Vibration is one of the most classical phenomenon and it has attracted the minds of great scientist right from the days of Sir Isaac Newton. A mechanical vibration in particular has many applications such as stimulus response analysis, reliability testing, vibration sweep testing, resonance study etc. Vibration testing refers to subjecting a device to some pre-defined profile of mechanical vibrations in terms of amplitude, frequency and time. Various industries like defense, space, railways, airways, embedded hardware manufacturing etc., during critical phase of testing of their products require vibration tests for precise defined profiles. In general, there is a great demand on increasing the reliability of devices making use of critical components. In fact, vibration tests have become one of the essential and critical tests for all the test and measurement systems including the tiny gadgets like personal digital assistants and home appliances. This is accomplished by intensive vibration tests as this is the main phenomenon responsible for the durability and serviceability study of various devices. Vibration testing also plays a major role in identifying faults in the machineries and in the prevention of failures leading to the mechanism of fault diagnostics. Electrodynamic shakers are used as a vibrating platform for carrying out such vibration tests. This research (largely experimental) is organized in two parts. The first section deals with the design and development of fuzzy logic based intelligent controllers for electrodynamic shaker while the second section deals with the measurement and presentation of complex vibration waveforms.

Sinusoid vibration testing is very important in the engineering development to search the product resonances and to determine the fatigue life. In the most common form, sine testing involves a logarithmic frequency sweep holding the specified acceleration magnitude at the base of the device under test. By sweeping the excitation frequency in either direction in the range of interest according to predefined profile, adequate test reliability is attained. The computer based modern vibration equipment, normally used to execute closed loop sine testing comprises of an
electrodynamic shaker, a power amplifier and an acceleration measurement, controlling and monitoring system.

The moving coil principle is almost universal in electrodynamic shakers for vibration testing. It offers good linearity (i.e. thrust per current invariance with frequency and with moving element instantaneous position) achievable over a wide frequency range. The moving coil principle for electrodynamic shaker works on the basis of the electromagnetic force generated between two interacting magnetic fields. The vibration exciter essentially transforms the electrical energy supplied to it into the physical movements. The electrodynamic shaker used in this research comprises of a permanent magnet giving constant magnetic field. Another moving coil suspended in a radial constant magnetic flux and connected to a table structure in an assembly is normally referred to as the armature. The moving coil also has its own magnetic field proportional to the current passing through the coil. The positioning of the coil and associated fixture table assembly is attended by means of a flexible suspension arrangement which constraints the movement to axial direction only and supports the weight of external payload.

The electrodynamic shakers offer wide operating frequency band and it is the most suited device for sine sweep vibration testing. The electrodynamic shaker system along with the test load dynamics forms a complex process having some inherent nonlinearity. The dynamics of the electrodynamic shaker system is very complex owing to complex frequency dependencies of the vibration response on account of the friction, heating effects etc. Both the resistance and the inductance of the moving coil also have non-linear frequency dependencies primarily due to the action of pole plating, which has the effect of increasing the resistance and decreasing the inductance with frequency. In addition, these electrical parameters are also subjected to secondary effects such as thermal and eddy currents. Additionally, test load dynamics changes the mechanical parameters of the shaker, especially the test mass. Shaker’s flexible suspension spring-mass system resonances and modeling errors equally contribute to make almost unusual open loop frequency response of the shaker system. In electrodynamic shakers for constant amplitude sinusoidal input
signal to armature, the vibration amplitude changes significantly with frequency, so the power amplifier used to drive the shaker is normally governed by a control system. This monitors the mechanical motion, usually measured by an accelerometer mounted on the table or the test objects itself, and corrects for amplitude variation as the drive frequency is swept. The control mechanism in the electrodynamic shaker is achieved by controlling the voltage applied to the armature. The control platform excites the shaker using an appropriate power amplifier by generating the required drive signal. Since a logarithmic frequency sweep is normally used in vibration tests, a controller needs to be robust to un-modeled dynamics and also fast enough to hold the desired acceleration amplitude within predefined limits throughout the sweep test. Most of works on the shaker controller design and testing have been done in frequency domain. This is a time consuming process. Most recent advances in the control technology like intelligent control i.e. fuzzy logic or neural network based controllers being ideal controller candidates for the complex and non-linear processes are not yet explored and experimented for the vibration testing systems like shakers. The proposed research work aims to bridge this gap.

The shaker dynamics, offering several challenges, as mentioned above make the shaker system a complex process and good candidate for researching intelligent controllers. This research focuses on the intelligent methods for controlled vibration generation and measurement. So, the plant to be controlled is the PC based electrodynamic shaker system. Two experiments were conducted on fuzzy logic based intelligent control of electrodynamic shaker. In the first experiment, a prototype shaker system is designed and developed in-house for laboratory teaching and research applications. Fuzzy logic based intelligent controller was designed, developed and tested in real time on this in-house designed and developed electrodynamic shaker working in relatively low frequency range The performance of the developed fuzzy logic controller was found to be superior to the conventional controller. The conventional controller was designed using a direct synthesis approach of controller design. LabVIEW based virtual instrumentation (VI) tools were used for simulation and experimental implementation of the developed controller.
Another experiment was carried out on an industrial grade electrodynamic shaker system working in automotive and aerospace vibration testing frequency range of 10Hz – 2 kHz. In lower frequency range operation the dynamics of the suspension mechanism of the shaker system becomes very prominent due to resonance effects. As a result, the shaker system suspension resonance needs to be compensated for smoother testing operation. A shaker suspension mode compensator was designed using an identified linear model of the shaker system. Model identification was done by carrying out some measurements done on the shaker system. In this study the fuzzy logic controller was cascaded to the shaker suspension mode compensator. For real time implementation a customized fuzzy logic controller was designed and developed in LabVIEW environment. Performance of the developed controller was investigated for the dynamic test load and it was observed that the acceleration tracking is sensitive to the test load resonances to certain extent. An approach for fuzzy logic controller design and real time implementation for electrodynamic shaker system has been thoroughly researched in this experiment.

Another research component of the intelligent methods for complex vibration measurement and control is the measurement and presentation of complex vibration waveforms. Sine sweep and frequency modulated signals being dynamic in nature changes their frequency with time. These signals are commonly used in sonar and radar applications, but also have other applications such as stimulus response analysis, vibration sweep testing and spread spectrum communications. Data acquisition and presentation of these periodic complex signals offer the challenge of live waveform presentation on the oscilloscope which is a common instrument for live waveform presentation and its basic measurements. For continuous and stable display, on the oscilloscope, the horizontal sweep time must coincide with the input waveform time period or to its integral multiples. This instrument makes use of level triggering in which the amplitude levels are sufficient to estimate the waveform time period. Conventional level triggering method, used in the oscilloscopes, finds limitation for these dynamic waveforms. When a dynamic signal, as mentioned above, is given to the oscilloscope for analysis it produces a jumbled display and it also fails to compute the
waveform measurement parameters. The reason being these signals possess more than one zero crossings in their one fundamental cycle. The oscilloscope fails to determine the correct fundamental period for these waveforms and hence it does not generate the proper trigger signal for the waveform presentation. The oscilloscope treats these dynamic signals as set of sinusoids and then presents them one over the other leading to jumbled presentation.

To cater to this problem, three time domain measurement and presentation methods were investigated in this research for complex waveform period estimation and oscilloscope triggering. In the first experiment, the auto-correlation based classical technique was studied for time period estimation and oscilloscope triggering. For sample-by-sample acquisition and real time oscilloscope triggering correlation method was evolved and implemented for oscilloscope triggering. Finally, a new robust technique, the Degree Of Difference (DOD) for real time oscilloscope triggering was introduced, investigated and implemented. Robustness study of all the proposed techniques have also been studied in simulation by adding random noise to the test signals. Finally, detailed comparisons among the studied and investigated methods have been done and presented in the thesis.

LabVIEW S/W based simulation and measurement tools have been used extensively in this research. All the hardware of virtual instrumentation used for signal acquisition and signal conditioning were from M/S National Instruments.