DYNAMIC TESTING WITH ILC

ILC is an advanced engineering modelling tool that is used for dynamic testing. It is a Windows-based, state-of-the-art, MATLAB application which is used off line to generate drive files, analyse and simulate rig responses and optimise test programs. The standard version can be used for both “square” and “non-square” rigs with 1 to 16 input channels and 1 to 16 output channels, although it can be adapted as a custom solution for rigs and installations comprising several hundred channels.

The specific benefits of ILC over the alternatives are:

- It is a **portable solution** that can be used for many types of rig, ranging from simple, single channel systems to very high channel count systems, and with more than one rig in a laboratory.
- It is a **frequency domain** tool which can represent resonant and harmonic behaviour in a specimen and which delivers good definition across a wide range of operating frequencies and load conditions.
- At very low frequencies and with “single shot” events (like hitting a pothole), where conventional approaches are less accurate or can break down, it uses **patented algorithms** applying a hybrid control approach to develop viable testing solutions.
- It is **adaptive and reactive** to testing responses, with an option to adjust control system parameters automatically to aid convergent and robust performance improvements in 2 or 3 iterations, avoid divergence and oscillation even when less conservative control system gains are used.

These benefits add up to better tests, faster results and better return on testing assets.

WHAT IS DYNAMIC TESTING?

Dynamic testing is undertaken to allow measured operating conditions to be reproduced faithfully on a test rig in the laboratory and predict performance of components or structures in normal service.

Tests can be undertaken as part of a short-term testing process, for example when setting up a racing car suspension to optimise it for measured track conditions, as part of the product development process to understand behaviour of a part under a variety of simulated operating conditions that cannot cost-effectively be tested in the real world, or as part of a long-term fatigue or durability testing program where long service cycles are reproduced to anticipate service problems.

In broad terms the process is to measure the dynamic behaviour of a piece of equipment, such as a car suspension, during normal operational conditions, and then to reproduce those conditions to high accuracy on a sample piece of equipment or specimen in a laboratory using servo-hydraulic or electromechanical actuators. The actuators subject the specimen to loads and the result is measured. The measurements are then used to repeat the test using improved drive signals, this process being repeated until the desired accuracy is achieved. The goal of any test is to ensure that it is as realistic as possible. There are in fact three parts to this.

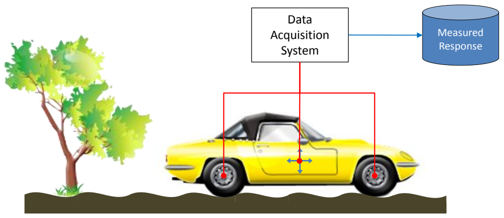
The first is to make sure that the rig generates as **realistic** a simulation of operating conditions as possible, above all ensuring that only the behaviour of the specimen under test is measured, without errors or artefacts introduced by the rig itself. Since no test rig is completely free from errors, can have interaction between channels, or has resonances and non-linear response characteristics of its own, an essential part of any test is therefore to **identify** or characterise the rig. This involves building a software model of rig behaviour so that errors and interactions can be anticipated and the instructions sent to the rig can be adjusted to minimise their effects.

The second is to ensure that the rig creates the required **behaviour** of the specimen at the operating condition of interest. This is often more difficult than it sounds because generally it is not obvious how to replicate actual load inputs and reactions acting on the specimen under operational conditions. The input signals required at the test rig actuator locations must be inferred in an iterative manner from the dynamic **response** of the specimen to loads measured at the position of interest. The characterisation model has to account for these differences to ensure that the desired and achieved performance is ultimately acceptabe.

The third is to integrate this information in an appropriate and usable way to ensure that the test can be conducted successfully by even relatively inexperienced or inexpert test engineers, with logical presentation of information, full control over the process and immediate identification and compensation for errors.

STEPS TO UNDERTAKING DYNAMIC TESTING

ACQUIRE FIELD DATA

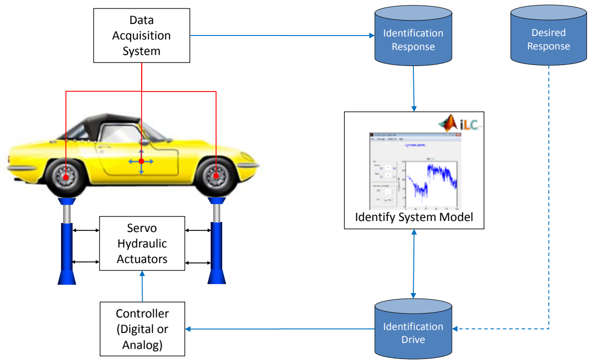


The first step in setting up a dynamic test is to acquire field data from the specimen under operational conditions. The purpose of the test will be to reproduce these operational conditions in a laboratory setting. In the case of road vehicles this is usually undertaken by measuring wheel inputs, strains, deflections etc. at critical points on the vehicle.

Using a data acquisition and recording system, several channels are recorded in real-time under conditions that represent the "normal" operations of interest. In the example above, a motor vehicle is shown driving on a test track with a number of sensors being used to measure inputs to the suspension and chassis.

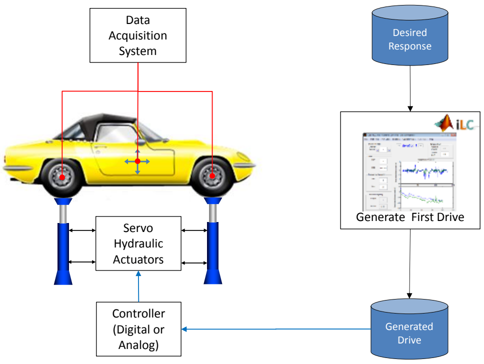
SYSTEM MODELLING – IDENTIFYING RIG BEHAVIOUR

The second step is to set up the rig to be used to simulate road conditions as accurately as possible in the laboratory. Inevitably there will be errors due to differences between actuator and reaction locations, actuator performance limitations, resonance and clearances within the rig, flow limit or response and overall system compliance. To compensate for these a **system model** for the rig is **identified** (computed) which describes how applied loads excite responses across a range of frequencies. The model also represents interaction between channels, for example when loads on one wheel generate responses at other wheels. This forms the basis for later iteration and analysis of data.



Generally model identification is achieved by putting the vehicle or component on the test rig and subjecting it to a randomised **identification drive** file that represents the spectrum of frequencies and loads that the experiment will simulate. ILC can create this identification drive from scratch or based on characteristics of the measured response. The **identification response** of the rig to this drive file is captured using sensors in the same locations of interest and at each actuator.

DRIVE FILE GENERATION

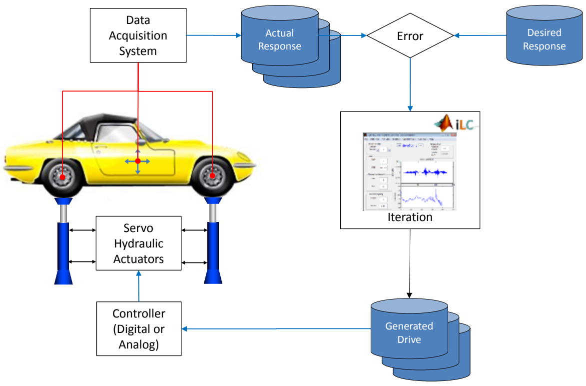


Once the model has been prepared, the third step is to generate a drive file for the rig that will be used to drive the actuators to achieve the desired response. The desired response is also called the **reference signal** because this is what we want out of the rig: The model is used to define the actuator signals needed to achieve it. The function that is used to transform the desired response into a generated drive is called the **operator** and ILC offers a number of options when defining what operator is to be used. The first attempt to do this is based on operations on the reference signal but subsequent iterations use the errors between the reference and observed rig behaviour.

When expensive specimens are being used, care is needed to minimise the risk of accidentally damaging them. ILC generates the initial drive using conservative operator and gain levels to minimise this risk. Gain levels are progressively increased in later stages once a satisfactory solution has been achieved.

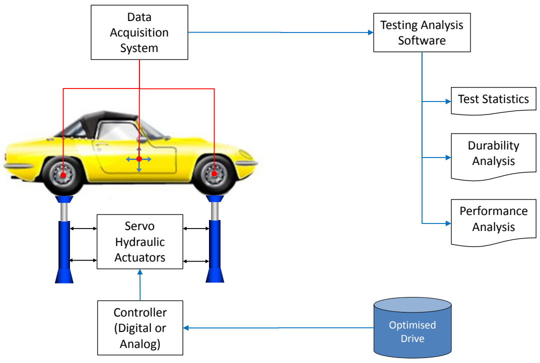
ITERATION

The generated drive file will generally create a reasonable simulation of operating conditions, but because most dynamic systems have complex interdependencies it is normal that some errors remain.



Iteration is the process of generating drives, running tests, collecting responses and comparing them against the desired response, then adjusting parameters and repeating the process until acceptable accuracy is achieved. ILC offers the engineer different tools to analyse and eliminate errors, from subtle gain changes to using different operators to account for specific issues with a specimen or rig. ILC also has a **simulation** function so that the ***probable*** effects of parameter changes can be visualised before running the drive file on the rig. This feature can save time and reduce needless iterations when a difficult test problem is encountered.

RUNNING THE TEST



Once errors have been reduced to an acceptable level and the test engineer is comfortable that the simulation is an accurate representation of reality, then testing desired loads can commence. ILC is no longer needed at this point and the final optimised drive file can be downloaded to a dedicated replay unit connected to the rig controller. Specialised test analysis software is used from this point onwards to prepare test statistics, undertake durability/fatigue and performance analysis, etc..