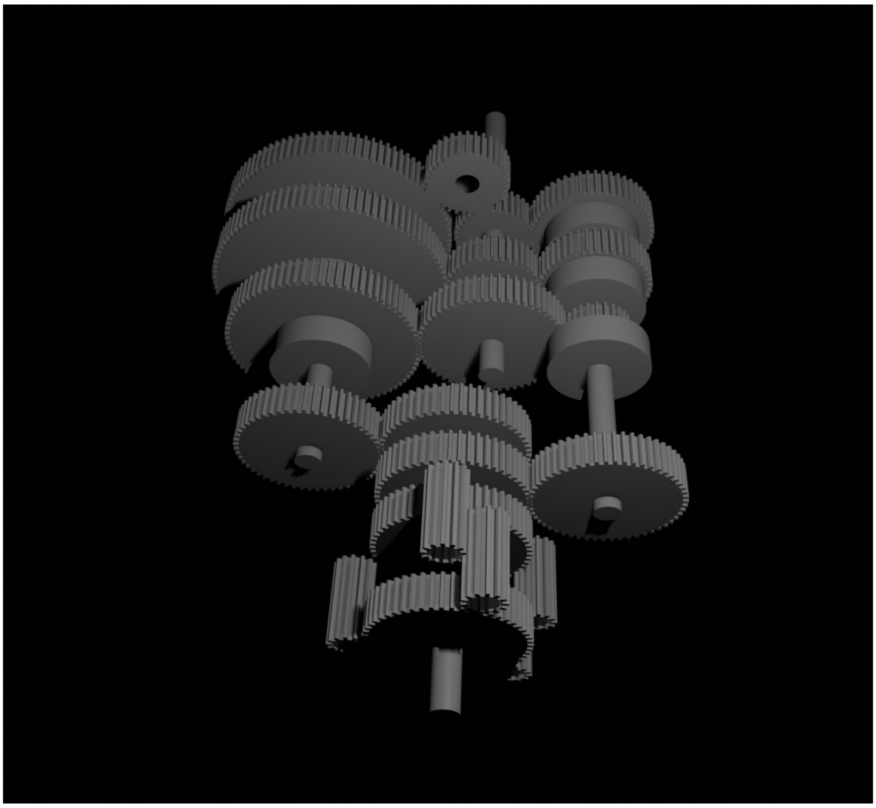
Differential Averaging Automatic Transmission



15 and 24 Ratio Variants with Extreme Low Range Capability

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1 Abstract

The Averaging Differential Transmission is a new gear train design that enables a high number of ratios, high torque carrying capability and fast shifting in a robust and compact package. This is achieved by splitting power into two simple gearsets, then recombining it in a differential. This provides tremendous advantages over previous transmission designs.

Mathematical averaging in the differential allows the transmission designer to select almost any desirable combination of output ratios, and overcomes the problems typically encountered with compound gearsets. The transmission may now have ratio spreads that are impossible to achieve with other automatic transmission designs. This can produce very high ratios, up to and including infinity, eliminating the need for external low range or splitters.

Incoming power may be split into any gearset of the designer's choosing. Planetary or conventional spur/helical gearsets may be utilized, however the preferred embodiment uses spur or helical gears as it is superior with respect to cost, size and final ratios. When relying on spur or helical gearsets, expensive planetary gearsets may be completely eliminated.

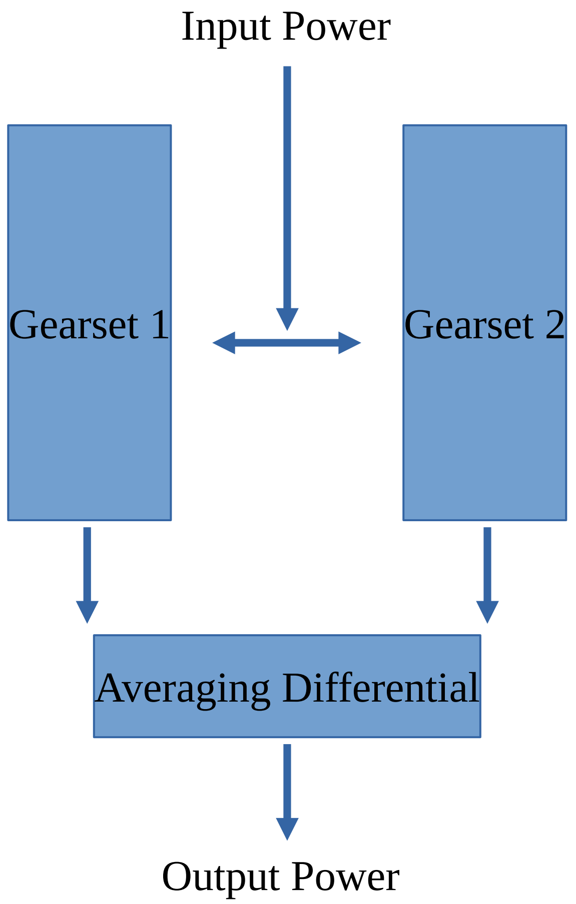
In most transmission configurations torque is shared between both gearsets, and teeth on both sides of the input shaft pinions are loaded. This results in a transmission that is inherently capable of handling high torque.

The large number of gear ratios and high torque carrying capability of this transmission make it perfectly suited to the narrow power band of large diesel engines.

2 Key Benefits

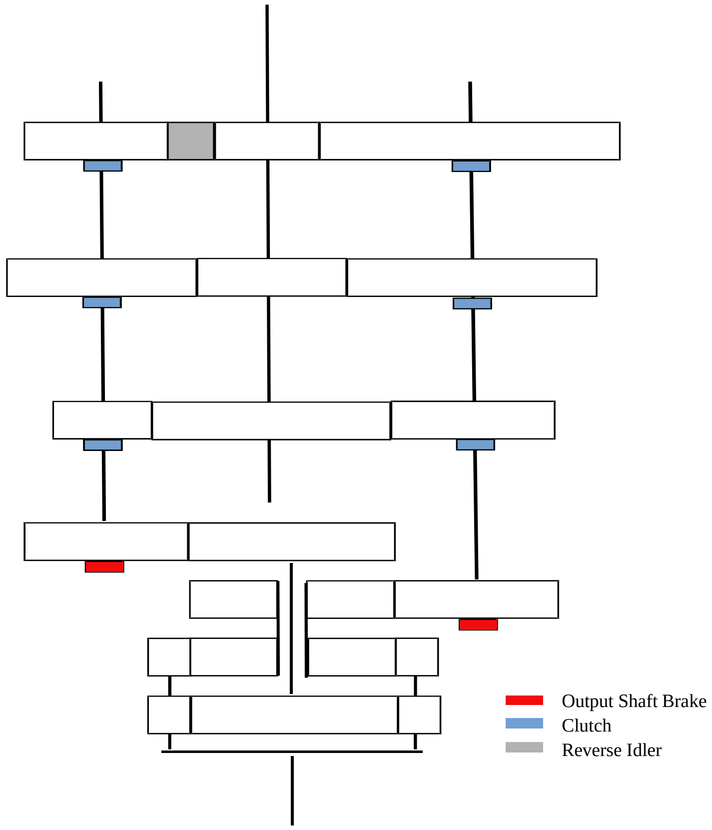
- High number of ratios
  - Ratios scale exponentially with number of shifting elements, x ($n = x^2 + 2x$)
    - 3 shifting elements results in 15 ratios
    - 4 shifting elements results in 24 ratios
    - 5 shifting elements results in 35 ratios
    - 6 shifting elements results in 48 ratios
- 15 ratios are achieved using only 6 clutches and 2 brakes
- 24 ratios are achieved using only 8 clutches and 2 brakes
- Large transmission ratio range
- Compact transmission case size
- Simple and cost effective construction
- High torque carrying capability
- Overcomes the problems with compound gearsets
- Smaller and lighter components due to power being split between two gearsets
- Elimination of low range and splitter gearsets
- High gear reductions are easily achievable with no external reductions required (50:1 or greater is possible without increasing transmission case size)
- Variable number of reverse speeds
- Simple shifting control logic similar to traditional automatic transmissions
- Use of clutch packs, dog clutches, or a combination of both
- Various configurations available
- Design software is available

3 Block Diagram and Power Flow



Input power is split into two sub-gearsets, each having a number of selectable ratios. The output shafts of the two sub-gearsets drive an averaging differential or epicyclic planetary gearset, which has the effect of combining the two different output shaft speeds. A differential is the preferred embodiment as it provides mathematical advantages over a planetary in this application.

The Differential Averaging Transmission overcomes all of the problems traditionally encountered by compound gearsets. Compounding gearsets necessarily produce mathematically diverging ratios, and the number of useful ratios are limited due to this divergence. The averaging transmission overcomes this limitation.



Power output is achieved by engaging one clutch (or brake) on each sub-gearset. In the example above (6) six clutches selectively allow gears to be coupled to the two output shafts, or alternatively the output shafts themselves may be constrained by one of (2) two brakes.

Clutches on output shaft gears may be employed to achieve (9) nine ratios. Both output shafts will be engaged and their rotation will be averaged by the differential to achieve varying ratios.

Brakes are applied on either output shaft to prevent rotation on that shaft. This has the effect of allowing the differential to operate as a “divide-by-two” for the remaining rotating gears. These two optional braking clutches provide an additional (6) six ratios.

4 Example Transmission and Mathematics

An example 15 speed transmission in a high speed configuration consisting of the following numbers of gear teeth, with a reverse idler between the first pinion (32 teeth) and right gear (97 teeth):

Left	Input	Right
51	32	97
45	38	97
25	58	77

Yields a transmission with the following ratios:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	Rev.
6.72	5.11	3.89	3.19	2.66	2.37	1.96	1.62	1.45	1.25	1.00	0.862	0.738	0.651	-6.06

And corresponding spread between ratios:

1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-10	10-11	11-12	12-13	13-14	Average
31%	31%	22%	20%	12%	21%	21%	12%	16%	25%	16%	17%	13%	19.8%

This example provides a high speed transmission with a range of 10.3:1 and the most aggressive gear change (1 to 2) is only 31%.

These very favorable ratio spreads are typically not achievable with other automatic transmission designs.

Output ratios are calculated by determining the two sub-gearset ratios, r_1 and r_2, and utilizing the following formula:

$$n=\frac{2}{\frac{1}{r1}+\frac{1}{r2}}$$

The total number of ratios available with a given transmission configuration is:

$n = x^2 + 2x$

5 Development Software

Nova Robotics has developed configuration software to search all possible gear combinations within a specified transmission case size.

In the 15 speed configuration, any change in gear teeth results in the change of at least (7) seven of the output ratios. This results in substantially greater mathematical complexity when determining gearsets. It is not possible to manually solve gearsets with the Differential Averaging Transmission; a computer must be utilized to search for viable gearset combinations.

Different configuration options are specified by the user, and the software searches all combinations for viable transmissions. Good gear design practise is employed and gear combinations with a GCF (greatest common factor) of greater than (1) one are discarded. All user options are applied against possibly viable gearsets. Gearsets not meeting user criteria are discarded. As acceptable transmissions are found they are written to the screen in real time.

The software currently provides solutions for the spur/helical configuration. If other gearsets (planetary) are desired please contact us as the software may be modified to search for acceptable planetary gearset configurations.

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