. In order to use the *Chappell Universal Metric Square* in imperial units, simply multiply the standard base run of 12 by the ratio value for the common rafter rise per unit. As an example, using a 30° roof pitch for an equal pitched system, the vertical rise per foot can be determined by multiplying the value given on Line 1 of the Equal Pitched Table. In this example; .5774

.5774: 12 x .5774 = 6.928.

The pitch would be 6.928/12. All subsequent calculations for dimensional and angular references can then be carried out using the values given on the *Chappell Universal Metric Square*. This can be carried out using any unit of measure you so choose, with absolute accuracy.

Stainless Steel Framing Squares

The Chappell Universal Square & Rule Company currently has five different models of stainless steel squares in both metric and imperial units, and two models of stainless steel center rules. Model numbers 1824 Master Framer, 1218 Traveler, 4560M Metric Master Framer and the 3050 Metric Traveler each have the Chappell Universal patented rafter tables that include: Equal Pitched, Unequal Pitched and 6 & 8 sided Polygons. Each square includes a 48 page instruction booklet. In addition, Chappell Universal has two models of Center Squares and a Gauging Square.

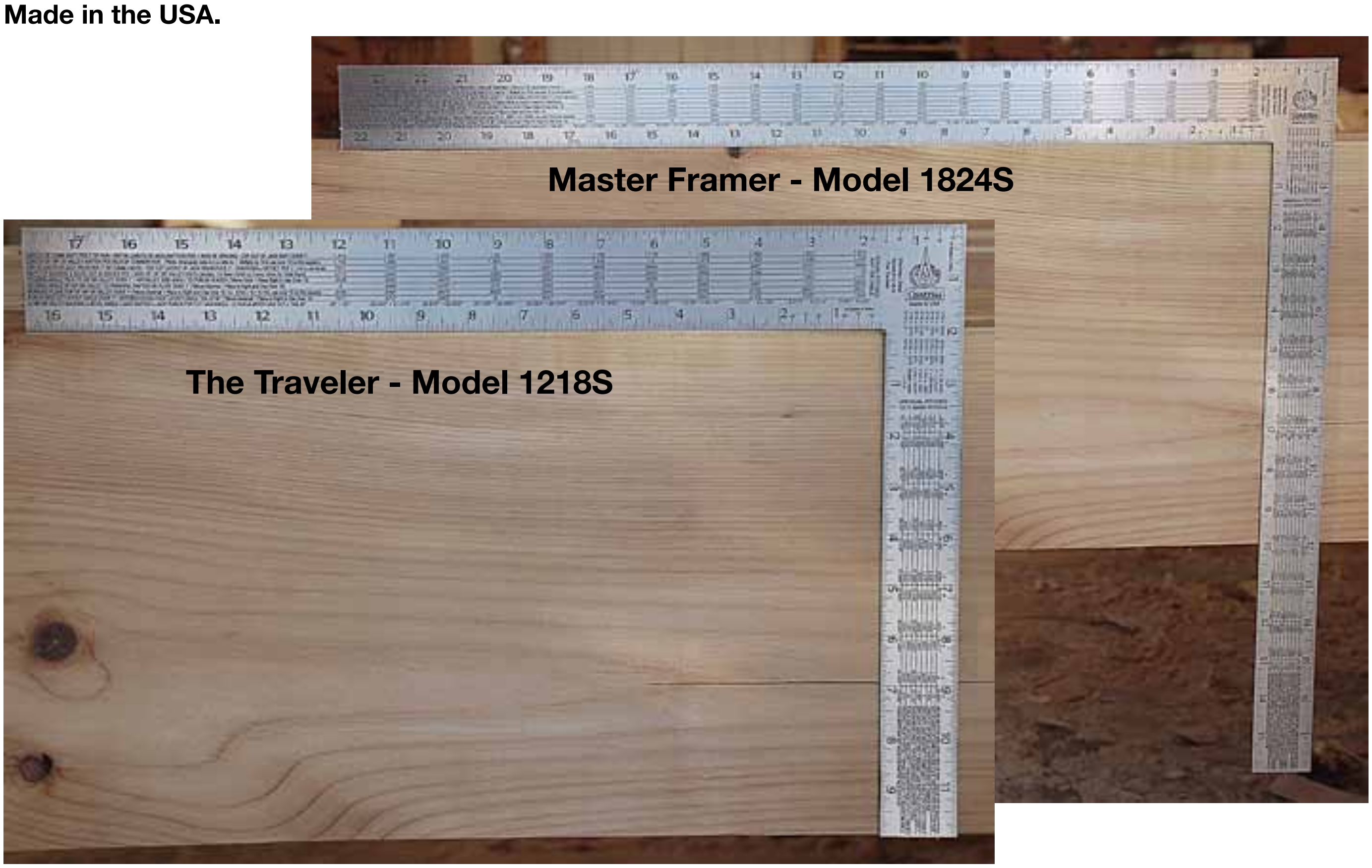
The Model 1824S is a full sized framing square with a 24 inch body and an 18 inch tongue. It is ideal for laying out roof systems in the shop or in the field. The 1824 Master Framer has the full array of rafter tables for roof pitches ranging from 2/12 to 18/12 for Equal Pitch and Polygon roof systems, and from 4/12 to 15/12 for Unequal Pitched roof systems. The model 4560M Metric Master Framer has a 61cm body and a 46cm tongue, with blades 4cm and 5cm wide. The metric Master Framer squares have rafter table for roof pitches ranging from 15 to 60 degrees.

The Model 1218S Traveler is a natural companion to the Master Framer. It is an exquisitely balanced slightly scaled down version with an 18 inch body and a 12 inch tongue. The Traveler is a fully functional framing square, and as the name implies, it is ideal when you are on the road as it will fit conveniently in your tool box. The size and weight make it a perfect layout tool that may soon become your favorite square for general layout such as laying out stair stringers, rafters and mortise and tenon joinery layout. Large enough for full scale roof framing layout, while small enough for detailed work, The Traveler may well prove to be one of the most popular framing squares to the modern carpenter. The smaller size allows for rafter tables for Equal Pitch and Polygon roof systems with pitches from 2/12 to 12/12, and Unequal Pitch roof systems for pitches ranging from 4/12 to 9/12. The Model 3050M Metric Traveler has all the same features, with a 50cm body and a 30cm tongue, with blades 4cm and 5cm wide. The metric Traveler squares have rafter table for roof pitches ranging from 15 to 50 degrees.

Made from rugged 13 gauge #304 stainless steel and are deep etched for long life, and guaranteed to be square within .003 of an inch.

Master Framer model 1824S: 1-1/2” x 18” tongue, 2” x 24” body, decimal inch ruling in .05 inches.
The Traveler model 1218S: 1-1/2” x 12” tongue, 2” x 18” body, decimal inch ruling in .05 inches.
Metric Master Framer 4560M: 4cm x 46cm tongue, 5cm x 61cm body, metric ruling in millimeters
Metric Traveler model 3050M: 4cm x 30cm tongue, 5cm x 50cm body, metric ruling in millimeters

Made in the USA.



Chappell Universal Square & Rule Co.

Stainless Steel Center Squares

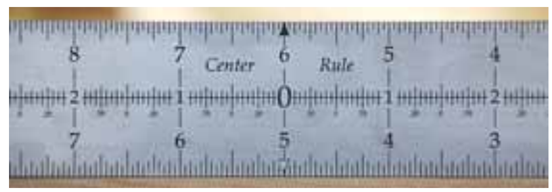
Center rules work great for detail layout when working from center lines. The **Chappell Universal Square & Rule Company** is the first to combine the center-rule with a square. Center Squares are now available in .05 decimal inch, 1/16 inch and metric ruling.

Models 912 and **68** are each center squares, and **Model 34** is a **Gauging Square**. All scales in both the body and tongues are in decimal inches, divided into 20ths (.05”), with divisions at 1/4 (.25”), 1/2 (.5”) & 3/4 (.75”) inches.

Models 912 and **68 Center Squares** each have center rulings along the center of each leg that allow for quick layout and checks for centering layout of mortises and mid-timber spacings quickly and easily. Ideal for laying our mortises or any layout that must originate from the center of the piece, and then easily squaring across.

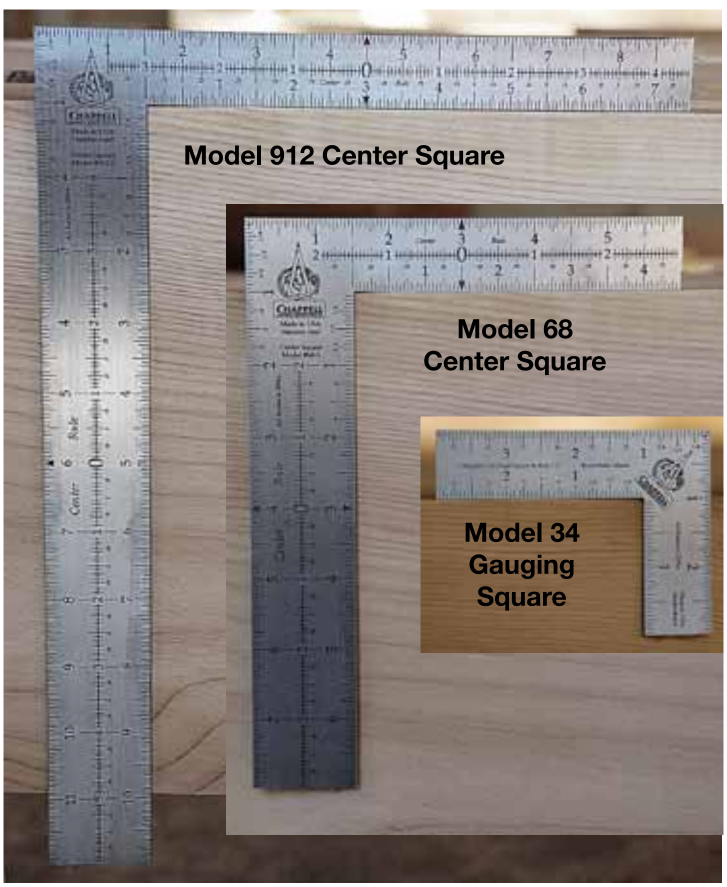
The **912 Center Square** has a body 1-1/2” by 12”, and a tongue 1” by 9”. Both legs have center rulings and regular edge rulings as shown in the enlarged detail below. This is a rugged stainless steel square that will last for generations. The **68 Center Square** has the same features as the model 912, with a body 1-1/2” x 8” and a tongue 1” x 6”.
The **34 Gauging Square** is ideal for gauging the square of mortise and tenon shoulders and intricate pieces in cabinetry and furniture making. It is also ideal squaring table saw and circular saw blades to the base and setting depths—especially for routers. It fits neatly in your pocket, so you are bound to find a multitude of other uses.

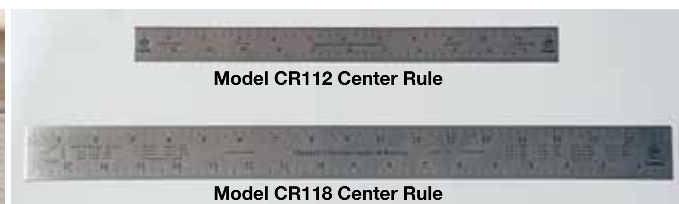
These squares are made from rugged 13 gauge #304 stainless steel and are deep etched for long life. Guaranteed to be square within .003” of an inch.



Model 912S Center Square: 1” x 9” tongue, 1-1/2” x 12” body
Model 68S Center Square: 1” x 6” tongue, 1-1/2” x 8” body
Model 34S Gauging Square: 1” x 3” tongue, 1” x 4” body

Metric Bench Squares
Model 2030M Center Square: 2.5cm x 20cm tongue, 4cm x 30cm body
Model 1524M Center Square: 2.5cm x 15cm tongue, 4cm x 24cm body
Model 810M Gauging Square: 2.5 x 8cm tongue, 2.5 x 10cm body





Flexible Stainless Steel Center Rules

Center rules work great for layout when working from center lines and for laying out detailed joinery. The **Chappell Universal Center Rules** are made from .029” stainless steel and are flexible enough to work on round logs and uneven surfaces.

The front sides have decimal inch rulings as in all Chappell Universal products, with the rulings top and bottom starting from opposite zero points, allowing them to be worked from either side without flipping them over and reading upside down. Model CR118 has a Fraction to Decimal Conversion Chart and Trigonometric Ratio Equations etched on the front side.

The backside is a center rule with edge rulings (as depicted in the enlarged photo above) to allow both center work and zero point work on the same rule.

Flexible Center Rules .029” stainless steel
Model CR112: 1” x 12” Stainless steel center rule
Model CR118: 1-1/2” x 18” Stainless steel center rule
Coming soon in metric.

Chappell Universal Square & Rule Co. LLC • PO Box 248 • 65 Corn Hill Road • Brownfield, ME 04010.
207-935-3720 • www.chappellsquare.com • info@chappellsquare.com

The Chappell Universal Square™

Bringing the Framing SQUARE into the 21st century

The Chappell Universal Square™ is the first major innovation to the carpenter's framing square in nearly 110 years, and will revolutionize the way carpenters—both do-it-yourselfer's and pros alike—approach their work. In the field or in the shop, the Chappell Universal Square puts a wealth of building knowledge right in the palm of your hand.

The Chappell Universal Square includes the following improvements

Expanded Hip & Valley Rafter Tables

The equal pitch rafter tables include over 14 key values to determine virtually every length and rotated angle in an equal pitched compound hip & valley roof system.

You can now quickly & easily determine the:

- length, angle and pitch of Hip & valley Rafters
- Difference in lengths of jacks for any spacing
- Depth and degree of hip & valley backing/bevel angles
- Fascia and sheathing cut angles
- Jack Purlin & Rafter top and side cuts
- Create compound mortise & tenon Timber Frame Joinery...

... and much more

Unequal Pitch Hip & Valley Rafter Tables

for the first time in any format The Chappell Universal Square™ includes a comprehensive unequal pitch rafter table. This includes over 13 key values to determine virtually every length and rotated angle in an unequal pitched compound hip & valley roof system.

You can now quickly & easily determine the:

- Angle, pitch & length of bastard Hip & Valley Rafters
- Difference in lengths of jacks for any spacing
- Depth and degree of hip & valley backing/bevel angles
- Fascia and sheathing cut angles
- Jack purlin & Rafter top and side cuts
- Create compound mortise & tenon Timber frame joinery...

... and much more

6 & 8 Sided Polygon Rafter Tables

Another first, The Chappell Universal Square™ includes a comprehensive polygon rafter table for pitches from 2/12 to 18/12. This includes values to determine virtually every length and rotated angle required to build a compound polygon roof system using conventional framing systems or mortise & tenon timber frame joinery.

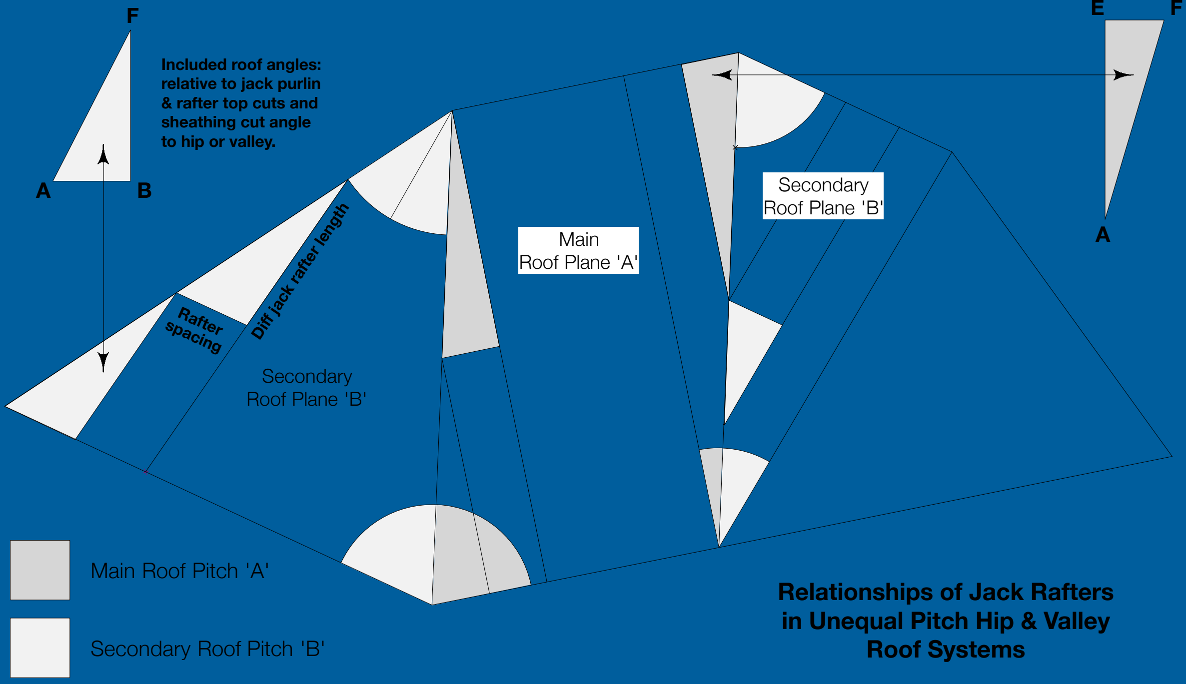
Truly Universal Cross Platform Calculations

Another first, The Chappell Universal Square™ truly is universal. Use metric or imperial units of measure with the same accurate results —feet & inches or millimeters & centimeters— it all converts seamlessly on the Chappell Universal Square™

You now have the power to create!

The Chappell Universal Square™ will make you a better carpenter & Builder...

Bastard roofs are a breeze with the Chappell Universal Square



...by making complex roof framing calculations & layout as easy as ABC...