Chapter 1

Introduction

1.1 Electromechanical Products

Figure 1.1 shows an assortment of products representing a cross section of modern electromechanical engineering. In some of these (e.g. the drill) the desired end product is inherently mechanical. In others (e.g. the CD player) the mechanical aspect is hidden inside and the desired function could be performed by a purely electrical or electronic technology (e.g. an MP3 player).

If we consider acoustical signals to be mechanical in nature, and take the pressing of a switch to be a mechanical action, then the MP3 player as well as nearly any other information or communication system could be added to our collection. Although the eyeball is directly sensitive to electromagnetic radiation, all other high capacity channels into and all channels out of the body rely on mechanical means.

If we consider an electromechanical system to be one which involves the exchange of power and information between electrical and mechanical domains, then there is very little in modern technology which is not electromechanical. As we've seen, even "pure" information and communication systems employ a mechanical interface to their human users (e.g. keyboards and microphones). At the other end of the scale even purely mechanical industrial machinery built during the 19th century has become electromechanical, with electric motors replacing steam engines as the prime mover.

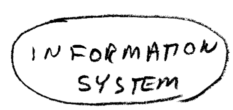
1.2 Electromechanical Design

There are two obvious directions from which to approach an electromechanical design problem: electrical or mechanical. Let's first consider how an EE might approach such a problem.

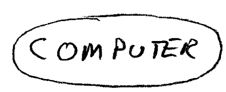
Figure 1.1: Gallery of Electromechanical Products

1.2.1 The Design Process, as Seen by the EE

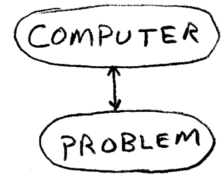
The central theme in modern Electrical Engineering is *information* and *information systems*, so to an Electrical Engineer, the solution to any problem looks like this:



Since the core of most information systems is a computer or microprocessor, the *realization* of the solution will probably look like this:

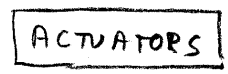


Such computer or information systems have been applied to an extremely broad range of problems, from weather forecasting to entertaining four year olds.

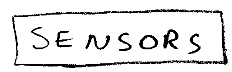


But unless it can interact physically with the outside world, it can't actually *implement* any of these solutions. So we need an intermediary between the internal electronic representation of information and the physical reality of the external world. These devices which transform energy and information between the mechanical and electrical domains are called *transducers.*

To convert the information system's *intentions* into *actions* we need:

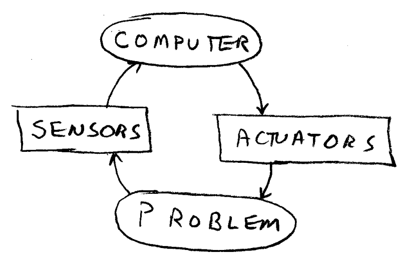


Similarly, to assess the state of the physical world to determine what actions need to be taken, and to monitor the effects of those actions we need:

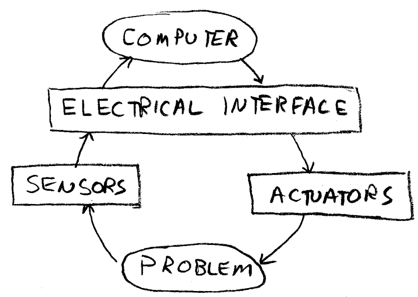


We will also refer to sensors and actuators together as *electromechanical devices*, or often just "devices."

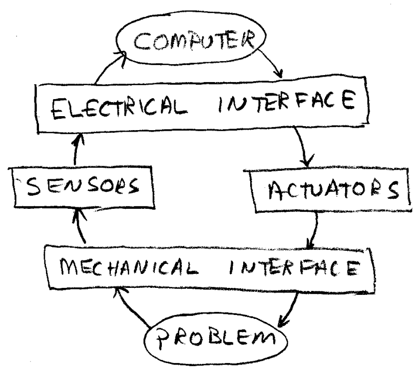
Adding these gives us a system which is conceptually complete, but omits some important details.



For example, the computer will probably have outputs of 1-10 V capable of delivering 1-10 mA (i.e. 1-100 mW). Producing the required action may require considerably more power. (For example the engine of a car can deliver several hundred kW.) Similarly, some sensors produce signals of only a few mV, too small to drive the computer's inputs. So to match the signals of the sensors and actuators to the computer, we add an *electrical interface.*



In a few cases, the sensors and actuators can interface directly to the problem, but often an additional *mechanical interface* is required. Since this entails primarily mechanical design, at this point a Mechanical Engineer would take over.

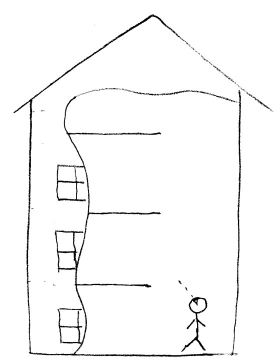


1.2.2 The Design Process, the ME's Version

Rather than hand the ME the partially completed design from the previous section, let's start over again, approaching the design from the ME's point of view.

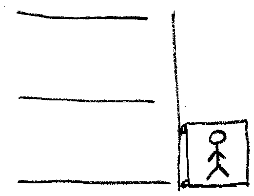
Mechanical Engineering has developed a more structured approach to design, so this time we'll concentrate more on the design process itself, rather than the resulting product. Also, to make things more interesting, we'll choose a specific product from the Gallery (the elevator) as an example. Finally, rather than starting with the solution, as our EE did, we'll start with the problem itself. Here's how we might proceed:

1. Define the problem. Qualitatively this is fairly simple: we want to move people up and down between the floors of a multi-story building.

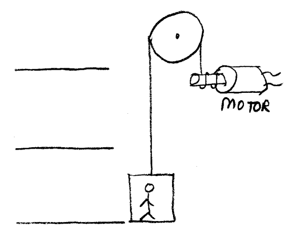


2. Determine the required motions. The car containing the passengers must move vertically, and be able to stop at each floor. The car must not tilt, rotate, or move horizontally. The position at each stop should be sufficiently accurate to prevent tripping or falling regardless of the load in the car. The motion should be sufficiently smooth to provide a comfortable ride.

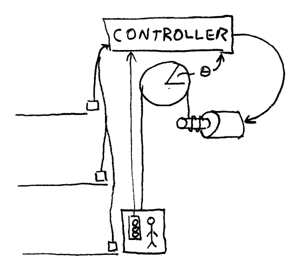
3. Design a mechanism to implement these motions. For simplicity we will consider this to consist of a number of components or subassemblies which move with respect to each other, along with the constraints which define the motion. For the elevator, the major component is the car and the constraints are provided by rails that guide the car and keep it from turning or moving side to side.



4. Add motion transfer and transformation components. Although the desired motion is linear, here it would be better to use a rotational actuator (motor) since a multistory linear actuator would be very expensive. In this case we will require additional components to convert the rotational motion to linear (a windlass), transfer that motion to the car (a cable), and possibly to transform the speed/torque characteristics of the motor to match the requirements of the load (a gearbox).



6. Attach actuators and sensors. The system may now be monitored and animated electrically. At this point we can hand the job over to the EE team members for the final two steps.



6. Design the Electrical Interface.

7. Design the Control.

1.2.3 Mechatronic Design

While there are many modern products which are essentially a microprocessor with a nominally mechanical user interface (e.g. a cell phone) or a mechanical device with an electric motor bolted on (e.g. a can opener) there are a substantial number where the electrical and mechanical portions are inextricably intertwined and could not exist independently. For example, in spite of the continuing increase in semiconductor memory density, the only economical way to store several hours of video is on a mechanically moving medium such as magnetic tape or optical disk. Yet the extreme precision with which the tape or disk must be moved can only be achieved by a combination of a precision mechanism and sophisticated electronic control. Neither the electrical nor the mechanical portion of a VCR is of any use without the other.

With a little imagination, we could rearrange the block diagram of our elevator system so that it looked like Figure 1.2. This figure has a pleasing symmetry to it and highlights the equal importance of the mechanical and control components. In fact, this figure defines

Figure 1.2: A model for an electromechanical system.

what we might call a generic modern product where a microprocessor determines the actions to be performed and a collection of sensors and actuators realize them. The style of design which gives rise to such a product is called *mechatronic design* or simply *mechatronics*.