

What Is a Planetary Gearbox? | Why Is It Named a Planetary Gearbox | Possibilities of Planetary Gearboxes.

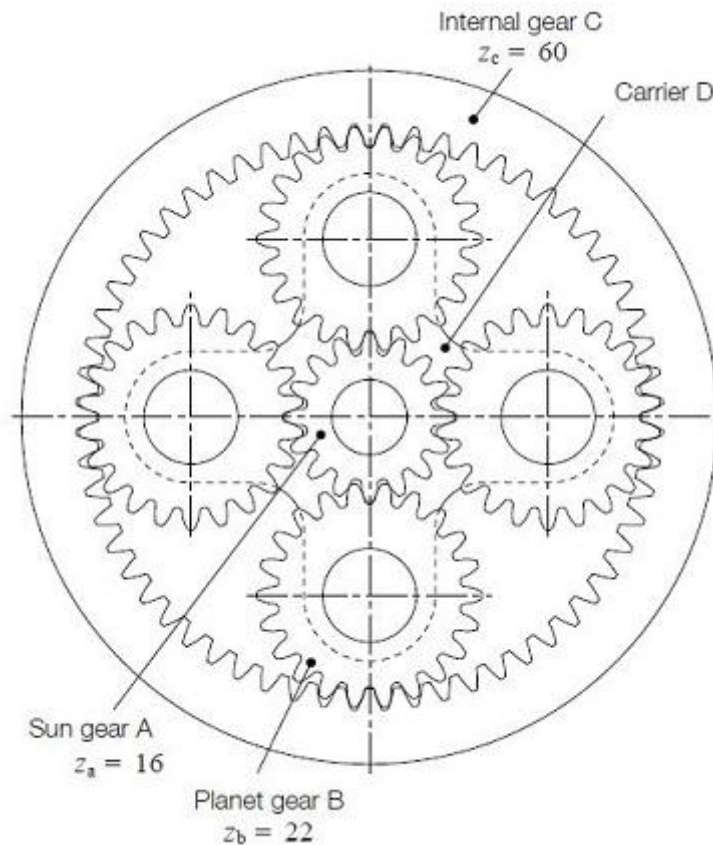
This introduces planetary gear systems, hypocycloid mechanisms, and constrained gear systems, which are special gear systems which offer features such as compact size and high reduction ratio.



Planetary GEAR System

The basic form of a planetary gear system shown it consists of a [sun gear](#) A, planet gears B, internal gear C and [carrier](#) D.

An example of a planetary GEAR system



The input and output axes of a planetary gear system are on a same line. Usually, it uses two or more planet gears to balance the load evenly. It is compact in space, but complex in structure. Planetary gear systems need a high-quality manufacturing process. The load division between planet gears, the interference of the internal gear, the balance and vibration of the rotating carrier, and the hazard of jamming, etc. are inherent problems to be solved.

This is also called 2K-H type planetary gear system. The sun gear, internal gear, and the carrier have a common axis.

Relationship Among the Gears in a Planetary GEARS System

In order to determine the relationship among the numbers of teeth of the sun gear(z_a), the planet gears B(z_b) and the internal gear C(z_c) and the number of planet gears N in the system, these parameters must satisfy the following three conditions:

Condition No.1

$$z_c = z_a + 2 z_b$$

This is the condition necessary for the center distances of the gears to match. Since the equation is true only for the standard gear system, it is possible to vary the numbers of teeth by using profile shifted gear designs. To use profile shifted gears, it is necessary to match the center distance between the sun A and planet B gears, α_1 , and the center distance between the planet B and internal C gears, α_2 .

$$\alpha_1 = \alpha_2$$

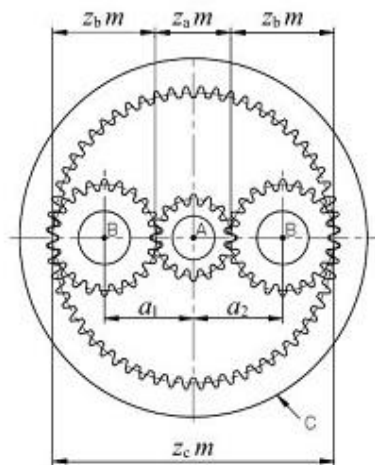
Condition No.2

$$\frac{z_a + z_c}{N} = \text{Integer} \quad (17.3)$$

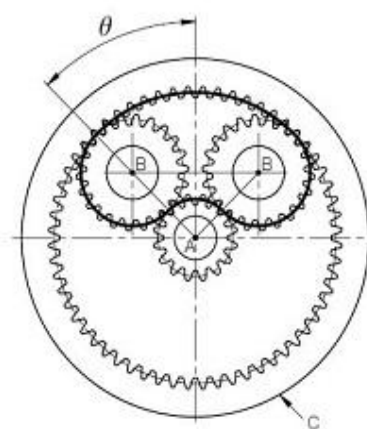
This is the condition necessary for placing planet gears evenly spaced around the sun gear. If an uneven placement of planet gears is desired, then Equation must be satisfied.

$$\frac{(z_a + z_c) \theta}{180} = \text{Integer} \quad (17.4)$$

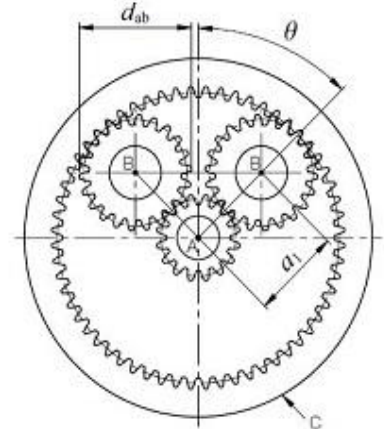
Where θ : half the angle between adjacent planet gears ($^\circ$)



Condition No.1 of planetary gear system



Condition No.2 of planetary gear system



Condition No.3 of planetary gear system

Conditions for Selecting GEARS

Condition No.3

$$z_b + 2 < (z_a + z_b) \sin \frac{180^\circ}{N} \quad (17.5)$$

Satisfying this condition insures that adjacent planet gears can operate without interfering with each other. This is the condition that must be met for standard gear design with equal placement of planet gears. For other conditions, the system must satisfy the relationship :

$$d_{ab} < 2a_1 \sin \theta \quad (17.6)$$

Where:

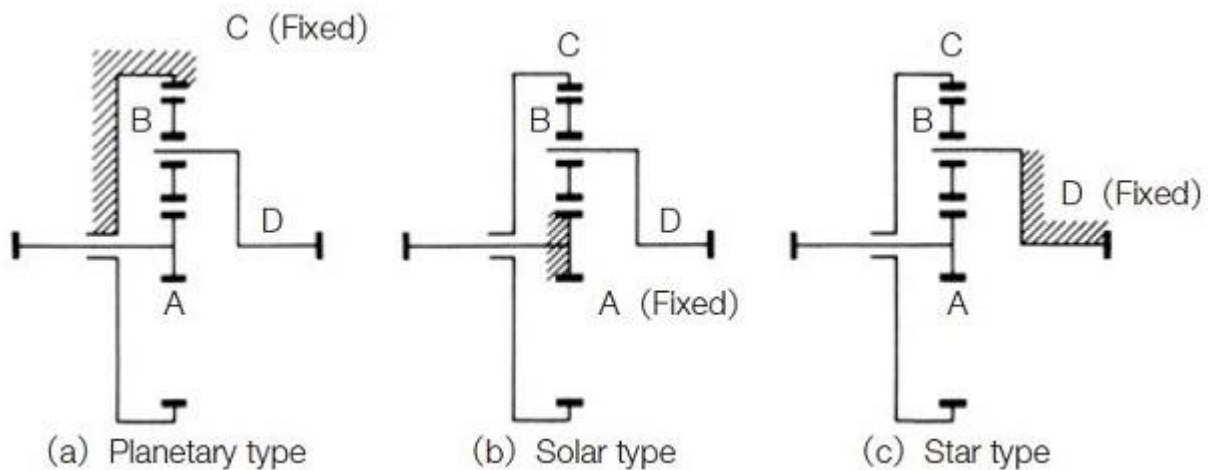
d_{ab} : Tip diameter of the planet gears

a_1 : Center distance between the sun and planet gears

Besides the above three basic conditions, there can be an interference problem between the internal gear C and the planet gears B. See Section 4.2 Internal Gears.

(2) Transmission Ratio of Planetary Gear System

In a planetary gear system, the transmission ratio and the direction of rotation would be changed according to which member is fixed & contain three typical types of planetary gear mechanisms,



Planetary GEAR mechanism

(a) Planetary Type

In this type, the internal gear is fixed. The input is the sun gear and the output is carrier D. The transmission ratio is calculated as,

Table 17.1 Equations of transmission ratio for a planetary type

No.	Description	Sun gear A z_a	Planet gear B z_b	Internal gear C z_c	Carrier D
1	Rotate sun gear once while holding carrier	+ 1	$-\frac{z_a}{z_b}$	$-\frac{z_a}{z_c}$	0
2	System is fixed as a whole while rotating	$+\frac{z_a}{z_c}$	$+\frac{z_a}{z_c}$	$+\frac{z_a}{z_c}$	$+\frac{z_a}{z_c}$
3	Sum of 1 and 2	$1 + \frac{z_a}{z_c}$	$\frac{z_a}{z_c} - \frac{z_a}{z_b}$	0 (fixed)	$+\frac{z_a}{z_c}$

$$\text{Transmission ratio} = \frac{1 + \frac{z_a}{z_c}}{\frac{z_a}{z_c}} = \frac{z_c}{z_a} + 1 \quad (17.7)$$

Note that the direction of rotation of input and output axes are the same.
Example: $z_a = 16$, $z_b = 16$, $z_c = 48$, then transmission ratio = 4.

(b) Solar Type

In this type, the sun gear is fixed. The internal gear C is the input, and carrier D axis is the output. The speed ratio is calculated as

Equations of transmission ratio for a solar type

No.	Description	Sun gear A z_a	Planet gear B z_b	Internal gear C z_c	Carrier D
1	Rotate sun gear once while holding carrier	+ 1	$-\frac{z_a}{z_b}$	$-\frac{z_a}{z_c}$	0
2	System is fixed as a whole while rotating	- 1	- 1	- 1	- 1
3	Sum of 1 and 2	0 (fixed)	$-\frac{z_a}{z_b} - 1$	$-\frac{z_a}{z_c} - 1$	- 1

$$\text{Transmission ratio} = \frac{-\frac{z_a}{z_c} - 1}{-1} = \frac{z_a}{z_c} + 1 \quad (17.8)$$

Note that the directions of rotation of input and output axes are the same. Example: $z_a = 16$, $z_b = 16$, $z_c = 48$, then the transmission ratio = 1.33333

(c) Star Type

This is the type in which Carrier D is fixed. The planet gears B rotate only on fixed axes. In a strict definition, this train loses the features of a planetary system and it becomes an ordinary gear train. The sun gear is an input axis and the internal gear is the output. The transmission ratio is :

$$\text{Transmission Ratio} = -\frac{z_c}{z_a} \quad (17.9)$$

Referring to the planet gears are merely [idlers](#). Input and output axes have opposite rotations. Example: $z_a = 16$, $z_b = 16$, $z_c = 48$, then transmission ratio = -3 .

Hypocycloid Mechanism

In the meshing of an internal gear and an external gear, if the difference in numbers of teeth of two gears is quite small, a profile shifted gear could prevent the interference. This is an example of how to prevent interference

under the conditions of $z_2 = 50$ and the difference of numbers of teeth of two gears ranges from 1 to 8.

The meshing of internal and external gears of small difference of numbers of teeth

z_1	49	48	47	46	45	44	43	42
x_1	0							
z_2	50							
x_2	1.00	0.60	0.40	0.30	0.20	0.11	0.06	0.01
α_b	61.0605°	46.0324°	37.4155°	32.4521°	28.2019°	24.5356°	22.3755°	20.3854°
a	0.971	1.354	1.775	2.227	2.666	3.099	3.557	4.010
ε	1.105	1.512	1.726	1.835	1.933	2.014	2.053	2.088

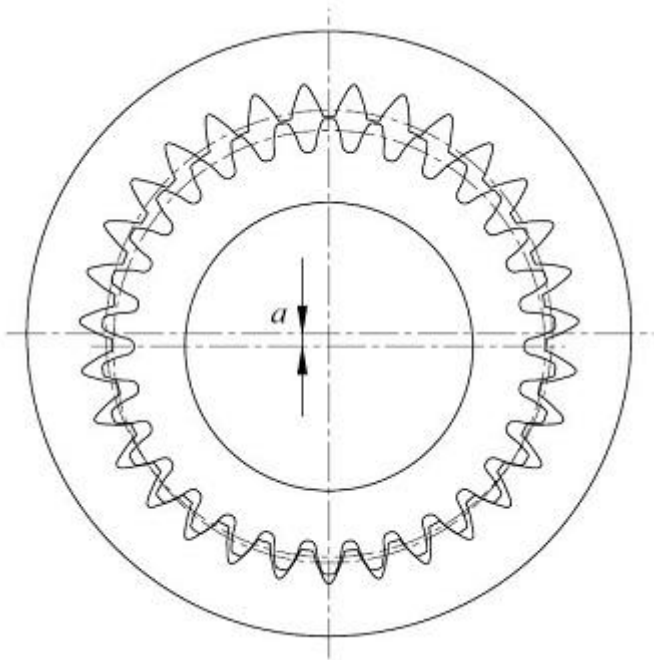
All combinations above will not cause involute interference or trochoid interference, but trimming interference is still present.

In order to assemble successfully, the external gear should be assembled by inserting it in the axial direction. A profile shifted internal gear and external gear, in which the difference of numbers of teeth is small, belong to the field of hypocyclic mechanisms, which can produce a large reduction ratio in single step, such as

$$\text{Transmission ratio} = - \frac{z_1}{z_2 - z_1} \quad (17.10)$$

1/100.

the gear train has a difference of numbers of teeth of only 1; $z_1 = 30$ and $z_2 = 31$. This results in a transmission ratio



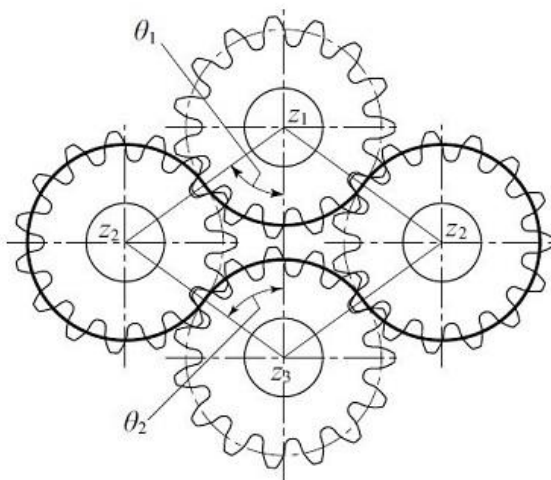
of .

The meshing of internal gear and external gear in which the numbers of teeth difference is 1

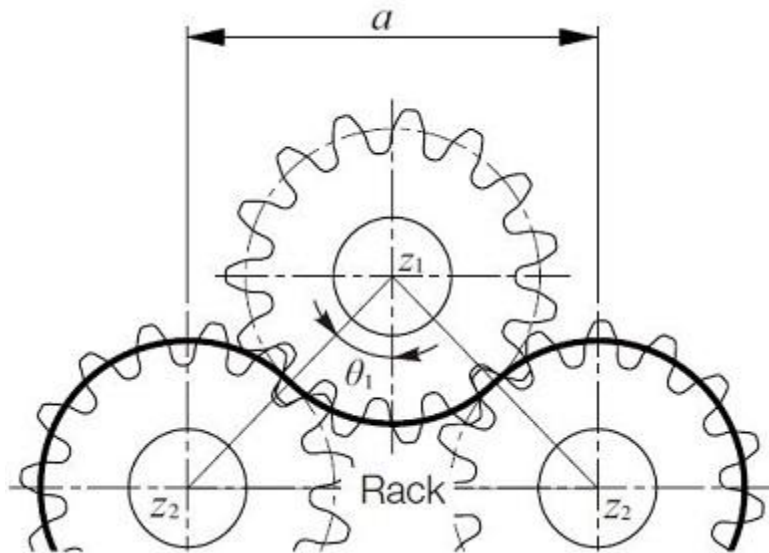
Constrained GEAR System

A planetary gear system which has four gears is an example of a constrained gear system. It is a closed loop system in which the power is transmitted from the driving gear through other gears and eventually to the driven gear. A closed loop gear system will not work if the gears do not meet specific conditions.

Let z_1 , z_2 and z_3 be the numbers of gear teeth, Meshing cannot function if the length of the heavy line (belt) does not divide evenly by pitch.



A constrained gear system in which a gear rack is meshed. The heavy line in corresponds to the belt in If the length of the belt cannot be evenly divided by pitch then the system does not work. It is described by Equation



Constrained gear system containing a rack

Planetary gear mechanism

