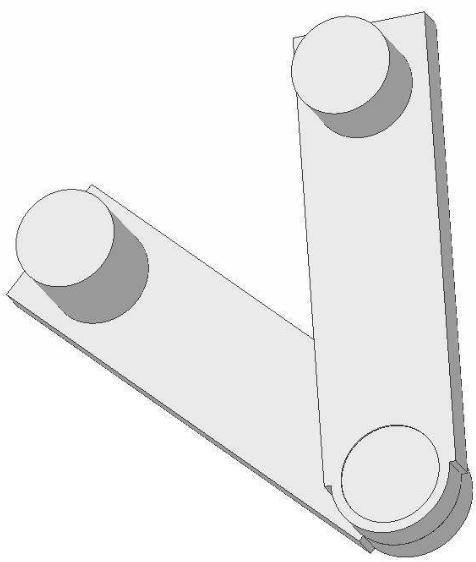
A Low Cost "Digital" Angle Gage, version 3

By R. G. Sparber



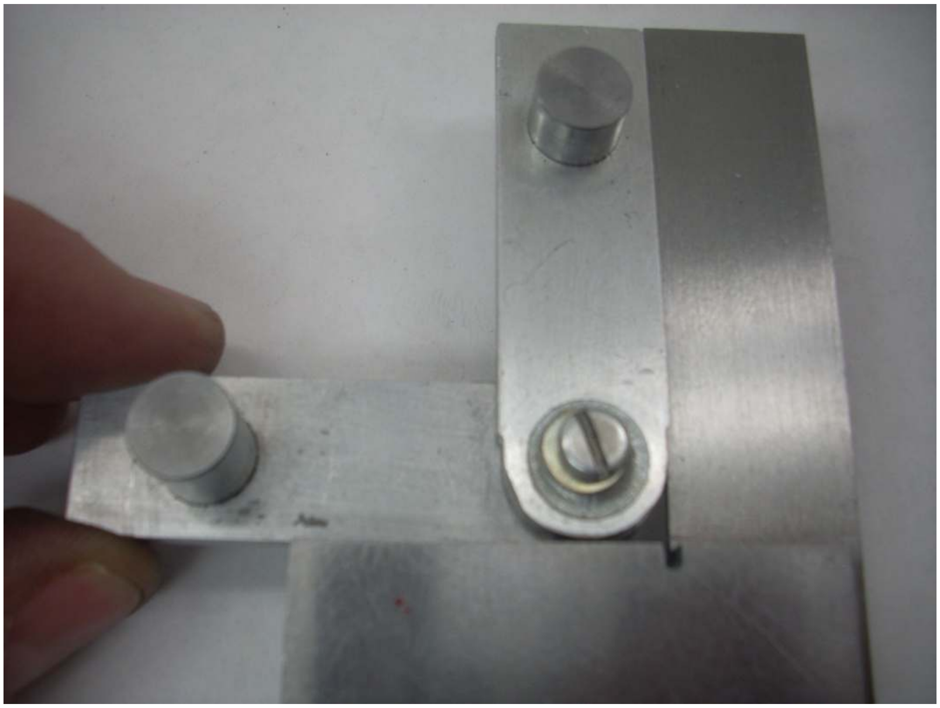
Sometimes re-inventing the wheel has advantages. What you see here is just a variation on a sine bar. The accuracy and simplicity is well documented so I won't get into that here.

There are rare times when I need a precision angle but can't justify buying a new instrument. Sure, if a digital angle gage was sitting on the pavement, I would bend over and pick it up. But it is just not something I wish to spend money on right now.

However, that doesn't mean I would not enjoy making something that uses what I already own. In this case, I have a perfectly good Harbor Freight® digital caliper. I also have a nice collection of scrap metal in my junk drawers.

The possibly new bit is the math that lets me calibrate this gage using a machinist square and then use the digital caliper to set any angle from about 10° to 180°.

Not shown in the above rendering is a 6-32 screw with assorted washers to help lock the pivot.



Here I am calibrating the gage with my 2” machinist square. Once the angle has been set to 90°, I lock the pivot.

Next I slip a thick washer over the post attached to the rear blade. This helps me align my digital caliper squarely on the sides of the posts. I record the reading.

It would be better if I make a more precise washer on my lathe.

Here is where those of you that hate math will go screaming from the room. Sorry about that. Am I left with just Malcolm in the room? I'll put the derivation in the appendix.

The best way to handle this math is to put it in a spreadsheet. You will find this spreadsheet at http://rick.sparber.org/ma.htm at the bottom of section 3.

Digital Angle Gage						
known angle =			90.00	<-E4		
known distance =			2.308	<-E5		
diameter of reference cylinders =			0.372	<-E6		
enter desired angle:		45.00	distance is		1.420	inches
		/\ is D8				
distance =((E5-E6)/SIN(E4*PI()/360))*SIN(D8*PI()/360) + E6						

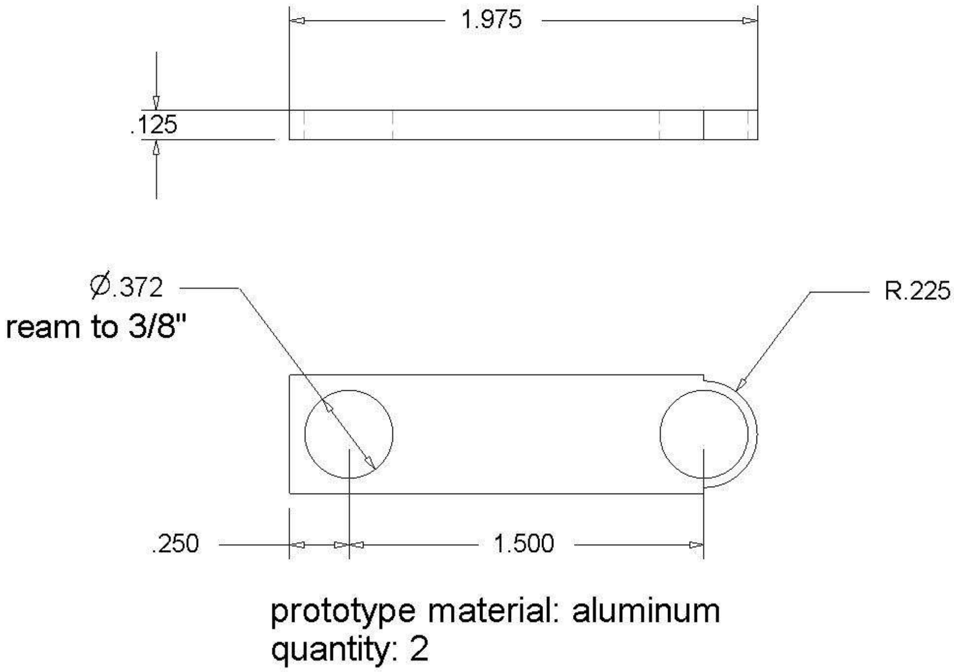
I will first show you how to use this spreadsheet and then present the equation.

I set my angle gage to 90° so that is what goes in the "known angle =" cell, E4. I measured the post to post distance and got 2.308" so it goes in the "known distance =" cell, E5. I have also measured the posts, or reference cylinders and know they are 0.372" in diameter. That is cell E6. The spreadsheet is now all set up.

I enter the desired angle into cell D8, 45.00°. The spreadsheet calculates the needed distance between posts as 1.420 inches. I set my digital caliper to this distance and adjust the angle gage to fit. That gives me my 45.00° angle.

Those two zeros to the right of the decimal point are a bit misleading. A change in angle of about 0.02" cause a 0.001" change in the distance. So you really can't have a resolution of 0.01" with my digital caliper.

The equation that goes into the cell marked "inches" is shown at the bottom of the spreadsheet. Excel® uses radians for its SIN function so the $\frac{PI}{360}$ term converts degrees to radians plus divides the angle in half.



I made my gage from aluminum since it was a proof of concept. Ideally it would be made from steel, hardened, and ground. Given how often I will probably use this gage, I'll probably stay with aluminum.

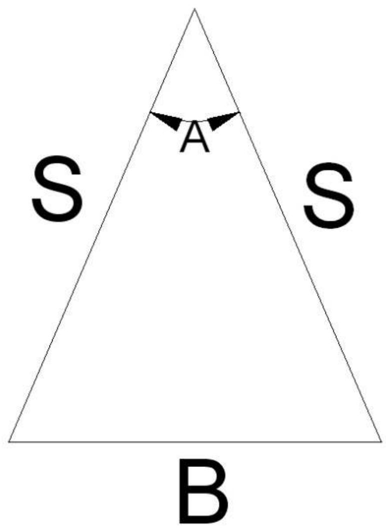
Few of the dimensions are critical. Have a snug fit between the holes and round stock. The hole spacing must be identical so it is best to stack the blades and drill through both parts at the same time. The outer edges do have to be true and flat. The posts must be perpendicular to the surface of the blades so it is best to side mill the blades and drill the holes without disturbing the parts.

You will need to cut off a 0.25" length of 3/8" CRS rod, face the ends for an overall length of about 0.24" and drill a clearance hole for a 6-32 screw. That is the pivot. If the rod is not round enough, you could use drill rod.

The post that fits into the lower blade is made 1/8" longer than the other post. I used ½" and 3/8" pieces but it is not critical. These posts should be a snug press fit into the reamed 3/8" holes but I also used Loctite® Red to keep them in place.

Lance of atlas_craftsman pointed out that if all 3 rods are made longer and extend through the blades, this gage could sit on the mill table.

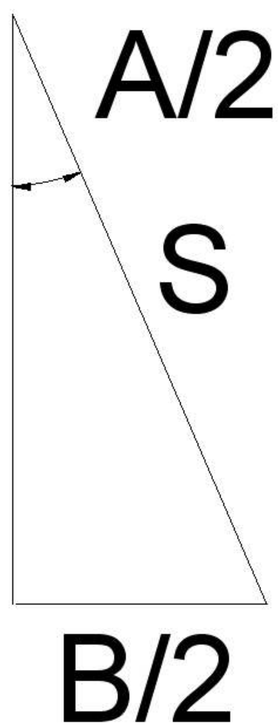
Appendix



In the following discussion, I will number each assumption that affects accuracy and then discuss them at the end.

Take a triangle with two sides with the same length (1). These sides form an angle, A, where they join (2).

The third side is the base and is marked B.



If I drop a line straight down from the top of this triangle to the base, I get a right triangle with hypotenuse, S, and an angle $\frac{A}{2}$. The base has a length of $\frac{B}{2}$.

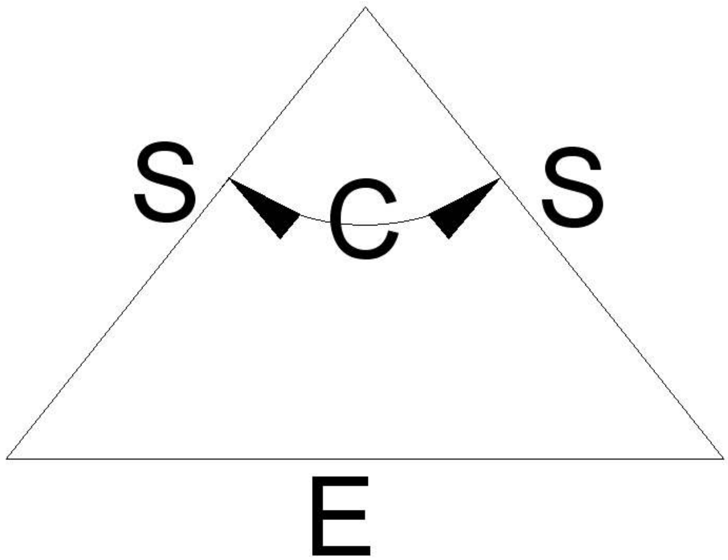
I can say

$$\sin\frac{A}{2} = \frac{(\frac{B}{2})}{S}$$

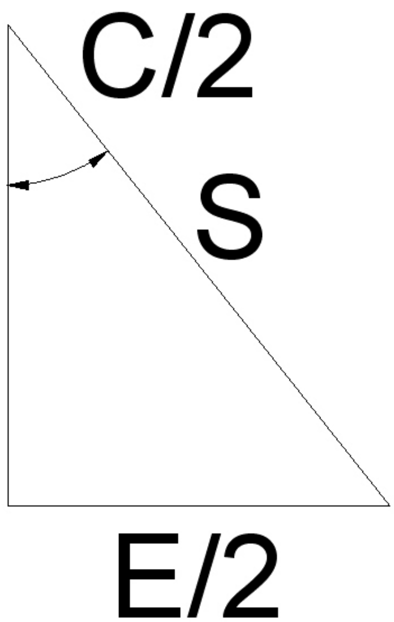
Solving for S I get

$$S = \frac{B}{(2\sin\frac{A}{2})}$$

In other words, we don't need to measure S as long as we know the angle, A, and the distance B.



Next, change the angle to C. The sides are still S but now the base is E.



I again drop a vertical line and create a right triangle. I can then say that

$$\sin\frac{C}{2} = \frac{(\frac{E}{2})}{S}$$

Solving for E I get

$$E = 2S\sin\left(\frac{C}{2}\right)$$

I know that

$$S = \frac{B}{(2 \sin \frac{A}{2})}$$

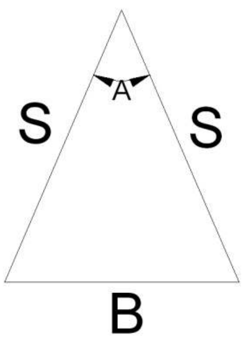
and

$$E = 2S \sin (\frac{C}{2})$$

So can combine these equations and eliminate the S variable

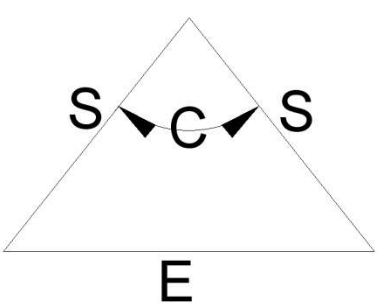
$$E = 2(\frac{B}{(2 \sin \frac{A}{2})}) \sin (\frac{C}{2})$$

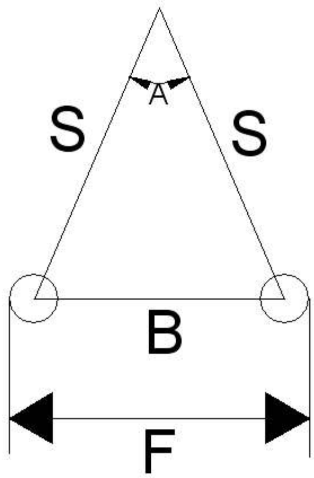
$$E = \frac{B}{(\sin \frac{A}{2})} \sin (\frac{C}{2})$$



This equation says that if I set angle A and measure distance B, I can then use this equation to set any angle, C, by setting distance E.

There is still one more step before this equation is usable. I must take into account the posts.





I have measured the diameter of one post. Since they were all cut from the same rod, they *should* both be the same diameter. If they are not, you can turn them to the same diameter or change to drill rod. You could also just live with the error by carrying the radius of each post in the equation. Now, if the posts are not round, then replace them.

Note that

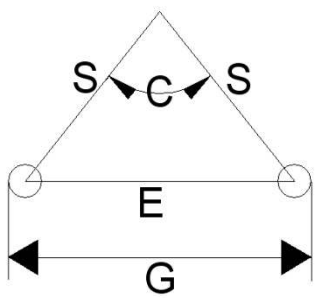
$$F = B + left\ radius + right\ radius$$

Assuming the posts are the same diameters, then

$$F = B + diameter$$

So

$$B = F - diameter$$



Similarly, I can say

$$E = G - diameter$$

∘

Putting this all together, I get

$$E = \frac{B}{(\sin\frac{A}{2})}\sin\left(\frac{C}{2}\right)$$

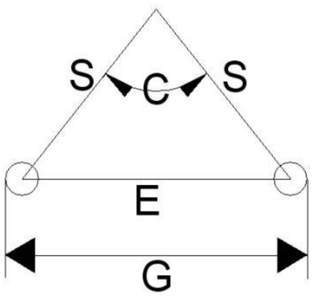
$$G - diameter = \frac{F - diameter}{(\sin\frac{A}{2})}\sin\left(\frac{C}{2}\right)$$

Or

$$G = diameter + \frac{F - diameter}{(\sin\frac{A}{2})}\sin\left(\frac{C}{2}\right)$$

When I calibrate the instrument, I set the angle, A, to 90° and measure F. I have already measured the diameter of the post.

$$G = diameter + \frac{F - diameter}{(\sin\frac{A}{2})} \sin(\frac{C}{2})$$



All parameters in red are known. So what is left is a way to translate the desired angle, C, into a distance between posts of G.

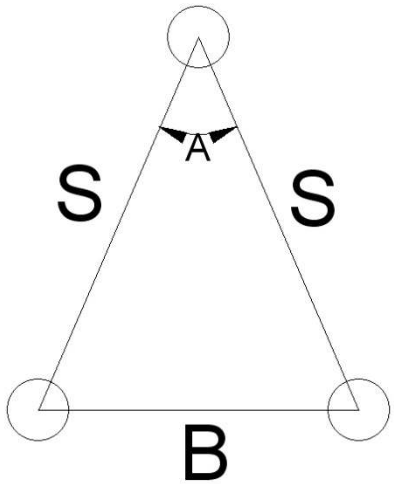
There is one more assumption made with these equations: that the angles A and C are between the sides of the triangle (3).

Damn Reality

It is time to face the reality of physically making this instrument. This is where my assumptions are challenged and, hopefully, addressed by machining procedures.

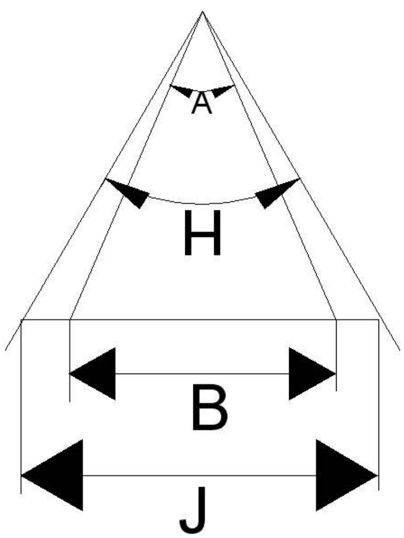
Assumption (1): Take a triangle with two sides with the same length.

If the blades are stacked up and clamped, I can drill and ream the two holes through both parts at the same time. Assuming the mill is decently aligned and the part set perpendicular to the center of rotation of the spindle, the hole spacing on one blade with be identical to the hole spacing on the other blade. Furthermore, the holes should be perpendicular to the surface of each blade.



Assumption (2): These sides form an angle, A, where they join.

The center of the pivot pin is the point where my theoretical sides, S, join to form angle A. If this pin is a snug, sliding fit in its reamed hole, the hole is perpendicular to the surfaces of the blades, and pin is round, then assumption (2) should be satisfied enough to not contribute to overall error in a significant way.

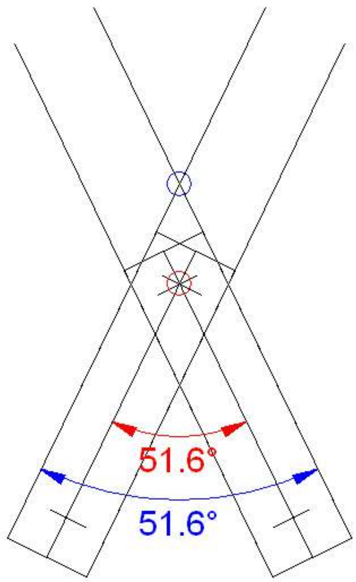


Assumption (3): The angles A and C are between the sides of the triangle. If the edges of the blades are not parallel to the theoretical sides, S, of my triangle, then I have error.

This error can be made “small” by side milling the blades and then drilling and boring the holes without disturbing the part. One way to do this is to place two strips of blade material down on a piece of Medium Density Fiberboard (MDF) one on top of the other and clamping the ends. The clamps must be narrower than the finished width of the blades.

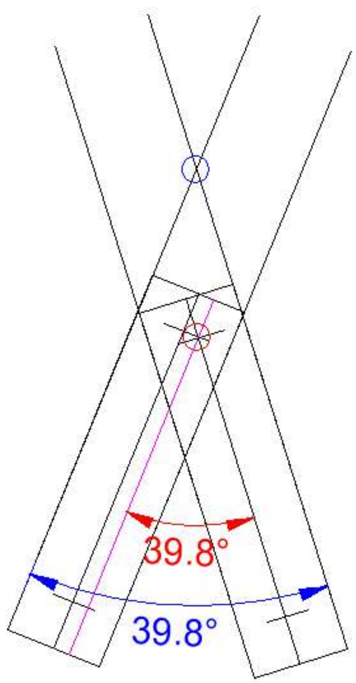
Then side mill both edges and drill and ream the two holes through both parts. This will insure that the edges are parallel to the centerline of the holes. Then side mill the ends. The overall length of each blade is not that important. You can free hand file or sand the smaller radius at the pivot end.

This should insure that the line between the centers of the holes is parallel to the sides of the blades within the accuracy of your mill.



There is one thing that is not important but it took me a while to realize it. The two holes do not have to be on the centerline of the blades. Rather than write up a proof, let me just demonstrate it with real numbers.

First look at the idea case. Here you see that my blades are set to 51.6° when measured at the center lines and through the pivot pin's center. But if you measure from the outer edges of the blades with respect to a different pivot point, you get the same number. This new pivot point is defined by extending these outer edges until they intersect.



Next, consider the case of one blade not having its holes on its center line. The angle formed by the line connecting the center of the left post with the pivot is the start of the angle. The center line of the right blade is the end of the angle. I read 39.8°.

Compare this to the angle formed by the outer edges of the blades. Again, my pivot point for this angle is defined by the intersection of lines along these edges but the angle is the same.

This demonstrates, but does not prove, that it is not important for the holes to be on the center lines of the blades.

Overall Check of Instrument

In the end, the only way to check this instrument is to calibrate it with one known angle and then test it against another known angle. This should give you an overall check of your work.

Acknowledgement

Thanks to Malcolm of gingery_machines for pointing out that the blades should be match drilled and also for checking my math. Thanks to Lance of atlas_craftsman for his suggested new application on a mill table. Thanks to Richard of atlas_craftsman for encouraging me to add the appendix.

I welcome your comments and questions.

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