Using the LPC4 ECU as a transmission controller
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Wiring, set up and tuning guide

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Contents

1 Introduction

LPC4 is an engine management system for spark ignition engines, capable of sequential fuel injection on up to 6 cylinders and sequential ignition on up to 4 cylinder engines, bank fire and waste spark or distributor spark on engines with up to 8 cylinders.
In addition to the more common four stroke engines, two strokes and Wankel type engines are supported as well.
While the standard LPC4 firmware contains some transmission control capability for traditional 4 speed transmissions, which it can perform in parallel with engine control duties, this manual is about using the LPC4 as a dedicated transmission controller which does not also run an engine, and is capable of controlling even the most complicated of modern clutch to clutch transmissions.
The transmission and body control firmware for the LPC4 is called MPC4, and can be installed on the ECU from the firmware update dialog in the BG Calibrator application.
It must be noted that many aspects of the configuration and strategies are also documented inside the configuration file. If you push F1 while editing a variable in the Calibrator application, you will get context sensitive help related to the category you are editing.

1.1 Terminology

Here is some of the jargon used throughout this manual and the Calibrator user interface for this application.

binding shift When during a clutch to clutch shift, the ongoing clutch engages before the offgoing clutch has disengaged sufficiently, causing the transmission to brake the vehicle momentarily.

clutch to clutch A shift performed by disengaging one clutch and engaging another in succession, requiring high precision control for good results. As opposed to a traditional shift or sprag to clutch shift, where the shift is performed by engaging a single clutch and a sprag will automatically release when the clutch grabs, requiring no finesse in control to make the shift.

flaring shift When the transmission slips during a shift and engine speed momentarily increases (during an upshift) rather than decreasing as it should.

garage shift A shift from park or neutral gear to a forward or reverse gear done at standstill.

line pressure In most automatic transmissions there is a sort of master fluid pressure from which everything runs, controlled by a solenoid that vents off pressure when energised, leaving the transmission with maximum pressure when this solenoid is electrically disconnected. The greater the line pressure, the greater the torque the transmission can handle without slipping, but also the harder the shifts. Depending on the transmission, the line pressure can also affect how spool valves that control shifts behave, and with insufficient line pressure the transmission may have difficulty shifting.

lock up A clutch in the torque converter of an automatic transmission, which when engaged makes the torque converter stop being a torque converter and behave like a flywheel instead.

postamble The period after the shift solenoids change state (shift time greater than 0), but before the transmission is considered in steady state again and ready for another shift.

preamble The period leading up to the shift solenoids changing state (shift time of 0), used if the transmission requires a pre-charge accumulator or anything else activated or adjusted before the shift is performed.

PWM Pulse Width Modulation. The act of applying a variable pulse width control signal to a load such as a solenoid, in order to emulate a variable voltage or current, to provide a variable force or flow rather than only having the options of on or off.

shift time A timer showing the progression of a shift, if preamble is used it will start negative, then cross zero once the shift solenoids command the shift.

sprag A one-way clutch, visually similar to a roller bearing but the rollers or fingers depending on the design grab in one direction but freewheel in the other, used in most transmissions in some places where otherwise a clutch would be called for, to automatically disengage once an element is turning faster than another element, simplifying the hydraulic control. Also used to allow the torque converter stator to rotate when the torque converter is not producing a torque multiplication.

tap shift When a manual shift is commanded by pressing a paddle or button while the transmission is in auto mode, as opposed to having a position on the shifter that enables manual shifts, that is tap shifting. A tap shift temporarily enters manual mode on a single button tap. On many controllers, it reverts automatically back to automatic mode after a set time, but on this controller you must hold a shift paddle or button for a set amount of time to return to automatic mode.

tiss Transmission input shaft speed, sometimes called turbine speed in reference to the turbine in the torque converter. Will be equal to engine speed when the torque converter is locked.

torque management A system where the ECU that is controlling the engine models the engine torque and allows feedback from the transmission controller as well as potentially other controllers to momentarily adjust the engine torque, and the engine ECU performs the necessary actions to decrease or increase torque.

toss Transmission output shaft speed, the speed of the output shaft of the transmission. It is proportional to vehicle speed, but the proportion changes if the car has a transfer case with selectable ratios.

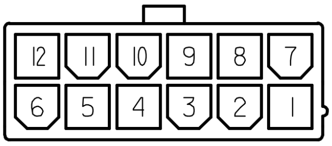
trans brake A method of intentionally applying an invalid combination of clutches in the transmission in order to seize it up and prevent the vehicle from moving and allow the engine speed to be brought up in preparation for a very hard launch with maximum acceleration. Often likened to applying two gears at once, a simplification that is not always technically accurate. On most transmissions, the design of the valve body makes it impossible to apply an invalid combination of clutches for safety reasons, as an electrical fault causing this to happen at speed would in the best case destroy the transmission and possibly other driveline parts beyond any hope of repair, or in the worst case cause complete loss of vehicle control.
So on most transmissions, valve body modifications which usually involve the addition of an extra solenoid to directly activate some element are required.

There are however some examples of clutch to clutch transmissions where it is possible to achieve this by just applying the right combinaton of the existing solenoids.

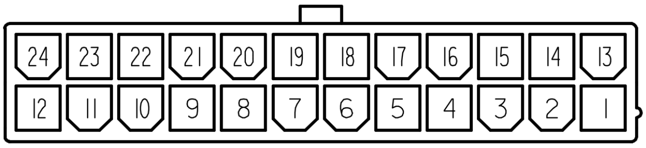
2 Wiring

2.1 Pin-outs and description

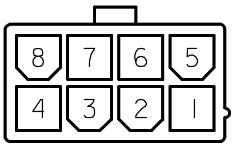
2.1.1 Pin numbering



(a) Connector B



(b) Connector A



(c) Connector C

Figure 2.1: Connectors on the controller and their pin numbering. A and B are located on the back, C is only present on units with serial number 100 and up and is located on the front face.

2.1.2 Connector A pin-out

Pin	I/O	Function	Note
1	OUT	5V sensor supply	200mA max
2	IN	Analog 0 0-5V	100kΩ pull-down
3	IN	Analog 1 0-5V	51kΩ pull-up
4	OUT	Ground return for analog sensors	
5	IN	Analog 4 0-5V	51kΩ pull-up
6	IN	Analog 5 0-5V	51kΩ pull-up
7	IO	CAN H	120Ω termination
8	IO	CAN L	120Ω termination
9	OUT	Output 1	Low-side switch, 5A max, 1kΩ pull-up to 12V
10	OUT	Output 2	Low-side switch, 5A max
11	IN	Power ground	
12	IN	Power ground	
13	IN	Digital input 4[1]	Active low, 5.7kΩ 5V pull-up, 12V safe
14	IN	Analog 2 0-5V - Fluid temperature sensor	3kΩ pull-up
15	IN	Analog 3 0-5V - Second fluid temperature sensor	3kΩ pull-up
16	OUT	Ground return for crank/cam sensors	
17	IN	Digital input 2[1]	2.2kΩ pull-up, 12V safe
18	IN	Digital input 1[1]	2.2kΩ pull-up, 12V safe
19	IN	Digital input 3[1]	Active low, 5.7kΩ 5V pull-up, 12V safe
20	OUT	Ground for signal shields	(or extra power ground)
21	OUT	Output 4	Low-side switch, 5A max
22	OUT	Output 3	Low-side switch, 5A max. Clamping diode to supply pin.
23	IN	Digital input 5[1]	Active low, 5.7kΩ 5V pull-up, 12V safe
24	IN	Switched +12V supply	Internally fused

[1] Naming convention differs from standard LPC4 firmware

2.1.3 Connector B pin-out

Pin	I/O	Function	Note
1	OUT	Output 5	Low-side switch, 5A max
2	OUT	Output 6	Low-side switch, 5A max
3	OUT	Injector 1	Low-side switch, 5A max
4	OUT	Injector 2	Low-side switch, 5A max
5	OUT	Injector 3	Low-side switch, 5A max
6	OUT	Injector 4	Low-side switch, 5A max
7	OUT	Output 7 / Injector 5	Low-side switch, 5A max
8	OUT	Output 8 / Injector 6	Low-side switch, 5A max
9	OUT	Ignition 1	5V logic, low-side switch or high-side switch, 5A max[2]
10	OUT	Ignition 2	5V logic, low-side switch or high-side switch, 5A max[2]
11	OUT	Ignition 3	5V logic, low-side switch or high-side switch, 5A max[2]
12	OUT	Ignition 4	5V logic, low-side switch or high-side switch, 5A max[2]

[2] Depending on build time options

2.1.4 Connector C pin-out

This connector is only present on units with serial number 100 and up.

Pin	I/O	Function	Note
1	OUT	Output 9	Low-side switch, 1A max
2	OUT	Output 10	Low-side switch, 1A max
3	IN	Ignition switch input	12V in to activate main relay, does not power ECU by itself
4	OUT	Main relay control	Low-side switch, 1A max
5	OUT	Output 11	Low-side switch, 1A max
6	OUT	Output 12	Low-side switch, 1A max
7	IO	CAN bus 2 H	Without 120Ω termination
8	IO	CAN bus 2 L	Without 120Ω termination

2.2 Wiring guidelines

2.2.1 Grounding

The controller should be connected to the battery negative terminal or another reliable grounding point by a pair of $1.5mm^2$ wires or a single $6mm^2$ wire joined to smaller wires near the connector. An improper ground connection will cause electrical noise and possibly faults with controller operation. If utilising factory wiring, joining all of the supply ground wires for the original ECU should suffice.

2.2.2 Ignition outputs

The default is to have four 5V logic-level outputs current limited to 18mA. Low side drivers or high side drivers (required by many Japanese transmissions that have the solenoids grounded in the valve body) can be specified at order time.

2.2.3 Gear lever

Some kind of a gear lever position input is required. Some transmissions provide this internally, while others have an external sensor on the transmission, or have a sensor built into the gear lever itself. If the gear lever has discrete outputs providing ground to a different wire depending on position, it's most convenient to connect each wire through a different value resistor to an analog input on the controller. It may also be possible to connect them to individual inputs and use the BCD function in the firmware to combine them into one value, if enough inputs are available. If the gear lever provides positive 12V voltage to the signal wires, an inverter circuit must be used to convert these signals to grounded signals if the shifter can not be rewired, unless there are enough 12V compliant digital inputs available (not being used for speed sensors or other 12V signals).

2.2.4 Speed sensors

The digital inputs on the controller are of schmitt trigger logic type, with 2.2kΩ pull-ups and with over-/undervoltage protection diodes. Thus they may be connected directly to open-collector or logic sensors (Hall effect, optical) or variable reluctance sensors. Some poorly designed VR sensors have an output voltage too small at low speeds for reliable signal pick up, for those an amplifier module must be installed

in the controller. An amplifier module is also required for magnetoresistive (2 wire hall effect) sensors.
Older transmissions may not have any speed sensors, or only an output shaft sensor. At a minimum, the transmission controller requires output shaft speed (which can be calculated from vehicle speed) and engine speed.
Digital input 5 is not capable of recording a speed sensor.
Input shaft speed is also required for closed loop control of clutch to clutch shifts and torque management, as well as closed loop control of torque converter clutch (PWM lock up).
For applications where an input shaft speed sensor is not available, input shaft speed can be calculated by the controller in order to adhere to downshift speed limits and such functions.
The output shaft speed may be calculated from wheel speeds received over CAN from the ABS if the transmission does not have such a sensor.

2.2.5 Transmission solenoids

Most transmissions have a mix of solenoids, some that are on/off and some that are PWM operated. PWM solenoids must be wired with a diode from the output to +12V supply (Output 3 has this built in, and so do the high-side drivers that can be installed on the ignition outputs.)
On older transmissions only the line pressure solenoid is PWM operated while the shift and lock up solenoids are on/off type. More modern transmissions may have a PWM lock up solenoid, a tell tale is if they have a turbine speed sensor (aka input shaft speed sensor) as it is not possible to do PWM torque converter control without knowing the slip rate. And the modern clutch to clutch transmissions perform most if not all shifts with PWM solenoids.
In the outputs configuration, on/off shift solenoids are named `Shift solenoid` A through E whereas PWM type shift solenoids are called `PWM transmission shift solenoid` 1 through 6.
In the same fashion, an on/off lock up solenoid output is configured as `Lock up solenoid` while a PWM type lock up solenoid is configured as `PWM torque converter lock up solenoid`. It is important to understand the function of each solenoid and double check all wiring before starting to drive a new installation. It can be useful if working without a good base map for the transmission in question, to first measure the resistance of each solenoid, and then if possible, measure currents of each solenoid during driving and shifting with the OEM controller, preferrably

using an oscilloscope that allows processing of the recorded signals after the fact, such as those sold by Pico Automotive.

3 Configuration and tuning guidelines

3.1 Introduction

Generally speaking, the lower the engine torque, the more difficult it is to make a shift feel smooth as the effects of shifting are relatively large compared to the steady state torque. A shift that feels like the car was rear ended when driving at a slow steady pace, all the same parameters may feel soft and smooth when accelerating at full throttle. For this reason, most parameters that have to do with shift performance are mapped based on indicated engine torque. If at all possible, this value should be calculated by the ECU that controls the engine and shared with the transmission ECU over a CAN network. Ideally the transmission controller should also be able to transmit torque management requests back to the engine ECU, both to control maximum torque during a shifts, and for the smoothest possible downshifts the minimum torque should be manageable as well.
On traditional transmissions, with no input shaft speed sensor, torque management is useful to make full throttle shifts crisper and also reduce wear on the transmission during said full throttle shifts. A shift performed at maximum line pressure can only be completed as quickly as the transmission clutches allow absorbing the extra torque caused by the inertia at the input side of the transmission. A slight reduction in torque during an upshift makes the upshift happen quicker as the oncoming clutch will stay in dynamic friction shorter and enter static friction where it has more torque capacity quicker. It should be noted that all of the Baldur's Control Systems series of engine controllers include the ability to do torque modelling and torque managemen for integration with transmission controllers.
On traditional transmissions, with on/off shift solenoids and no clutch to clutch shifts, the line pressure is the only parameter that controls how soft or hard the transmission shifts. On a clutch to clutch transmission the line pressure still plays an important role in how the transmission performs during a shift, too much line pressure and there is usually no way to make a low torque shift feel smooth, regardless

of the timing of the clutches.

In the transmission controller firmware, there are steady state maps for what the solenoids do when in each gear. For traditional transmissions, this is all the set up needed to make them shift right. Some transmissions such as the 4L60E and A442F have one solenoid that is used to pre-charge a pressure accumulator before a 2-3 shift is performed, in this case a shift preamble period must be configured for that shift, and the solenoids must be given appropriate values during that period before the shift is performed. In some cases it may be beneficial to configure a postamble period after shifts also, in order to be able to have a different line pressure value during a shift than is used in steady state operation. There are also separate solenoid state maps for the postamble period that must be configured correctly if this feature is used.
PWM shift solenoids (clutch to clutch transmissions) use a different set of maps and are unaffected by preamble and postamble as far as PWM solenoid states go, but instead they have their own maps to control how a transition from each gear to adjacent gears is performed.
For each clutch to clutch shift, the role each solenoid plays in the shift must be defined in the `Clutch to clutch shift logic` table. For each shift if there is a solenoid that is activating a clutch that grabs, that solenoid's function should be configured as `Ongoing` whereas a solenoid that controls a clutch that is releasing should be configured as `Offgoing`. It is not a requirement to have both or even one of those configured, if the shift in question is done with only one PWM solenoid or perhaps without the PWM solenoids altogether, as is the case with many older transmissions which are not fully clutch to clutch but incorporate one or two shifts performed in this manner.

3.2 Clutch to clutch shift process

For each clutch to clutch shift, there is a map covering the parameters that govern the shift. These parameters can be described as follows, and note that the duty cycles in these tables do not represent electrical duty cycle, but rather it is expected that the solenoid characterisation functions translate these numbers to an actual electrical duty cycle. In that way, the shift logic does not even have to know that some solenoids are normally open and others are normally closed etc, the characterisation function should translate 0 to 100 to whatever electrical duty cycle it takes to have the clutch completely free or fully engaged.

Clutch to clutch shift logic

	PWM sol 1		PWM sol 2		PWM sol 3		PWM sol 4		PWM sol 5		PWM sol 6	
5 -> 6	Steady	v	Steady	v	Ongoing	v	Offgoing	v	Steady	v	Steady	v
6 -> 5	Steady	v	Steady	v	Offgoing	v	Ongoing	v	Steady	v	Steady	v
4 -> 5	Offgoing	v	Steady	v	Steady	v	Ongoing	v	Steady	v	Steady	v
5 -> 4	Ongoing	v	Steady	v	Steady	v	Offgoing	v	Steady	v	Steady	v
3 -> 4	Steady	v	Ongoing	v	Steady	v	Offgoing	v	Steady	v	Steady	v
4 -> 3	Steady	v	Offgoing	v	Steady	v	Ongoing	v	Steady	v	Steady	v
2 -> 3	Steady	v	Steady	v	Offgoing	v	Ongoing	v	Steady	v	Steady	v
3 -> 2	Steady	v	Steady	v	Ongoing	v	Offgoing	v	Steady	v	Steady	v
1 -> 2	Steady	v	Steady	v	Ongoing	v	Steady	v	Steady	v	Steady	v
2 -> 1	Steady	v	Steady	v	Offgoing	v	Steady	v	Steady	v	Steady	v
N -> 1	Ongoing	v	Steady	v	Steady	v	Steady	v	Steady	v	Steady	v
1 -> N	Offgoing	v	Steady	v	Steady	v	Steady	v	Steady	v	Steady	v
R -> N	Steady	v	Steady	v	Steady	v	Offgoing	v	Steady	v	Steady	v
N -> R	Steady	v	Steady	v	Steady	v	Ongoing	v	Steady	v	Steady	v

Figure 3.1: Clutch to clutch shift logic function

atptorque (Nm) 2 -> 3 shift

	-50.0	0.0	50.0	100.0	200.0	400.0	500.0	600.0	700.0	800.0
Shift completion exit delay (ms)	200	200	200	200	200	200	200	200	200	200
End torque management trigger delay (ms)	40	40	40	40	40	40	40	40	40	40
Ongoing ramp up phase closed loop trigger (	40	40	40	40	40	40	40	40	40	40
Off clutch shift ramp slope (%/sec)	0	0	0	0	0	0	0	0	0	0
Off clutch shift ramp initial current (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Off clutch release end current (%)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Off clutch release ramp duration (ms)	100	100	100	100	100	50	50	50	50	50
Off clutch equalisation end current (%)	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Off clutch equalisation start current (%)	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00
Off clutch equalisation duration (ms)	900	900	900	811	633	278	100	100	100	100
On clutch shift ramp slope (%/sec)	400	400	400	400	400	400	400	400	400	400
On clutch shift ramp initial current (%)	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00	40.00
On clutch apply end current (%)	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00	90.00
On clutch apply ramp duration (ms)	100	100	100	100	100	100	100	100	100	100
On clutch equalisation end current (%)	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00	50.00
On clutch equalisation start current (%)	10.00	10.00	10.00	12.00	17.00	26.00	30.00	30.00	30.00	30.00
On clutch equalisation duration (ms)	1200	1200	1200	1111	933	578	400	400	400	400
On clutch prefill current (%)	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00	30.00
On clutch prefill duration (ms)	100	100	100	100	100	100	100	100	100	100
On clutch delay (ms)	50	50	50	46	37	20	20	20	20	20

Figure 3.2: Clutch to clutch shift parameters for a single shift

Shift completion exit delay

A closed loop shift parameter, where after the shift is detected as completed (gear ratio matches the correct gear), this time has to pass before the controller exits shift mode and resets all solenoid states to steady state, ready for another shift to occur. A zero value disables this function and the shift will complete on time only.

End torque management trigger delay
A closed loop shift parameter, where after the shift is detected as completed (gear ratio matches the correct gear), this time has to pass before the torque management exits during-shift torque limit mode.

Ongoing ramp up phase closed loop trigger delay
A closed loop shift parameter, where after the shift is detected as completed (gear ratio matches the correct gear), this time has to pass before the ongoing clutch enters ramp up mode, in order to prepare it for receiving full torque. A zero value disables the function and if the clutch is still in the equalisation phase when the shift completes, it will continue that phase as timed.

On/Off clutch shift ramp slope
A closed loop shift parameter to control the release of the off going clutch once the shift has actually started. What it does is set by a map named [Action performed when shift detected as started]. If the action is [Do nothing] then this parameter is ignored. If the action is [Add during shift] or [Switch to during shift] then this function gradually adds the specified percentage for every second the controller is in shift mode after the controller has detected that the transmission has started to perform the shift it was commanded to (Gear ratio no longer exactly matches the previous gear).

On/Off clutch shift ramp initial current
A closed loop shift parameter to control the release of the off going clutch once the shift has actually started. What it does is set by a map named [Action performed when shift detected as started]. If the action is [Do nothing] then this parameter is ignored. If the action is [Add during shift] then the value in this function along with the ramp slope are added to the curve the clutch is on already. If the action is [Switch to during shift] then this function along with the ramp slope replaces the value of the equalisation ramp. If the action is [Direct to end ramp] then the off going clutch switches directly to the end ramp to quickly release what remains of its pressure.

Off clutch release end current
The duty cycle at the end of the end ramp once the pressure is relieved completely off the offgoing clutch, the moment before it switches to steady state mode.

Off clutch release ramp duration
The time in which the off going clutch goes from the end of the equalisation phase to fully open.

On/Off clutch equalisation end current
The duty cycle at the end of the equalisation phase.

On/Off clutch equalisation start current
The duty cycle at the start of the equalisation phase.

On/Off clutch equalisation duration
The longest possible time of the equalisation period, if it is not ended early by the closed loop strategy.

On clutch apply end current
The duty cycle at the end of the end ramp once the clutch has fully grabbed before it switches to steady state mode.

On clutch apply ramp duration
The time from the end of equalisation phase until full force has been applied to the ongoing clutch.

On clutch prefill current/duration
For a brief period after the shift is commanded, the ongoing clutch solenoid can be given a high current to advance the fluid in the circuit and prepare it for the shift.

On clutch delay
In order to give the offgoing clutch more time to disengage the timing of the ongoing clutch solenoid can be delayed before it enters prefill, then equalisation and all that.

Each shift starts with all clutches in steady state mode for the gear the transmission is currently in. If the shift that has just started has both ongoing and offgoing clutches (a true clutch to clutch shift) it will start by placing the offgoing clutch into the equalisation phase. During the equalisation phase the offgoing solenoid is supposed to vent pressure off the offgoing clutch gradually until it starts to slip and then finally fully disengages. After the given optional delay, the ongoing solenoid enters the optional pre fill phase momentarily before entering the equalisation phase. After each solenoid has spent the specified time in the equalisation ramp,

it enters the end ramp and once the end ramp is over, they go into steady state mode, with the state as defined for the gear that is being selected.
There are some closed loop functions for making the shifts more consistent, but it's best to get the initial low torque tune sort of right before starting to fully utilise the closed loop functions.
The closed loop functions that can be performed are:

- Exit shift mode once the calculated gear ratio of the input and output shaft speeds has been consistent with the selected gear for a set duration. This is useful not only to reset everything to steady state once the transmission is clearly ready for it, but it also indicates to the controller when the transmission is actually ready to perform the next shift if multiple shifts are requested in a short time.
- End torque management and resume normal engine torque once the gear ratio has been consistent with the selected gear for a set duration.
- Change on going solenoid state from equalisation phase to end ramp once the gear ratio has been consistent with the selected gear for a set duration.
- Change off going solenoid state from equalisation phase to end ramp once a change in gear ratio is detected (start of the actual shift detected)
- Change on and off going solenoid equalisation ramp rate and offset once a change in gear ratio is detected.
- Change torque management state once a change in gear ratio is detected, so no torque limit or increase is applied before the transmission actually requires it.
- Modify torque management values depending on the shift progress, as the shift progress is the calculated progression from the previous gear ratio to the new desired gear ratio.
- On transmissions with state memory valve bodies like the 722.6/NAG1, where there is a possibility of a wrong state in the valve body, detection of the wrong gear selection is performed and corrected by issuing shifts to get to the correct gear.

Making use of the closed loop functions does require extending some of the ramp times and postamble timer if being used, in order to give the closed loop functions

some space to work in. If all the solenoids are already in steady state before the transmission reacts mechanically then there is nothing for the closed loop functions to do.
The best starting point in tuning clutch to clutch shifts is to have the offgoing equalisation ramp very short, so the offgoing clutch disengages quickly and the transmission flares on the shift. The ongoing equalisation ramp should be low and slow to start with, and the current numbers raised until the ongoing clutch starts to actually engage within the equalisation phase. Once the ongoing clutch timing has been established, the offgoing clutch equalisation phase can be gradually made longer and at higher current throughout to delay the disengagement of the offgoing clutch and bring the flare under control. Applying too much force too early to the ongoing clutch and not releasing the offgoing clutch quickly enough results in a binding shift, which will not feel smooth, and will accelerate wear on the transmission. Ideally for longevity of the transmission, the shift should have a little bit of a flare, which should then be brought under control by torque management. Generally, for a comfortable shift, the off going clutch must start to slip before its equalisation phase is over, and the ongoing clutch must start to grab before its equalisation phase is over.
And again the line pressure is the basis that everything else the transmission does is based on. Too much line pressure and the low torque shifts will always be harsh. Generally the line pressure should be as low as possible while still allowing the transmission to function normally and not slip while in gear.
Not all clutch to clutch transmissions, or transmissions with even one clutch to clutch shift offer direct control of a particular clutch element by a particular solenoid. In some cases there may be one or more spool valves in the valve body that move under control of a single solenoid but the spool valve can control more than one hydraulic function as it moves. In other cases a spool valve may have pressure on both ends, controlled by two solenoids, and in that case the ongoing solenoid can go to full current but nothing actually changes until the offgoing solenoid starts to bleed off fluid from the other end. And different gears may be very different in how their function is achieved in the transmission itself as well as in the valve body. It helps to have good documentation, hydraulic diagrams, mechanical diagrams, power flow diagrams and whatever information one can get their hands on for the transmission being tuned. A better understanding of what is supposed to go on inside the transmission makes the tuning process more methodical and generally produces better results quicker. Usually the best information is found in repair manuals for the transmission in question. The good ones have in depth explanation of all the processes going on in the transmission during each shift, to aid in troubleshooting

transmissions that are not doing what they should. But this same information is useful in setting up control of the transmission.

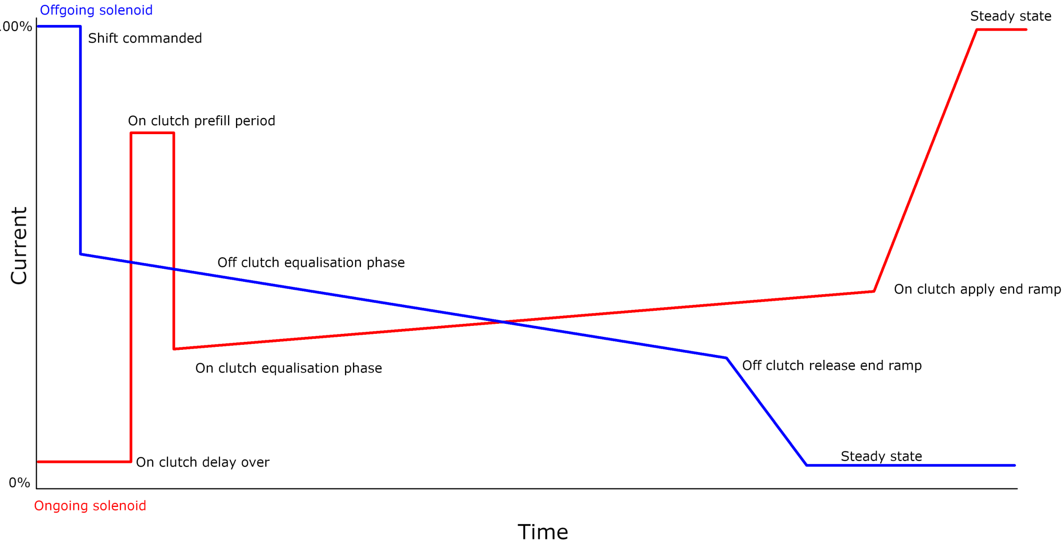


Figure 3.3: Typical clutch to clutch shift process phases without any closed loop reaction

3.3 Torque management

Torque management in a transmission controller serves two purposes. One is to decrease wear on the transmission as well as increase the torque capacity of the transmission on full throttle shifts, and this applies to traditional transmissions as well, they can shift with more power if the torque is momentarily reduced during the shift. If all that is important to you is the ability to make good full throttle shifts without grenading the transmission, you can stop reading here, the rest of the chapter is not relevant to your application.
The other purpose of torque management is to make the shifts smoother, and for this purpose you want torque management active even during low torque shifts. The engine and torque converter have inertia to them, and any upshift without torque management will cause a momentary increase in acceleration which is provided

by the inertia of the engine and torque converter. Conversely, any downshift without torque management causes a momentary increase in engine braking for the same reason.

There are two ways of dealing with this. One is by extending the shift, reducing the acceleration/deceleration rate, spreading the inertia energy over a longer period. Doing this can make the inertia torque small enough to be tolerable, but it means very long shift times at low engine torque. But through a combination of lower pressure slower shifts at low torque levels, and carefully tuned torque management the inertia effect can be completely eliminated. The prerequisite is that with any given shift, the engine is producing enough torque to be able to absorb the inertia torque via torque reduction. If the shift is too hard, shutting the engine off completely may not be enough to offset the inertia.

An upshift at any engine torque, where the torque reduction on the engine side matches what the inertia adds, is a shift that can be heard but not felt. The faster the shift is completed, the greater the torque reduction is required to achieve this, as the inertia torque is proportional to the derivative of the engine speed and torque converter turbine speed.

For the absolute smoothest shifts, it helps if the engine torque at any given accelerator position decreases at the right rate as the engine speed increases, to avoid an upshift causing a sudden reduction in torque at the wheels. In other words, when the vehicle accelerates, for smooth acceleration it is ideal that a steady accelerator pedal produces as much of a steady power output as possible across the engine speed range, rather than a steady torque output. If the transmission input torque (after torque converter) remains the same before and after a shift, a step reduction in acceleration happens at the moment of each shift. Whereas if the power is constant, the input torque will increase after the shift and the torque at the wheels follows a steady curve inversely proportional to vehicle speed without any steps or bumps.

In most cases an automatic transmission is tuned in such a way that it will never downshift with the engine above idle speed when slowing down with no throttle input in automatic mode, and minimum torque management is not useful for downshifts that are done with the torque converter clutch disengaged and the engine idling far below the minimum speed for the torque converter to transmit torque effectively.

Minimum torque management (sometimes called throttle blip) is however essential for smooth manual or performance map coasting downshifts with the engine at speed or torque converter clutch locked.

The torque management has three phases, before, during and after shift. The before shift (entering into shift maps) is time based and is mostly used for dropping torque in open loop full throttle shifts (4 speed transmissions with no input shaft speed sensor). However on transmissions that do have an input shaft speed sensor and thus are capable of performing closed loop shift control, the torque management can be applied more precisely, letting it only apply when the speed sensors indicate the transmission clutches have actually started performing the shift. The after shift tables then apply for a set period after the speed sensors indicate the shift is completed to prevent transmission slip before the clutch pressure has reached equilibrium and full torque holding capacity is achieved.

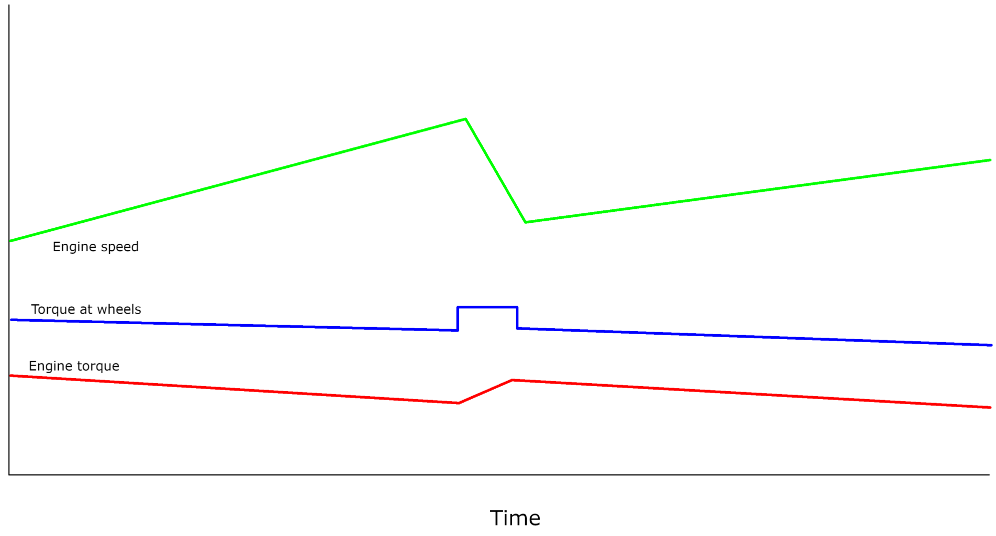


Figure 3.4: The inertia torque transmitted to the wheels on an upshift without torque management

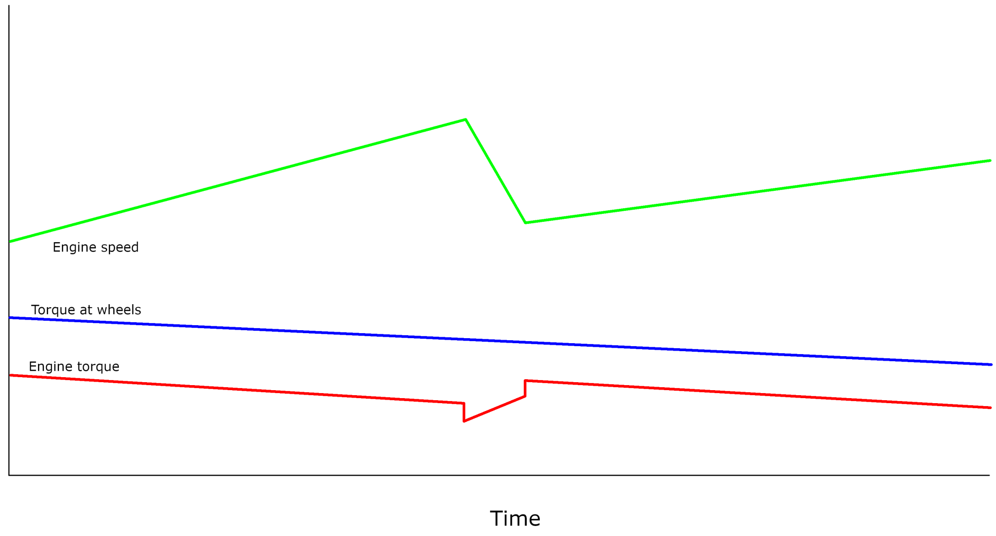


Figure 3.5: Correctly set up torque management can eradicate the momentary torque increase felt when the engine gets decelerated by the transmission shifting gears.

3.4 Torque converter lock-up

The torque converter plays an important part in getting the vehicle moving from a stand still, and being essentially a hydraulic continuously variable transmission by itself, it is the reason automatic transmissions were able to provide decent performance with only two or three speeds in the past. However the transmission of power via hydraulic fluid is less efficient than a direct mechanical link. So some automatic transmissions have since the 1980s used a torque converter lock up clutch to improve fuel efficiency at higher speeds, and since the 1990s nearly all mass produced torque converter based automotive transmissions utilise this. The earliest examples only used the torque converter lock up clutch in the transmission's tallest gear, but later developments started using this feature at lower speeds in lower gears. The problems with locking up the torque converter at low speeds, in low gears, are during acceleration the torque converter keeps the engine in a narrower speed window and the torque converter also provides some damping between the driveline and the engine. The first problem has been addressed by adding more gears to modern transmissions and the second problem has been addressed by utilising controlled slip as well as added torsional vibration dampers in the system.
In a modern gazillion speed automatic transmission, the torque converter typically takes care of getting the vehicle moving in first gear and once the turbine speed is close enough to engine speed the lock up clutch starts to engage, and due to the short first gear these transmissions typically employ, the transmission is already in second gear around the same time.
Generally the torque converter should lock up as soon as it feels comfortable to drive around with it locked. You may experience more noise, harshness and vibration at low speeds with a locked converter. Older transmissions may not have torque converters that have the ability to transfer the full torque of the engine so unlocking becomes a requirement at full throttle, but more modern converter with multi disc lock up clutches have no problems grabbing lock up at full throttle. And it can be highly beneficial to do so as reduced losses increase acceleration.

4 Transmission specific information

4.1 Mercedes-Benz 722.6/NAG1

The Mercedes-Benz 722.6 series of transmissions was manufactured and supplied in new cars for over 2 decades, in both Mercedes-Benz cars, as well as Dodge, Jeep, Jaguar, Porsche and others.
It is a 5 speed transmission with some clutch to clutch functionality mixed with sprag to clutch functionality. The timing of clutch elements is done entirely by hydraulic logic in the valve body. When a shift is not being performed, none of the solenoids in the transmission require power to stay in gear. The shift solenoids each are responsible for a set of elements in the transmission used for a certain shift, and the valve body toggles between states of those elements when each shift solenoid is energised. And energising the same solenoid again will reverse the state back to where it was (perform a downshift if the previous shift done by that solenoid was an upshift or vise versa). So unless the transmission controller knows which gear the transmission is in, done by calculating the ratio of input and output speeds, it can not know for sure whether the transmission will upshift or downshift when energising a shift solenoid.
Whenever the engine shuts off and the valve body loses hydraulic pressure, it has springs that return its configuration to a default state.
A good list of available gear ratios in different versions of the transmission may be found at `https://en.wikipedia.org/wiki/Mercedes-Benz_5G-Tronic_transmission` and general mechanical information about the transmission may be found at `https://www.w124performance.com/docs/mb/transmission/722.6/trans_722.6_ATSG_2004.pdf` or by searching for the terms `atsg 722.6` on the web.
The transmission has a fluid temperature sensor situated in the oil pan but it is connected via a switch that only activates it when the shifter is in R or D.
Most versions of this transmission have no output shaft speed sensor so an external

speed sensor is required. In most factory setups this speed is provided by the ABS/ESP system.
This transmission has no input shaft speed sensor either, but it has two speed sensors, n2 which reads the speed of the planet carrier of the front planetary gear, and n3 which reads the speed of the sun gear of the front planetary. Together with information about the gear ratio of the front planetary (difference between first and second gear) these are used to calculate the input shaft speed.
The transmission contains a total of 6 solenoids. Their functions can be described as follows:

Modulating pressure solenoid (Y3/6y1)
: Basically performs the function of what is in most transmission nomenclature called a line pressure solenoid and gets configured as [Transmission pressure control solenoid] in the MPC4 configuration. PWM controlled and bleeds off pressure from the pressure control valve hydraulic circuit. With minimum duty cycle, the maximum pressure is achieved and thus the firmest shifts and maximum torque capacity without slippage. For race only operation, where soft shifts are never required, this solenoid may be omitted completely.

Shift pressure solenoid (Y3/6y2)
: Used alongside the modulating pressure solenoid to control transmission pressure during shifts. PWM operated and gets configured as [PWM transmission shift solenoid 1] in the MPC4 configuration, and this solenoid is then configured as an "ongoing clutch solenoid" for all shifts in the clutch to clutch configuration. Typically this solenoid gets minimum duty cycle for maximum pressure when a shift is not being performed, but when a shift is performed, the shift process can be slowed down and controlled by reducing the pressure of this solenoid (increasing its duty cycle). If there is not enough pressure on this circuit the shift may not complete successfully, it may start but flip back into the previous gear instead of staying in the target gear. For race only operation, where soft shifts are never required, this solenoid may be omitted completely.

Lock up solenoid (Y3/6y6)
: This solenoid controls the torque converter clutch. Usually operated by PWM on this transmission, and configured as [PWM torque converter lock up solenoid] in the MPC4 configuration. With minimum duty cycle to this solenoid the torque converter clutch is open. With increased duty cycle the torque converter cluch locks and can hold more torque without slipping.

1-2/4-5 shift solenoid (Y3/6y3)

This solenoid is responsible for shifts between first and second gear, as well as 4th and 5th. It toggles between brake B1 holding (first and fifth gear) and clutch K1 holding (2nd and 4th gear). Sprag F1 holds in first and freewheels once K1 grabs, while B1 provides engine braking capability in 1st gear. Since the F1 sprag holds in 5th but freewheels in 4th, it is possible for the transmission to flare slightly when selecting 5th, but the 1-2 upshift can not flare on a healthy and correctly tuned transmission.
Energising this solenoid while in 3rd gear has no immediate effect, but will change what happens when a shift out of 3rd is performed.

2-3 shift solenoid (Y3/6y5)

This solenoid is responsible for shifts between second and third gear. It toggles between clutch K3 holding (second gear) and clutch K2 holding (third gear). Sprag F2 holds in 2nd and freewheels once K2 grabs, while clutch K3 provides engine braking capability in 2nd. A flare is not possible on this upshift with a healthy and correctly tuned transmission.
Energising this solenoid when driving in first gear will result in a direct shift into third, skipping second, but the valve body will be configured wrong for the 3-4 shift which will result in a shift directly from 3rd into 5th.

3-4 shift solenoid (Y3/6y4)

This solenoid is responsible for shifts between third and fourth gear. It toggles between brake B2 holding (3rd gear) and clutch K3 holding (4th gear) but between those elements there is no sprag so the transmission will enter neutral (flare) momentarily while the shift is performed, unless a modification is performed to the valve body to speed up the application of K3 by drilling out a restriction in the intermediate plate.

4.1.1 Wiring information

Connections made to the transmission, also shown is the pin out of the break out adaptor we offer to convert from EGS5x controller to LPC4:

Trans pin	Function	OEM EGS5x pin	Adaptor pin	LPC4 pin
1	n3 speed signal	35	16	A13 digital in 4
2	Line pressure solenoid	36	15	A22 output 3
3	n2 speed signal	12	19	A19 digital in 3
4	Fluid temperature sensor	34	17	A14 analog in 2
6	+12V supply	38	24	join to +12V supply
7	+5V supply	13	18	A1 5V out
8	2-3 shift solenoid	16	3	B4 inj out 2
9	3-4 shift solenoid	15	4	B5 inj out 3
10	Shift pressure solenoid	37	13	A21 output 4 [1]
11	Lock up solenoid	17	14	B6 inj out 4 [1]
12	Sensor return	33	6	A4 sensor ground
13	1-2/4-5 shift solenoid	14	5	B3 inj out 1

Remaining connections of the original EGS51/EGS52/EGS53 controller that do not go to the transmission. In most cars it's only +12V, ground and CAN bus that are connected.

[1] Flyback diode required to +12V. Flyback diodes present on adaptor board.

OEM EGS5x pin	Function	Adaptor pin	LPC4 pin
1	K line diag	23	N/A
2	Kickdown switch 0V	9	A3 analog input 1
3	W/S winter summer switch	10[2]	A6 analog input 5
4	Park lock signal	22	N/A
7	Park/neutral signal	21	A10 output 2
9	Stop lamp signal	7	A23 digital input 5
23	Vehicle speed signal	8	A18 digital input 1
25	Analog shifter W0	20[2]	A5 Analog input 4
26	Analog shifter W1	20[2]	A5 Analog input 4
27	Analog shifter W2	20[2]	A5 Analog input 4
28	Analog shifter W3	20[2]	A5 Analog input 4
29	+12V supply	24	A24
30	Chassis ground	11, 12	A11, A12
H	CAN H	1	C7 or A7
L	CAN L	2	C8 or A8

[2] Goes through circuitry on the adaptor board changing the original signal

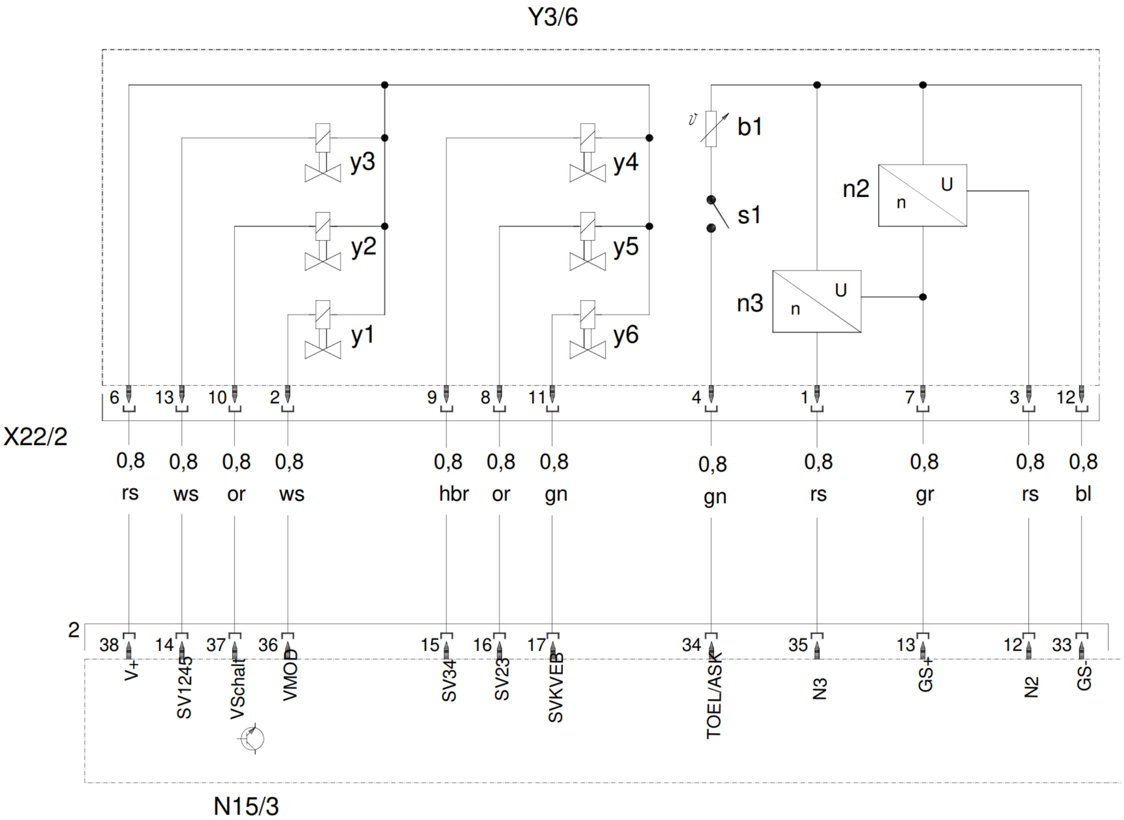


Figure 4.1: 722.6 transmission connections to the original EGS5x controller

5 Software configuration

Refer to BG calibrator manual for introduction to the software.

5.1 Performing firmware upgrades

Whenever new features are introduced, new firmware becomes available for download at `https://controls.is/firmware/`. See the release notes if you are unsure of whether you should update or not. To perform a firmware upgrade:

1. Open the Calibrator software
2. Connect the ECU via USB to the PC. If you have any other ECUs, disconnect their USB cables before continuing.
3. Power on ECU, do not start engine.
4. If it's an ECU you have used before, you must connect to it and ensure you have its configuration saved.
5. Select the `Firmware upgrade` option from the communications menu at the top of the BG Calibrator window.
6. If the ECU is currently running LPC4 firmware, you must select MPC4 from the drop down box to get the transmission control firmware.
7. Select the latest firmware version and click the upgrade button.
8. Wait until the upgrade finishes.
9. Power ECU off.
10. Let Calibrator convert the configuration and save a new upgraded configuration file

11. Power the ECU back on and upload the new configuration to it.
12. Power the ECU off again prior to attempting to start the vehicle.