COVENANT UNIVERSITY
NIGERIA

TUTORIAL KIT
OMEGA SEMESTER

PROGRAMME: MECHANICAL ENGINEERING

COURSE: MCE 527

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MCE 527: Introduction to Mechatronics

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1 What is mechatronics?
2 Explain four (4) relevancies of mechatronics to the modern engineering discipline?
3 What do you understand by
   a. Measurement?
   b. Transducers?
   c. Sensors?
   d. Signal Processor?
   e. Microprocessor system?
   f. Actuator?
4 What are the main components of mechatronics?
5 What is the meaning of smart devices?
6 State ten (10) examples of mechatronics system? State for each example why it classified as a mechatronics system.
7 State the major components of the five mechatronics systems mentioned above (2i) that make you classified the as mechatronics system.
8 If an item contains a microprocessor, describe the function performed by the microprocessor**.**
9 What is the main operational difference between an actuator and a transducer?
10 What are the five (5) signal domains for the transfer of information in mechatronics by transducers?
11 State at least two (2) major parameters cover by each signal domain mentioned above (3i).
12 What are the three (3) ways in which transducers can be classified? Explain briefly each that you have mentioned.
13 Mention five (5) of the factors to be considered by the designer for the high level specification and design of a measurement system.
14 What are the two major concerns in the design of a measurement system? Explain briefly what can give birth to those two concerns.
15 What are the five (5) modular approaches requiring for detailed design process in mechatronics once the high level specification has been produced?
16 Suppose you are a consultant to a client and your job is to consider the design of a measurement system to provide the vertical position, velocity and acceleration of the wheels relative to the body of the vehicle for a smart suspension system. This information, together with vehicle speed and steering angle, will form the input data to the microprocessor acting as suspension controller to determine the output settings

of the system actuators. As a consultant, give all possible scenarios you understand and select the option(s) you consider as the best base on your tangible reasons.

Hint: Before proceeding to the design of measurement modules, the high level specification has been determined that the maximum travel of the suspension is 250mm and that position is to be measured to within 1 mm. The road input to the suspension contains frequencies from 1 to 25Hz, with an amplitude variation defined by the curve of Figure. 1.0. On the basis of this information, a sampling rate of 20 ms is chosen in line with the sampling theorem to avoid loss of information.

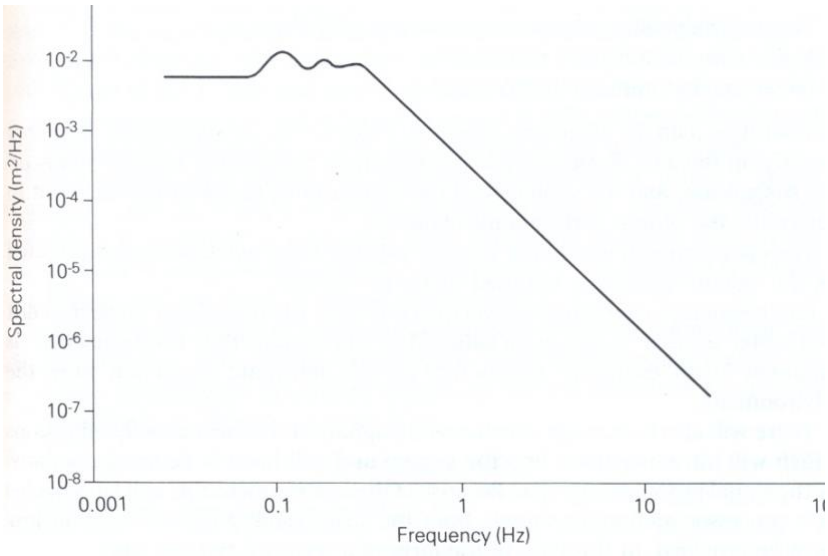

Figure 1.0 Road input to a suspension system

MODEL ANSWER TO MCE528

1 Mechatronics is defined as the field of study involving the analysis, design, synthesis, and selection of systems that combine electronic and mechanical components with modern controls and microprocessors.

2 The four (4) relevancies of mechatronics to the modern engineering discipline are: precision, automation, programming, reliability, repeatability, discipline integration, flexibility, manufacturing and product enhancement, improve effectiveness and efficiency, open-up new area of research and learning, optimization, robotics, space technology, transportation, etc.

a. Measurement: the role measurement is to provide information on system status which, in a mechatronics system, is used to control the operation of the system. The measurement of comprises three basic parts, namely: the transducer, signal processor and the recorder.

b. Transducers is a sensing device that converts a physical input into an output, usually a voltage.

c. Sensor is a detecting instrument: a device capable of detecting and responding to physical stimuli such as movement, light, or heat. The term sensor is at times refer to as the combination of transducer and signal processor.

d. The **signal processor** performs filtering, amplification, or other signal conditioning on the transducer output.

e. Microprocessor system is embedded semi-conductor chip that can be programmed.

f. Actuator converts output voltage motion or cause action such as in stepper motor, DC and AC motors.

3 The main components of mechatronics are: (i) physical systems modeling, (ii) sensors and actuators, (iii) signals and systems, (iv) computers and logic systems, and (v) software and data acquisition.

4 **Smart devices:** Mechatronic systems are sometimes referred to as smart devices. While the term smart is elusive in precise definition, in the engineering sense we mean the inclusion of elements such as logic, feedback, and computation that in a complex design may appear to simulate human thinking processes.

5 Examples of mechatronics systems include an aircraft flight control and navigation system, automobile electronic fuel injection and antilock brake systems, automated manufacturing equipment such as robots and numerically controlled (NC) machine tools, smart kitchen and home appliances such as bread machines and clothes washing machines, and even toys, etc.

6 The major components of the five mechatronics systems mentioned above (2i) that make them classified the as mechatronics system are sensors, transducers, signal processor, recorder, embedded microprocessor or microcontroller, etc.

7 The function performed by the microprocessor is to execute instructions from a program stored in memory at very high speed.

8 Transducers converts physical inputs into an output, usually a voltage but actuator convert output usually voltage to a motion or an action.

9 The five (5) signal domains for the transfer of information in mechatronics by transducers are radiant, mechanical, thermal, electrical, magnetic, and chemical.

10 The two (2) major parameters cover by the signal domain mentioned above (3i) are:
Radiant – frequency, phase, intensity, polarization.
Mechanical – distance, velocity, size, force, etc.
Thermal – thermal capacity, latent heat and phase change properties.
Electrical – current voltage, resistance, capacitance.
Magnetic – strength and flux density.
Chemical – concentration of materials, crystal structure and aggregation state.

11 The three ways in which transducer can be classified are:

- by their functions
- by their performance and
- by their output signal.

Explanation

a. Classification by function

In a mechatronic system the majority of measurements will be concerned with providing information about parameters in the mechanical domain. Typical measurands within this domain are as follows:

- Displacement: Linear and angular.
- Velocity: Linear and angular;
- Flow rate or speed.
- Acceleration
- Vibration
- Shock or impact
- Dimensional, Position, size, area, thickness, volume, roughness, strain.
- Mass, Weight or load, density.
- Force (absolute or relative), static, dynamic and differential pressures, torque, power, stress.
- Other: Hardness, viscosity, etc

Similar functional tables can be drawn up for each of the other domains identified earlier.

Classification by Performance

Performance can be assessed in terms of parameters such as accuracy. repeatability. linearity. sensitivity and range. The selection of an appropriate device then requires that the available devices must be examined against each of the relevant performance parameters in terms of the application under consideration to produce a subset of suitable devices.

Classification by output

Output signals fall into one of a number of groupings as follows:

- Analogue output provides a continuous output signal, some property of which is directly related to the value of the measurand.
- Digital output generates a digital representation of the measurand in either serial or parallel form. Information may be produced either at regular time intervals or on demand.
- Frequency output provides frequency signal which is a function of the measurand. Output may be a continuous or a pulsed waveform which can be readily converted to a digital format by the use of counters and timers.
- Coded output: various forms of coded signal can be produced including amplitude and frequency modulation, pulse width and pulse position modulation.

Provided overall performance parameters are met, the choice of transducer is not necessarily dependent upon the nature of its output, as the use of analogue to digital (A/D) and digital to analogue (D/A) converters enables a signal in either the analogue or the digital domain to be used to generate an equivalent signal in the other domain.

i. For the production of the specification for and the high level design of a measurement systems require the designer to consider a wide range of factors covering:

1. The information required and the identification of the physical parameters of the system that must be measured in order to provide this information;
2. The nature, quality and performance of the measurement in terms of parameters such as linearity, accuracy and resolution;
3. A determination of the most inaccurate measurement that would be acceptable given the function of the measurement;
4. The effect on system performance of any drift in the measurement circuit. particularly on variation of the zero;
5. The environmental conditions under which the sensors and transducers are expected to operate;
6. The cost targets to be met;
7. The nature and form of the information transfer required;
8. The reliability of the system;
9. The form of the interface to adjacent modules in the system.

12 A major concern in the design of a measurement system lies in the provision of either too much or too little information, both of which are conditions which arise from a misunderstanding of the role of measurement.

The first condition, which of providing too much information, arises from the continuously increasing ability of measurement systems to rapidly provide high quality information over a wide range of functions and environments. There is, therefore, a tendency towards the gathering of all available information, at high levels of accuracy and resolution. As a result, it is possible that the relevant information may be lost within a large mass of irrelevant data, putting a heavy demand on the data processing stages of the system.

The second condition, that of making available too little information. generally arises as a result of insufficient consideration being given to the function and purpose of measurement within the context of the overall system. The failure to make available the necessary information imposes an obvious limitation on overall performance.

13 Once the high level specification has been produced, the detailed design of the measurement system can then proceed. This detailed design process will again involve a modular approach requiring:

i. The identification of means by which the required parameters can be measured taking into account the performance requirements;
ii. The selection of appropriate sensors and transducers;
iii. The specification and provision of any local processing power that may be required;
iv. The specification and production of any special purpose electrical or mechanical hardware associated with the operation of the sensors and transducers;
v. The specification of associated software and the control of the production of such software.

14. The design of the measurement modules can now proceed since the high level specification has been determined. Options for the measurement of the required parameters include:

1.The direct measurement of position only, with velocity and acceleration obtained by differentiation;

2.The direct measurement of acceleration only, with velocity and position obtained by integration:

3.The direct measurement of all three parameters;

4.The direct measurement of two out of the three parameters, with the third obtained by integration or differentiation of one or other of the measured parameters.

The measurement of position alone together with the use of differentiation presents problems of stability and drift. In addition, any high frequency components that may be present in the signal from the transducer will be emphasized by differentiation. The measurement of acceleration alone together with the use of integration has some problems of drift and stability, but acts to reduce the levels of high frequency noise. The measurement of all three parameters is unnecessary as the parameters are directly related. The measurement of position and acceleration together with the use of integration to obtain velocity provides a means of checking the

measurement and simplifies the signal processing at the transducers.
The option chosen was to measure position and acceleration and to obtain velocity by integrating the output from the accelerometer.
Position can be measured by a number of sensors, including:

1. linear potentiometers (wirewound or conducting film)
2. driven rotary potentiometers (wirewound or conducting film)
3. linear variable displacement transformers (LVDTs)
4. linear variable inductive transducers
5. linear magnetoresistive transducers.

Acceleration can be measured using a piezoelectric accelerometer mounted directly on the axle. Position transducers may be mounted at various points on the suspension, and the geometry of the system must be taken into account to determine the output performance obtained.
The option chosen was to use a linear variable inductive transducer mounted on the axle to reduce the required stroke to 100 mm.
Environmental conditions are very severe, with the transducer subject to dirt and water as well as corrosive salts. This will require that the transducer is mounted in an enclosure which will provide adequate protection from the environment.
There will also be a range of extraneous signals in the form of body vibrations which will introduce noise into the system and will have to be accommodated by the signal processing system. Because of the environment this will be provided by a processor mounted remotely from the suspension: a communication link must be provided, in this case in the form of a screened twisted pair.