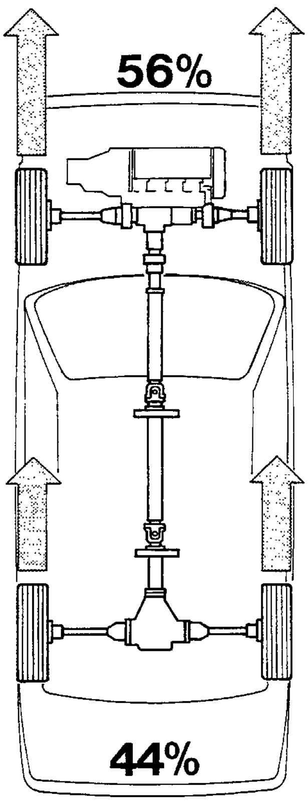

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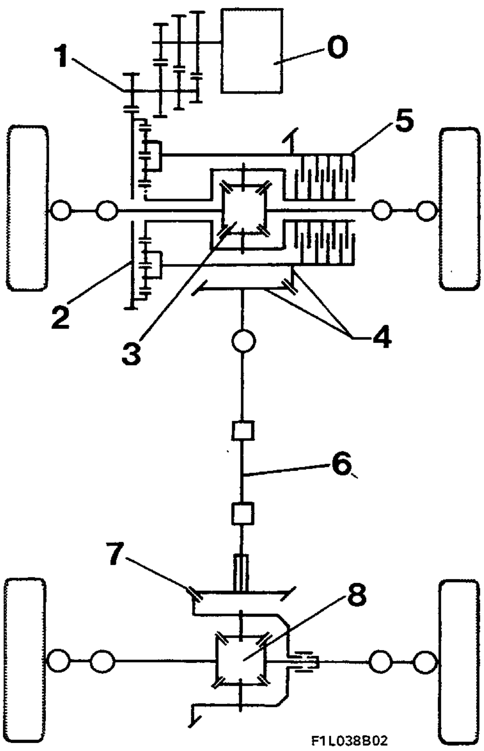
FOUR WHEEL DRIVE

The main feature of the LANCIA four wheel drive system is an asymmetrical torque distribution of 56% to the front axle and 44% to the rear axle. This system provides slightly more driving torque at the front axle to permit maximum possible speed under slippery conditions for a front-engined vehicle.
Compared to two-wheel drive, a four-wheel drive system permits the torque to be distributed over two wheel contact surfaces. This permits:

a. Better traction on poor road surfaces, especially when the friction coefficient is extremely low as on gravel, snow, ice, mud etc.
b. improved hill-climbing ability
c. better grip during cornering.



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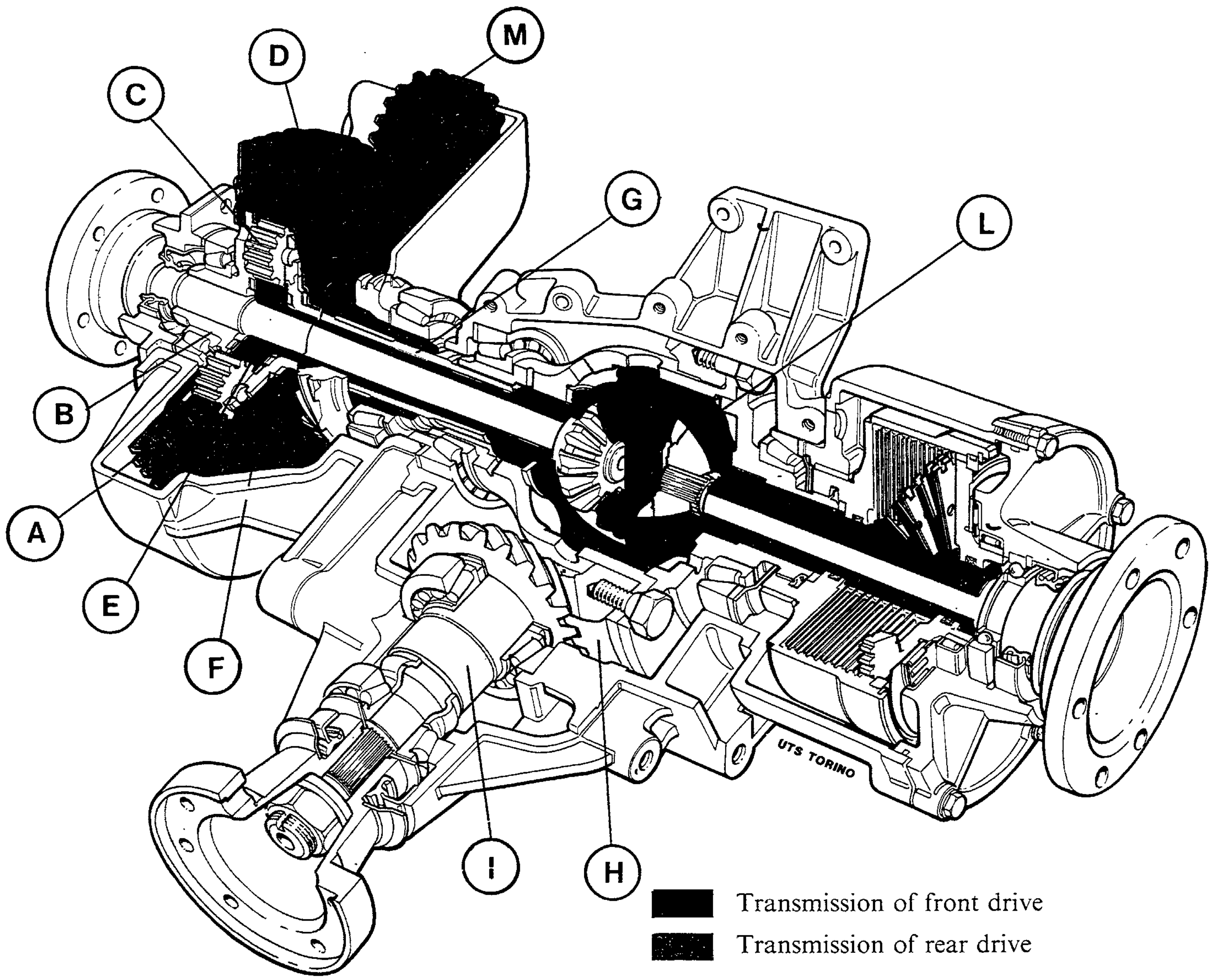
DRIVE TRANSMISSION

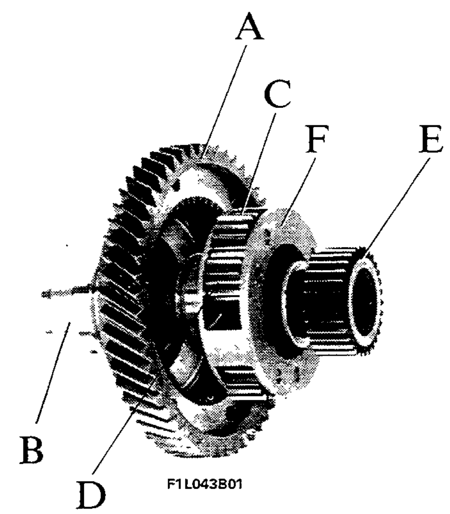
The four wheel drive system hinges around an epicyclic differential or torque distributor (2). This receives drive produced by the engine via the gear layshaft (1) and transmits it via an epicyclic gear system to the differentials at the front (3) and rear (8) axles.
The epicyclic distributor consists of a crown wheel (A) with internal and external teeth that receives drive via its external teeth and transmits it via the internal teeth to the first satellite (C) which meshes with the second satellite (D) that in turn meshes with pinion (E). Three pairs of satellites (120° apart) evenly distribute the transmitted force. The satellites turn freely on their shafts that are fixed to carrier (F). Hollow shaft (G) is integral with ring wheel (H) that transmits drive across bevel pinion (I) and propellor shaft (6) to rear differential (8).
The pinion hollow shaft is integral with front differential casing (L) and drive is therefore transmitted directly to the front wheels.

Key
0. Engine
1. Gearbox
2. Epicyclic differential or torque distributor
3. Car front differential
4. Bevel drive
5. Ferguson viscous coupling
6. Propeller shaft
7. Bevel reduction drive
8. Car rear differential

* A conventional differential can only transmit an equal torque to each satellite and thus to each drive shaft. The torque distributor or central differential can: 1) transmit the same torque, or different torques, to the 2 axles of the car 2) produce a different number of revs at front and rear axles. This function is essential since it prevents transmission components and tyres being subjected to harmful forces (when one set of wheels faces a bump or pot-hole while the other travels over flat ground) and therefore permits safe driving up to top speed.

DIFFERENTIAL ASSEMBLY WITH EPICYCLIC DISTRIBUTOR (photograph) **AND FRONT DIFFERENTIAL**





Key

A. Crown wheel of epicyclic system
B. Crown wheel shaft
C. 1st satellite
D. 2nd satellite
E. Pinion
F. Epicyclic gear train
G. Epicyclic train hollow shaft
H. Ring gear
I. Propeller shaft bevel pinion
L. Front axle differential
M. Gearbox spur pinion.

Operation of epicyclic differential with good grip on road

If the wheels do not slide over the ground, the 3 components of the epicyclic system turn together with the same angular velocity. The satellites are locked and transmit drive through the system components without turning about their shafts. In this case Ferguson coupling (5) that can connect the pinion shaft to the satellite carrier does not come into operation. Each pair of satelllites is subject to a force system in equilibrium.

The difference between the torques transmitted by the planetary train (rear axle) and pinion (front axle) arises because, although the same force is transmitted to both systems by the crown wheel, their torque arms (i.e. arms through which the force acts) are very different and therefore give rise to two quite different torques. A first glance suggests that the torques transmitted by the planetary train and pinion should be very different from the stated ratio of 56 (front) to 44 (rear). Indeed one would imagine that the torque transmitted by the planetary train (with its much larger arm) would be greater than that transmitted by the pinion (with its much smaller arm).

In order to resolve this apparent discrepancy (see explanation on following page) we need only consider that although all teeth engaged transmit the same force, i.e. that produced by the crown wheel, the reaction of the pinion, an equal and opposite force, acts on the second satellite. As a result of this the resultant force acting on the first satellite shaft will be directed in the direction of rotation whereas the force acting on the shaft of the 2nd satellite is lesser and directed in the opposite direction. The resultant force generated by the two satellites on the epicyclic train is thus much smaller than the force transmitted by the crown wheel (and therefore than the force acting on the pinion) and acts with an arm equal to the mean radius of the rays passing through the 2 satellite shaft centre lines. For this reason the torque transmitted to the epicyclic train connected to the rear axle (44%) is smaller than the force (56%) transmitted to the pinion shaft (front axle).

Operation of epicyclic differential on roads with low friction coefficient

If the friction coefficient of one of the 2 axles is very low and does not permit the transmission of all the torque, the other axle will transmit a reduced torque that still respects the 56%-44% ratio. The 2 satellites will now start to turn on their shafts and the revs of the crown wheel will be discharged to the epicyclic train and pinion according to the reactions offered by these components. In this event, the Ferguson coupling comes into operation almost immediately to establish a measured degree of locking with continual variations between pinion and epicyclic train dependent on the reciprocal difference in revs. Ferguson coupling operation is described on page 64. When drive reaches the 2 front or rear differentials it is relayed to the 2 drive shafts with equal or differential speed depending on the grip of the 2 wheels on the ground. The torque transmitted by each of the 2 wheels is always the same whatever the circumstances. Rear differential operation is explained on page 74.

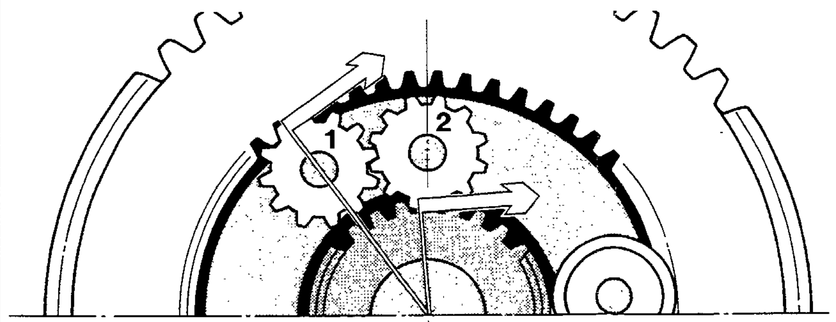
Demonstration of asymmetrical torque distribution
T = Drive - R = Resistance applied at pinion (R equal and opposite to T) - Resultant of T and R: on satellite 1 S_1, on satellite 2 S_2 -Tangential resultants of S_1 and S_2: $S_1 = T_1$; $S_2 = T_2$ -Momentum generated by forces acting on satellite shafts : $T_1 \times r_1 = M_1$ (clockwise); $T_2 \times r_2 = M_2$ (anticlockwise) - $M_1 - M_2$ = MTR (resultant momentum applied to epicyclic train)

Simplified indirect demonstration of asymmetrical distribution of drive

Let us suppose that the crown wheel transmits a force of 10 daN to the 1st satellite, since the two satellites have the same no. of teeth, the 2nd satellite is bound to transmit the same force to the pinion. In a system of meshed gears, the primary radii are proportional to the number of teeth and therefore the drive transmitted by the crown wheel is proportional to 10 x 54 (54 = No. of crown wheel teeth) = 540;
while the drive transmitted by the pinion (front axle) is proportional to 10 x 30 (30 = no. of pinion teeth) = 300.
The drive component that must be transmitted to the other part of the system, i.e. the epicyclic train, will be
540 - 530 = 240
If we now compare the torques transmitted, we will obtain:

$$\frac{300}{240} = \frac{\text{pinion torque}}{\text{epicyclic train torque}} = \frac{56 \text{ (front axle)}}{44 \text{ (rear axle)}}$$

NOTE *If we decrease the no. of pinion teeth and the no. of crown wheel teeth remain the same, the ratio will approach 50:50.*



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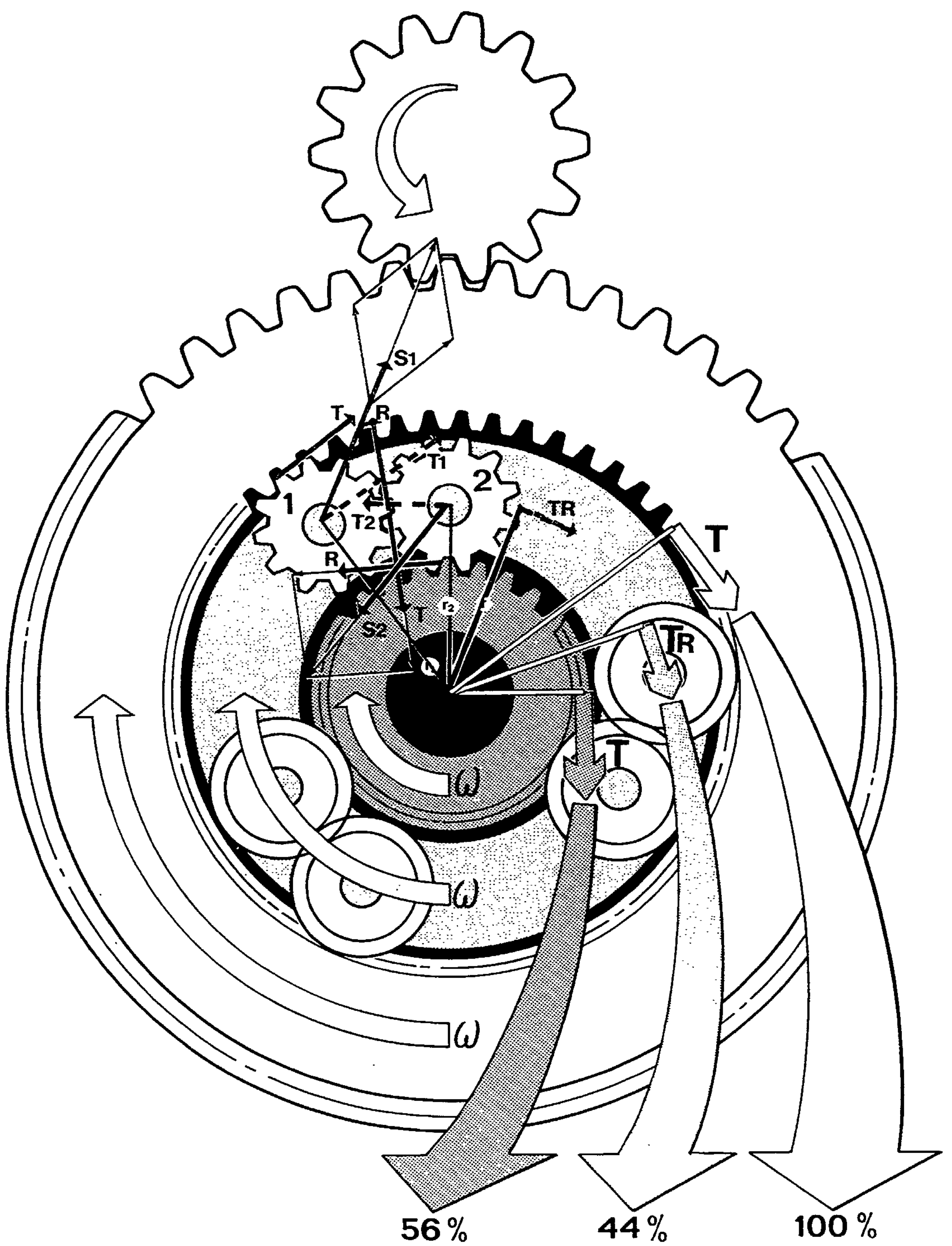

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