Path Following Safety Checklist AN-6021 Rev 4





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Path Following Safety Checklist

AB Dynamics' driving robots can be used to control a vehicle's speed and heading (Path Following). Due to the complex nature of the software and hardware, human error in the setup process or equipment malfunction can lead to **potentially dangerous situations**, even when there are no objects (e.g. vehicles or walls) in close proximity to the vehicle under test.

In general it is not recommended to run path following tests in close proximity to stationary objects due to the risk of collision. If such a test is unavoidable it is even more important to ensure that all available safety precautions are taken.

This application note describes a **safety checklist** which should be followed when running path following tests.



The EURO NCAP VRU test shown here requires close passing to stationary objects

1 – Correct Control Box

It is important that the driver can easily regain control if judged necessary.

Only use the control stick (also known as "dead-man handle") to activate the robot. Upon release, it will deactivate the steering robot and allow the driver to control the vehicle. It should be positioned within easy reach of the driver such that he/she can immediately take hold of the steering wheel upon releasing the control stick.

The activate/stop box should never be connected during a path following test. It is designed for use with other robots.



2 – Firmly Secure GPS Equipment



The motion pack must be **securely** positioned within the vehicle such that it will not move even during sudden dynamic manoeuvres.

Ensure that no passengers will grab hold of the motion pack or the mounting strut under any circumstances.



Ensure that the GPS base station antenna will not be accidently moved or obstructed. On windy days the antenna must be sufficiently secured.

If the motion pack were to come loose, or the GPS base station antenna were to move, this would be likely to **cause a sudden and potentially dangerous change in the vehicle heading**.

If this were to happen at high speed it could cause the vehicle to lose control and/or rollover.

3 – Use Physical Road Markers





Use cones (or similar) to mark the correct entry path. This gives an early visual cue for the driver that the vehicle is on course.

If the vehicle is clearly not on the intended path, the driver can regain control and steer the vehicle to safety.

Note that the length of the test path must be such that any necessary 'splining' to path is completed well in advance of any nearby parked vehicles.

4 – Apply Motion Pack Limit



Setup > Transducer connections > Motion pack > Setup > Advanced Setup Select 'Only allow highest accuracy motion pack operation'.

This will allow path following to be activated only when the motion pack is in differential correction mode and cause the test to abort if the accuracy drops.



5 – Apply Steering Limits

RC Robot Controller v8.15.1 - Test Setup	- 🗆 X
New Trest New Group	Set up insducers Run Test Results Import/ Export
Test Vehicle - Tests:	Details
	Type PF Standard Select
Up Page Move lest	Name PF Standard 39 Runs 0
V () 1 System Group	Specification
 ● (€) 1 Home ● (Ø) 2 SR Zero Steering ■ (***) 3 SR Offset Mass 	Preview Preview Speed Profile
V C 2 New Group	File name
E 🔴 🎿 Pristandard	Join anywhere
	Maximum auto join distance 0.0 m
	Control Robot steering V
	Maximum steering wheel amplitude 90.0 °
	Maximum steering wheel velocity 360.0 °/s
	Maximum steering wheel acceleration 5000.0 "/s"
	Advanced Setup
Page Move Test	Start: Closed Loop Test: NA Value: NA Value: NA Filter: NA
Down Down	Setup Speed: File AR/BR Inhibit: NA
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Vehicle Edit / Test > Tests & Results

Reduce the maximum steering wheel amplitude down from its default value, e.g. to 90°.

Reduce the maximum steering wheel velocity down from its default value, e.g. to 360°/s.

Reduce the maximum steering wheel acceleration down from its default value, e.g. to 5000°/s²

This will help to prevent any extreme heading change during the test.

Please set these limits appropriately for your test. For some tests (e.g. limit testing) it will be necessary to increase these values, otherwise the vehicle will be unable to follow the desired path and the test will fail.

Note that for Power PMAC systems from version 8.8.1 onwards, the steering wheel amplitude & velocity limits specified here **apply only during the test itself – not during the lead in**.

Lead in limits for these systems are detailed on the next page.

5 – Apply Steering Limits (cont.)



Vehicle Edit / Test > Edit Details > Path Following

For Power PMAC systems from version 8.8.1 onwards the steering wheel amplitude and velocity limits **during the lead in** are specified here.

Limit the Max SR angle (lead in), e.g. to 90°.

Limit the Max SR velocity (lead in), e.g. to 360°/s.

Note that if 0 is entered into either of these fields:

- Max SR angle (lead in): the lock limit is used
- Max SR velocity (lead in): the SR Limit (specified in Setup > Control Limits > SR Limits) will be used.

6 – Apply Path Following Error Limit

RC Robot Controller v8.15.1 - V	/ehicle Edit			– 🗆 X
Copy from Vehicle	Defaults	ehicle Import / Export F ary <u>I</u> uning Params	PF Auto Tune	EXIT
Up	General			
Key Data General Steering General Steering Seed Control Gearbox Subject Dimensions Subject Dimensions Subject Dimensions Subject Dimensions	Tuning Parameters Proportional gain Look ahead constant Integral gain Differential nain	0.0000	<u>R</u> everse gain scale factor Re <u>v</u> erse look ahead scale factor	1.00
→ ☐ General	Limits Default max SR amplitude Default max	360.0 °	Max <u>S</u> R angle (lead in)	180 °
	SR velocity Default max SR acceleration	1600,0 °/s 25000.0 °/s ²	Max SR vel <u>o</u> city (lead in) Max lateral a <u>c</u> celeration (lead in)	360 °/s
	Configuration Forward shift (from gyro)	1.850 m	Forward shift may also be set up in the Vehicle Dimension page	
Down				

Vehicle Edit / Test > Edit Details > Path Following

 Reduce the maximum path error to approximately 0.5m. If the vehicle error exceeds this value, the robot will indicate a failed test and will hold the steering angle until the driver releases the dead man handle. At this point, the driver can regain control of the vehicle and can steer to safety.

7 – Display Path Following Error



Vehicle Edit / Test > Tests & Results > Set up Transducers > Screen view It is helpful for the driver to have a visual display of the real-time path following error during the test. Select '**Targets on**' to specify a tolerance window to notify the driver when outside these limits (see next page).

Be sure to select an appropriate number of decimal digits.



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7 – Display Path Following Error (cont.)

	NG SK, BR, AR, GR1, GR2]		_	υх
Start STOP	(Č) Modify	Save Test	<u>C</u> hart	EXIT
Test: 5 Type: PF Standard PF Standard Image: Standard	Path following test at Test ABD: "C:\Users\davidh\Downloads\Test pa Max angle: 90.0°, buzzer speed: Var	ith.tem" iable.	Nex 1 Rui 0	t ID: Add Notes
IF CBJA CR OR Closed Loop Image: CBJA Image: CBJA Image: CBJA Warn Foll Error Image: CBJA Image: CBJA Image: CBJA Fatal Foll Error Image: CBJA Image: CBJA Image: CBJA Fatal Foll Error Image: CBJA Image: CBJA Image: CBJA Brake Switch Image: CBJA Image: CBJA Simulating MP: OK Image: CBJAA Image: CBJAA Joystick Disabled in Playout Image: CBJAA SR Mult: 100% Amplitude: Image: CBJAA	following error).(D
Time s 13 Look at m First Test running	head distance 1.5	9 SR Velocity	-0.	19 Right First

Vehicle Edit / Test > Tests & Results > Run Test

The path following error digital display turns red when outside the '**Targets on**' specified boundary.

In this example, the target min and target max were -0.20m and +0.20m respectively.



Vehicle Edit / Test > Tests & Results > Run Test

8 – Enable Beeping to Signal End of Test

RC Robot Controller v8.15.1 - Setup			– 🗆 X
External System			EXIT
▲ Up	General Preferences		
Analogue IMU	General Preferences Setup		
> - I SR Torque Setup SR Joystick Steering Angle Feedback	General preferences settings defined	it user level	
> Height Sensors	Test Run		
BR Connections	Beep on test start/finish	Default screen view	Bar Chart 🗸 🗸
Plato	User form timeout	Live data update rate	10 Hz
ADAS Target Feedback	Countdown to test finish	Enable test start from C	CAN
Simulation	Beep - 10 sec $\qquad \lor$	Enable test start from E Enable test start from u	ithernet Iser script
✓ - Control Limits	Miscellaneous		
> SR Limits	The second se		
> - S BR Limits	Coordinate system	ISO 🗸	
Software Setup	✓ Transducers defined at group level by on the second	default 🗹 Enable BR Io default	ad cell offset in home
Steering Amp Multiplier	New test copies previous transducers	Always 🗸	
Calibration Setup	Spinner style	Plus/Minus 🗸	
Path Following	Comms thread priority	Highest V	
Driverless / Base Station	Unicode export and spec files	Show run co	ount in test list
User scripting Default Tuning & Settings	Allow user defined SR lock limits		
< >	Use DBC comment field for message an	nd signal description	
Down	User-test filter <u>m</u> ethod	Running Average 🗸 🗸	
A amics			

Setup > Software Setup > General Prefs

Tick the 'Beep on test start/finish' checkbox. This alerts the driver if the test has finished prematurely (e.g. path following error has exceeded limit). The driver can then regain manual control and steer the vehicle to safety.

9 – Reduce Speed Multiplier

Advanced Setup						>	×	
Start	Time-Tolerance Parameters	Speed	Synchro	Driverless	Test	Abort		
Speed	✓ <u>U</u> se speed control ✓ Use <u>B</u> R for speed o <u>I</u> nitial mode Speed <u>m</u> ultiplier Te <u>s</u> t mode D <u>r</u> ive direction	ontrol Use PF file 34 As initial m Forwards	data	 Use distance Preview Preview Preview 	e correction Speed			It is important to initially run the test at a reduced speed. If the test is at high speed, conduct a trial run at a much lower speed in order to check correct path alignment etc.
	Speed bu <u>z</u> zer activ	re NOTE: This u the Speed Co have a speed	ses speed readings fr onnection so you must d source selected.	om	ОК	Cancel		Note that before running the test you should always view the speed profile in this window, to check that the programmed speed is as expected:

Vehicle Edit / Test > Test & Results > Setup > Speed

Vehicle Edit / Test > Test & Results > Setup > Speed > Preview Speed

Crosshair

120 140

OK

Parameters

Speed Preview

30-28-24-220-[4]myl 18-14-12-8-4-2--2-

Cancel

OK

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×

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10 – Preview Path & Speed Profile

ew Test	New Group	Delete	Copy	Set up Transducers	Ru	i Jest	Results	[mpo Expo			EX	00
st vehi	cle - Tests			Details	PF Stand	lard					Sel	ect
▲ Up	≜ Pa	ige	A Move Test	Name	PF Stand	iard				-	Runs	0
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100	<u>—</u> Pa	ge	. Move Test	Advance *	ed Setup Start	Closed Loop		iest NA		127 N	6	

Vehicle Edit / Test > Test & Results

 For Path Following tests the programmed path should always be checked by previewing the path prior to running the test. This is achieved using the Preview button:



Vehicle Edit / Test > Test & Results > Preview

In addition, for **all** tests, the programmed speed should be previewed as detailed on the previous page.

11 – Critical Sections



Vehicle Edit / Test > Test & Results > Run Test

In the path generation utility, sections of path can be defined as **critical sections**. These are regions which, if the path following error exceeds a given value, a user-defined abort procedure will occur. This needs to be tailored to each specific test.

In this example, the red car is parked and the yellow car is in path following mode. The two red lines either side of the main path show the critical section and are the user-defined boundaries.

If the yellow vehicle's lateral error travels outside these boundaries, the Steering Robot has been programmed to perform a left turn in order to avoid the collision (see following pages).



A comprehensive guide to critical sections is provided in the AB Dynamics Path Following User Guide which **must be carefully read and understood** before using Critical Sections. The following slides provide only a very brief introduction.

11 – Critical Sections (cont.)

RC Robot Controller v7.	32 - Path Generation					
Generate	2? ck Lap Save Path	Advanced	Critical Sections	Stop Points	Collision Check	EXIT
Putis	Extras		Pre	view		
@1 0 2 0 3 0 4	5 🕅 Show run:	Edit	Мо	de XY	-	
boa_path.tem	Show RTF	Ls Edit		Map view for XY di Show segment ider	ata ntifiers in XY mode	Show XY grid
Main path DEntry	path 🕐 Exit path					
Main Details Origin and	Offset Additional					
Template					1	
Segments						
- 1: Straight					10	
- 2: Straight						A DECEMBER OF
				1		
Add Segment	Open Template					
	Save remplate					
Insert Segment	Add Template					
Delete Segment(s)			and the second s			
Copy Segment(s)	Paste Segment(s)					
Bhamics				-41		

Utilities > Path Generation > Use Template

To create a critical section in the Path Generation Utility, select 'Critical sections' and then 'New' in the dialog window.



Utilities > Path Generation > Use Template > Critical Sections

11 – Critical Sections (cont.)



Note that the values shown here are examples. All parameters need to be configured specifically for each test.



Utilities > Path Generation > Use Template > Critical Sections

12 – Additional Safety Precautions

For high-sided vehicles, or where there is a significant risk of the vehicle overturning, additional safety precautions should be considered, including:

- Use of outriggers
- Use of a roll cage
- Additional safety equipment for the driver

