Automotive Transmission Systems

Lecture delivered by:

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PEMP
AEL2501

Session Objectives

- Through this session, the students will understand-
  - The need for transmission in an automobile
  - How the engine power is modified and transmitted to the road wheel
  - Functions of the transmission different configurations of transmission in MT and ATs.
  - New developments in the transmissions

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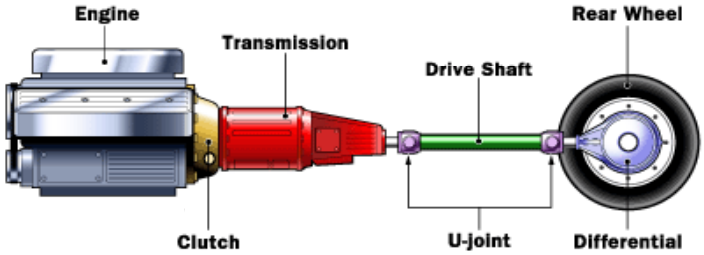
Topics

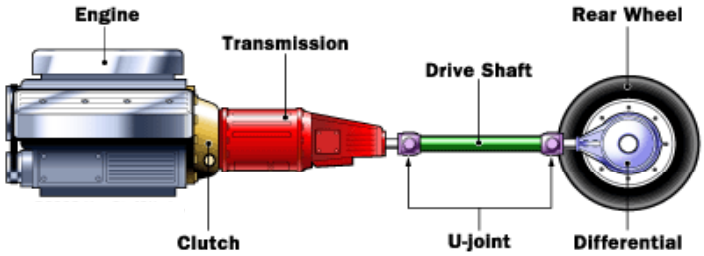
- Drivetrain – introduction
- Layouts of powertrain
- Functions of transmission
- Types of transmission and other drive train elements
- Manual Transmission and clutches
- Automatic Transmission and Torque converter
- New developments in transmissions - CVTs and DCTs

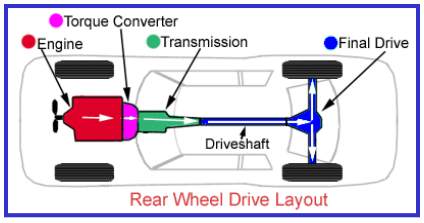
Drive Train - Introduction

- From the back of the engine to where the rubber meets the road, the 'drive train' encompasses one of the most complicated systems of a vehicle
- The drive train in a vehicle serves two functions:
  - it transmits power from the engine to the drive wheels,
  - it varies the amount of torque.

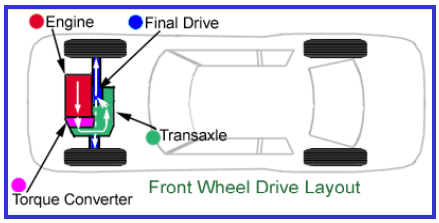


- There are actually <u>two sets of gears</u> in the drive train:
  - The transmission
  - The differential.





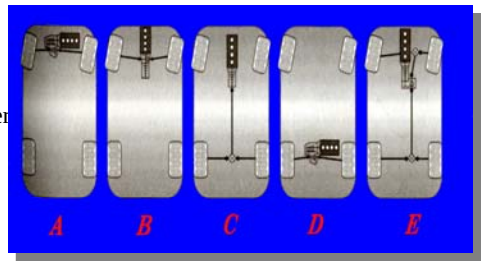
- On a <u>rear wheel drive</u> car, the transmission is usually mounted to the back of the engine.
- A drive shaft connects the rear of the transmission to the final drive which is located in the rear axle and is used to send power to the rear wheels.
- Power flow on this system is simple and straight forward going from the engine, through the torque converter, then through the transmission and drive shaft until it reaches the final drive where it is split and sent to the two rear wheels.



- On a <u>front wheel drive</u> car, the transmission is usually combined with the final drive to form what is called a <u>transaxle</u>.
- The engine on a front wheel drive car is usually mounted sideways in the car with the transaxle.
- Front axles are connected directly to the transaxle and provide power to the front wheels.
- Power flows from the engine, through the torque converter to transmission that is along side the engine.
- From there, the power is routed through the transmission to the final drive where it is split and sent to the two front wheels through the drive axles.

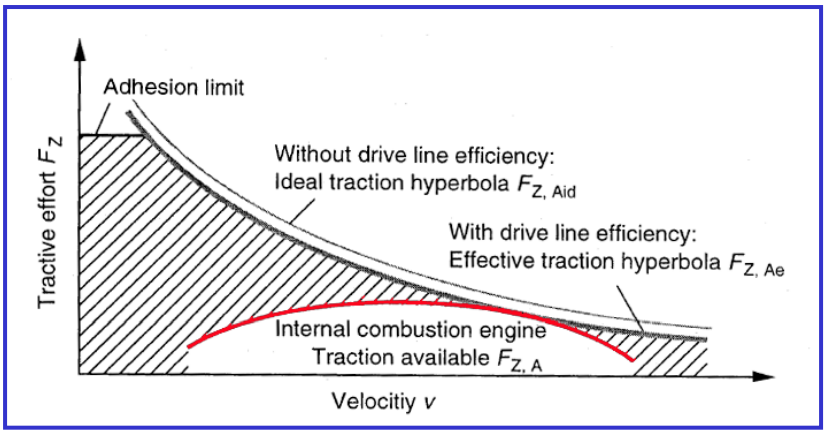
The layout of the Powertrain

- The position of the powertrain within the vehicle has implications both for the engineering of the vehicle and the drivetrain components including the transmission itself.
- Effects include:
  - The space available
  - The weight distribution
  - The structure to support the power and react
  - Vehicle handling and ride
  - Safety and passenger protection



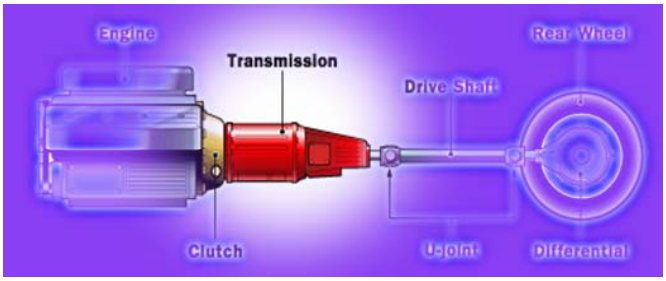
Few facts about an engine…

- From the earlier days of automobiles, IC engines have been the source of propulsion power for automobiles.
- Some of the facts that need to be considered for automotive propulsion:
  - An engine can generate only a limited torque at low speeds.
  - Without sufficient torque, the vehicle can not move from rest.
  - The engine crankshaft always rotates in the same direction hence driving vehicle in reverse direction is not possible without a gearbox.
  - Engine has to run at some minimum speed to deliver useful output power (idling)



Secondary map of IC engine without GB

Transmissions - Functions



- Allow the vehicle to start from rest, with the engine running continuously
- Let the vehicle stop by disconnecting the drive when appropriate
- Enable the vehicle to start at varied rates, under controlled manner
- Vary the speed ratio between the engine and wheels
- Allow this ratio to change when required
- Transmit the drive torque to the required wheels.

Transmissions - Types

- There are two types of transmissions:
  - Manual
  - Automatic
- In a manual transmission, the gears are shifted manually usually, with a stick located on the console and the clutch pedal.
- In an automatic transmission, the mechanism changes without any help from the driver. Now the trend is to use electronic control to shift the gears.

- All automotive transmissions are equipped with –
  - A varied number of forward speed gears,
  - A neutral gear,
  - One reverse speed.
- Some transmissions are fitted with overdrive. The overdrive has gear ratio of less than 1:1. Thus, it -
  - Reduces engine speed at a given vehicle speed
  - Improves fuel economy
  - Lowers engine noise
- The transmissions can be grouped based on number of forward gears.
  - 3 speed transmission
  - 4 speed transmission
  - 5 speed transmission
  - 6 speed transmission (may be 2 O/Ds, lower final drive for acceleration in lower gears)

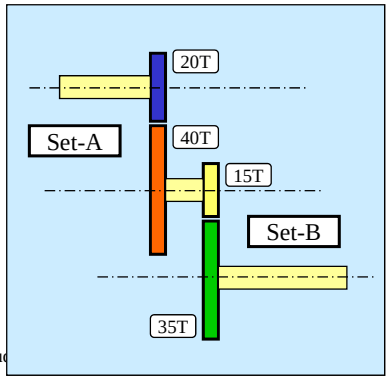
Transmission gear sets

- Power is moved through the transmission via four gears (two sets of two gears)
- Gear ratio of entire set:

$$\frac{\text{driven (A)}}{\text{driver (A)}} \times \frac{\text{driven (B)}}{\text{driver (B)}}$$

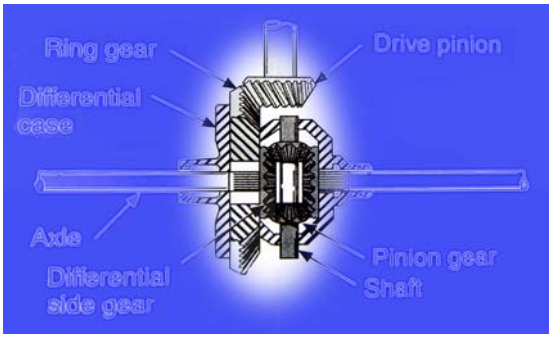
- Ex:
  - Set A – Driver 20T, Driven 40T
  - Set B – Driver 15T, Driven 35T

$$\frac{\text{driven (A)}}{\text{driver (A)}} \times \frac{\text{driven (B)}}{\text{driver (B)}} = \frac{40}{20} \times \frac{35}{15} = 4.67:1$$



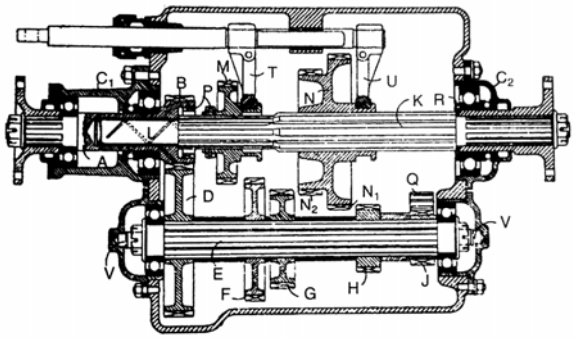
- The driveline gear ratios are further <u>increased</u> by the <u>final drive.</u>
- Typical final drive (axle ratio)- 2.5 to 4.5:1.
- The overall gear ratio is given as:

$$\text{Overall gear ratio} = \text{Transmission ratio} \times \text{Final drive ratio}$$



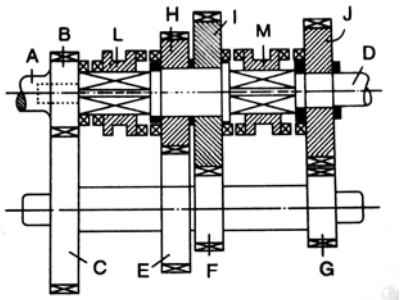
Manual Transmissions

- As the name suggests, the driver has to change the gear ratio.

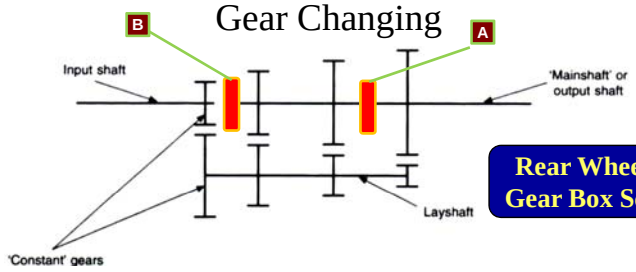


Sliding Mesh Transmission

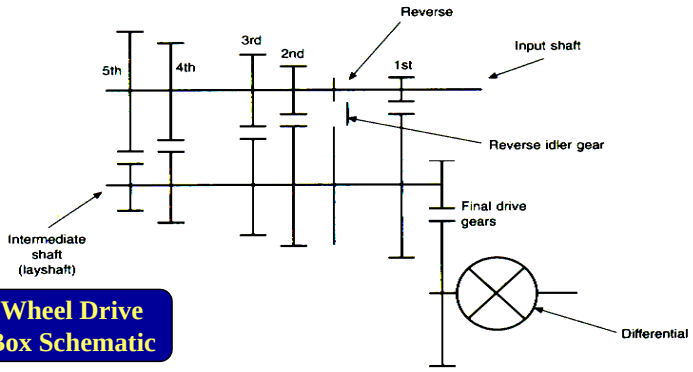
- Most of the MTs are constant mesh, synchronized units.
- In constant mesh gears, whether the gear is locked to the output shaft, it is in mesh with its counter gear.
- All gears rotate in the transmission as long as the clutch is engaged.
- A synchromesh gear unit uses a mechanism of brass rings and clutches to bring the gears to the same speed before shift occurs.



Gear Changing

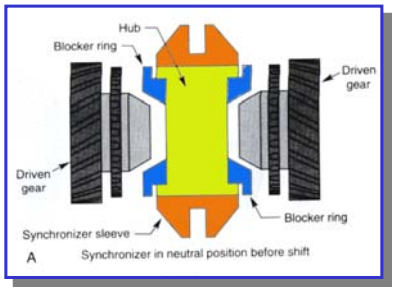


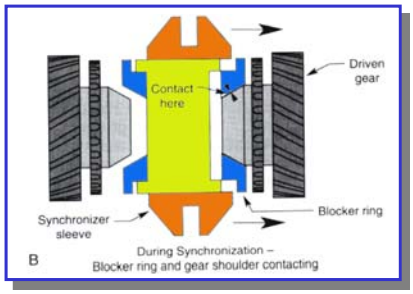
Rear Wheel Drive Gear Box Schematic

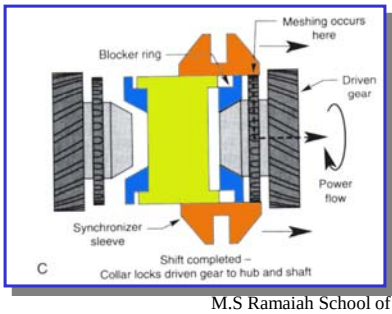


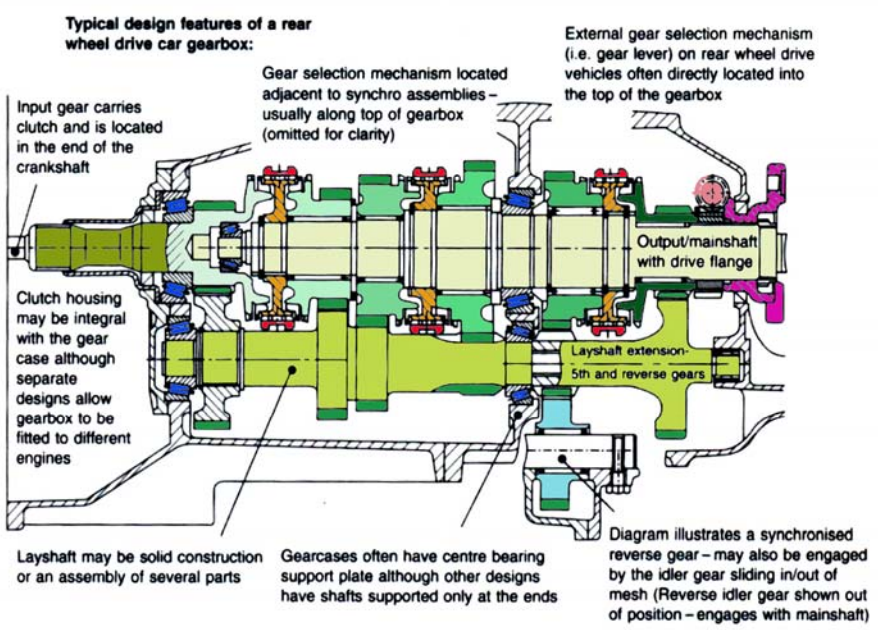
Front Wheel Drive Gear Box Schematic

Synchronizing Unit

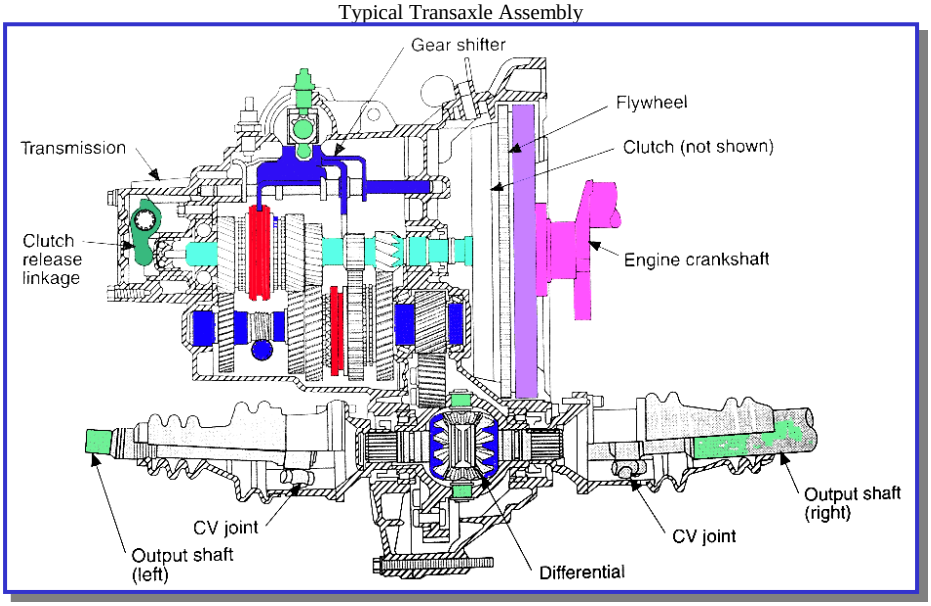








Typical Transaxle Assembly



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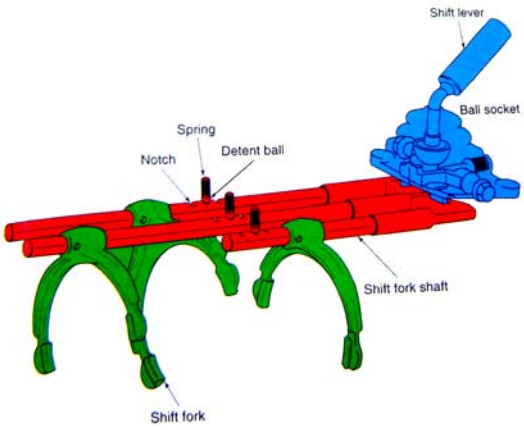
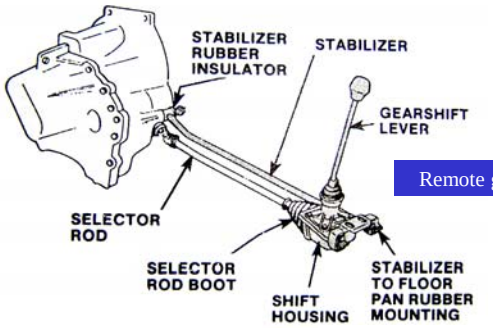
Gear Shift Mechanisms

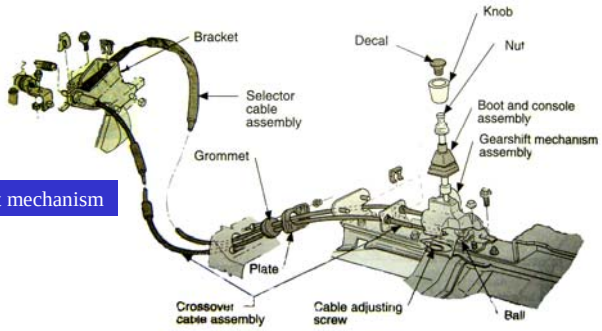
- The shifter lever either move the fork directly or moves the cables that transfer the shifting motion to the transmission.
- Interlocks are provided in the shifter linkage itself or inside the transmission.
- They prevent the accidental selection of reverse except when shifting from neutral.
- They also prevent engaging two gears at the same time.



Typical shift mechanism



Remote gearshift mechanism



Cable-type external gearshift mechanism

Advantages (MT):

- Usually have high mechanical efficiency
- Arguably the most fuel efficient type of transmission, although this depends on the driver selecting the most appropriate gear.
- Relatively cheap to produce (50%)
- Light weight (50-70%)
- Easier to package in the vehicle

Disadvantages (MT):

- Some driver skill is required
- Emission and fuel consumption can be heavily influenced by the driver's gear selection
- Clutch operation and changing the gears can be tiring (In heavy traffic).
- Not suitable for all drivers.

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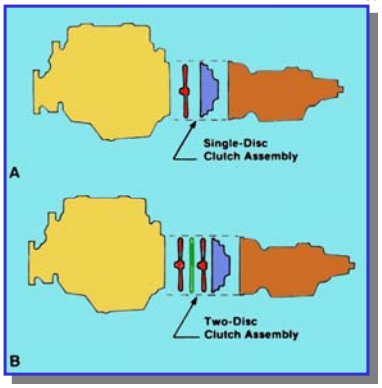
Clutch assembly

- In its simplest form, the clutch allows engine power to be applied gradually when a vehicle is starting out and interrupts power to avoid gear crunching when shifting.
- Engaging the clutch allows power to transfer from the engine to the transmission and drive wheels.
- Disengaging the clutch stops the power transfer and allows the engine to continue turning without force to the drive wheels.



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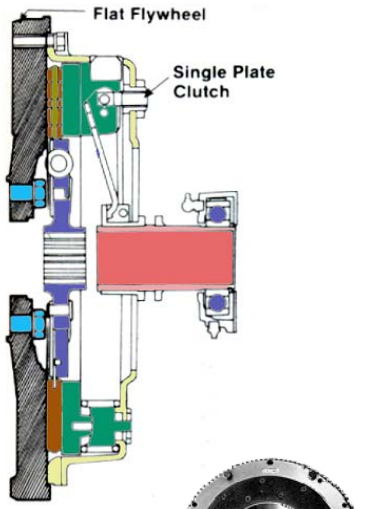
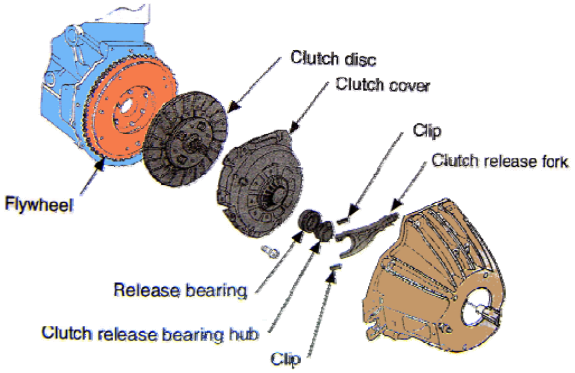
Basic components of a clutch assembly:

- Flywheel
- Clutch Disk (Friction Disk) (Wet type, Dry type, Single Plate and multi-plate)
- Pressure Plate
- Clutch Release (Throw-out) Bearing
- Linkage

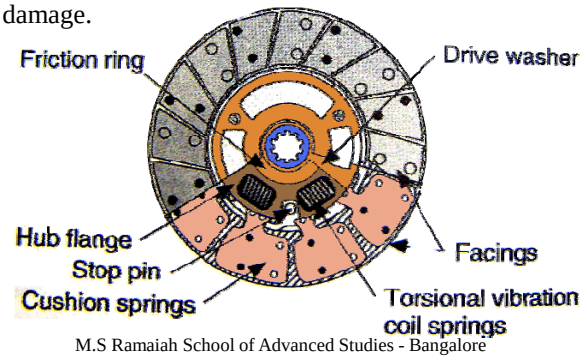


- The flywheel and the pressure plate are the drive or driver members of the clutch.
- The Clutch disc (friction disc) is the driven member connected to the transmission input shaft.
- When the clutch pedal is depressed, the drive members turn independently of the driven member, and the engine is disconnected from the transmission.
- When the clutch is engaged, the pressure plate moves toward the flywheel and the clutch disc is squeezed between the two revolving drive members and forced to turn at the same speed.

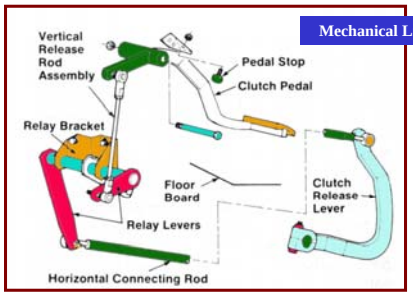


Clutch disc:

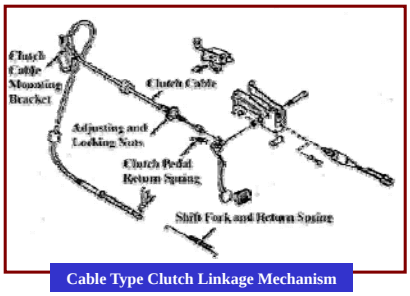
- Receives the driving torque from the flywheel and pressure plate assembly and transmits that to the transmission input shaft.
- The friction surfaces are usually lined with material having a good coefficient of friction and sufficient compressive strength and temperature resistance.
- Linings may be molded, woven, sintered or of solid material.
- Molded linings - use polymeric resins to bind a variety of powdered filled or fibrous materials. Preferred – withstands higher loading without damage.



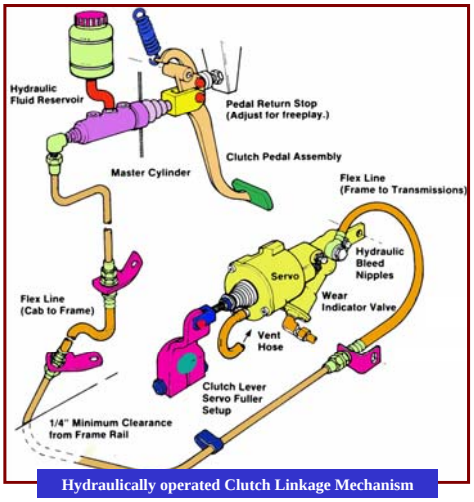
- The friction disc is also designed to absorb-
  - Certain crankshaft vibration,
  - Abrupt clutch engagement
  - Driveline shocks
- For this, the torsional springs are used number of these springs is governed by the engine torque and vehicle weight.
- The clutch is actuated by linkages of different types such as:
  - Mechanical linkage
  - Cable type
  - Hydraulic actuator type



Mechanical Linkage Type Clutch Mechanism



Cable Type Clutch Linkage Mechanism



Hydraulically operated Clutch Linkage Mechanism

Automatic Transmissions

Introduction:

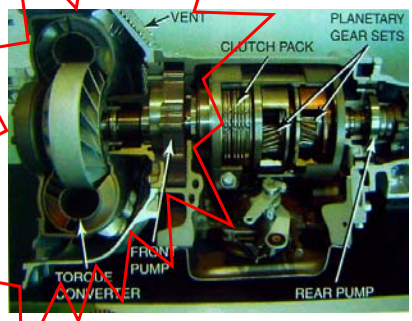
- Automatic transmissions are found on many rear wheel drive and four-wheel drive vehicles.
- An automatic transmission selects gear ratios according to
  - engine speed
  - power train load
  - vehicle speed
  - other operating factors.
- Driver operated clutch is not required; vehicle can be brought to a stop without shifting to neutral.
- Convenient in a stop-and-go traffic.
- The driver can select a lower forward gear, reverse, neutral or park.
- Transmission can provide engine braking during deceleration (coasting).

- Most commonly used ATs are 4-speed with an overdrive fourth gear.
- 3-speed and 5-speed* transmissions are also used.
- Recent ATs also feature lock-up torque converters.
- Earlier, ATs were controlled by hydromechanical systems ; modern ATs are controlled by electronic controllers and hydraulics.

Torque Converters

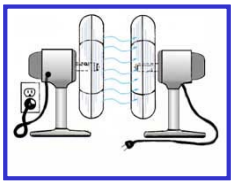
Introduction:

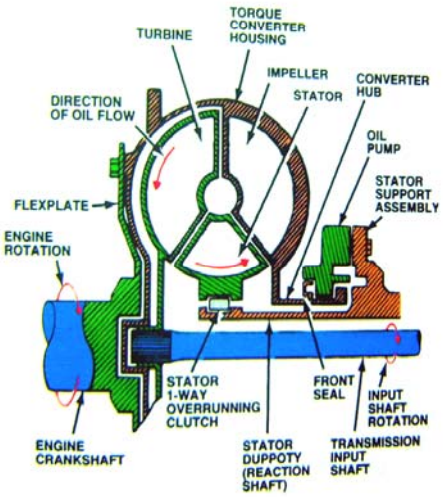
- ATs use torque converters in place of a conventional clutch assembly.
- T/c is used to transfer the engine torque from the engine to the transmission.
- Operates through hydraulic force provided by automatic transmission fluid (Transmission oil).
- It changes or multiplies the engine torque and directs it to through the transmission.
- It automatically engages and disengages power from engine to the transmission in relation to the engine RPM.



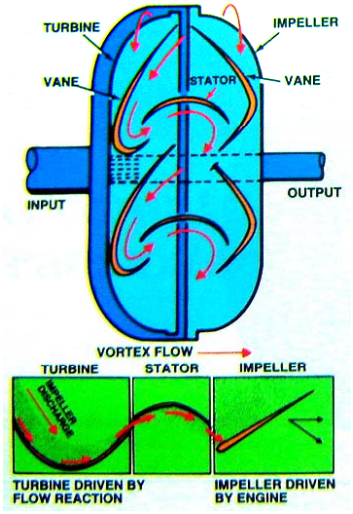
Components

- A typical T/C consists of 3 elements:
  - Pump assembly (impeller) is the input member, receives power from the engine.
  - Turbine is the output (driven) member.
  - Stator assembly is the reaction member or torque multiplier. It is supported on a one-way clutch, which operates as a overrunning clutch. This arrangement permits rotation in one direction and locks in reverse direction.
- The exterior of the T/C is shell shaped.



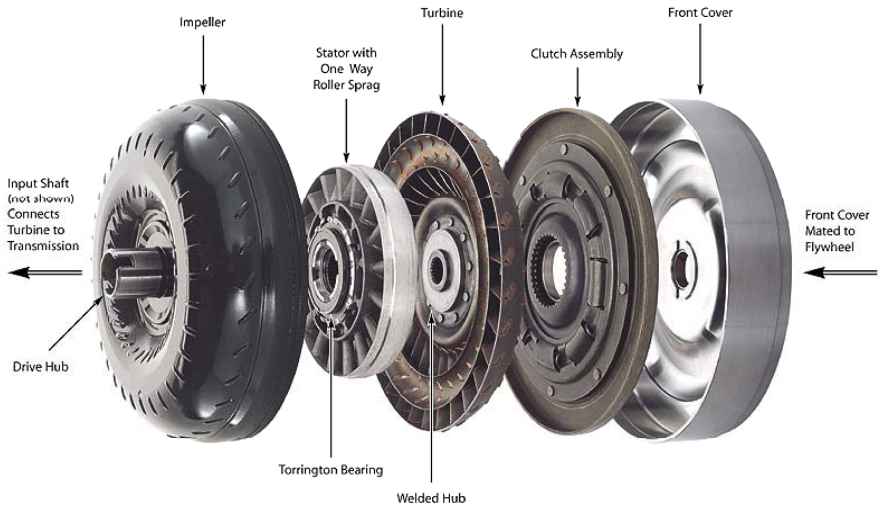


- The impeller has a number of curved blades that rotate as a unit with the shell.
- It turns at engine speed , acting like a pump to start the transmission oil circulation within the shell.
- The turbine is positioned with its curved blades facing the impeller assembly.



Basic operation:

- The transmission oil is the medium to transfer energy in T/C
- As the pump impeller rotates, centrifugal force throws the oil outward and upward due to the curvature of the blade.
- The faster the impeller rotates, the centrifugal force becomes larger.
- The oil thrown by the impeller strikes the curved vanes of the turbine, causing the turbine to rotate.
- An oil pump driven by the converter shell and engine continuously delivers oil under pressure into T/C.
- Oil leaving the T/C is directed into an oil cooler and then to the transmission's oil sump or pan.



- A lockup T/C eliminates the ~10% slip that takes place between the impeller and turbine at the coupling stage of operation.

- This lockup action-
  - Improves fuel economy
  - Reduce T/C operational heat
  - Reduce engine speed
- Lock-up piston clutch – most widely used lockup arrangement.
- Other arrangements –
  - Mechanical lockup converters
  - Centrifugal lockup T/Cs
  - T/Cs with viscous coupling

Electronic control of the Lockup Torque Converter:

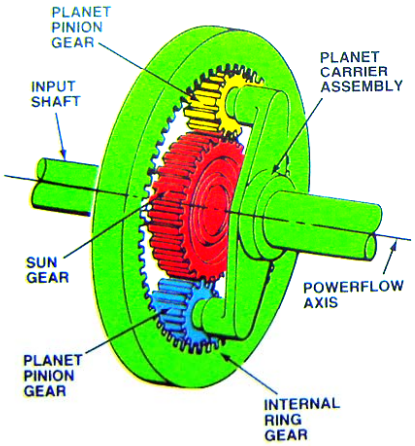
- A controller is used to control the converter solenoid.
- When the solenoid is turned on, the clutch is engaged.
- When the solenoid is de-energized the clutch gets disengaged.
- A typical lockup action:
  - Engine coolant temp – at least 65^{o}C
  - Engagement possible if inputs from other sensors are within the limit.
    - Speed 25 to 60 kmph no lockup, required speed – 65kmph.
    - Throttle position sensor – unsteady output – no engagement of the lockup clutch.
    - Frequent opening of the brake switch, no lockup action.
- When all the input signals from sensors indicate a favorable condition for lockup, the controller energizes the solenoid to lockup the clutch.

*NVH issues

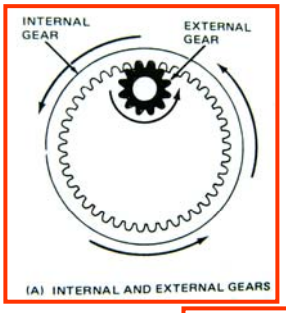
Planetary Gears

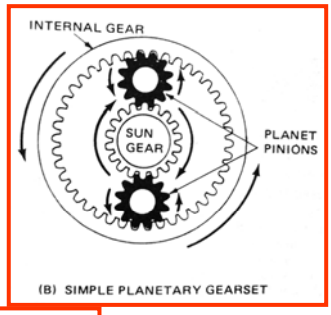
Introduction:

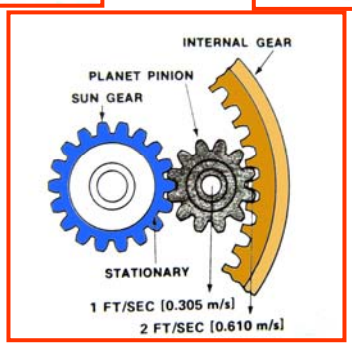
- Almost all ATs rely on planetary gearsets for transfer of power and multiply engine torque to the drive axle.
- A simple planetary gear set consists of –
  - A sun gear
  - A carrier with planetary pinions mounted on it
  - Annulus – an internally toothed ring gear
- Compound gears combine two simple planetary gearsets - greater load spread and larger number of gear ratios.



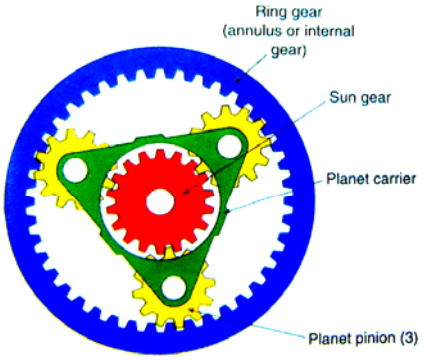
Simple Planetary Gear Train

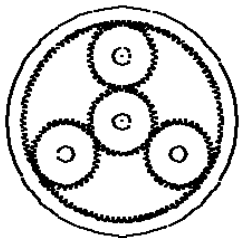






- The sun gear is located at the centre of the assembly
- It can be either a spur or helical gear.
- It meshes with the planetary pinion gears.
- Planetary pinions are small gears (3 or 4) fitted into planetary carrier on needle bearings.
- Planetary carrier – CI, Aluminum or steel plate
- The planetary pinions surround the sun gear's centre axis and they are surrounded by the annulus or ring gear.

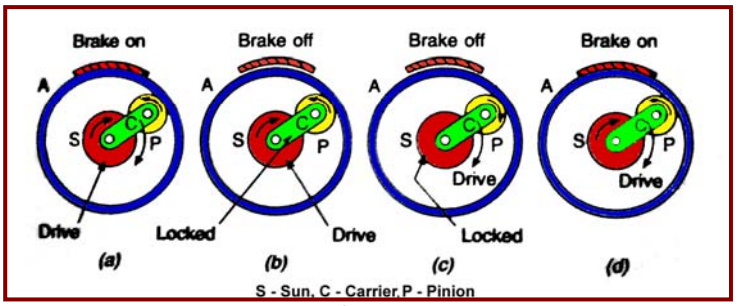




Basic working:

- Each of a planetary gearset can spin (revolve) or be held at rest.
- Power transfer through a planetary gear is only possible when-
  - one of the members is held at rest or
  - two of the members are locked together
- Any one of the three members can be used as the driving or input member.
- Another member might be kept from rotating and thus becomes the held or stationary member.

- The third member then becomes the driven or output member.
- Depending upon which is held, and which is driven, either a torque increase or a speed increase is produced in the planetary set.
- Output direction also can be reversed through various combinations.



Laws of simple Planetary gear operation

Sun Gear	Carrier	Ring Gear	Speed	Torque	Direction
1.Input	Output	Held	Max Reduction	Increase	Same as input
2. Held	Output	Input	Min Reduction	Increase	Same as input
3. Output	Input	Held	Max Increase	Reduction	Same as input
4. Held	Input	Output	Min Increase	Reduction	Same as input
5. Input	Held	Output	Reduction	Increase	Reverse of input
6. Output	Held	Input	Increase	Reduction	Reverse of input
7. When any two members are held together, speed and directions are the same as input. Direct drive 1:1 occurs.					
8. When no member is held or locked together, output can not occur. The result is neutral condition.					

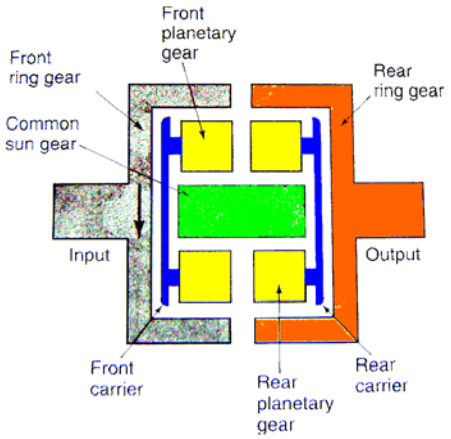
Compound Planetary Gearsets

- To increase the number of available gear ratios, gear sets can be compounded.
- A typical automotive transmission with 3 or 4 forward speeds has at least two planetary gearsets.
- Commonly used compound planetary gear sets:
  - Simpson gearset
  - Ravingeaux* gearset

*Pronounced *Raveno*

Simpson Gearset

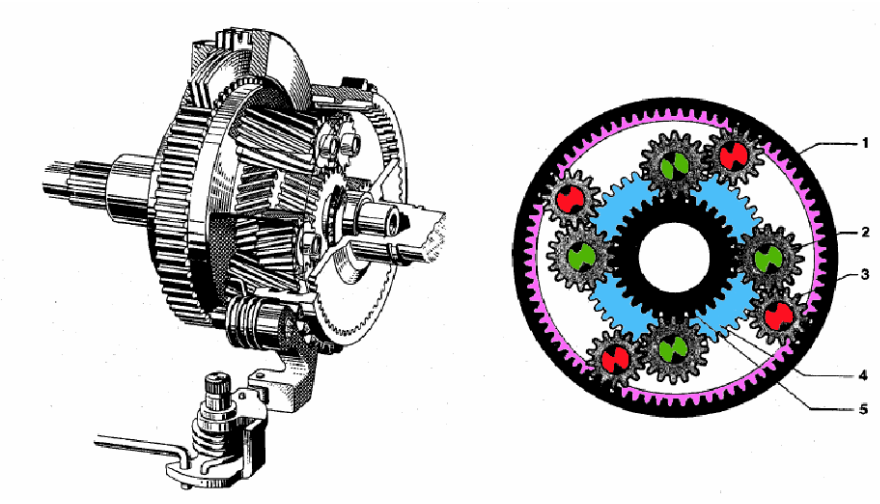
- Simpson gearset consists of –
  - Two separate planetary gearsets with common sun gear
  - Two ring gears
  - Two planetary pinion carriers
- Commonly used gearsets – provides 3 forward gears
- It can provide-
  - Neutral
  - First reduction gear
  - Second reduction gear
  - Direct drive
  - Reverse

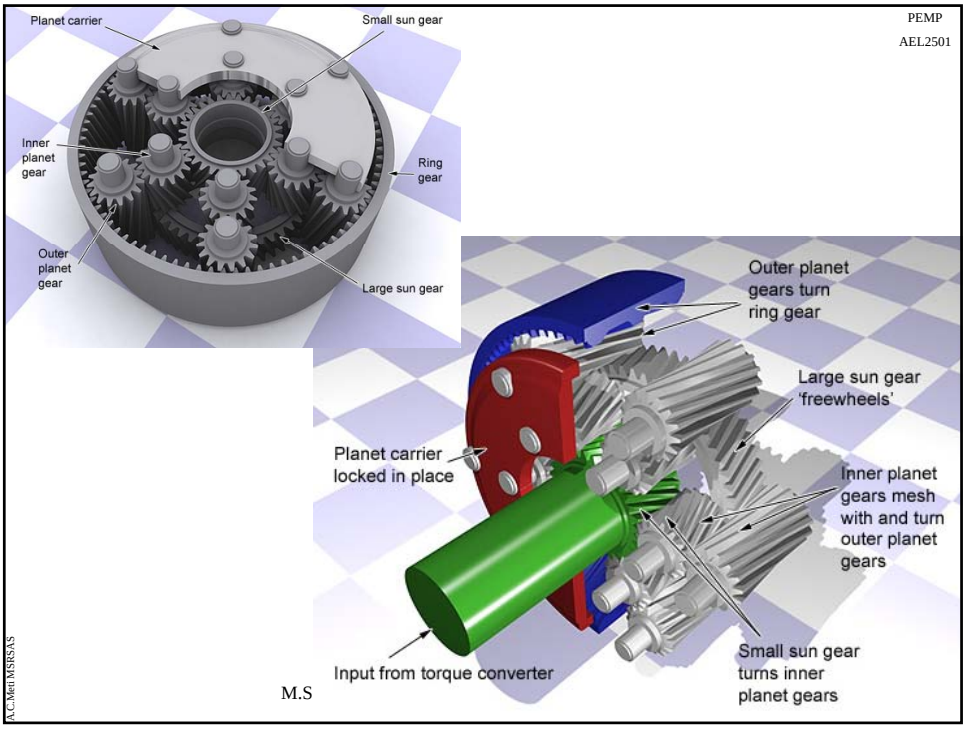


Simpson Gearset Components

- The two planetary gear set need not be same size or have the same number of teeth
- The actual gear ratio is determined by the size and number of gear teeth in the gear assembly.
- Gear ratios and direction of rotation are the result of applying torque to one member of either planetary unit, holding at least one member of the gearset, and using another member as output.

Ravigneaux planetary gear set assembly





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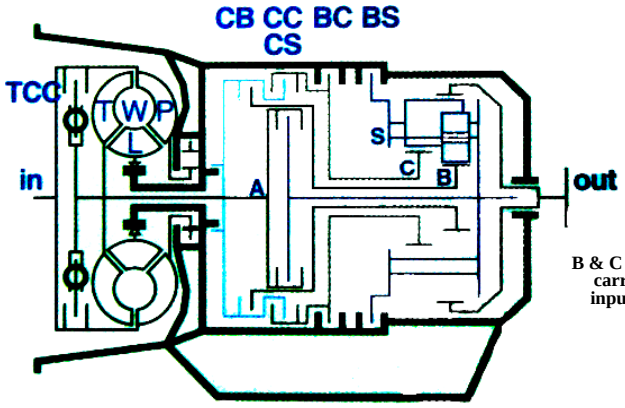
Schematic of a 4-Speed AT (Based on Ravigneaux planetary gear set)



B & C Sun gears, S Planetary gear carrier, CB, CC & CS clutches, A input shaft, BS & BC Band brakes

- Sun gears B, C and planetary –gear carrier S can be connected via clutches CB, CC and CS to shaft A, which is guided by the converter turbine into the transmission.
- Shafts S and C can be connected with the aid of brakes BS and BC to the transmission housing

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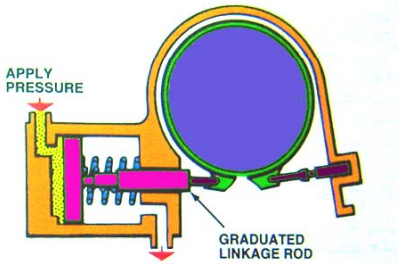
Planetary Gear Controls

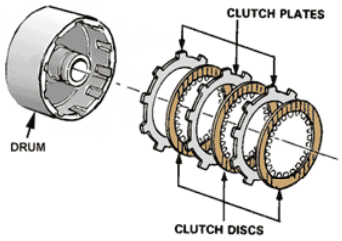
Apply devices:

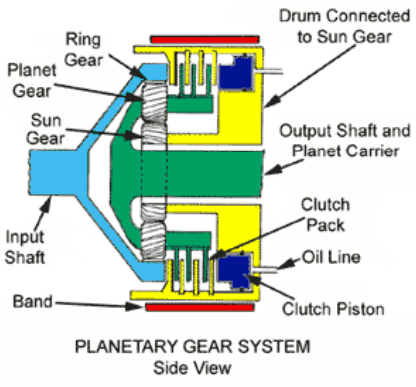
- These are mechanical assemblies that provide the holding and driving forces.
- ATs typically use –
  - Transmission bands (CI, steel + lining)
  - Multi-disc clutches
  - One-way clutches
- The transmission bands are holding devices providing holding forces, they can not provide driving force.
- The planetary gearset member held by the band is known as reaction member.
- The reaction member has a control surface for the band to ride on known as drum.
- A hydraulically operated piston and cylinder assembly is known as Servo.



Transmission clutches:

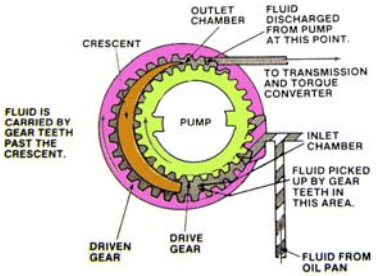
- They are capable of both holding and driving members.
- A multi-disc clutch uses a series of friction discs to transmit the torque or apply braking force.
- The discs have internal teeth to mesh with the splined clutch assembly hub.
- The hub in turn is connected to a member of the planetary gearset that will receive the desired braking or transfer force when the clutch is applied or releas



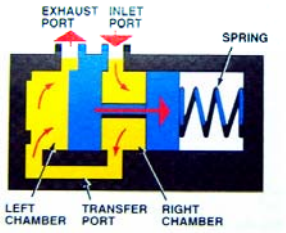


Hydraulic System Components

- A pump supplies the fluid flow and pressurizes the system.
- Most of the oil pumps are mounted directly behind the torque converter and are usually driven by the TC hub.
- Oil Pumps:
  - Gear type*
  - Vane type
- Pressure regulating valves are used to regulate the pressure in the system.

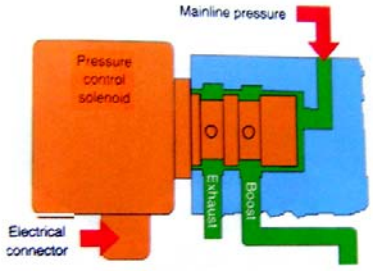


A gear type pump



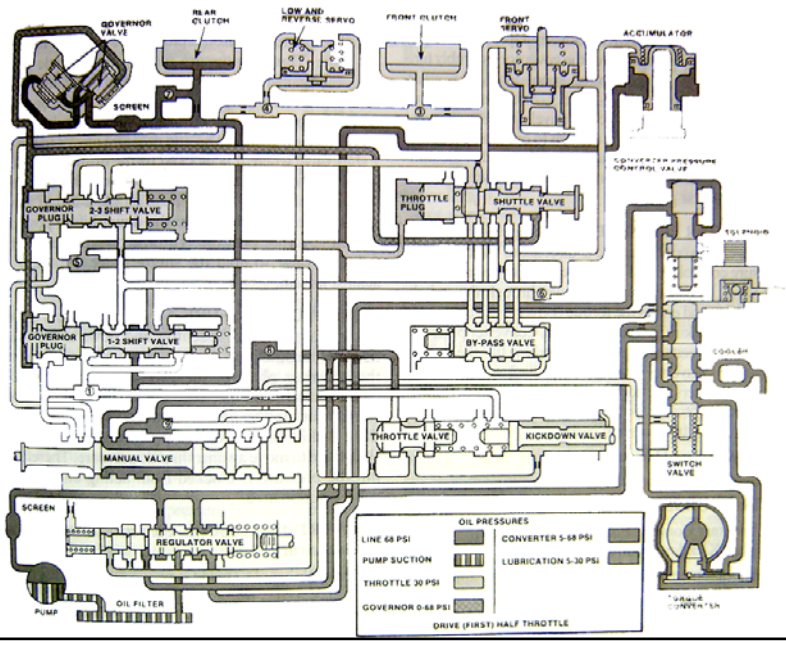
Pressure regulating valve (balanced valve)

- In electronic ATs pressure is often regulated using <u>pressure controlled solenoids</u>, <u>variable force solenoids</u> (VFS) or <u>Force motors</u>.
- The pressure control solenoid is driven by the controller using PWM.
- This allows precise hydraulic pressure regulation.

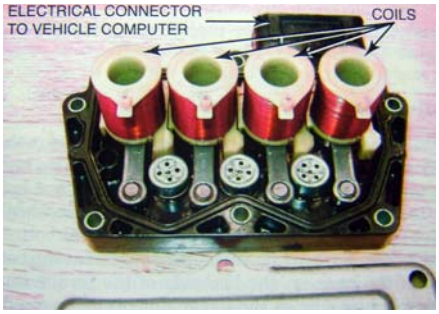


Computer operated pressure control solenoid

Typical Hydraulic Circuit for AT.

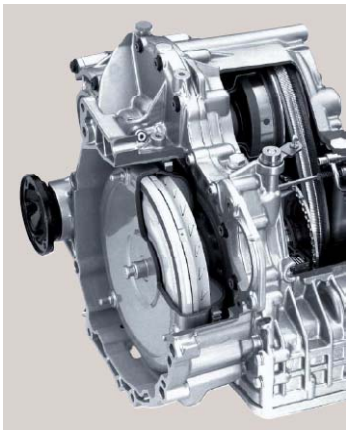


- In <u>electronically</u> controlled transmissions, the <u>shift solenoids</u> replace the shift valves.



Continuously Variable Transmissions - CVTs

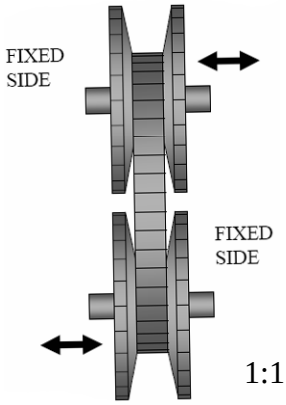
- CVT is a unconventional transmission design
- It is a transmission with no fixed forward speeds.
- Under this category, Infinitely Variable Transmission is also included.
- An IVT gives a zero output speed within operating range.

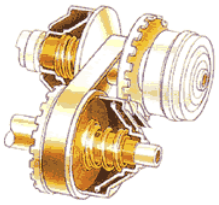


- A good CVT will resolve the compromises in –
  - Reliability
  - Durability
  - Efficiency
  - Controllability at low cost.
- In present CVTs, variable pulleys with flexible belt or chain are used for power transmission with varied drive ratio.
- These use the sliding friction.
- In traction drives with rotating surfaces rolling contact and shear friction are used.

Variable Pulley CVTs

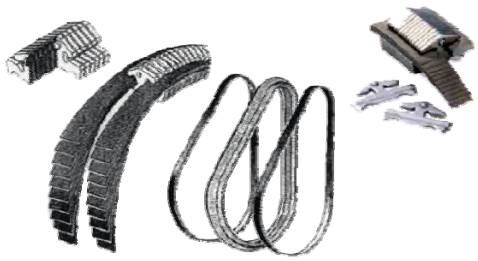
- The CVTs use belt (steel) and pulleys to provide drive ratios.
- One pulley is the driven member and the other is the driver.
- Each pulley has a movable face and a fixed face.
- When the movable face moves, effective diameter is changed
- This change in effective diameter changes effective pulley (gear) ratio.



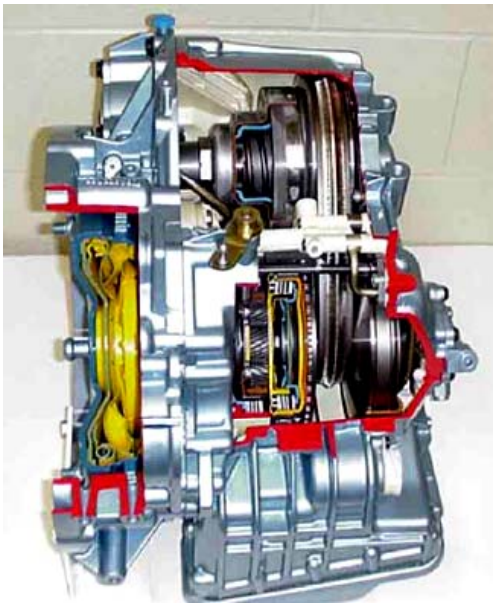


Van Doorne Type CVT

- One of the most commonly used CVT
- Uses two variable pulley assemblies and a steel belt.
- The belt is a segmented steel belt or a push belt system.
- It consists of a set of belt elements about 2 mm thick, with slots on each side to fit two high-tensile steel bands which hold them together.



- The belt transmits power by compressive force between the belt elements instead of tension.
- The Van Doorne system is efficient and has lower noise and wear.
- It is suitable for low power applications like small size passenger cars and snowmobiles.



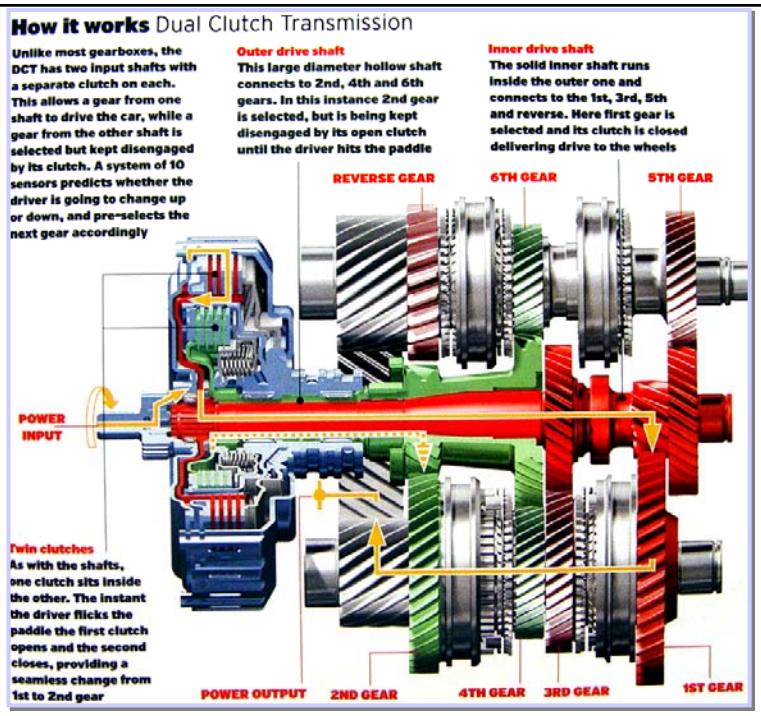
CVT Featuers

- No gear shift
- Continuous transmission of torque
- Control of engine speed independent of vehicle speed.
- Ability to operate engine at peak power over wider range of vehicle speeds
- Operation at most fuel efficient point for required output power.
- Mechanical efficiency of variator: losses appear as a speed or slip in addition to torque loss due to internal friction.
- The hydraulic pump draws power from engine.
- Compromise between fuel economy and torque margin to achieve driveability (avoid elastic band feel). i.e less torque available immediately with a CVT than with a gear transmission.

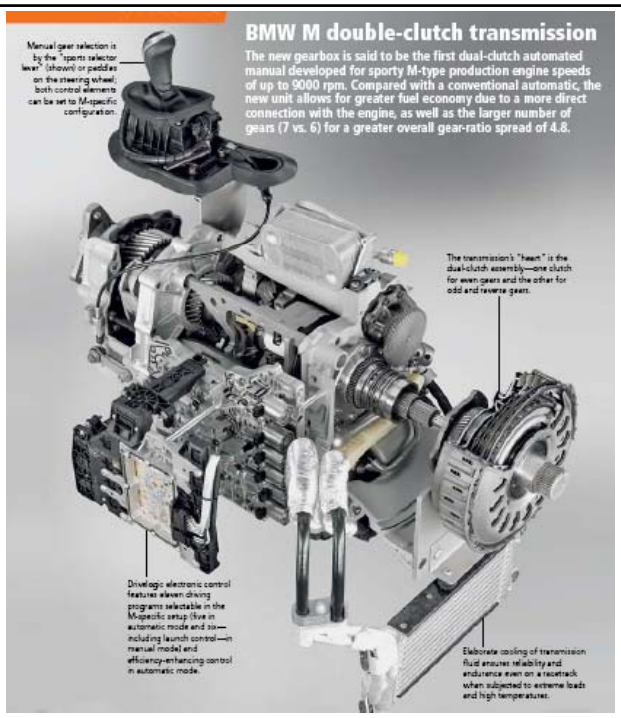
Dual Clutch Transmission - DCT

- Operates without interruption of tractive force
- Main benefit – lower fuel consumption as compared to the ATs
- Porsche introduced in 1992, now used by AUDI & VW…
- Used in the superior, luxury class of vehicles
- Design characterized by:
  - Basic design as for manual transmission
  - Two clutches
  - Actuation of clutch and shifting elements using transmission-shift control and actuators

PEMP
AEL2501



A.C.Met MSRSAS



- Features:
  - Similar levels of convenience to an AT
  - High efficiency
  - No interruption of tractive force
  - Skipping of a gear a possible
  - Takes up more space
  - High bearing forces and solid construction

Summary

- Various types of drivetrain layouts used in automobiles and functions of transmissions have been discussed.
- Manual Transmission for RWD, FWD vehicles and single plate and multi plate clutches have been discussed
- The constructional details and working of typical Automatic Transmission and Torque converter have been discussed
- Advanced transmissions such as CVTs and DCTs have been explained