MotionSystems

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SOFTWARE MANUAL

R1.5

Vehicle physics simulation application

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Publisher

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1 Integration

1.1 Introduction

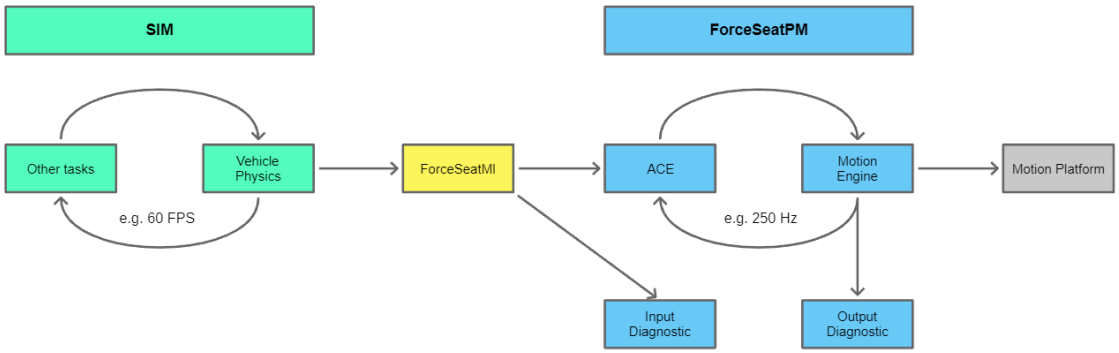
ForceSeatMI is an user friendly and powerful interface that allows to add a motion platforms support to any application or game (referred as **SIM** in the next sections). In the most applications there is no need to control the hardware directly from the **SIM** and the **SIM** can use **ForceSeatMI** to forward telemetry data to **ForceSeatPM** for further processing. This approach delegates the responsibility of transforming telemetry data to actual **top table** motion from the **SIM** to **ForceSeatPM**. It also simplifies error handling that the **SIM** has to implement.

1.2 Glossary

- **SIM** - an application or a game that generates telemetry data (e.g. using physics engine or reading a CSF file) and sends it to ForceSeatPM via provided set of APIs.
- **top table** - this is an alternative name for top frame of the motion platform.
- **ForceSeatPM** - platform manager application that runs ACE and controls motion platforms.
- **ForceSeatMI** - API that allows the SIM to send telemetry data to the ForceSeatPM.
- **ACE** - an Acceleration Control Engine that implements modified classical washout algorithm.
- **classical washout algorithm** - it is the most widely used motion-cueing algorithm.
- **motion cues** - name for accelerations, which exert forces on the user's body. They should convince the passengers that they are driving in a real car. The algorithms which are responsible for generating these cues are named motion cueing algorithms.
- **IK** - inverse kinematics.
- **FK** - forward kinematics.
- **quick tunes** - mechanism in ForceSeatPM that allows end users to quickly and safely adjust motion platform operation to their preferences without the need for understanding how the system works under the hood.

1.3 Forwarding telemetry data to the platform manager

The **SIM** must update **FSMI_TelemetryACE** periodically when vehicle physics engine generates new physics frame and then must call **ForceSeatMI_SendTelemetryACE** to forward telemetry data to the **ForceSeatPM**. Once **ForceSeatPM** receives telemetry data, it passes the data to **ACE** (Acceleration Control Engine) which calculates series of required **top-table** positions (motions). The **ACE** usually is running at higher rate than the SIM to guarantee smooth motion platform operation.



The telemetry mode requires that at least following fields are filled with correct data:

- **state** - indicates if the motion platform should operate or enter pause mode.
- **bodyLinearAcceleration** - linear accelerations in vehicle coordinate system. The accelerations might contains gravity vector.
- **bodyAngularVelocity** - angular rotation velocity in vehicle coordinate system.

Refer to ForceSeatMI examples to see details about fields in the telemetry structure:

- **Telemetry_CPP** - it shows how to create structure in C++.
- **Telemetry_CS** - it shows how to create structure in C#/.NET.
- **Telemetry_Matlab** - it shows how to create structure in Matlab.
- **Telemetry_Python** - it shows how to create structure in Matlab.
- **Telemetry_Fly_Unity** - it shows how to get simple plane telemetry data in Unity.
- **Telemetry_Fly_Unreal** - it shows how to get simple plane telemetry data in Unreal Engine.
- **Telemetry_Veh_Unity** - it shows how to get vehicle telemetry data in Unity.
- **Telemetry_Veh_Unity** - it shows how to get vehicle telemetry data in Unreal Engine.

1.4 Telemetry structure

The full structure specification in C++ is presented below for reference. The same structure is available in C#, Python and Matlab formats.

```
struct FSMI_TelemetryACE
{
    // Put here sizeof(FSMI_TelemetryACE). NOTE: This field is mandatory.
    FSMI_UINT8  structSize;

    // Only single bit is used in current version.
    //  (state & 0x01) == 0 -> no pause
    //  (state & 0x01) == 1 -> paused, FSMI_STATE_PAUSE
    FSMI_UINT8  state;

    FSMI_INT8  gearNumber;                // Current gear number, -1 for reverse,
                                          // 0 for neutral, 1, 2, 3, ...
    FSMI_UINT8 accelerationPedalPosition; // 0 to 100 (in percent)
    FSMI_UINT8 brakePedalPosition;        // 0 to 100 (in percent)
    FSMI_UINT8 clutchPedalPosition;       // 0 to 100 (in percent)
    FSMI_UINT8 dummy1;
    FSMI_UINT8 dummy2;
    FSMI_UINT32 rpm;                  // Engine RPM
    FSMI_UINT32 maxRpm;               // Engine max RPM
    FSMI_FLOAT  vehicleForwardSpeed; // Forward speed, in [m/s]. For dashboard apps.

    // Lateral, vertical and longitudinal acceleration from the simulation.
    // UNITS: [m/s^2]
    FSMI_TelemetryRUF bodyLinearAcceleration;

    // Angular rotation velocity about vertical, lateral and longitudinal axes.
    // UNITS: [radians/s]
    FSMI_TelemetryPRY bodyAngularVelocity;

    // Position of the user head for accelerations and angular velocity effects
    // generation in relation to the top frame center. UNIT: [meters]
    FSMI_TelemetryRUF headPosition;

    // Additional translation for the top frame. UNIT: [meters]
    FSMI_TelemetryRUF extraTranslation;

    // Additional rotation for the top frame. UNIT: [rad]
    FSMI_TelemetryPRY extraRotation;

    // Rotation center for the 'extra' transformation in relation to
    // the top frame center. UNIT: [meters]
    FSMI_TelemetryRUF extraRotationCenter;

    // Custom field that can be used in script in ForceSeatPM to trigger user actions.
    FSMI_FLOAT  userAux[FSMI_UserAuxCount];

    // Custom field that can be used in script in ForceSeatPM to trigger user actions.
    FSMI_UINT32 userFlags;
};

struct FSMI_TelemetryRUF
{
    FSMI_FLOAT right;   // + is right,   - is left
    FSMI_FLOAT upward;  // + is upward,  - is downward
    FSMI_FLOAT forward; // + is forward, - is backward
};

struct FSMI_TelemetryPRY
{
    FSMI_FLOAT pitch; // + front goes up,        - front goes down
    FSMI_FLOAT roll;  // + right side goes down, - right side goes up
    FSMI_FLOAT yaw;   // + front goes left,      - front goes right
};
```

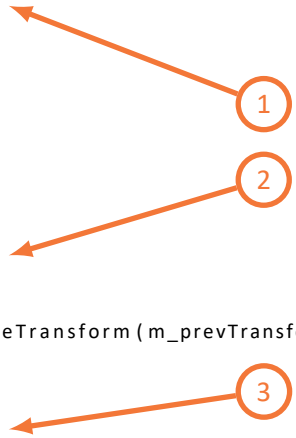
1.5 Gathering vehicle telemetry data

There are different ways of gathering telemetry data and chosen approach depends on the capabilities and interfaces of the vehicle physics engine the **SIM** is using. If it is possible, it is always recommended to get angular velocities and linear accelerations directly from the vehicle physics engine. Calculating angular velocities from roll/pitch/yaw changes and linear accelerations from linear velocity changes is **NOT RECOMMENDED** and should be used only if there is no other option.

1.5.1 Suboptimal solution

Below example comes from Unreal Engine 4 example. Similar example is also available for Unity. It is also possible to get vehicle telemetry data from CSV file and then playback it or use Matlab to generate necessary data.

```
void ForceSeatMI_Vehicle::Update(float deltaTime, FSMI_TelemetryACE& telemetry)
{
    const auto  velocity         = m_vehicle.GetVelocity();
    const auto& currentTransform = m_vehicle.GetActorTransform();
    // ...
    auto forwardSpeed = ForceSeatMI_Helpers::toMeters(
                          FVector::DotProduct(m_vehicle.GetActorForwardVector(),
                                              velocity));
    auto rightSpeed   = ForceSeatMI_Helpers::toMeters(
                          FVector::DotProduct(m_vehicle.GetActorRightVector(),
                                              velocity));
    auto upSpeed      = ForceSeatMI_Helpers::toMeters(
                          FVector::DotProduct(m_vehicle.GetActorUpVector(),
                                              velocity));

    if (m_firstCall)
    {
        // ...
    }
    else
    {
        ForceSeatMI_Helpers::lowPass(
            telemetry.bodyLinearAcceleration.forward,
            (forwardSpeed - m_prevSurgeSpeed) / deltaTime,
            FSMI_VT_ACC_LOW_PASS_FACTOR);
        //...
        auto rotationEulerDeg = currentTransform.GetRelativeTransform(m_prevTransform).
            GetRotation().Euler();

        ForceSeatMI_Helpers::lowPass(
            telemetry.bodyAngularVelocity.pitch,
            FMath::DegreesToRadians(rotationEulerDeg.Y / deltaTime),
            FSMI_VT_ANGLES_SPEED_LOW_PASS_FACTOR);
        // ...
    }

    m_prevSurgeSpeed = forwardSpeed;
    m_prevSwaySpeed  = rightSpeed;
    m_prevHeaveSpeed = upSpeed;
    m_prevTransform  = currentTransform;
}
```



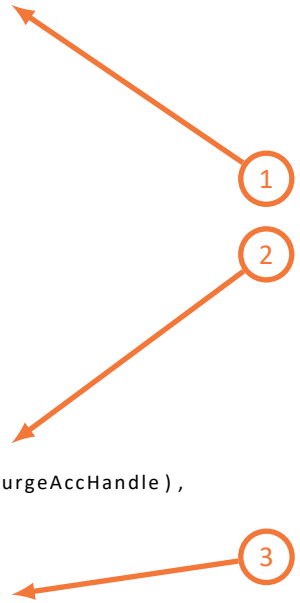
- (1) - transform object velocity from global coordinates system to vehicle coordinates system.
- (2) - calculate linear acceleration as derivate of linear velocity. This is NOT RECOMMENDED approach. If it is possible, always get linear accelerations directly from vehicle physics engine and only convert coordinates system.

- (3) - calculate angular velocity as derivate of (in this case) pitch. This is NOT RECOMMENDED approach. If it is possible, always get angular velocities directly from vehicle physics engine and only convert coordinates system.

1.5.2 Optimal solution

In this example **CarSim** physics engine is used and it provides an interface that allows to get linear accelerations and angular velocities directly from the engine. This is the best possible way of getting correct telemetry data. Only (optional) smoothing is performed, everything else comes directly from the vehicle physics engine.

```
void ForceSeatMI_CarSim::InitializeHandles()
{
    auto movement = m_car.GetCarSimMovement();

    if (movement)
    {
        // ...
        m_surgeAccHandle    = movement->GetOutputHandle_Implementation(TEXT("AX"));
        m_swayAccHandle     = movement->GetOutputHandle_Implementation(TEXT("AY"));
        m_heaveAccHandle    = movement->GetOutputHandle_Implementation(TEXT("AZ"));

        m_pitchSpeedHandle = movement->GetOutputHandle_Implementation(TEXT("AVY"));
        m_rollSpeedHandle  = movement->GetOutputHandle_Implementation(TEXT("AVX"));
        m_yawSpeedHandle   = movement->GetOutputHandle_Implementation(TEXT("AVZ"));
    }
}

void ForceSeatMI_CarSim::Update(float deltaTime)
{
    auto movement = m_car.GetCarSimMovement();

    if (movement)
    {
        // ...

        if (m_firstCall)
        {
            // ...
        }
        else
        {
            ForceSeatMI_Helpers::lowPass<float>(
                m_telemetry.surgeAcceleration,
                movement->GetFloatValue_Implementation(m_surgeAccHandle),
                LOW_PASS_FACTOR_LIN_ACC);
            // ...

            ForceSeatMI_Helpers::lowPass<float>(
                m_telemetry.pitchSpeed,
                movement->GetFloatValue_Implementation(m_pitchSpeedHandle),
                LOW_PASS_FACTOR_ANG_VEL);
            // ...
        }
    }
}
```



- (1) - get handles to the vehicle physics engine properties/variables.
- (2) - get linear acceleration directly from vehicle physics engine. This is a RECOMMENDED approach.
- (3) - get angular velocity directly from the vehicle physics engine. This is a RECOMMENDED approach.

1.6 Profile selection

In order for the system to work, a correct profile has to be active in **ForceSeatPM**. For vehicle simulations it should be **SDK - Vehicle Telemetry ACE** (or custom profile that inherits from it). For flight simulations it should be **SDK - Plane Telemetry ACE** (or custom profile that inherits from it).

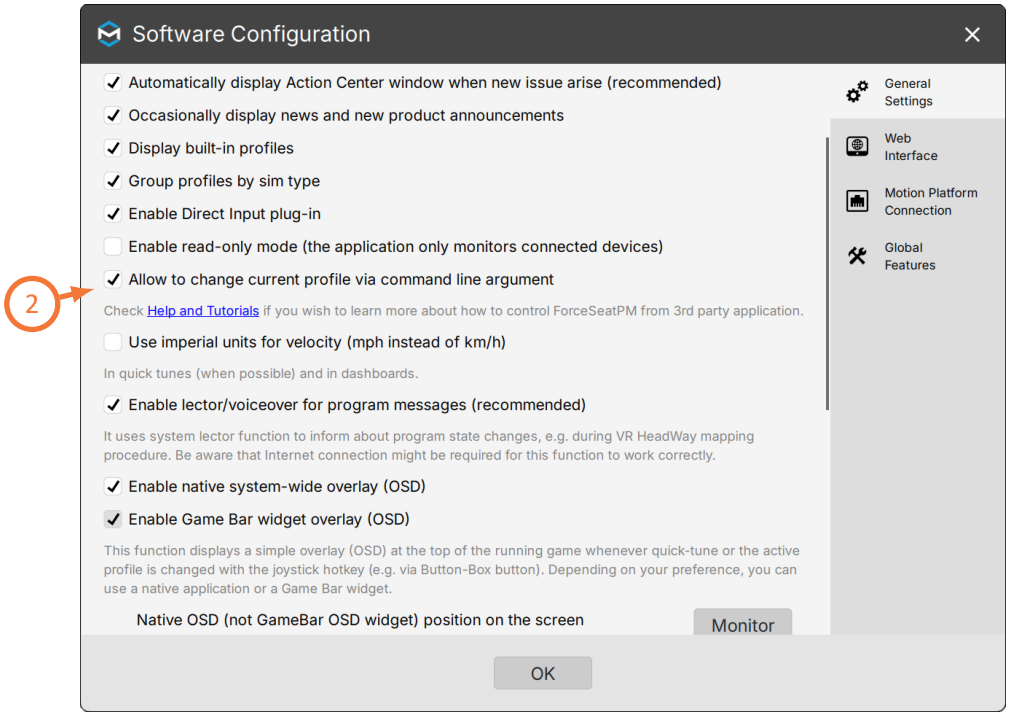
By default all telemetry examples force ForceSeatPM to activate one of the built-in profiles. This is hardcoded in examples source code.

If you want the **SIM** to use different profile, search source code for **ActivateProfile** (1) and update to use new profile name or remove completely this function call from your source code (if you want your users to change profiles themselves).

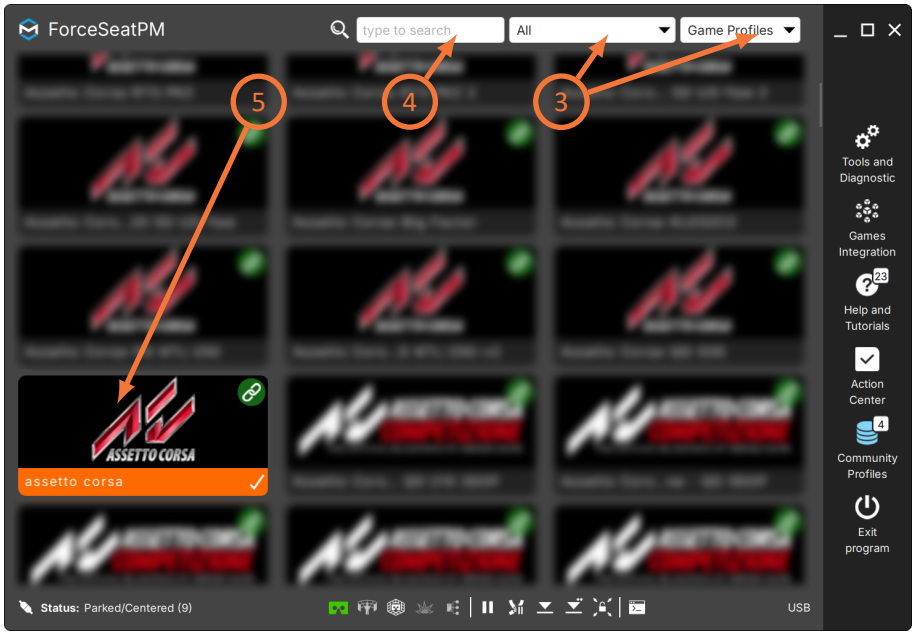
```
FSMI_Handle api = ForceSeatMI_Create();
if (! api)
{
    // ...
    return -1;
}

// Activate appropriate ForceSeatPM profile. If you have dedicated app id,
// remove ActivateProfile calls rom your code
ForceSeatMI_SetAppID(api, "");
ForceSeatMI_ActivateProfile(api, "SDK - Vehicle Telemetry ACE");
```

1

Alternatively you can configure **ForceSeatPM** to ignore external profile change requests and to allow only manual profile change by users. In order to do it, click **Tools and Diagnostic**, then **Software Configuration** and uncheck (2).

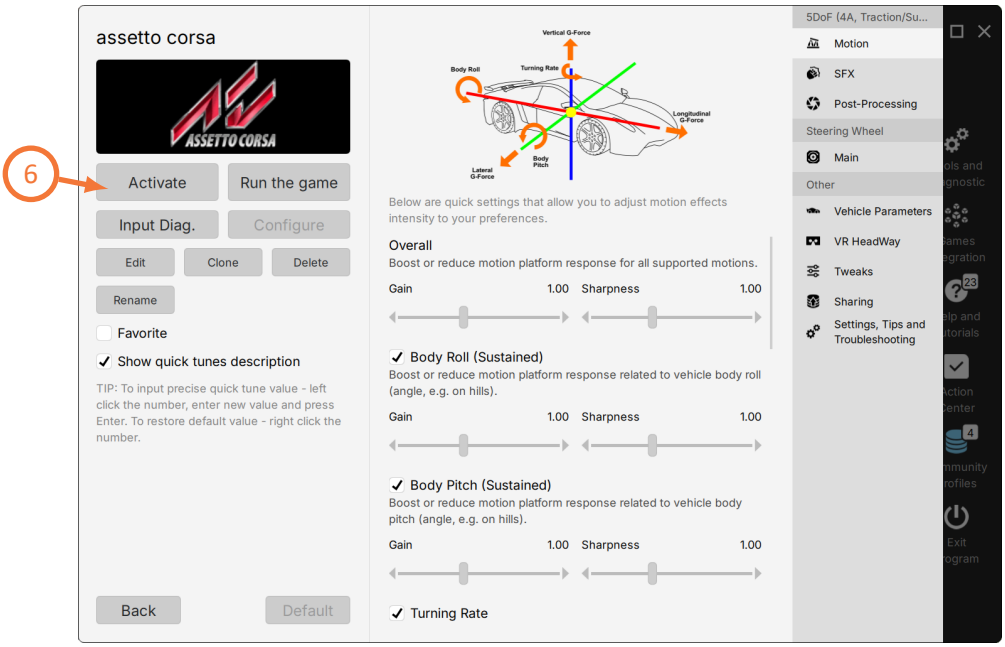


If you want to change profile from **ForceSeatPM**, make sure that correct view filter is selected (3). You can also type ”sdk” in search area to temporary hide other profiles (4). Then click on profile to open details (5).



When the profile is active, it is being highlighted and there is a check mark next to the profile name.

To activate a profile double click on it or click **Activate** (6).



TIP

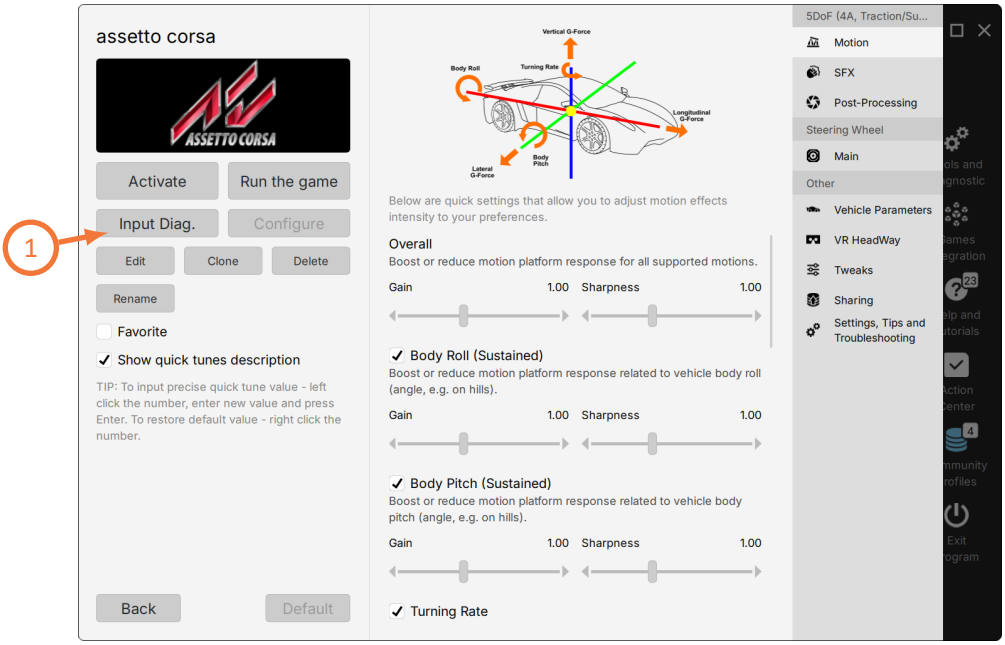
Two sets of profiles exist: **SDK - Vehicle Telemetry** (under **Standard + user's** view) and **SDK - Vehicle Telemetry ACE** (under **ACE + user's** view). The first one is deprecated and is being kept mainly for backward compatibility. For new applications it is **RECOMMENDED** to use **SDK - Vehicle Telemetry ACE** together with **FSMI_TelemetryACE**.

1.7 Basic diagnostic

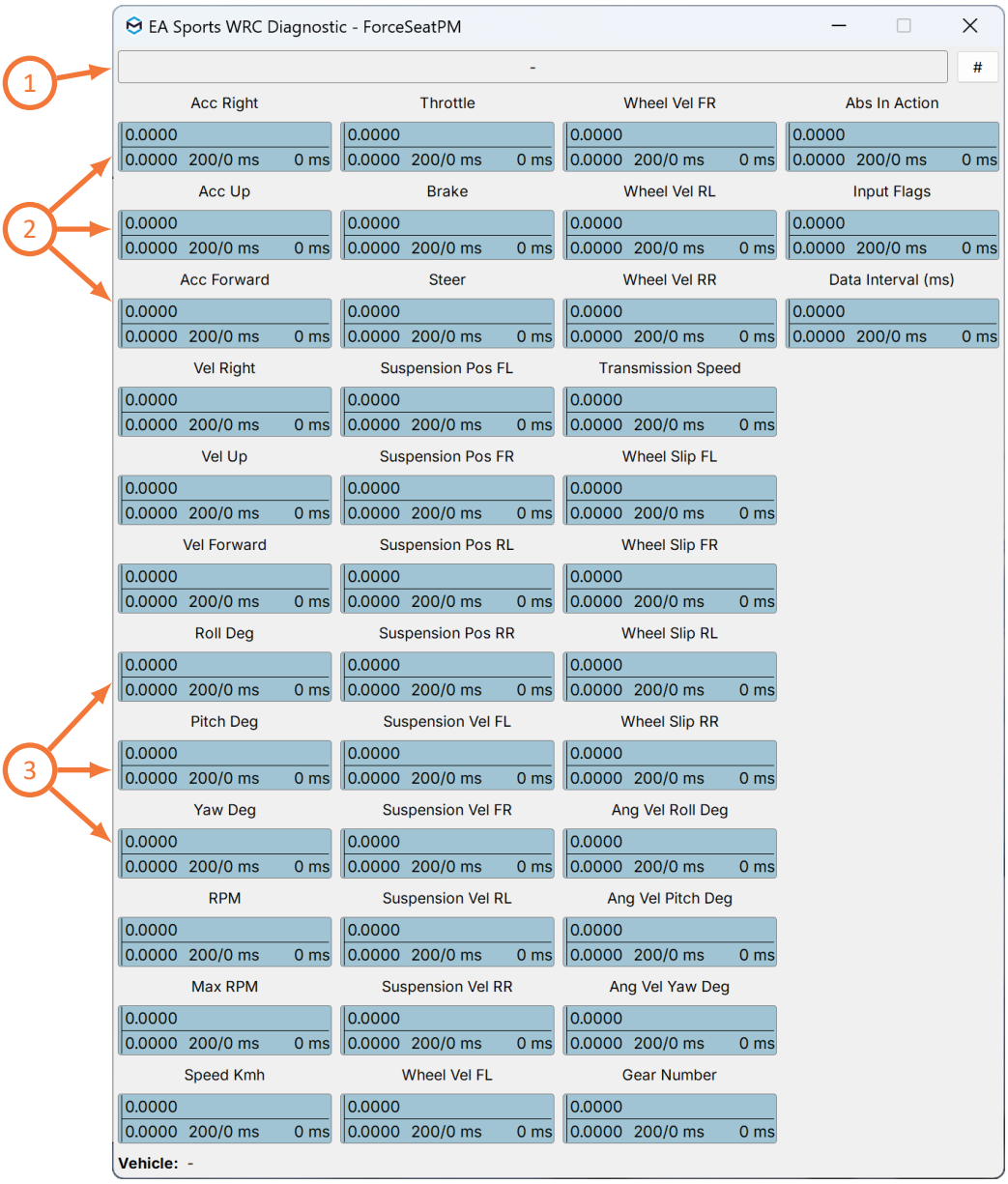
Once the **SIM** has been started to send vehicle telemetry data the next step is to confirm that all necessary fields are filled correctly and that correct output to the motion platform is being generated and then sent.

1.7.1 Input data diagnostic

Open profile details and click **Input Diag.** (1).

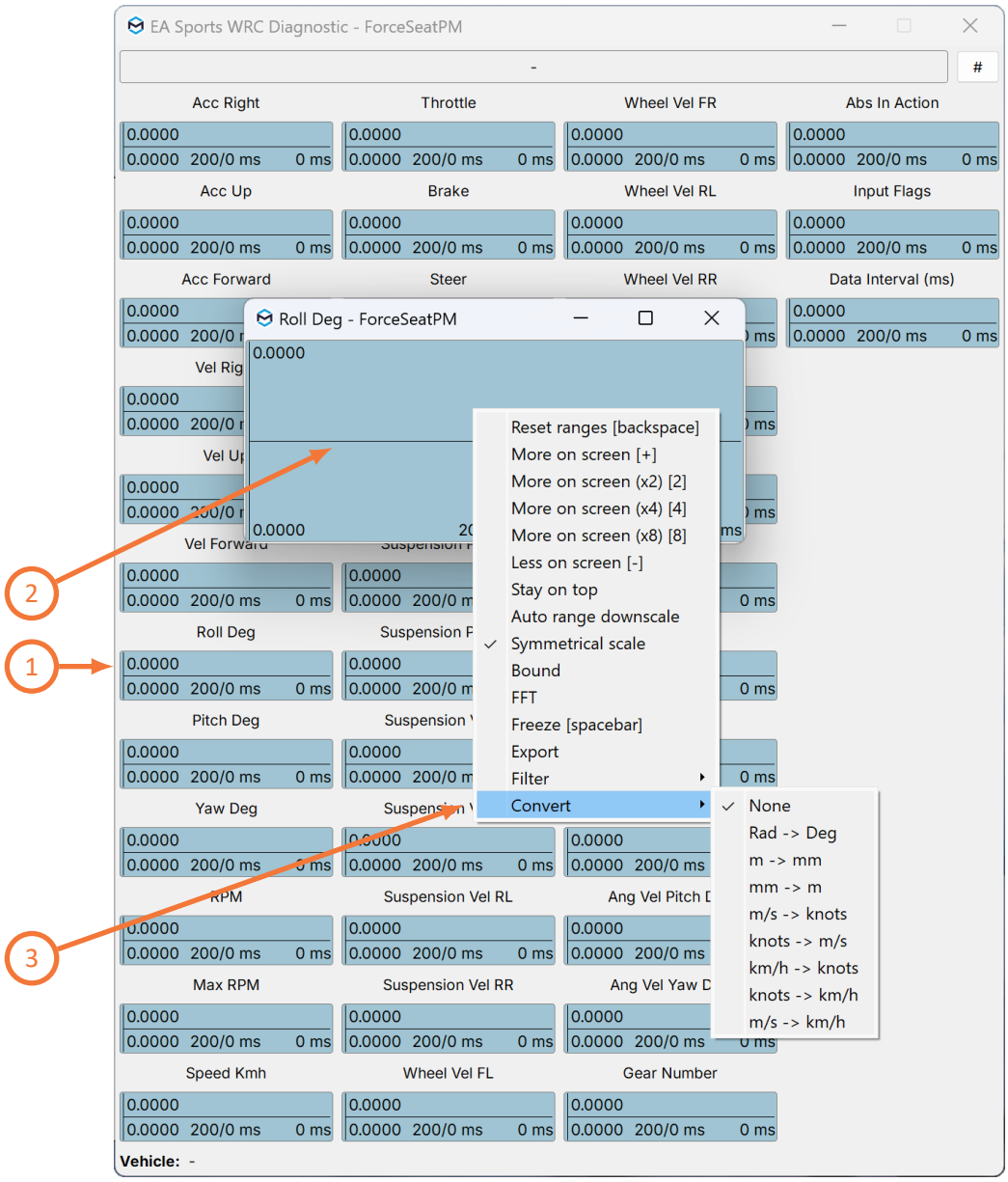


Run the **SIM** in windowed mode so you can still see all graphs and then make sure that data for all mandatory fields is being received by the **ForceSeatPM**. If all fields are being filled correctly by the **SIM**, the graphs will show changes while your are driving vehicle in the **SIM**.



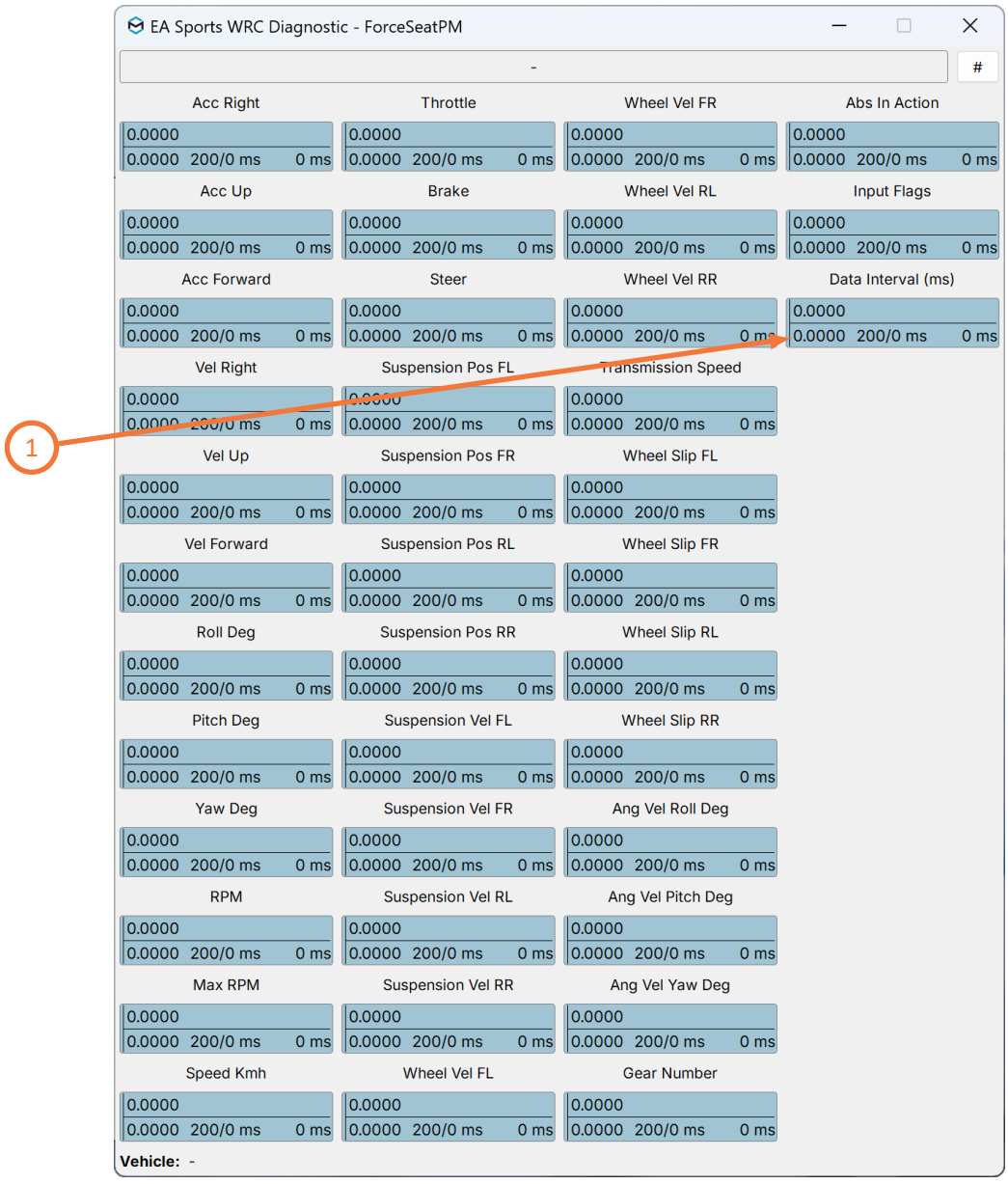
- (1) - confirm that status changes to **PAUSED** when the **SIM** is paused and returns back to **RUNNING** when the **SIM** resumes operation.
- (2) - confirm that **Acc Right**, **Acc Up** and **Acc Forward** are correct. You can left click on the single graph view to enlarge.
- (3) - confirm that **Roll**, **Pitch** and **Yaw** are correct. You can left click on the single graph view to make it bigger.

Once presence of the all necessary data is confirmed, double check units. Angular velocities are received in [$\frac{rad}{s}$] but display format can be changed in the **ForceSeatPM** to [$\frac{rad}{°}$]. In order to change display format, open context menu (right click) on smaller (1) or bigger (2) graph and then select **Convert** (3)

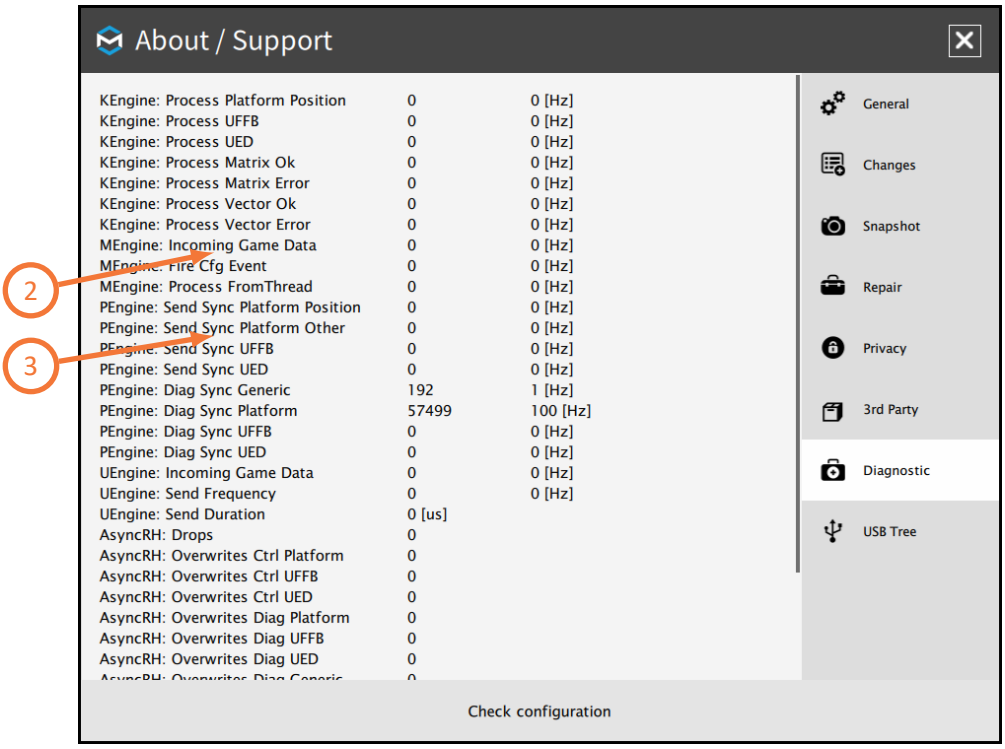


1.7.2 Input data receiving frequency

Telemetry data frequency can be checked in numerous places. First way is to check **Data Interval** (1) in **Input Diagnostic** - it will also show how the rate fluctuates.



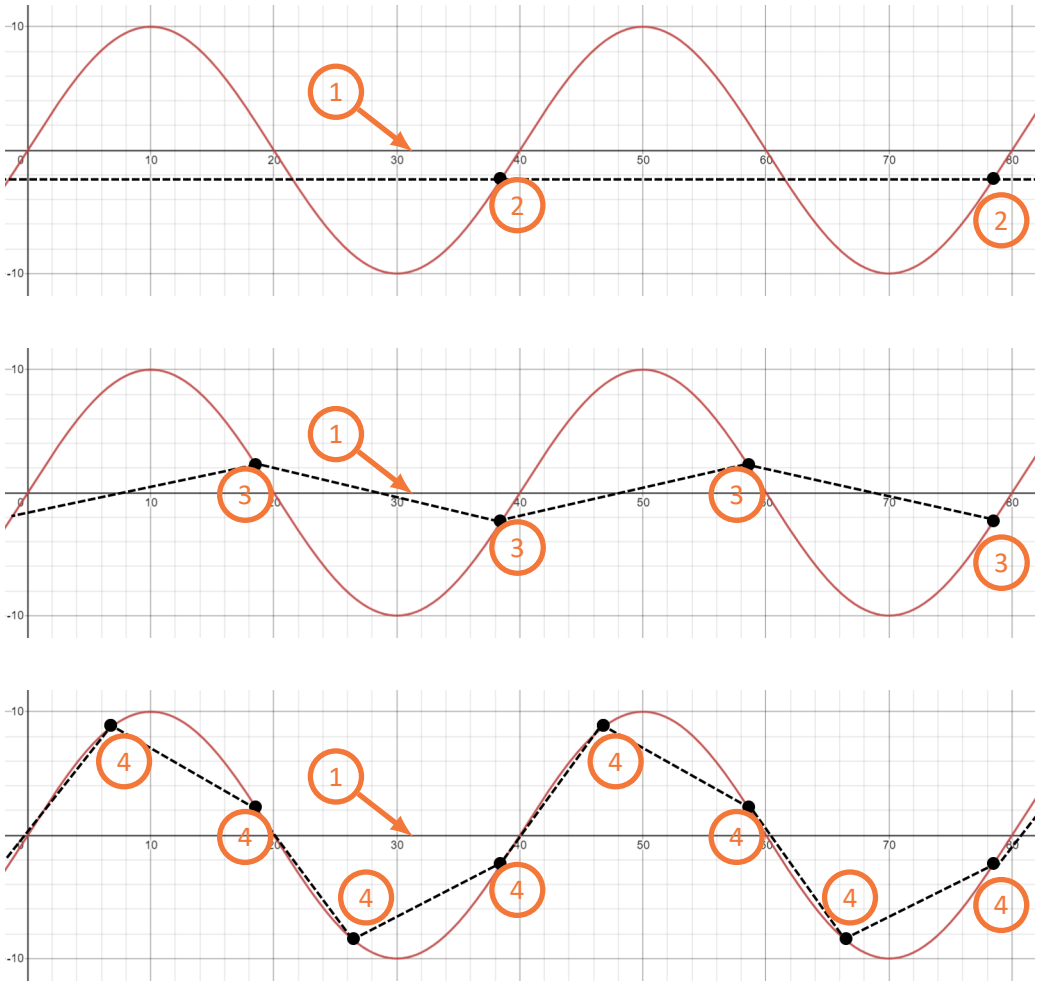
Second place to check the **SIM** telemetry rate is **Diagnostic** tab in **Help and Support**. It is possible to check there both telemetry rate (2) but also **motion-cueing** algorithm (**ACE**) operation rate (3).



1.7.3 Required telemetry data frequency

The **ACE** operation frequency is independent of the **SIM** telemetry data rate, but there are some requirements for telemetry data rate if the **SIM** wants the motion platform to reproduce vibrations (embedded in linear accelerations) of specified frequency.

For **rectangle** type vibrations (rarely used), minimal required telemetry rate is 2x the vibration frequency. For **sinus** type vibrations (the most common used), minimal required telemetry rate is 4x the vibration frequency.



- (1) - the frequency of the vibration is 25 [Hz] which gives period of 40 [ms].
- (2) - if the telemetry rate is equal to 1x vibration rate, the **ForceSeatPM** receives constant signal - exact value (amplitude) depends on phase shift.
- (3) - if the telemetry rate is equal to 2x vibration rate, the **ForceSeatPM** might still receive value that is close to zero (or at least much less than required amplitude) - depending on phase shift.
- (4) - if the telemetry rate is equal to 4x vibration rate, the **ForceSeatPM** receives some approximation of the sinus which should be good enough to reproduce it on the motion platform.

Alternative solution is to use **SFX** system that allows to generate vibrations per actuator with the main difference being that the vibrations are being generated by the motion controller or by actuator/motor driver - not on PC. It means that vibrations frequency does not depend on the **SIM** FPS, vehicle physics engine operation rate, telemetry data frequency or even on the **ACE** operation frequency.

Below is code snippet that shows how to use SFX. Please notice that **ForceSeatMI_SendTelemetryACE3** is called instead of **ForceSeatMI_SendTelemetryACE**.

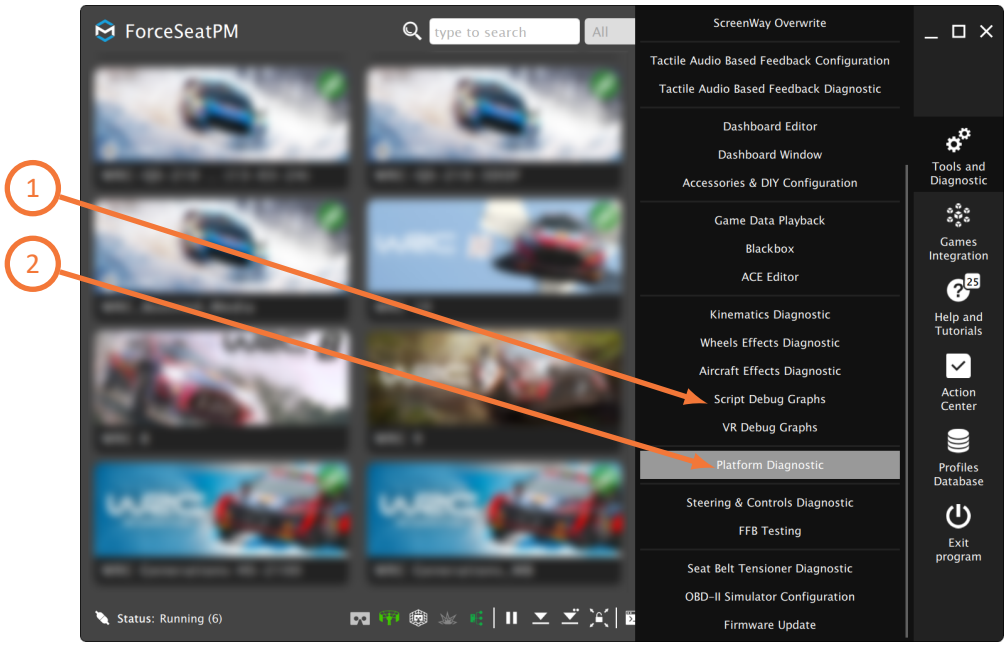
```
// ...
FSMI_SFX sfx;
memset(&sfx, 0, sizeof(sfx));
sfx.structSize = sizeof(sfx);

// Configure SFX
// Level 2 is supported by "PS" and "QS" motion platforms,
// Level 3 and 4 are supported by "QS" motion platforms.
sfx.effects[0].type      = FSMI_SFX_EffectType_SinusLevel2;
sfx.effects[0].area      = FSMI_SFX_AreaFlags_FrontLeft;
sfx.effects[0].amplitude = 0.05f;
sfx.effects[0].frequency = 0;
sfx.effectsCount         = 1;

// ...
ForceSeatMI_BeginMotionControl(api);
while (GetKeyState('Q') == 0)
{
    // ...
    sfx.effects[0].frequency = (byte)(sfxIterator);
    ForceSeatMI_SendTelemetryACE3(api, &telemetry, &sfx, nullptr, nullptr);
    ++sfxIterator;
    if (sfxIterator > 50)
    {
        sfxIterator = 0;
    }
    // ...
}
ForceSeatMI_EndMotionControl(api);
// ...
```

WARNING

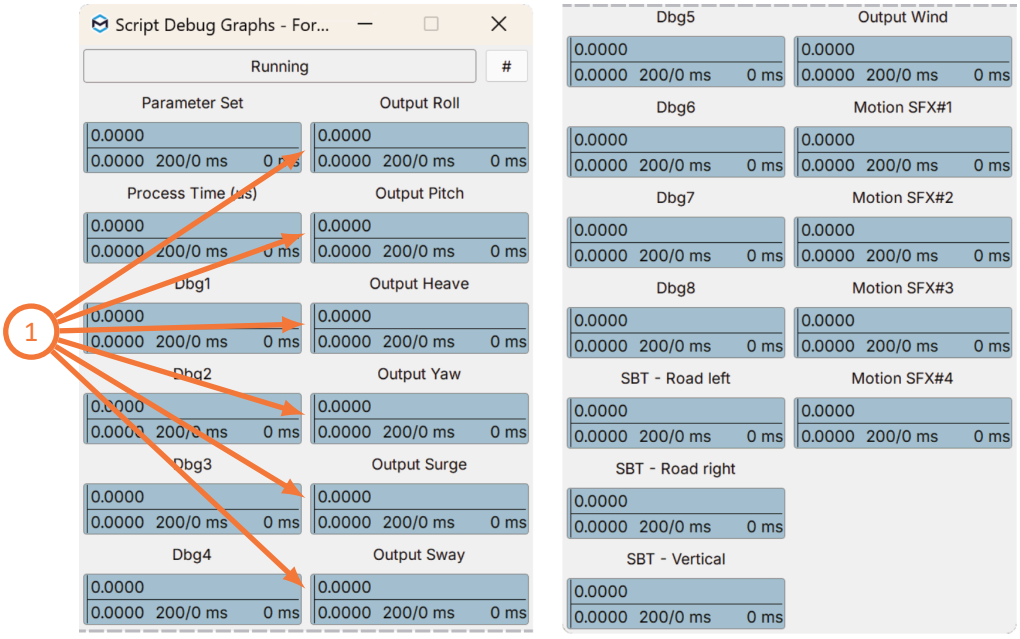
The **SIM** FPS, vehicle physical engine operation frequency and in the result telemetry sending frequency might be different when the **SIM** is executed under **Unreal Engine** editor, **Unity editor** or other editor. It is recommended to run the **SIM** as standalone prebuild release binaries when motion cueing algorithm is being tuned.

1.7.4 Output data diagnostic

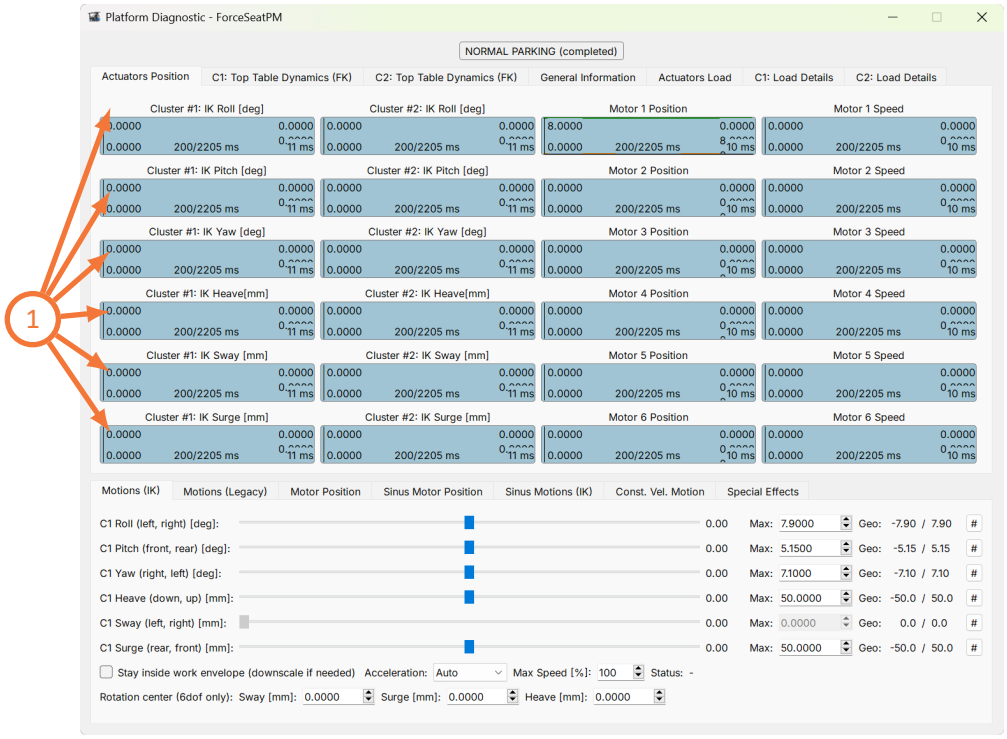
Result of the motion cueing algorithm operation can be checked in following places - **Script Debug Graphs** (1) or in **Platform Diagnostic** (2).



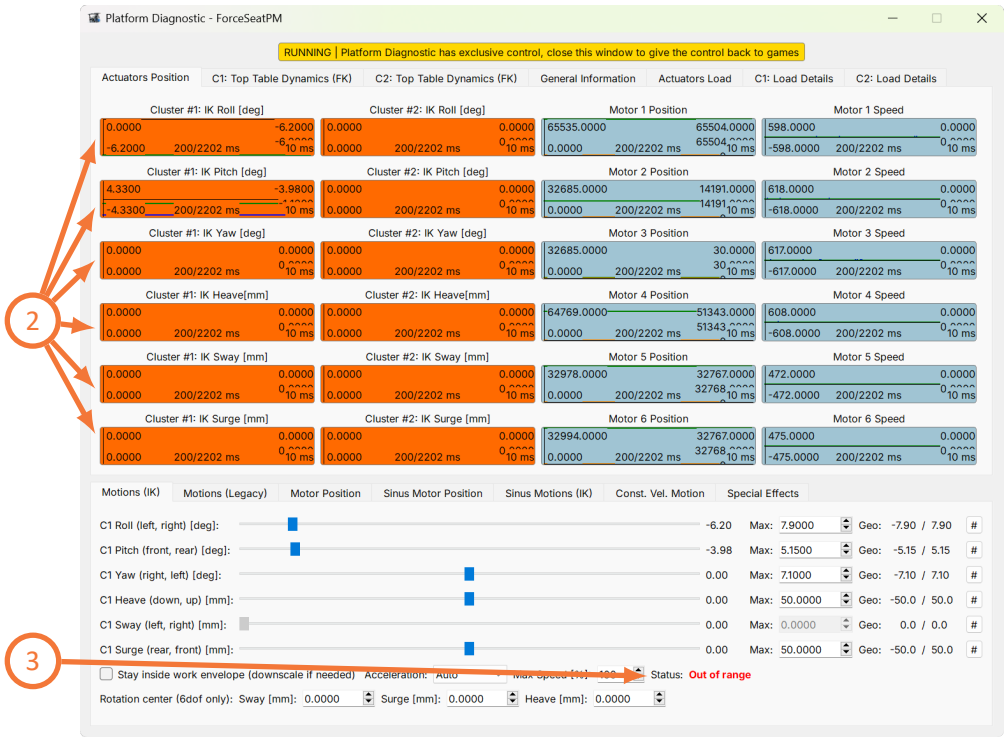
In **Script Debug Graphs** you can check output to the motion platform (2). The **ACE** diagnostic is covered in another chapter. The output to the motion platform does NOT indicate if the requested motion combination is within the work envelope - this can be checked only in **Platform Diagnostic**.



The **Platform Diagnostic** is able to perform different tests on the motion platform to determinate if the motion platform is operating correctly, but from the motion-cueing algorithm point of view the most important components are **IK Roll**, **IK Pitch**, **IK Yaw**, **IK Heave**, **IK Sway** and **IK Surge** from **Actuators Position** tab. These graphs display how requested position (orientation and translation) of the **top table** changes over time (1).



Once the **ACE** generates required **top table** position, then the kinematics processor calculates required actuators extends (sometime named also as actuator position or arm angle).



If the specified combination of motions is outside of the **top table**'s work envelope, the motion is downscaled back to work envelope boundaries. The **Platform Diagnostic** indicates occurrence of this event by displaying IK graphs in **ORANGE** (2) and displaying **"Out of range"** status (3). Each graph contains two plots, first is required IK position, second is downscaled achievable IK position that is going to be used.

> **INFORMATION**
>
> It is perfectly acceptable if out-of-work-envelope issue occurs once in a while in some extreme cases (e.g. vehicle hits a wall). However if this case starts to occur too often, the motion-cueing algorithm parameters might require some adjusting.

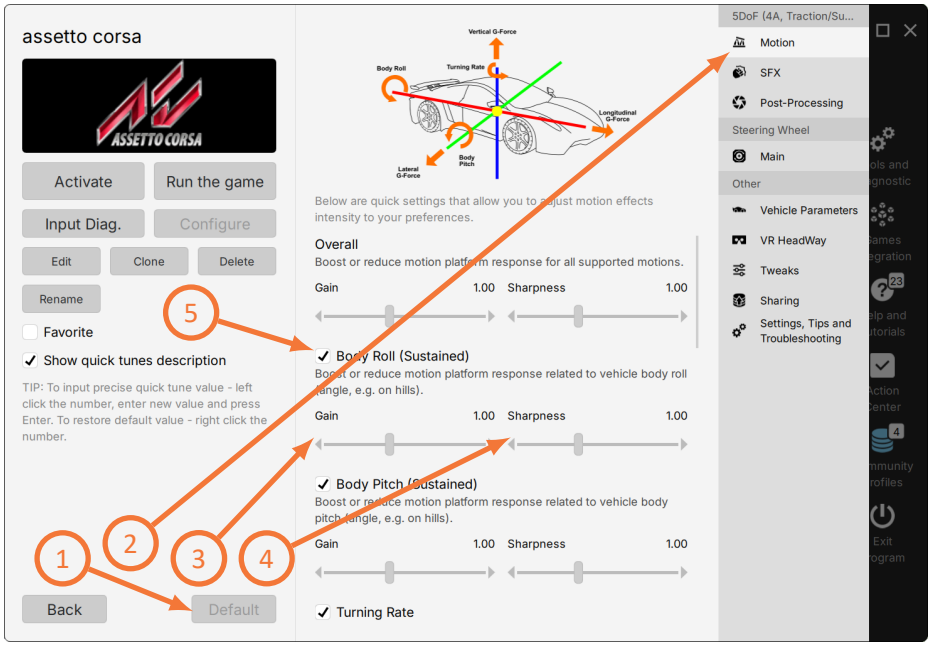
1.8 Profile parameters tuning

When the integration with the **SIM** works correctly and the motion platform operation (**top table** motions) is close to expected with only minor tweaking required, then the easiest solution is to use **quick tunes** system built-in in the **ForceSeatPM** to adjust the **ACE** operation.

> **INFORMATION**
>
> If for some reason serious changes in the motion platform operation are required, then it is recommend to make full copy (NOT shallow copy) of the built-in profile and use **ACE Editor** to retune motion-cueing algorithm. This scenario is covered in a different chapter.

1.8.1 Main motion quick tunes

Open built-in profile details. Before you begin tuning, click **Default** (1) to establish common baseline for tuning. Switch to **Motion** (2) tab and start adjusting quick tunes Gain (signal increase or decrease)(3) and sharpness (signal more detailed or smoother)(4). Change one tune a time and always use **SIM** to confirm how new value affects motion platform operation. Untick a box next to a motion effect to disable it completely (5).



Following motion quick tunes are available to tweak the **ACE** operation of main motion movements:

- **Overall** - it is a global tune that affects all other tunes (except **Weight Transfer Bias**).
- **Body Roll** is a relative constant angle related to track surface (e.g. hills) or angular velocity (roll rate) that represents intermittent vehicle body rotation. The latter is usually meaningful only in flight simulators. The first component is controlled by **Body Roll (Intermittent)** quick tune, the second by **Body Roll (Sustained)** quick tune.
- **Body Pitch** is a relative constant angle related to track surface (e.g. hills) or angular velocity (pitch rate) that represents intermittent vehicle body rotation. The latter is usually meaningful only in flight simulators. The first component is controlled by **Body Pitch (Intermittent)** quick tune, the second by **Body Pitch (Sustained)** quick tune.
- **Turning Rate** (only for platform capable of yaw movement) - it modifies the transformation of vehicle angular velocity (yaw rate) into **top frame** yaw.
- **Vertical G-Force (Intermittent** (not available in 2DoF) - it modifies the transformation of vertical linear acceleration into **top frame** heave.
- **Longitudinal G-Force (Intermittent** (only for platform capable of surge movement) - it modifies the transformation of longitudinal linear acceleration into **top frame** surge.
- **Longitudinal G-Force (Sustained)** - it modifies the transformation of longitudinal linear acceleration into **top frame** pitch. This is mainly for sustained accelerations and it is also known as **Tilt Coordination**.
- **Lateral G-Force (Intermittent** (only in platform capable of sway movement) - it modifies the transformation of lateral linear acceleration into **top frame** sway.
- **Lateral G-Force (Sustained)** - it modifies the transformation of lateral linear acceleration into **top frame** roll. This is mainly for sustained accelerations and it is also known as **Tilt Coordination**.
- **Weight Transfer Bias** - it allows to change proportion (bias) between intensity of acceleration and deceleration (braking) effects. This purely subjective, depends on user's preferences, there is no science behind this bias.
- **Road Harshness** - modifies the vertical low amplitude movements caused by the road harshness and bumps on the road. For flight simulation use **Param set #2** for the on-the-ground scenario.
- **Sideslip** - increase or decrease platform's response to oversteer sideslip. If yaw is not available, it can be simulated by roll movement. Moving the pivot point (center of gravity) is available in **Vehicle Parameters** - **CoG Bias**.

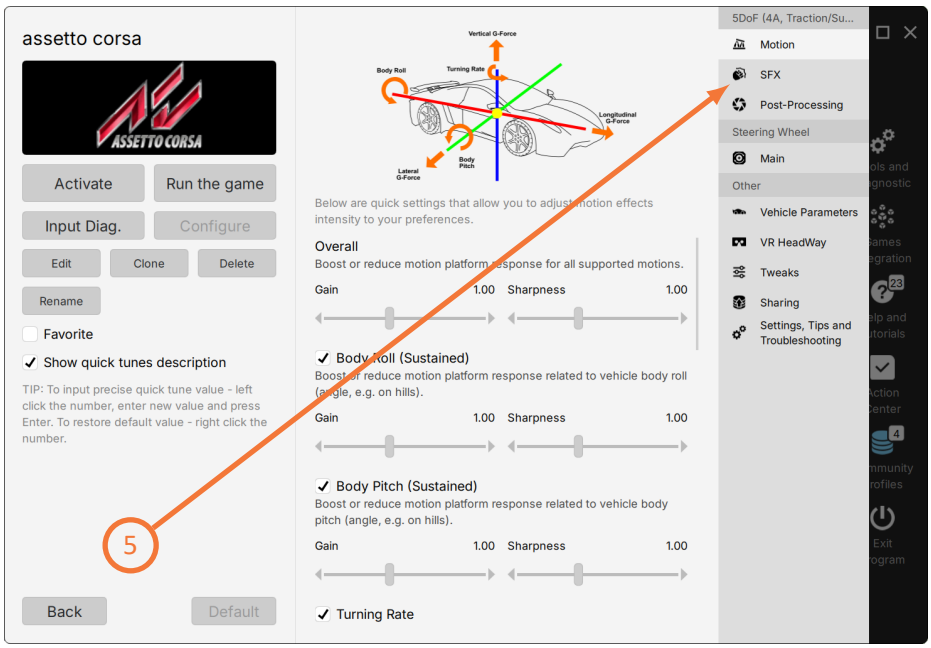
Motion tunes for flight simulations only:

- **Gravity Correlation for Lateral Acceleration** - removes gravity vector from lateral acceleration to make it more natural. This will influence other maneuvers.
- **Gravity Correlation for Longitudinal Acceleration** - removes gravity vector from longitudinal acceleration to make it more natural. This will influence other maneuvers.
- **Flight/Ground Harshness** - amplifies or reduces the low amplitude turbulence movement and uneven runway effects.

INFORMATION

Not all game/simulations will have all the motion tunes listed above.

1.8.2 Special effects quick tunes



Switch to **SFX** tab to start adjusting special effects of the motion platform:

- **Rev Limiter Intensity** - modifies the intensity of rev limiter additional vibrations when vehicle engine reaches maximum revolutions. Go to **Vehicle Parameters** for more tuning options.
- **Rev Limiter Frequency Bias** - modifies the frequency of rev limiter additional vibrations when vehicle engine reaches maximum revolutions. Go to **Vehicle Parameters** for more tuning options.
- **Gear Change Effect Time** - modifies the time (duration) of additional gear change effect which overwrites the longitudinal acceleration signal of gear changes.
- **Gear Change Up Shift Intensity** - modifies the intensity of up shifts for the additional gear change effect. It is artificially calculated from current vehicle speed. It also is able to partially suppress gear change effect from longitudinal acceleration (when set to 0).
- **Gear Change Down Shift Intensity** - modifies the intensity of down shifts for the additional gear change effect. It is artificially calculated from current vehicle speed. It also is able to partially suppress gear change effect from longitudinal acceleration (when set to 0).
- **Wheel Forward Slip/Lock** - modifies additional vibration when front or rear wheels forward slip because of traction loss or brake lock. More options on wheel slip are available at **Vehicle Parameters**.
- **Wheel Slip Angle** - modifies additional vibration when wheels suffer from lateral slip. It activates when maximum allowed wheel slip angle is exceeded. More options on wheel slip are available at **Vehicle Parameters**.
- **Rumble Strip Frequency** - modifies the frequency of rumble strips effect in relation to vehicle forward velocity.
- **Rumble Strips Intensity** - modifies the intensity of rumble strips effect in relation to vehicle forward velocity. A difference between setting for 20km/h and for 300km/h that differs from each other will be automatically calculated by the program.
- **Violent Movement Threshold** - modifies the threshold after which the suppression of violent movements occurs to prevent rapid and unpleasant motion of platform (during crashes, spinouts and big jumps in racing).

- **Violent Movement Suppression Time** - sets violent movement suppression time (in seconds).
- **Engine Vibration Frequency** - sets a graph of the vibrations frequency at specific revolutions per minute.
- **Engine Vibration Intensity** - sets a graph of the vibrations intensity at specific revolutions per minute.
- **Engine Vibration Location** - moves the longitudinal center point of engine vibrations front or back.
- **ABS Active** - modifies vibrations frequency and intensity when Anti-lock Brake System activates (if the vehicle exceeds the traction limit when braking).
- **Traction Control Active** - modifies vibrations frequency and intensity when Traction Control activates (if the vehicle exceeds the grip limit when cornering or accelerating).

Special effects for flight simulations only:

- **Gear opening effect** - increases or decreases a landing gear effect
- **Artificial Tarmac Effect** - artificially generated effect to substitute the vertical acceleration effect to amplify on-the-ground road harshness.
- **Positive G Warning** - controls the frequency and intensity of vibration indicating exceeding the positive (plane is getting heavier) G-warning threshold. Connected with the settings in **Aircraft parameters**.
- **Negative G Warning** - controls the frequency and intensity of vibration indicating exceeding the negative (plane is getting lighter) G-warning threshold. Connected with the settings in **Aircraft parameters**.
- **Effective Translation Lift** - controls frequency and intensity of vibrations when a helicopter enters an ETL window.
- **Stall Shudders/Vortex Ring State** - controls frequency and intensity of vibrations when a plane stalls or helicopter enters VRS state.
- **Tail Rotor Vibration Frequency** - controls frequency of vibrations imitating tail rotor operating, divided into RPM ranges. Applies only to helicopters.
- **Tail Rotor Vibration Intensity** - controls intensity of vibrations imitating tail rotor operating, divided into RPM ranges. Applies only to helicopters.
- **Tail Rotor Vibration Location** - moves the center point locating the tail rotor vibrations placement. Applies only to helicopters.
- **Artificial Cannon Fire Intensity** - artificially generated effect to substitute the longitudinal acceleration part of using a fire cannon. Controls the vibration intensity. Does not work in unlimited weapons mode.
- **Artificial Cannon Fire Frequency Bias** - artificially generated effect to substitute the longitudinal acceleration part of using a fire cannon. Controls the vibration frequency bias. Does not work in unlimited weapons mode.
- **Artificial Cannon Fire Min Duration** - artificially generated effect to substitute the longitudinal acceleration part of using a fire cannon. Controls the minimum duration (in milliseconds) to ensure smoothness.
- **Telemetry Cannon Fire Effect Suppressor** - suppresses or increases the cannon fire effect from telemetry to distinguish it from from the artificially generated one. Move the duration slider maximum to the left to turn it off. It is recommended to use only one effect - the artificial or telemetry data one.
- **Seat Eject Effect** - increase or decrease duration of the seat ejection effect. ”Recenter after” defines the time after which the platform will go back to center position.
- **Missile Launch Effect** - artificially generated effect to substitute the longitudinal and lateral

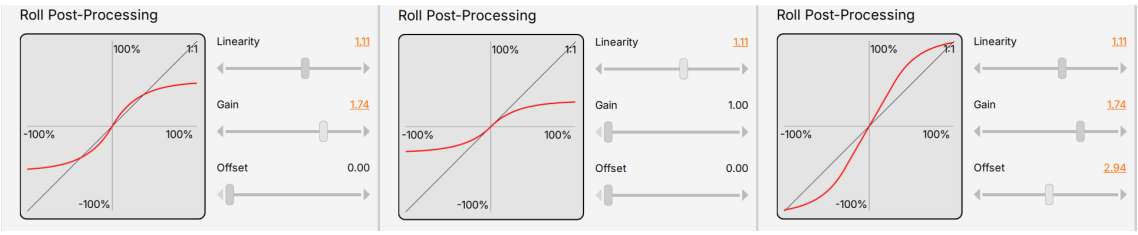
acceleration part of missile launch effect. Controls the frequency, intensity and duration of the vibrations.

- **Flare/Chaff Dispense Effect** - control the frequency, intensity and duration of vibration during flare or chaff launching.
- **Cockpit Shake** - controls the vibration of the platform simulating the cockpit vibration in the roll and pitch axes. Make sure to set the threshold which specifies cut-off amplitude.

INFORMATION

Not all game/simulation will have all the special effect listed above.

1.8.3 Post-processing quick tunes



Switch to Post-processing to start adjusting roll, pitch, yaw, heave, sway and surge. Post-processing acts as filter for sim/game data input and reduces linearity on incoming data. The horizontal X axis represents input data and vertical axis Y represents output data. The red line represents the degree of signal change.

- Linearity is able to reduce long-travel movements leaving the minor movements intact.
- Gain amplifies or reduces the overall signal - boosting or reducing linearity of input data.
- Offset adjusts the size of the signal that will be modified - increasing the offset will result in boosting or decreasing medium travel movements, instead of small ones.

INFORMATION

List of quick tunes in Post-processing depends on type of game/simulation and amount degrees of freedom that the motion platform is able to produce.

WARNING

Post-processing is not intended to serve as a range restriction for safe motion platform operations. This feature was added as a practical way to assist customization of motion platforms and suit personal preferences. This is **NOT** a safety feature. Even with very little linearity, if input signals have peaks, the top frame may still reach extreme positions. There must always be sufficient open space for the platform to move in full motion range.

1.8.4 Vehicle Parameters

Switch to **Vehicle Parameters** tab to start adjusting additional parameters which influence the Motion and SFX tunes.

- **Rev Limiter** - sets operating boundaries for rev limiter effect. ”Max Gear” determines the limit on effect generating gear and ”Offset” sets an amount of RPMs before maximum revolution per minute of an engine that the effect will start.
- **Wheel Forward Slip/Lock Threshold** - defines a percentage threshold of a forward wheel grip loss before the effects will be generated with a distinction between front and rear wheels.
- **Wheel Slip Angle Threshold** - defines degree threshold of a lateral wheel grip loss before the effects will be generated with a distinction between front and rear wheels. ”Escalation” determines the range of degrees when the effect generates from minimum to maximum (for the effect to be at its maximum from the start - set to 0).
- **Wheel Base** - sets the distance in meters between the center points between front and rear wheels. Affects multiple different effects.
- **Turning Circle** - sets a vehicle turning circle for other effects to calculate correctly. Go to Tools and diagnostics → Wheels Effects Diagnostics to see the conversion from steering wheel input into front wheels angle.
- **CoG Bias (Center of Gravity Bias)** - sets the center longitudinal point of the vehicle (1 - rear, 0 - front). Crucial for oversteer and understeer.

INFORMATION

Parameters listed above are included and will generate a graph in the ”Tools and Diagnostics” → ”Wheels Effects Diagnostics” or Profile → ”Input diagnostics” tab.

1.8.5 Aircraft Parameters

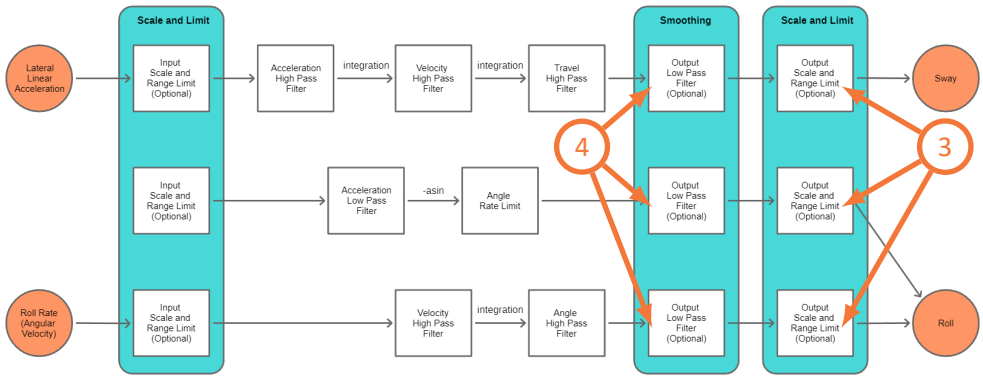
Switch to **Aircraft Parameters** tab (in flight simulations profiles only) to start adjusting additional parameters which influence the Motion and SFX tunes.

- **ETL - thresholds** - sets the Indicated Airspeed threshold (in knots) for the Effective Translational Lift effect to work. ”Low” sets a threshold when the effect starts and ”High” ends it.
- **VRS - thresholds** - sets the thresholds for Vortex Ring State phenomenon specific for currently selected aircraft - Indicated Airspeed in knots and Vertical Velocity in meters per seconds.
- **Maximum AoA** - sets the threshold for a maximum Angle of Attack degree after which the warning effect will start. ”Warn before” defines how many degrees before maximum AoA the warning will go start.
- **G Warnings** - sets a threshold for positive and negative G-force exceeding for a warning effect to start.

INFORMATION

All parameters listed above are included and will generate a graph in the ”Tools and Diagnostics” → ”Aircraft Effects Diagnostics” tab.

1.8.6 Software limitations

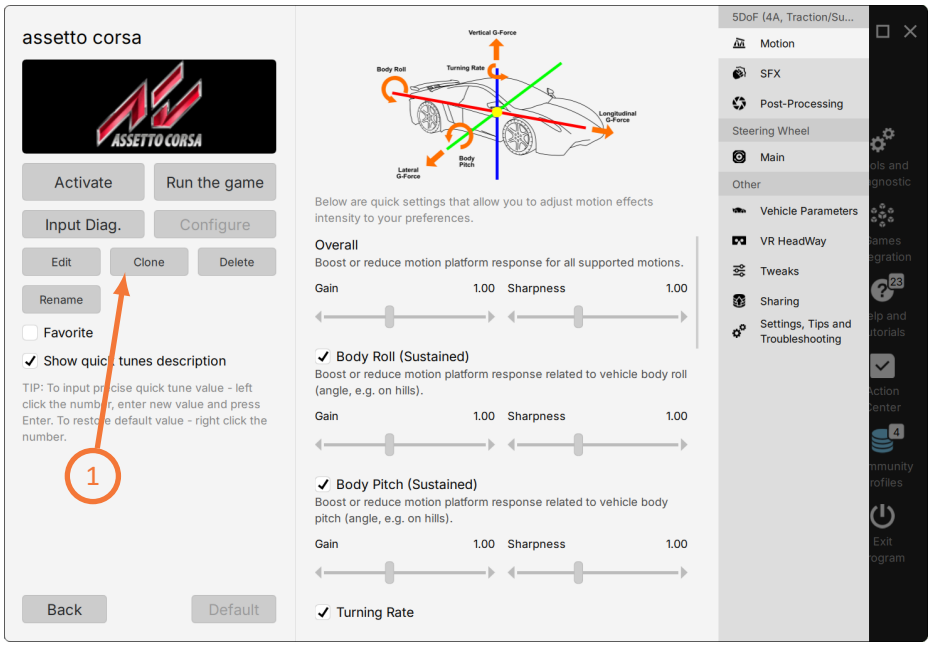


Not all tunes are available for all motion platform models. **Gain** (3 - **Scale and Limit** functional block) is a coefficient that is applied to the output of the **ACE** to amplify the signal. **Sharpness** (4 - **Smoothing** functional block) controls low-pass filter applied to the output signal. More detailed description can be found in the chapter about the **ACE Editor**.

1.8.7 Built-in profile with custom name

If it is required to hide all games profiles and other built-in profiles, there are a few steps that will help you to adjust the **ForceSeatPM** GUI to your needs.

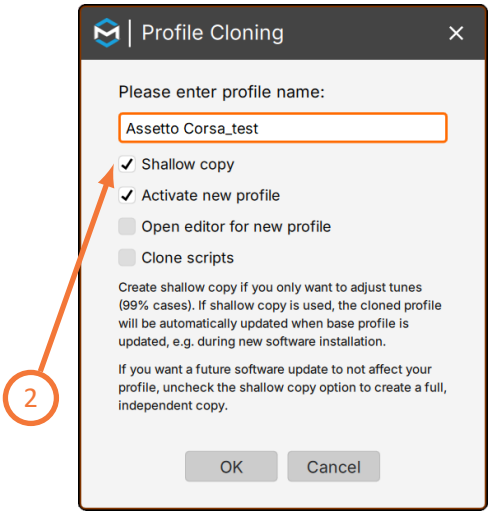
First step is to clone built-in profile (1)



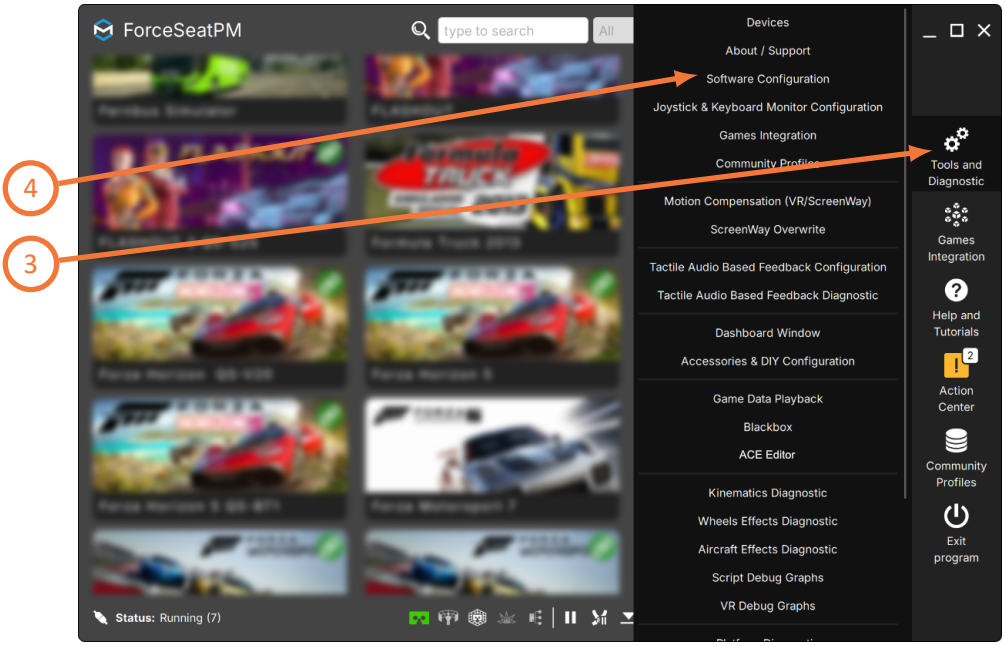
It is suggested to keep it a **shallow copy** (2). The shallow copy:

- it keeps reference to original built-in profile;
- it uses motion scripts and all other configuration from original built-in profile;
- only quick tunes values are unique for the new profile.
- changes to original profile apply also to the cloned one

When shallow copy is used then the new profile is automatically updated when the **ForceSeatPM** is updated. If you do not plan to edit the motion script, we RECOMMEND to use shallow copy profiles.

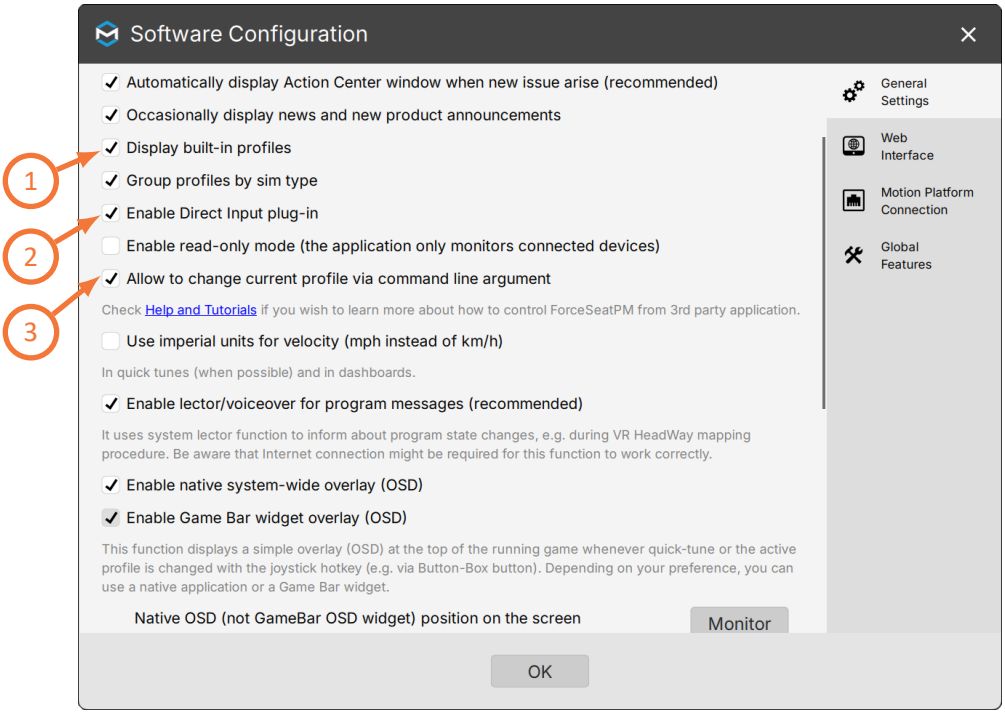


Next go to **Tools and Diagnostic** (3) and open **Software Configuration** (4).

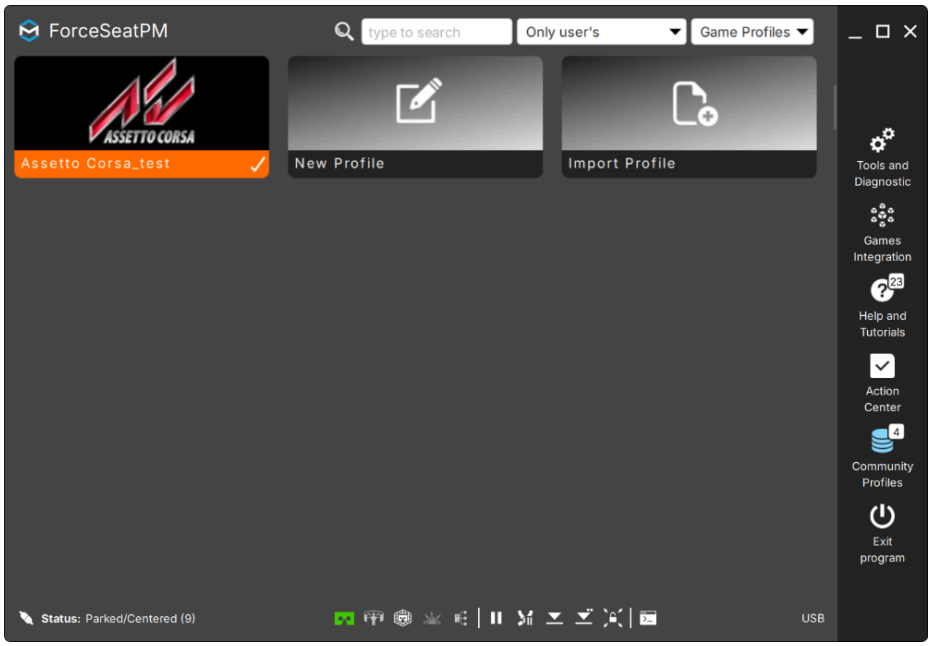


In **Software Configuration** you can find following parameters you might want to change:

- (1) - **uncheck** to hide all built-in profiles and leave only your custom profiles.
- (2) - **uncheck** to disable option to control motion platform with joystick.
- (3) - **uncheck** to make sure that the **SIM** won't change the active profile.



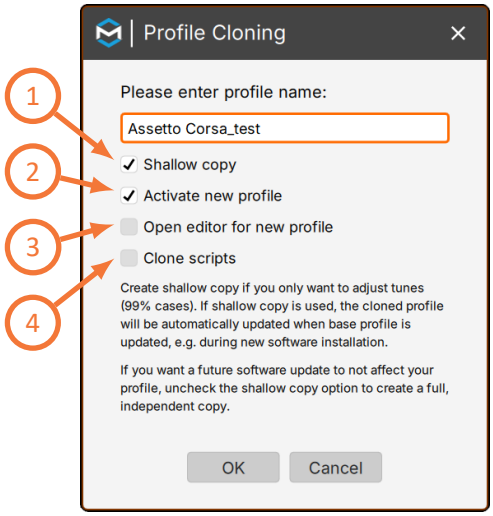
After **ForceSeatPM** restarts, there will be only user's cloned profile on the list:



Now you can start adjusting quick tunes in the created profile - the procedure is exactly the same as described in the previous section.

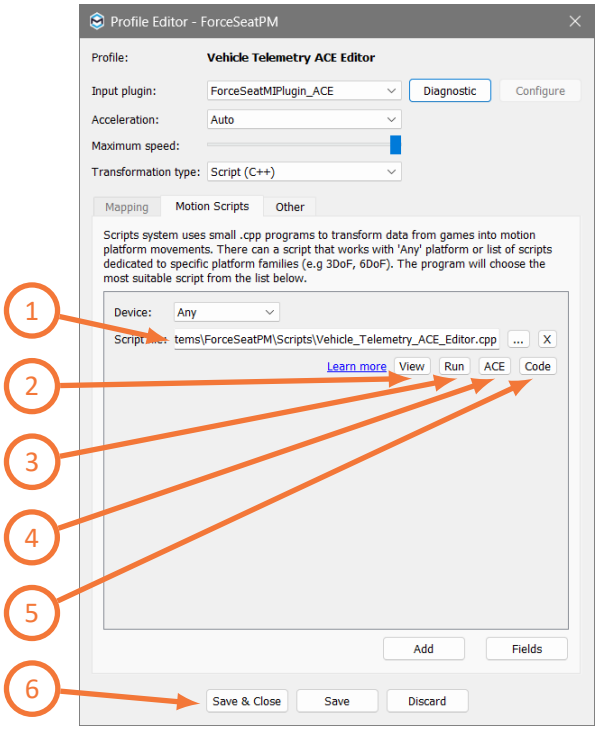
1.8.8 Editing profile with ACE Editor

The **ACE** configuration is stored in **JSON** format embedded in motion script. In order to modify it, full copy of the profile has to be made, including motion scripts cloning. The new profile will not be updated automatically when there are changes introduced to the original profile.



- (1) - uncheck **Shallow copy**
- (2) - check **Activate new profile**
- (3) - check **Open editor for new profile**
- (4) - check **Clone scripts**

Once you click **OK**, the **Profile Editor** will be opened.

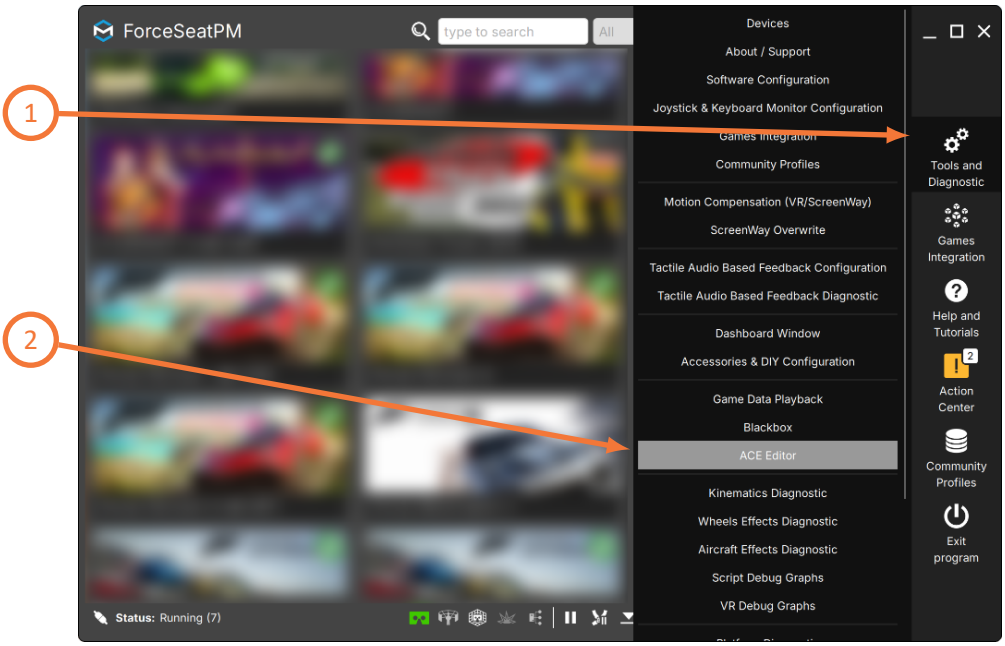


- (1) - it is the path to the motion script. There can be more than one motion script if different motion platform types (e.g. HS-xxx, QS-xxx, PS-xxx) require slightly different parameters. Having multiple motion scripts is typical scenario for games.
- (2) - it opens **Windows Explorer** in the directory containing the motion script.
- (3) - it runs the script to check if there are any errors.
- (4) - it loads current script to the **ACE Editor**.
- (5) - it opens the motion script in **Visual Studio Code**. This function is not used when **ACE Editor** is used to edit motion-cueing algorithm parameters. You can find more about **Visual Studio Code** in an appendix to this document.
- (6) - it saves changes (if there are any) and closes the editor.

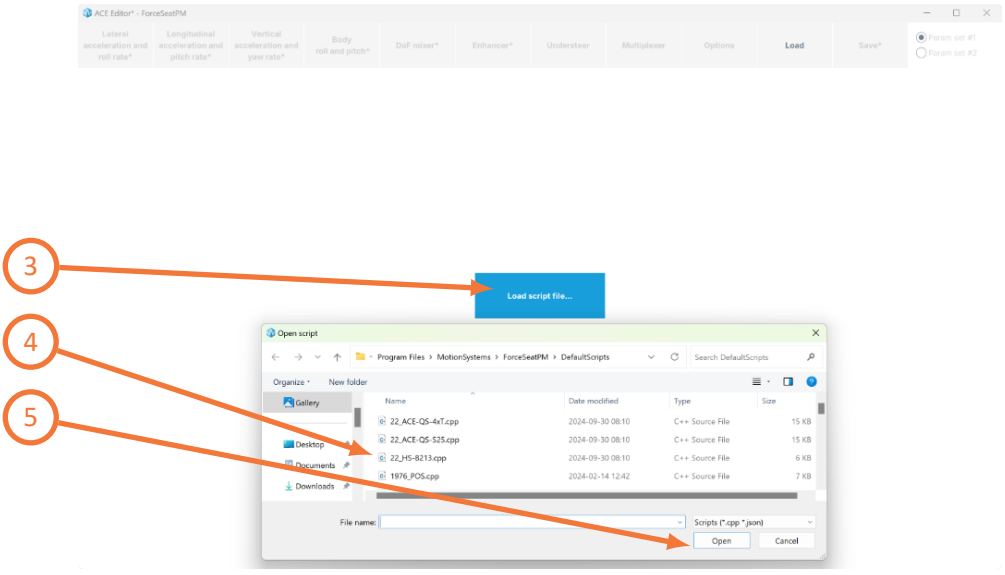
Click **ACE** (4) and then switch back to the **Profile Editor** and click **Save & Close** (5) - the **Profile Editor** will not be needed anymore.

You can also open the **ACE Editor** for the current motion script by pressing **Win + Shift + Q**. Check an appendix to this document to learn more about keyboard hotkeys.

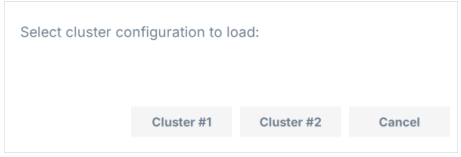
Third way to open ACE software is directly from ForceSeat (”Tools and Diagnostics” (1) -> ”ACE Editor” (2)):



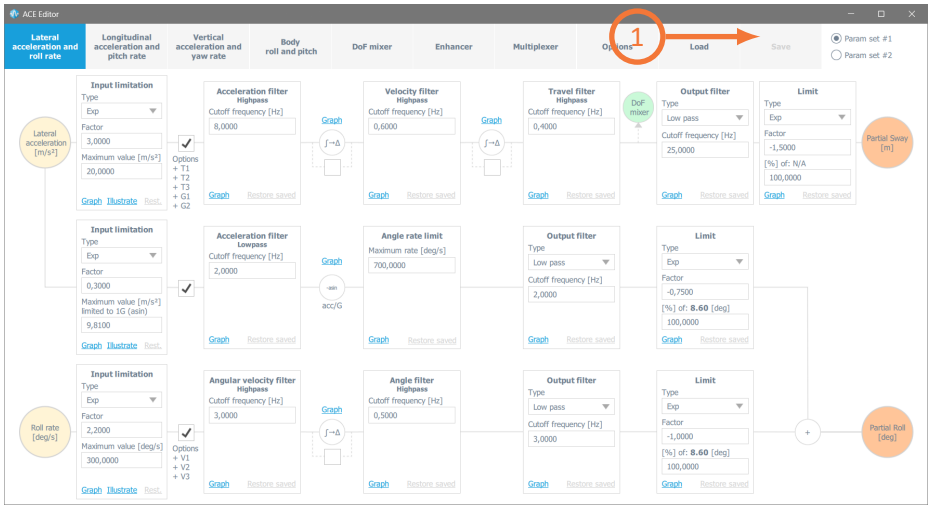
Click on ”Load script file...” (3) and pick the right profile from ”DefaultScripts” folder (4), click ”Open” (5):



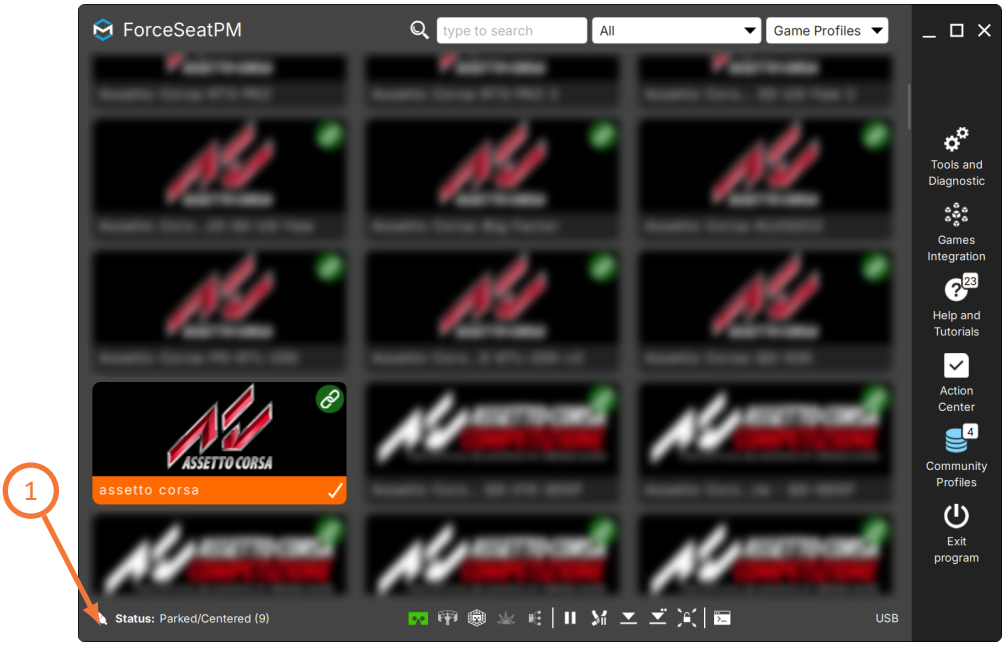
Next, select ”Cluster #1” for QS-series devices or ”Cluster #2” for other devices.



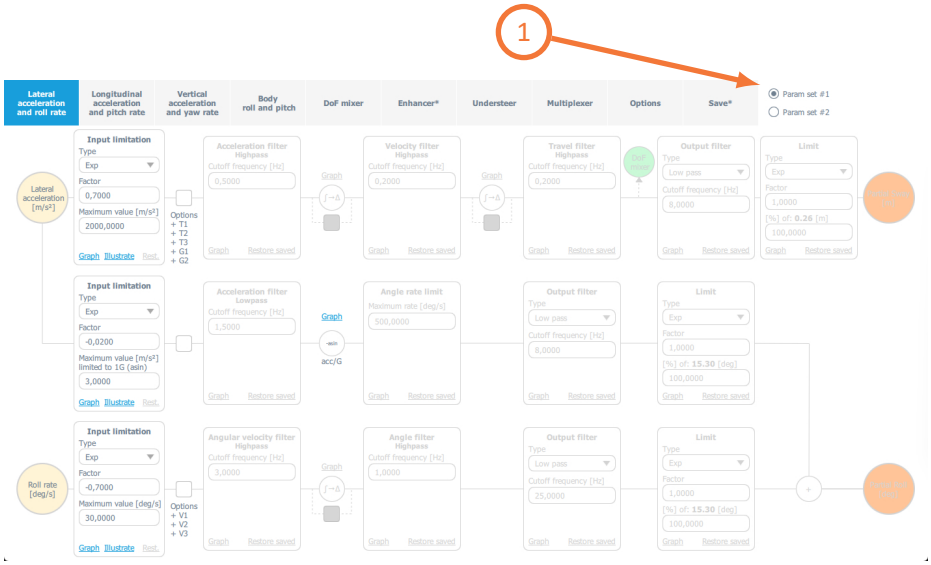
Once you change parameters, click **Save** (1) and **ForceSeatPM** will automatically reload the motion script and apply new parameters. It gives you the possibility to check how the new configuration works with the **SIM** without closing **ACE Editor**. Please check **ACE Editor** chapter to learn more about the editor.



Shortcut **Win + Shift + Q** will always open the **ACE Editor** for currently selected motion script. If there is more than one script attached to the profile, you can check which one is used with your motion platform (when it is connected to PC) by hovering the mouse cursor over the chip icon (1):



1.8.9 Parameter sets



Parameter set separates settings for different scenarios in various game/simulations. ACE interpolates values between parameters set during transition from ground to air and back. All check boxes, filter types and limits type are shared between parameters set, only numerical values can be different.

Param set #1 - For all vehicle and flight simulations. In flight simulation this allows you to set parameters for in-the-air scenario only.

Param set #2 - Only for flight simulations - allows you to set parameters for on-the-ground scenario.

WARNING

Keep the values of the same polarization for smooth transition between in-the-air and on-the-ground scenarios (both param sets in + or both in -).

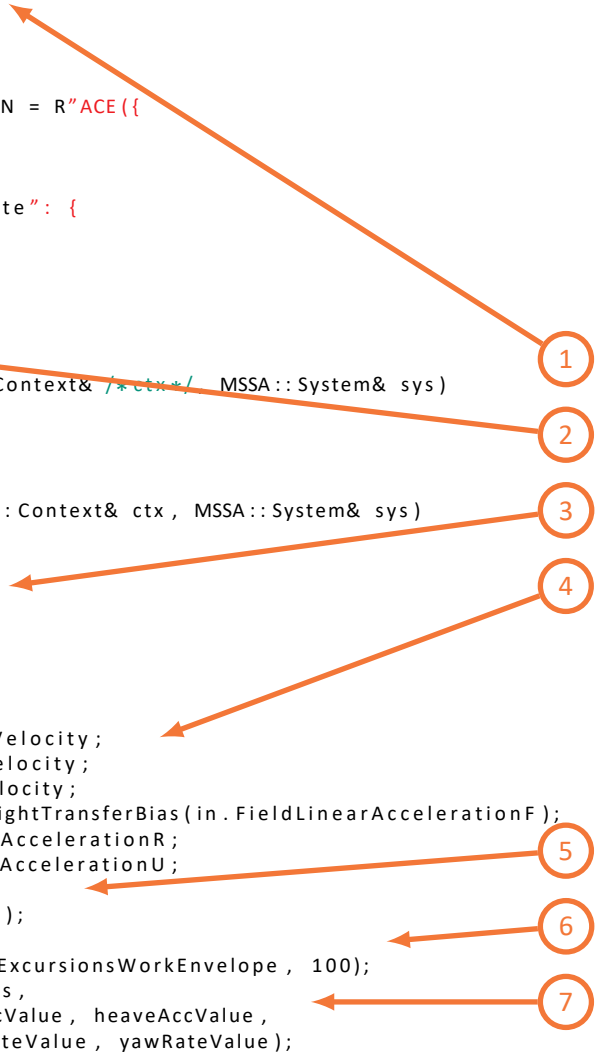
1.8.10 Inside motion script

This document does not cover manual editing of the motion script. As a result, description of the motion script content in this section is general - its purpose is just to show what to expect in the script.

INFORMATION

Motion script source code is kept in text file so it can be easily edited, even in system notepad. However once **ForceSeatPM** is ready to load the motion script, it compiles the C++ source code into native DLL and then uses only the DLL. This approach allows to combine easiness of motion script editing with high performance of C++ code compiled to native binary.

```
#include "GameSpecific.h"
#include "ScriptsAPI.h"

namespace
{
    static const char* const CONFIGURATION = R"ACE({
        "algorithm": {
            "...": "..."
        },
        "lateral_acceleration_and_roll_rate": {
            "...": "..."
        },
        "...": "..."
    })ACE";
}

MOSY_SCRIPT_API_EXPORT void setup(MSSA::Context& /*ctx*/, MSSA::System& sys)
{
    sys.ace.setup(CONFIGURATION);
}

MOSY_SCRIPT_API_EXPORT void process(MSSA::Context& ctx, MSSA::System& sys)
{
    auto& in = ctx.input.fromGame.named;
    // ...
    if (sys.mpu.fsmiHandleParking(ctx))
    {
        return;
    }

    auto pitchRateValue  = in.FieldPitchVelocity;
    auto rollRateValue   = in.FieldRollVelocity;
    auto yawRateValue    = in.FieldYawVelocity;
    auto surgeAccValue   = MoSy_ApplyWeightTransferBias(in.FieldLinearAccelerationF);
    auto swayAccValue    = in.FieldLinearAccelerationR;
    auto heaveAccValue   = in.FieldLinearAccelerationU;

    ACE_Experimental_ApplyQuickTunes6DoF();

    sys.ace.updateWorkEnvelope(ctx.singleExcursionsWorkEnvelope, 100);
    sys.ace.process(ctx, ctx.systemTime_us,
                    surgeAccValue, swayAccValue, heaveAccValue,
                    rollRateValue, pitchRateValue, yawRateValue);
    // ...
}
```



- (1) - the **ACE** configuration in **JSON** format is embedded in motion script. The **ACE Editor** can extract it from the motion script and then put it back.
- (2) - **setup** is called when the motion script is reloaded - e.g. when **ACE** configuration is changed - and in this case it configures **ACE** to use specified **JSON** configuration.
- (3) - **process** is called every **ACE** loop tick (not telemetry loop). This function takes telemetry data (if no new data arrived, historical are used) and then process them according the implementation. In this example, at the beginning the motion script checks if **ForceSeatMI** has sent parking command and if yes, there is no need to run further steps.
- (4) - assigning telemetry data to local variables is for convenience only to make optional units conversion and weight transfer bias application easier.
- (5) - it loads current values of quick tunes into **ACE**.
- (6) - it loads motion platform work envelope limits and scale (100%) into **ACE**.
- (7) - it runs the **ACE**.

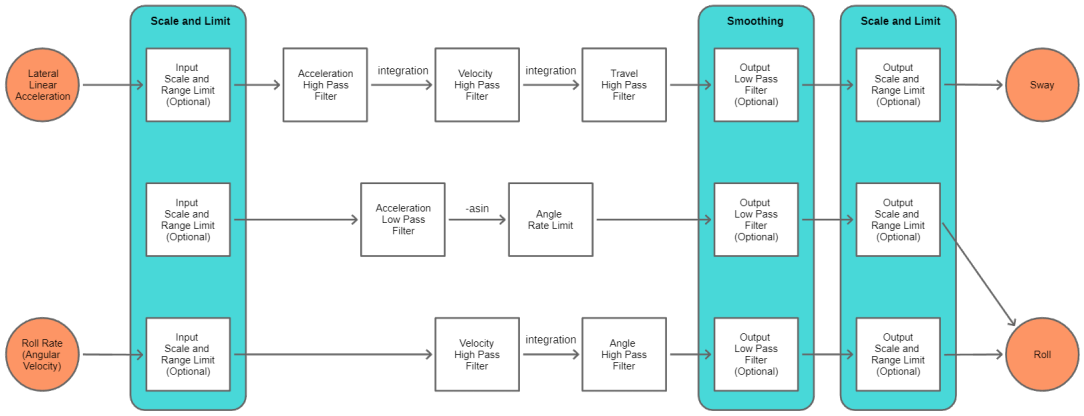
2 Acceleration Control Engine

2.1 Introduction

ACE is an implementation of motion-cueing algorithm known as **classical washout**. The description of the classical washout algorithm is beyond the scope of this document. If you want to learn more, please check list of recommended articles.

From https://en.wikipedia.org/wiki/Motion_simulator:

"The **classical washout filter** is simply a combination of high-pass and low-pass filters; thus, the implementation of the filter is compatibly easy. However, the parameters of these filters have to be empirically determined. The inputs to the classical washout filter are vehicle-specific forces and angular rate. Both of the inputs are expressed in the vehicle-body-fixed frame. Since low-frequency force is dominant in driving the motion base, force is high-pass filtered, and yields the simulator translations. Much the same operation is done for angular rate."



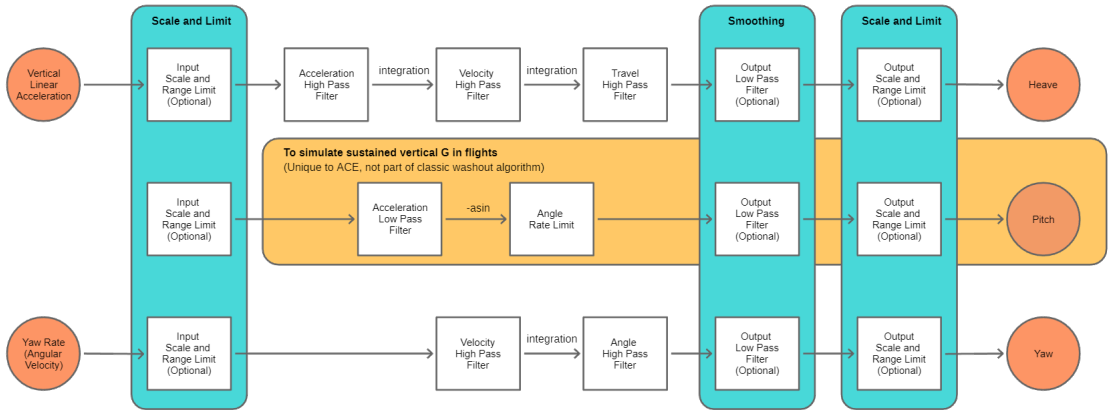
2.2 Recommended reading

In alphabetical order:

- Control of a Dynamic Driving Simulator: Time-Variant Motion Cueing Algorithms and Prepositioning; Cornelius Weiß
- Development of a Full-flight Simulator for Ab-initio Flight Training with Emphasis on Hardware and Motion Integration; Jonathan Plumpton
- Implementation of a washout filter used in stewart platform; Rodrigo Lemes, Moreira De Souza, Ricardo Afonso Angélico, Ricardo Breganon, Caio Barbosa
- Motion cueing algorithms for a real-time automobile driving simulator, Zhou FANG, Andras KEMENY
- Motion Cueing Algorithms for Small Driving Simulator; Lamri Nehaoua, Hichem Arioui, Hakim Mohellebi, Stéphane Espié

2.3 Differences

The main difference between **classical washout** and **ACE** from the functionality point of view, is a presence of additional path that is not available in the **classical washout** algorithm. This vertical linear acceleration to pitch transformation has been introduced by MotionSystems to enable simulation of sustained vertical G during maneuvers in flight simulations (e.g. turning). It supports both positive and negative G.



2.4 ACE and ForceSeat relation

In order to create a new profile, the user must create a clone of a Input signal generated by the game or simulation is received by the ACE software.

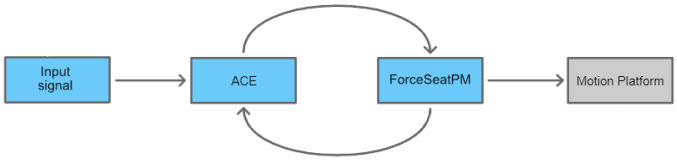
In order for this extra path to operate correctly, the natural vertical 1g has to be removed from the vertical acceleration to avoid constant **top table** pitch on ground and during stable flight. This can be done inside the motion script or with usage of **G1** and **G2** options.

```
MOSY_SCRIPT_API_EXPORT void process(MSSA::Context& ctx, MSSA::System& sys)
{
    // Remove gravity downward force from heave to get rid of
    // constant motion platform pitch on ground
    auto tmpAccY = in.FieldAccY - 1.f;
    // ...
    auto heaveAccValue = tmpAccY * 9.81f;
    // ...
    sys.ace.process(ctx, ctx.systemTime_us,
                    surgeAccValue, swayAccValue, heaveAccValue,
                    rollRateValue, pitchRateValue, yawRateValue);
    // ...
}
```

TIP

This feature is not used (or even needed) in vehicle (car) simulation applications.

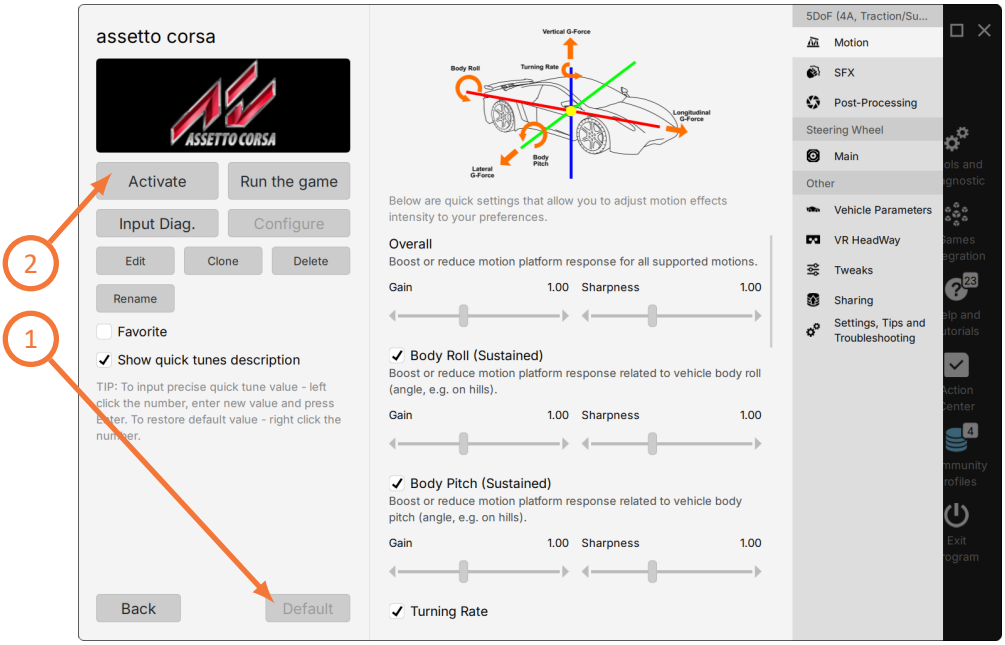
ACE is a motion-cuing software that creates the base profile and defines what type of motion is available and calibrates it. ForceSeatPM profile tuning capabilities are based on that profile and can only reduce or increase already specified output signal. It is possible however to disable certain motion effect in ForceSeatPM which will result in disabling the inputs on ACE software.



Therefore before calibrating any profile in ACE software it is strongly recommended to restore ForceSeatPM all tuning settings to default.

While in profile settings click **Default** (1) and confirm by clicking **Yes to all**.

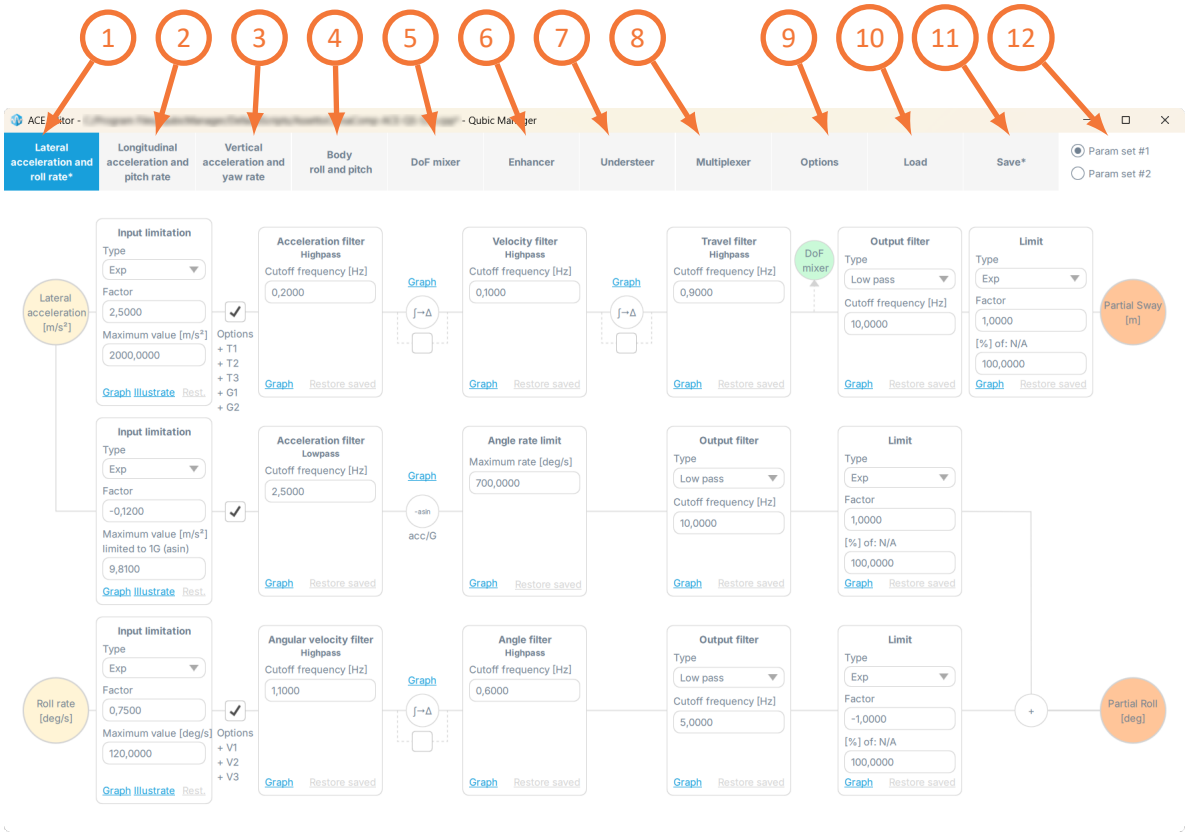
Before calibrating any profile on ACE - **Activate** it (2).



3 ACE Editor

3.1 Main window

The main editor's window consists of 4 tabs, **Save** button and parameters set switch.



- (1) - switches to lateral acceleration and roll rate parameters.
- (2) - switches to longitudinal acceleration and pitch rate parameters.
- (3) - switches to vertical acceleration and yaw rate parameters.
- (4) - switches to body roll and pitch parameters
- (5) - switches to degrees of freedom mixer parameters
- (6) - switches to enhancer parameters
- (7) - switches to understeer parameters
- (8) - switches to multiplexer parameters
- (9) - shows global options.
- (10) - loads a new file.
- (11) - saves changes to file, which the **ForceSeatPM** detects and automatically reloads the motion script. You can also use **Ctrl + S** to save the parameters.

- (12) - switches between parameter sets. For vehicle simulations only first parameters set (#1) is used. For flights, the first parameter set (#1) is used for in-the-air scenario and the second parameters set used for on-the-ground scenario (#2). **ACE** interpolates values between parameters set during transition from ground to air and back. All check boxes, filter types and limits type are shared between parameters set, only numerical values can be different.

INFORMATION

In flight simulations ”Param set #1” and ”Param set #2” should not be polarized into negative and positive value - the transition between runway and after take-off (in-the-air scenario) will be incorrect (for example: negative values in Factor will inverse platform’s movement).

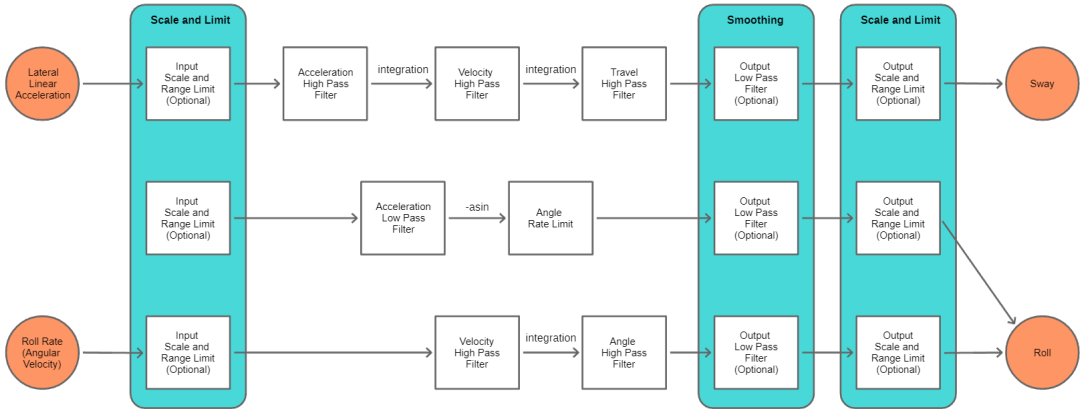
3.2 Parameters tuning guidelines

The general guidelines are as follows:

- Work in small steps - change one parameter at a time and retest.
- Disable all output filters and limitations if you are tuning low-pass filters.
- Make sure to scale input correctly, especially for tilt coordination (e.g. lateral acceleration to roll transformation).
- Tune each path individually and then start combining them. Very often each path separately works correctly but once combined the output motion is outside of the available work envelope.

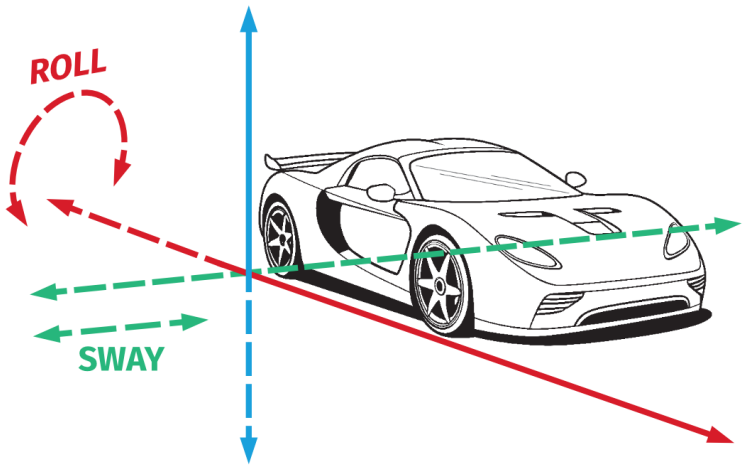
3.3 Lateral acceleration and roll rate

This view allows to configure parameters for each block of the classical washout algorithm.

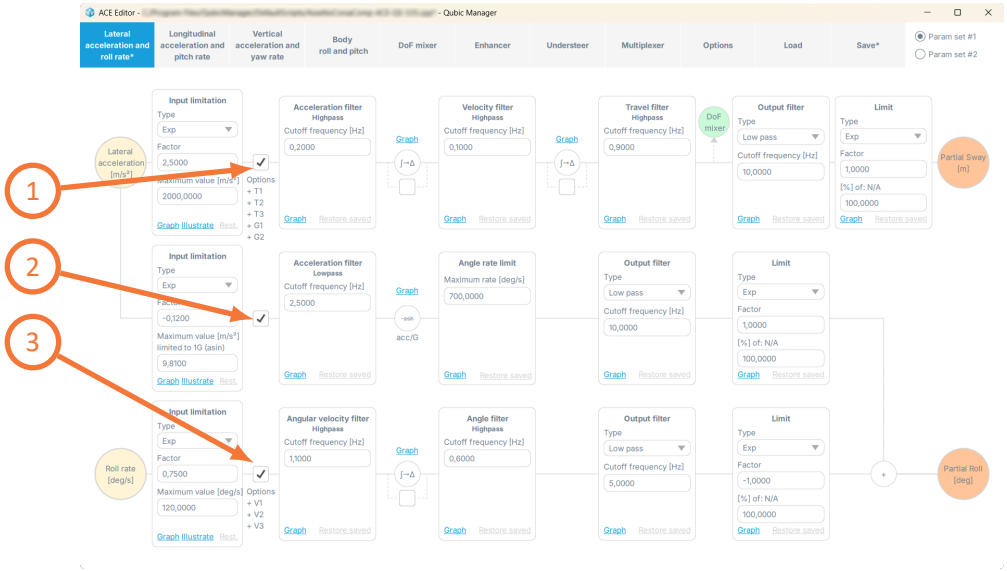


There are 3 paths that transform and combine **lateral acceleration** and **roll rate** into **sway** and **roll**:

- lateral acceleration to sway;
- lateral acceleration to roll - known also as **tilt coordination**;
- roll rate to roll.

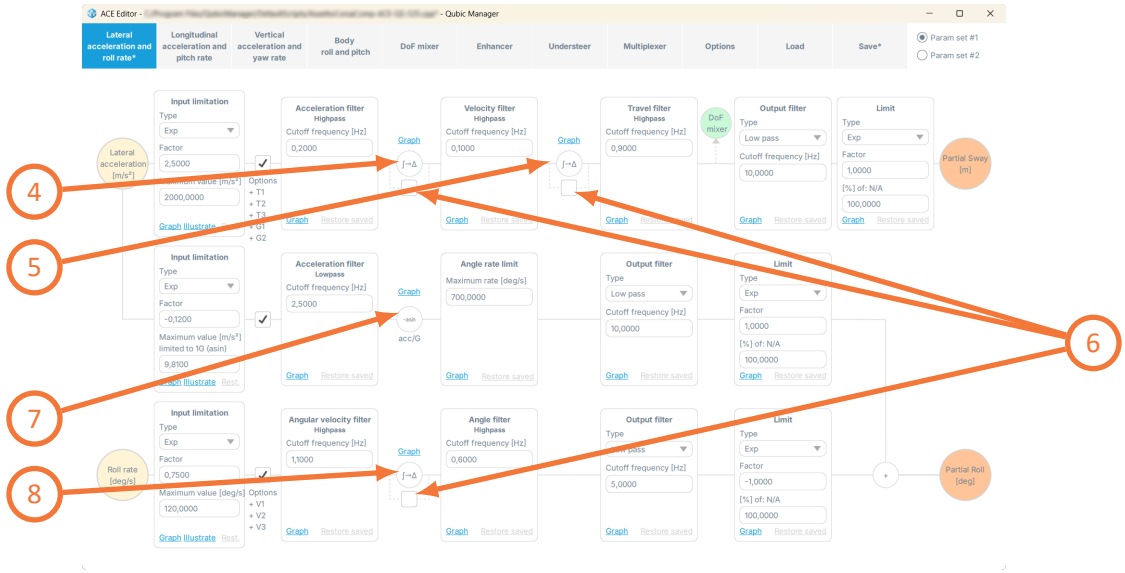


Each path can be enabled or disabled individually (1), (2) and (3). It is recommended to tune one path a time and then start combining them.



- (1) - enables **lateral acceleration** to **sway** transformation. There are optional transformations that can be applied (**T1**, **T2**, **T3**, **G1** and **G2**) - check **Options** tab description to learn more.
- (2) - enables **lateral acceleration** to **roll** transformation. This path is also called **tilt coordination**.
- (3) - enables **roll rate** (angular velocity) to **roll** transformation. There are optional transformations that can be applied (**V1**, **V2** and **V3**) - check **Options** tab description to learn more.

There are also crucial operations that cannot be parametrized nor disabled.



- (4) - it computes integral of acceleration to get instantaneous velocity. In other words, it uses acceleration and time interval (4ms for 250Hz rate) between **ACE** loop calls to calculate velocity.

$$\mathbf{v} = \int_0^{0.004[s]} a(t)\,dt$$

- (5) - it computes integral of velocity to get instantaneous travel. In other words, it uses velocity and time interval (4ms for 250Hz rate) between **ACE** loop calls to calculate travel.

$$\mathbf{s} = \int_0^{0.004[s]} v(t)\,dt$$

- (6) - check these boxes to bypass the integrals.

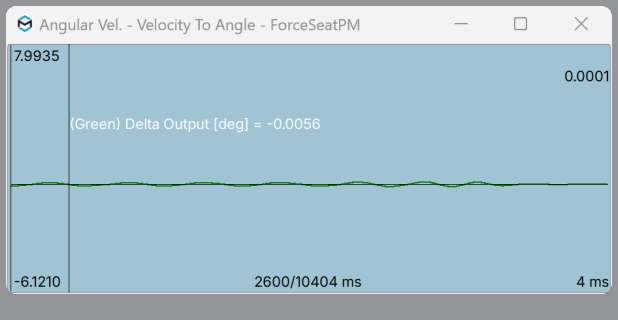
WARNING

Bypassing integration may result in unstable and unpredicted platform movement. In the worst scenario machine may reach end of the work envelope and stop. Are you sure you want to continue?

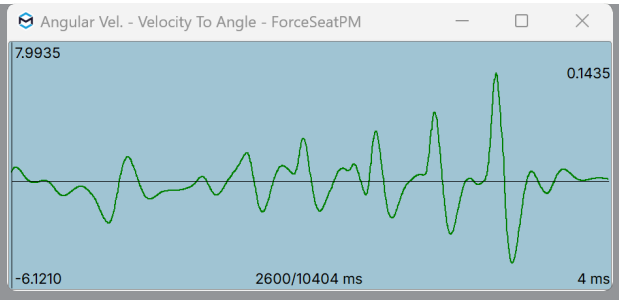
Yes Cancel

If you decide to bypass the integral, keep in mind the movement of the platform may become abrupt and intense. Examples:

Integral is used:

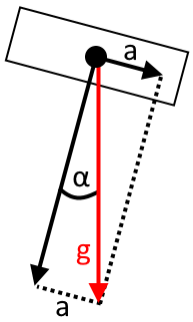


Integral is bypassed:



- (7) - it calculates angle of gravity vector to figure out what **top table** roll is required to simulate lateral force with usage of gravity force. This bases on assumption that human senses are not perfect and people are used to feel and ignore gravity when it points down. Once the gravity is felt at angle, it can be easily mistaken with lateral acceleration. This is the trick that **tilt coordinate** block uses.

$$\alpha = -asin(\frac{a}{g})$$



- (8) - it computes integral of angular velocity to get instantaneous angle. In other words, it uses angular velocity and time interval (4ms for 250Hz rate) between **ACE** loop calls to calculate angle.

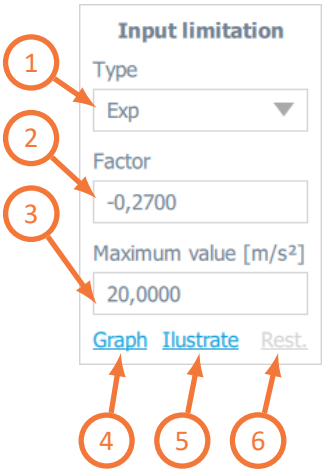
$$\theta = \int_0^{0.004[s]} \omega(t)\, dt$$

WARNING

The physics behind tilt coordination implies that the absolute theoretical maximum sustained lateral acceleration the motion platform is able to simulate is 1g (arcsin argument maximum value). This is for motion platform that offers 90° roll as work envelope. For motion platform that offers 20° roll, the maximum lateral acceleration is 3 $[\frac{m}{s^2}]$. For 10° roll, the value is limited to 1.5 $[\frac{m}{s^2}]$. If the **SIM** generates sustained accelerations greater than the motion platform is able to handle, **Input limitation** block must be used to scale down and limit the input acceleration.

3.3.1 Input limitation

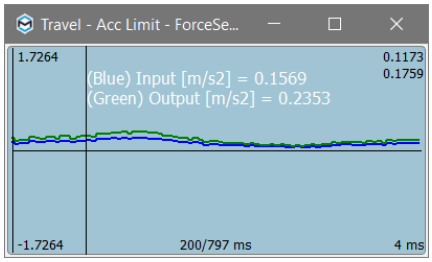
This block has exactly the same function for all 3 paths, the difference is only in units.



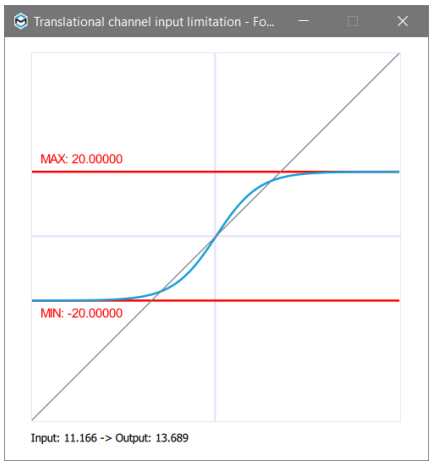
- (1) - defines type of the limitation function. Following options are available: **None** and **Exp**. It is recommended to use **Exp** as limitation function as it offers smooth close to boundaries experience. You can click **Illustrate** to check how **Factor** and **Maximum value** affects the input signal.

$$f(x) = max \cdot \left(\frac{-2}{1 + e^{2x \cdot \frac{factor}{max}}} + 1\right)$$

- (2) - defines first parameter for limitation function. You can click **Illustrate** to check how it affects the input signal. Use **negative factor** to inverse the signal and fix incorrect polarity.
- (3) - defines second parameter for limitation function. You can click **Illustrate** to check how it affects the input signal. Due to **Exp** function characteristic, sometimes it is necessary to use greater maximum value than normally required. You can click **Illustrate** to check how it affects the input signal.
- (4) - opens a pop-up with graph that plots input (blue) and output (green) of the block. When the **SIM** is running in the background, you can see how **Input limitation** block alters the original signal.



- (5) - it opens a graph that shows how the selected limitation function modifies incoming data. Use **Ctrl + mouse scroll** to zoom the view. Below example is for Factor = 1.5 and Maximum value = 20.



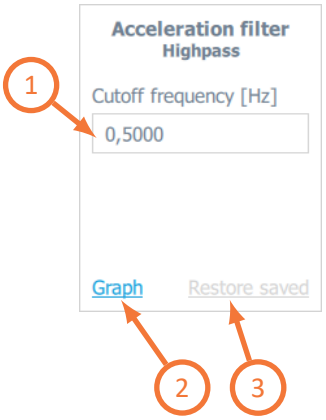
- (6) - it resets all parameters in the block to values stored in the file (recently saved).

WARNING

Correct selection of **Factor** and **Maximum value** are crucial for tilt coordination component (lateral acceleration to roll transformation) to operate correctly. **Input limitation** together with **Acceleration low-pass filter** must reduce input acceleration to value which after being processed by **asin** and transformed into roll is within motion platform's work envelope.

3.3.2 High-pass filter: acceleration, velocity, travel, angular velocity and angle

All high-pass filters blocks work exactly the same way. The only difference is in input data units which are irrelevant for filtering algorithm. The only required parameter is cutoff frequency [Hz].

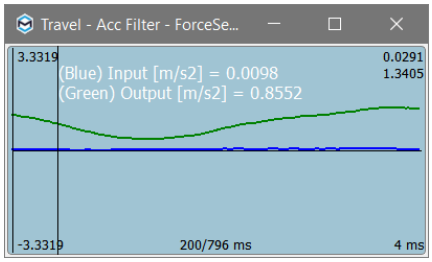


- (1) Cutoff frequency (Hz) - defines the cutoff frequency for the high-pass filter. The filter is implementation of the following formula:

$$\mathbf{y_n} = \frac{\mathbf{x_n} - \mathbf{x_{n-1}} - (2\pi f * dt - 1) * \mathbf{y_{n-1}}}{2\pi f * dt + 1}$$

where **dt** is interval between calls, usually 0.004 [s], **f** is cutoff frequency, **x** is input and **y** is output.

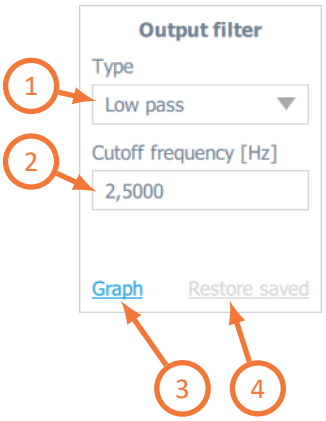
- (2) Graph - opens a pop-up with graph that plots input (blue) and output (green) of the block. When the **SIM** is running in the background, you can see how **High-pass filter** block alters the original signal.



- (3) Restore saved - resets all parameters in the block to values stored in the file (recently saved).

3.3.3 Output filter

Output filter block is just a filter, usually low-pass, that smooths the output data before is it being processed by the next functional block.

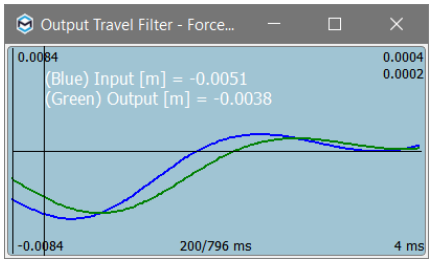


- (1) Type - defines the type of the filtering function. Following options are available: **None** (no output filter), **Low-pass** (recommended when smoothing is required).
- (2) Cutoff frequency (Hz) - defines the cutoff frequency for the Low-pass filter. It implements the following formula:

$$\mathbf{y_n} = \mathbf{x}\frac{dt}{dt+\tau} + \mathbf{y_{n-1}}\frac{\tau}{dt+\tau}, \tau = \frac{1}{2\pi f}$$

where **dt** is interval between calls, usually 0.004 [s], **f** is cutoff frequency, **x** is input and **y** is output.

- (3) Graph - opens a pop-up with graph that plots input (blue) and output (green) of the block. When the **SIM** is running in the background, you can see how **Output filter** block alters the original signal.



- (4) Restore saved - resets all parameters in the block to values stored in the file (recently saved).

3.3.4 Limit and Angle limit

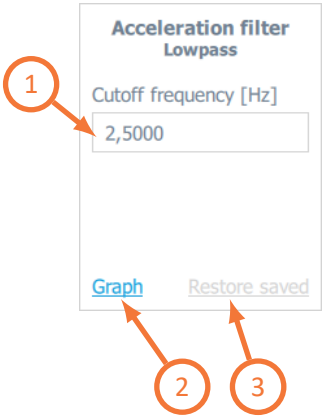
Limit and **Angle limit** blocks work the same way as **Input limitation** block with two main differences:

- they are used on output data, NOT on input data;
- the maximum value is read automatically from the connected motion platform and cannot be changed.

Refer to **Input limitation** description to learn more about limitation function types and parameters.

3.3.5 Acceleration low-pass filter

This low-pass filter is used only in tilt coordination path and its role is to smooth sustained acceleration before it is transformed into rotation.

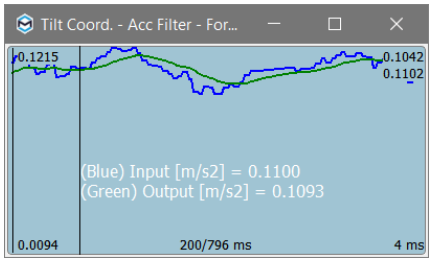


- (1) Cutoff frequency (Hz) - defines the cutoff frequency for the low-pass filter. The filter implements the following formula:

$$\mathbf{y_n} = \mathbf{x}\frac{dt}{dt+\tau} + \mathbf{y_{n-1}}\frac{\tau}{dt+\tau}, \tau = \frac{1}{2\pi f}$$

where **dt** is interval between calls, usually 0.004 [s], **f** is cutoff frequency, **x** is input and **y** is output.

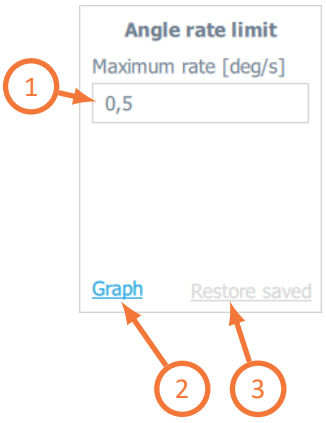
- (2) Graph - opens a pop-up with graph that plots input (blue) and output (green) of the block. When the **SIM** is running in the background, you can see how **filter** block alters the original signal.



- (3) Restore saved - resets all parameters in the block to values stored in the file (recently saved).

3.3.6 Angle rate limit

Tilt coordination uses the fact that the vestibular system cannot distinguish between inertia force produced by a linear acceleration and the effect of gravity. Since humans are very sensitive to the tilt rate, the rate should be within user's perception threshold. Good starting point is 2∼4 $[\frac{^\circ}{s}]$, however very often this value is too limited to reproduce a realistic driving simulation and has to be tuned (increased). This blocks allows to configure tilt rate with **Maximum rate** parameter.

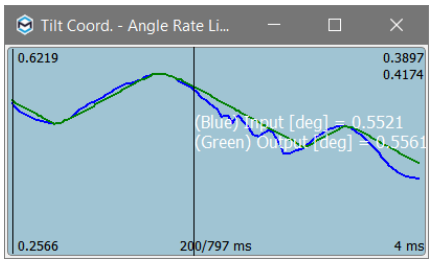


- (1) Maximum rate (deg/s) - defines maximum tilt rate. The block implements following generic (simplified for better readability) formula:

$$\mathbf{y_n} = \begin{cases} \mathbf{y_{n-1}} + rate \cdot dt, & \text{if } x_n \geq y_{n-1} + rate \cdot dt \\ \mathbf{y_{n-1}} - rate \cdot dt, & \text{if } x_n \leq y_{n-1} - rate \cdot dt \\ x_n, & \text{otherwise} \end{cases}$$

where **dt** is interval between calls, usually 0.004 [s], **rate** is the maximum rate, **x** is input and **y** is output.

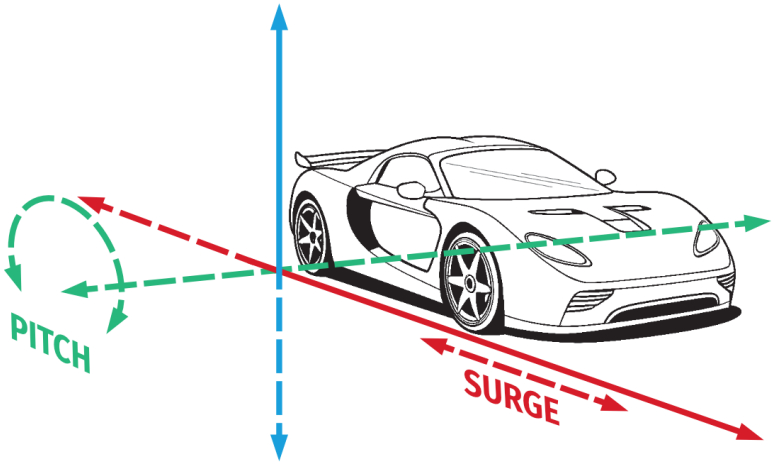
- (2) Graph - opens a pop-up with graph that plots input (blue) and output (green) of the block. When the **SIM** is running in the background, you can see how **Angle rate limit** block alters the original signal.



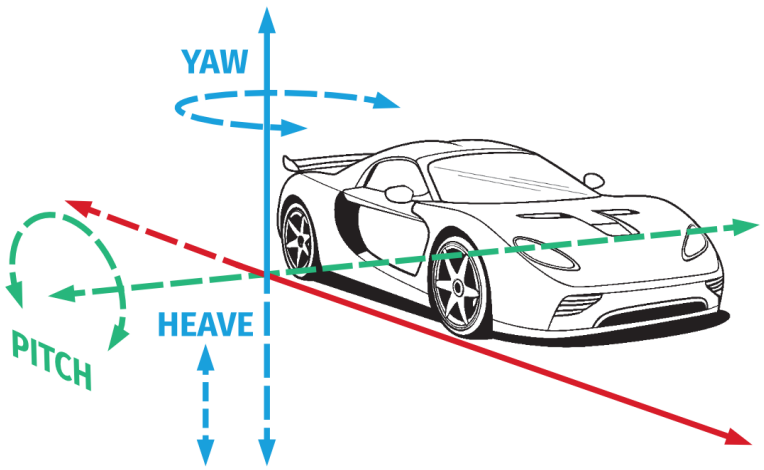
- (3) Restore saved - resets all parameters in the block to values stored in the file (recently saved).

3.4 Longitudinal acceleration and pitch rate

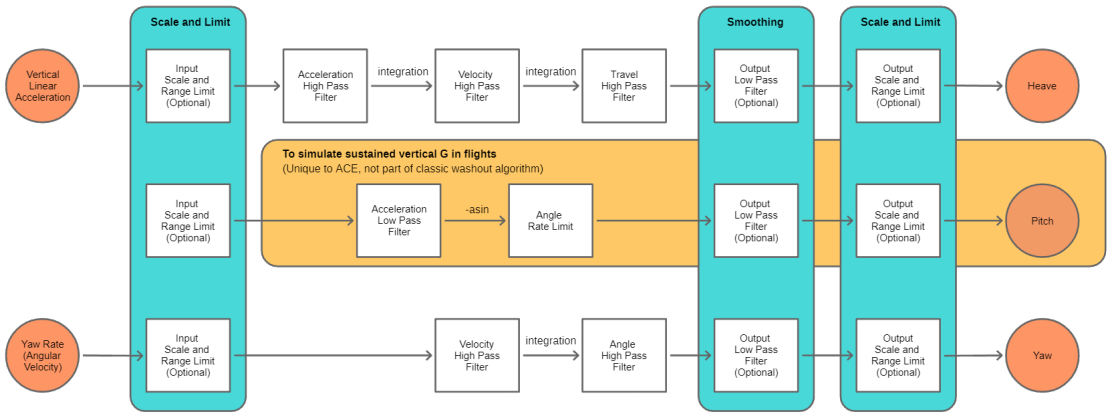
This view allows to configure parameters for each block of the classical washout algorithm related to longitudinal acceleration and pitch rate. Parameters and functions are analogical to **Lateral acceleration and roll rate** component and are described in previous chapter.



3.5 Vertical acceleration and yaw rate



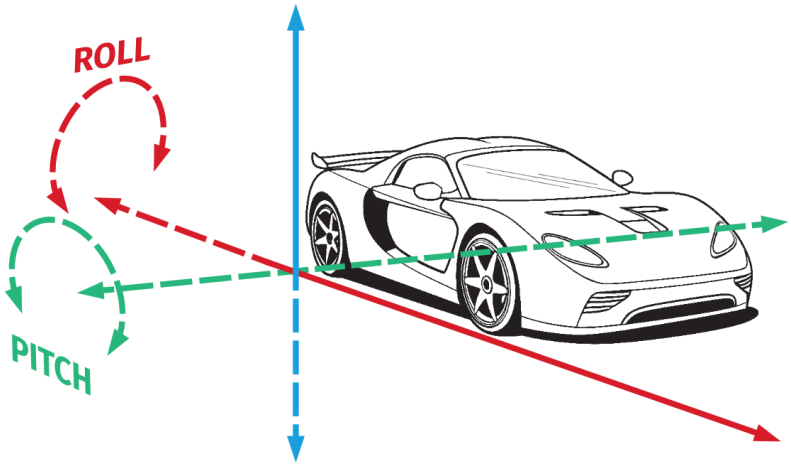
This view allows to configure parameters for each block of the classical washout algorithm related to vertical acceleration and yaw rate. Parameters and functions are analogical to **Lateral acceleration and roll rate** component with one exception - **Vertical acceleration to pitch rate** path is unique.



This additional path is not part of the **classical washout** algorithm and has been introduced to enable simulation of sustained vertical G during maneuvers in flight simulations (e.g. turning). It includes both positive and negative G.

3.6 Body roll and pitch

This view allows to configure parameters for body roll and pitch. As opposed to **Longitudinal** and **Lateral acceleration and pitch rate** which imitates G-forces, body pitch and body roll translates vehicle in-game position in relation to x and z axis into platform sustained angled position (e.g. on a hill or a steep banked turn or flight sim during turn inclination).



3.6.1 Body roll

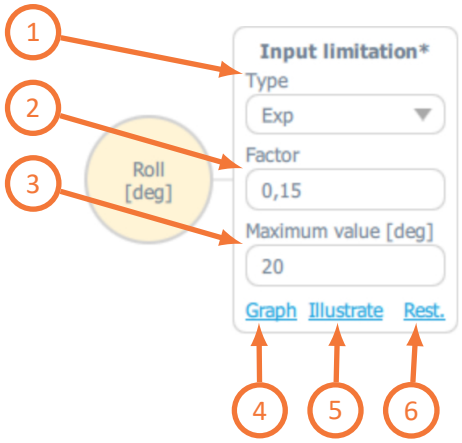
This parameter allows for sustained body roll configuration (e.g. vehicle on a steep banked turn). It is combined of input signal limitation, output filter and output limit.

INFORMATION

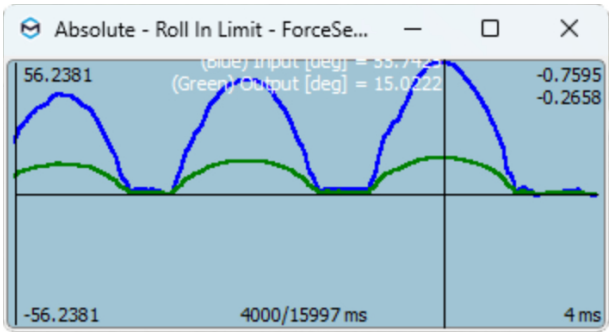
Modifying settings has an instant effect on platform's motion characteristic as long as the changes are saved (right top tab in ACE window or keyboard shortcut "CTRL+S").

3.6.2 Input limitation

Input limitation options block adjusts telemetry data from the game/simulation before it is translated into output data for the platform.



- (1) Type: none - no limitation.
  Type: gain - more intense input with abrupt freeze at endpoint.
  Type: exp - exponential increase or decrease of the input data.
- (2) Factor - overall signal gain, exponentially increases input data from the game/simulation (visualized in "Illustrate"). Set to negative inverts the input data.
- (3) Maximum value [deg]: limits the input data on a maximum available degree angle (visualized in "Illustrate").
- (4) Graph - opens a pop-up with graph that plots input (blue) and output (green) data of the block. When the **SIM** is running in the background, you can see how **Input limitation** block alters the original signal.



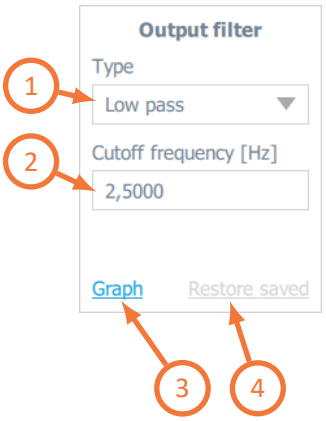
- (5) Illustrate - opens up a graph that shows how the **Factor** (blue line) and **Maximum value** (red lines) limitation function modifies incoming data. Use Ctrl + mouse scroll to zoom the view. Below are examples of Factor exponential increase. From the left: 0.15, 0.35, 0.7,

2.0 and Maximum value in degrees = 20

- (6) Rest. - restores all parameters in the block from a previously saved file.

3.6.3 Output filter

Output filter block is just a filter that smooths out or sharpens the output data before it is being processed by the next functional block.



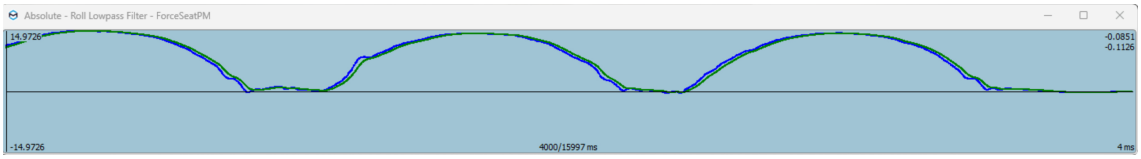
- (1) Type - defines the type of the filtering function. Following options are available: **None** (no output filter), **Low-pass** (recommended when smoothing is required).
- (2) Cutoff frequency (Hz) - defines the cutoff frequency for the Low-pass filter. It implements the following formula:

$$\mathbf{y_n} = \mathbf{x}\frac{dt}{dt+\tau} + \mathbf{y_{n-1}}\frac{\tau}{dt+\tau}, \tau = \frac{1}{2\pi f}$$

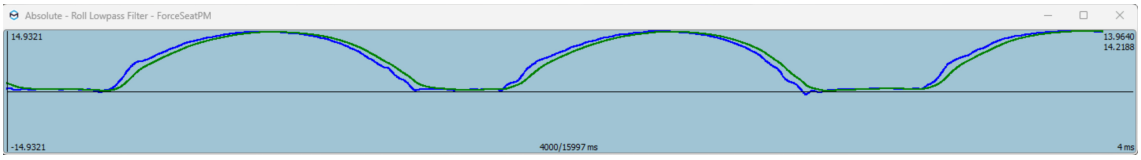
  where **dt** is interval between calls, usually 0.004 [s], **f** is cutoff frequency, **x** is input and **y** is output.
- (3) Graph - opens a pop-up with graph that plots input (blue) and output (green) of the block. When the **SIM** is running in the background, you can see how **Output filter** block alters the original signal.
- (4) Restore saved - resets all parameters in the block to values stored in the file (recently saved).

In order to better understand the output filter influence on output signal, refer to illustrations below (blue is input data, green is output data):

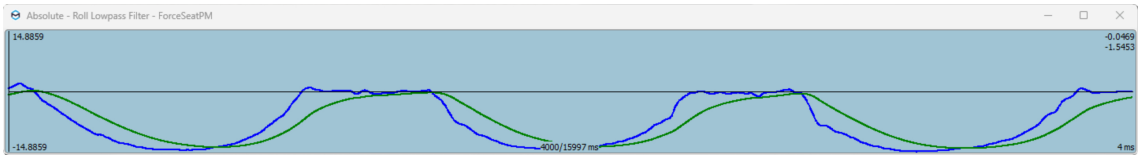
- Low-pass cutoff frequency - 2.0 Hz



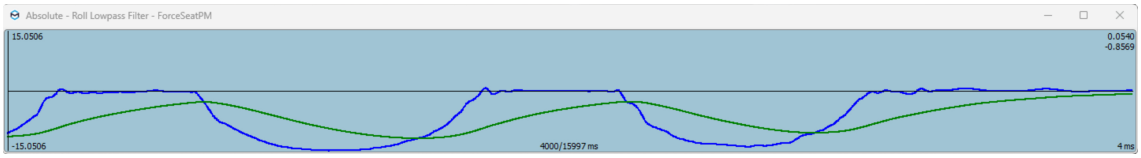
- Low-pass cutoff frequency - 1.0 Hz



- Low-pass cutoff frequency - 0.3 Hz



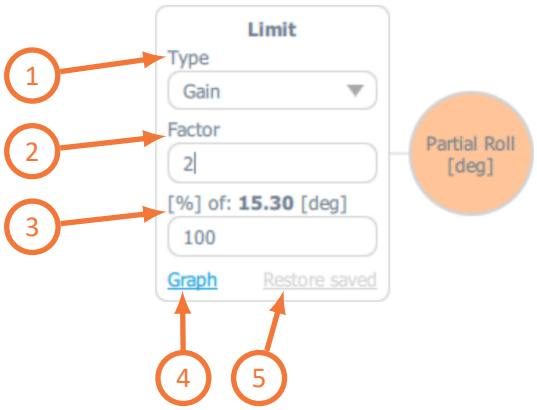
- Low-pass cutoff frequency - 0.1 Hz



3.6.4 Limit

Limit block works the same way as Input limitation block with two main differences:

- they are used on output data, NOT on input data;
- the maximum value is read automatically from the connected motion platform and cannot be changed.

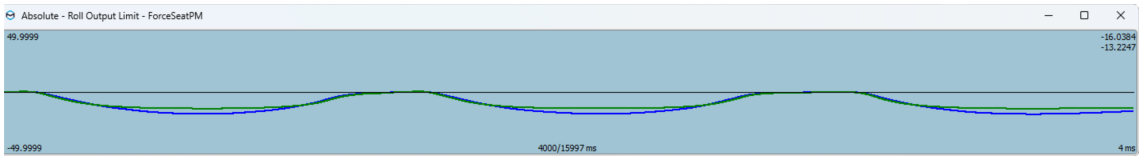


- (1) Type - defines the type of the limiting function. Following options are available: **None** (no limitation), **Gain** (more intense output with abrupt freeze at endpoints) and **Exponential** (more smooth output).

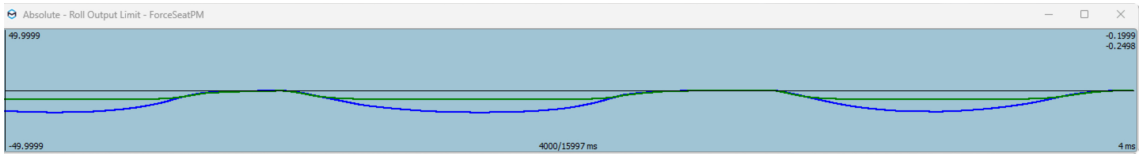
- (2) Factor - overall extent of the limitation on the output data.
- (3) % of maximum available degrees of sustained roll (software provides the maximum degree value automatically) - limits the output data on a maximum available degree angle.
- (4) Graph - opens a pop-up with graph that plots input (blue) and output (green) data of the block. When the SIM is running in the background, you can see how output limitation block alters the original signal.
- (5) Restore saved - resets all parameters in the block to values stored in the file (recently saved).

In order to better understand the output limit influence on output signal, refer to illustrations below (blue is input data, green is output data):

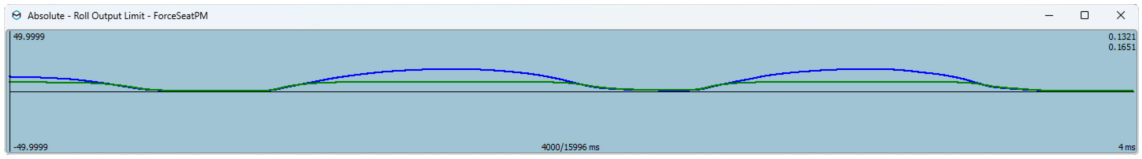
- Exponential limit, factor 0.5, 100% of degrees



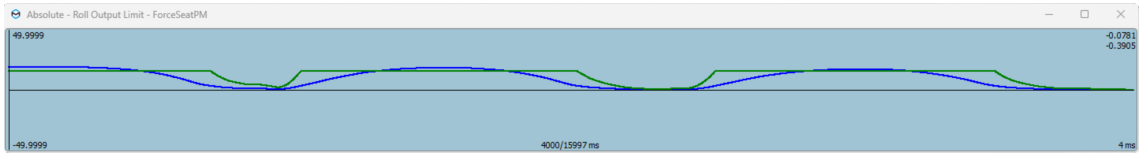
- Exponential limit, factor 0.5, 50% of degrees



- Gain limit, factor 0.5, 100% of degrees



- Gain limit, factor 2.0, 100% of degrees



3.6.5 Body pitch

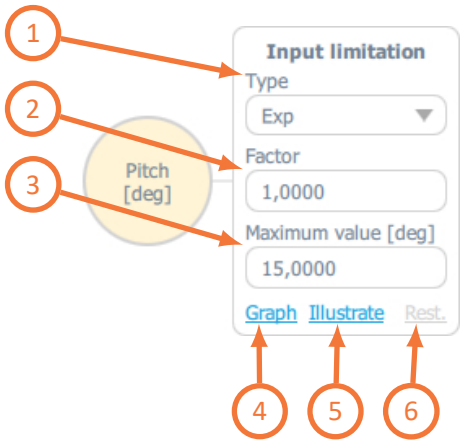
This parameter allows for sustained body pitch configuration (e.g. vehicle on a steep hill, plane diving). It is combined of input signal limitation, output filter and output limit.

INFORMATION

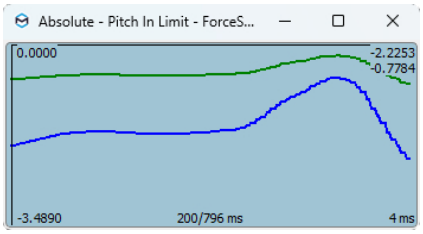
Modifying settings has an instant effect on platform's motion characteristic as long as the changes are saved (right top tab in ACE window or keyboard shortcut "CTRL+S").

3.6.6 Input limitation

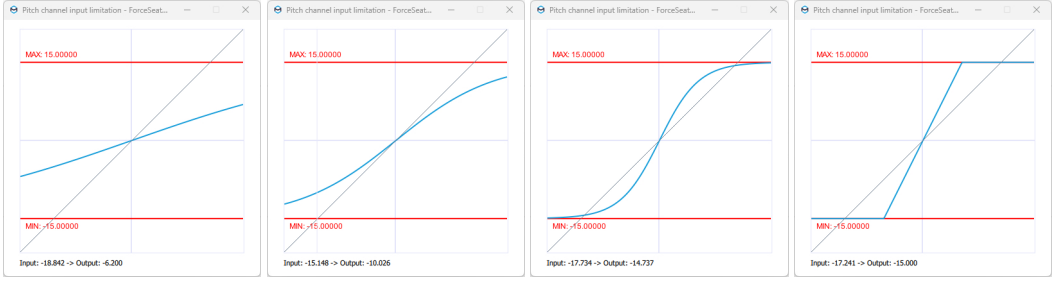
Input limitation options block adjusts telemetry data from the game/simulation before it is translated into output data for the platform.



- (1) Type: none - no limitation.
  Type: gain - more intense input with abrupt freeze at endpoint.
  Type: exp - exponential increase or decrease of the input data.
- (2) Factor - overall signal gain, exponentially increases input data from the game/simulation (visualized in ”Illustrate”). Set to negative inverts the input data.
- (3) Maximum value [deg]: limits the input data on a maximum available degree angle (visualized in ”Illustrate”).
- (4) Graph - opens a pop-up with graph that plots input (blue) and output (green) data of the block. When the **SIM** is running in the background, you can see how **Input limitation** block alters the original signal.



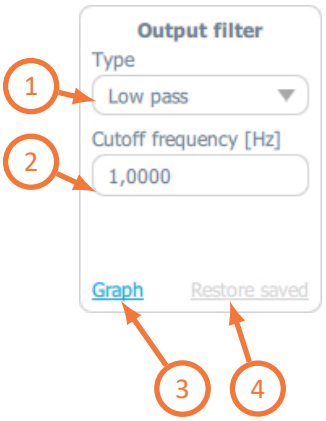
- (5) Illustrate - opens up a graph that shows how the **Factor** (blue line) and **Maximum value** (red lines) limitation function modifies incoming data. Use Ctrl + mouse scroll to zoom the view. Below are examples of Factor increase. From the left: exp 0.35, exp 0.8, exp 2.0, gain 2.0 and Maximum value in degrees = 15.



- (6) Rest - restores all parameters in the block from a previously saved file.

3.6.7 Output filter

Output filter block is just a filter that smooths out or sharpens the output data before it is being processed by the next functional block.



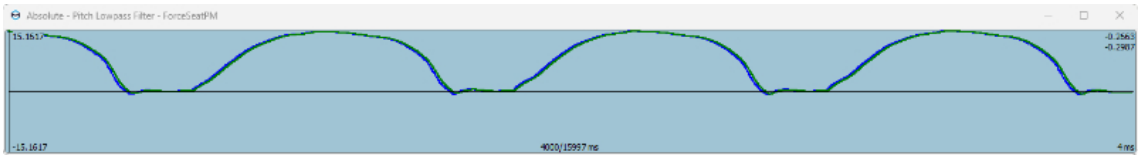
- (1) Type - defines the type of the filtering function. Following options are available: **None** (no output filter), **Low-pass** (recommended when smoothing is required).
- (2) Cutoff frequency (Hz) - defines the cutoff frequency for the Low-pass filter. It implements the following formula:

$$\mathbf{y_n} = \mathbf{x}\frac{dt}{dt+\tau} + \mathbf{y_{n-1}}\frac{\tau}{dt+\tau}, \tau = \frac{1}{2\pi f}$$

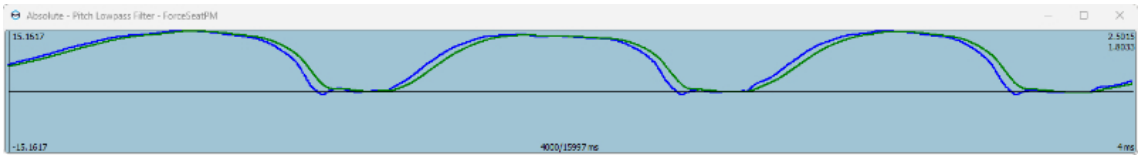
  where **dt** is interval between calls, usually 0.004 [s], **f** is cutoff frequency, **x** is input and **y** is output.
- (3) Graph - opens a pop-up with graph that plots input (blue) and output (green) of the block. When the **SIM** is running in the background, you can see how **Output filter** block alters the original signal.
- (4) Restore saved - resets all parameters in the block to values stored in the file (recently saved).

In order to better understand the output filter influence on output signal, refer to illustrations below (blue is input data, green is output data):

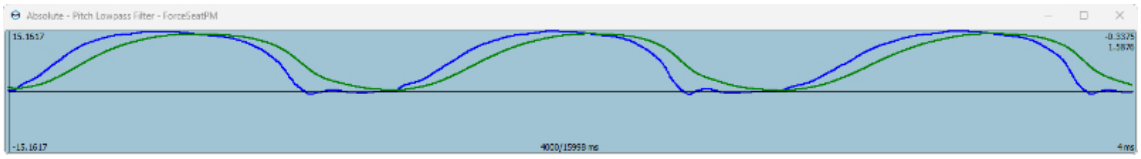
- Low-pass cutoff frequency - 4.0 Hz



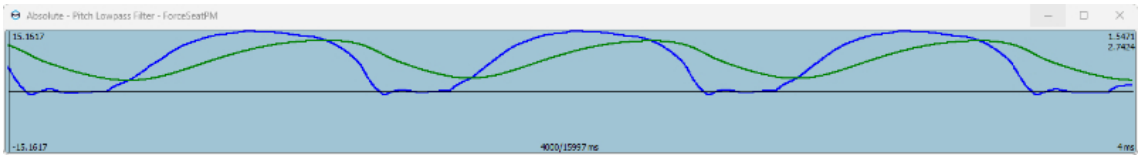
- Low-pass cutoff frequency - 1.0 Hz



- Low-pass cutoff frequency - 0.35 Hz



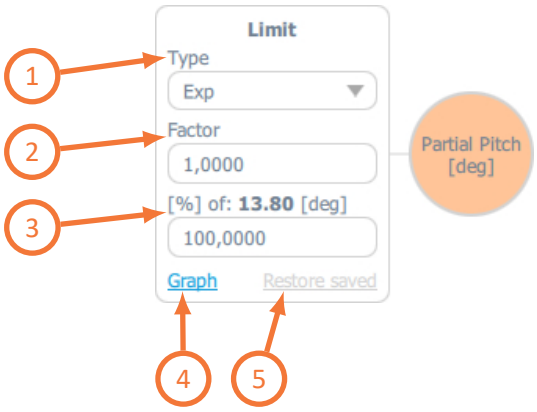
- Low-pass cutoff frequency - 0.15 Hz



3.6.8 Limit

Limit block works the same way as Input limitation block with two main differences:

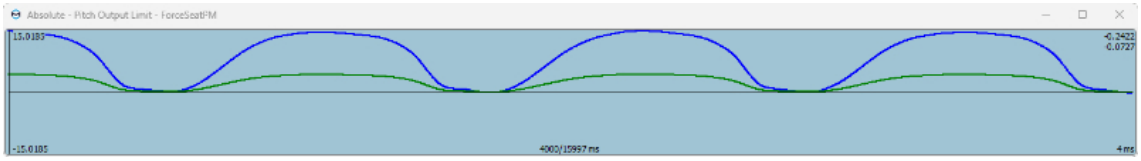
- they are used on output data, NOT on input data;
- the maximum value is read automatically from the connected motion platform and cannot be changed.



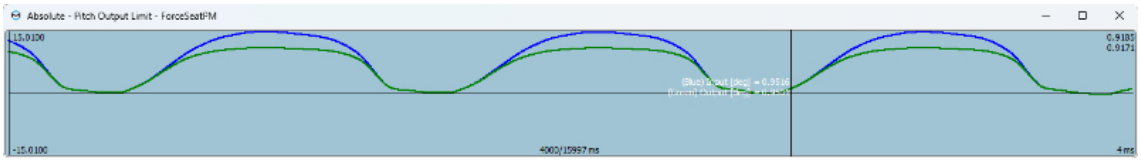
- (1) Type - defines the type of the limiting function. Following options are available: **None** (no limitation), **Gain** (more intense output with abrupt freeze at endpoints) and **Exponential** (more smooth output).
- (2) Factor - overall extent of the limitation on the output data.
- (3) % of maximum available degrees of sustained pitch (software provides the maximum degree value automatically) - limits the output data on a maximum available degree angle.
- (4) Graph - opens a pop-up with graph that plots input (blue) and output (green) data of the block. When the SIM is running in the background, you can see how output limitation block alters the original signal.
- (5) Restore saved - resets all parameters in the block to values stored in the file (recently saved).

In order to better understand the output limit influence on output signal, refer to illustrations below (blue is input data, green is output data):

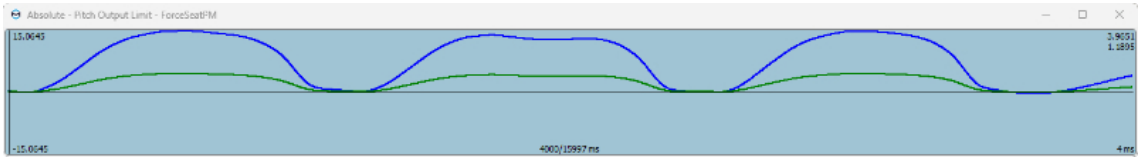
- Exponential limit, factor 0.3, 100% of degrees



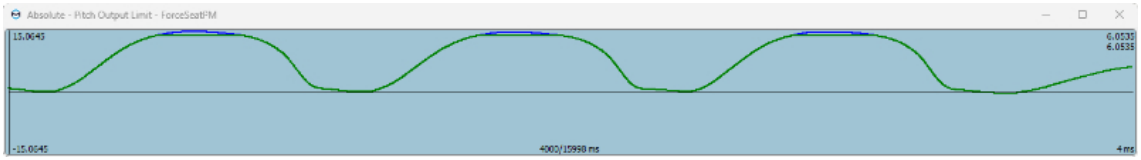
- Exponential limit, factor 1.0, 50% of degrees



- Gain limit, factor 0.3, 100% of degrees



- Gain limit, factor 1.0, 100% of degrees



3.7 DoF mixer

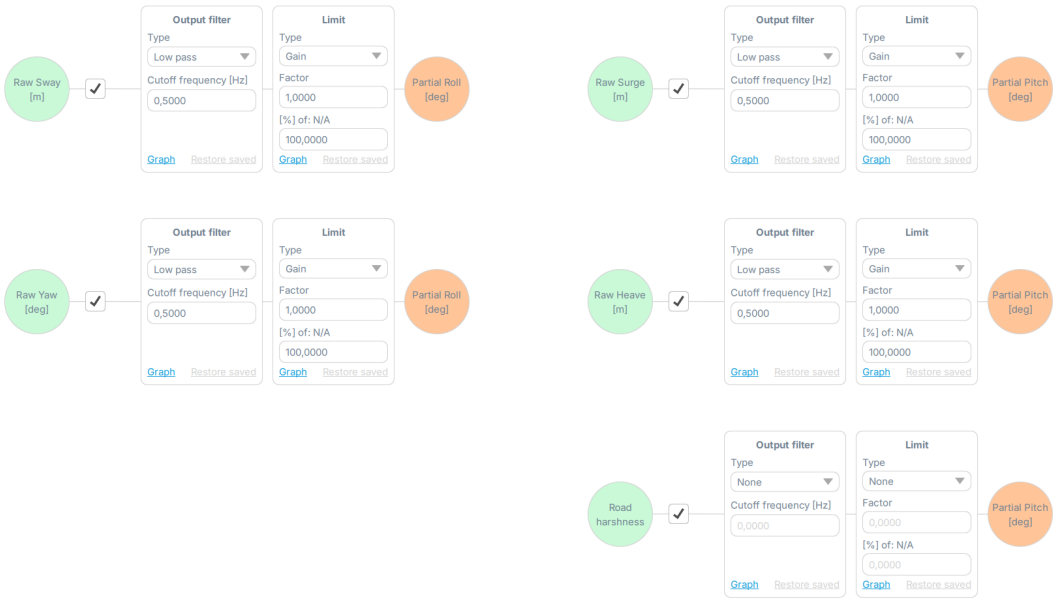
This parameter allows for configuration of the substitution of a missing degree of freedom. If the motion platform lacks certain motion capability, it can be substituted with a similar one to give the impression of that movement. All of the DoF mixer parameters are independent of each other.

INFORMATION

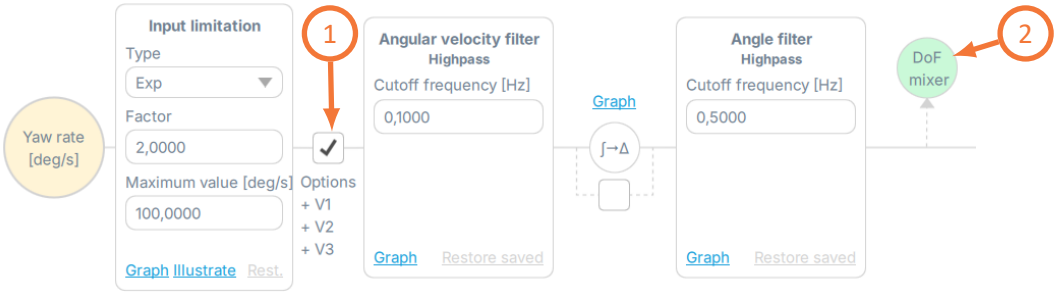
It is unnecessary to enable DoF mixer block on the platform that is already able to generate certain degree of freedom - it will be redundant with the original (raw) effect and will not affect the motion of the platform.

It is possible to transform:

- Raw sway into Partial roll
- Raw yaw into Partial roll
- Raw surge into Partial pitch
- Raw heave into Partial pitch
- Road harshness into Partial pitch

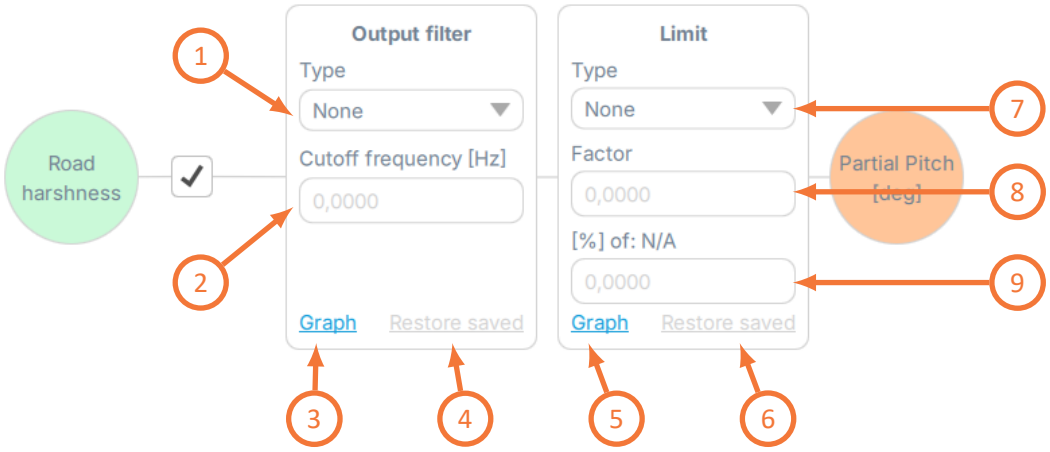


In order for the DoF mixer to work, the path of the Raw Effect must be activated and adjusted. For example, for the ”Raw yaw into Partial roll” effect to work, go to **Vertical acceleration and yaw rate** tab, activate bottom ”Yaw rate” effect (1) and adjust every filter that generates calculations for ”DoF mixer” Raw Yaw effect (2).



3.7.1 Output filter and limit

All parameters are combined of output filter and output limit block.



Output filter block:

- (1) Type - defines the type of the filtering function. Following options are available: **None** (no limitation) and **Low-pass** (recommended when smoothing is required).
- (2) Cutoff frequency (Hz) - defines the cutoff frequency for the Low-pass filter. It implements the following formula:

$$\mathbf{y_n} = \mathbf{x}\frac{dt}{dt+\tau} + \mathbf{y_{n-1}}\frac{\tau}{dt+\tau}, \tau = \frac{1}{2\pi f}$$

  where **dt** is interval between calls, usually 0.004 [s], **f** is cutoff frequency, **x** is input and **y** is output.
- (3) Graph - opens a pop-up with graph that plots input (blue) and output (green) data of the block. When the SIM is running in the background, you can see how output limitation block alters the original signal.
- (4) Restore saved - resets all parameters in the block to values stored in the file (recently saved).

Limit block:

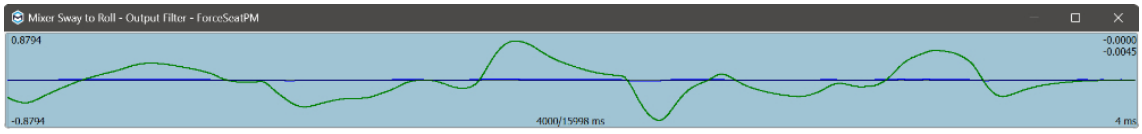
- (7) Type - defines the type of the limiting function. Following options are available: **None** (no limitation), **Gain** (more intense output with abrupt freeze at endpoints) and **Exponential** (more smooth output).
- (8) Factor - overall extent of the limitation on the output data.
- (9) % of maximum available interval in degrees (software provides the maximum value automatically) - limits the output data on a maximum available movement.
- (5) Graph - opens a pop-up with graph that plots input (blue) and output (green) data of the block. When the SIM is running in the background, you can see how output limitation block alters the original signal.
- (6) Restore saved - resets all parameters in the block to values stored in the file (recently saved).

INFORMATION

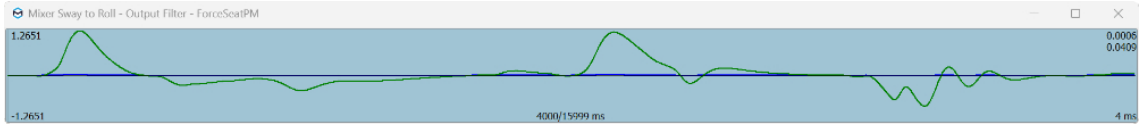
Ensure that the demanded raw effect is enabled first, since it transmits input data into the DoF mixer block. For example in order for the **Road harshness into partial pitch** parameter to work, road harshness (from Enhancer menu) must be activated and set correctly. Open the **Output filter** graph to check if the input data is available (blue line).

In order to better understand the output filter influence on output signal, refer to illustrations below (blue is input data, green is output data):

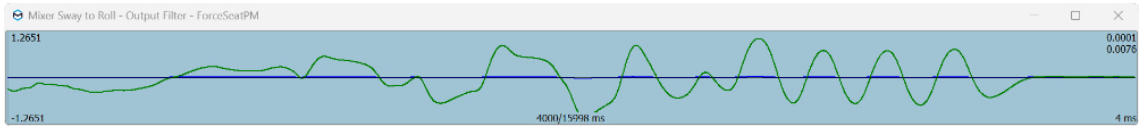
- Low-pass cutoff frequency - 0.5 Hz



- Low-pass cutoff frequency - 1.9 Hz

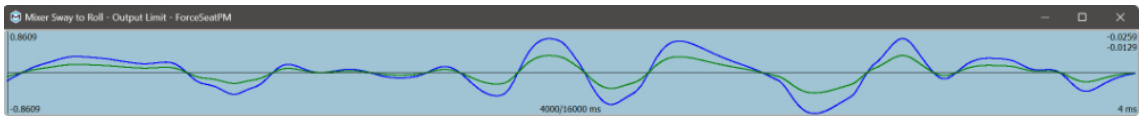


- Low-pass cutoff frequency - 3.0 Hz

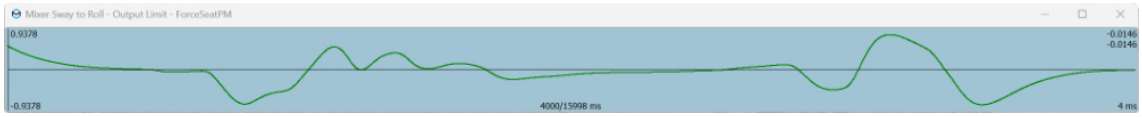


In order to better understand the output limit influence on output signal, refer to illustrations below (blue is input data, green is output data):

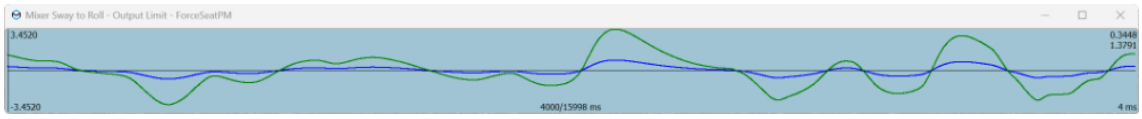
- Gain limit, factor 0.5, 100% of degrees



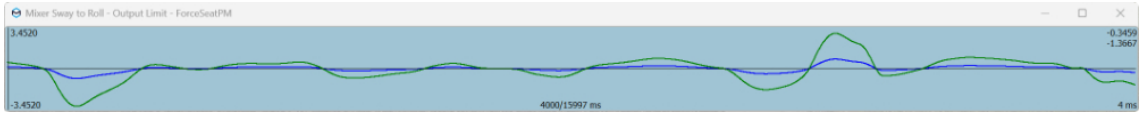
- Gain limit, factor 1.0, 100% of degrees



- Gain limit, factor 4.0, 100% of degrees



- Exponential limit, factor 4.0, 100% of degrees

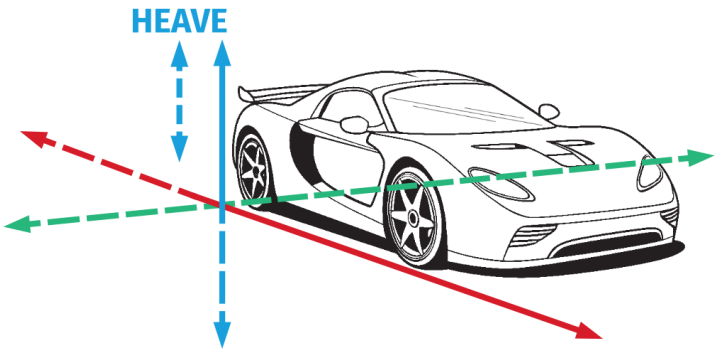


3.8 Enhancer - road harshness

This parameter allows for configuration of the road harshness into intermittent heave action. In ”Param set 1” it only applies to vehicles (for flight configuration e.g. landing strip harshness - go to ”Param set 2” in top right corner).

As opposed to **Vertical acceleration** it only communicates uneven texture of the road (e.g. driving over patched tarmac, over a curb, grass) and will not heave the platform to simulate change in vehicle’s weight (g-force).

Enhancer is an autonomous effect that can be configured with every other effect disabled.

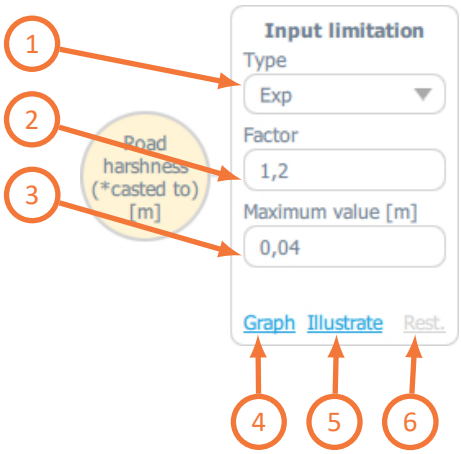


INFORMATION

Modifying settings has an instant effect on platform’s motion characteristic as long as the changes are saved (right top tab in ACE window or keyboard shortcut ”CTRL+S”).

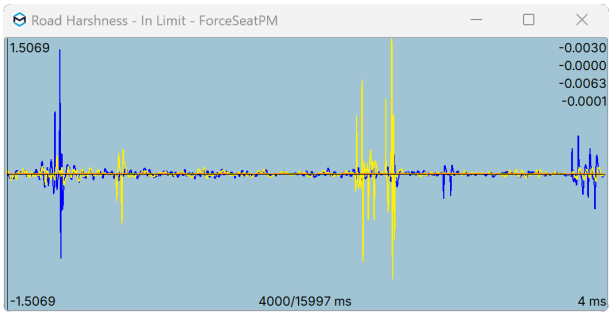
3.8.1 Input limitation

Input limitation options block adjusts telemetry data from the game/simulation before it is translated into output data for the platform.

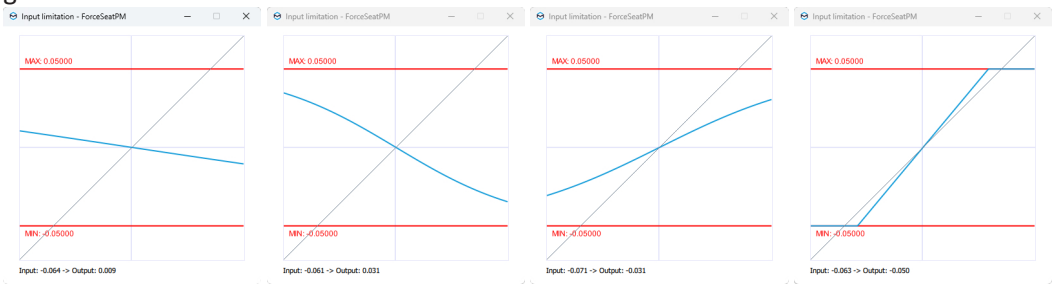


- (1) Type: none - no limitation.
  Type: gain - more intense input with abrupt freeze at endpoint.
  Type: exp - exponential increase or decrease of the input data.

- (2) Factor - overall signal gain, exponentially increases input data from the game/simulation (visualized in ”Illustrate”). Set to negative inverts the input data.
- (3) Maximum value [m] - limits the input data to a specific number metres (0.XX for centimeters) number (visualized in ”Illustrate”).
- (4) Graph - opens a pop-up with graph that plots left input (blue), right input (yellow), left output (green) and right output (orange) data of the block. When the **SIM** is running in the background, you can see how **Input limitation** block alters the original signal.



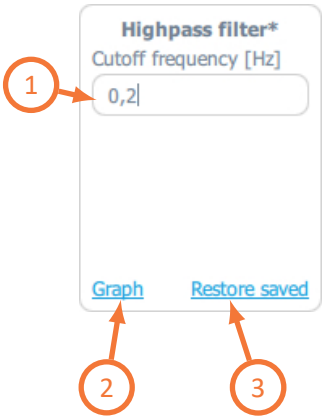
- (5) Illustrate - opens up a graph that shows how the **Factor** (blue line) and **Maximum value** (red lines) limitation function modifies incoming data. Use Ctrl + mouse scroll to zoom the view. Below are examples of Factor increase. From the left: exp -0.15, exp -0.6, exp 0.5, gain 1.2 and Maximum value in meters = 0.05 m.



- (6) Rest. - restores all parameters in the block from a previously saved file.

3.8.2 High-pass filter

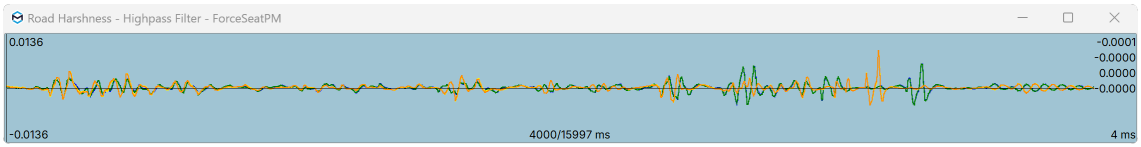
High-pass filter attenuates the low-frequency components and preserves the high-frequency components. It acts as a gateway for the input data - lower cutoff frequency in high-pass means that more detailed information is preserved for the next block. Higher cutoff frequency means that only the more noticeable stronger input data comes through to the next block and the details are reduced.



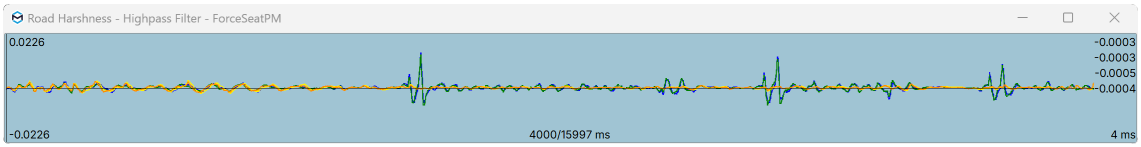
- (1) Cutoff frequency (Hz) - defines the cutoff frequency (Hz) for the high-pass filter.
- (2) Graph - opens a pop-up with graph that plots input (blue) and output (green) of the block. When the **SIM** is running in the background, you can see how **High-pass filter** block alters the original signal.
- (3) Restore saved - resets all parameters in the block to values stored in the file (recently saved).

In order to better understand the high-pass filter on output signal, refer to illustrations below (blue is input data, green is output data):

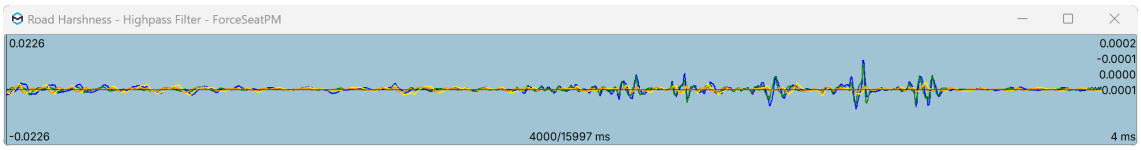
- Cutoff frequency - 0.2 Hz



- Cutoff frequency - 0.8 Hz

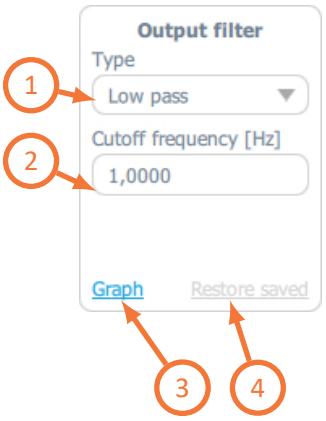


- Cutoff frequency - 2.0 Hz



3.8.3 Output filter

Output filter block is just a filter that smooths out or sharpens the output data before it is being processed by the next functional block.



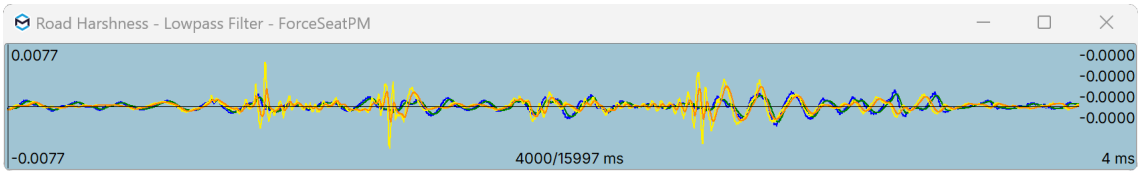
- (1) Type - defines the type of the filtering function. Following options are available: **None** (no output filter), **Low-pass** (recommended when smoothing is required).
- (2) Cutoff frequency (Hz) - defines the cutoff frequency for the Low-pass filter. It implements the following formula:

$$\mathbf{y_n} = \mathbf{x}\frac{dt}{dt+\tau} + \mathbf{y_{n-1}}\frac{\tau}{dt+\tau}, \tau = \frac{1}{2\pi f}$$

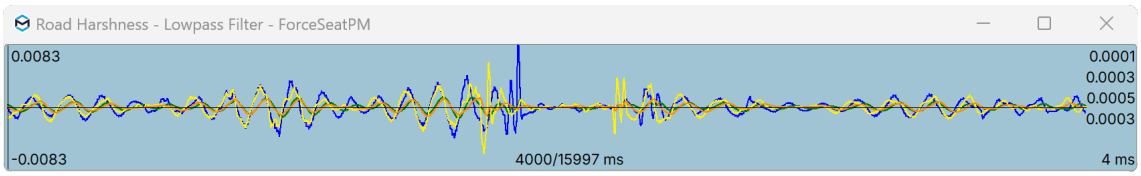
  where **dt** is interval between calls, usually 0.004 [s], **f** is cutoff frequency, **x** is input and **y** is output.
- (3) Graph - opens a pop-up with graph that plots input (blue) and output (green) of the block. When the **SIM** is running in the background, you can see how **Output filter** block alters the original signal.
- (4) Restore saved - resets all parameters in the block to values stored in the file (recently saved).

In order to better understand the output filter influence on output signal, refer to illustrations below (blue is input data, green is output data):

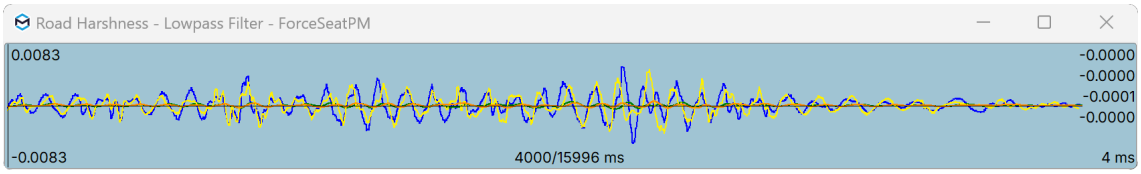
- Low-pass cutoff frequency - 4.0 Hz



- Low-pass cutoff frequency - 1.0 Hz



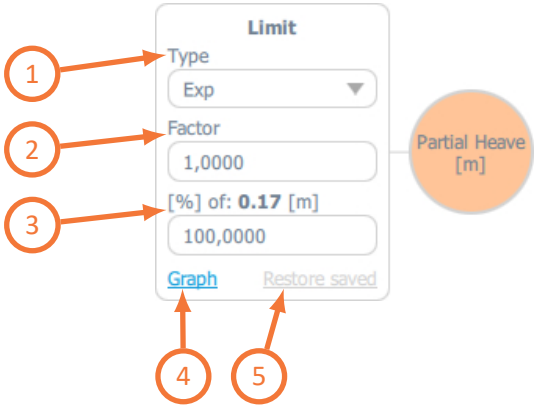
- Low-pass cutoff frequency - 0.3 Hz



3.8.4 Limit

Limit block works the same way as Input limitation block with two main differences:

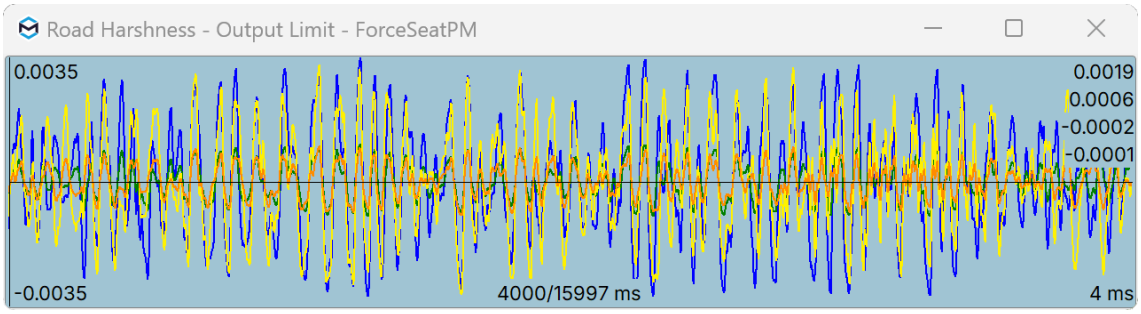
- they are used on output data, NOT on input data;
- the maximum value is read automatically from the connected motion platform and cannot be changed.



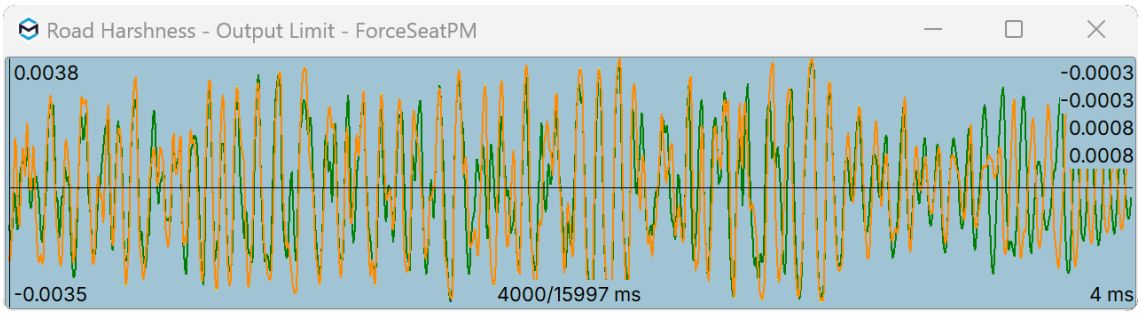
- (1) Type - defines the type of the limiting function. Following options are available: **None** (no limitation), **Gain** (more intense output with abrupt freeze at endpoints) and **Exponential** (more smooth output).
- (2) Factor - overall extent of the limitation on the output data.
- (3) % of maximum available interval in meters (software provides the maximum degree value automatically) - limits the output data on a maximum available heave movement.
- (4) Graph - opens a pop-up with graph that plots input (blue) and output (green) data of the block. When the SIM is running in the background, you can see how output limitation block alters the original signal.
- (5) Restore saved - resets all parameters in the block to values stored in the file (recently saved).

In order to better understand the output limit influence on output signal, refer to illustrations below (blue is input data, green is output data):

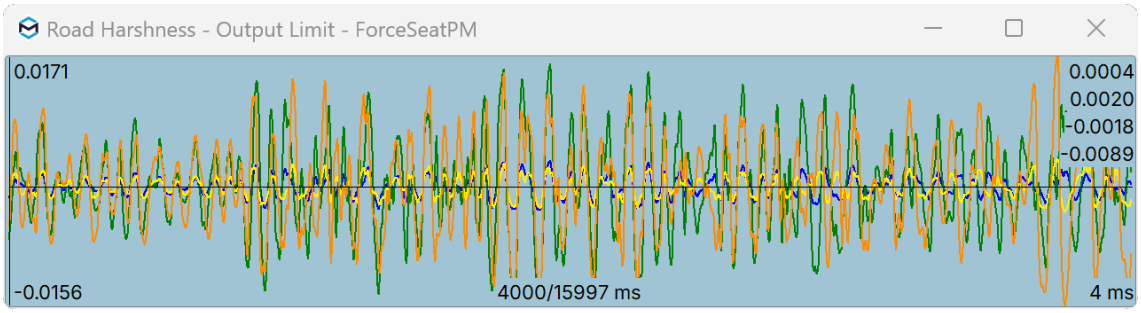
- Exponential limit, factor 0.3, 100%



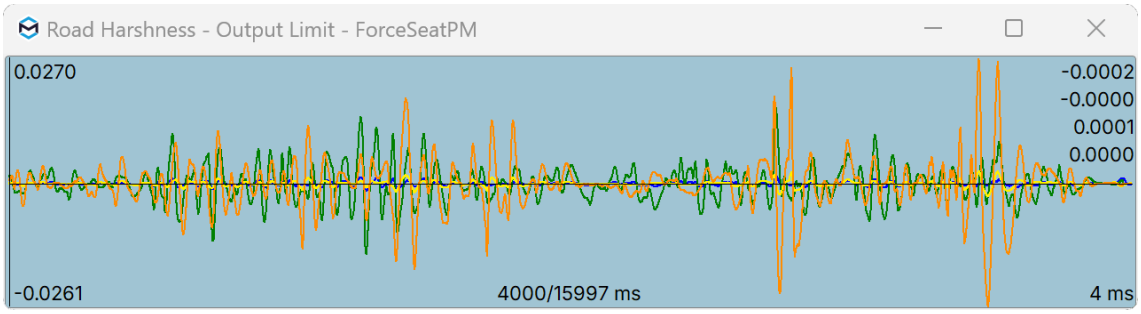
- Exponential limit, factor 1.0, 100%



- Exponential limit, factor 5.0, 100%



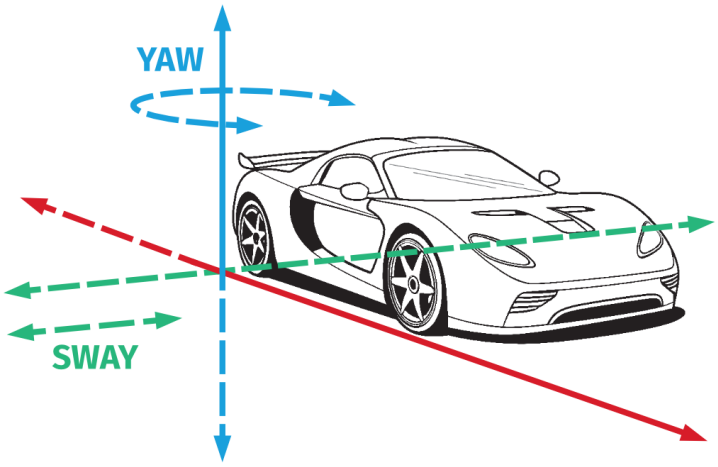
- Gain limit, factor 10.0, 100%



3.9 Enhancer - Side slip into Partial Yaw and Sway

This parameter allows for configuration of side slip (oversteer grip loss) of the vehicle translated into both yaw and sway movement. It is combined of input signal limitation, rate limit, output filter and output limit.

Enhancer is an autonomous effect that can be configured with every other effect disabled.



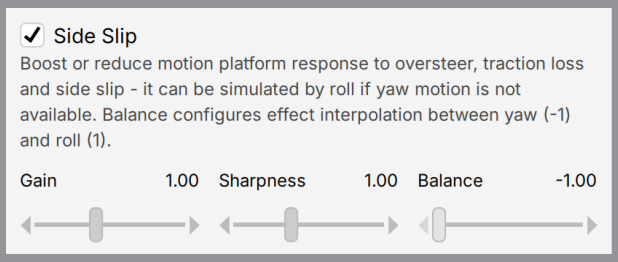
INFORMATION

Modifying settings has an instant effect on platform's motion characteristic as long as the changes are saved (right top tab in ACE window or keyboard shortcut "CTRL+S").

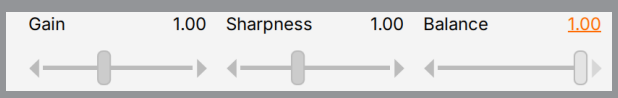
INFORMATION

Before starting configuration on sideslip parameters - Roll to yaw Balance slider must be set in QubicManager:

- For yaw configuration - set the Balance to -1

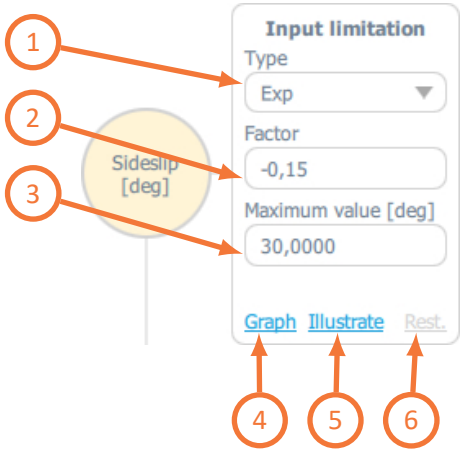


- For roll configuration - set the Balance to +1

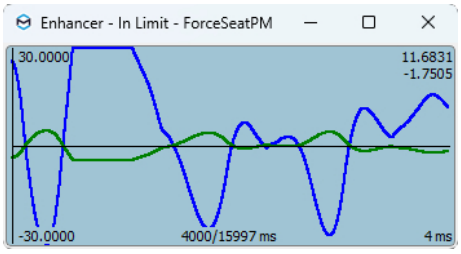


3.9.1 Input limitation

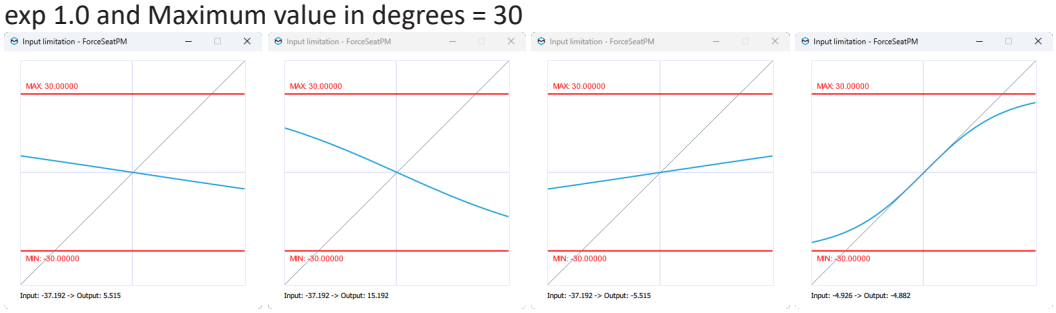
Input limitation options block adjusts telemetry data from the game/simulation before it is translated into output data for the platform.



- (1) Type: none - no limitation.
  Type: gain - more intense input with abrupt freeze at endpoint.
  Type: exp - exponential increase or decrease of the input data.
- (2) Factor - overall signal gain, exponentially increases input data from the game/simulation (visualized in ”Illustrate”). Set to negative inverts the input data.
- (3) Maximum value [deg]: limits the input data on a maximum available degree angle (visualized in ”Illustrate”).
- (4) Graph - opens a pop-up with graph that plots input (blue) and output (green) data of the block. When the **SIM** is running in the background, you can see how **Input limitation** block alters the original signal.



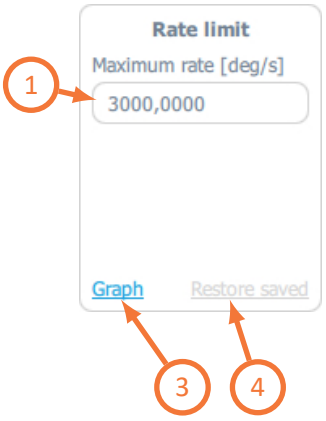
- (5) Illustrate - opens up a graph that shows how the **Factor** (blue line) and **Maximum value** (red lines) limitation function modifies incoming data. Use Ctrl + mouse scroll to zoom the view. Below are examples of Factor increase. From the left: exp -0.15, exp -0.45, exp 0.15, exp 1.0 and Maximum value in degrees = 30



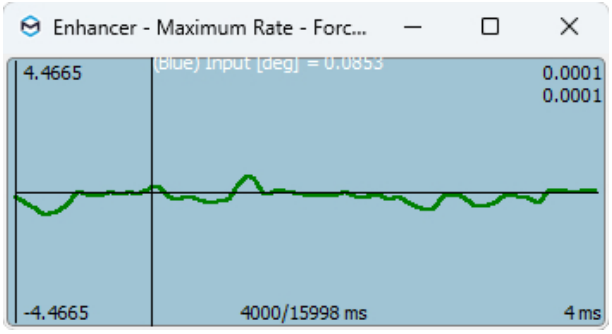
- (6) Rest - restores all parameters in the block from a previously saved file.

3.9.2 Rate limit

Rate limit configures the output velocity of platform movement during a side slip event in degrees per second. The higher the value, the quicker is the platform's movement.



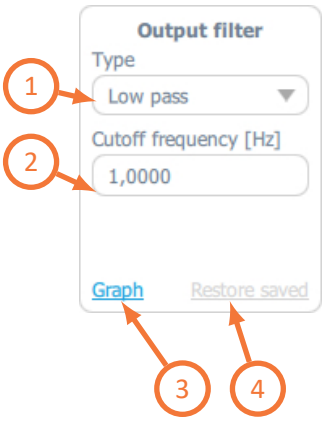
- (1) Maximum rate (deg/s) - overall velocity gain of platform yaw and sway movement.
- (2) Graph - opens a pop-up with graph that plots only the output (green) data of the block.



- (3) Restore saved - resets all parameters in the block to values stored in the file (recently saved).

3.9.3 Output filter

Output filter block is just a filter that smooths out or sharpens the output data before it is being processed by the next functional block.



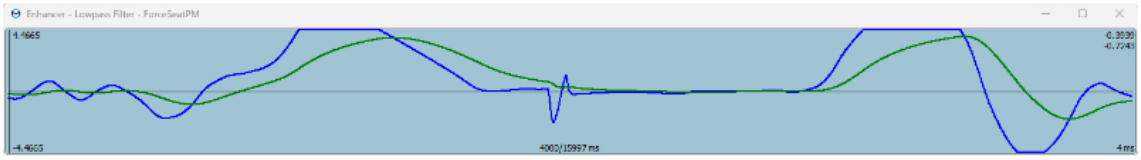
- (1) Type - defines the type of the filtering function. Following options are available: **None** (no output filter), **Low-pass** (recommended when smoothing is required).
- (2) Cutoff frequency (Hz) - defines the cutoff frequency for the Low-pass filter. It implements the following formula:

$$\mathbf{y_n} = \mathbf{x}\frac{dt}{dt+\tau} + \mathbf{y_{n-1}}\frac{\tau}{dt+\tau}, \tau = \frac{1}{2\pi f}$$

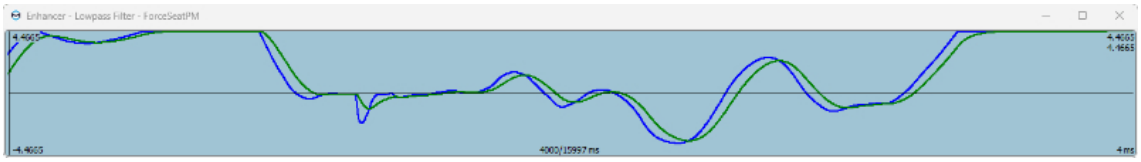
  where **dt** is interval between calls, usually 0.004 [s], **f** is cutoff frequency, **x** is input and **y** is output.
- (3) Graph - opens a pop-up with graph that plots input (blue) and output (green) of the block. When the **SIM** is running in the background, you can see how **Output filter** block alters the original signal.
- (4) Restore saved - resets all parameters in the block to values stored in the file (recently saved).

In order to better understand the output filter influence on output signal, refer to illustrations below (blue is input data, green is output data):

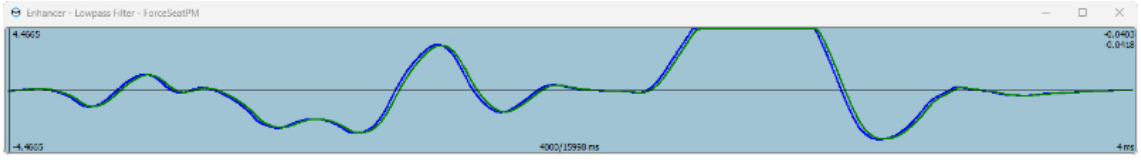
- Low-pass cutoff frequency - 0.2 Hz



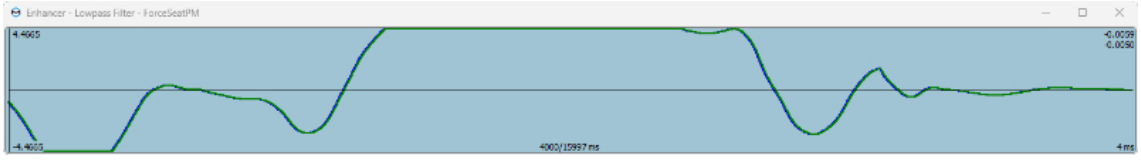
- Low-pass cutoff frequency - 0.9 Hz



- Low-pass cutoff frequency - 3.0 Hz



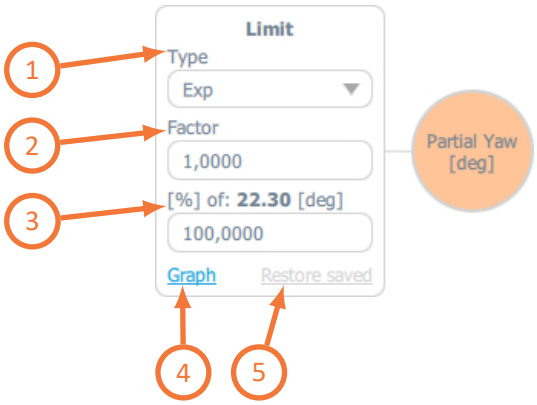
- Low-pass cutoff frequency - 10.0 Hz



3.9.4 Limit

Limit block works the same way as Input limitation block with two main differences:

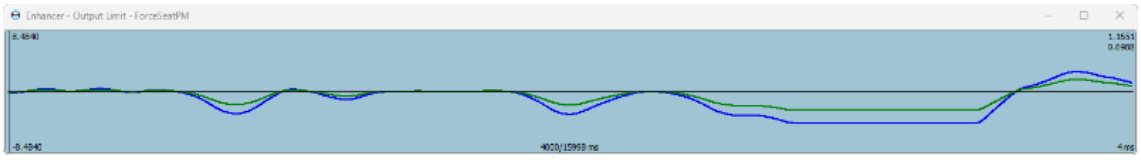
- they are used on output data, NOT on input data;
- the maximum value is read automatically from the connected motion platform and cannot be changed.



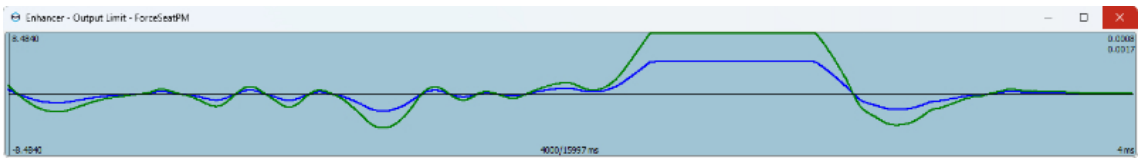
- (1) Type - defines the type of the limiting function. Following options are available: **None** (no limitation), **Gain** (more intense output with abrupt freeze at endpoints) and **Exponential** (more smooth output).
- (2) Factor - overall extent of the limitation on the output data.
- (3) % of maximum available degrees of yaw (software provides the maximum degree value automatically) - limits the output data on a maximum available degree angle.
- (4) Graph - opens a pop-up with graph that plots input (blue) and output (green) data of the block. When the SIM is running in the background, you can see how output limitation block alters the original signal.
- (5) Restore saved - resets all parameters in the block to values stored in the file (recently saved).

In order to better understand the output limit influence on output signal, refer to illustrations below (blue is input data, green is output data):

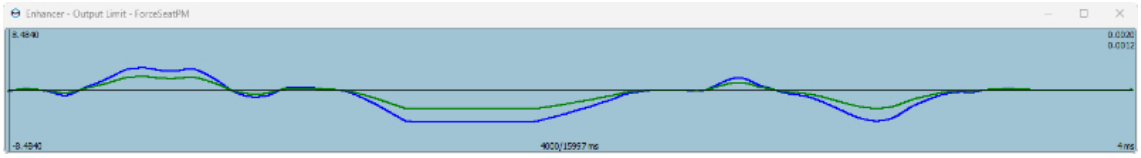
- Exponential limit, factor 0.3, 100% of degrees



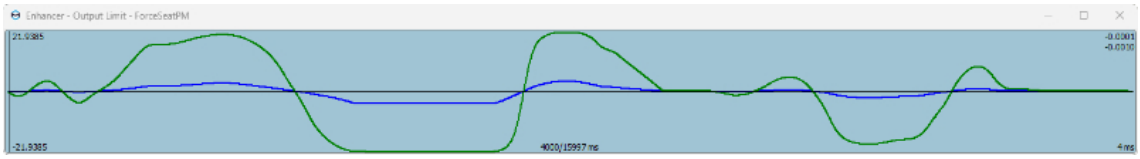
- Exponential limit, factor 1.0, 50% of degrees



- Exponential limit, factor 3.0, 100% of degrees



- Exponential limit, factor 6.0, 100% of degrees

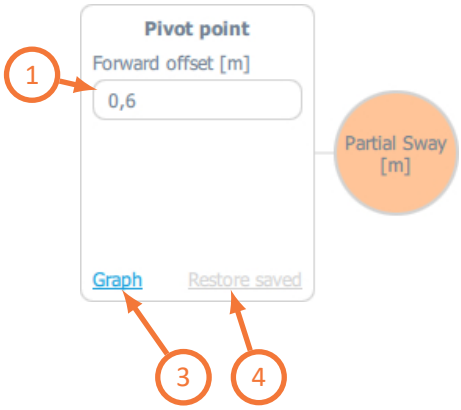


INFORMATION

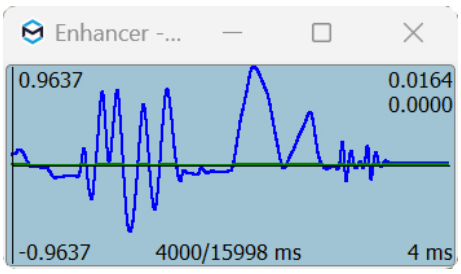
Ensure that the settings are balanced correctly and not set too high - the effect will become unpleasant for the user and the sideslip configuration can activate platform's movement even before the in-game vehicle looses traction, which will be misleading.

3.9.5 Pivot point

Pivot point configuration allows for moving the static point forward and modifying the movement geometry characteristic. This setting must be matched precisely into different motion platforms since they are constructed differently.

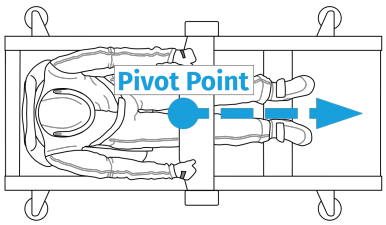


- (1) Forward offset (m) - distance of center pivot point shift forward in meters.
- (2) Graph - opens a pop-up with graph that plots input (blue) and output (green) data of the block. When the SIM is running in the background, you can see how the pivot point setting alters the original signal.

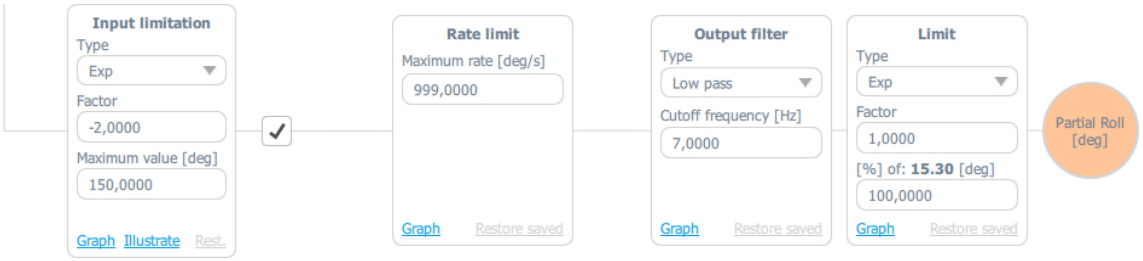


- (3) Restore saved - resets all parameters in the block to values stored in the file (recently saved).

Setting it to zero will cause the platform to rotate around its center point. In order for the platform to swing its front - set it forward for the platform to swing its back to feel more realistic oversteer.



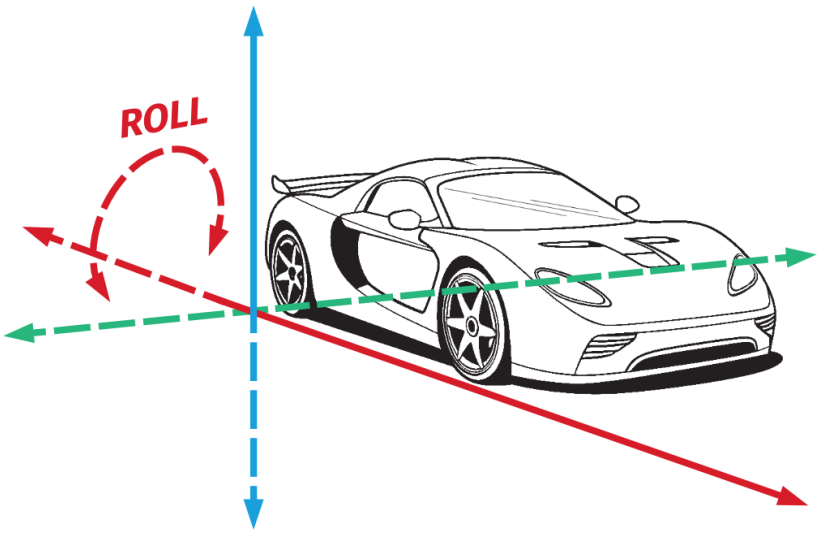
3.9.6 Sideslip into partial roll



This parameter allows for configuration of side slip (oversteer grip loss) of the vehicle translated into **partial roll** movement (independent of the yaw and sway). It is combined of input signal limitation, rate limit, output filter and output limit (no pivot point setting).

It is configured the same way as the **Sideslip into yaw and sway** - refer to the previous section for details.

Enhancer is an autonomous effect that can be configured with every other effect disabled.



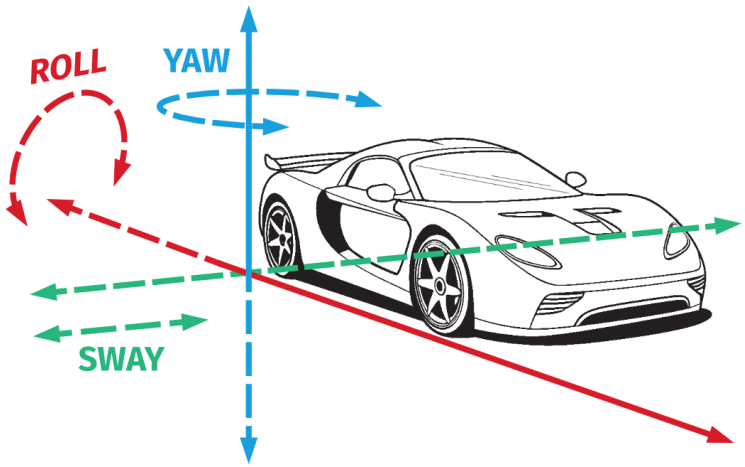
3.10 Understeer

This parameter allows for configuration of understeer grip loss (front wheels) of the vehicle translated into both yaw, sway and roll movement. It is combined of low-pass filters, rate limit, output filters and output limits.

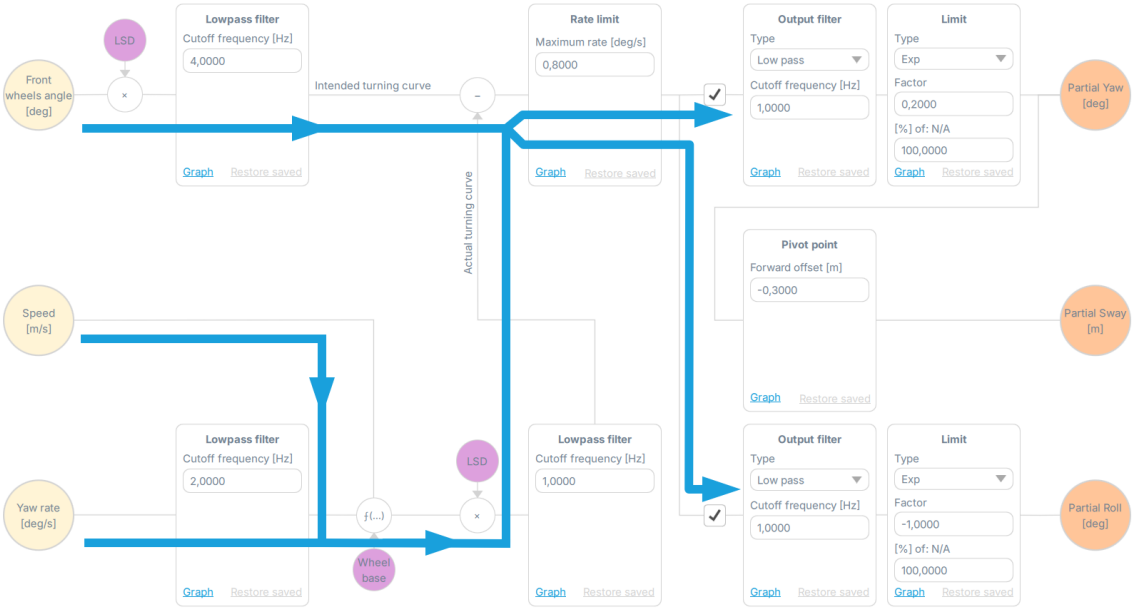
INFORMATION

Mathematical formula for Understeer is:

$$\text{Understeer} = \text{front\_wheel\_steering\_handle} - \arctan\left(\frac{\text{wheel\_base} \cdot \text{yaw\_rate}}{\text{forward\_speed}}\right)$$



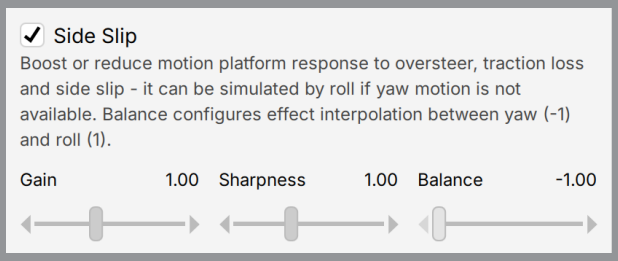
Yaw rate, then combined with speed parameter meets with Front wheels angle and allows to configure combined output signal in Rate limit. Then it is filtered and limited into Yaw and Sway movement. Same output from Rate limit then is filtered and limited into Roll movement and works independently.



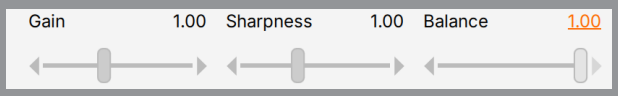
INFORMATION

Before starting configuration on understeer parameters - Roll to yaw Balance slider must be set in QubicManager:

- For yaw configuration - set the Balance to -1

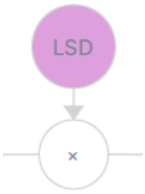


- For roll configuration - set the Balance to +1



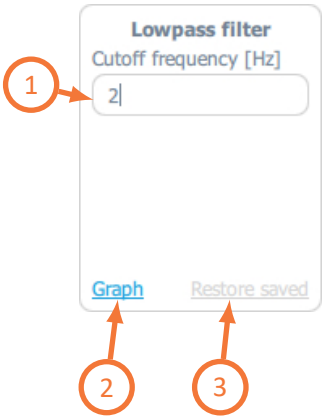
3.10.1 Yaw rate, speed, and front wheels angle

Low-pass filter blocks for Yaw rate, Speed, and Front wheels angle allow for filtering configuration of the input data. The Yaw rate influenced by understeer input data from game/simulation is then combined with speed and is filtered again. Front wheels angle is filtered as well and then combined with the prior mentioned.



LSD stands for ”Low speed dampening”.

Low-pass filter is recommended for smoothing the output data. Opening the graph shows the difference between input data (blue) and output data (green).



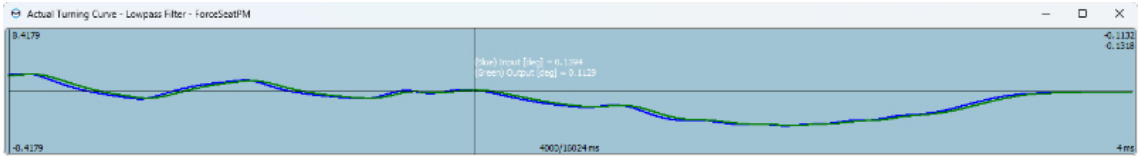
- (1) Cutoff frequency (Hz) - defines the cutoff frequency (Hz) for the low-pass filter. It implements the following formula:

$$\mathbf{y_n} = \mathbf{x}\frac{dt}{dt+\tau} + \mathbf{y_{n-1}}\frac{\tau}{dt+\tau}, \tau = \frac{1}{2\pi f}$$

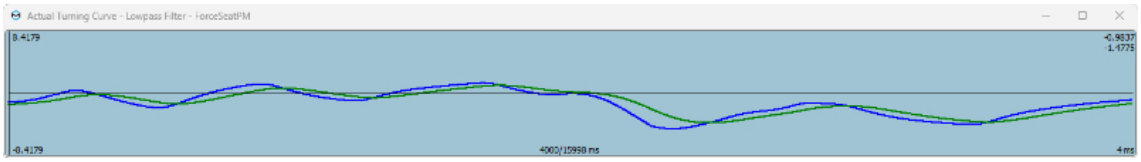
  where **dt** is interval between calls, usually 0.004 [s], **f** is cutoff frequency, **x** is input and **y** is output.
- (2) Graph - opens a pop-up with graph that plots input (blue) and output (green) of the block. When the **SIM** is running in the background, you can see how **Low-pass filter** block alters the original signal.
- (3) Restore saved - resets all parameters in the block to values stored in the file (recently saved).

In order to better understand the input low-pass filter influence on output data, refer to illustrations below (blue is input data, green is output data):

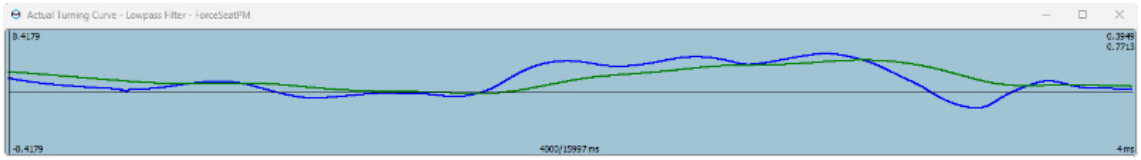
- Low-pass cutoff frequency - 1.0 Hz



- Low-pass cutoff frequency - 0.3 Hz

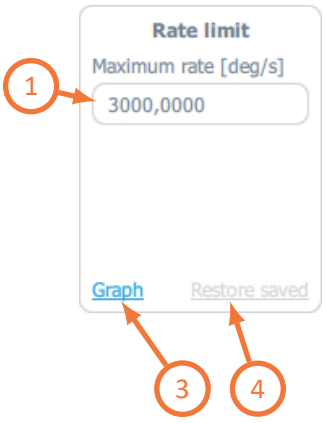


- Low-pass cutoff frequency - 0.1 Hz



3.10.2 Rate limit

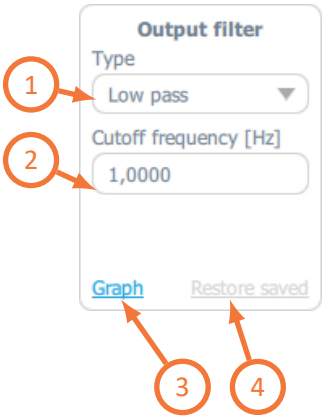
Rate limit configures the output velocity of platform movement during an understeer event in degrees per second. The higher the value, the quicker is the platform's movement.



- (1) Maximum rate (deg/s) - overall velocity gain of platform yaw, sway and roll movement.
- (2) Graph - opens a pop-up with graph that plots only the output (green) data of the block.
- (3) Restore saved - resets all parameters in the block to values stored in the file (recently saved).

3.10.3 Understeer into yaw and sway - output low-pass filter

Output filter block is just a filter that smooths out or sharpens the output data before it is being processed by the next functional block.



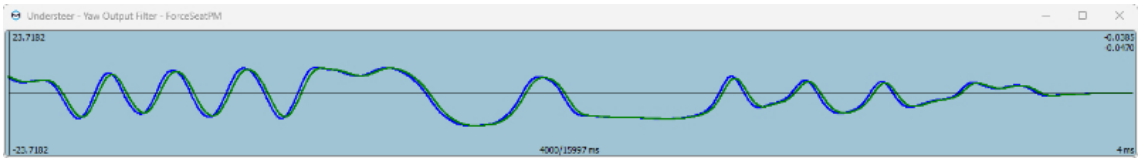
- (1) Type - defines the type of the filtering function. Following options are available: **None** (no output filter), **Low-pass** (recommended when smoothing is required).
- (2) Cutoff frequency (Hz) - defines the cutoff frequency for the Low-pass filter. It implements the following formula:

$$\mathbf{y_n} = \mathbf{x}\frac{dt}{dt+\tau} + \mathbf{y_{n-1}}\frac{\tau}{dt+\tau}, \tau = \frac{1}{2\pi f}$$

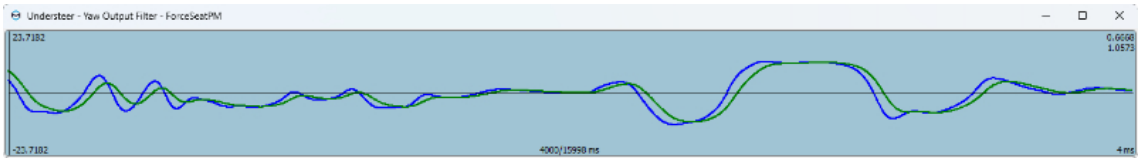
  where **dt** is interval between calls, usually 0.004 [s], **f** is cutoff frequency, **x** is input and **y** is output.
- (3) Graph - opens a pop-up with graph that plots input (blue) and output (green) of the block. When the **SIM** is running in the background, you can see how **Output filter** block alters the original signal.
- (4) Restore saved - resets all parameters in the block to values stored in the file (recently saved).

In order to better understand the output filter influence on output signal, refer to illustrations below (blue is input data, green is output data):

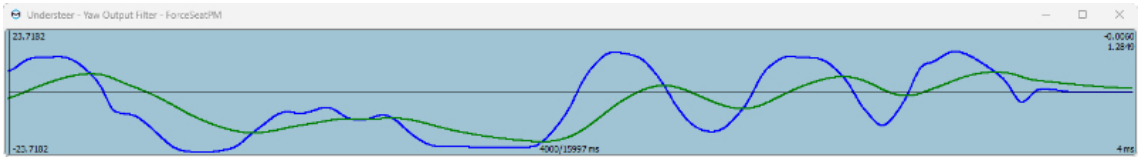
- Low-pass cutoff frequency - 3.0 Hz



- Low-pass cutoff frequency - 0.9 Hz



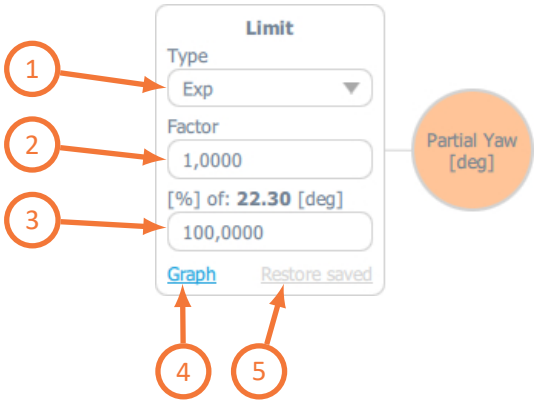
- Low-pass cutoff frequency - 0.15 Hz



3.10.4 Understeer into yaw and sway - limit

Limit block works the same way as Input limitation block with two main differences:

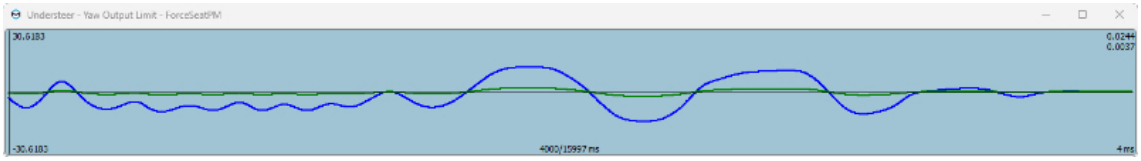
- they are used on output data, NOT on input data;
- the maximum value is read automatically from the connected motion platform and cannot be changed.



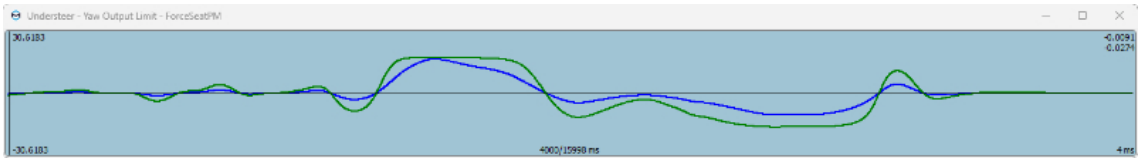
- (1) Type - defines the type of the limiting function. Following options are available: **None** (no limitation), **Gain** (more intense output with abrupt freeze at endpoints) and **Exponential** (more smooth output).
- (2) Factor - overall extent of the limitation on the output data.
- (3) % of maximum available degrees of yaw (software provides the maximum degree value automatically) - limits the output data on a maximum available degree angle.
- (4) Graph - opens a pop-up with graph that plots input (blue) and output (green) data of the block. When the SIM is running in the background, you can see how output limitation block alters the original signal.
- (5) Restore saved - resets all parameters in the block to values stored in the file (recently saved).

In order to better understand the output limit influence on output signal, refer to illustrations below (blue is input data, green is output data):

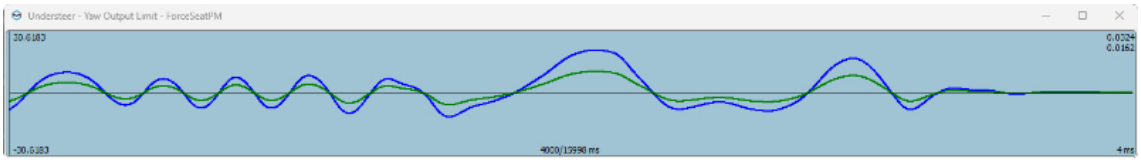
- Exponential limit, factor 0.15, 80% of degrees



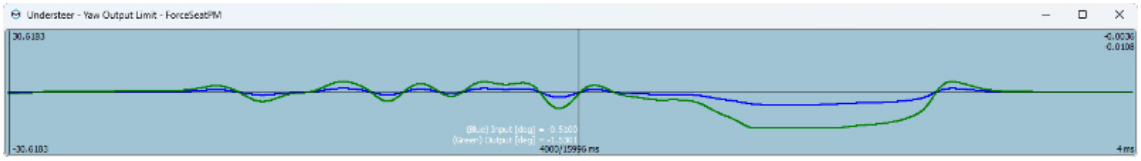
- Exponential limit, factor 3.0, 80% of degrees



- Gain limit, factor 0.5, 80% of degrees



- Gain limit, factor 3.0, 80% of degrees

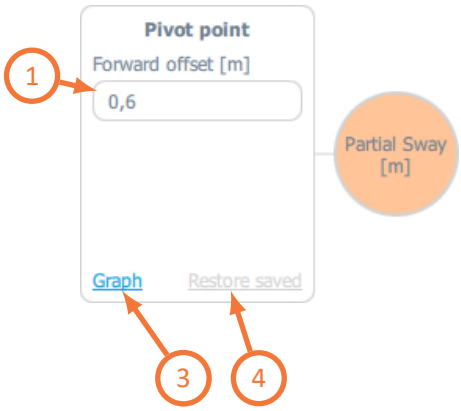


INFORMATION

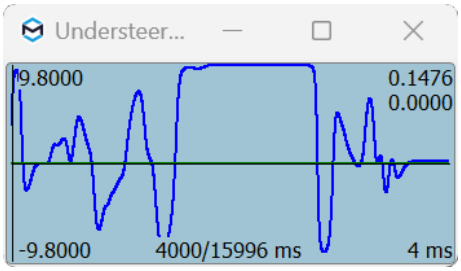
Ensure that the settings are balanced correctly and not set too high - the effect will become unpleasant for the user and the understeer configuration can activate platform's movement even before the in-game vehicle looses traction, which will be misleading.

3.10.5 Pivot point

Pivot point configuration allows for moving the static point forward and extending the simulation of oversteer. Also it must match every motion platform's dimensions since they are build differently.

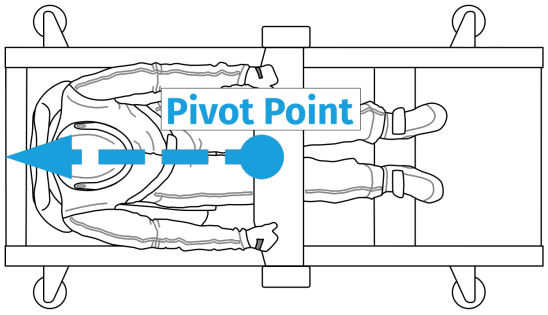


- (1) Forward offset (m) - distance of center pivot point shift forward in meters (for backwards pivot point - set it to negative value).
- (2) Graph - opens a pop-up with graph that plots input (blue) and output (green) data of the block. When the SIM is running in the background, you can see how the pivot point setting alters the original signal.



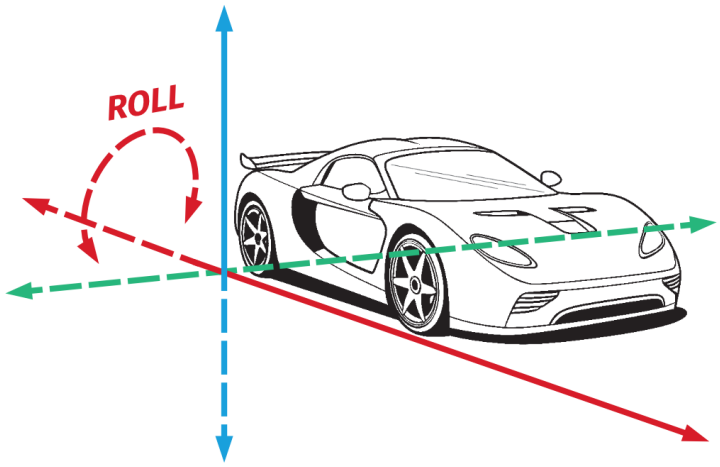
- (3) Restore saved - resets all parameters in the block to values stored in the file (recently saved).

Leaving it at zero will cause the platform to rotate around its center point. Set it backwards for the platform to swing its front to feel more realistic understeer.



3.10.6 Understeer into roll

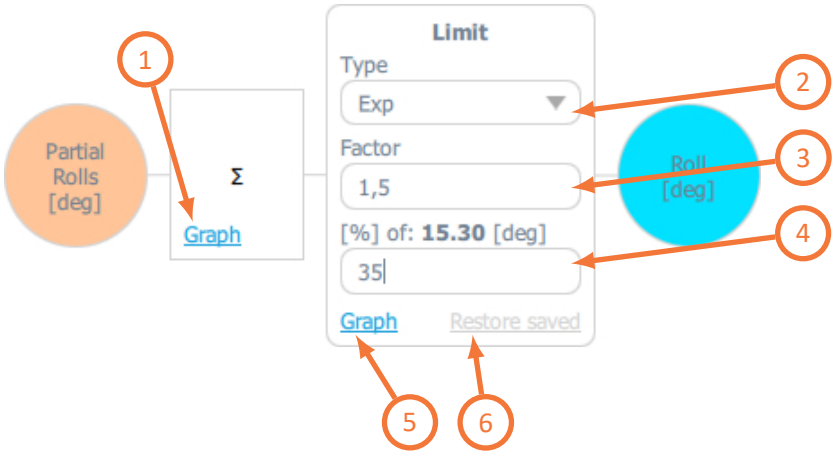
Partial roll action is generated the same way, as the yaw and sway action, only without the pivot point configuration. Refer to the section before the previous one for detailed information.



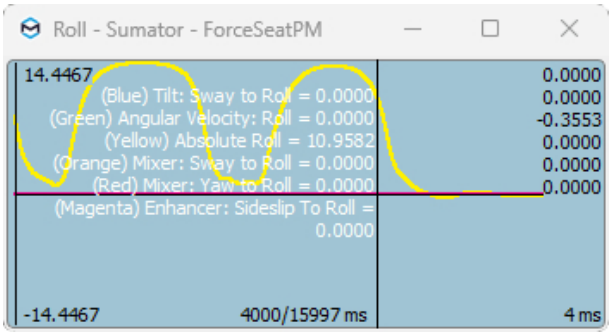
3.11 Multiplexer

This parameter allows for boosting or decreasing all of the existing degrees of freedom separately, without the interference with already perfected settings.

It is combined of independently configured surge, sway, heave, pitch, roll and yaw. All of which are enhanced/decreased via exponential limit factor or gain limit factor and restricted via specifying a percentage of available degrees of movement.



- (1) Sigma graph - opens a pop-up with graph that plots inputs from all available degrees of freedom in the platform (colors are described in the illustration below). When the SIM is running in the background, you can see how the input signal draws the line on the graph.

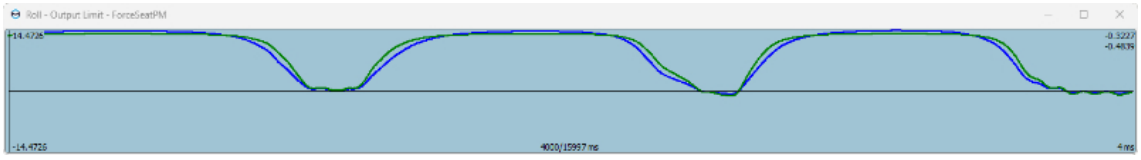


- (2) Type - defines the type of the limiting function. Following options are available: **None** (no limitation), **Gain** (more intense output with abrupt freeze at endpoints) and **Exponential** enables
- (2) Factor - overall extent of the limitation on the output data.
- (3) % of maximum available angle degree (software provides the maximum degree value automatically) - limits the output data on a maximum available movement.
- (4) Graph - opens a pop-up with graph that plots input (blue) and output (green) data of the block. When the SIM is running in the background, you can see how output limitation block alters the original signal.
- (5) Restore saved - resets all parameters in the block to values stored in the file (recently saved).

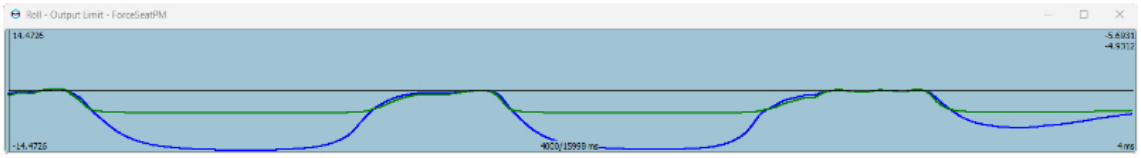
3.11.1 Example of use - partial rolls into roll

Since all of mentioned parameters are adjusted in an identical way - body roll will serve as an example. In order to better understand the output limit influence on output signal, refer to illustrations below (blue is input data, green is output data):

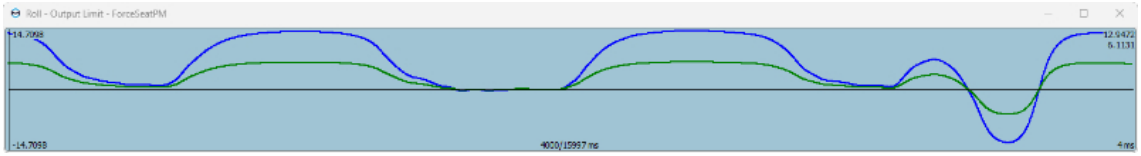
- Exponential limit, factor 1.5, 100% of degrees



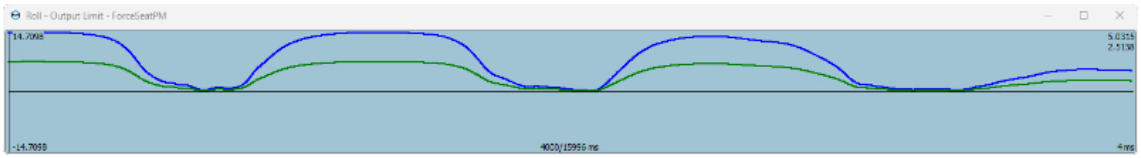
- Exponential limit, factor 1.5, 35% of degrees



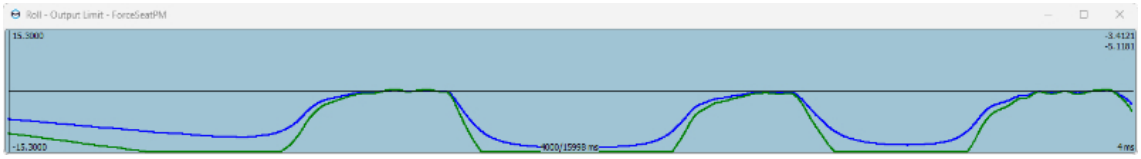
- Exponential limit, factor 0.5, 100% of degrees



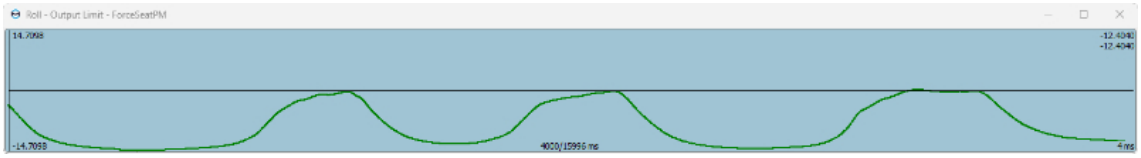
- Gain limit, factor 0.5, 100% of degrees



- Gain limit, factor 1.5, 100% of degrees



- Type: none

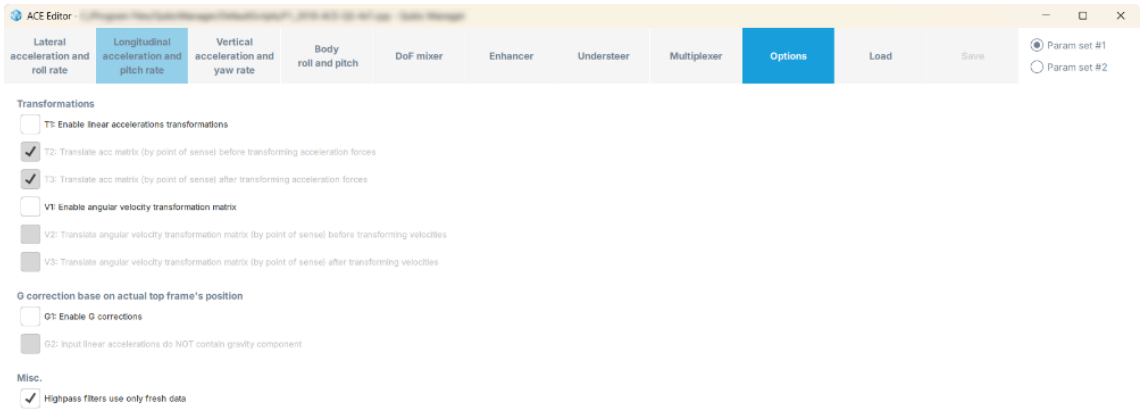


3.12 Options

All global options can be found in the **Options** tab.

INFORMATION

All changes must be saved in order for them to take effect.



3.12.1 T1: Enable linear accelerations transformations

When this option is enabled, the input linear accelerations vector is transformed by the current **top frame** orientation - roll, pitch and yaw output from previous **ACE** run.

$$\mathbf{a_2} = \mathbf{R_1} \cdot \mathbf{a_1}$$

R_1 is rotation matrix generated from the most recent **top table** roll, pitch and yaw. a_1 is a vector containing input linear accelerations. a_2 is a vector containing transformed linear accelerations that is going to be used for further processing.

$$\mathbf{a_x} = \begin{bmatrix} a_{longitudinal} \\ a_{lateral} \\ a_{vertical} \end{bmatrix}, \mathbf{R_1} = \begin{bmatrix} r_1 & r_2 & r_3 & 0 \\ r_4 & r_5 & r_6 & 0 \\ r_7 & r_8 & r_9 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

3.12.2 T2/T3: Translate acceleration matrix by point of sense

Both **T2** and **T3** have to be turned on to enable point of sense shift for liner accelerations.

3.12.3 V1: Enable angular velocity transformation

When this option is enabled, the input angular velocities vector is transformed by the current **top frame** orientation - roll and pitch (yaw is not used here) output from previous **ACE** run.

$$\omega_2 = \mathbf{R_2} \cdot \omega_1$$

R_2 is rotation matrix generated from the most recent **top table** roll and pitch. ω_1 is a vector containing input angular velocities. ω_2 is a vector containing transformed linear accelerations that is going to be used for further processing.

$$\mathbf{a_x} = \begin{bmatrix} a_{longitudinal} \\ a_{lateral} \\ a_{vertical} \end{bmatrix}, \mathbf{R_2} = \begin{bmatrix} 1 & sin(roll)tan(pitch) & cos(roll)tan(pitch) & 0 \\ 0 & cos(roll) & -sin(roll) & 0 \\ 0 & \frac{sin(roll)}{cos(pitch)} & \frac{cos(roll)}{cos(pitch)} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

3.12.4 V2/V3: Translate angular velocity transformation matrix by point of sense

Both **V2** and **V3** have to be turned on to enable point of sense shift for angular velocities.

3.12.5 G1: Enable G correction

When this option is enabled, the gravity vector is substracted from the linear accelerations vector (calculated by **T1**). The gravity vector is being calculated using current **top frame** orientation - roll and pitch output from previous **ACE** run.

$$\mathbf{a_3} = \mathbf{a_2} - \mathbf{g_1}$$

g_1 is gravity vector generated from the most recent **top table** roll and pitch. a_2 is a vector containing linear accelerations, transformed by **T1** if it was enabled. a_3 is a vector containing transformed linear accelerations that is going to be used for further processing.

$$\mathbf{a_x} = \begin{bmatrix} a_{longitudinal} \\ a_{lateral} \\ a_{vertical} \end{bmatrix}, \mathbf{g_1} = \begin{bmatrix} 9.81\frac{m}{s^2}sin(pitch) \\ 9.81\frac{m}{s^2}sin(roll)cos(pitch) \\ 9.81\frac{m}{s^2}cos(roll)cos(pitch) \end{bmatrix}$$

TIP

Using G correction is OPTIONAL and decision if this option should be enabled depends on end user preferences.

3.12.6 G2: Input linear accelerations does NOT contain gravity component

If **G1** is enabled and **top table** roll and pitch are close to 0 (zero), the g_1 vector equals to:

$$\mathbf{g_1} = \begin{bmatrix} 0 \\ 0 \\ 9.81\frac{m}{s^2} \end{bmatrix}$$

It is perfectly fine if input linear accelerations contains gravity component. Otherwise **top frame** and motion cues are shifted in space. **G2** option helps to compensate it but removing this 1[g] constant from the gravity correction vector g_1.

$$\mathbf{a_3} = \mathbf{a_2} - \mathbf{g_1} + \mathbf{g_2}$$

Where:

$$\mathbf{a_x} = \begin{bmatrix} a_{longitudinal} \\ a_{lateral} \\ a_{vertical} \end{bmatrix}, \mathbf{g_1} = \begin{bmatrix} 9.81\frac{m}{s^2}sin(pitch) \\ 9.81\frac{m}{s^2}sin(roll)cos(pitch) \\ 9.81\frac{m}{s^2}cos(roll)cos(pitch) \end{bmatrix}, \mathbf{g_2} = \begin{bmatrix} 0 \\ 0 \\ 9.81\frac{m}{s^2} \end{bmatrix}$$

3.12.7 Highpass filters use only fresh data

When this option is enabled, highpass filter will use input data directly from the game/simulation, instead of ForceSeat (which is transmitted at several times higher frequency). That will result in a smoother platform operation (for flight simulations mainly).

4 Appendixes

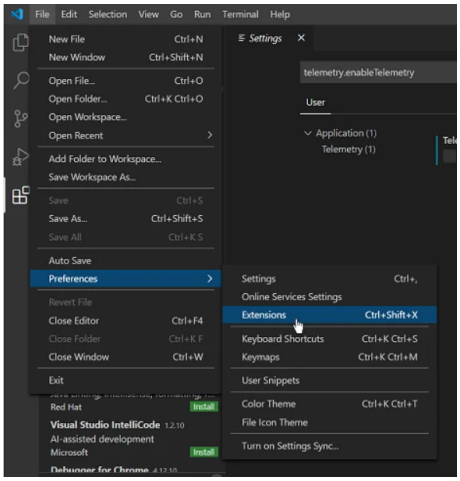
4.1 Visual Studio Code as motion script editor

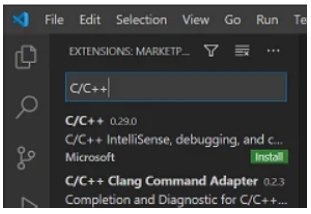
This short tutorial shows how to use **Visual Studio Code** to edit motion scripts associated with profiles in the **ForceSeatPM**. Using **Visual Studio Code** enables code completion (**IntelliSense**), syntax highlighting and contextual help. It allows also to browse API classes and functions directly from the editor.

> **INFORMATION**
>
> This tool is NOT REQUIRED to use **ACE Editor**. It is useful only in cases when motion script needs to be enhanced or heavily modified.

4.1.1 Installation and configuration

Download and install Visual Studio Code: `https://code.visualstudio.com/`. Next start the program, go to **File**, **Preferences**, **Extensions** and install **C/C++** extension.



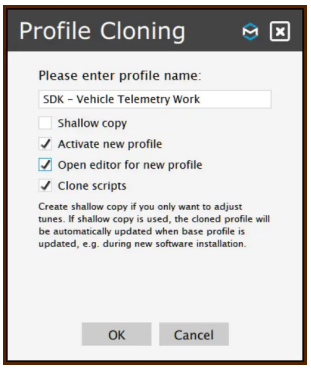


Wait until the extension and all dependencies are installed and then close the program.

4.1.2 Usage

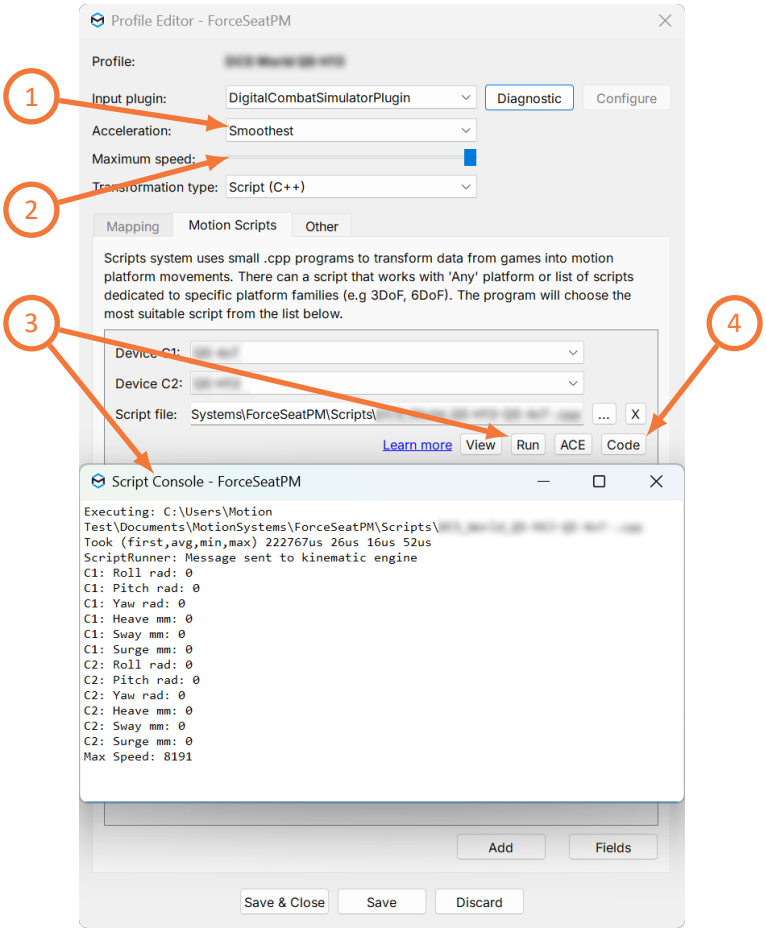
Clone the selected profile, e.g. **SDK – Vehicle Telemetry**:

- disable **Shallow copy**
- enable **Activate new profile**
- enable **Open editor for new profile**
- enable **Clone scripts**

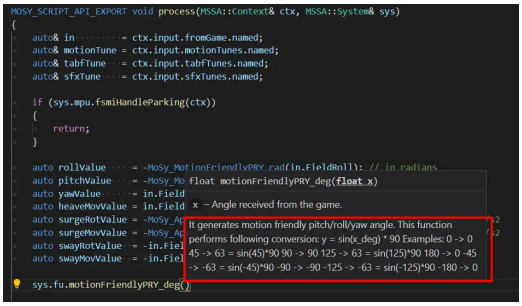


In **Profile Editor** go to **Motion Scripts** tab and find a script that matches your motion platform:

- Select Acceleration profile (1): Auto, Rapid, Balanced, Smoothest. It regulates how fast will the motion platform perform.
- Set Maximum speed of the motion platform (2) to any value - machine will not exceed that speed at any point.
- Press **Run** button (3) next to the script to verify that the script works correctly and there are no errors in the the output console.


Profile Editor - ForceSeatPM
Profile:
Input plugin:
DigitalCombatSimulatorPlugin
Diagnostic
Configure
Acceleration:
Smoothest
Maximum speed:
Transformation type:
Script (C++)
Mapping
Motion Scripts
Other
Scripts system uses small .cpp programs to transform data from games into motion platform movements. There can a script that works with 'Any' platform or list of scripts dedicated to specific platform families (e.g 3DoF, 6DoF). The program will choose the most suitable script from the list below.
Device C1:
Device C2:
Script file:
Systems\ForceSeatPM\Scripts\
Learn more
View
Run
ACE
Code
Script Console - ForceSeatPM
Executing: C:\Users\Motion Test\Documents\MotionSystems\ForceSeatPM\Scripts\
Took (first,avg,min,max) 222767us 26us 16us 52us
ScriptRunner: Message sent to kinematic engine
C1: Roll rad: 0
C1: Pitch rad: 0
C1: Yaw rad: 0
C1: Heave mm: 0
C1: Sway mm: 0
C1: Surge mm: 0
C2: Roll rad: 0
C2: Pitch rad: 0
C2: Yaw rad: 0
C2: Heave mm: 0
C2: Sway mm: 0
C2: Surge mm: 0
Max Speed: 8191
Add
Fields
Save & Close
Save
Discard
1
2
3
4

- Click **Code** (4) to open the script in **Visual Studio Code**/



At this point there are two scenarios:

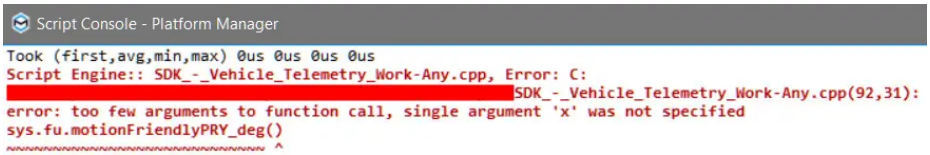
- If you are editing the script when the game is running in the background and you plan to switch (Alt+Tab) to the game to check your changes (e.g. changed filter parameters) - you can close the **Profile Editor**. **ForceSeatPM** will detect any changes made to the script and reload it. If there is any syntax error in the script, details will be displayed in **Action Center**.
- If you are editing the script without the game running in the background or you want to check the script manually and see results in the output console, then don't close the **Profile Editor** - you will be clicking **Run** button later.

Code completion and context help can be used normally during script development. All headers (with embedded comments/documentation) that define scripts API are located in:

```
C:\Program Files (x86)\MotionSystems\ForceSeatPM\ScriptsAPI
```

You can browse them from **Visual Studio Code**.

When you finish making changes to the script, save it and then go to **Profile Editor** and click **Run** (or switch to the game). If there is any error, it will be displayed in **Action Center** or in output console (if you clicked **Run** button).



4.2 List of keyboard hotkeys

Current list of keyboard hotkeys is always displayed in the **ForceSeatPM** in **Software Configuration**. Go to **Tools and Diagnostic**, **Software Configuration** and then **Keyboard Hotkeys** tab. It is not possible to change keys binding, it is possible only to disable all hotkeys if they interfere with other applications.