



ImSystems
— Drive Innovation —

DF1
Technical Document

Cutting Edge Technology and Industrial Quality

The Archimedes Drive is a new traction-based speed reducer, engineered to be more accurate & more controllable than any other solution on the market.

It has been specifically designed to increase the capabilities of factory automation equipment and to open-up new design opportunities for industrial robots, collaborative robots, surgical robotics and many more mechatronic systems.

Our product is a unique, new technology that can deliver 'best in class' performance in several key technical areas. Innovative Mechatronic Systems B.V. is committed to developing this enabling technology that is required to drive innovation in the global automation market.

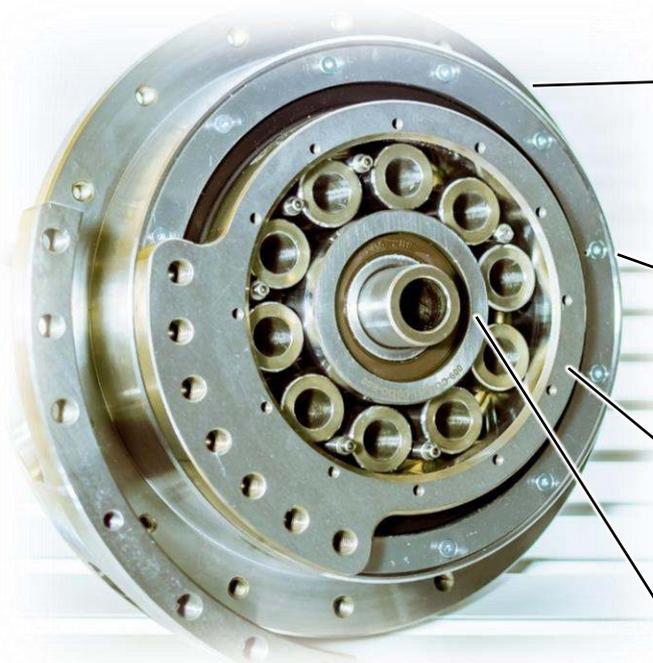
This document will lay out the working principle of the technology, as well as the high-level technical specs of the 'development-kit' drive which is available for purchase.



1. Working Principle and Terminology

1.1. Introduction

The Archimedes Drive is a type of compound planetary transmission, which uses high-pressure roller contact to transmit torque. The core components of the drive are described in Figure 1. Normal gear profile compound planetary drives have been used for more than one hundred years to obtain a high gear ratio in a single stage, and the basic principle of a compound gear dates back to at least 1786, with James White's 'infinite wedge' transmission.



Output annulus

The **output annulus** is a ring of hardened bearing steel that is driven by the **flexrollers** running on the interior raceway. The **output annulus** has a slightly different internal diameter than the **ground annulus** which controls the gear ratio.

Ground annulus

The **ground annulus** is a ring of hardened bearing steel that anchors the **flexrollers** running on the interior raceway.

Flexrollers

The **flexrollers** are planetary rollers which have a sections with two different diameters. This difference in diameter matches the difference between **annuli** and controls the gear ratio

Sunwheel

The **sunwheel** is the high speed contact for the drive, and is used for the connection to the motor.

Figure 1: Explanation of the Archimedes Drive Core Components

The Archimedes Drive uses a normal compound type layout, but rather than use teeth, uses high contract pressure rollers. This simplifies the manufacturing process & improves the quality of gear mesh in the drive.

1.2. The Working Principle

With the Archimedes Drive, IMSystems combines two working principles. The first principle, the 'compound planetary principle' (also known as a Wolfrom drive) was invented years ago. This speed reducer could reach a much higher gear ratio (higher precision) than the standard planetary drives. However, the drive did not work well in practice due to manufacturing difficulties caused by gear teeth, which made the drive very inefficient in power transmission. Using the second working principle, 'traction rollers', IMSystems could remove the gear teeth, drastically decreasing the manufacturing difficulties and increasing the efficiency of the drive. These two principals were combined to form the patented 'compound planetary traction drive', also known as the Archimedes Drive.

The basic working principle is explained in Figure 2. This drive is comprised of an input axis in the center, called the 'sun wheel', which is surrounded by the planet wheels. These wheels are surrounded by an outer ring called the 'annulus'. In a normal planetary gear, the wheels have traditional gears which mesh with the teeth of the sun and annulus. Since there are no gear teeth in the Archimedes Drive, everything rolls against each other. Torque is transferred because the planet wheels are hollow cylinders, called 'flexrollers'. The annulus and sun wheel will compress the flexrollers, thereby generating enough elastic deformation in the planets to turn them into springs. Each of these springs exerts a force on the sun and annulus, which generates traction. Since the planets act like springs, they can spread the stresses over the whole ring instead of just two gear teeth.

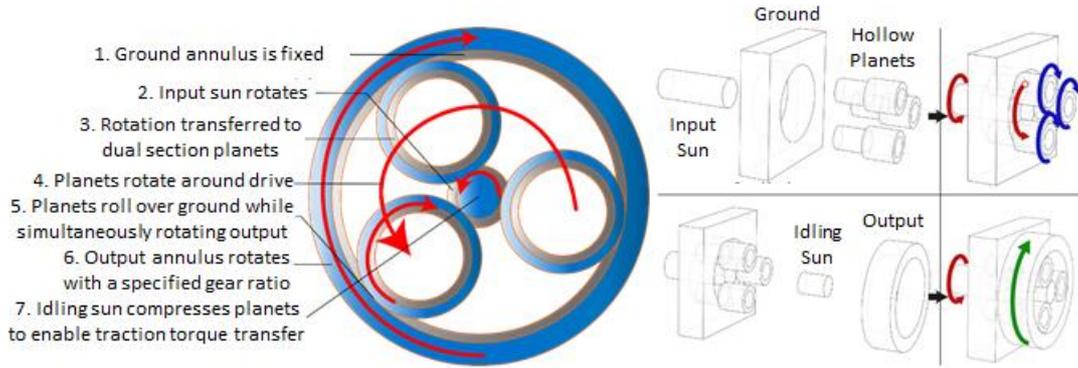


Figure 2: Working principle of the Archimedes Drive

In geared planetary drives, the sun wheel receives rotational input from an engine and the output rotation comes from the planets. The planets are therefore attached to the gearbox via an output carrier which holds the drive and the planets in place and provides for the output torque. Since the Archimedes Drive has hollow planets that deform, no connecting carrier can be used, which means that with this construction the drive cannot be fixated. However, by using the principle of compound drives, the output torque can be generated by using a second annulus, connected to the output of the system, and a multi-section flexroller, each with a slight difference in diameter compared to each other. In addition to solving the routing problem, it ensures that the drive can reach an extremely high gear ratio in a single stage, more than 30 times higher than is currently possible. This is the fundamental patented principle which is applied to all drives produced by IMSystems.

1.3. The Drive Code

The ordering code which will be used for all drives is shown in Table 1. Currently, only one version can be ordered (The DF1 Development Kit). More variants will be released in the future, following the structure shown in in Table 1.

Table 1: Drive Ordering Code

DF1 - 15 - 25 - EYS

Series	Size	Ratio					Model
DF1	10***	25	50	100	125	150	EYS* - External Yoke System IYS** - Internal Yoke System
	15* ***	25*	50	100	125	150	
	20***	25	50	100	125	150	
	25	25	50	100	125	150	
	30	25	50	100	125	150	
	40	25	50	100	125	150	
	45	25	50	100	125	150	
	50	25	50	100	125	150	
	60	25	50	100	125	150	
65	25	50	100	125	150		

*Only the DF1-15-25-EYS size drive is available as a demonstrator unit.

As can be seen in Table 1 there will be two models of the drive ('IYS' or 'EYS'). The 'EYS' model of the drives will be released first, these models have a yoke around the exterior of the drive. This Yoke is required for the working principle of the drive; however, it does restrict the output rotation. The IYS version, enabling full rotation is currently in development and will be available at the end of the year.

2. The DF1-15-25-EYS

2.1. Introduction

The DF1 series of drives was built from the ground up to provide a highly accurate, exceptionally stiff drivetrain for compact robotic & mechatronic applications. Building around the inherently zero-backlash Archimedes Drive technology, the DF1 includes robust main support bearings and an optional high-resolution encoder.

The DF1 EYS series of drives are housed inside of an external ‘open yoke’ (EYS) type of housing. This open yoke provides a secure mounting fixture for direct installation into a mechatronic platform. Additionally, integrated twin support bearings provide ample off-axis stiffness with superior load carrying capabilities. The drive’s high-level features are described below:

- True-zero backlash
- Exceptional stiffness
- Integrated encoder
- Complete load support
- High rotational & positional accuracy
- High efficiency
- Excellent shock load resistance

In mechatronic applications, the DF1 series should be used where controlled accuracy is paramount. The low input friction, high stiffness & integrated sensor all support these applications. The DF1 is also an excellent choice for cobot systems, as the inherent shock load resistance and excellent backdrive torque are both superior features.

2.2. Specification

The specifications for the DF1-15-25-EYS are shown in Table 2. The efficiency of the drive is shown in Figure 3. These specs of the drive are compared to that of similar harmonic drives. As shown in the table the Archimedes drive excels in certain aspects as when compared to available harmonic drives.

Table 2: Specifications of the IMS-15-25-EYS

Performance Figure	Unit	IMS DF1-15-25-EYS
Limit Average Torque	Nm	7.5
Limit for Repeated Torque	Nm	14.7
Limit for Momentary Peak Torque	Nm	16
Starting Torque	Ncm	2.5
Backdrive Torque	Nm	0.8
Average Input Speed	Rpm	3,500
Standard Accuracy	arc min	0.01
Output Rotation	deg.	220
Reduction Ratio	[-]	25
Diameter	mm	72
Length	mm	60
Mass	kg	0.98
Torsional Stiffness	Nm/rad	40,000
Efficiency	%	93

The specifications in Table 2 are compared to existing comparable technologies below:

- **DF1-15-25-EYS has better torque values:**
 - High usable torque compared to total drive volume.
 - If over-loaded, it acts as a friction brake and the drive will not fail.
 - Starting torque is 60% less than the competition.

- Backdrive torque is 66% less than the competition.
- **DF1-15-25-EYS has higher accuracy and torsional stiffness:**
 - Standard accuracy is 99.5% less than the competition.
 - Torsional stiffness is 11.7x greater than the competition.
- **DF1-15-25-EYS has a different form-factor and weight:**
 - It cannot rotate 360 degrees.
 - It is shaped more like a ‘cylinder’ rather than a ‘pancake’.
 - It currently has a slightly higher weight compared to competitors.

(Note: This is the first commercially available iteration of the DF1 series drive, therefore currently, it has not been optimized for weight/size, next versions of this series will be much competitive in that aspect)

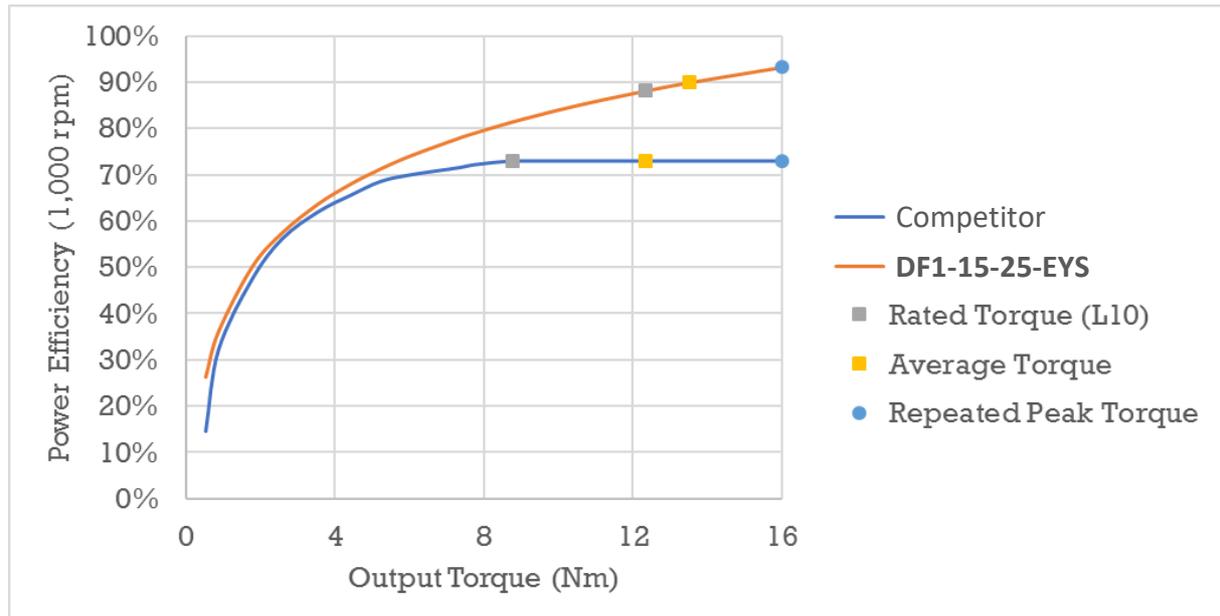


Figure 3: Efficiency of the DF1-15-25-EYS

The comparison in Figure 3 is summarized below:

- **DF1-15-25-EYS has better efficiency across the board:**
 - Efficiency at rated, average and repeated torque is higher than the competition
- **DF1-15-25-EYS efficiency is superior at higher torques:**
 - Efficiency flattens out at a later stage as compared to competition
 - Efficiency greater than 90% is achievable
 - Highest efficiency is achieved at maximum torque

In conclusion, the Archimedes drives will offer exceptional accuracy, stiffness and efficiency characteristics while still being competitive in usable torque. With the DF1 series drive our partners/customers will experience first-hand the unique capabilities of the Archimedes drive technology, making the initial step towards revolutionizing the mechatronic industry.

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