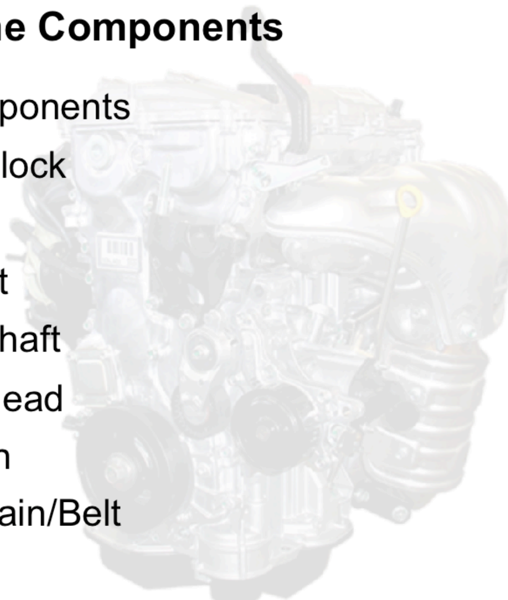
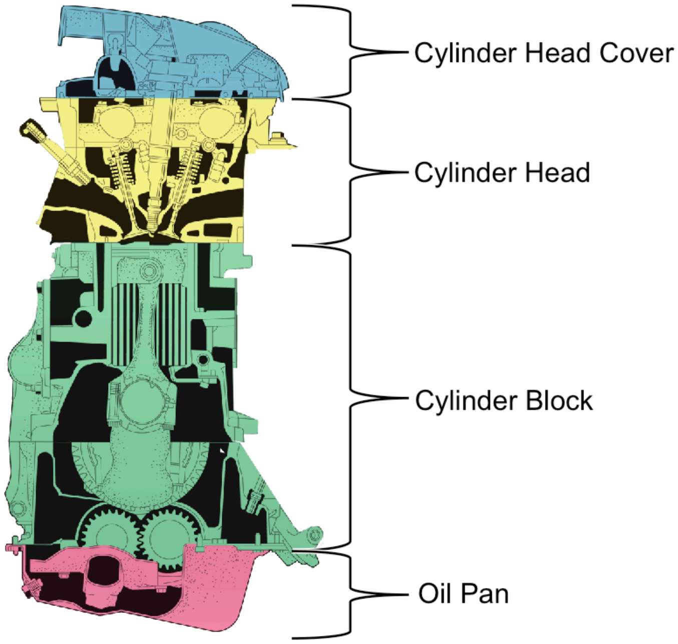
Section 2 Topics

Basic Engine Components



- Main Components
- Cylinder Block
- Pistons
- Crankshaft
- Balance Shaft
- Cylinder Head
- Valve Train
- Timing Chain/Belt

Main Components



Main Components

When you remove the intake system and exhaust system from the engine, the main engine components that remain are the:

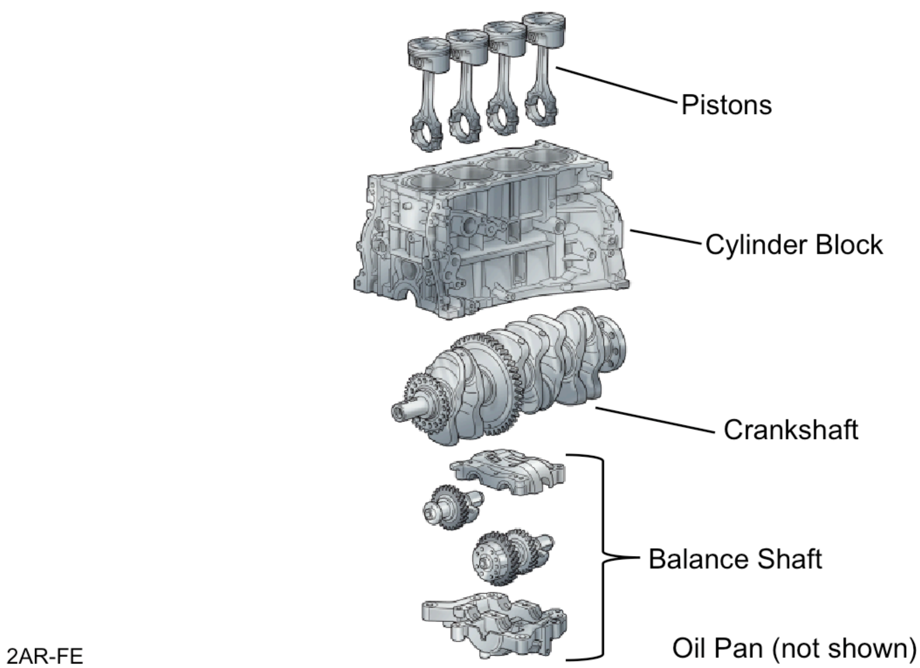
- **Cylinder Head Cover** – Seals the top end of the engine to keep lubricating oil in and dirt and contaminants out.
- **Cylinder Head** – Houses the valve assemblies and is the attachment point for the intake and exhaust manifolds. In engines with overhead cam (OHC), the camshaft and cams are also in the cylinder head.
- **Cylinder Block** – Houses the pistons and crankshaft. In engines equipped with a balance shaft, the balance shaft is contained in the cylinder block.
- **Oil Pan** – Seals the bottom end of engine and provides a collection point for lubricating oil to be recirculated by the oil pump.

Short Block vs. Long Block

A short block is a replacement cylinder block containing the crankshaft, connecting rods, and pistons.

A long block, otherwise known as a Partial Engine Assembly, is a fully assembled engine without manifolds or most accessories.

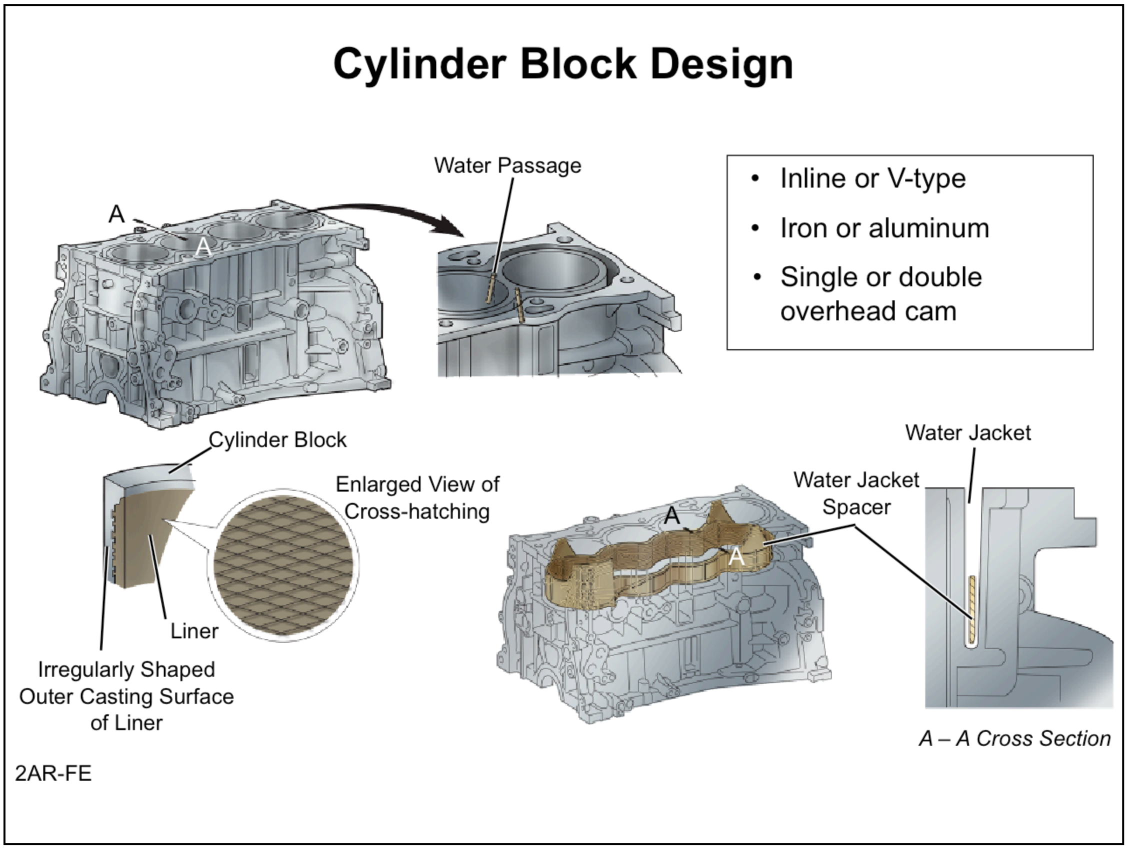
Cylinder Block Major Components



Cylinder Block Major Components

The major components in the cylinder block are:

- Pistons
- Crankshaft
- Balance Shaft



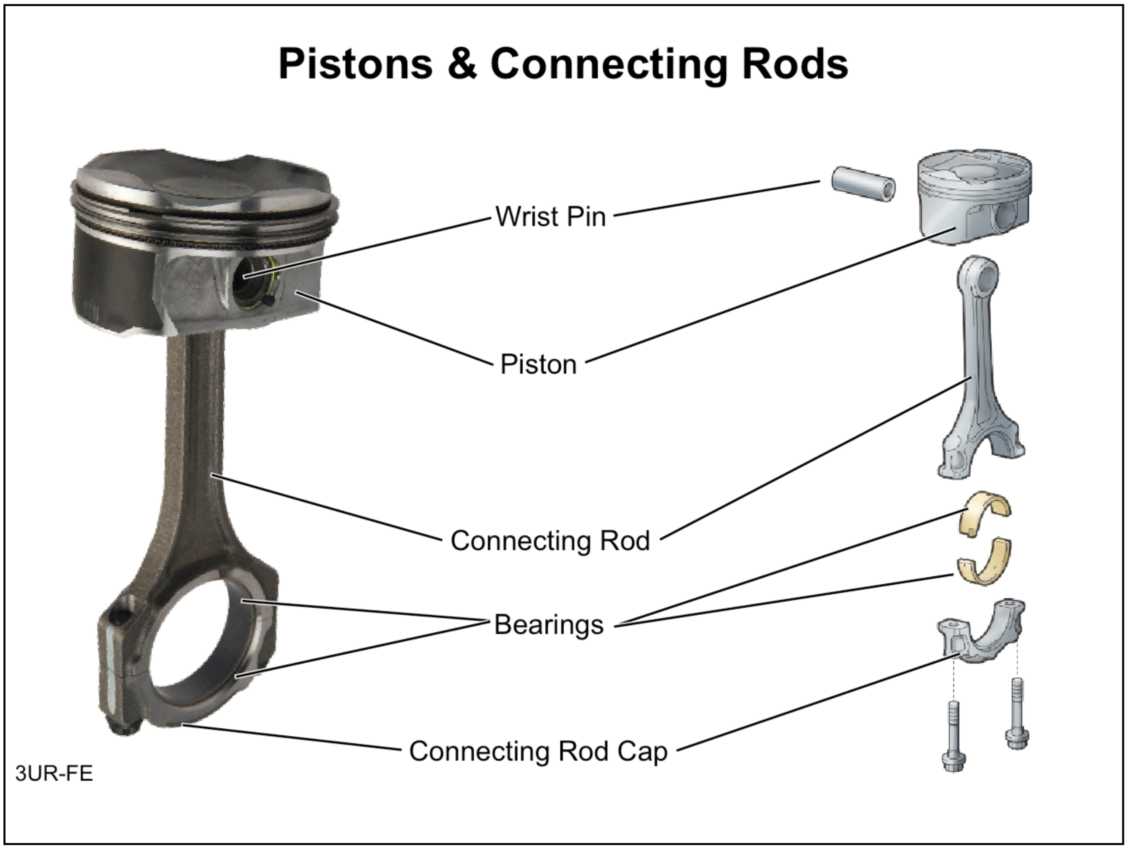
Cylinder Block Designs

Engine designs based on piston count and piston arrangement – such as inline, v-type, or horizontally opposed – are only the beginning of engine design evolution.

Some engines are manufactured with **iron cylinder blocks** and some are **made of aluminum**. Iron blocks are strong and lower cost but aluminum blocks are much lighter weight and dissipate heat better.

In an engine with a single overhead cam design, the cam lobes that open and close the intake and exhaust valves are on the same camshaft. Most Toyota engines use the double overhead cam design that provides individual camshafts for the intake valves and exhaust valves.

These are only a few of the more significant differences in cylinder block designs.



Pistons and Connecting Rods

Because pistons are subject to extremely **high temperatures and pressures**, they are normally made of aluminum for durability and reduced weight.

NOTE

The piston skirt has a resin coating to reduce friction. Be careful not to remove this coating.

The **piston** is fastened to a **connecting rod** by a wrist pin that allows the rod to move back and forth as the crankshaft rotates. In some designs, the wrist pin is **press-fit** into the connecting rod leaving the piston to rotate freely. In other designs, the wrist pin is held in place by **snap rings** at each end.

A pair of **bearings** provide the proper oil clearance where the connecting rod fastens to the crankshaft. Bearings are held in place by the **connecting rod cap**.

NOTE

The connecting rod and connecting rod cap are a matched set. If the connecting rod cap is removed, be sure it is reassembled with the correct connecting rod and in the correct direction.

Piston Rings

Piston rings create the seal to prevent combustion gases from leaking into the crankcase (blow-by) and prevent crankcase oil from entering the combustion chamber.

To prevent blow-by, the piston uses two compression rings. Ring tension and compression/combustion pressure seat the rings in the bottom of their grooves thus creating a seal.

The oil ring is designed to scrape oil from the cylinder walls and return it to the crankcase. When an oil ring fails, oil is burned in the combustion chamber resulting in bluish exhaust smoke.

NOTE Note the 2nd compression ring has a lip and must be installed with the correct side up.

High vs. Low Tension Rings

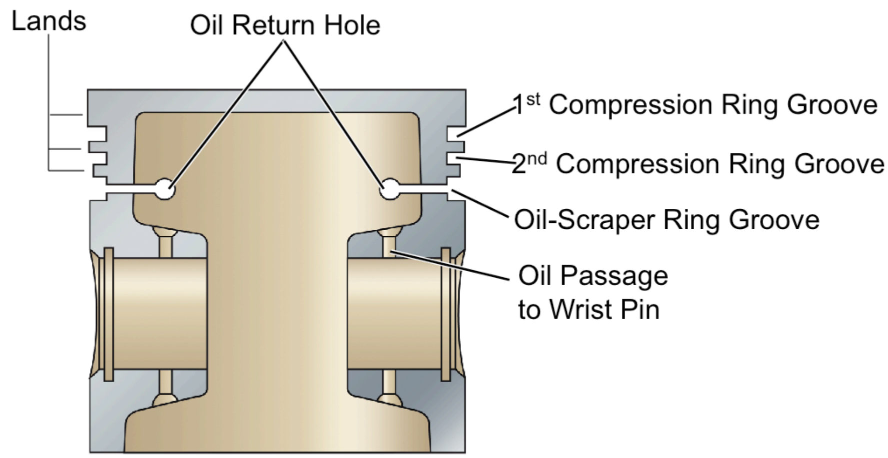
In older engines, piston rings were made of high tension steel. Because of their spring strength, they pressed tightly against cylinder walls and were difficult to remove from the piston without a special tool.

Piston rings in modern Toyota engines are low tension to reduce friction and increase gas mileage. The use of low tension rings has been made possible in part by low viscosity oils such as 5W20 and 0W20.

NOTE Although low tension rings are easy to remove without a special tool, they are also easier to break, so remove piston rings with care.

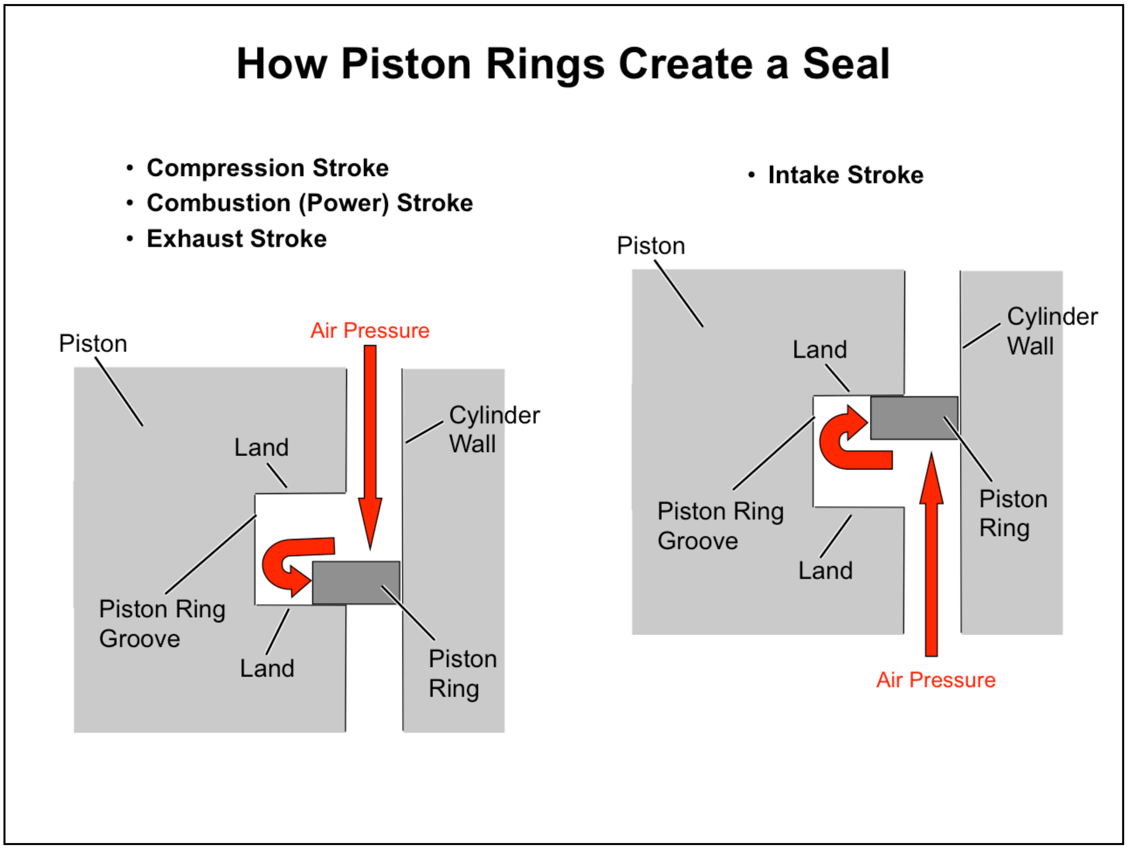
A *physical vapor deposition* (PVD) coating on ring #1 creates an ultra-hard surface that reduces wear and increases ring life.

Piston Ring Grooves



Piston Ring Grooves The groove for the oil ring has two passages within the piston body that allow oil to flow back to the wrist pin and ultimately back into the crankcase.

Piston rings are not solid, but have a gap resembling a snap ring, though the piston ring gap is very small. The gap allows the ring to be expanded and slipped over the piston for installation. Piston rings sometimes have an “up” side, and the gaps in the rings must be arranged on different sides of the piston.

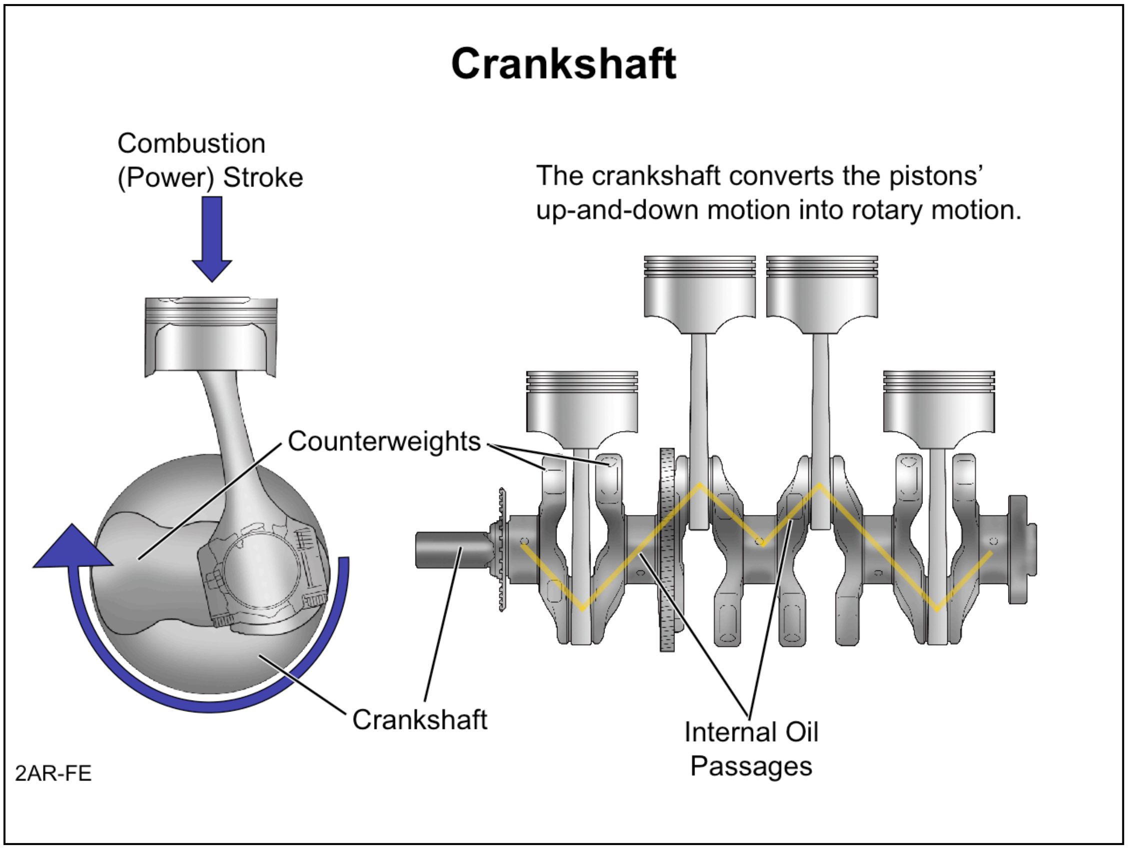


Piston Ring Function

The flat surfaces at the top and bottom of the piston ring groove are called “lands.”

During the compression, combustion, and exhaust stroke, higher air pressure above the piston forces the ring tightly against the lower land. Air pressure behind the ring then forces it tightly to the cylinder wall creating a seal.

During the intake stroke, the higher pressure is below the ring which forces it to seal against the upper land.



Crankshaft

The crankshaft converts the pistons' up and down motion into rotary motion that is transmitted to the transmission and drive axles. It is a one-piece component made of cast iron or forged steel. Components of the crankshaft include:

- Main bearing journals
- Rod bearing journals
- Counterweights

Oil Passages

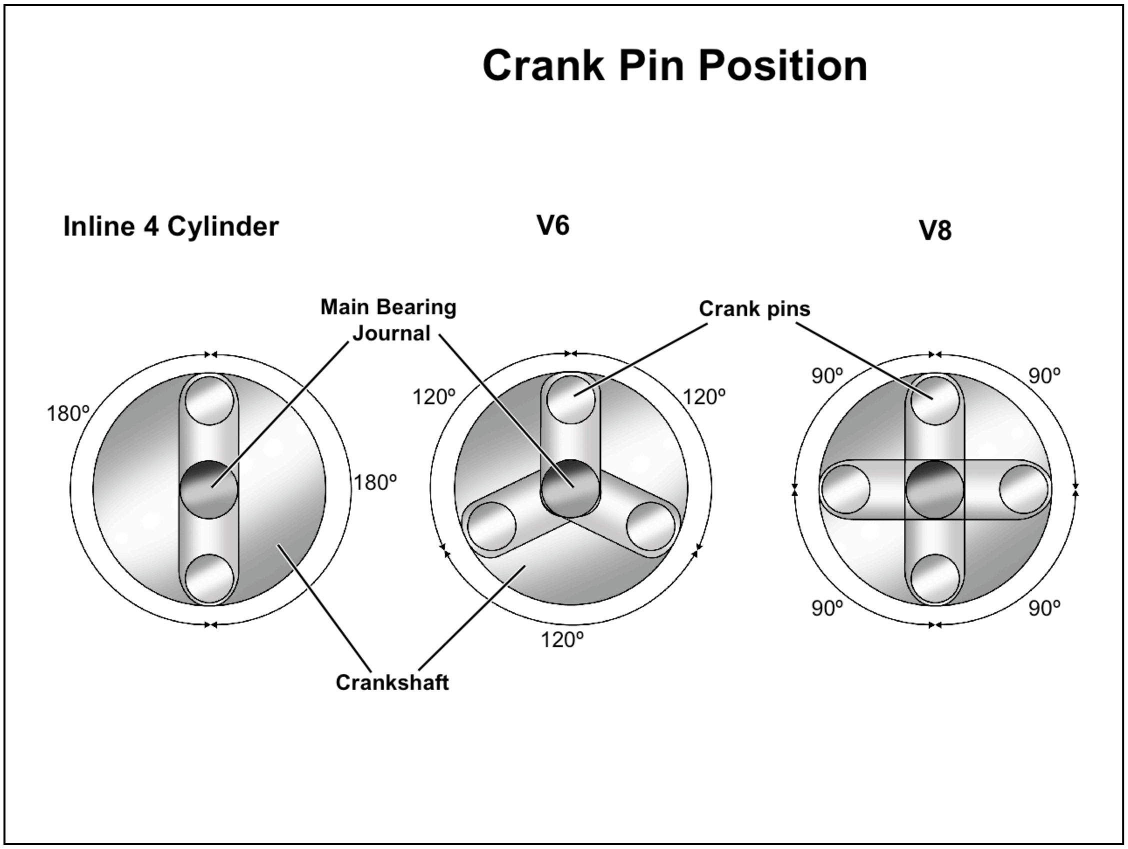
The crankshaft rotates on an axis formed by the main bearing journals. Rod bearing journals are offset from the crankshaft center so the rod and piston move up and down as the crankshaft rotates. Oil passages within the crankshaft direct oil to main bearing journals and rod bearing journals.

Counterweights

Because the rods and pistons are offset from the crankshaft center, their weight when in motion can induce tremendous vibration. To prevent this vibration, the crankshaft has counter weights built into it that are offset in the opposite direction from each piston and rod.

Flywheel

To absorb rotational pulses generated by the sequential firing of the cylinders, a flywheel is attached at the rear end of the crankshaft outside the engine.

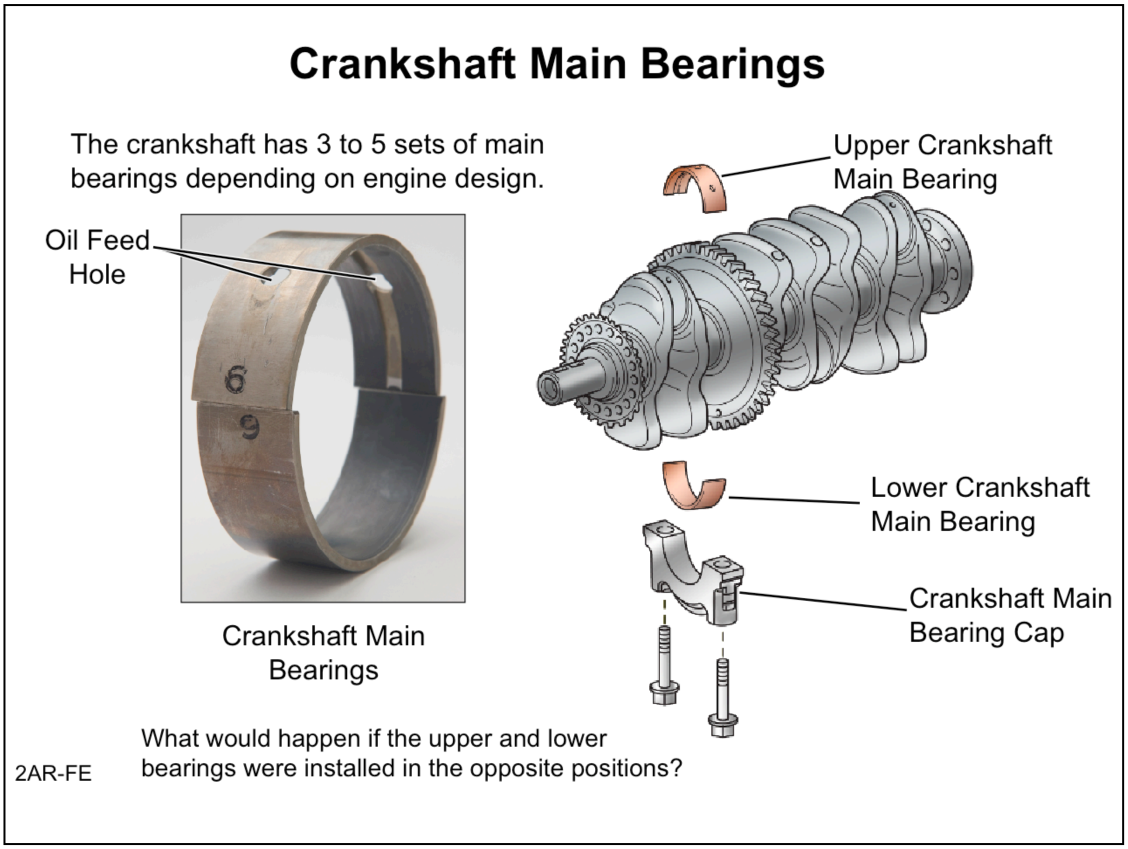


Crank Pin Position

Rod bearing journals (also called “crank pins”) are offset from the crankshaft center so the rod and piston move up and down as the crankshaft rotates.

In 4 cylinder engines, the crank pins are offset 180º. For example, crank pins for pistons 1 and 4 are on the opposite side of the crankshaft from the crank pins for pistons 2 and 4.

In 6 cylinder engines, the crank pins are 120º apart, and in 8 cylinder engines, they are 90º apart.



Crankshaft Main Bearings

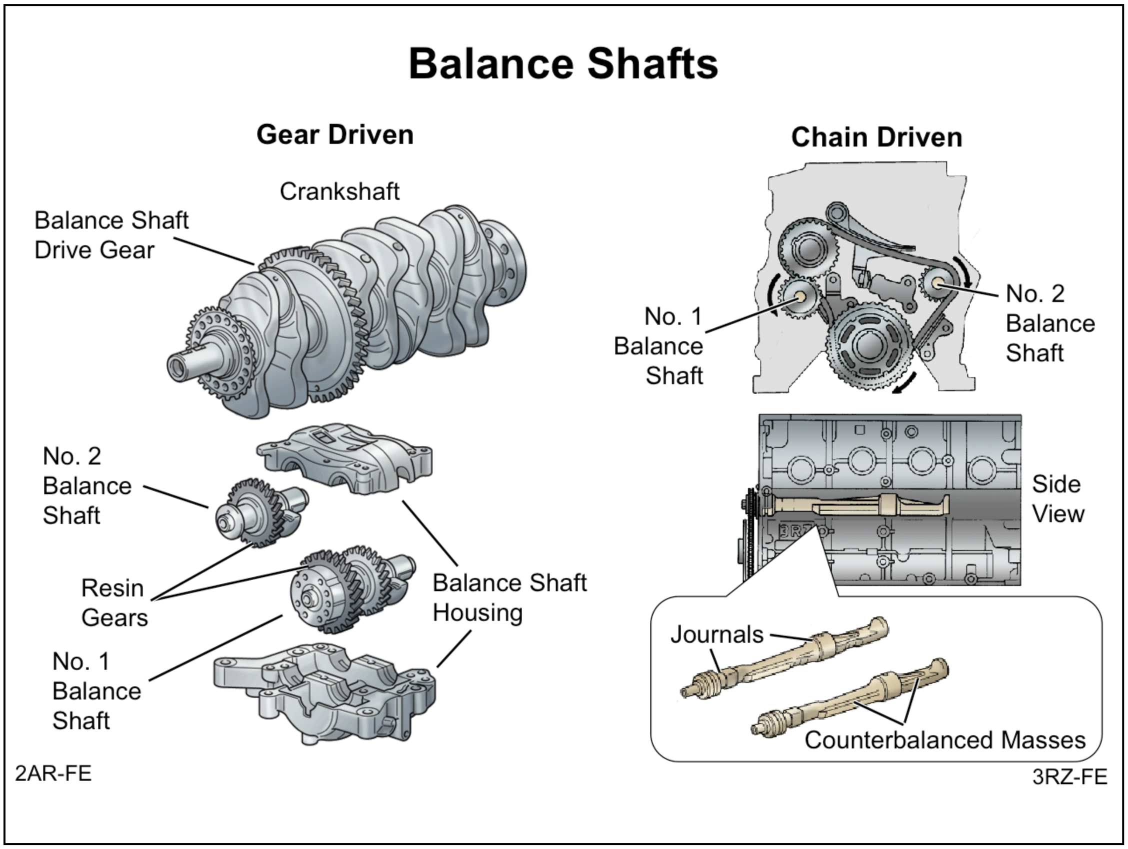
Crankshaft main bearings are held in place by a bearing cap. The bearing is just a few thousandths of an inch larger in diameter than the shaft rotating inside it. The thin space between the bearing and the shaft is filled with oil, and therefore the shaft rotates on a film of oil rather than on the metal bearing itself.

The part of the shaft that rotates inside the bearings is called a journal. Main bearings are inspected by visually looking for wear and by measuring the clearance between the bearing and the journal. This clearance is called the **oil clearance**. The procedure for measuring oil clearance is described later in this handbook.

Because of the forces on the crankshaft applied by the pistons, the crankshaft will have more than just two end bearings – usually from 3 to 5 pair.

NOTE

Oil is supplied to the crankshaft main bearings and journals through oil passages in the cylinder block above the upper bearing. The upper bearing has oil feed holes to allow oil to reach the inner bearing surfaces and crankshaft journals. If the upper and lower bearings were installed in the opposite positions, the bearings would quickly fail from insufficient lubrication.



Balance Shafts

The crankshaft is designed with counterweights specifically calibrated to balance out the uneven momentum of piston motion. Balancing this momentum is essential for eliminating potentially violent vibration.

Because dynamic forces acting on the pistons vary as engine speed increases, static counterweights on the crankshaft can't eliminate absolutely all vibration. Therefore, some engine designs include additional rotating shafts with counterweights that create equal but opposite dynamic forces to more effectively cancel out engine vibration.

Balance shafts are typically found in pairs so they balance each other and don't introduce any new unbalanced vibration.

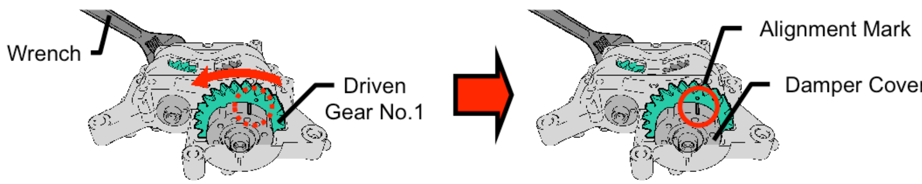
To be effective, these balance shafts must be properly timed to the crankshaft and to each other so all the opposing rotational forces are in correct alignment.

Balance Shaft Timing

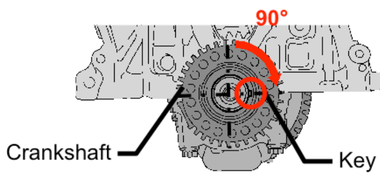
For proper operation, balance shafts must be timed to the crankshaft.

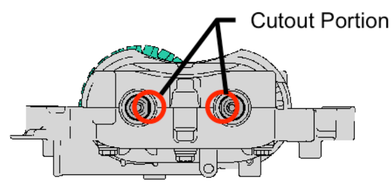
Example: 2AR-FE

1. Using a wrench, hold balance shaft No.2
2. Align the alignment mark on driven gear No.1 to the alignment mark on the damper cover by rotating driven gear No.1



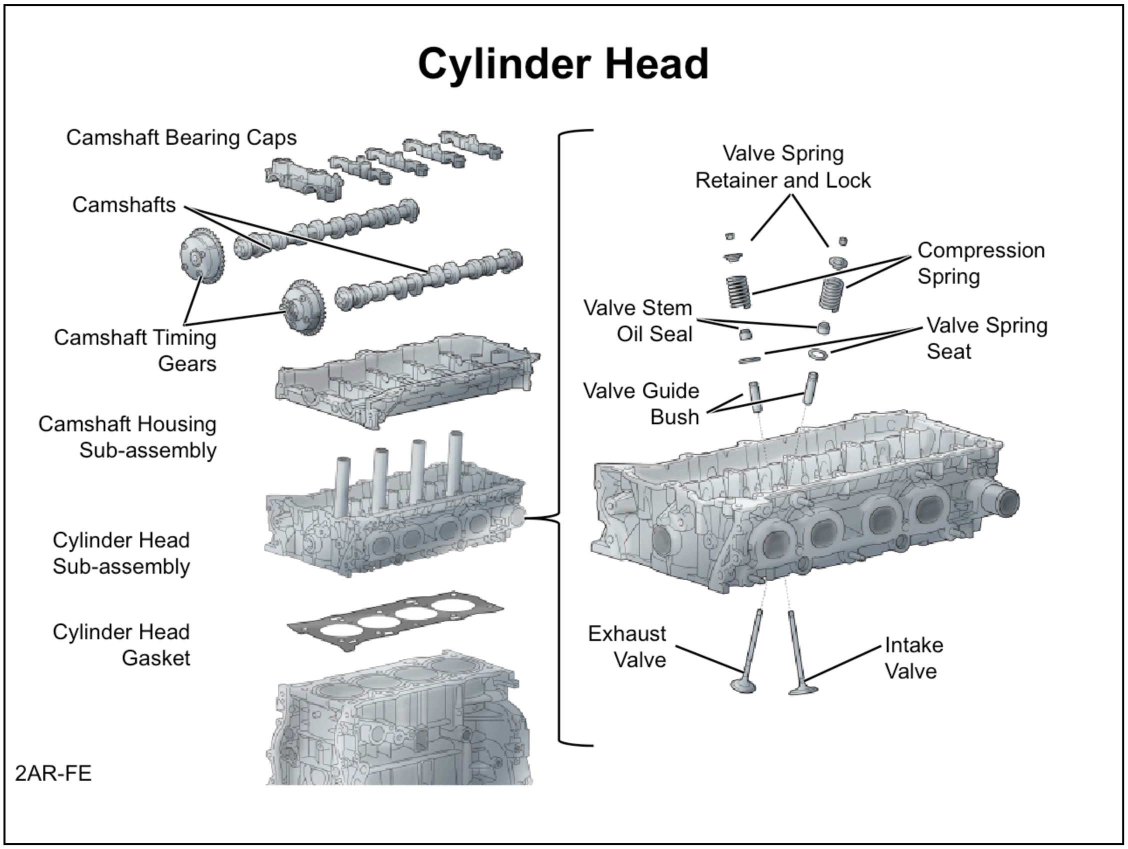
3. Rotate the crankshaft to align the crankshaft key as shown





4. Align the balance shafts as shown
5. Install the balance shaft assembly to the cylinder block

Balance Shaft Timing Toyota's balance shaft assemblies have resin gears to reduce gear noise. During installation it is extremely important to properly time and torque the balance shaft assembly to the cylinder block.



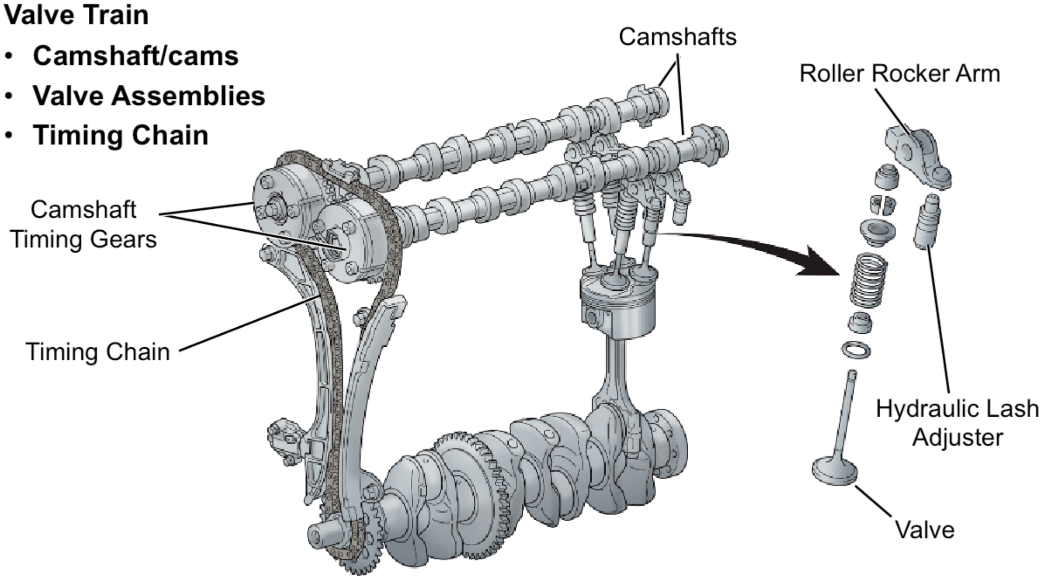
Cylinder Head

The cylinder head is bolted to the top of the cylinder block, forming the "roof" of the combustion chamber and sealing it. Valve-regulated openings over each cylinder allow the air-fuel mixture to enter the combustion chamber and exhaust gases to exit. In the dual overhead cam (DOHC) design, the camshafts are also located in the cylinder head above the valve assemblies.

The fuel injectors and spark plugs are also located in the cylinder head.

Valve Train

Valve Train
- **Camshaft/cams**
- **Valve Assemblies**
- **Timing Chain**



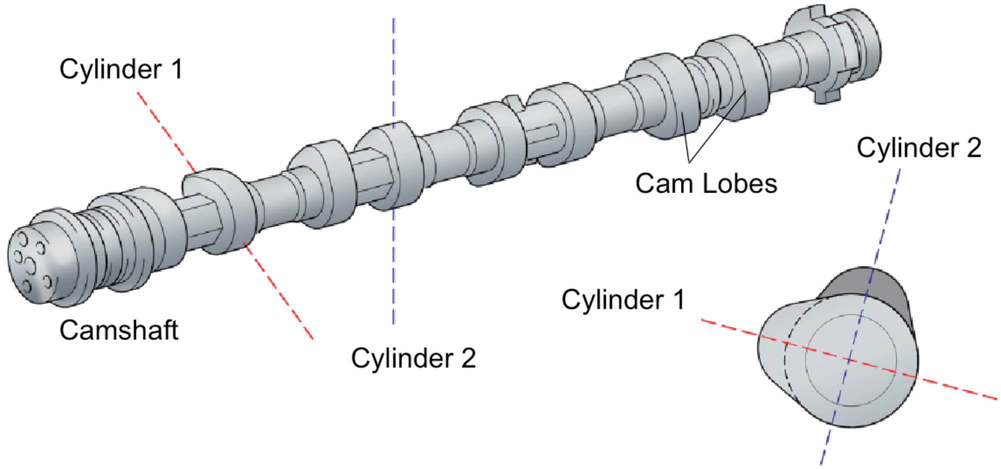
2AR-FE

Note: Toyota engine designs use two intake valves and two exhaust valves per cylinder.

Valve Train The valve train refers to the valve assemblies, camshaft/cams, and timing chain. Together, these mechanisms form the system that synchronizes the opening of the intake and exhaust valves in time with the pistons' strokes. This synchronization is referred to as "engine timing." Precise engine timing is critical to engine performance.

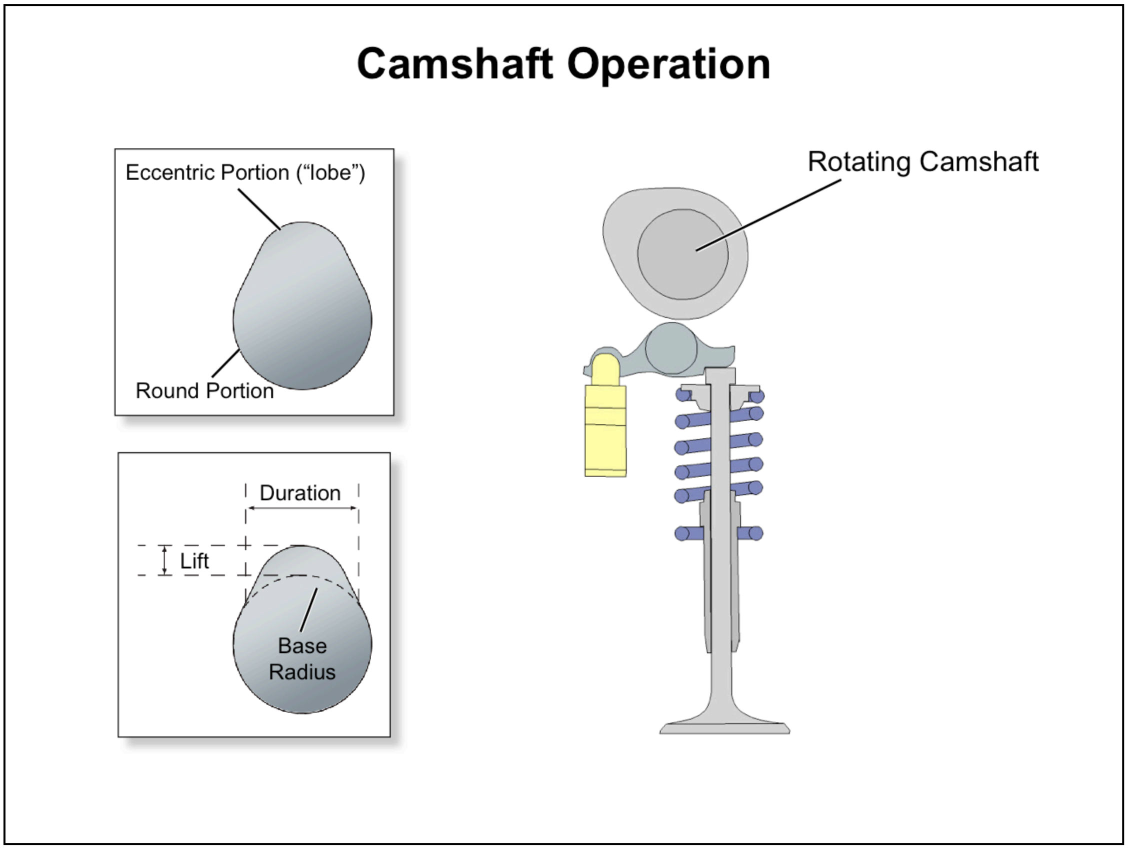
Camshaft

Cam lobes are at different angles for each cylinder to synchronize valve opening and closing with piston movement.



Camshaft Because of the arrangement of the valves, the dual overhead cam (DOHC) design uses two camshafts – one for the intake valves and one for the exhaust valves. Toyota engines use two intake valves and two exhaust valves per cylinder.

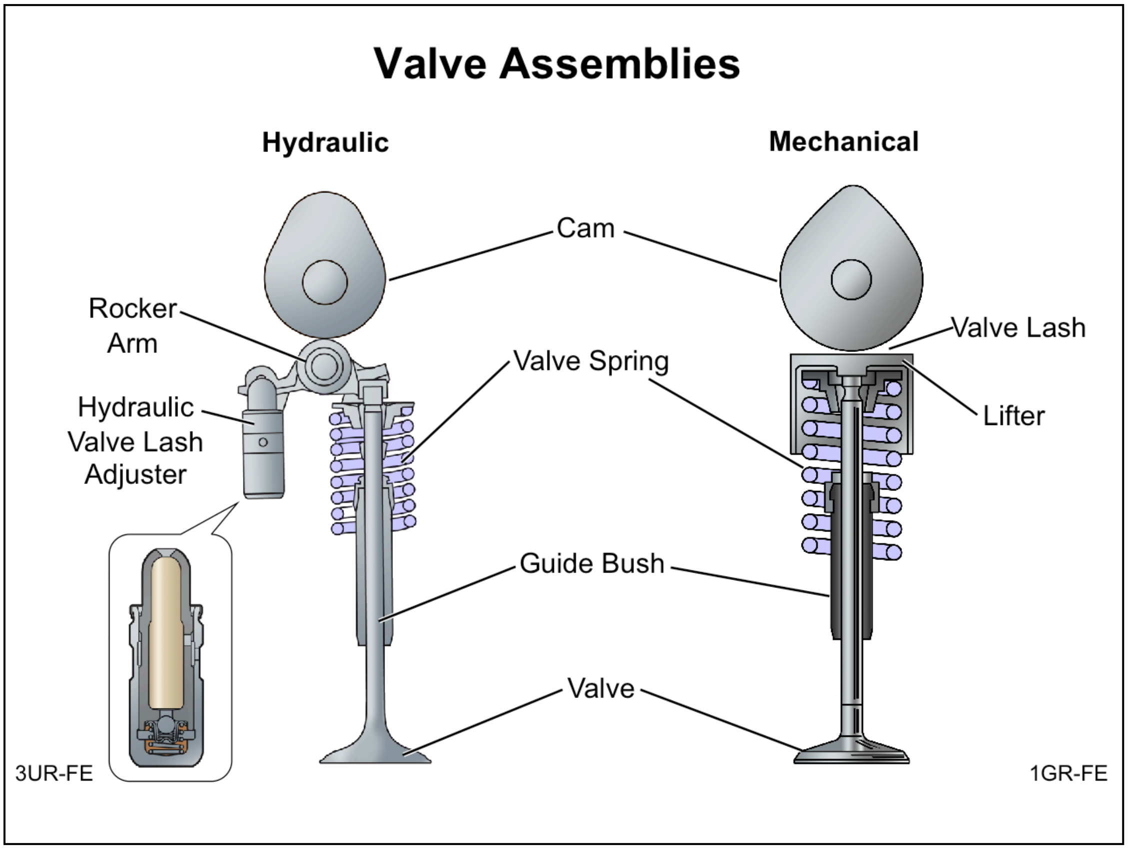
On the intake camshaft for example, there are two cam lobes for each cylinder to operate the two intake valve assemblies simultaneously. Also note that the cam lobes are at different positions for each cylinder to synchronize valve opening and closing with piston movement.



Camshaft Operation

While the round portion of the cam is in contact with the valve assembly, the valve spring holds the valve **closed**. When the eccentric portion of the cam (the "lobe") contacts the valve assembly, it forces the valve **open**.

The shape of the cam determines how far the valve opens and how long it remains open. How far the valve opens is determined by the cam's lift, which is the height of the lobe above the cam's base radius. The duration of the valve opening is determined by the width of the lobe.



Valve Assemblies

The valve assemblies in overhead cam engines may be mechanical or hydraulic.

Mechanical Lifters and Valve Lash

The mechanical lifter is a metal cap that covers the valve spring and valve stem. As the cam rotates, it presses against the cap, which in turn pushes the valve down to open it.

When the valve is closed, a very small clearance is required between the lifter and the cam. This allows for expansion of components as the engine reaches operating temperature. Without this clearance, the cam could press down slightly on the lifter at all times after engine warm-up, preventing the valve from closing fully. This clearance is called valve lash.

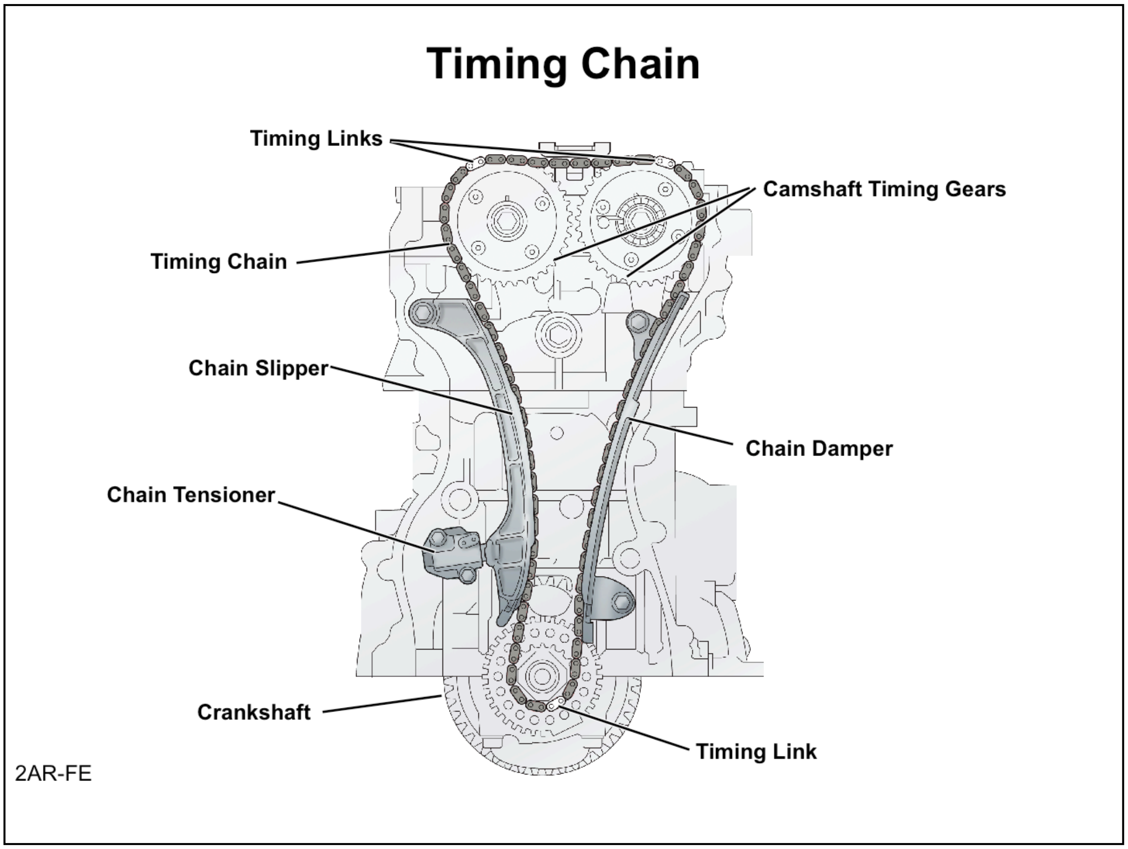
But as the surfaces of the cam and lifter wear, the valve lash increases. At some point, the cams striking the top of the lifters create an audible clicking sound. This requires the valve lash be adjusted to return it to specifications.

Hydraulic Valve Lash Adjuster

The hydraulic valve lash adjuster uses oil pressure and spring force to maintain a constant zero valve lash throughout a variety of engine operating conditions, including wear.

This design uses a rocker arm positioned on top of the lash adjuster and the valve stem. When the cam lobe presses down on the rocker arm, it pushes down on the lash adjuster’s plunger and the valve stem at the same time. A sealed oil-filled chamber keeps the lash adjuster from compressing, resulting in the rocker arm forcing the valve open.

As the parts wear, oil pressure keeps extending the lash adjuster plunger to eliminate any clearance that might otherwise develop between the cam lobe and rocker arm.



Timing Chain

The timing chain is driven by the crankshaft and turns the camshaft timing gears to open and close the intake and exhaust valves at the precise moment required. Since the valves open once for every two revolutions of the engine, the crankshaft and timing gears have a 2 to 1 gear ratio.

A chain slipper, chain damper, and chain tensioner are used to eliminate the slack after the chain is installed.

Installing the timing chain correctly is critical for proper engine performance.

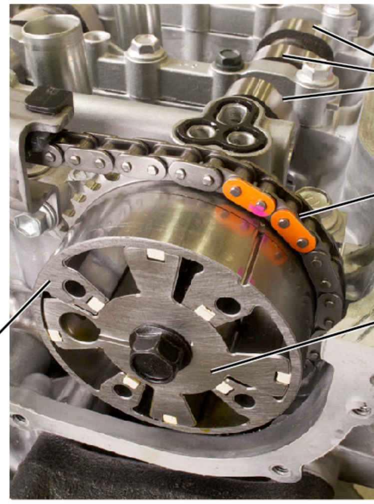
Interference Engines

Incorrectly timing the engine can result in a valve being open when the piston reaches top dead center. In some engine designs, this could cause the piston to actually come into contact with the valve resulting in a bent valve, damaged piston, and/or broken chain. This type of engine is called an **interference engine.** Most timing chain engines are interference engines.

Variable Valve Timing – Intelligent (VVT-i)

To improve operation under varying conditions, the ECM controls the VVT-i actuator to advance or retard valve timing as needed.

Warning: The bolts on the VVT-I cover should never be removed. The cover is shown removed here for training purposes only.

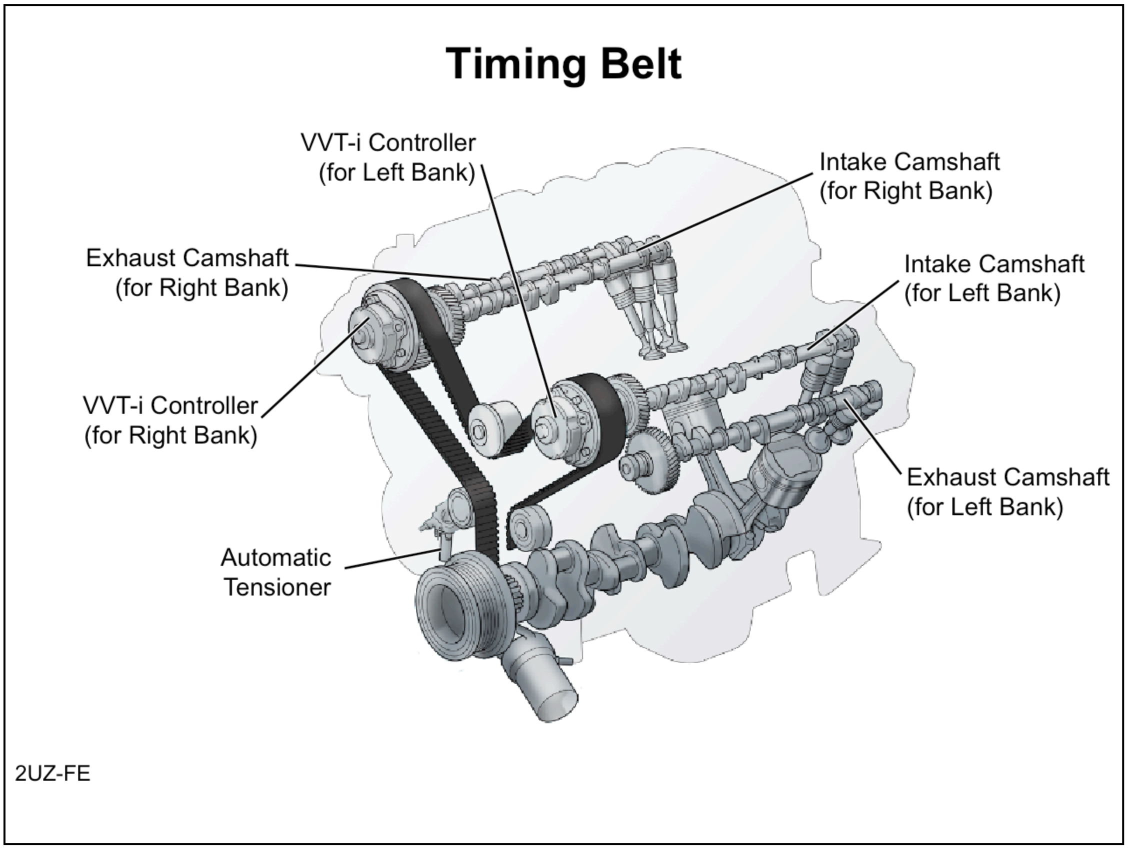


VVT-i Under some load conditions, the engine operates more efficiently if the exhaust valve closes before the intake valve opens.

Under other conditions, efficiency improves if the exhaust valve closes after the intake valve opens.

To improve operation under varying conditions, the ECM controls the VVT-i actuator to advance or retard valve timing as needed. This is referred to as **Variable Valve Timing – intelligent (VVT-i).**

To vary valve timing, the actuator rotates the camshaft slightly in relation to the timing gear. The actuator is driven by oil pressure from an oil control valve controlled by the ECM.



Timing Belt

A timing belt performs the same function as a timing chain; it's just made of a different material. A timing belt is "toothed" so that it doesn't slip, an event which would clearly alter engine timing and performance.

Timing belts also have a different maintenance interval and inspection procedure than timing chains.

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