Introduction

“dSpace Real-Time System“

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1 Introduction

The goal of this introduction is to provide an overview of the procedures which are possible adopting this really useful application tool.

The procedure essentially consists of the following six points:

1. Develop a mathematical model of the system in Matlab-Simulink.
2. Analyze the system, assisted by the models obtained (Simulation, Linearization, etc.)
3. Extend the controller with Input-Output blocks from the dSpace Library to connect the Simulink environment to the real world (depending on the hardware).
4. Compile the Simulink model in the dSpace Processor via dSpace Compiler (only discrete system).
5. Prepare an environment for the experiment with dSpace ControlDesk.
6. Activate the real-time processor and optimize the parameters directly on the test bench.

In the idle speed controller exercise most of these points have been prepared in advance, so that your exercise will be reduced to the real application of the controller (points 1, 2, and 6). However, it is important to know how this system has to be prepared and used, for it can be really interesting and for the actual trend in the application of controllers tends towards these “rapid prototyping” tools. This tool will be described and presented on the Water tank exercise.

2 What is dSpace?

The dSpace system is a so-called rapid prototyping tool. Rapid prototyping means that the generation of a working prototype should be direct and obviously rapid, in order to apply the model developed to the actual system with the smallest procedural delay. Another advantage is that the applied system will be the same as the tested one, thus reducing possible translation errors. Before the real-time system’s era, the development times were very long. The real world and the model were not directly connected, i.e. the system used for the application was quite different from the system used for the development. This difference obliged the engineers to translate the results obtained in one system to the other. This was a time-consuming activity and a source of extra errors.
The need to reduce the development times has brought to the market these systems, which have become very powerful with the evolution of real-time processors. Among the real-time systems available, dSpace is one of the most comfortable to use because of its strong ties with Matlab-Simulink.

In fact, the dSpace system is very easy to integrate in Simulink and the generation of the code for its processor can be started directly in Matlab.

The dSpace system has a wide range of different hardware. The hardware is composed from several real-time processors mounted on a PC board and a large choice of input/output boards. For the supported hardware dSpace offers a toolbox for Simulink with the optimized drivers.

3 Starting Point

The starting point for this introduction is a functioning Simulink model of the water tank with a good working controller (Points 1, and 2).

As explained before, the idea of this procedure, which is also known as „rapid prototyping“, is the fastest and most direct connection between test phase and application phase. This leads to a direct and automatic generation of the real-time code for the processor. This should save time and avoid possible errors generated by the translation of the Matlab/Simulink program in a real-time language by a programmer. Obviously, since we want to implement the controller rather than the model itself, the starting point is the controller shown in Figure 1.

4 Extend the controller with Input-Output Blocks from the dSpace Library

dSpace has a wide range of hardware and drivers for the most known applications. In addition to that, it is still possible to implement proprietary drivers for special hardware. At this point it is important to know exactly what kind of hardware is needed for dSpace to communicate with the real world. Examples of hardware that may be needed are AD and DA

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1 In reality, some errors can still occur!
converters\textsuperscript{2}, because the real world is a continuous environment, while the PC is a discrete environment. In our case, the test bench is equipped with a dSpace DS1102 card with a Motorola processor with four AD channels, four DA channels, and a serial interface. In the water tank system the level sensor measures the level of the water yielding an analog signal. The output valve management is performed by giving an analog signal to the electrical motor of the valve. Therefore, we need two channels, one input (AD) and one output (DA). This is the minimal dSpace hardware requirement to control this system.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{system_diagram.png}
\caption{System prepared to be compiled}
\end{figure}

Note that the controller has to be digital, for it is not possible to compile a system which is not completely digital. In addition, the controller is designed to work on a difference in meters outputting a correction in \% from the steady-state value \(u_0\). Therefore the sensor signal, which is in Volt, has to be converted to meters, and the correction signal has to be transformed into Volts.

5 Compile the Simulink Model in the dSpace Processor

In order to start with the application of the controller we need to compile the system in the dSpace processor. This is performed with the Menu \textbf{Tools\textgreater{}Real-Time Workshop\textgreater{}Build Model}. The program is compiled and run: The system is ready.

6 dSpace ControlDesk

As explained, the main advantage of a real-time system is the fact that the parameters of the system can be changed during operation. Virtually all the parameters in the model can be measured and/or modified on-line. In order to do this, dSpace offers the ControlDesk program. This program reads and writes in the memory blocks reserved for the dSpace processor and is able to show/change the value of every variable due to a memory map generated during the compilation of the program. ControlDesk offers a wide choice of visualization and editing tools, as for instance gauges, displays, radio buttons, graphs, level bars, etc.

\textsuperscript{2} AD = Analog to Digital
DA = Digital to Analog
Figure 3: ControlDesk layout manager

Figure 4: ControlDesk layout for the water tank control