



Document Number		CTN0004	
Title		Gear Change Ignition Cut	
Approved By			
Revision	Date	Prepared By	Change History
1.0	30/04/09	MM	

Scope

The following document details the setup of the Gear Change Ignition Cut function (GCIC) available in MoTeC ECUs. The document is based on the version 3.5 and above software for the hundred series ECUs (M400, M600, M800 and M880). Earlier versions of hundred series software and other MoTeC ECU types and not specifically detailed in this document but the information presented with still be relevant.

Gear Change Ignition Cut

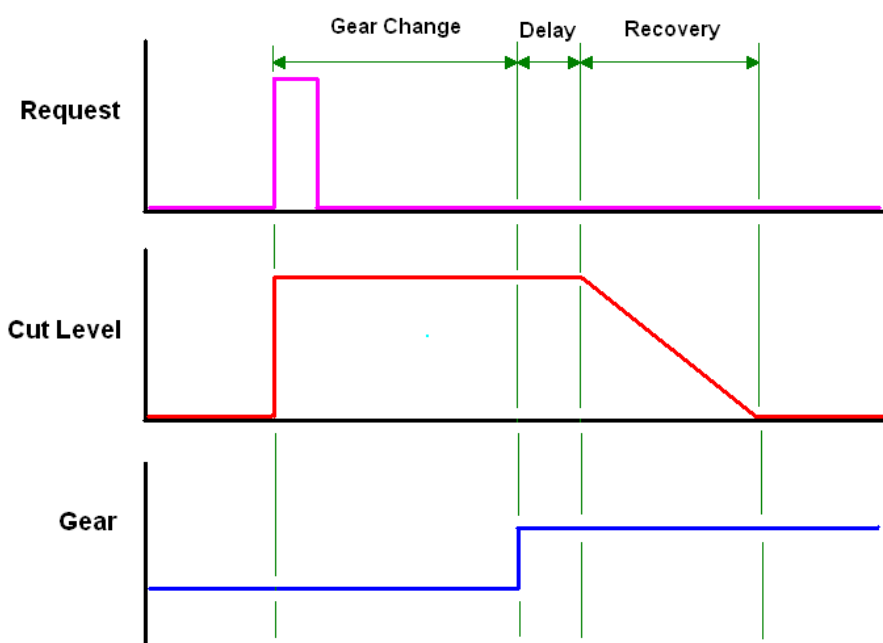
The MoTeC GCIC function is used to allow the driver to change gears without lifting the throttle or (in most cases) the clutch, it is also often referred to as "Flat Shift" or "Shift without Lift". The system allows a short ignition or fuel cut and/or ignition timing retard to reduce the engine's load on the transmission so that the gear can be changed. It is also possible to have the position of an Electronic Throttle (Drive by Wire) reduced for a short amount of time as well.

The function is designed with both H pattern and sequential, dog engagement gear boxes in mind, it should be noted that this function is not completely suitable for synchromesh gearboxes.

Cut Modes

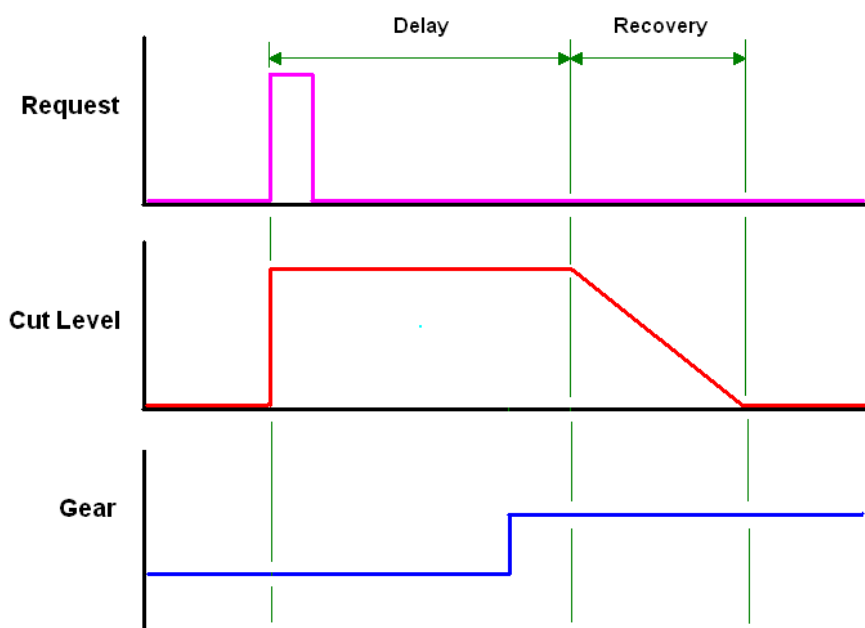
Mode 1, Delay from next gear stable

This mode is only suitable when the ECU has a gear position input. The ignition cut starts as soon as a valid shift signal is detected and will hold for however long it takes for the gear position pot or gear calculation to detect the next gear has been reached or the Minimum RPM or Minimum Throttle Position have been reached. The Delay time starts when the new gear is detected to allow time for full engagement then the ignition is phased back in linearly over the recovery time.



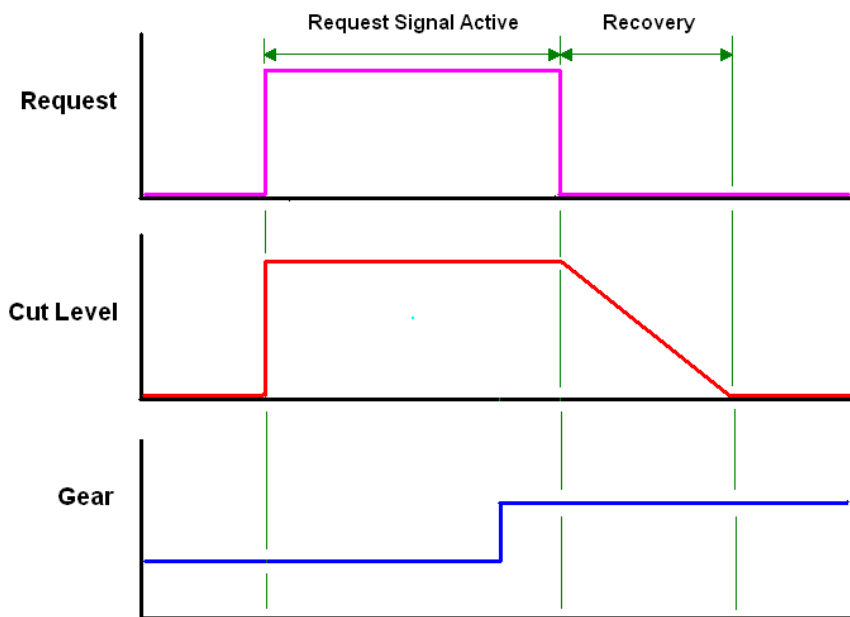
Mode 2, Delay from Cut Signal

The Delay from Cut Signal mode starts the ignition cut when the cut source becomes active and runs for the user defined Delay time (as set in Delay Table). After the delay has timed out the ignition Recovery time starts.



Mode 3, Cut While Signal is active

This mode will simply cut the ignition for as long as the shift signal is active. No delay times are entered for this mode. Mode 3 is mainly designed for external gear box control systems that are able to send a GCIC signal to the ECU; the cut time is calculated in the external controller.



It can be seen from the previous two diagrams that the gear position does not affect the cut at all.

Cut Source

To make the GCIC system work the ECU needs a request that the driver wishes to make an up shift, there are a number of options for this. It is possible that race class rules may only allow certain methods for GCIC so the rule book will need to be checked.

1. A simple momentary (on/off) switch the driver activates when an up shift needs to be made
2. A momentary switch on the clutch pedal
3. The request can be started when the RPM Limiter is reached
4. A strain gauge may be installed on the gear lever
5. The request can be started based on a rate of reduction of throttle position
6. The up shift request can come from the request linked to the Gear Shift function ("semi-auto" or controlled gearboxes)

How the gear request device or condition is setup can have a very large effect on the performance of the GCIC function. One fairly important aspect of a gearbox that cannot be ignored is the mechanical free play from moving the gear shift lever to moving the dog ring. Another factor is how much force should be used to "preload" the gearbox shift mechanism to get the best shifts.

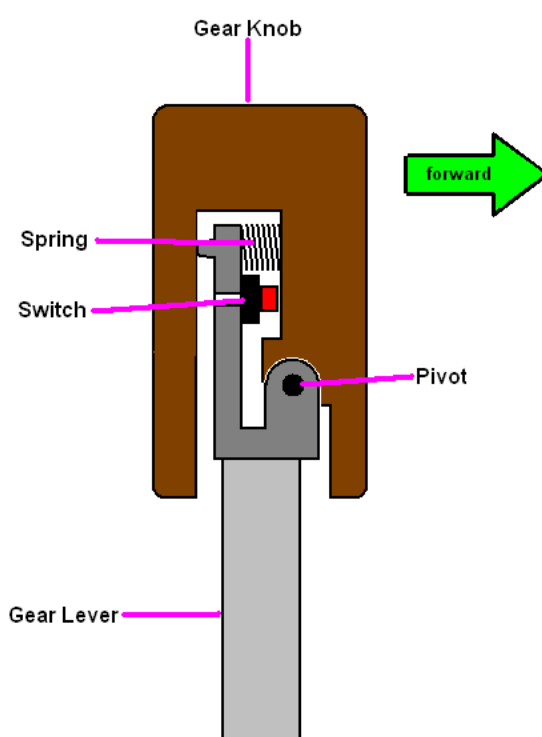
To make a positive shift the driver needs to move to gear lever enough so that all the free play is eliminated and then apply enough force so that when the GCIC starts the gearbox will move almost instantly. Some problems that can arise from incorrect setup of the shift request are:

1. If the request system does not allow the driver to move the gear lever far enough to remove all the free play in the gearbox the GCIC will start too early. Starting the GCIC too early will mean that the total cut time will have to be longer to compensate.
2. If the driver does not have enough "preload" force on the gear lever before the GCIC starts the gearbox mechanism will not accelerate quickly, again needing a longer cut time to compensate.
3. If too much force is required to start the GCIC the driver may become fatigued or the gear box may be damaged.

1 and 2. Digital (Switched) Input

A switched input can be located almost anywhere within reach of the driver but the best logical solution is to have it located on the gear lever. The switch may also be located on the clutch pedal but this may defeat the purpose of GCIC where clutchless shifts are desired. Some racing classes specify a switch location, e.g. steering wheel but this, like a clutch switch, means that the driver must co-ordinate the state of GCIC and the moving of the gear lever correctly and repeatably to get the best performance.

The diagram below shows a basic example of a “double jointed” gear knob for a sequential gearbox where GCIC is only needed on the up shift. The knob is able to pivot for a short distance on the gear lever when pulled towards the rear; this activates the switch giving the ECU its GCIC request. It is recommended that the spring be adjustable for preload so that the correct amount of force can be applied before the GCIC function is started.



If an H pattern system is needed or GCIC is required for both up and down shifts on a sequential gearbox a dual switch setup can be made.

The switch can be wired to either a Digital input or a Switched (Analogue Temperature) input. A switch wired to a Digital input must connect the input to 0v to pull it low and can be normally open or normally closed, whether the request is active when the switch is open or closed can be selected with the Logic Polarity parameter.

A switch that is wired to a Switched (Analogue Temperature) input can be connected to a voltage higher than 5v as the trigger levels can be defined by the user but it is most common practice to connect the input to 0v via the switch the same as the Digital input. Again a normally open or normally closed switch can be used.

3. RPM Limit

The RPM limiter can be used to request GCIC. The GCIC function request is active when the driver reaches the RPM limit. This method does not require any extra sensors to be added to the car but the driver must be aware that any time they reach the limiter they will get prolonged engine cutting if a gear change is not desired at that time. Delay from next gear stable may not be suitable for this method.

4. Gear Shift Force - Strain Gauge

The Strain Gauge works by being bonded onto the surface of an item, its electrical properties change as it is deformed by the small amounts of tension and compression in the item. For GCIC the strain gauge is bonded onto the front or back of the gear lever. As the driver puts force on the gear lever it bends slightly causing a change in signal from the strain gauge.

The voltage signal for a strain gauge is very small and must be amplified to become useful to the ECUs input. When considering bonding a strain gauge onto a gear lever a suitable strain gauge amplifier is needed, this can add a considerable amount to the cost of the system.

The major benefit of the strain gauge is that it is an analogue input with a voltage reading proportional to the drivers force on the gear lever. With the analogue input to the ECU the tuner is able to program the level of force needed to trigger the GCIC request. Another benefit is to be able to data log how the driver is using the gear lever with much more information made available when compared to a simple on/off switch.

The Strain Gauge amplifier's output can be connected to either an Analogue Voltage input or an Analogue Temperature input although it must be noted that the signal will be slightly non-linear when connected to the Analogue Temperature input due to its internal 1K ohm, 5v pull-up.

When calibrating the Gear Shift Force channel there is no need for the reading to be completely correct as the force level for the request will be set later. As a basic setting the calibration for 5v = 100N will be acceptable, if a more accurate reading is desired a custom calibration (using a fish scale for example) may be required.

5. Throttle Position Reduction

The rate at which the throttle is reduced can be a request for the GCIC function. The request is active when a user defined rate of reduction (TP% per second) of the Throttle Position Channel is reached or exceeded.

This method does not require any additional sensors to be added to the vehicle. Again, driver education and correct setup is needed as the function will not be able to determine if the driver has lifted the throttle for a gear change or if it is a correction for a loss of traction for example. Again, the delay from next gear stable mode may not be suitable for this method.

Thinking outside the square for experienced users some conditions could be used where no cut is applied (from the cut level table) if there is any wheel slip, allowing the driver to quickly lift the throttle without inadvertently requesting GCIC.

6. Gear Shift Function

The gear box control function will already have a request for an up-shift, so it is possible to link the two functions in software so that the GCIC is automatically triggered when an up-shift request is made by the driver.

Minimum RPM

A lower level of RPM is set so that the function cannot be requested. For example, if the car is being driven through the pit lane it would be unnecessary to have GCIC active for the slow shifting needed, the driver would most likely want to use the clutch.

The Minimum RPM can work in different ways in different modes so care must be taken in setup. For the Delay From Cut Signal and Cut While Signal Active modes the Minimum RPM is only a condition that needs to be met at the start of the request and will not affect the cut event once it has been started. For example: If the Minimum RPM is 5000rpm and the engine is at 5050rpm, the GCIC can start. Clearly the RPM will drop as soon as there is any cut. If the engine drops below 5000rpm while the GCIC event is going cut WILL NOT be stopped, the GCIC event will continue for its programmed time.

For the Delay from Next Gear Stable mode the minimum RPM is used in two ways, as a condition to allow the GCIC request to be valid and also as a safety measure for the RPM dropping to low. Because the Delay from Next Gear Stable mode can cut for a much longer time than the other two modes it is possible that the engine may stall if the driver makes a mistake.

Some special versions of software for controlled categories may have this value locked.

It is generally good practice to set the Minimum RPM to a relatively low level as this will also allow the driver to short-shift.

Minimum Throttle Position

As per Minimum RPM there is also a parameter for a Minimum Throttle Position below which a request is ignored by the ECU. The different mode selected will affect how the Minimum Throttle is used in the same way as the Minimum RPM, for the Delay from Cut Signal and Cut While Signal Active modes the Minimum Throttle is used as a condition to allow the request and start the GCIC event, if the throttle position drops below this value during the GCIC event the cut will not be stopped, for the Delay From Next Gear Stable mode the Minimum Throttle is used as a condition to accept the request and if the throttle drops below this during the GCIC event the cut WILL be stopped.

Gear Cut Force High and Low

The Cut Force parameters are only used when a strain gauge is used as the Cut Source GCIC. If the Gear Shift Force channel goes below the Gear Cut Force Low level a GCIC request is activated (also based on Minimum Throttle and RPM settings), if the Gear Shift Force channel goes above the Gear Shift Force High level a GCIC request is activated. The resting force (when there is no driver input) of the strain gauge does not have to be calibrated to be 0N as both the High and Low Gear Cut Force settings can be positive or negative values.

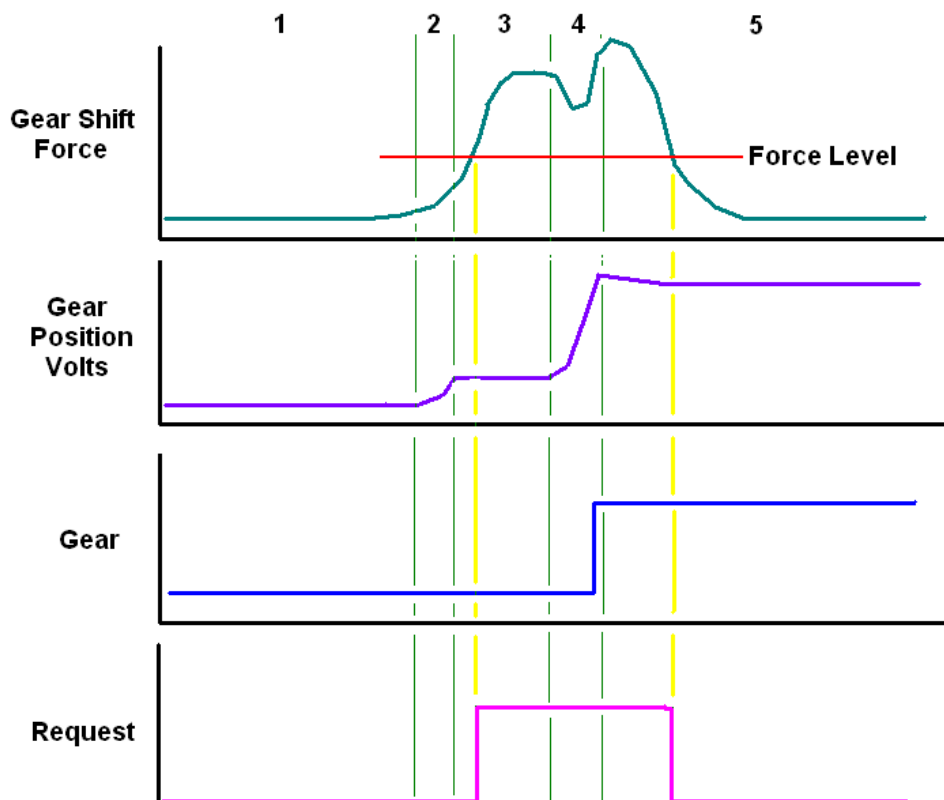
Having both a High and Low force level is useful for an H Pattern gearbox where the shift lever must operate in more than one direction. Most strain gauges have a resting state that allows both tension and compression to be measured. For a sequential gearbox it is possible that only one of the Gear Cut Force channels will be needed.

Something that must be remembered when setting the force levels is that they should not be so light as to allow the driver to request GCIC before he is actually ready to shift. The force must be set at a level that allows all the mechanical clearances to be taken up before the GCIC is activated.

The following diagram is typical of what will be seen from a strain gauge Gear Shift Force sensor when used with a sequential gearbox with a rotary position sensor to show gear position (sensor is mounted on the gear selector barrel).

1. The gearbox is in a gear and the driver starts to pull the gear lever for an up-shift. The selector barrel of the gearbox has not started to rotate.
2. The driver has pulled the gear lever with enough force that the gear selector barrel starts to turn. The dog ring has not started to move at this time, all the barrel rotation is from internal gearbox tolerances.
3. All gearbox tolerances have been taken up and the selector barrel stops rotating and is still in the starting gear. The driver is placing more load on the gear lever but the request has not started straight away, a small amount of extra force is required. The cut will start as soon as request becomes active.
4. The selector barrel starts to move towards engagement of the next gear.
5. The driver releases the gear lever and the Gear Shift Force returns to its resting level.

The level chosen to start the GCIC can have a very big effect on the speed of the gear change, too little and the gearbox tolerances are not removed, too much and there is a possibility the driver could pull the gearbox out of gear before GCIC starts or the driver could become fatigued by having to put too much effort into changing gear. Data logging is the most useful tool for setting up the Gear Cut Force levels.



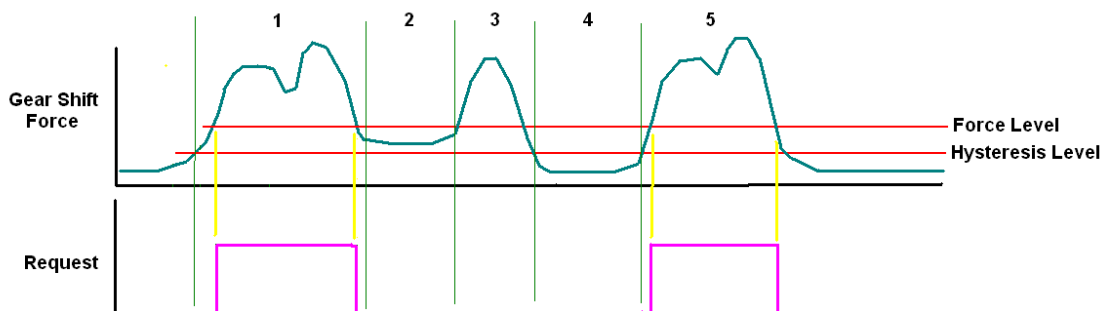
Gear Cut Force Hysteresis

The Hysteresis value is used to make sure the GCIC does not restart unexpectedly if the driver does not completely release the gear lever after a successful shift and is again only relevant when a strain gauge is used for the GCIC request. The driver will have to make sure enough force is released from the gear lever before the next shift is to be made.

The actual force due to the Hysteresis setting is Gear Cut Force High minus the Gear Cut Force Hysteresis or Gear Cut Force Lo plus Gear Cut Force Hysteresis. For example: If the resting force of a gear lever in a standard H pattern gear box is 20 and the Gear Cut Force Low is 10, to make a 3rd to 4th shift the driver must push the gear lever forward (causing compression in the strain gauge) until the force drops from 20 to just below 10 to activate the request. If the Hysteresis is 3 the driver must let the gear lever force reading increase to 13 before another shift is able to be made. On a shift from 4th to 5th the strain gauge reading will increase above the resting force of 20, if the Gear Cut Force High is 30 the driver increase the force on the gear lever to this level and the next GCIC event starts, after this shift the Gear Force needs to drop to 27 before the next shift can be made.

In the diagram below:

1. The driver starts the shift and once the Gear Shift Force is above the Force level a request is activated, this will lead to a successful GCIC event.
2. After completing the first shift the driver does not release the gear lever completely and the force level does not go below the Hysteresis level.
3. Still with too much force the driver tries to make another shift but the request will not activate.
4. The driver must release the force on the gear lever enough for it to go below the Hysteresis level.
5. Once below the hysteresis level the driver is able to make the next shift with a valid request.



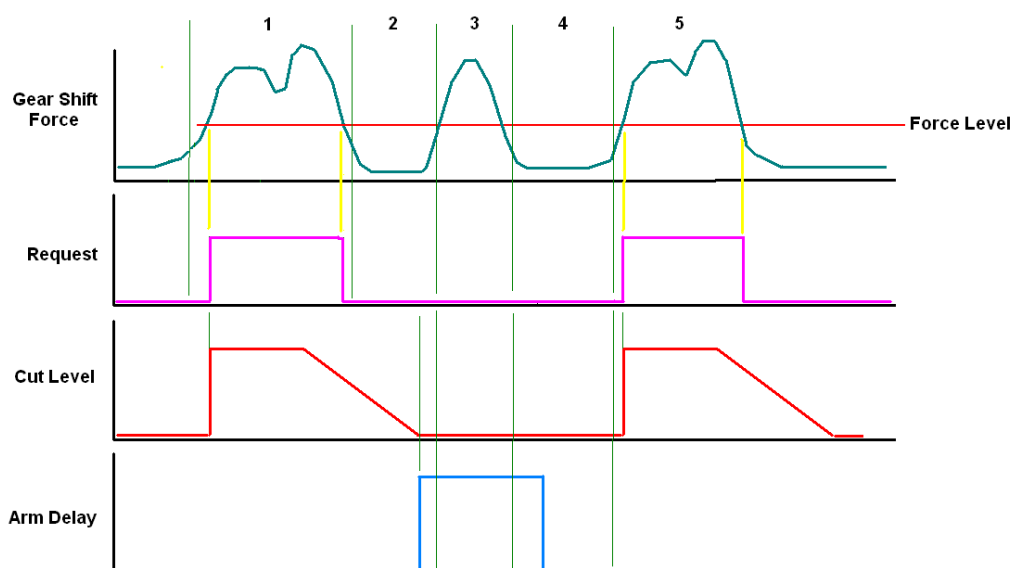
Arm Delay

The Arm delay is very similar in logic to the Hysteresis; it simply sets a minimum time between GCIC events. Again this is mainly to stop the driver accidentally requesting another shift too early if their hand is still on the gear lever or clutch pedal slightly.

The Arm Delay time starts as soon as the preceding GCIC event stops, i.e. the cut level has returned to 0. The Arm Delay is the same for all modes and input sources.

In the diagram below:

1. The driver makes a successful shift.
2. The driver releases the gear lever while the GCIC event is still happening (cut level greater than 0%). The Arm Delay time starts as soon as the Cut Level returns to 0%.
3. The driver applies force to the gear lever in an attempt to make another shift. Because the Arm Delay time is still active no GCIC request is activated.
4. The Arm delay timer ends.
5. The driver has applied force to the gear lever again and with the Arm Delay time finished another GCIC request is activated and a second shift can be made.



TP Rate of Change

When the Cut source is set to "Throttle Position Reduction" the tuner must set a rate of throttle reduction that will trigger the GCIC request, the parameter refers to the percentage change of throttle position per second. It is recommended that some testing is done with the driver first to establish what rate the throttle is lifted at during a gear change, the channel called "Accel Rate of Change" should be logged.

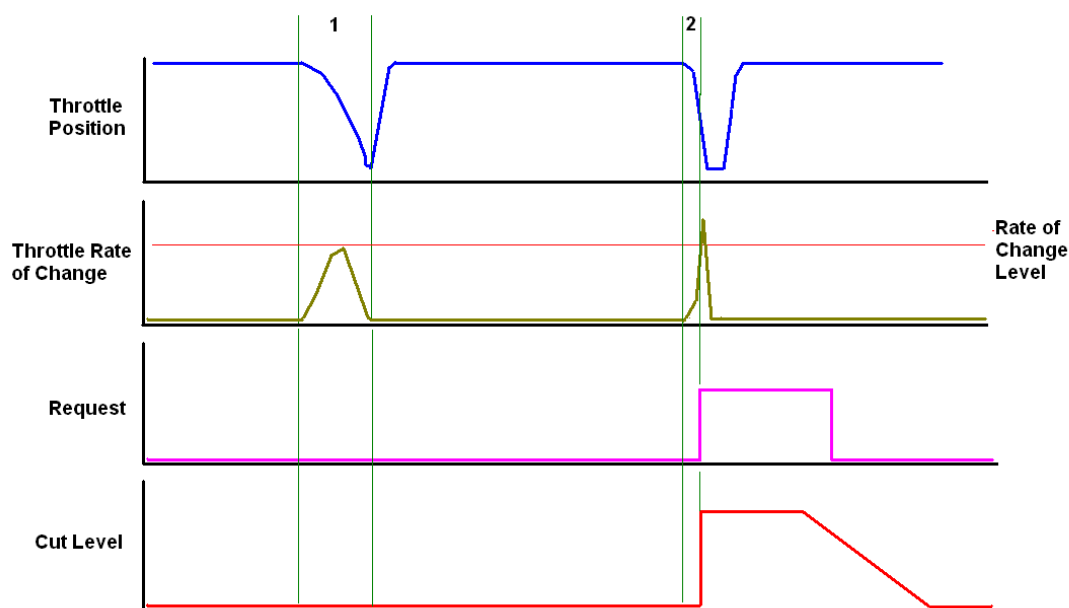
One thing that must be considered when using this mode is that the driver may need to lift the throttle for other reason besides wanting to change gear, this may cause unwanted cutting during loss of traction for example. It best to make sure the overall time out cannot be too long when using the delay from next gear stable mode in the event of unwanted cuts.

The quality of the Throttle position signal is very important in any function using the calculated Rate of Change. As an example an average driver can reduce the throttle at a rate of 300-350% per second. A noisy throttle position signal with bad earths or worn out sensor can easily

go beyond a driver's rate of throttle change because the variation of throttle position is very small but over very short times giving very high rates of change. A filter value may need to be entered into the Throttle Position input in the Sensor Setup.

In the diagram below:

1. The driver reduces the throttle but at a slow rate of change, this does not trigger a request
2. The driver tries again but this time lifts off the throttle much more quickly allowing the request to activate.



Next Gear Terminate

When using Mode 2, Delay from Cut Signal and a gear position sensor it is possible to have the ECU stop the cut event early if the driver has managed to get to the next gear before the ends of the delay time.

The next gear terminate can only reduce the cut time. It cannot extend it if the driver has not made it to the next gear before the Delay Time has elapsed.

Delay Table

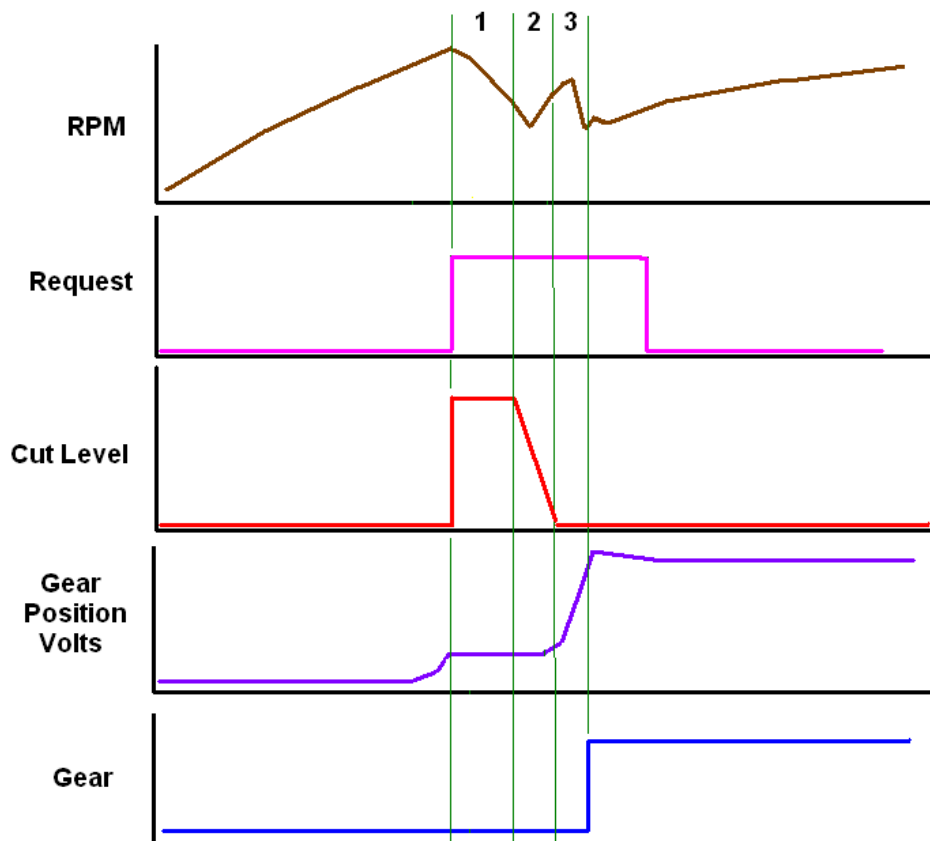
The Delay Table sets the amount of time the ECU must cut the engine power so that the driver can make a successful shift. The Delay table works in two different ways depending on which Cut Mode is used.

For Mode 1, Delay from Next Gear Stable the request starts the cut and the ECU will continue to cut until the next gear is acquired or the Time Out period has elapsed. The Delay Table sets extra cut duration once the next gear has been reached; this allows time to ensure that the next gear has been successfully engaged. This time is generally short when compared to the Mode 2, Delay from Cut Signal and is often left as 0msecs.

For Mode 2, Delay from Cut Signal the Delay Table sets the time that the ECU cuts the engine power for, this time is started as soon as the cut request becomes active. Enough time must be allowed so that the driver is able to get to the next gear; this mode will not allow for

mistakes and will reinstate the engine power after the Delay plus Recovery Time regardless of what position the gear box is in, see example below:

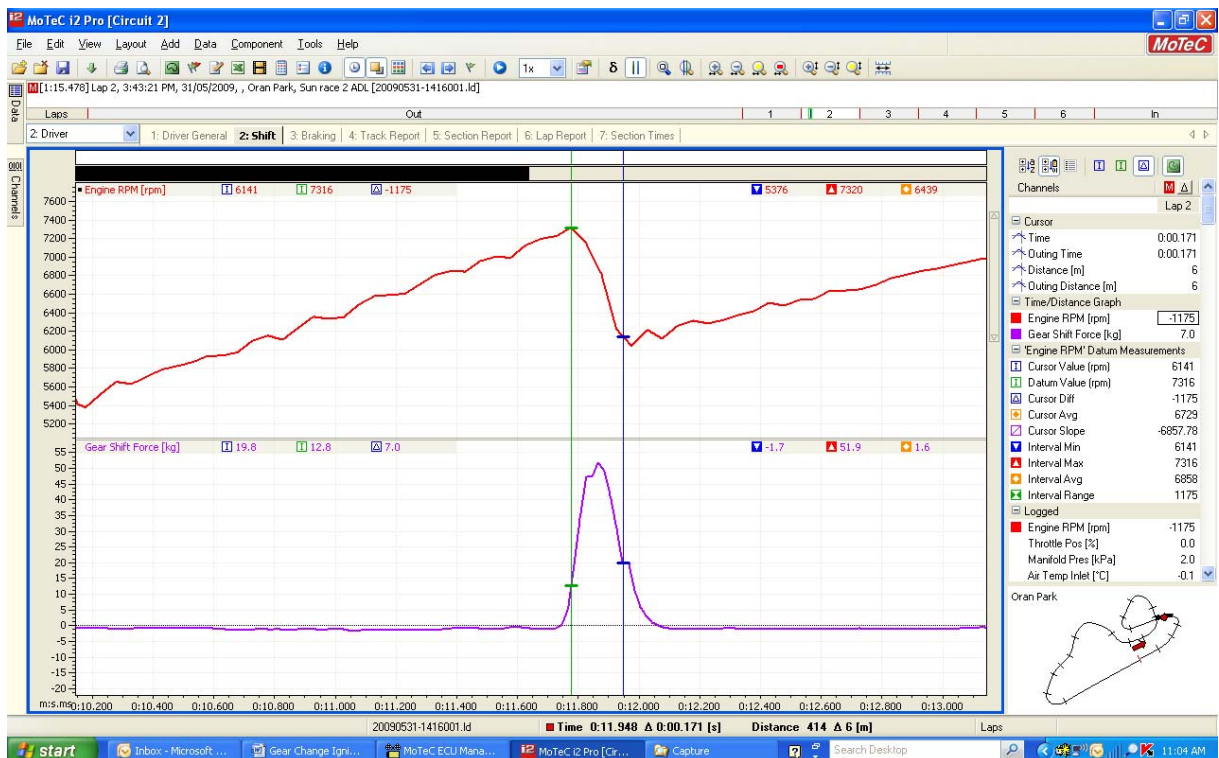
1. Driver has successfully started a shift and cut has become active
2. The driver has not completed the shift into the next gear and the delay time has been set too short. The RPM will start to rise as the engine power is reinstated.
3. With no cut the driver has forced the gearbox into the next gear, this feels fast to the driver but can result in gearbox damage. The delay time should be increased.



For Mode 3, Delay While Signal is Active the Delay table is not used.

From data logging of the RPM without any GCIC it should be quite easy to work out roughly how long it takes a driver to change gear. The use of a sequential gearbox with a gear position sensor makes working out gear change times much easier. It is recommended that a relatively long time is used in initial testing as it can take a driver a little while to get used to the fact that they do not have to lift the throttle (except when using throttle rate of change). The driver will be able to give feedback on how the system feels and the starting cut time can be reduced, the logged data will also show if the time is getting too short.

Below is an example of working out the basic shift time from data logging, in this case the gearbox is sequential and the time is 171 milliseconds, for an H pattern gearbox the times can be longer.



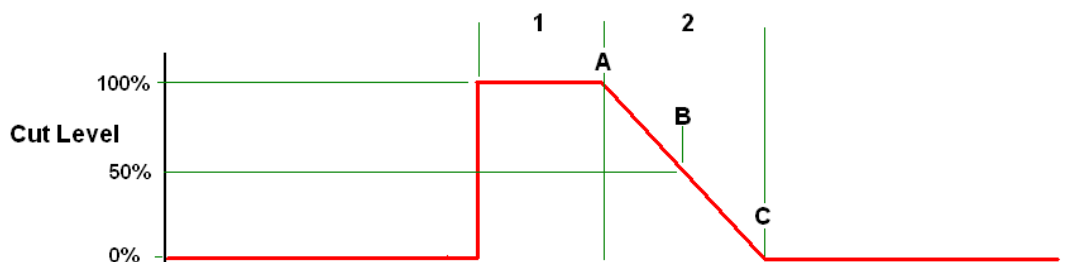
The delay table can be configured as just one single value which is used for every up shift or a 2D or 3D table. It may be found that each different gear requires a different cut time (H pattern gearbox).

Recovery Time

When a GCIC Delay event has finished it is possible to steadily ramp engine power back in to the drive train rather than switching full engine power back on. The Recovery Time sets the duration for a linear decrease in cut level.

Example:

1. GCIC Delay Time event at 100% cut level
2. Delay Time has finished and recovery time starts.
 - A. Cut is at 100%
 - B. At half the recovery time the cut will be at 50%
 - C. At the end of the recovery time cut is at 0% and full engine power is restored



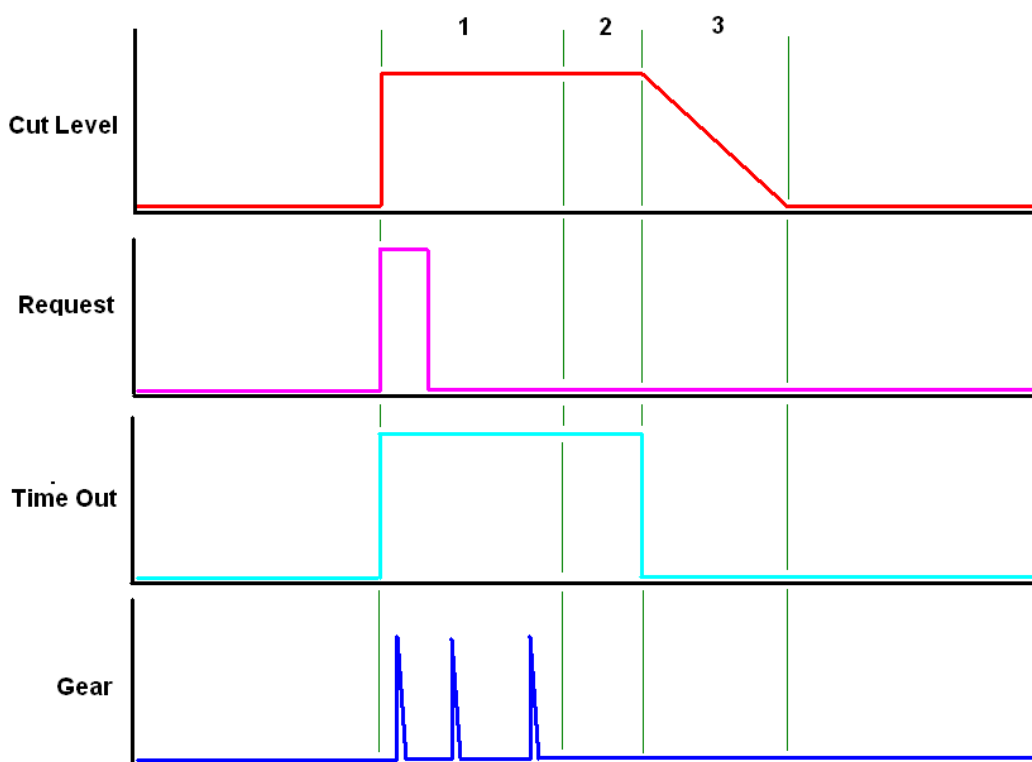
Most Recovery Time settings will be very short, e.g. 50msecs, although this time would probably be reduced based on driver feedback.

Time Out

When using Mode 1, Delay from Next Gear Stable, sometimes the driver may have a miss-shift and not reach the next gear. Based on Mode 1 the ECU will continue to cut the engine power waiting for the next gear. A Time Out can be used to limit the total time the engine is cut.

The Time Out is the maximum time the normal cut can be active and does not include the Recovery Time. If the driver has not reached the next gear before the Time Out has elapsed the ECU will automatically start the recovery time.

1. Driver has requested GCIC for an up shift but is having difficulty getting to the next gear
2. The driver has decided to leave it in the starting gear and shortly after the Time out elapses
3. After the Time Out normal recovery starts



The Time Out should be set at an amount that allows for the drivers slowest possible shift using data gathered from the logging.

It should also be noted that the cut will also be stopped if the driver reduces the Throttle position so that it goes below the Minimum Throttle Position or if the RPM goes below the Minimum RPM.

It should also be noted that the Timeout will allow the Recovery Time to start regardless of where the gearbox mechanism is. It is hoped that in the event of a missed shift the driver will have used the clutch pedal to help with the problem.

Stopping the GCIC event in this way does not change the normal Arm Delay. In the event of a missed shift the driver will still need to wait for the Recovery Time and Arm Delay to have elapsed before another attempt at shifting can be made.

Cut Level

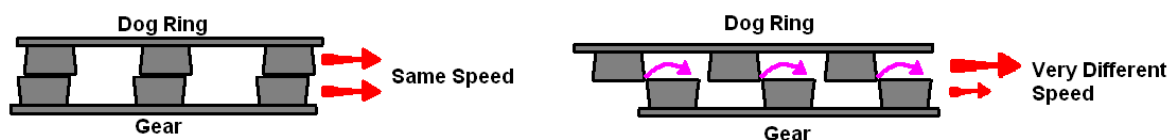
The cut level refers to the percentage of normal cylinder firing events that will be removed from the engine. The cut is quite literal in its meaning, the cylinder firing will be cut, the ignition advance (or timing) will remain the same but the cylinder will not be fired. 100% cut means that all cylinder firing events are stopped, 50% means half of them are stopped. The pattern in which the cylinders are cut is based on the main RPM Limit Randomizer.

While the name of the function suggests the GCIC function cuts ignition events it is the RPM Limit Type setting in the main RPM Limit that dictates whether the ECU cuts fuel, ignition or both. The cut level will be highly dependent on the particular engine and gearbox combination being used. A starting point of 100% cut is a basic recommendation.

Good data logging will be very useful in deciding what the Cut Level should be. The idea of GCIC is to remove enough engine power to unload the gearbox dog teeth so that the driver can shift out of the starting gear. The once the driver has started the shift the RPM must drop enough to allow the next gear dog teeth to engage without damage.

To successfully engage dog teeth in a gearbox the teeth on the dog ring and the gear need to be travelling at slightly different speeds. If the speeds are the same there is the possibility of a "dog clash" when the tooth on the dog ring comes face to face with the tooth on the gear, obviously the dog ring can move no further towards engagement until the two sets of teeth move relative to each other. If 100% cut is being used in a dog clash situation there may be no power to slide the dog faces away from each other.

If the speeds of the dog teeth are very different there can be a problem where there is not enough time for the teeth to engage before they hit the edge of the next tooth and simply bounce out of engagement.



Having too much relative speed could be caused by not having enough cut and the engine still having enough power to accelerate or there could be too much cut on an engine with very light rotating mass and very high compression causing the engine RPM to drop too rapidly. Some careful experimentation may be required and, again, data logging is an invaluable tool. Cut levels of 75-95% are common.

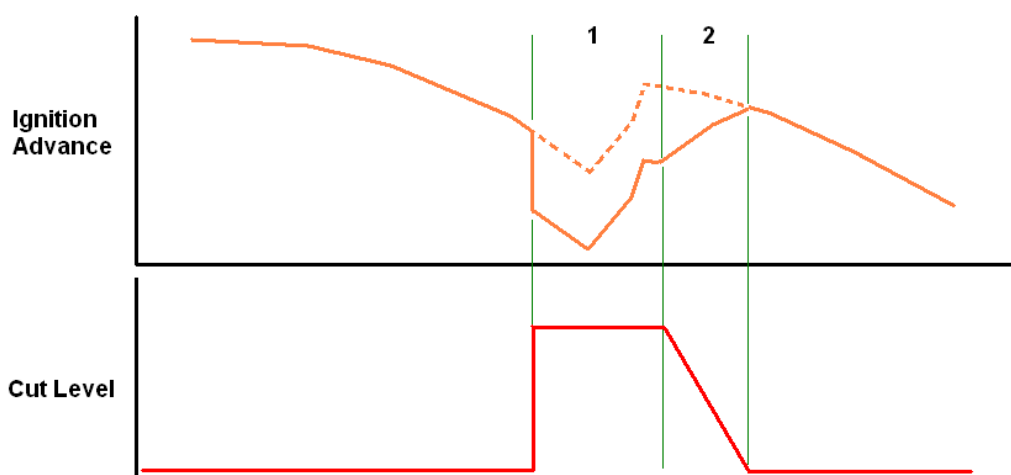
Retard

Another effective way of removing engine power is to retard the ignition advance, i.e. fire the spark plug much later in the engine's cycle to reduce cylinder pressure. A good understanding of how much ignition timing relates to how much of a drop in power is probably best tested on a dynamometer. Ignition Cut can be easily related to engine power in that 25% cut would give 25% reduction in engine power because 25% of the power producing combustion strokes is removed; Ignition Retard is not so simple and highly dependent on the type of engine.

The ignition retard applied to the GCIC event acts exactly the same as the Cut. The retard is applied as soon as a valid request is detected, it is held for the same delay time as with cut and also obeys the same conditions for Recovery Time.

The Retard table values can have two different results depending on what is set for the Ignition Percent/Degrees parameter in the Ignition Setup, e.g. does a number of 20 result in 20 degrees being removed from the ignition advance or is 20% of the current value removed. The tuner must be aware that the ignition retard will follow the current ignition advance derived from the main ignition table and its compensations. The diagram below compares the Cut to Retard during a GCIC event

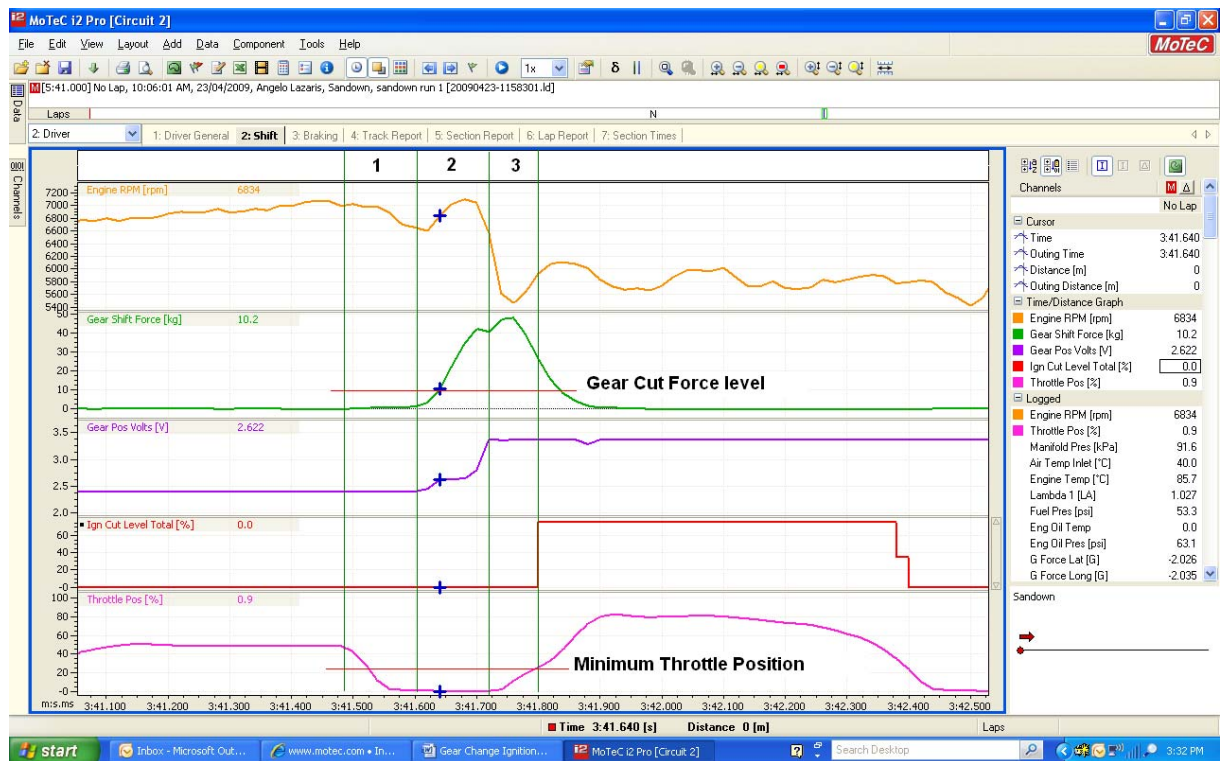
1. A GCIC cut event is started and the ignition is retarded by a set amount but stays relative to the normal ignition curve (dotted line).
2. Ignition retard is reduced over the Recovery Time.



Driver Education

For drivers who have spent most of their racing career quickly lifting the throttle to change gear it can be quite difficult to convince them not to lift once GCIC function has been switched on. This can cause problems for the tuner who needs to set minimum and maximum values, especially throttle position, to make the function work. There are many cases of the driver not obeying the instruction to keep the throttle wide open on a shift and this can cause many problems for the logic of the function, below is a common example.

1. The driver has lowered the throttle position until it is well below the Minimum Throttle position.
2. The driver then pulls on the gear lever and is able to change gear with ease because there is no engine torque.
3. Because the driver is still holding enough force on the gear lever as the throttle is reapplied the cut starts. In this example the Mode was Delay from Next Gear Stable meaning that the cut is applied for the full Time Out because the driver triggered the GCIC request after the shift was made and not before.



This is a common example of a driver not trusting that the GCIC will do its job. In an attempt to "help" the function the driver has caused another problem. Data logging is the best way to show the driver that they are misusing the function. Drivers do not like their mistakes being made obvious in logged data and tend to learn quickly afterwards.