Ferrari SF15-T.

The Ferrari SF15-T car is fitted with Ferrari's Tipo 059/4 Power Unit, this is a hybrid system that involves multiple components. This document will explain those components and their functions, as well as providing the information required for drivers to be able to optimise the use of the power unit via in car controls whilst on track.

The following abbreviations will be used in this document:

PU: Power Unit

SOC: State of Charge

ICU: Internal Combustion Unit

ECU: Electronic Control Unit

ERS: Energy Recovery System

DRS: Drag Reduction System

MGU-H: Motor Generator Unit-Heat

MGU-K: Motor Generator Unit-Kinetic

- ICU: This is a relatively standard V6 internal combustion engine, which on its own is not abnormal, though as with all things in the world's premier racing series, the unit's internal technology is intricate and fascinating. In this case the Ferrari Tipo 059/4 is a 1.6 litre V6 unit with the V set at 90 degrees, as dictated in the ruleset defined by the series in 2014. The ICU is connected to a turbocharger allowing the engine to be more compact but produce similar power to the 2.4 litre V8 engines used prior to 2014. The turbocharger is a device used to efficiently utilise the energy stored within the engine's exhaust gases, comprising of a turbine and compressor supported by bearings on the same axis.

  Exhaust gas energy rotates the turbine powering the compressor, which in turn compresses and increases air fed into the engine's combustion chamber, thus allowing for more fuel combustion and a higher power output. The ICU output is approximately 600 horsepower (hp).

Due to regulations introduced from 2014 onwards, the rev limit of ICUs was reduced to 15,000 rpm, along with a maximum regulated fuel flow of 100Kg/hour capped at 10,500 rpm. Thus, as power output increases proportionately with the amount of fuel burned, higher revs burn more fuel, and increase output, in a shorter time. By capping the maximum fuel flow at 10,500 rpm, the same amount of fuel flow is available with revs above this point, increasing mechanical resistance, and decreasing the merits of revving higher than 10,500 rpm. In this series the engines of the past were designed to maintain higher revs to create higher output, but the new hybrid rules shift the focus to designing engines that use energy more efficiently. This efficiency drive is focussed by the series regulations stating that vehicles may only use 100Kg of fuel during a Grand Prix.

- MGU-K: The MGU-K is an electrical component, not dissimilar to the KERS systems that the series has used since 2009. The MGU-K takes electrical energy harvested from the rear axle under braking, stores it in the ERS battery, and deploys it to the rear wheels when under power. When powering the car using electrical energy stored in the battery, the MGU-K adds 160hp (at maximum deployment) to the ICU's 600hp.

  This is not unlike the systems used in some modern road cars. Within the series rulebook, however, the electrical energy charging the battery from the MGU-K is limited to 2 MegaJoules (MJ) per lap, and the maximum energy allowed from the battery to power the MGU-K is limited to 4 MJ per lap, presenting a compromise in management of this energy over a lap. These design restrictions ensure that energy is harvested at a lower rate than it can be deployed, thus compromise is essentially built in to the performance equation.

- MGU-H: The MGU-H is another electrical component within the PU, which adds to the overall efficiency of the unit. The MGU-H converts heat energy from exhaust gases expelled by the ICU into electrical energy to recharge the ERS battery. ERS-H is yet to be used in road going hybrid cars and consequently is a major area of research that may eventually benefit the greater motoring world.

  Unlike the MGU-K, the series rulebook does not place any energy usage restrictions on the MGU-H. Electrical power generated by the MGU-H may be fed directly into the MGU-K, effectively bypassing the MGU-K regeneration restrictions and tapping the full 160hp. This highlights the importance of developing a system to fully utilize the MGU-H, and any new power unit heavily depends on how effectively the MGU-H performs. The overall level of charge harvested from the MGU-H is usually negligible when balanced against the overall output of the PU, this remains a major area of research in power unit development.

In-car controls

Assetto Corsa's detailed model of the Ferrari SF15-T allows the virtual driver to manipulate the various configuration settings of the 059/4 PU in much the same way Ferrari's race drivers do in real life. The default control assignments, and their functions are noted below:

- **CTRL+1:** MGU-K Regen rate. This is covered by 10 settings (0%-100%). This manages how aggressively the MGU-K harvests energy from braking events on the rear axle. With 100% being the most aggressive setting and thus harvesting the most energy into the battery at a given time. Thus, management of this setting can affect the handling of the car in a number of ways:

    - A higher percentage of energy regeneration in the MGU-K will mean for a greater level of retardation upon the rear axle when off throttle (coast) and braking, possibly resulting in entry oversteer. Higher regen will also result in longer braking distances. With the offset being that the internal ERS battery SOC will increase faster based on the higher percentage.

    - A lower percentage of energy regeneration will mean less energy is being charged into the ERS battery for deployment on power. The offset to this is a more precise level of braking control via normal brake balance, and shorter braking distances.

- **CTRL+2:** MGU-K Deployment profiles: These are named profiles that define variable rates of MGU-K power output to the rear wheels under power.

  When adjusting MGU-K deployment settings it is key to recognise that the benefits of adding MGU-K power output to the ICU's power output are most applicable under mid-range acceleration; which in a car of this performance level covers the area from 140-280kmh. Provided there is sufficient traction available to the tyres, this is where the most gains will be seen by utilising the hybrid powertrain. The Ferrari SF15-T utilises "profiles" for deployment of MGU-K energy, these profiles try to optimise MGU-K power output during these acceleration phases of a lap, sometimes sacrificing top speed in the process. Some profiles also reduce MGU-K output at very low speeds where there may not be enough traction available to the rear wheels to manage the available torque. We will go through the six available profiles below:

    - **Charging (0):** The lowest deployment setting. It deploys no ERS battery power and leaves the ICU to do all the work. This allows the fastest battery re-charge rate in conjunction with MGU-K regen rate settings.

    - **Balanced Low (1):** This profile commences MGU-K power delivery at 120kmh at a rate of 10% total MGU-K deployment, on an increasing scale based upon speed, throttle opening, and gear selection, peaking at 80% of total MGU-K power between 170-250kmh. Then, from 250-300kmh total output reduces to 40% of total MGU-K power, reducing still to 0% above 300kmh.

      When on the throttle in this profile, the driver will receive MGU-K power only when the pedal is above 50% deflection. Below 50% throttle there will be no MGU-K power supplementing the ICU.

These areas (Road speed, throttle deflection) are multiplied together and then multiplied once again with gear selection according to the below chart:

1st: 0%
2nd: 0%
3rd: 20%
4th: 50%
5th: 100%
6th: 100%
7th: 100%
8th: 0%

Examples:

1.) In the balanced low profile the driver is proceeding at 220kmh (80% or 0.8), on full throttle (1.0), in third gear (20% or 0.2), giving a multiplied MGU-K output of: 1.0 x 0.8 x 0.2 = 0.16 or 16% total MGU-K deployment.

2.) In the balanced low profile the driver is proceeding at 255kmh (40% or 0.4), on full throttle (1.0), in fifth gear (100% or 1.0), giving a multiplied MGU-K output of: 1.0 x 1.0 x 0.4 = 40% total MGU-K deployment.

- **Balanced High (2):** This profile is a more aggressive form of the previous profile, using a similar multiplier. MGU-K power delivery commences at 120kmh at 70% total MGU-K deployment, on an increasing scale based upon speed, throttle opening, and gear selection, peaking at 100% of total MGU-K power between 160-260kmh. Then, from 260kmh MGU-K power delivery ramps downwards, with 270kmh giving 70% power, 280kmh giving 40%, scaling gradually to reduce to 0% deployment at 300kmh or above.

  When on the throttle in this profile, the driver will receive MGU-K power only when the pedal is above 50% deflection. Below 50% throttle there will be no MGU-K power supplementing the ICU.

  These areas (Road speed, throttle deflection) are multiplied together and then multiplied once again with gear selection according to the below chart:

  1st: 0%
  2nd: 50%
  3rd: 70%
  4th: 100%
  5th: 100%
  6th: 100%
  7th: 70%
  8th: 0%

  Examples:

  1.) In the balanced high profile the driver is proceeding at 220kmh (100% or 1.0), on full throttle (1.0), in third gear (70% or 0.7), giving a multiplied MGU-K output of: 1.0 x 1.0 x 0.7 = 0.70 or 70% total MGU-K deployment.

2.) In the balanced high profile the driver is proceeding at 255kmh (100% or 1.0), on full throttle (1.0), in fifth gear (100% or 1.0), giving a multiplied MGU-K output of: 1.0 x 1.0 x 1.0 = 100% total MGU-K deployment.

- **Overtake (3):** Probably the highest MGU-K deployment rate generally used in races, this setting provides good power output at higher speeds for a situation whereby the driver is in a battle with another car and needs as much power as they can get for short bursts. Naturally the battery SOC will deplete faster on this setting so it cannot be used for extended periods.

  MGU-K power delivery commences on the overtake profile at 160kmh with 50% total MGU-K deployment, this then adopts an increasing scale of MGU-K deployment based on road speed peaking at 100% deployment at 260kmh. Then, from 260kmh MGU-K power delivery ramps downwards somewhat, with 270kmh giving 70% power, but unlike previous profiles the deployment rate stays at 70% from 270kmh to maximum speed.

  When on the throttle in this profile, the driver will receive MGU-K power only when the pedal is above 80% deflection. Below 80% throttle there will be no MGU-K power supplementing the ICU, suggesting that this profile is primarily used for situations when the driver is really pushing. At 80% deflection the driver will receive 40% deployment, at 90% deflection 80%, and 100% deployment at 100% throttle opening.

  These areas (Road speed, throttle deflection) are multiplied together and then multiplied once again with gear selection according to the below chart:

  1st: 0%
  2nd: 0%
  3rd: 50%
  4th: 100%
  5th: 100%
  6th: 100%
  7th: 100%
  8th: 100%

  Examples:

  1.) In the overtake profile the driver is proceeding at 220kmh (82.5% or 0.825), on full throttle (1.0), in third gear (50% or 0.5), giving a multiplied MGU-K output of: 1.0 x 0.825 x 0.5 = 0.4125 or 41.3% total MGU-K deployment.

  2.) In the overtake profile the driver is proceeding at 255kmh (97.5% or 0.975), on full throttle (1.0), in fifth gear (100% or 1.0), giving a multiplied MGU-K output of: 1.0 x 1.0 x 0.975 = 97.5% total MGU-K deployment.

- **Top Speed (4):** As the name suggests, the Top Speed profile is setup to deliver the highest performance at higher speeds and gears. This profile is mostly specific to circuits such as Monza, as it works to save as much ERS battery power as possible at lower speeds to be able to deploy more MGU-K power at higher speeds.

  MGU-K power delivery commences in the top speed profile at 120kmh scaling from 0% to 60% MGU-K deployment at 200kmh. Then through

200-250kmh deployment is fixed at 60%, with a gradual decrease in deployment to 50% from 250-330kmh where it stays at 50% to maximum speed.

When on the throttle in this profile, the driver will receive MGU-K power only when the pedal is above 80% deflection. Below 80% throttle there will be no MGU-K power supplementing the ICU. At 80% deflection the driver will receive 40% deployment, at 90% deflection 80%, and 100% deployment at 100% throttle opening. This is the same throttle map as the overtake profile.

These areas (Road speed, throttle deflection) are multiplied together and then multiplied once again with gear selection according to the below chart:

1st: 0%
2nd: 0%
3rd: 0%
4th: 100%
5th: 100%
6th: 100%
7th: 100%
8th: 100%

Examples:

1.) In the top speed profile the driver is proceeding at 220kmh (60% or 0.6), on full throttle (1.0), in third gear (0%), giving a multiplied MGU-K output of: 1.0 x 0.6 x 0 = 0 or 0% total MGU-K deployment.

2.) In the top speed profile the driver is proceeding at 255kmh (59.38% or 0.5938), on full throttle (1.0), in fifth gear (100% or 1.0), giving a multiplied MGU-K output of: 1.0 x 1.0 x 0.5938 = 0.5938 or 59.4% total MGU-K deployment.

- **Hotlap (5):** This profile is the highest setting for MGU-K deployment but it is not a simple matter of 100% deployment throughout all areas, as deployment must still be balanced to provide a drivable car and enough energy deployment to cover a single lap.

  This setting is usually used in qualifying in conjunction with minimal regen rates to deliver maximum performance from the PU. At this setting, on most circuits, the battery SOC will be depleted to zero in one or two laps.

  MGU-K power delivery commences in the hotlap profile at 100kmh scaling from 0% to 20% MGU-K deployment at 120kmh. Then through 120-160kmh deployment scales up from 20% to 100% where it stays until maximum speed.

  When on the throttle in the hotlap profile, the driver will receive MGU-K power when the pedal hits 10% deflection at a rate of 10% MGU-K deployment. With a linear scale moving up to 100% MGU-K deployment on 100% throttle. Providing a linear throttle response to MGU-K power delivery in this profile is designed to allow the driver to extract the maximum possible performance from the car over a single lap.

These areas (Road speed, throttle deflection) are multiplied together and then multiplied once again with gear selection according to the below chart:

1st: 20%
2nd: 70%
3rd: 70%
4th: 70%
5th: 70%
6th: 70%
7th: 70%
8th: 70%

Examples:

1.) In the hotlap profile the driver is proceeding at 220kmh (100% or 1.0), on full throttle (1.0), in third gear (70% or 0.7), giving a multiplied MGU-K output of: 1.0 x 1.0 x 0.7 = 0.7 or 70% total MGU-K deployment.

2.) In the hotlap profile the driver is proceeding at 255kmh (100% or 1.0), on full throttle (1.0), in fifth gear (70% or 0.7), giving a multiplied MGU-K output of: 1.0 x 1.0 x 0.7 = 0.7 or 70% total MGU-K deployment.

It may seem surprising that the hotlap profile balances MGU-K deployment to 70% in gears above 2nd and does not scale to 100%. This is to preserve enough SOC to complete the lap. It would be assumed that over a qualifying lap, the driver would configure the MGU-H to MOTOR mode (See **CTRL+3** section below) to supplement the MGU-K power and provide the maximum manageable power output over one lap.

- **CTRL+3:** MGU-H Mode: This setting controls how the MGU-H operates in conjunction with other PU components:
  - **Motor:** In this mode the MGU-H will recover energy from exhaust gases and direct this power directly into the MGU-K, thus supplementing overall power output.
  - **Battery:** In this mode the MGU-H recovers exhaust gases and diverts this energy into the ERS battery to increase the SOC.

- **CTRL+4:** Engine Brake (Range 1-13): This setting sets the ECU within the ICU to retain a small percentage of fuel flow to blow onto the diffuser, reducing engine braking from the ICU on coast. This offsets the high level of coast locking on the rear axle that is generated with higher MGU-K regen settings (CTRL+1).
  - Lower settings reduce the level of engine braking and thus reduces retardation from the drivetrain onto the rear axle under coast. This provides easier management of rear axle locking with MGU-K regen and brake balance. Due to the increase in diffuser exhaust flow, a lower setting will also provide additional rear downforce and stability. However, a lower engine brake settings will consume more fuel and thus affect fuel consumption over a stint.

    - Higher settings allow a more conventional drivetrain linkage and thus more retardation to the rear axle from the ICU, this needs to be balanced against MGU-K regen settings to provide a comfortable balance for the driver along with suitable fuel consumption numbers.

- **KERS:** As with other cars in Assetto Corsa, the KERS button can be mapped in the SF15-T. This provides an instant “max power” button for use in battles with other cars. Applying the KERS button essentially reflects the following ERS settings:
    - MGU-K regen to 0%
    - MGU-K deploy profile to Hotlap
    - MGU-H mode to Motor

  This persists while the KERS button is held down, and thus must be used carefully as it will dramatically reduce battery SOC.

- **DRS:** DRS opens a slot gap in the rear wing on certain denoted parts of the circuit that significantly reduces drag and increases top speed. This is freely usable in practice and qualifying sessions, but restricted in the race to being used only when within one second of the car in front. Upon entering the DRS zone the white LED light on the top far-left of the steering wheel will illuminate, and upon pressing the DRS button the second light in will also illuminate to indicate that the DRS is open. Opening of the DRS has to be engaged by the driver when the car enters the DRS zone. In the DRS zone the driver should press the DRS button as soon as possible to maximise performance through the zone the DRS will close when the driver applies the brakes at the end of the zone. Opening the DRS in the rear wing has a knock-on effect of reducing rear downforce and thus upsetting the front to rear downforce balance. This is something the driver must be aware of when the DRS is open.

Managing the SF15-T on track.

At all times that the Ferrari SF15-T is on track, as long as the driver sets the above switches accordingly, energy is either being harvested into the ERS battery, or is being deployed from the ERS battery in different ways depending on what the car is doing.

Under braking the MGU-K generates electricity from part of the kinetic energy lost when the car is braking, and stores that electricity in the ERS battery. As the MGU-K's maximum output is 160hp (or 120 kiloWatts) and the amount of energy allowed to be stored in the battery is 2MJ per lap, the SF15-T needs to brake for around 16.7 seconds per lap to reach this maximum charge.

Upon acceleration out of corners the car can accelerate faster by adding the power output of the MGU-K to the ICU's power output, in the process depleting the SOC of the ERS battery. However, concurrently the MGU-H can be utilising the exhaust gases to recharge the ERS battery (when in **BATTERY** mode), while the ICU's turbocharger uses its compressor to send compressed air into the engine. Under full-acceleration, the exhaust energy fed to the turbine can increase to a point where it exceeds the amount of air the compressor can handle to feed into the engine, in this situation the MGU-H converts this excess exhaust energy into electricity, which it can then send directly to the MGU-K for deployment to the rear wheels, or used to increase the battery SOC.

There are no rules for how much electricity the MGU-H is allowed to generate, so the MGU-K's output can be added to the ICU's output without worrying about the rules on the amount of electricity that the battery can charge or discharge. Thus, unused exhaust energy can be efficiently used to accelerate faster.

The MGU-H also solves the problem of turbo "lag" on power application by using an electrical motor to power the turbo's compressor, saving the turbine from having to wait for the exhaust gas to do so.

At different stages of a race two cars can have very different braking performance due to MGU-K harvesting (regen), and thus a driver must be mindful of their competitor's actions on track with regard to their regen rate. This is visible to a following driver by the red rain light flashing under braking or coast conditions.

Managing the SF15-T's various in car systems is crucial for a driver to achieve the best performance from the car and thus potential success. Each circuit will present different car configurations as battery recharge is dependent on braking events and total deployment will vary based on the amount of time spent on throttle over a lap. The key to this configuration is to find an optimum balance between deploy and regen on the MGU-K that you can work within to maintain a reasonable SOC, whilst using the push-to-pass button to increase power at required intervals. A driver must constantly be aware of, and manage the battery SOC.

Ideally, a driver will want to maximise performance with the highest possible MGU-K deployment setting over a stint. If you perform a lap with a deploy profile of “Hotlap”, and a regen rate of zero then you may find on some circuits that the ERS battery is flat within one lap, with the maximum deployment of 2MJ completed well before the end of the lap. Thus you will need to start to dialing in some regen. The assumption would be that maximum regen would be desirable, to always recover as much battery in braking events, but the compromise here comes in braking performance. As the MGU-K works to harvest energy from the rear axle, there is a an additional diff locking effect that not only increases braking zones, but also introduces handling instability into the corner entry phase. Depending on the steering angle in the car this can be understeer or oversteer. Understeer can be seen when the MGU-K regen is taken into account by the dynamic brake balance system that attempts to re-balance braking performance by reducing rear brake pressure, to prevent rear wheel locking; this gives the feeling that brake bias is moved forward (though it should be understood that no additional brake pressure is moved forward, there is only a reduction in rear brake pressure). Oversteer can potentially be seen on the entry phase of a corner as the driver turns in and releases the brake, at this point the MGU-K regen setting will retain a braking effect upon the rear axle that can initiate oversteer as the steering angle increases.

This behavior, and potentially variable braking performance is to be expected with higher MGU-K regen rates.

It is the case that with the lowest possible regen settings on the MGU-K, the shortest braking distances can be achieved, and thus faster laptimes. As well as that, the feeling of the car on entry is “cleaner”, whereby the driver feels more in control of the car’s balance upon entry to the corner via their own foot pedals and relative brake balance setting. As the driver adjusts the MGU-K regen and deploy settings the balance of the car on entry and exit can change notably, meaning a driver has to become adaptable to these changes as they drive. A qualifying run with heavily aggressive MGU settings will suit for one lap, but when given the balancing act that may be required to maintain efficiency over a full race it is not unlikely to see a very large laptime difference between the two sessions.

To find the optimum average laptime over a race stint in the Ferrari SF15-T a driver must work to find a balance between MGU-K deployment and regeneration that suits the particular track layout and their driving style, all the while maintaining sufficient ERS battery SOC for when it is needed to overtake. Additionally, depending on the race configuration, a driver must keep fuel consumption under control, hit the DRS button in the right places, manage brake bias and engine braking settings as fuel load changes, and use the conventional steering wheel and pedals to keep the car on the road.

Good luck!

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