



<a href='http://www.4x4wire.com/phpAdsNew/adclick.php?n=a28d6850' target='\_blank'><img src='http://www.4x4wire.com/phpAdsNew/adview.php?what=zone:17&target=\_blank&n=a28d6850' border='0' alt=''></a>

# Degreeing a Cam on the 22R-Series [Engine](#)

[4x4Wire](#) [TrailTalk BBS](#) [Galleries](#) [Search](#)

[http://www.4x4wire.com/toyota/tech/cam\\_degreeing/](http://www.4x4wire.com/toyota/tech/cam_degreeing/)

| [Toyota Section](#) | [Toyota Tech](#) | [Toyota Reviews](#) | [Toyota Maintenance](#) |

## Short Cuts

Navigation Menu ✖

<input type="submit" value="Go" name="submit">

By: [Jeff Moskovitz](#) - January, 2002.

Before I explain why you should degree your camshaft, let's review the function of the crankshaft and camshaft in a four stroke, internal combustion engine.

As the name implies, four stroke internal combustion engines go through four distinct strokes for each combustion cycle: intake, compression, power, and exhaust, also known as **suck, squish, bang, and blow**. This means that for each combustion cycle, the piston moves up and down twice. This corresponds to two complete revolutions of the crankshaft. Interesting fact: because the camshaft rotates at half the speed of the crank, that means the camshaft only rotates a quarter turn for each of these strokes.

**Great Prices On Camshafts**  
Low Cost Stock Replacement  
Cams! American Made, High Quality

**Evinrude Outboard Engines**  
Think two-stroke E-TEC.  
Superior to four-stroke in every major category

**JE Pistons on Sale Here.**  
JE Pistons and Rings on sale now. Free Shipping on sets. Order today.

**Internal Coatings (New)**  
Ultra-hard, anticorrosion, antiwear Pipes, valves, pumps, and much more

From the crankshaft end of things, the operation is very simple: the piston is moving straight up or straight down every 180 degrees of crankshaft rotation. The camshaft, however, has a much more complex series of tasks to perform, as each valve must be opened and closed at precisely the right moment. To accomplish this, the camshaft rotates once for every two crankshaft revolutions, or one complete revolution per four stroke cycle.

As the piston is being pulled down, the intake valve is opening, and the intake mixture is being sucked into the cylinder, or pushed into the cylinder in the case of forced induction motors.

Once the mixture has been pulled into the cylinder, the intake valve closes, and the piston begins to rise on the compression stroke.

As the piston is rising and the mixture in the cylinder is being compressed, a spark event is initiated at some predetermined point. This ignites the fuel mixture, and as it expands it forces the piston downwards on the power stroke.

Once the power stroke is complete, the piston rises again, the exhaust valve opens, the combusted gasses are expelled, and the cycle is repeated.

Needless to say, all of these events must occur at just the right time, in the correct order, and for the correct duration. The point where an intake valve is first opened, how much it is ultimately opened, when it closes, and how these events relate to the same events taking place on the corresponding exhaust valve are critical, determining factors in an engine's performance.

These characteristics are all built in to your camshaft, and you change them by changing cams.

**The relationship of these valve events to one another cannot be changed in a 22R engine except by changing camshafts. However, the relationship of these events to the movement and position of the pistons/crankshaft CAN be changed.** This is referred to as **cam timing**, and small changes in your cam timing can make noticeable, and sometimes even dramatic changes in your performance. To determine your actual cam timing and make these changes in an informed, logical manner, it is necessary to "degree in" your cam.

### What is "degreeing in" your cam, and why is it necessary?

By "degreeing in" a camshaft, we mean determining its \*exact\* relationship to the crankshaft. While it would be nice if we could trust the timing marks on the crank pulley and oil pump housing for this, the reality is that there are many components that actually determine cam timing, and small variations in any or all of these components can make the actual cam timing several degrees advanced or retarded from the timing as shown on the stock timing marks.

Consider all of the components that figure in cam and crank timing: the crankshaft and camshaft, obviously, but also the timing gears, timing chain, thickness/height of the head, thickness/height of the cam bearing journals, height of the deck, thickness of the headgasket, precision of the marks on the cast oil pump housing, and the integrity of the stock crank pulley (which is actually a two piece affair on all but the early 22R engines). Quite a few factors to trust, and all it takes is milling a few thousandths off the head and/or deck to retard stock cam timing by a few degrees.

So, to be as precise as possible, it is necessary to degree in your camshaft.

### What do you need to do this?

To degree in a camshaft on a 22R series engine, you need the following special parts and tools:

- a camshaft degree wheel (I used the [Mr. Gasket 7" wheel, p/n 1570](#), about \$21 from [Summit Racing](#))
- a piston stop (I used the [Crane Cams p/n 99412-1](#), which is made from brass and features a center hole to relieve cylinder pressure while you rotate the engine. And the brass will dent before your piston does. This was about \$12 from Summit).
- a dial indicator with a magnetic base and adjustable arm.
- a 14MM X 1.5MM X 75MM bolt.
- two or three nuts of the same size and pitch as the above bolt.
- a number of 14MM (or 1/2" or 9/16") washers.
- a piece of stiff wire to use as a pointer (e.g., a wire coat hanger).
- an adjustable cam gear. You can measure your cam timing without an adjustable cam gear, but you will need such a gear to change your cam timing.
- patience and the dedication to be as accurate as possible, even if it takes a while.



### First things first: let's get set up

It is much easier to degree a cam when the engine is out of the vehicle...but I'm going to assume that your engine is still in your vehicle. If it's out of the vehicle, pat yourself on the back, because this just became a whole lot easier for you. For everyone else, roll up your sleeves...

To degree in the cam, you will need to have clear access to the crank pulley. I found that I

needed to remove both the power steering belt and the alternator belt. I also found that I needed to remove my fan and pulley from the front of the water pump (you want to remove the four 10MM nuts, and extract the fan and fan clutch as one unit, if possible). Some folks may also need to remove the fan shroud. I got lucky and didn't, but you might, depending on the exact year and style of fan shroud you have installed. If you have an aftermarket electric fan and shroud combo, I believe you will also need to remove that as well.

You will also need to remove the stock crank pulley bolt. This can be a major PITA if you haven't done it before, but it's actually pretty easy once you master the basic technique of using the starter and a breaker bar braced against the frame. I am going to assume that you have a method for removing this bolt that you are familiar with, as removing this bolt could make up a decent article in its own right.

So, remove the following:

- belt(s).
- fan and fan clutch.
- crank pulley bolt.
- fan shroud (if necessary).
- spark plugs.
- valve cover.

### Attach the degree wheel

Once the belts and fan are out of the way, you can attach the degree wheel to the crank pulley.

As I said above, I used the Mr. Gasket 7" degree wheel. This wheel comes with a big hole in the center and two aluminum bushings to size this hole down for the more common domestic sized bolts. If you use this wheel, you will need to enlarge the opening of one of these bushings to make it work with the larger Toyota crank pulley bolt. I held the bushing with a pair of Vise Grips and used a 9/16" drill bit to enlarge the hole, which worked fine.

To actually attach the degree wheel to the crank shaft, I used a long bolt of the same thread size/pitch as the stock crank bolt, and a number of washers and nuts to allow me sufficient stand-off to keep the degree wheel from touching the crank pulley. The picture to the right illustrates the improvisation required to make this setup work.



Two things to keep in mind: you will need to be able to move the degree wheel a *little bit* after you determine positive TDC (explained below), and you will need to use this bolt to turn the engine both forwards and backwards. For these reasons, I used a metric nylon lock nut to keep the washer stack and degree wheel pressed very-firmly-but-not-quite-immobilized against the head of the bolt. You want to have a lot of friction between the two clamping surfaces, but not so much that you can't rotate the wheel a little bit when you need to. I then used a standard nut as a jam nut and spacer against the lock nut, because I was going to be using this bolt to turn the engine and really didn't want anything in the stack to move once I had the degree wheel in position.

Finally, I used several very stout washers between the jam nut and the end of the crank shaft. Even though I was doing this operation with the crank pulley still in place, I didn't want these final washers to touch anything other than the surface of the crank, because washers that would be wide enough to span the crank pulley opening might deform when this bolt was tightened, or even worse, then the engine was turned, which would move my TDC marker and force me to start over. So I went with stout washers of a diameter small enough to allow me to tighten this bolt firmly against the crankshaft.



Your finished degree wheel and pointer assembly should look similar to this.

**After assembling the degree wheel, bolt it firmly to the front of the crank shaft!** You will be using this bolt to rotate the engine in both directions, so this bolt needs to be on there tightly, or you might inadvertently break it free when you are moving the engine in reverse rotation. If that happens, you will need to begin this procedure all over again, so make sure that this bolt is on there tight.

Finally, after you have the degree wheel in place, attach the heavy wire pointer to any convenient bolt on the timing chain cover or water pump. I chose the lower right timing cover bolt, because this was a convenient spot from which to read the degree wheel.

### Locate positive top dead center (TDC)

As mentioned above, you just can't trust the stock timing marks for this operation. Consequently, it is necessary to determine *positive TDC* before you begin. By positive TDC, I mean the point where the piston is at TDC after you have taken up all of the slack in the timing chain and the engine's other rotating parts.

The overview of this procedure is to install the degree wheel and bring the engine to TDC on the stock marks, and rotate the degree wheel so that it, too, indicates TDC on the wire pointer, as explained below. Next, the engine is backed off 30-40 degrees, and a piston stop is inserted into the cylinder. The engine is then rotated forward until the piston hits the stop, and the position of the degree wheel is noted. The engine is then rotated in the opposite direction until the piston again contacts the piston stop, and the position of the degree wheel is again noted. Positive TDC will be at the middle point of these two readings, and the degree wheel is moved so that it indicates true TDC. For example, if the piston initially contacts the piston stop at 16° BTDC, and then after being rotated in the reverse direction contacts the piston stop again at 20° ATDC,  $16 + 20 = 36$ . Divide  $36 \div 2$  to get the average, 18. Subtract the average from the greater number, and rotate the degree wheel (NOT the engine!) by the difference to bring the degree wheel to true TDC. If the side before TDC was greater, you will rotate the wheel clockwise, and vice versa if the side ATDC was greater. In this example, rotate the wheel 2° counter-clockwise. Repeat the test again to verify that the degree wheel now reads the same each time it hits the piston stop.

### Here are the step-by-step instructions to determine positive TDC:

1. Remove the spark plugs and valve cover, and disconnect the negative battery terminal.
2. Bolt your degree wheel firmly to the crank shaft, keeping in mind everything described in the previous section.
3. Bend a piece of coat hanger wire into the shape of a pointer, and bolt it to the underside of the engine. I found that the lower right timing cover bolt worked well for this. Use wire that's strong enough so that it won't be moved or bent by accidental contact -- if this wire gets moved at any point after you establish positive TDC, you will need to start over, and reestablish positive TDC.
4. Using a socket or wrench, rotate the engine so that it is at TDC, using the stock timing marks.
5. Adjust the degree wheel so that it's TDC mark lines up with the pointer.
6. Reverse rotate the engine 40 degrees or so, so that the piston is down in the cylinder.
7. Insert the piston stop into the cylinder until it bottoms out. If you contact the piston before the piston stop bottoms out, I recommend backing the engine up further, so that you can really make sure the piston stop is bottomed out.
8. Take a Sharpie pen and mark a vertical line on the head of the piston stop at the 12:00 position. **[NOTE: Because of the relatively shallow angle between the spark plug and the piston top, as well as the proximity of the piston stop to the intake valve, there will be valve to piston stop contact when you try to rotate the engine through a complete revolution. Consequently, the best method I found was to mark the piston stop and then pull it out while you rotate the engine. This isn't ideal, but it's also not going to**

**introduce too much inaccuracy as long as you are careful. Remember, too, that if the piston stop is made of brass it will deform easily, so don't torque this down as if it were a spark plug.]**

9. Rotate the engine slowly forward until it is stopped by the piston stop.
10. Note the position of the degree wheel in degrees before TDC, and write this number down.
11. Remove the piston stop.
12. Rotate the engine through TDC, and about 40 degrees past TDC.
13. Reinsert the piston stop, making sure that it is aligned the same as when you removed it.
14. Reverse rotate the engine until it contacts the piston stop.
15. Note the position of the degree wheel in degrees after TDC.
16. Subtract the smaller number from the bigger number, and divide the difference by 2. This is the number of degrees you will need to rotate your \*degree wheel\*. If the BTDC number is greater than the ATDC number, you are going to rotate the degree wheel clockwise. If the ATDC number is greater, rotate the wheel counter-clockwise.
17. Repeat the procedure one more time, just to make sure the two piston stop numbers are the same. If they are not, adjust and repeat until they are. *Be as exacting as possible -- there's no point in going through this process if you aren't willing to take the time to be exact.*
18. Remember to remove the piston stop when you are done!

### Find the centerline of the intake lobe

Now that you know the exact location of true TDC, you are ready to find the centerlines of the intake lobe. The intake centerline is used because this is information that is typically included on the cam card that ships with most cams. Note that "intake centerline" is different from "lobe separation angle." If your cam card doesn't have the intake centerline listed, call your cam manufacturer!

*Our goal is to find the highest point on the cam's intake lobe, and map that position to a point on the crankshaft degree wheel.*

With the engine still set to TDC on the degree wheel, set the valve lash to 0.000". For measuring purposes, valve lash just increases cam retard, so it's important to make sure things are set to zero before we go any further.

Next, get your dial indicator, and mount it to a sturdy location where you will be able to track the movement of the valve spring retainer, such that the dial indicator's tip will move parallel to the valve spring.

Most dial indicators have a magnetic base. Because the head and intake manifolds are aluminum, this can make it hard to mount the dial indicator in a position where it will do you any good. I found that by sandwiching a small piece of flat stock between two nuts on one of the valve cover retainer studs, I was able to work on both intake and exhaust valves pretty easily. My mount is visible in the picture (shown on the exhaust valve, because it made for an easier picture).



Dial indicator shown on the exhaust valve spring retainer; mount yours on the intake valve retainer!

You are going to be take your readings from the valve spring retainer as it moves downwards. This might be counter-intuitive, but it's a lot easier to measure valve movement on the retainer than on the lobe of the cam -- the presence of the cam follower makes it very difficult to get good readings from the lobe itself.

Consequently, it is important to preload the dial indicator against the valve spring retainer such that you will get readings throughout the full range of valve's movement. In other words, if you start the dial indicator at 0.00" (no preload), you are only set up to measure the compression of the indicator tip. We are actually going to be measuring the droop of the tip, so we need to preload the gauge accordingly. How much preload doesn't really matter, as long as the gauge never bottoms out.



Again, this picture was taken on the exhaust side because it was easier to see, but set yours up on the intake valve.

Also, when mounting the indicator, remember to pay attention to the angle at which the tip of the dial indicator intersects the valve spring retainer. Ideally, the tip should be perpendicular to the retainer, so that the movement of the tip is identical to the movement of the shaft:

Don't get fooled by the valve lash adjuster, either. It's the valve's movement you want to follow.

Once you have things set up, rotate the crankshaft in the direction of engine rotation until you come up near the toe of the intake lobe (the point of maximum lift). As the valve spring is depressed by the cam follower, the dial indicator dives downward, and its reading decreases. At the point of maximum valve lift, the dial indicator will seem to hesitate for a moment, and then its readings will begin to increase. When this happens, you know that you have just passed through maximum lift. Back the engine up, and locate this point of maximum lift again. Once you have it, align the dial indicator's dial such that the zero on the dial lines up with the needle on the face of the gauge.

As when we located positive TDC, we are now going to take two crank degree measurements on either side of this point of maximum lift. I like to take these measurements at .075" less than the point of maximum lift, but any point greater than .030" will probably do, as long as you use the same measurement for both sides of the lobe. (**Note:** I use .075" because the Toyota rocker arms use a 1.5:1 ratio. Most cam measurements are taken at .050", but if you are going to measure at the valve retainer, you need to factor in the built-in mechanical advantage of the rocker arm.)

Begin by backing the engine up so that the dial indicator moves about .200" from max lift.

Next, slowly rotate the engine forward, until the dial indicator shows that the valve spring is .075" before maximum lift. Try to be as exact as possible. This can be a little frustrating, as the motor always seems to want to move .005" more than you want it to. If you overshoot the mark, be sure to back the motor up about .100" and try again (you do this to eliminate the slop in the valvetrain). Once you have the cam at exactly .075" before max lift, note the position of the degree wheel.

Once you have the first measurement down, rotate the engine past the point of max valve lift, and take the same measurement on the other side, when the cam reaches .075" past max lift. Write this measurement down.

**IMPORTANT: all figures need to be referenced to 360 degrees of total cam rotation.** The Mr. Gasket degree wheel I used was marked in 90° increments, so all marks over the first 90° had to be converted to their respective 360° equivalents. For example, my first measurement was 69° ATDC. My second measurement was 29° BBDC...which is really 151° ATDC (BDC = 180° ATDC, so 180° - 29° = 151°).

Your intake centerline is:

$$\frac{(\text{the first measurement}) + (\text{the second measurement})}{2}$$

So in this case, my intake centerline is (69° + 151°)/2, or 110°. Compare your result to the number on your cam card. In my case, my intake centerline on the cam card was also listed as 110°, so no adjustment was necessary to bring my cam back to zero. I can now advance or retard the cam with some confidence that I am starting from the proper position.

However, what if my numbers had come out different? When the measured intake centerline is less than the centerline specified on the cam card, the cam is said to be advanced. Similarly, when the measured intake centerline is greater than the centerline listed on the cam card, the cam is considered to be retarded.

For example, if my measured intake centerline had come out to 114°, my cam would be installed 4° retarded. If the intake centerline was measured as being 108°, my cam would have been installed 2° advanced.

### What to do with this info?

Advancing or retarding a cam moves peak torque lower or higher in the rpm range, respectively. If you add torque to the bottom of the rpm range, you take torque off the top, and vice versa. Because the cam is only one engine component, and all engine components need to work together, some engines can benefit from more advance or more retard.

22R/RE engines typically benefit from 2°-3° of cam advance. Since many engines inadvertently develop several degrees of cam retard after their heads have been decked, actually bringing the cam to a true 2° or 3° of advance can make a very noticeable difference in performance. In the case of turbo engines, which typically breathe better at higher rpms, you will usually see more peak power by retarding the cam timing several degrees. However, this increase in peak power will come at the expense of some low end torque. If your turbo is already feeling pretty laggy and you want more torque down low, you may want to forsake more top end power and advance the cam several degrees, which will definitely translate into more seat of the pants/off the line acceleration.

Finally, keep in mind that 6° is about as much as you would want to move the cam in either direction without making absolutely certain that you have sufficient piston-to-valve clearance. Because the 22RTE pistons have a dish to them, you have a fair amount of clearance, but advancing the cam increases the likelihood of contacting the intake valve, while retarding the cam increases the likelihood of contacting the exhaust valve. Go slow and use your head -- nothing would be worse than bending a valve trying to squeeze another 5 hp from your motor.

### Related Links:

- [Jeff's 22R-TE Page](#)
- [Jeff's LC Engineering Turbo Header Review](#)
- [CompCams' catalog, especially page 23, "Degreering in a Camshaft"](#)
- [Crane Cams' "Degreering in a Cam"](#)
- The article "[Cam Truth](#)", by Buddy Rawls
- [Toyota Review- D.O.A. Racing Engines 22R Timing Chain](#)
- [Toyota Maintenance- 22R Timing Chain Replacement](#)
- [Toyota Tech Section](#)
- [Toyota Main Page](#)

### Sources:

- [D.O.A. Racing Engines](#)
- [LC Engineering](#)
- [Summit Racing](#)
- [CompCams](#)
- [Crane Cams](#)

[4X4Wire](#)	[Site Index](#)	[Links Index](#)	[Search 4x4Wire](#)
[Trail Talk BBS](#)	[Events Calendar](#)	[Photo Galleries](#)	
[Advertiser's Guide](#)	[Information](#)	[About Us](#)	

Please support 4x4Wire by visiting our featured sponsors






[Tuff Country](#)



[4Wheel Online](#)



[Rough Country](#)

 <a href="http://4WS.com">4WS.com</a>	 <a href="http://SuspensionConnection.com">SuspensionConnection</a>	 World's Best Selection
<a href="#">Advertise Here</a>		

This site and all original materials contained herein are Copyright © 1999,2000,2001,2002,2003,2004,2005,2006 by OutdoorWire, Inc.. -- All Rights Reserved.

The use of this website, OutdoorWire, or any of its publications or services is subject to the [terms of use agreement](#). You may link freely to this site, but no further use is allowed without the express written permission of the owner of this material.

All corporate trademarks are the property of their respective owners.

This publication and OutdoorWire, Inc. assume no liability for your use of the material contained within this site.

OutdoorWire, 4x4Wire, SUVWire, JeepWire are all trademarks and publications of OutdoorWire, Inc.

Current advertisers: Rough Country, Edelbrock, TRDParts4U.com, Tuff Country, SuspensionConnection.com, 4Wheel Online, All Pro Offroad, Marlin Crawler, Aussie Locker, 4Wheelers Supply