# Test Protocol

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## DOCUMENT HISTORY

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| 0.1 | 2022-10-23 | First draft | Whole group | |

# 1 INTRODUCTION

This document is the test protocol for the project *Machine Learning and Adaptive Control for Improving Servo Performance* within the project course *Automatic Control, TSRT10*. The main purpose of this document is to include all information and results gathered from tests executed during the project. Not all requirements are to be tested and those will therefore not be present in this document.

## 1.1 Test Protocol

The tests will be described and documented according to the procedure below. The test number is corresponding to the test specified in the test plan and the requirement number is likewise describing which requirement/requirements from the requirement specification that is tested. The test formulation is the title of the test from the test plan document, while the test description is describing how the test is conducted. The result will describe the outcome of the performed test and if the test was successful or not.

**Test number:** -
**Requirement number:** -
**Test formulation:** -
**Test description:** -
**Results:** -

# 2 TESTS

The tests are divided in the same way as for the test plan document.

## 2.1 Tests of Raspberry Pi

**Test number:** 2
**Requirement number:** -
**Test formulation:** Measure the analog output signals from the Raspberry Pi with an oscilloscope.
**Test description:** The output signals are measured using the oscilloscope. It is apparent that the signals are in the realm of what is to be expected and it is determined that the Raspberry Pi has the correct setup.
**Results:** The Raspberry Pi can be used in the test rig and run the throttle as HIL. The test is deemed **successful** since all requirements tested are fulfilled.

## 2.2 Tests of Control Model and Engine Simulation

**Test number:** 3
**Requirement number:** 6-9,12,14,15,19
**Test formulation:** Control the throttle from the Raspberry Pi in real time with parameters ~~changed during the run~~ and also collect data from the throttle.

**Test description:** The throttle is actuated using a drive cycle. The Machine Learning algorithm uses data from the already executed parts of the drive cycle to estimate the friction and limp home parameters ~~in real time~~.
**Results:** The controller works well with the throttle parameters recieved from the ML algorithm. The test is deemed **successful** since all requirements tested are fulfilled.

**Test number:** 4
**Requirement number:** 3,6,11
**Test formulation:** Run the vehicle simulink model for different drive cycles.
**Test description:** The throttle is run as HIL and tested for different drive cycles.
**Results:** At first the throttle is tested on the NEDC cycle which is a rather "calm" cycle and it works relatively well. After this the cycle is changed and the reference following is noticeably worse. It is apparent that the controller doesn't do as good of a job on the other, less ideal cycles such as for example USA-city II. The throttle controller has to be tuned further to get an acceptable reference following. The test is deemed **successful** since all requirements tested are fulfilled.

**Test number:** 5
**Requirement number**: 2,20,23
**Test formulation**: Test run the throttle with an adaptive regulator active while the throttle angle moves in and out of the limp home region.
**Test description**: The throttle is actuated using different drive cycles with an adaptive controller that changes the parameters in real time.
**Results**: The throttle showed very oscillating and unstable behaviour. The adaptive regulator approach is abandoned to free up time for other parts of the project. The test is deemed **unsuccessful** since requirement 23 is not fulfilled.

**Test number:** 6
**Requirement number:** 18,21,22
**Test formulation:** Test run the throttle with the regulator active with different model parameters.
**Test description:** A small step is made from the limp home region up to around 20 % opening. This is done without the PID-controller, i.e. only controlling using the limp home and friction compensation scripts. This is first done using friction parameters determined manually. Then the same test is made using parameters from running the machine learning script on data received from the throttle during normal operation.
**Results:** The controller gets a much better step response using the parameters received from the machine learning script. The test is deemed **successful** since all requirements tested are fulfilled.

### 2.3 Tests of Throttle Characteristics

**Test number:** 7
**Requirement number**: 4,10,11,16,17,31
**Test formulation**: Basic tests of throttle characteristics such as hysteresis in cold, normal and warm environments performed on an old and new throttle.
**Test description**: Firstly the throttle is tested in normal operating conditions (around 20 degrees C). A selection of ramps, steps and drive cycle tests are conducted. From these tests the basic throttle characteristics can be identified. These tests are then repeated when the throttle is cold. To cool the throttle it was placed in a freezer for an extended period of time. Tests are also made when the throttle is warm. This is done using a hairdryer to warm the throttle. By

doing this it is possible to determine what effects warm and cold weather has on the throttle. All of the tests are made for both the new throttle and for the old throttle.
**Results**: It seems that the different temperatures and whether the old or new throttle is used doesn't have a big enough effect on the reference following to be noticeable. The test is deemed **successful** since all requirements tested are fulfilled.

**Test number:** 8
**Requirement number**: 32
**Test formulation**: The control signal generated to measure the throttle characteristics shall be measured with an oscilloscope before being applied to the throttle.
**Test description**: A PWM signal is generated using the Raspberry Pi and then measured using a oscilloscope.
**Results**: Successful, the PWM signal is visible and has the correct frequency on the oscilloscope. The Raspberry Pi is therefore safe to use to control the throttle. The test is deemed **successful** since all requirements tested are fulfilled.

### 2.4 Tests on Final Product

**Test number:** 9
**Requirement number**: 5,17,24
**Test formulation**: ~~Test the software on a real engine.~~
**Test description**: This test could not be conducted due to time constraints.
**Results**: The test is deemed **unsuccessful** since the requirements where not fulfilled.

**Test number:** 10
**Requirement number**: 25-29,31-33
**Test formulation**: A step response test on the throttle control.
**Test description**: The step response of the controller is investigated by doing steps in reference signal at under and above 50%.
**Results**: The controller can not meet the requirements and they have to be adjusted. Vi vill diskutera detta med er på tisdag.

**Test number:** 11
**Requirement number**: 1
**Test formulation**: Compare hysteresis constructed through ML with documented measured ("real") hysteresis of the throttle.
**Test description**: The hysteresis from a running the throttle in a drive cycle is compared with the boxes created from running the ML script using the data from the same test. The covariance between the ML and real data is analyzed.
**Results**: The ML script manages to estimate the friction boxes relatively well. This is also apparent when doing steps using only the friction and LH compensation blocks. With the manually adjusted parameters the controller can not take the step whereas with the ML parameters it handles the step very well. The test is deemed **successful** since all requirements tested are fulfilled.