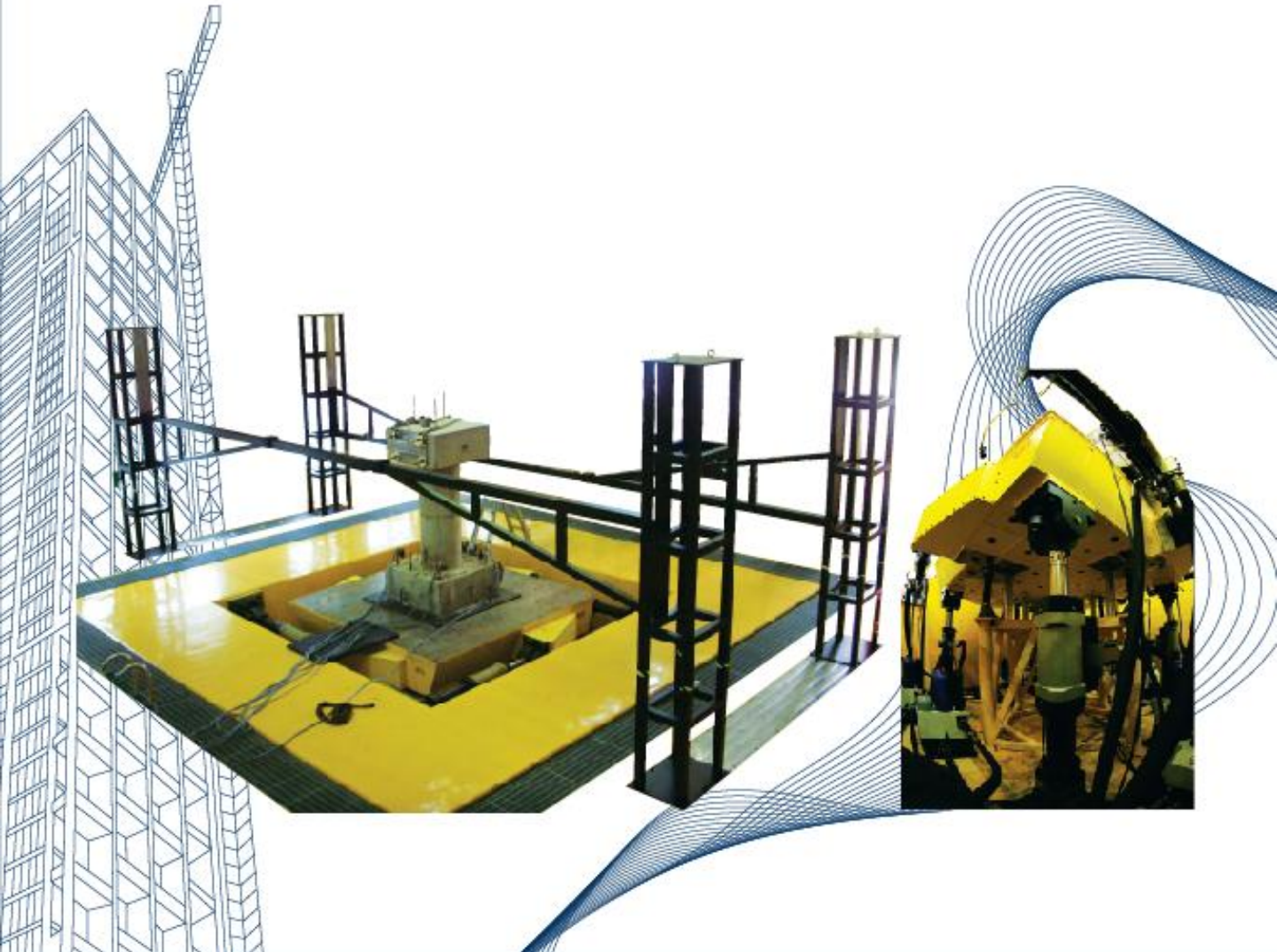
6-DOF Seismic Simulation System

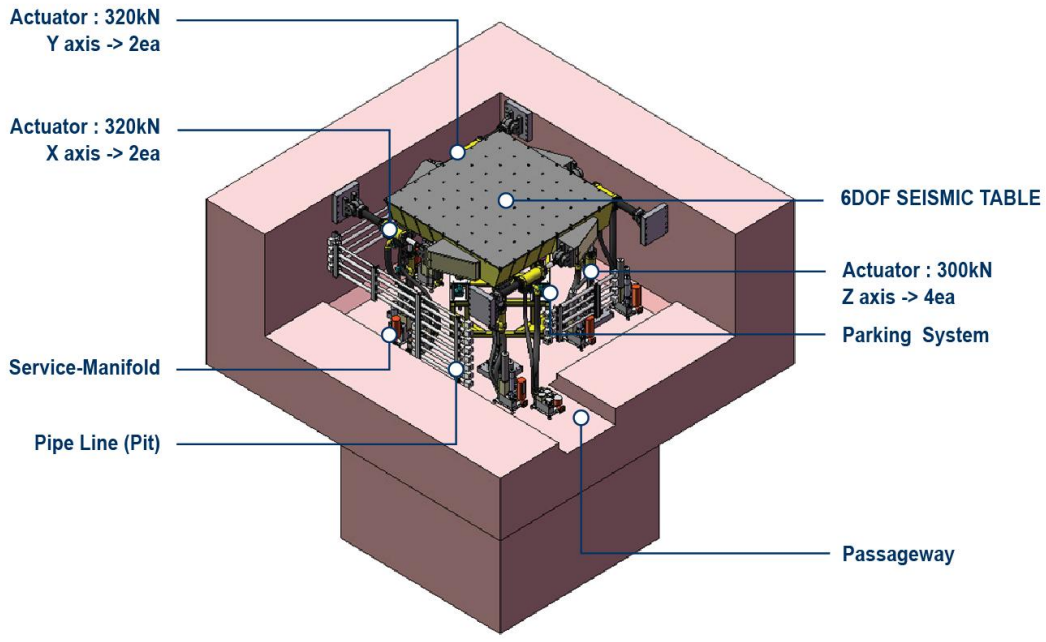
It is used for various civil engineering applications including fundamental research for seismic isolation of buildings and bridges, seismic qualification of components, piping systems and nuclear power facilities.

The seismic test systems are used worldwide and include many different types of earthquake shaking table configurations with specimen capacities ranging from small test articles to full scale buildings.

Typical table configurations include one, two, three, and six degrees of freedom motion.

KNR also can provide Multi-Axes Shake table for Subassembly Testing system by special requirement.





List of Possible Tests

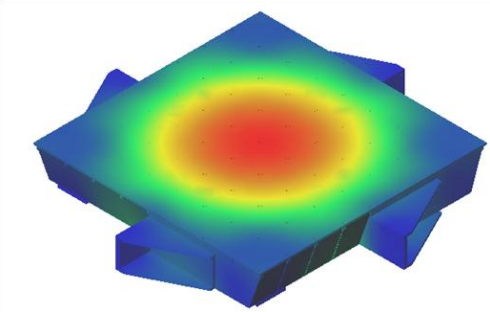
Uni-axial horizontal earthquake simulation test
Bi-axial horizontal earthquake simulation test
Vertical earthquake simulation test
Complex(6-DOF) earthquake simulation test
Performance test for earthquake-resistance bridge structures/components
Multi-purpose vibration test for structure /mechanical components

System Specification

6-DOF seismic simulation system provide that allows X, Y, Z, Roll, Pitch and Yaw motions as either independent or simultaneous motions.
4.1 x 4.1 meter 6 DOF seismic table is capable of testing up to a 30 ton specimen with the ability to play back real earthquake records, random records, sinusoidal and sweep motions, etc.
The seismic mass prevent harmful vibration influence toward adjacent testing facilities/ equipments as well as building itself.

Seismic Table

The table is constructed to provide a high natural frequency using a welded honeycomb structure. Natural frequency is over 100Hz.
The top surface of the table is flat within 2mm over the entire table surface and include recessed M24 x 3.0 thread pattern on a 50cm square pattern with sealing plugs to protect threads. These threads has Heli-coil inserts for long service life.
The table design is incorporated a minimum of 9 accelerometers rigidly attached to the base of the table and strategically located for optimum performance. The accelerometers and controls cover all 6 degrees of freedom and account for the table's flexible modes as well as the rigid modes.



Hydraulic Actuator Systems

KNR uses reliable hydraulic hydrostatic actuators which are proved in various fields.

The actuators are equipped with differential pressure stabilization capabilities to minimize oil column resonance effects and designed to provide minimum friction and to allow for high overturning moments. The Intima actuators utilize polymer hydrostatic rod bearings or ball joints with close tolerance machining and elimination of high pressure seals. Engineering hydraulic cushions are included in the cylinder end-caps to protect the actuators from an unplanned open loop condition. A fatigue rated one-piece piston rod is used to ensure long service life.

The actuators are designed to keep the resonance frequency high and any resulting amplifications low

The swivel joints which provide zero backlash using preload adjustable bearing are used at each front and rear end.

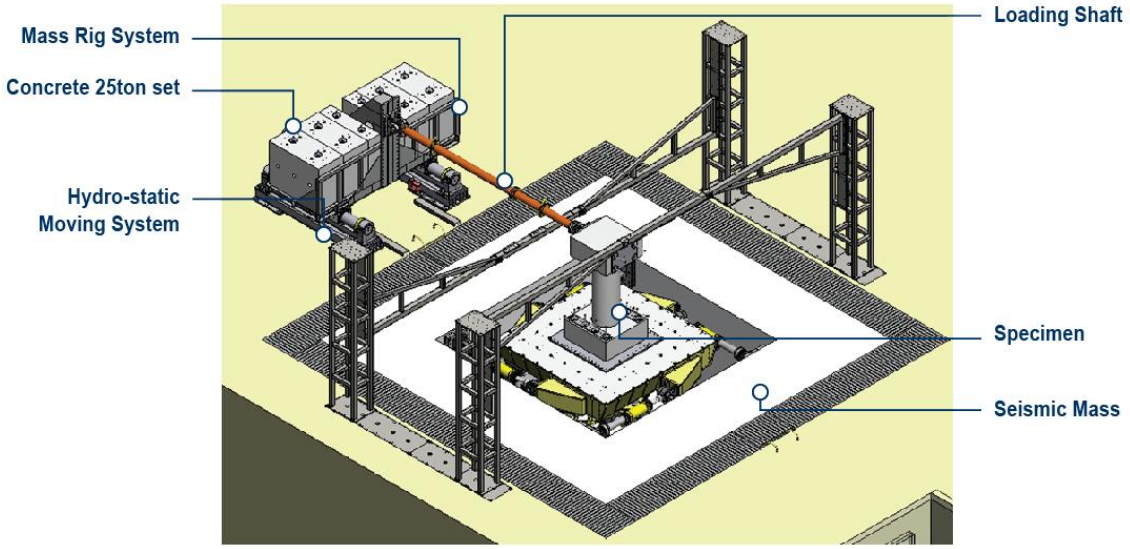
The swivel joints have the proper angular displacements to allow the table to exercise through all extreme displacement conditions. The swivel joints are rated to allow full dynamic loading and worst case loading conditions.

Local close coupled accumulation and flow averaging line accumulation are considered to allow smooth performance of the system if needed.

Static Support System

To optimize the power efficiency of the system, a static support system is provided to offset the gravity loads generated from the table and specimen. For the case of vertical actuators, they have customized feature to balance the load of the table and specimen that uses a secondary piston and nitrogen gas.

01	Table size : 4.1 x 4.1 meters			
02	Full payload : 30 tons			
03	Nominal payload : 20 tons			
04	Frequency of operation : 0.1 ~ 60Hz			
05	Overturning moment : 1200kN-meters for lateral(or longitudinal) direction.			
06	Center of gravity on the table : 2.5 meters			
		Longitudinal	Lateral	Vertical
07	Actuator stroke	±300mm	±300mm	±200mm
08	Velocity at 1Hz with full payload	1.3m/s	1.3m/s	1.2m/s
09	Acceleration at 1Hz with full payload	0.8g	0.8g	0.8g
10	Velocity at 2Hz with full payload	1.0m/s	1.0m/s	1.3m/s
11	Acceleration at 2Hz with full payload	1.3g	1.3g	1.7g
12	HPU flow-rate	4080LPM, 21Mpa(option)		



Seismic Mass Foundation

Overall seismic simulation system is placed on floating type seismic mass foundation.

The seismic mass foundation prevent harmful vibration influence toward adjacent testing facilities/equipments as well as building itself. The seismic mass weight is over 30 times of the maximum payloads including table mass.

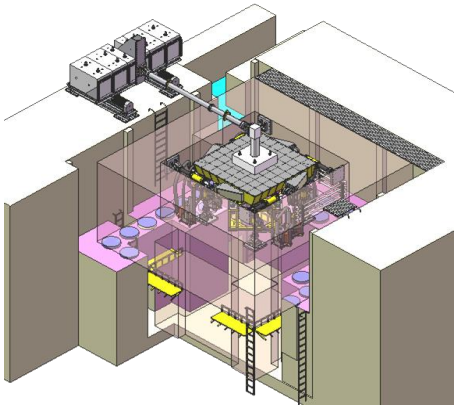
Air-spring type vibration isolation system is able to float the seismic, and to help in balance.

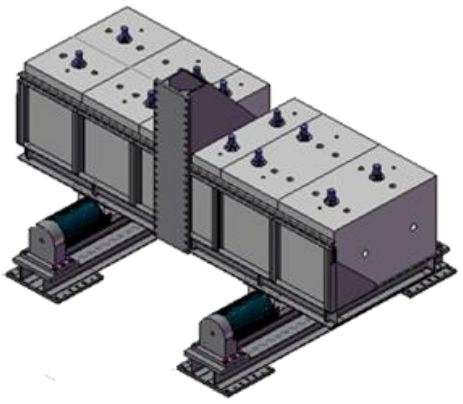
And control system is monitoring seismic mass position during test

Mass Rig System

In case of earthquake simulation test of bridge leg, the mass rig system provide mass effect of bridge upper structure.

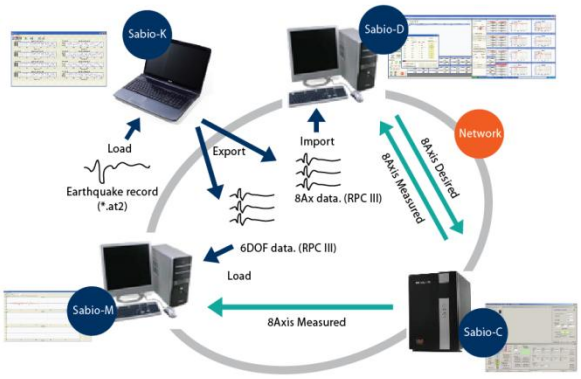
Dummy mass : 25 tons
Mass rig main frame
Hydro-static linear bearing system
Load connecting shaft



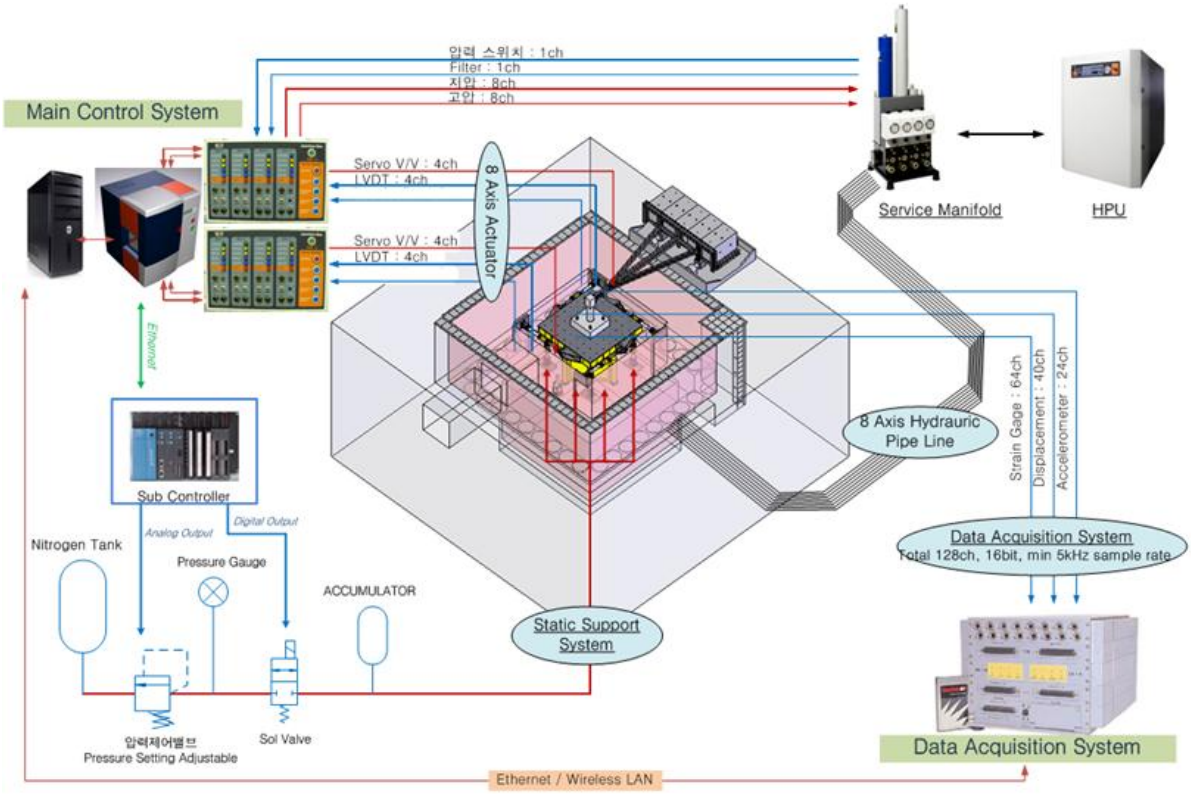


6 DOF Seismic Simulation System Controller

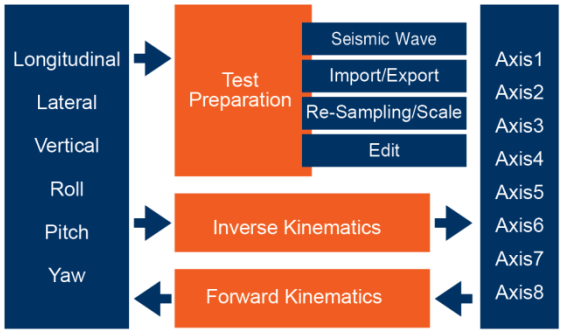
The controller for 6DOF Seismic Simulation System has four modules as the right side figure. It has Deneb-DE which gives real time control for each sensor and actuator, Sabio-Dynamic which shows the actuator's information in real time and pass the user's command to Deneb-DE, Sabio-K, and M which are pre and post processing module that converts the information from the sensors and actuators to the designated information for the user. The Deneb-DE is connected with hardware components which are actuators and service manifolds and transfer the signal and gets the input signal from the LVDT, Load cell, and Accelerometer and transfer to the user.



Sabio-K is only for 6DOF seismic simulation system which produces 6DOF executable file from the text file of real seismic signal through kinematics calculation. Also, it provides editing feature of the 6DOF executable file.



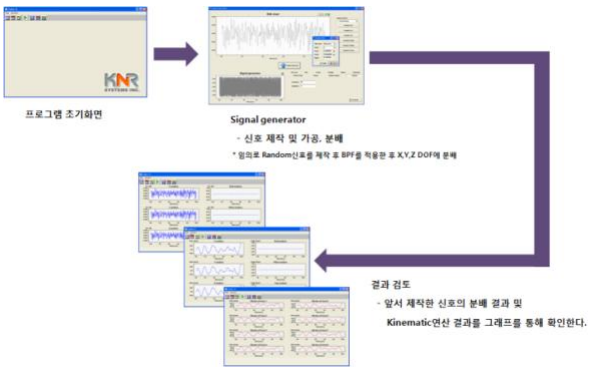
Sabio-K & Sabio-M



Sabio-K

pre-processor; using seismic data or producing arbitrary signal, it makes signals that can be adopted to the real control.

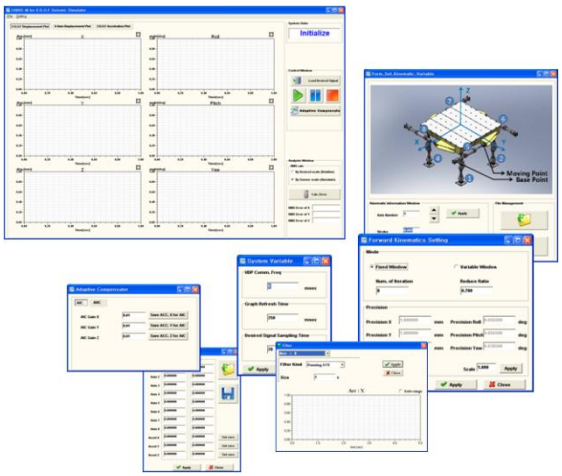
Function	Specifications
Inverse kinematic	6DOF data to 8 axes data conversion
Signal generation	Earthquake File load (*.at2)
	Sine, Cosine, Triangle, Square
	Trapezoid, Point to Point
	Sweep, Random square
Signal edit	Random
	Digital filter (LPF, BPF)
	Signal scaling



Sabio-M

post-processor; using forward kinematics calculation from the result of Deneb-DE and Sabio-C, it gets the real time results and provides various data.

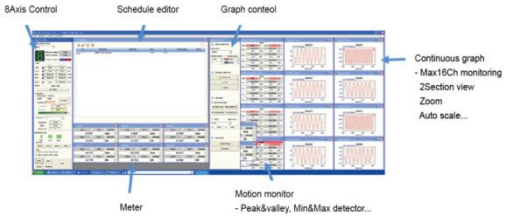
Function	Specifications
Forward kinematic	8 axes data to 6DOF data conversion
Data displa	6DOF displacement
	6DOF acceleration
	8Ax displacement
Data acquisition	6DOF displacement
	6DOF acceleration
	8Ax displacement
Adaptive harmonic cancellation	



Sabio-D

Sabio-D provides data from the analysis of the inverse kinematics to each actuator and also gives some complementary features and monitoring as well.

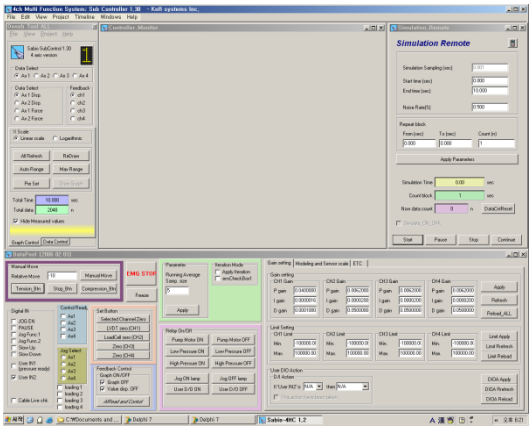
Function	Specifications
Scheduler	8 axes data load
	repeat, hold, event
Compensator	Amplitude phase compensator
	Force balance compensator
	Overturning moment compensator
	Off center load compensator
Set point	Auto initial point moving



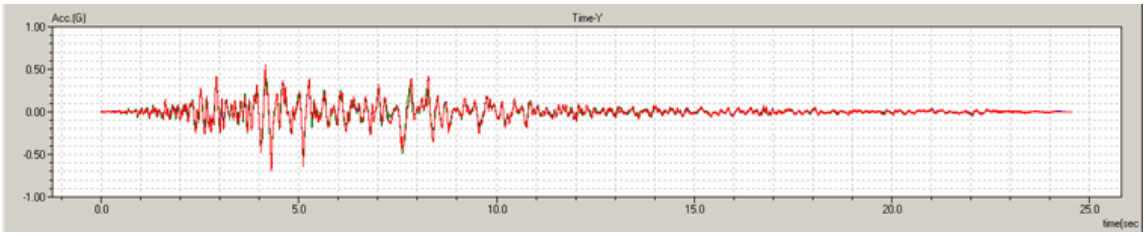
Sabio-C

Sabio-C gets the reference command from Sabio-D and controls the actuator. It's an intermediate interface between the hardware and Sabio-D and the user doesn't have to operate it.

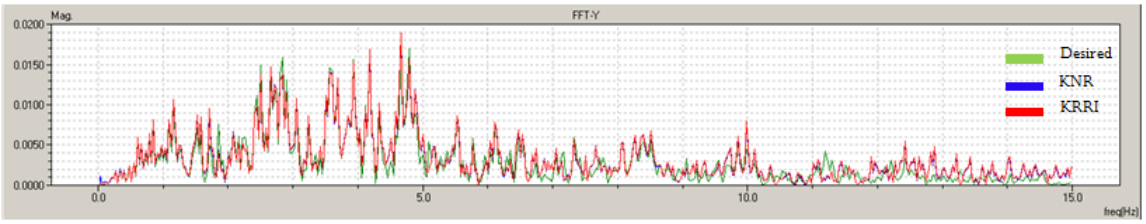
Function	Specifications
8 axes control	
Three variable control	Displacement,
	Velocity,
	Acceleration
On - line iteration	
Limit detect	
HSM, Parking system control	



Desired & measured signal under Nothridge earthquake signal



Time history



FFT

Coherence function (Window Size = 1024)