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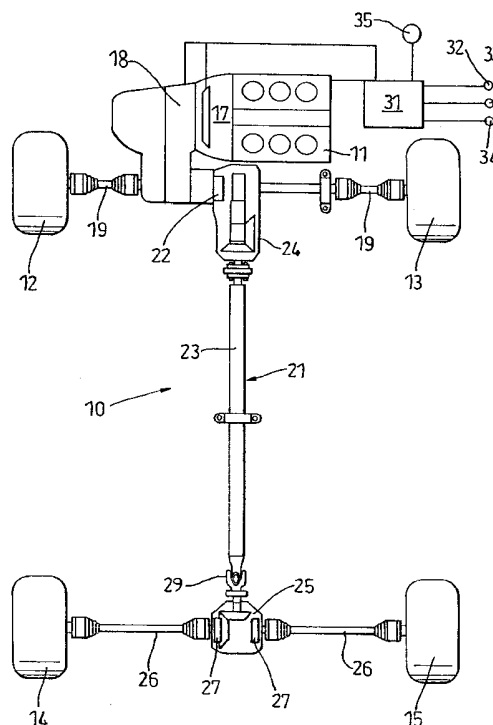
**US 6817434 B1** **US 5105901 A**  
**US 4779698 A**

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(54) Abstract Title: **Four wheel drive driveline transition**

(57) A switchable four wheel drive vehicle 10 has a mode in which an engine 11 drives a first pair of wheels, typically the front wheels 12,13, and an auxiliary drive line 21 to a second pair of wheels is disconnected from the engine 11 and from the second pair of wheels. The auxiliary drive line 21 comprises a first clutch 22 adjacent to the engine 11 and typically comprises a drive shaft 23 which is connected to the rear wheels 14,15 via a differential 25 which comprises clutches 27. Changing from two wheel to four wheel drive is controlled so that the auxiliary drive line 21 is reconnected to either the engine 11 or the second pair of wheels, typically the rear wheels 14,15, to rotate at least part of the auxiliary drive line 21 for a sufficient time period prior to fully reconnecting it to provide drive torque to the rear wheels 14,15. Thus transition to engagement of four wheel drive occurs in two stages, reducing any acceleration jerk perceived by the driver.



**Fig. 1**

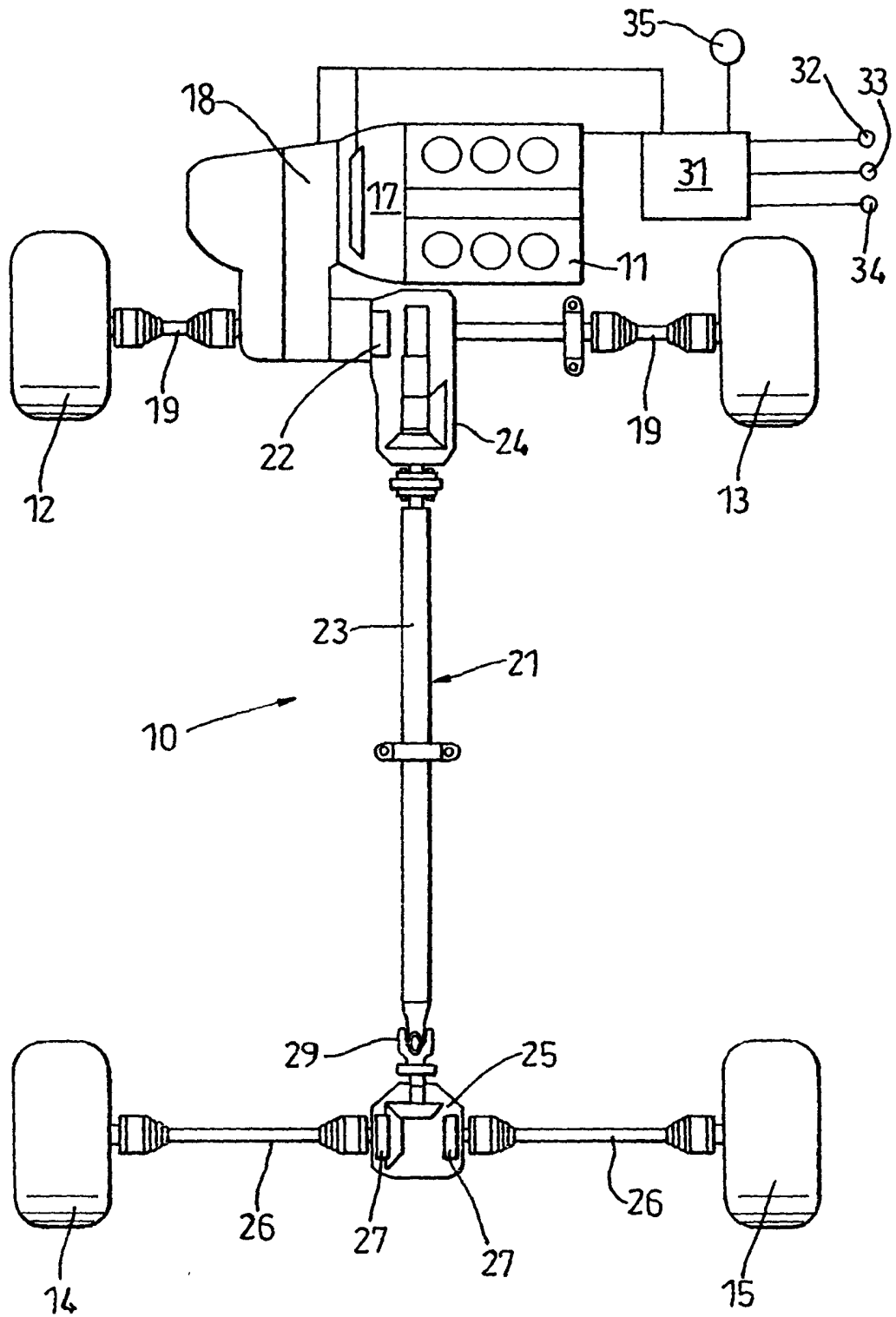
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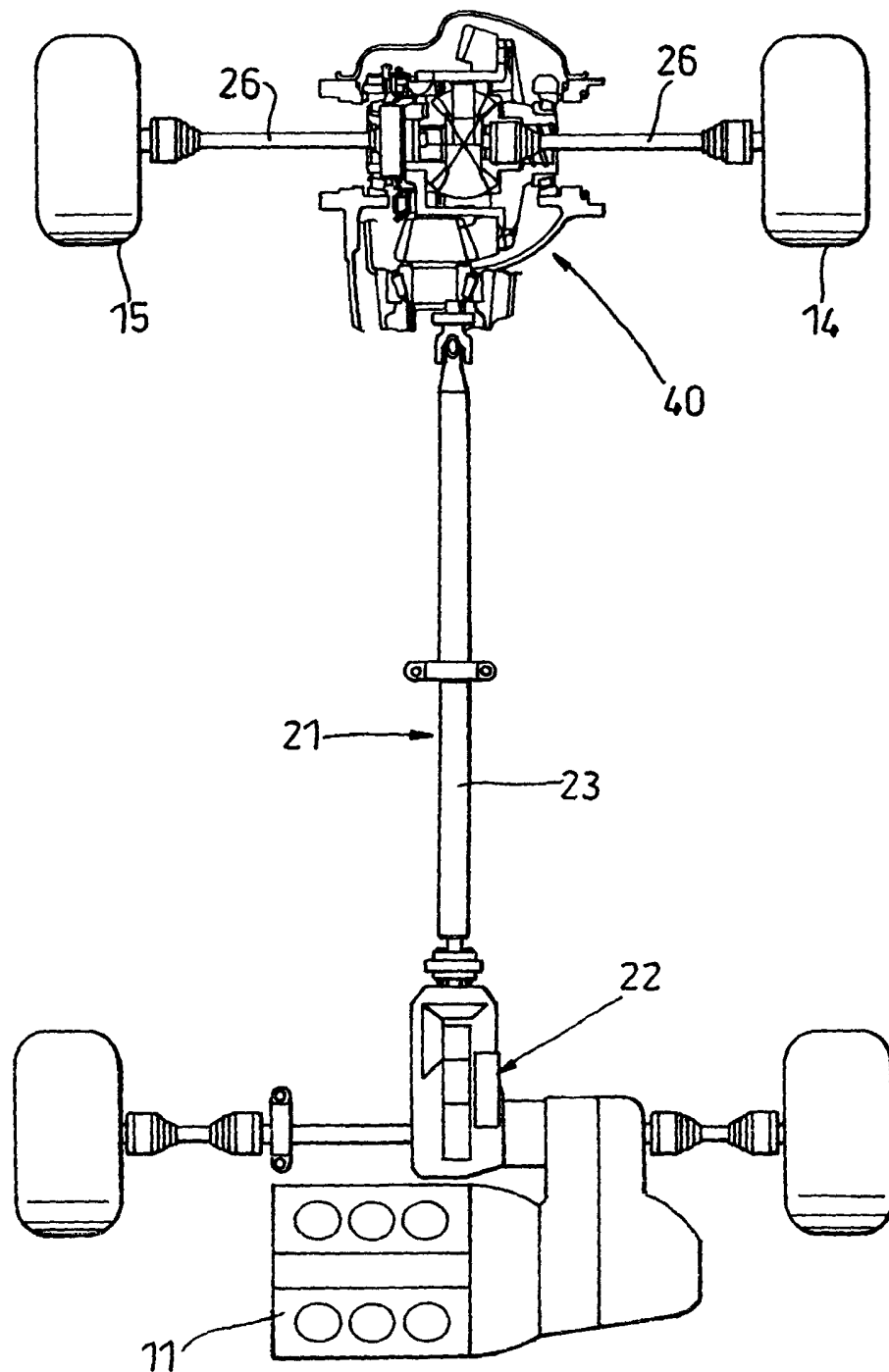
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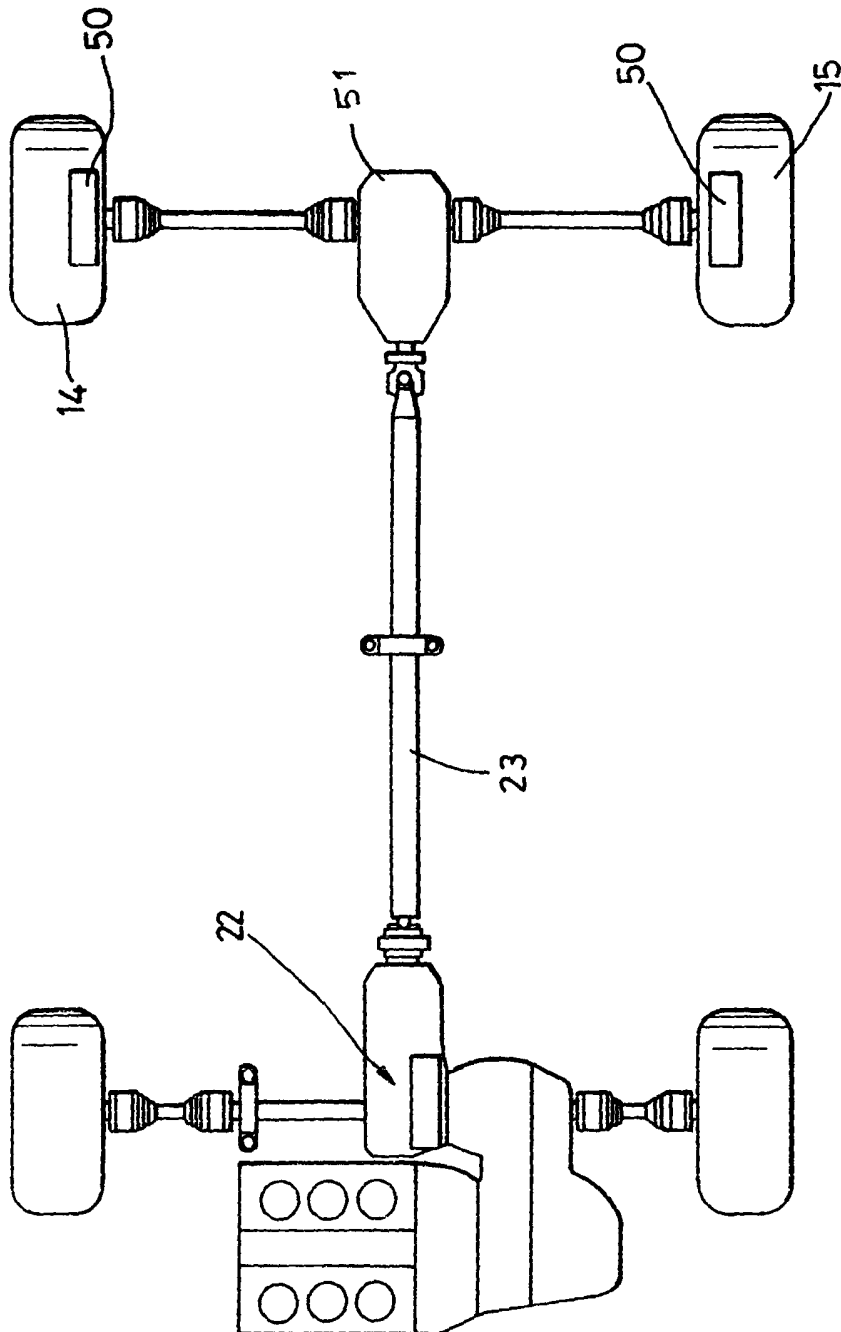


**Fig. 1**

2/3



**Fig. 2**



*Fig. 3*

Motor Vehicle Driveline

This invention relates to drivelines for motor vehicles and in particular for motor vehicles such as all terrain vehicles which have selective two wheel drive or four wheel drive.

Some all terrain vehicles which have a four wheel drive system are provided with a means of disconnecting two of the driving wheels when the vehicle is driven on less challenging terrain e.g. "on road". An example of a such a four wheel drive system is shown in US-A-5105901 in which the drive to the rear wheels may be broken through a clutch device to establish two wheel drive when four wheel drive is not necessary. The drive to the rear wheels is also controlled by wheel clutches which are utilised for controlling the torque distribution between the right and left rear wheels to improve controllability when cornering.

During two wheel drive conditions, the driveline components connected to the rear wheels may be caused to rotate due to frictional drag between the components in the driveline.. This driveline drag is a major contributor to fuel inefficiencies and ways have been sought to minimize the residual drag in four wheel drive systems operating in two wheel drive mode. One method of reducing driveline drag is to disconnect the main rear wheel drive shaft from the rear wheel rear drive shafts using a differential of the type sold by GKN <sup>RTM</sup> under the name of the TFS free running differential. This differential allows the rear drive shafts to be disconnected from the differential casing so that there are no losses between the differential bevel gears and the pinions and no drive to the main drive shaft. Such systems are generally switched between four wheel drive mode and two wheel drive mode when the vehicle is stationary.

The present invention seeks to provide a four wheel drive system in which the re-connection between two wheel drive mode and four wheel drive mode may be made while the vehicle being driven. This may be termed "dynamic driveline reconnect". However, a

problem with dynamic driveline reconnection is that the reconnection may be felt by the driver as an unacceptable jerk, i.e. a spasmodic acceleration. The invention also seeks to minimise any acceleration forces acting on the driver during the reconnection.

According to one aspect of the present invention there is provided a motor vehicle  
5 having an engine, two pairs of wheels, a driveline to connect the engine to the wheels such that one pair of wheels is driven by the vehicle engine when the vehicle is in a two wheel drive mode and the other pair of wheels is additionally connected to the engine when the vehicle is in a four wheel drive mode, the driveline including an auxiliary driveline comprising a first clutch means to connect to the engine, a differential downstream of the  
10 first clutch means and releasable torque transmitting means operable to connect and disconnect drive from the differential to said other pair of wheels, and control means operable to switch the vehicle between the four wheel drive and the two wheel drive modes such that in the two wheel drive mode the auxiliary driveline is disconnected from both the engine and said other pair of wheels and when switching the vehicle from the two wheel  
15 drive mode to the four wheel drive mode while the vehicle is moving the control means operates one of the first clutch means and the releasable torque transmitting means to connect the auxiliary driveline to the engine or said other pair of wheels respectively to cause the auxiliary driveline to rotate before the other of the first clutch means and the releasable torque transmitting means connects the engine to said other pair of wheels.

20 The first clutch means may comprise a wet clutch .

The releasable torque transmitting means may comprise second clutch means located between the differential and the second pair of wheels. In an alternative arrangement the releasable torque transmitting means is incorporated within the differential, for example a free running differential of the type marketed by GKN<sup>RTM</sup> as the TFS differential or by  
25 connecting to the respective rear drive shafts through a pair of differential clutches or hydraulic couplings, e.g. as is shown in US-A-5310388 and in US-A-5105901.

The control means may include a driver operable switch which allows the driver to select a desired drive mode from the two wheel drive mode and the four wheel drive mode.

The control means may include a programmable controller which receives signals indicative of vehicle operating conditions and is operable to switch from the two wheel drive  
5 mode to the four wheel drive mode when various vehicle operating parameters have been detected.

The invention also provides, according to another aspect thereof, a method of controlling a change in the transmission of torque from a motor vehicle engine to the driving wheels in a motor vehicle having a driveline and two pairs of wheels, one pair of wheels  
10 being driven by the engine when the vehicle is in a two wheel drive mode and the other pair of wheels being additionally connected to the engine when the vehicle is in a four wheel drive mode, the driveline including an auxiliary driveline comprising a first clutch means to connect to the engine, a differential downstream of the first clutch means and releasable torque transmitting means operable to connect and disconnect the drive from the  
15 differential to said other pair of wheels, wherein the auxiliary driveline is disconnected from both the engine and said other wheels when the vehicle is in two wheel drive mode and, on switching the vehicle from two wheel drive mode to the four wheel drive mode while the vehicle is moving, the auxiliary driveline is connected to one of the engine and said other wheels to cause the auxiliary driveline to rotate prior to reconnecting the drive through from  
20 the engine to said other pair of wheels.

Preferably the first clutch means connects the auxiliary driveline to the engine prior to the releasable torque transmitting means connecting the differential to said other pair of road wheels.

Preferably, when the vehicle is stationary, the vehicle is placed or retained in the four  
25 wheel drive mode and retained in that mode for a period when the vehicle is started off

from rest. This may dependent upon the gear selected, e.g. operate only when in first gear. The preferred period is at least one second.

Preferably, when the vehicle is moving, the period of time for which the auxiliary driveline is connected to the engine or said wheels prior to the connection of the engine to said wheels, for acceptable acceleration forces (about 0.01g) on the driver, is related to the speed of the vehicle. Preferably, below a vehicle speed of 10mph, said period of time is greater than 100ms and increases progressively for higher vehicle speeds.

The invention will be described by way of example and with reference to the accompanying drawings, in which:

10 Fig.1 is a schematic layout of the driveline of a first example of a motor vehicle according to the present invention;

Fig.2 is a schematic drawing of the driveline of a second example; and

Fig.3 is a schematic drawing of the driveline of a third example.

With reference to Fig.1, there is shown in schematic form the driveline of a four wheel drive vehicle 10 having a pair of front wheels 12,13 and a pair of rear wheels 14,15. The vehicle is driven by an internal combustion engine 11, e.g. a diesel engine or petrol engine, mounted transversely at the front of the vehicle. The torque output from the engine 11 is connected to a gearbox 18 conventionally through a friction clutch 17. The gearbox 18 drives the two front wheels 12,13 when the vehicle is in two wheel drive mode and is connected thereto by a conventional differential ( not shown) and drive shafts 19.

The gearbox 18 is connected to the rear wheels 14,15 through first clutch means in the form of a PTO (Power Take-off) clutch 22, typically a multiplate wet clutch, driven only when four wheel drive mode is operable. The PTO clutch 22 is connected to a longitudinally extending main drive shaft 23 through a transmission assembly 24. The main drive shaft 23 is in turn connected to a rear wheel differential 25 through a universal joint



29. The main drive shaft 23 and parts which are permanently coupled to it form an auxiliary driveline 21 connecting the PTO clutch 22 to the rear wheels 14,15.

The differential 25 drives a pair of rear drive shafts 26 each of which is connected to a respective rear wheel 14 or 15. The torque from the main drive shaft 23 is transmitted to  
5 each rear drive shaft 26 through a respective differential clutch 27 which act as releasable torque transmitting means. Examples of differentials which include a pair of differential clutches are disclosed in US-A-5310388 and in US-A-5105901.

By selective control of the PTO clutch 22 and the differential clutches 27 it is possible to disconnect the auxiliary driveline 21 to the rear wheels 14,15 when the vehicle is in two  
10 wheel drive mode. This removes driveline drag and can reduce fuel consumption by approximately 3.5 to 5%. The PTO 22 and the differential clutches 27 can be controlled by a programmable controller 31 which may also control the gearbox 18 and main friction clutch 17. The controller 31 is connected to the main engine control unit (ECU) (not shown) or may be a part of the ECU.

15 In order to prepare the vehicle for a dynamic change from two wheel drive to four wheel drive (dynamic driveline reconnect) and to render the change acceptable to a driver, it is necessary to minimise the acceleration forces acting on the driver during the change. This is achieved by "spinning-up" the auxiliary driveline 21 before connecting the engine drive through to the rear wheels so that the rotational speed of the auxiliary driveline 21  
20 substantially matches the speed when driven by the engine and/or the rear wheels 14,15. This is achieved by the controller 31 engaging the clutch or clutches at one end of the driveline with the main drive shaft 23, i.e., either the PTO clutch 22 or the differential clutches 27, to connect the main drive shaft 23 with the rear wheels 14,15.

Once the auxiliary driveline 21 has been spun-up to the desired rotational speed, the other clutch at the other end of the auxiliary driveline is engaged to seamlessly complete the drive connection from the engine 11 to the rear wheels 14, 15.

The controller 31 may be connected to a driver operable switch 35 which can switch  
5 between "Off-Road" and "On-Road" modes. In the Off-Road mode the auxiliary driveline 21 may be permanently spun-up and ready for instantaneous connection. In the On-Road condition the auxiliary driveline 21 will be disconnected most of the time and will then be spun-up to the desired rotational speed during various vehicle operating conditions.

The controller 31 may also receive signals representing vehicle operating conditions  
10 as represented by sensors 32-34 either directly or indirectly by connection to the ECU and other vehicle controllers, e.g. the ABS controller. Such signals may include, but are not restricted to, ambient temperature, engine speed, engine torque output, wheel speeds, gear selection, throttle angle, vehicle accelerometers, yaw, etc. The controller 31 may utilise the signals to detect various vehicle operating modes such as: a) frost conditions  
15 using ambient temperature, b) driving styles using rate of steering and rate of throttle, c) low friction surfaces detected through steering angle, speed, throttle maps, lateral acceleration forces, d) gradient as detected using throttle maps, speed and velocity change, e) towing (detected as for "d" above), and f) wheel spin detected using throttle rate versus vehicle speed.

20 By monitoring the vehicle operating conditions the controller can predict when four wheel drive should be engaged and, if the vehicle is in two wheel drive mode, may automatically spin-up the auxiliary driveline 21 ready for automatic connection into four wheel drive mode.

In order to spin-up the auxiliary driveline 21 to the correct rotational speed and to  
25 minimise the acceleration forces on the driver, the first clutch connection should be

engaged with the driveline for a minimum time period before the second clutch connection is completed. This time period is related to the speed of the vehicle and is referred to as the "spin-up time". For acceptable acceleration forces (about 0.01g) on the driver, the spin-up time should be as long as possible, e.g. 5 seconds. However, this is impractical for  
5 a dynamic change when the vehicle is being driven. In practice, for a change below 10mph, the spin-up time should be at least 100ms. The spin-up time should increase for higher vehicle speeds, preferably progressively, so that the acceleration on reconnection remains at an acceptable level. There may be a maximum vehicle speed above which the reconnection to four wheel drive is prevented.

10 In a preferred arrangement, the PTO clutch 22 is used to spin-up the auxiliary driveline 21 prior to final engagement of the wheels through the differential clutches 27. The controller 31 may interact with the ECU to cause the engine torque output to rise to match the torque absorbed by the auxiliary driveline 21 by way of the sudden increase in inertia and frictional drag so that the driver is not aware of the driveline spin-up.

15 If the vehicle is stationary in two wheel drive mode the driveline may be switched into four wheel drive mode and remain in that mode for at least one second while the vehicle is driven away. This may dependent upon the gear selected, e.g. operate only when in first gear. The smooth transfer of torque to the rear wheels 14,15 is ensured using the main clutch 17 as it engages the engine 11. Any slippage of the front wheels 12,13 will  
20 automatically result in a transfer of torque through the PTO clutch 22 to the rear wheels 14,15.

In the second example of the invention shown in Fig.2, only those features that are substantially different from the example shown in Fig.1 will be described in detail. The main difference is that, in the auxiliary driveline 21 to the rear wheels 14,15, the main drive  
25 shaft 23 transmits torque to a free running differential 40 of the type marketed by GKN as the TFS differential. The differential 40 disconnects the rear drive shafts 26 from the main

drive shaft 23 eliminating side gear and pinion meshing losses in the differential and removing energy losses from spinning the main drive shaft 23. The differential 40 may include a dog clutch or a one-way (e.g. roller sprag type) clutch in which case the spinning-up of the auxiliary driveline 21 must be synchronised before the clutch is re-  
5 engaged. A synchroniser device may be incorporated within the differential 40 which thus acts as releasable torque transmitting means.

A control strategy for operation of a dog clutch for a dynamic change in two wheel drive mode causes the clutch 22 to spin-up the auxiliary driveline 21 to the best estimated synchronisation speed for connection to the rear wheels 14,15. The clutch 22 would then  
10 disengage quickly whilst simultaneously the synchroniser device would smoothly engage the dog clutch. The clutch 22 then re-engages quickly.

With reference now to Fig.3, there is shown an arrangement in which there is a clutch disconnection downstream of a conventional rear differential 51 by means of hub clutches 50 housed in the hub of each rear wheel 14, 15 or immediately adjacent thereto. The hub  
15 clutches 50 may each be in the form of a wet clutch or an electronically operated clutch device including friction clutches and dog clutches and thus act as releasable torque transmitting means.

Although in the examples described above the vehicle has a transverse front engine with a permanent drive to the front wheels and a disconnectable drive to the rear wheels,  
20 the invention is equally applicable vehicles with a longitudinally mounted engine or where the vehicle has a front engine with a permanent drive to the rear wheels and a disconnectable drive to the front wheels. Indeed the invention is applicable irrespective of the position of the engine, e.g. it may be applied to a vehicle having a rear engine with a permanent drive to the rear wheels and a disconnectable drive to the front wheels.

CLAIMS

1. A motor vehicle having an engine, two pairs of wheels, a driveline to connect the engine to the wheels such that one pair of wheels is driven by the vehicle engine when the vehicle is in a two wheel drive mode and the other pair of wheels is additionally connected to the engine when the vehicle is in a four wheel drive mode, the driveline including an auxiliary driveline comprising a first clutch means to connect to the engine, a differential downstream of the first clutch means and releasable torque transmitting means operable to connect and disconnect drive from the differential to said other pair of wheels, and control means operable to switch the vehicle between the four wheel drive and the two wheel drive modes such that in the two wheel drive mode the auxiliary driveline is disconnected from both the engine and said other pair of wheels and when switching the vehicle from the two wheel drive mode to the four wheel drive mode while the vehicle is moving the control means operates one of the first clutch means and the releasable torque transmitting means to connect the auxiliary driveline to the engine or said other pair of wheels respectively to cause the auxiliary driveline to rotate before the other of the first clutch means and the releasable torque transmitting means connects the engine to said other pair of wheels.
2. A vehicle as claimed in claim 1 wherein the first clutch means comprises a wet clutch.
3. A vehicle as claimed in claim 1 or claim 2 wherein the releasable torque transmitting means comprises second clutch means located between the differential and the second pair of wheels.
4. A vehicle as claimed in claim 1 or claim 2 wherein the releasable torque transmitting means is incorporated within the differential.
5. A vehicle as claimed in claim 4 wherein the differential comprises a free running differential.

6. A vehicle as claimed in claim 6 wherein the differential connects each of the second pair of wheels through a respective wet clutch or hydraulic coupling.
7. A vehicle as claimed in any one of claims 1 to 6 wherein the control means further includes a driver operable switch which allows the driver to select a desired drive mode from the two wheel drive mode and the four wheel drive mode.
8. A vehicle as claimed in any one of claims 1 to 7 wherein the control means includes a programmable controller which receives signals indicative of vehicle operating conditions and is operable to switch from the two wheel drive mode to the four wheel drive mode when various vehicle operating parameters have been detected.
9. A method of controlling a change in the transmission of torque from a motor vehicle engine to the driving wheels in a motor vehicle having a driveline and two pairs of wheels, one pair of wheels being driven by the engine when the vehicle is in a two wheel drive mode and the other pair of wheels being additionally connected to the engine when the vehicle is in a four wheel drive mode, the driveline including an auxiliary driveline comprising a first clutch means to connect to the engine, a differential downstream of the first clutch means and releasable torque transmitting means operable to connect and disconnect the drive from the differential to said other pair of wheels, wherein the auxiliary driveline is disconnected from both the engine and said other wheels when the vehicle is in two wheel drive mode and, on switching the vehicle from two wheel drive mode to the four wheel drive mode while the vehicle is moving, the auxiliary driveline is connected to one of the engine and said other wheels to cause the auxiliary driveline to rotate prior to reconnecting the drive through from the engine to said other pair of wheels.

10. A method as claimed in claim 9 wherein the first clutch means connects the auxiliary driveline to the engine prior to the releasable torque transmitting means connecting the differential to said other pair of road wheels.
11. A method as claimed in claim 9 or claim 10 wherein, when the vehicle is stationary, the vehicle is placed or retained in the four wheel drive mode and retained in that mode for a period when the vehicle is started off from rest
12. A method as claimed in any one of claims 9 to 11 wherein, when the vehicle is moving, the period of time for which the auxiliary driveline is connected to the engine or said wheels prior to the connection of the engine to said wheels, for acceptable acceleration forces on the driver, is related to the speed of the vehicle.
13. A method as claimed in claim 12 wherein, below a vehicle speed of 10mph, said period of time is greater than 100ms and increases progressively for higher vehicle speeds.
14. A method of controlling a change in transmission of a motor vehicle having a selected two wheel or four wheel drive mode and which is substantially as described herein.



INVESTOR IN PEOPLE

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-12- Examiner: Mark Thwaites

Claims searched: 1 to 13

Date of search: 4 March 2005

## Patents Act 1977: Search Report under Section 17

### Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
A,E	-	US6817434 B1 (SWEET) esp fig 1 & abstract
A	-	US4779698 A (IWATA) esp figs 2 & 7, abstract & col 3 ln 33-39, col 5 ln 41 - col 6 ln 31
A	-	US5105901 A (WATANABE) whole document relevant

### Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art
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&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

### Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC<sup>X</sup>:

B7H

Worldwide search of patent documents classified in the following areas of the IPC<sup>07</sup>

B60K

The following online and other databases have been used in the preparation of this search report

Online: EPODOC & WPI