Subaru CVT

Can you have your cake and eat it too? Can you bolt an automatic tranny onto a small displacement engine and still enjoy the performance and fuel economy of a 5-speed gearbox? According to Subaru engineers, you can. Matter of fact, they're introducing this "can-do" drivetrain in the 1989 1.2 L Justy subcompact.

The "can-do" automatic tranny is a continuously variable transmission (CVT). A CVT uses a drive belt and a set of adjustable pulleys to transmit the engine's power to the driving wheels. Because the pulleys are adjustable, a CVT automatically and constantly adjusts its ratios to match engine RPM to engine load and vehicle speed.

Due to some serious design limitations, CVTs have never enjoyed much success in the automotive market. CVTs have worked well in industrial machinery, in snowmobiles, and in farm and garden equipment. However, Subaru has revived the automotive CVT by revamping it with the latest materials, a steel belt, and a smooth, reliable, magnetic clutch setup.

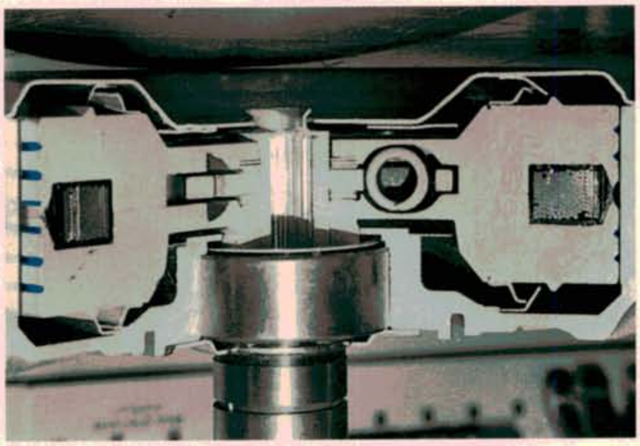
How's A CVT Work?

The adjustable pulleys are the key to a CVT's automatic ratio changes. Imagine that you slice a pulley on your bandsaw so that the pulley looks like a pair of saucers or cymbals. Imagine that you ''reassemble'' the two halves of the pulley by sliding them onto a shaft. Now the two halves of the pulley look like a pair of saucers facing away from each other.

Got that picture locked in your head? Okay, mount a split pulley on an input shaft that's bolted to the flywheel. Mount the other split pulley on an output shaft that's connected to the driving wheels.

Now wrap a drive belt around this set of pulleys. When you spread the halves of a split pulley, you make it a smaller diameter pulley. Why? Because the drive belt will ride lower and deeper in the pulley.

When you push the two halves of the pulley together, you force the belt to ride higher in the pulley. This effectively makes it a larger diameter pulley.



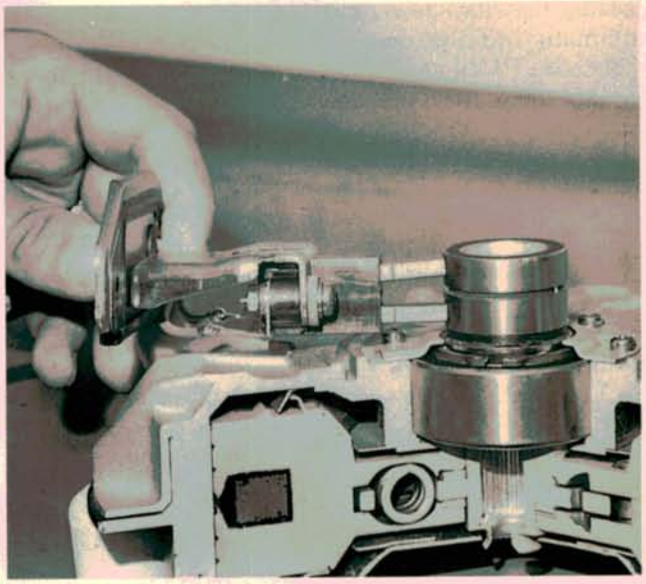
In this cutaway of the magnetic clutch assembly, you can see the magnetic coil's wire strands in the center of the rotor unit. When the clutch engages, the stainless steel powder in the rotor grooves (highlighted in blue) locks the rotor to the drum. Subaru engineers say this unit will be sealed and non-serviceable.

The Ratio/Diameter Relationship

Think about what you do when you shift gears in a car or on a bicycle. Think about what happens when you change speeds on a drill press or on a lathe:

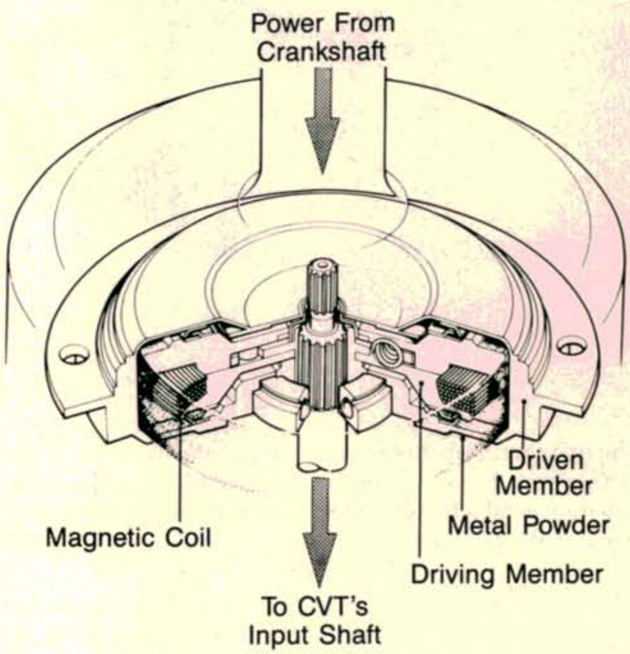
- You change ratios or speeds by changing the *diameter* of gears and pulleys;
- You can change ratios by changing the diameter of the driving component, the driven component, or both components;
- You always interrupt power flow for a short period of time when you change ratios.

Let's get back to our CVT. In a CVT, the split pulleys allow it to make smooth and gradual ratio changes without interrupting power flow.



The apply current for the magnetic clutch flows through these brushes and slip rings on the rear side of the clutch assembly. The brushes, which are serviceable, are sealed to protect them against dirt and moisture. The ECVT computer regulates current flow through the clutch.

SUBARU ECVT MAGNETIC POWDER CLUTCH

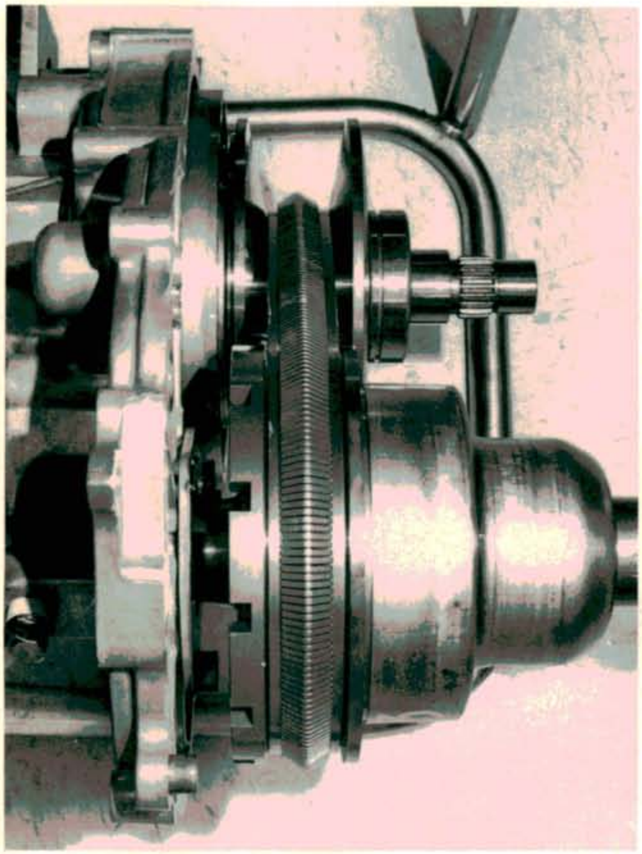


CVT Benefits

Technicians and engineers can find lots to like in a CVT. For example:

- CVTs are easier to manufacture and easier to repair

because they have fewer moving parts than traditional automatic trannies do.
• Because CVTs are lighter and more compact than regular automatics, they're better suited for a subcompact car.
• CVTs offer as wide a ratio spread as any 5-speed transmission does. This means the CVT can match the acceleration of the conventional trans in the lower gears and its fuel economy in the overdrive range. In an automatic transmission-conscious market such as the United States, it lets the driver enjoy stick-shift acceleration on a lower torque engine without manually shifting gears.



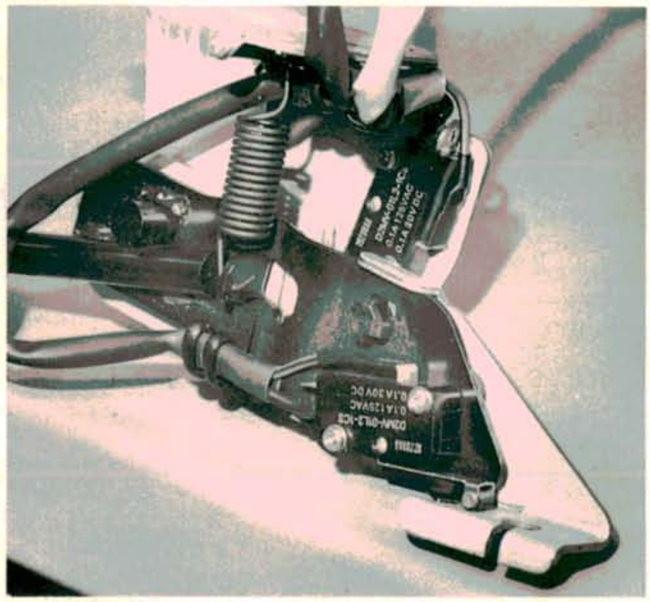
The drive pulley is in the background, the driven is in the foreground. The ECVT will use a basic Dexron-type fluid. You only need a handful of special tools to tear down and reassemble the entire unit.

• On steep hills, CVTs outperform regular automatic trannies because they don't have to constantly hunt for the correct gear ratio as the car climbs the hill.

CVT Then, CVT Now

Since the earliest days of the automobile, car designers have dabbled with the CVT. However, reliability and cost problems plagued the automotive CVT. Until recently, the only automotive CVT in use was a rubber-belted European unit called the Variomatic. The Variomatic, which uses a combination of a vacuum system and centrifugal weights to control its pulleys, reportedly gobbles drive belts in 10,000-20,000 miles.

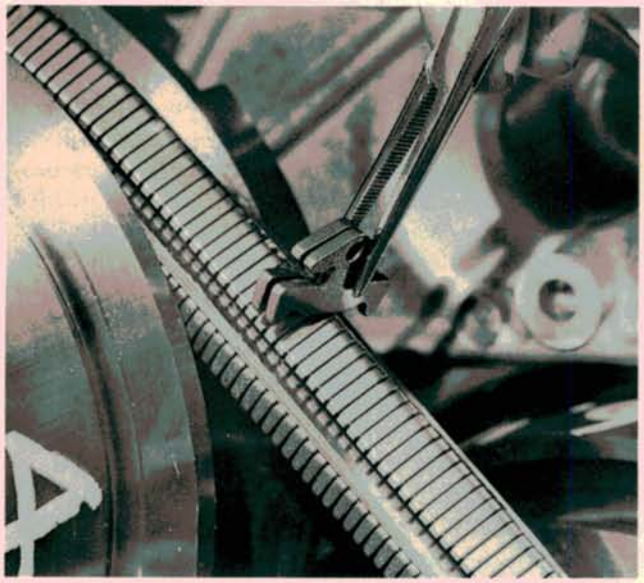
If you can credit a single development with the revival of the automotive CVT, it's the Van Doorne belt. Van Doorne Transmissie, a Dutch company, developed a segmented steel drive loop or belt that Subaru, Fiat, and Ford of Europe have adopted. Several factors contribute to the Van Doorne belt's efficiency and longevity:
• It operates under compression instead of tension. A standard belt operates under tension. Each tiny steel segment in the Van Doorne belt actually pushes the segment ahead of it in the direction of rotation. This pushing creates a domino effect among the segments as the belt turns. Unlike a conventional rubber V-belt, the Van Doorne belt doesn't stretch as it runs.
• It's as flexible as a rubber belt and more flexible than a chain. Therefore, it runs smoother and quieter.
• The large number of steel segments in the Van Doorne belt distributes the pressure the belt exerts on the pulleys more evenly than a rubber belt does. This also helps reduce belt noise. And it improves durability and eliminates the need for exotic lubricants.
• It's stronger than a rubber V-belt, so it can handle more torque than a rubber belt can.



This pair of simple on-off switches mounted on the gas pedal assembly gives the ECVT computer its throttle position signals. Because these switches mount in fixed positions, you don't even have to adjust them when you replace them.

Subaru CVT Details

Subaru calls its CVT the ECVT, or electronic continuously variable transmission. A computercontrolled magnetic powder clutch makes the ECVT unique. This clutch setup is light, efficient, smooth,



Here are two of the 280 or so steel segments that make up the Van Doorne drive belt. As you can see, it's really more of a loop than it is a "belt." In a giant and constant domino effect, each little steel segment pushes the segment ahead of it. This belt transmits power by pushing instead of pulling.

and reliable. You know the sensation of a standard clutch when it's perfectly engaged by a skilled driver? That's the sensation you feel when you drive an ECVT-equipped Justy. Regardless of how you accelerate from a standstill, there's no bucking, lurching, or overrevving. The ECVT computer applies the clutch smoothly every time. And unlike an automatic transmission's torque converter, the magnetic powder clutch generates no appreciable slippage or heat.

Inside this clutch, a drum-shaped piece is bolted to the flywheel. A rotor turns inside this drum. The rotor and a magnetic coil are splined onto the ECVT input shaft. There's a special stainless steel powder between the drum and the rotor. When the ECVT computer energizes the magnetic coil, the coil magnetizes the powder. The magnetized powder actually solidifies and locks the rotor to the drum. Once the rotor is mechanically locked to the drum, power flows efficiently from one to the other.

When the ECVT computer shuts off the magnetic coil, the solidified powder falls back into its powdery state.

When the car stops at a traffic signal, the ECVT computer automatically shuts off the magnetic clutch so the engine doesn't stall.

Network News

Subaru's ECVT computer networks with the Justy's engine control computer. That is, the engine computer shares some of its already processed information with the ECVT computer. Sharing information—networking—reduces the amount of sensors and wiring required for both computers to do their jobs.

To control the magnetic clutch, the ECVT computer monitors:
- vehicle speed;
- throttle opening;
- brake application;
- air conditioning operation;
- inhibitor/neutral safety switch;
- altitude signals;
- engine torque;
- engine coolant temperature.

The ECVT computer receives the last three of these inputs through its networking with the engine control computer. Based on this information, the ECVT computer regulates current flow through the magnetic clutch coil.

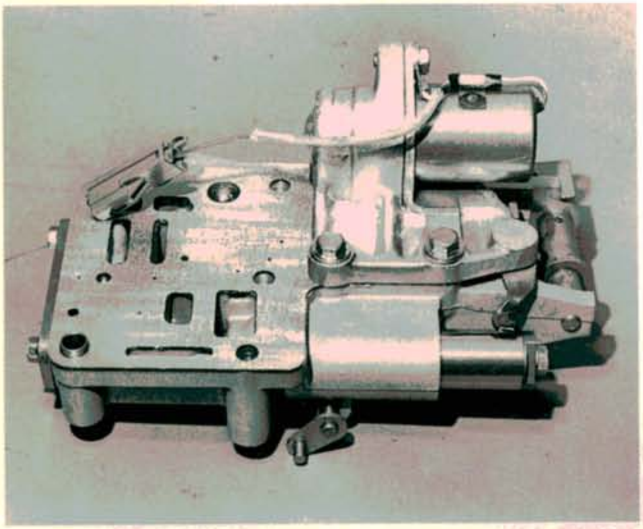
These fine steel bands keep all those little segments together. The Van Doorne loop is quieter, stronger, and as flexible as a rubber V-belt.

When a problem with the ECVT occurs, a "Check ECVT" light on the dashboard lights up. The ECVT computer, which has a long term fault memory, reportedly detects intermittent problems and remembers them. The computer uses the "Check ECVT" light to flash one or more of its 16 codes at you. To put the computer into its self-diagnostic mode, you plug two underdash connectors together.

Thankfully, you need no special equipment to troubleshoot the electrical/electronic side of the ECVT system!

Hydraulic System Highlights

Compared to a traditional automatic transmission, the ECVT is an exercise in simplicity. Half of the drive and driven pulleys remain fixed. Fluid pressure moves the other half of each pulley. Fluid pressure maintains both of the pulleys' grips on the belt and also adjusts the width of the pulleys. Remember that changing the pulley width changes the ECVT ratios.



ECVT valve body only has three valves inside it: a pressure regulator valve, a shift control valve, and an engine braking valve. The three-way solenoid on the valve body reduces pulley clamping pressure during light throttle cruising.

The ECVT's hydraulic system is fairly straightforward. Each of the adjustable CVT pulleys contains an apply piston similar to the pistons you've seen in regular automatic tranny clutch drums. The ECVT oil pump supplies fluid pressure to each piston. When the fluid pressure moves the pistons, the pistons move the pulleys and change the "gear" ratios. To change ratios, a shift control valve in the ECVT valve body progressively varies the pressure going to the drive pulley.

Several devices help tailor fluid pressure within the ECVT:

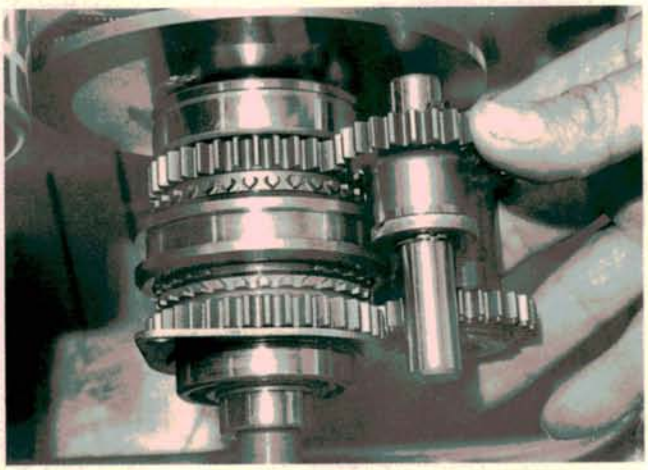
1) the pitot valve. A pitot valve, which is a tube with a calibrated orifice, is a hydraulic speed sensor. Pitot valves are commonly used as speed sensors on aircraft and on boats. As a drum attached to the ECVT drive pulley spins, it hurls trans fluid into the pitot tube. The fluid pressure coming out of this tube, which is called pitot pressure, is proportional to input shaft speed. Pitot pressure helps adjust the position of the shift control valve. Therefore, the pitot valve performs a job similar to that of a governor in a regular automatic trans.

2) throttle linkage cam. This is similar to the TV (throttle valve) linkage you see on a conventional automatic box. When the driver mashes the pedal, this cam tells the shift control valve to reduce pressure to the drive pulley, thus changing ratios.

3) ratio sensor. The ratio sensor is nothing more than a piece of linkage that moves back and forth with the movement of the drive pulley. The ratio sensor helps tailor the drive pulley pressure to different driving conditions. During acceleration, the pulleys need more clamping pressure so they can grip the drive belt tighter. But as the ratios approach overdrive, the pulleys need less clamping pressure. Therefore, the ratio sensor also tells the system to lower the clamping pressure.

4) three-way solenoid valve. When the car is cruising in overdrive, this valve further reduces pulley clamping pressure. Lowering the pressure here prolongs the life of the drive belt and pulleys. It also increases transmission efficiency by reducing friction.

The drive pulley is larger in diameter and has the larger apply piston. So, it clamps the drive belt tighter than the driven pulley does during "up-shifts." This tighter clamping action also tends to make the belt run higher on the driven pulley. On the smaller diameter driven pulley, the belt tends to run lower on the pulley. Because of the design of the ECVT valve body, the end result is that all things being equal, the drive belts always tend to move toward an overdrive ratio.



To change directions, the ECVT uses this simple, fully synchronized gear set and hub assembly. On the output side of the drivetrain, the Justy ECVT has a conventional spider gear-equipped differential setup. It also has a set of reduction gears.

New Sensations

The ECVT's designed to keep the Justy's engine RPM within its part-throttle and full-throttle power curves. It allows the engine to rev very quickly and smoothly into its power band. The ECVT allows the engine to rev so quickly that your first impression may be that the trans is slipping and the engine's revving too high.

If you want more revs for quicker throttle response or to improve engine braking on steep hills, you can shift the ECVT into its "Ds" range. Shifting into Ds moves the shift control valve slightly and cues the pulleys that you want steeper ratios for more get-up-and-go.

—By Dan Marinucci