

Electric Drives Experiment 1

Familiarization and Systems Check of the Electric Drives Lab

The instructor or TA will inform you how many students should work together at one lab station.

1.1 Objective

The objective of this experiment is to introduce students to the electric drives lab and to verify that the lab's different components are working properly. Note that this and all subsequent electric drives lab activities were derived from those developed and distributed by the University of Minnesota (UMN).

1.2 Fundamental Hardware Components

The fundamental components of an electric drive system are shown in Figure 1.1. In this lab, the input commands as shown in the figure will be derived from control algorithms that you develop in MATLAB Simulink. The dSPACE Advanced Control Education Kit #1104 (ACE1104) will serve as the controller, implementing your Simulink design in real time. The HiRel / Vishay electric drives inverter board #75771 will serve as the power processing unit (PPU), and that board also contains some sensors (for example, current sensors). The MotorSolver Dyno-Kit will serve as the motor and load, and some of the motors have encoders which will be used to determine the motor's position and speed.

Find a lab computer that contains the dSPACE PC board (DS1104), as shown in Figure 1.2. Then collect the electric drives lab components shown in Figure 1.3 from the lab's file cabinets, and place these items near your lab computer but do NOT connect them yet. Check that one motor in the MotorSolver kit is labeled as the "DC Generator," the other motor is labeled "DC Motor," and all of the motor kit's components are solidly connected.

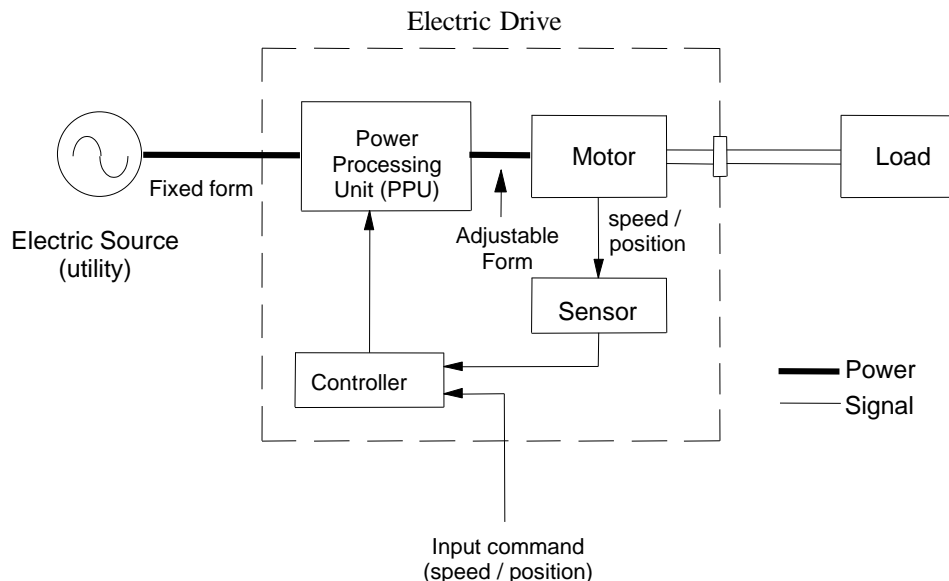


Figure 1.1: Basic components of an electric drive system (UMN, Mohan).

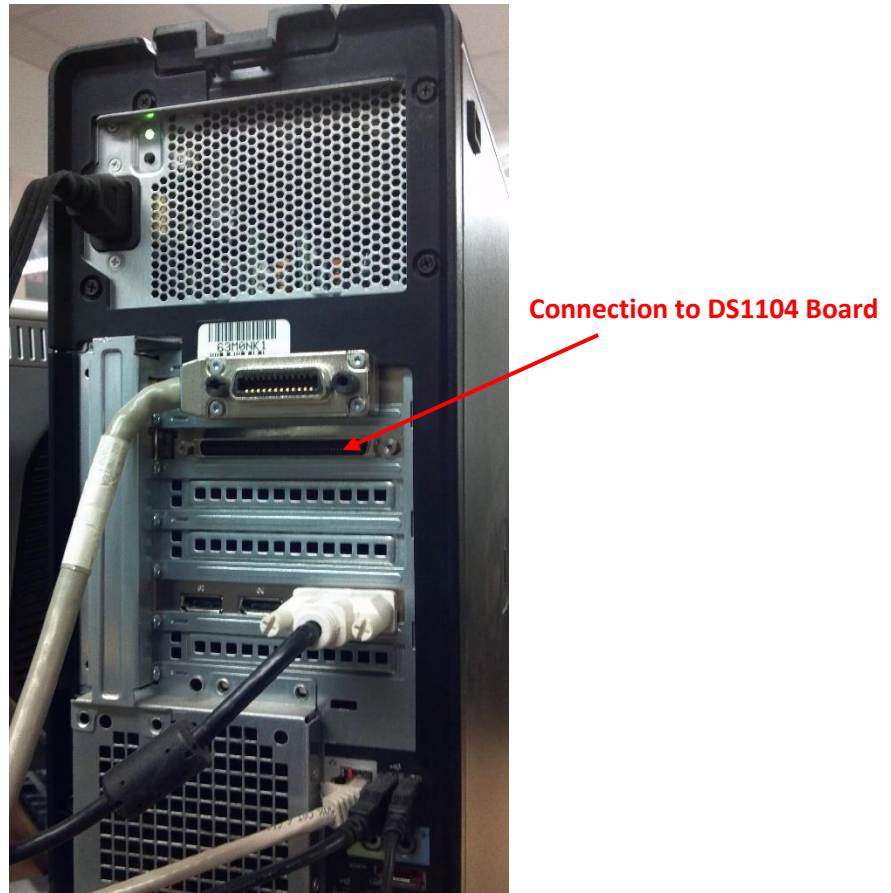


Figure 1.2: dSPACE PC board (DS1104) mounted in a lab computer.

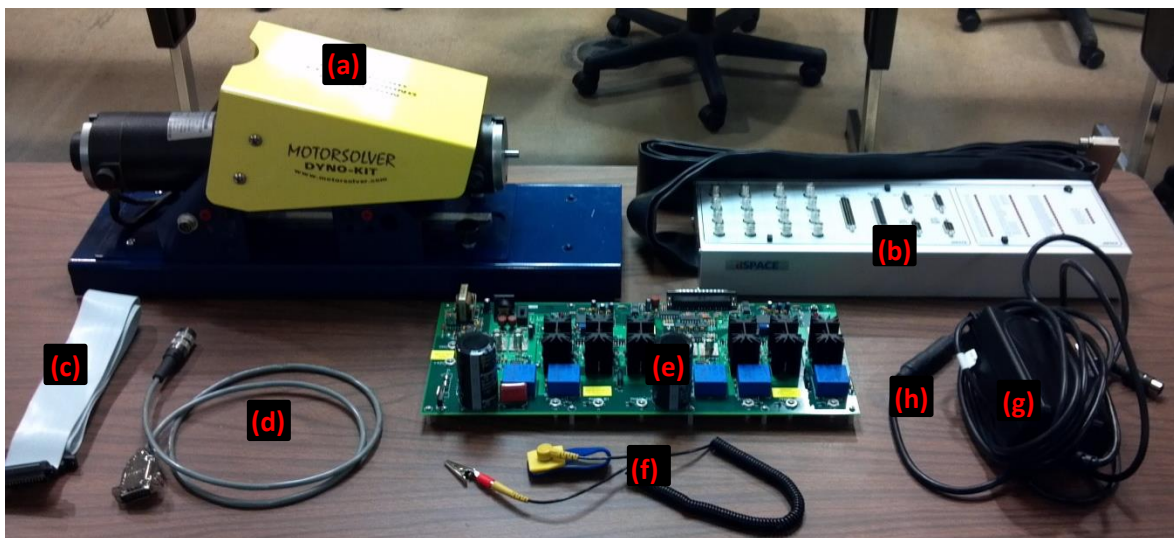


Figure 1.3: Components of the electric drives lab that are stored in the lab's cabinet: (a) MotorSolver Dyno-Kit, (b) dSPACE CP1104 connector / LED panel, (c) 37-pin DSUB cable, (d) 8-pin encoder cable, (e) HiRel / Vishay electric drives inverter board #75771, (f) grounding wrist strap, and (g) +/- 12V analog power supply connected to (h) a pin conversion cable.

1.3 Hardware Connections

Designate which team member will handle all of the inverter board's connections. That team member should wear the grounding wrist strap and connect that strap to the test bench's electrical ground. Use the bolt that protrudes from the test bench's metal frame, located on a bench leg directly below the bench's work area. Do not connect your wrist strap to painted metal, as the paint will block the electrical path to ground. Without the grounding wrist strap, given the lab's dry environment, it is common for students to create an electrostatic discharge onto the inverter board, destroying semiconductor components and causing costly repairs.

Note that you need to step through the following procedures carefully, not making any connections to the inverter board until instructed to do so. These instructions are ordered so that the board's three power sources (digital, analog, and input DC) are not supplied until you have finished making all connections. When the board is powered, it is very easy to accidentally brush your hand or a cable across two different voltages, creating stray current paths which damage the board. Also, monitor your area throughout the lab time to ensure that no cables, papers, or other items are ever draped across the inverter board, again creating stray current paths which can destroy some of the board's components. If you ignore these recommendations and damage the board, you may be liable for up to \$2,000 in repair costs.

Without connecting any cables, use the Voltage-Coarse and Fine knobs on the test bench's high-power DC power supply (the BK Precision model) to set its DC output to 40 V, and then **turn off the power supply**. The grounded team member may then use banana cables to connect the '+' port on the DC power supply to the "+42V" port on the left side of the inverter board, as shown in Figures 1.4 and 1.5. (Note that our lab's power supplies cannot reliably provide the full 42 V listed on the board, which is why you set the DC voltage to 40 V.) Next, connect the DC power supply's '-' port to the GND connection at the left side of the inverter board. Do **NOT** connect the ground port of the DC power supply to the inverter board. Do **NOT** turn on the DC power supply at this time.

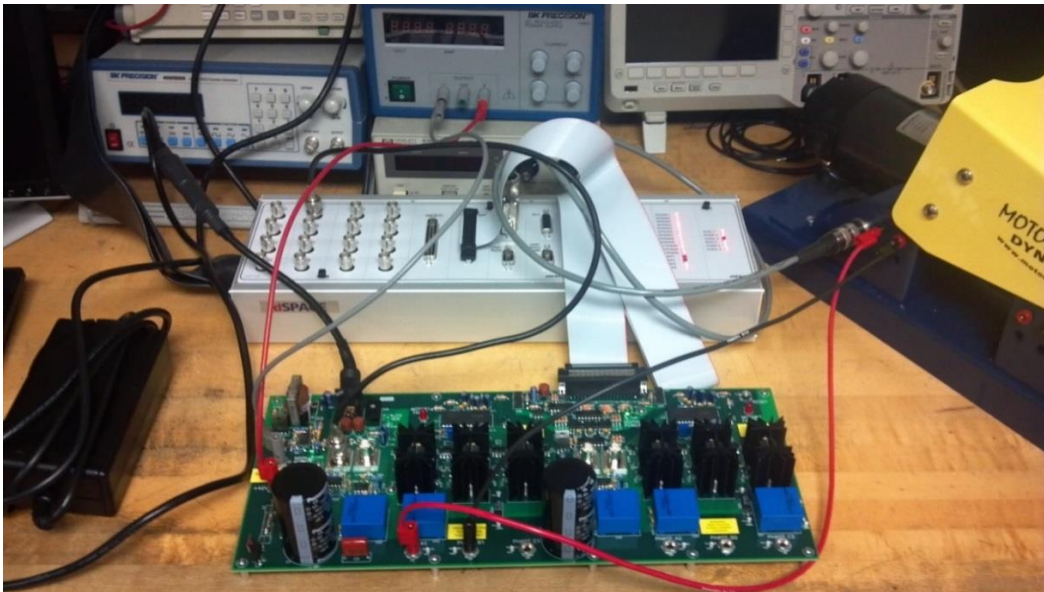


Figure 1.4: Photo showing hardware connections for electric drives lab #1.

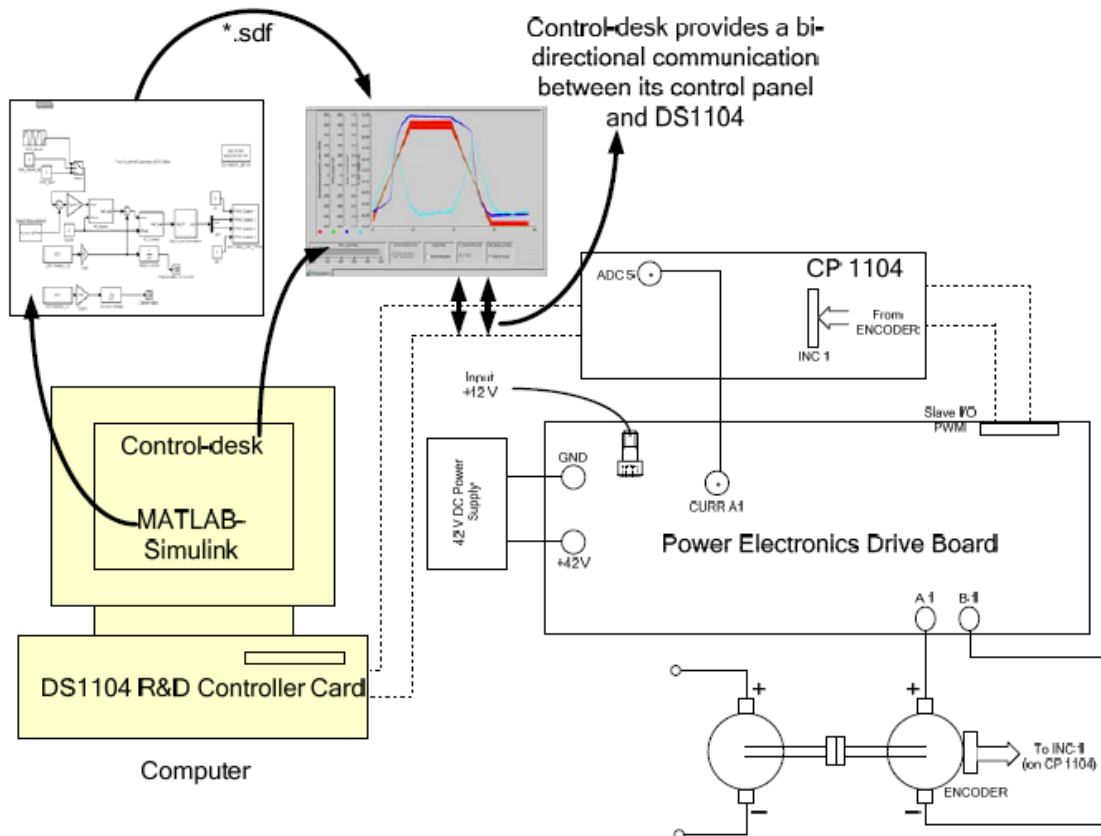


Figure 1.5: Diagram showing hardware connections for lab #1 (UMN).

Now connect the +/- 12V analog power supply shown in Figure 1.3 to the inverter board's analog power connection (located in the upper-left region of the inverter board), as shown in Figures 1.4 and 1.5, making sure that the +/- 12V power supply's pin conversion cable is securely in place. Turn the analog power toggle switch, which is located near the +/- 12V connector, to the "ON" position. If the green LED next to the toggle switch becomes lit, the input analog power is good. If the green LED does not light, double-check or change the +/- 12V power supply's outlet connection and tighten the pin conversion cable's connections. If the problem persists, turn off the toggle switch, and check the two cylindrical brown fuses located below the +/- 12V connection – to do this, carefully remove each fuse and check its resistance with the test bench's multimeter. If the fuse is ok, it will have a very low resistance, perhaps a few Ohms. If the fuse is blown, it will have a very high resistance (open circuit). Notify the instructor or TA if you need a new fuse.

The grounded team member should now connect the 37-pin DSUB cable between the CP1104's "Slave I/O PWM" port and the associated port on the inverter board, as shown in Figures 1.3-1.6 above and below. Among other things, this cable will bring digital power and PWM control signals from the computer's DS1104 board to the inverter board. The CP1104's large black cable should **NOT** be connected to the back of the PC computer yet, as you aren't done making connections and therefore don't want to provide any type of power to the inverter board.

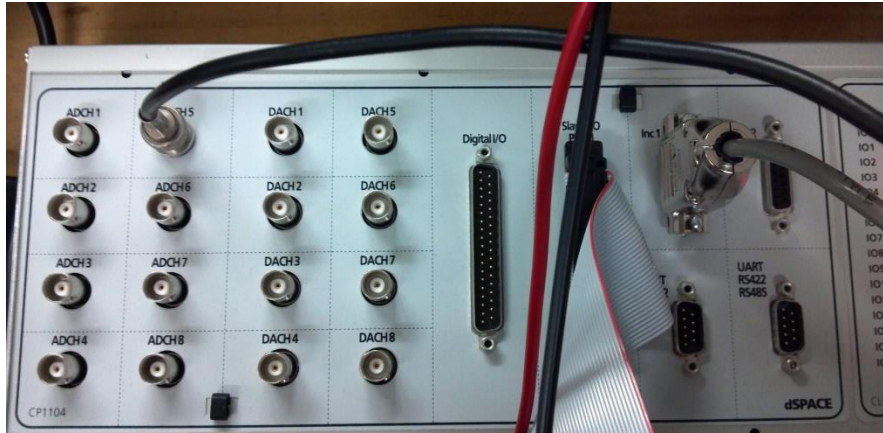


Figure 1.6: Photo showing the CP1104 connections for electric drives lab #1.

Find the connections to the output Phase A1 and Phase B1 voltages at the bottom of the inverter board. These voltages will power your drive motor. The grounded student may connect the “Phase A1” voltage output on the inverter board to the **black** connector on the MotorSolver Kit’s **DC Generator** (being used as a motor rather than a generator in this lab). Connect the inverter board’s “Phase B1” voltage to the DC Generator’s **red** connector. Unfortunately, in our version of this lab, the motor’s red and black cables were internally connected in a manner opposite to the usual standard, so you will always have to make this non-intuitive connection between the inverter board’s higher output voltage and the motor’s black connector.

Use the 8-pin encoder cable to connect the CP1104 Inc1 port to the MotorSolver Kit’s encoder connection (see Figures 1.3-1.6 for details). This sensor will provide the controller information about the motor’s location and speed. The grounded team member should next use a BNC-BNC cable (hanging on the side of the lab cabinet, by the classroom door) to connect the CP1104’s analog-to-digital ADC-5 port to the inverter board’s CURR A1 port. The inverter board’s A1 current sensor will provide information about the current being drawn by the drive motor.

Finally, connect the CP1104’s large black cable to the DS1104 PC board, using the connection at the back of the lab computer as shown in Figure 1.2. Take care that the cable is fully seated into the PC board’s connector, such that the cable’s screws easily thread, and tighten the cable to the computer. Although you don’t have to tighten the screws completely, a loose CP1104-DS1104 cable is a frequent source of error in these labs, so do take care with this step.

Review Figures 1.2-1.6 and ensure that all of your hardware connections are correct. Keep the 40 V DC power supply turned OFF for now.

1.4 MATLAB Simulink Control System Model

Your electric drive control algorithms will be modeled in MATLAB Simulink and then executed on the dSPACE PC board (DS1104). The MATLAB Simulink model is provided for this lab. Create a folder called Exp1 on the lab computer’s desktop, and download the file “Exp1.mdl” from the location specified by the TA or instructor to this folder. If the downloaded file is

automatically saved as Exp1(1).mdl, rename it back to Exp1.mdl, as MATLAB does not work with parentheses in filenames.

Double-click on the downloaded file, and it should automatically open the 32-bit version of MATLAB Simulink. If not, find and start the 32-bit version using the Search capability of the Windows Start menu. (The 32-bit rather than the 64-bit version of MATLAB Simulink must be used because that option was selected for compatibility purposes when dSPACE was installed on the lab computers.)

When a pop-up window asks you to select the dSPACE RTI Platform Support, choose the RTI1104 option, and select the checkbox that will prevent this window from coming up again. If another pop-up window suggests that some parameters should be automatically set to values that are more suitable for your chosen RTI configuration, allow the values to be set automatically, and check the box that will prevent this pop-up window in the future. After the startup process is complete, you should see the MATLAB Simulink model shown in Figure 1.7. If not, try starting the 32-bit MATLAB version first (found by typing MATLAB in the Search box under the Windows Start menu) and then opening the Exp1.mdl file from within MATLAB.

If the DS1104 blocks in the Simulink model are colored red and/or have a “Bad Link” label, double-check that your computer contains the DS1104 PC board (Figure 1.2). If your computer does not have this board, you’ll have to move to another lab station. If the board is in place, verify that you’re using the 32-bit version of MATLAB Simulink and that you selected the “DS1104” board option when MATLAB started (see the command window’s log). If that doesn’t work, check whether the dSPACE ControlDesk software is installed on your computer (look for a desktop icon and/or use the Search utility under the Windows Start menu). If the ControlDesk software is missing, notify the instructor and check whether another available lab computer has both the DS1104 board and the ControlDesk software. If you continue to have problems, ask the instructor or TA for assistance.

Set MATLAB’s current / working directory to your Exp1 folder, as displayed and set in the upper-left region of the MATLAB **command** window.

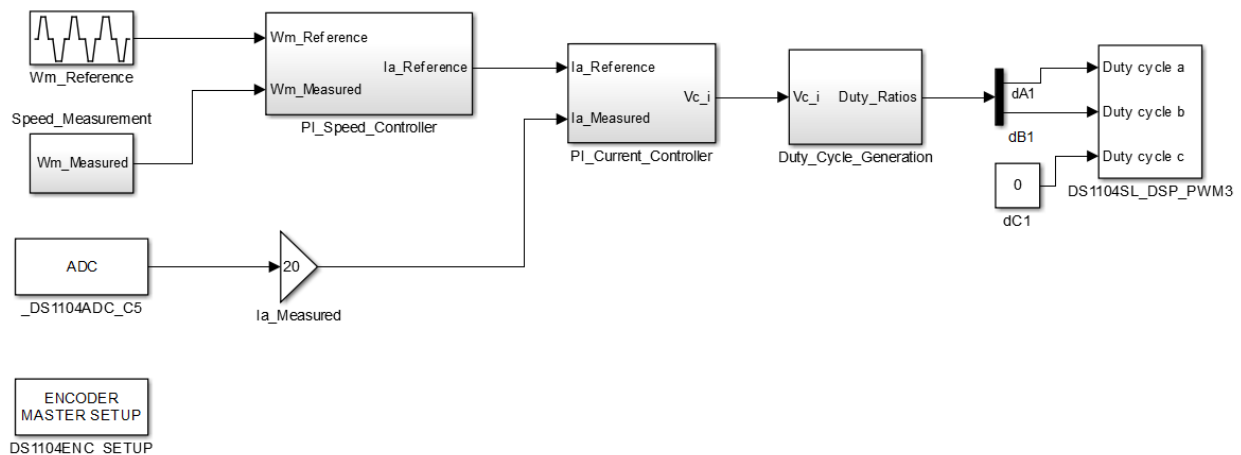


Figure 1.7: MATLAB Simulink model of this lab’s control system.

Analyze the MATLAB Simulink model of the control system. Double-click on the “Wm_Reference” block in MATLAB Simulink to *find the maximum and minimum values of the reference or desired motor speed in this case, in radians per second*. The “Speed_Measurement” block estimates the motor’s speed, using data from the MotorSolver kit’s encoder. The motor’s measured speed is then compared to its desired speed, and a proportional-integral (PI) speed controller uses the error between these two values to calculate an updated value for the motor’s armature current, I_a . The “DS1104ADC_C5” block in MATLAB indicates that the sensor data provided to the DS1104 board’s Analog-to-Digital Conversion (ADC) port #5 will be used in the subsequent calculations. You connected the inverter board’s A1 current sensor data to this DS1104 C5 port. The current sensor’s measured data is then corrected (scaled properly) and compared to the desired current, and a PI current controller uses the result to determine the average voltage which should be provided to your motor. The remaining blocks determine the characteristics of the Pulse-Width-Modulated (PWM) signals that will be used to create this average voltage. The ‘dA1’ and ‘dB1’ variables output by the controller represent the duty ratios being assigned to the Phase A1 and Phase B1 transistors on the HiRel / Vishay electric drives inverter board (via the DS1104 PWM signals and the inverter board’s IR2133 drivers). Recall that you connected the 37-pin cable which will help carry these signals from the CP1104 board to the PWM drivers on the inverter board. You will learn more about all of these MATLAB blocks later in the semester, including how to design the PI control systems.

Ensure that the Simulink window (the one with the block diagram) is active, and enter Ctrl-B to generate C code that will implement the modeled control system in real time. After several seconds, MATLAB’s command-line window should pop-up and display informative messages as the C code is generated, compiled, and linked. After this, an executable representing the control system should be uploaded onto the DS1104 board. If nothing seems to happen for about 30 seconds after you press Ctrl-B, ensure that the **Simulink** window containing the block diagram of the control system is active, and try pressing Ctrl-B again. If this doesn’t fix the problem, and assuming that you had no earlier errors that went unfixed, go to the MATLAB command-line window, and select the “Apps” tab at the top of the main window. Check whether the MATLAB installation on your lab computer contains the “MATLAB Coder” app / module. If not, notify the instructor and/or TA, who will work with IT support to have both the Coder and Simulink Coder modules added to the installation. (These modules require a supplemental purchase to the institution’s primary MATLAB license.)

When the “make” process is complete, you should see a file named “exp1.sdf” in your Exp1 folder. If not, go to MATLAB’s command window and set the Current Folder (shown on the upper-left side of the screen) to your Exp1 folder and repeat the “make” process (type Ctrl-B in the Simulink window).

1.5 Setup for the dSPACE ControlDesk Real-time Control and Data Display

Open the dSPACE ControlDesk software by either double-clicking on the desktop icon or using the Windows Start menu’s Search utility. An initial start-up window will ask you to accept some conditions before using the software, and you have to scroll to the end of the text box before you can select the “Accept” button. You may also want to uncheck the appropriate box to prevent this window from popping up in the future.

In the ControlDesk software, select **File->New->Create New Project and Experiment**. In the subsequent two pop-up windows, you may (but don't have to) name the new project and new experiment. In the third window ("Add Platform / Device"), select the DS1104 R&D Controller Board. In the subsequent step, use the "Import from File" option to open the "exp1.sdf" file that you created from MATLAB, which is located in the desktop Exp1 folder and includes the experiment's variable definitions. After you select the "Finish" button, the ControlDesk window should look similar to the one shown in Figure 1.8.

A model tree of your variables should now be located in the lower-left corner of the ControlDesk window. Click the "+" sign next to the "exp1.sdf" item in this window, and then expand the "Model Root" item to see the model tree of variables that you just created in MATLAB.

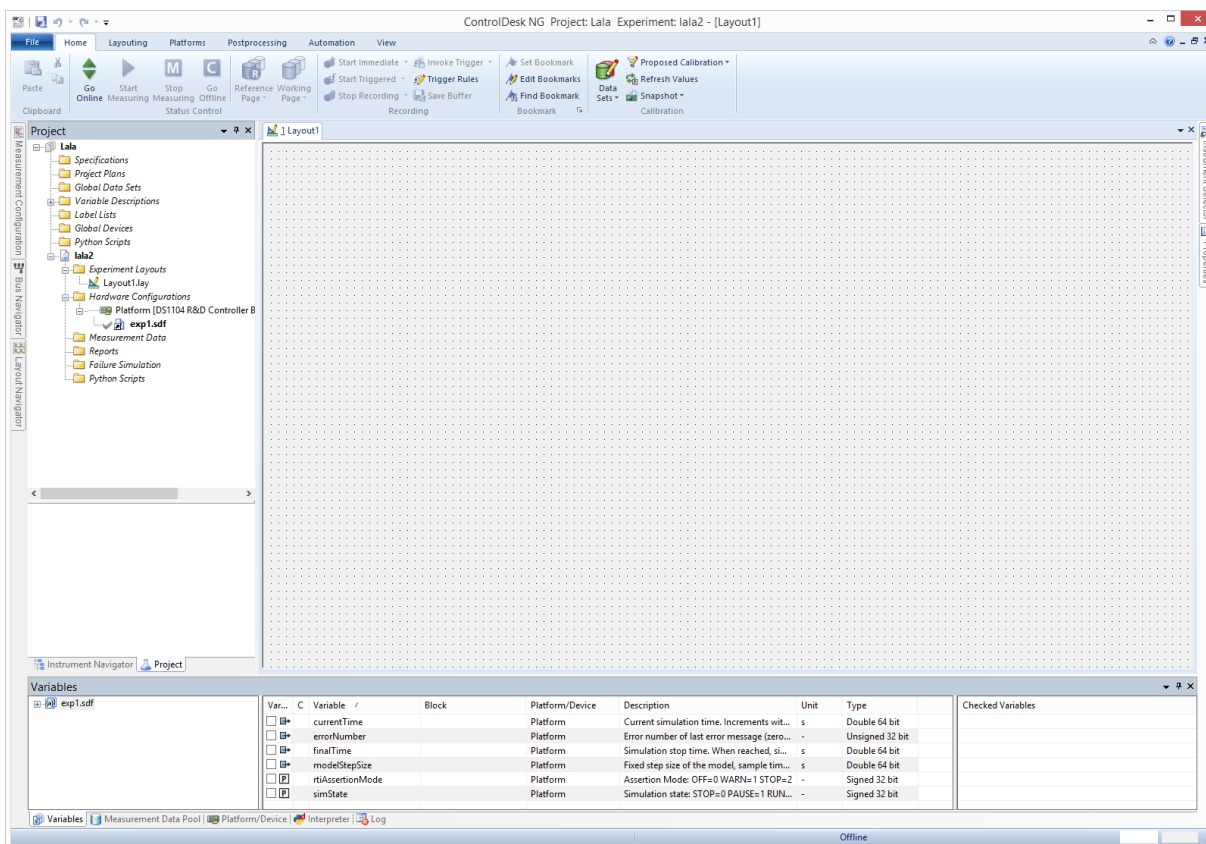


Figure 1.8: ControlDesk software window after the exp1.sdf file has been uploaded.

You'll now select some methods for graphically displaying the real-time sensor and control data in the electric drives experiment. First, click on the "Instrument Selector" tab on the **right** side of the main ControlDesk window. Select and drag the "Plotter" option shown on the resulting list into the graphing / layout area. This graph will display a variable's values as a function of time. Expand the "exp1.sdf" model tree in the lower-left corner of the software window until you see the "Speed_Measurement" listing. Click on "Speed_Measurement," and notice that a list of variables associated with this topic is now shown in the lower-center area of the main window. Select the "Wm_Measured" variable and drag it onto the Plotter.

Back on the model tree, find and select the “Wm_Reference” entry, which represents the desired motor speed in radians/second. Select the “Out1” variable associated with this item as shown in the lower-middle area of the software window, and click and drag this variable onto the **y-axis label** of the existing “Plotter” display. This will cause the desired and actual motor speeds to be displayed on the same y-axis.

Select and drag a “Display” item from the “Instrument Selector” onto the layout, and then drag the “Wm_Measured - Out1” variable onto this instrument to see a precise numerical value of the motor’s instantaneous speed. You may want to resize the instrument to see the data better.

Select the “Measurement Configuration” tab located near the upper-left side of the main ControlDesk software window. Expand the “Duration Triggers” list by clicking on the arrow to its left, and then select “Duration Trigger 1.” Use the new entry box at the bottom of the Measurement Configuration window to set “Duration Trigger 1” to 24 s. This will increase the time window for your Plotter instruments. Click in the main layout / graphing area to hide the Measurement Configuration window.

Save your ControlDesk project.

1.6 Testing the Complete Electric Drive System

In the ControlDesk software window, select the “Start Measuring” icon on the top toolbar (under the “Home” tab). As an initial test, manually spin the coupler between the two MotorSolver motors, which should cause the ControlDesk graph associated with the motor’s measured speed to change.

On the inverter board, check that the toggle switch associated with the +/- 12V analog power supply is ON. Finally, turn on the test bench’s DC power supply that you set to 40 V previously. After a few seconds, the motor should start spinning as commanded by the control algorithm created in MATLAB. Your first ControlDesk plotter window should show that the sensed motor speed is tracking the desired speed fairly well. **If you are getting a sustained motor fault current, indicated by a red Motor1 Fault LED and no motor movement**, try holding the “Reset” button located in the upper-right corner of the inverter board for a few seconds, to help your motor overcome the initial surge current.

If your motor’s sensed speed does not track the desired speed (i.e., if it runs much faster and/or does not change direction periodically), check that the analog power supply is on, as indicated by the green LED. If that doesn’t work, turn off the 40 V DC power supply and use the toggle switch to turn off the +/- 12V power supply. Also remove the 37-pin DSUB cable connecting the inverter board and the CP1104. With all of those power sources turned off, remove (pull off) and check all three brown cylindrical fuses located on the inverter board. If you continue to have problems, ask the instructor or TA for assistance.

Once your ControlDesk graphs are displaying good data and a complete waveform is displayed, select the “Stop Measuring” icon in the ControlDesk toolbar. Also turn off the 40 V DC power supply, and don’t worry about the squealing sounds created by the discharging capacitors. Right-

click on the motor speed plot and select the “Print” option. *Select the option to Copy the graph to the Clipboard, and paste the image into an M.S. Word document for use in your lab report.*

Save your ControlDesk and MATLAB files, and then close both software programs.

1.7 Shutdown Procedures

Always turn off the three sources of power to the inverter board first, starting with the 40 V DC power supply, and then proceed with disconnecting the other cables:

- Turn off the high-power DC power supply first, without reducing its output voltage.
- Turn off the toggle switch associated with +/- 12V power supply, and unplug this power supply.
- Remove the ribbon cable from the inverter board and the CP1104 board.
- Remove the black cable from the DS1104 PC board (at the back of the lab computer).
- Remove the BNC-BNC and encoder cables.
- Remove all banana cables and store them at the lab benches as usual.
- Replace the inverter board inside the protective electrostatic cover.
- Return all of the specialized electric drives components to the lab cabinet. The TA or the instructor will help you organize the equipment.
- Check that all of the test bench equipment is turned off, and leave the test bench area clean and organized. Your lab grade will be lowered if you are not careful using the lab equipment and/or if you leave trash in the test bench area.

1.8 Lab Report

There is not a formal report for this introductory lab. Create and print a file with the requested information (repeated below), along with your names. Hand your print-out to the TA or instructor before leaving.

Checklist of items requested in these lab procedures:

- The maximum and minimum values of the desired motor speed for this lab.
- A plot showing the desired and actual motor speed as a function of time.