32 Digital Potentiometer

A digital potentiometer is a three-terminal variable resistor that behaves just like its mechanical analog potentiometer counterpart (see Chapter 7 on page 27) but with a digital numerical value to set the virtual knob position. The digital potentiometer provides a convenient replacement for mechanical potentiometers, offers computer-adjustable gain control for amplifiers, and software adjustment of trim potentiometers used to null resistive sensor circuit offsets. Figure 32.1 pictures the NI myRIO Embedded Systems Kit digital potentiometer with 10 kΩ end-to-end resistance and 8-bit resolution; SPI serial bus conveys the digital wiper position.

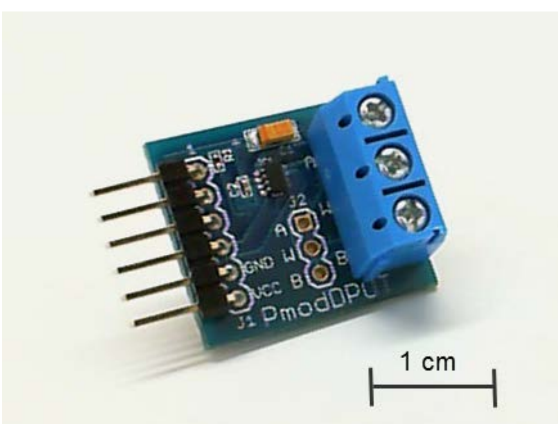

Figure 32.1: NI myRIO Embedded Systems Kit digital potentiometer.

Learning Objectives: After completing the activities in this chapter you will be able to:

1. Adjust the digital potentiometer wiper position with SPI serial communications,
2. Properly connect and operate the digital potentiometer as either a rheostat or as a potentiometer (voltage divider), and
3. Discuss the principles of the "virtual wiper" as implemented by an array of solid-state switches.

32.1 Component Demonstration

Follow these steps to demonstrate correct operation of the digital potentiometer.

Select these parts from the NI myRIO Embedded Systems Kit:

- Digital potentiometer (PmodDPOT), `http://digilentinc.com/Products/Detail.cfm?NavPath=2,401,1075&Prod=PMOD-DPOT`
- Jumper wires, F-F (5×)
- Jumper wires, M-F (3×)
- Small screwdriver

Build the interface circuit: Refer to the schematic diagram shown in Figure 32.2 on page 149; the digital potentiometer requires five connections to NI myRIO MXP Connector A and three connections to MXP Connector B (see Figure A.1 on page 233):

1. +5-volt supply → A/+5V (pin 1)

2. Ground → A/GND (pin 6)
3. SPI receiver → A/SPI.MOSI (pin 25)
4. SPI clock → A/SPI.CLK (pin 21)
5. Chip select → A/DIO0 (pin 11)
6. "A" → B/+5V (pin 1)
7. "B" → B/GND (pin 6)
8. "W" → B/AI0 (pin 3)

Run the demonstration VI:

- Download `http://www.ni.com/academic/myrio/project-guide-vis.zip` if you have not done so previously and unpack the contents to a convenient location,
- Open the project `Dpot demo.lvproj` contained in the subfolder `Dpot demo`,
- Expand the hierarchy button (a plus sign) for the myRIO item and then open `Main.vi` by double-clicking,
- Confirm that NI myRIO is connected to your computer, and
- Run the VI either by clicking the Run button on the toolbar or by pressing Ctrl+R.

Expect to see a "Deployment Process" window showing how the project compiles and deploys (downloads) to NI myRIO before the VI starts running.

NOTE: You may wish to select the "Close on successful completion" option to make the VI start automatically.

Expected results: The demo VI provides a front-panel slide control to set the virtual wiper position as an 8-bit value. The five-volt power supply connected across the end terminals of the potentiometer creates a proportional variable voltage at the wiper terminal "W" which is read by an analog input and displayed on the indicator dial. Move the slide and you should see a corresponding change on the dial position. Press the page-up and page-down keys to make single-bit changes to the digital value.

If you have an ohmmeter handy, disconnect all three potentiometer terminals from NI myRIO and then measure the resistance between the "W" and "B" terminals as you vary the digital wiper position; repeat for the "W" and "A" terminals. If the measurement does not seem sufficiently stable, try connecting either "A" or "B" to one of the NI myRIO ground terminals.

Click the Stop button or press the escape key to stop the VI and to reset NI myRIO.

Troubleshooting tips: Not seeing the expected results? Confirm the following points:

- Glowing power indicator LED on NI myRIO,
- Black Run button on the toolbar signifying that the VI is in run mode,
- Correct MXP connector terminals — ensure that you are using Connector A to power the digital potentiometer board and Connector B to establish the potentiometer variable voltage, and
- Correct SPI connector terminals — double-check your connections, and ensure that you have connected the NI myRIO SPI "MOSI" output to the digital potentiometer "SDI" input and digital output DIO0 to the chip select input.

32.2 Interface Theory

Interface circuit: The Digilent PmodDPOT board provides a convenient set of interface connectors for the Analog Devices AD5160 digital potentiometer. The digital potentiometer provides the conventional trio of terminals like a mechanical potentiometer, and an 8-bit value between 0 and 255 transmitted via SPI (serial peripheral interface) sets the virtual wiper position by closing exactly one of 256 solid-state switches that establish the connection point to a string of 256 equal-valued resistors between terminals "A" and "B."

Study the video *Digital Potentiometer Interfacing Theory* (`youtu.be/C4iBQjWn7OI`, 9:15) to learn

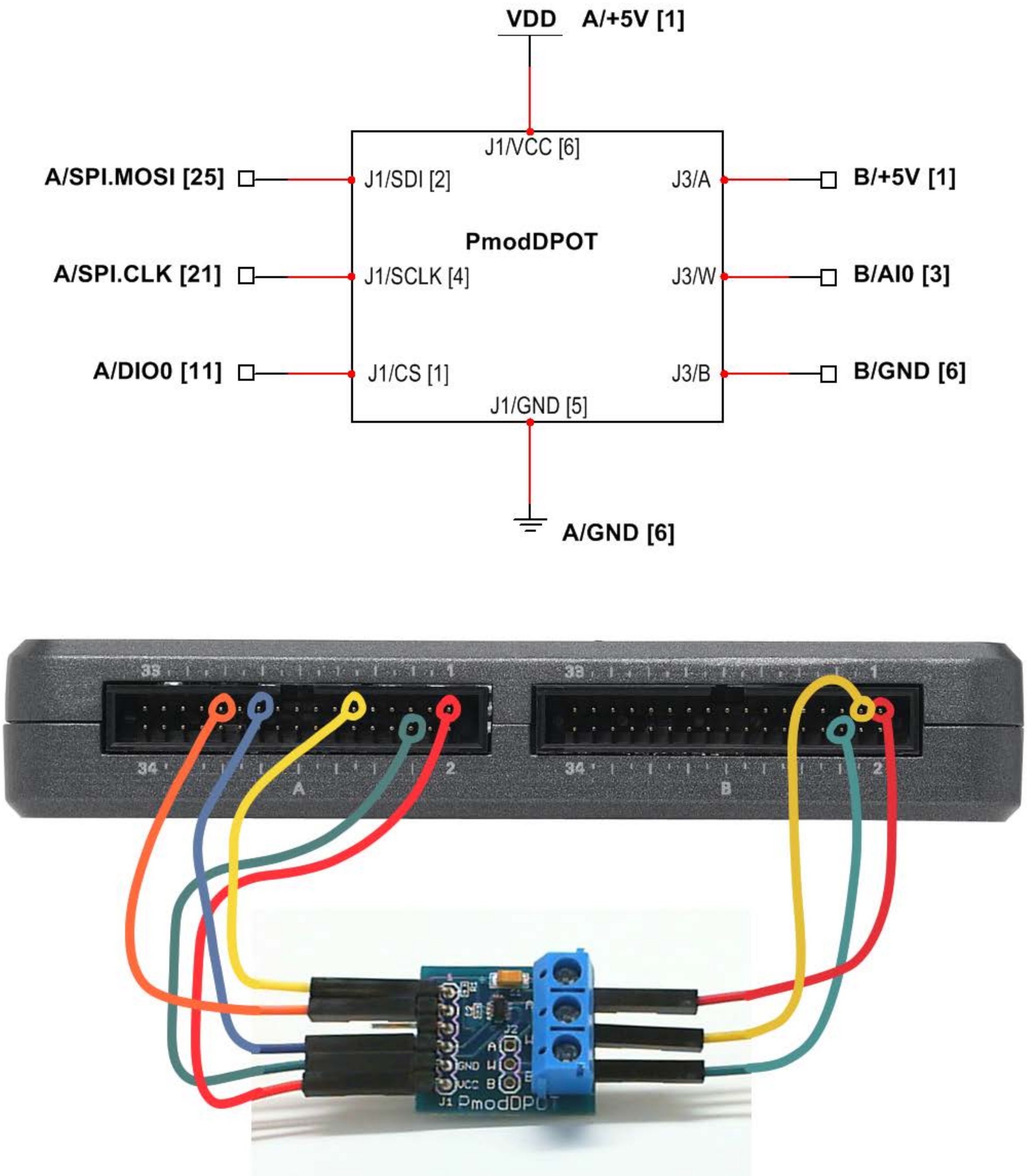

Figure 32.2: Demonstration setup for digital potentiometer connected to NI myRIO MXP Connector B. Use the M-F jumper wires and a screwdriver for the three potentiometer terminals.

more about the digital potentiometer theory of operation including SPI bus and chip select timing, internal switch array circuit, and design equations for using the digital potentiometer in rheostat mode (a single variable resistance) and in potentiometer mode (a voltage divider providing an adjustable voltage). Study *Serial Communication: SPI* (`youtu.be/GaXtDamw5As`, 7:02) to understand how the SPI Express VI configuration options relate to the signaling waveforms between SPI transmitters and receivers.

LabVIEW programming: Study the video *SPI Express VI* (`youtu.be/S7KkTeMfmc8`, 5:51) to learn how to use the SPI Express VI.

32.3 Basic Modifications

Study the video *Dpot Demo Walk-Through* (`youtu.be/dtwXOj5vvy4`, 4:57) to learn the design principles of `Dpot demo`, and then try making these modifications to the block diagram of `Main.vi`:

1. Interchange the "A" and "B" connections, and confirm that the analog voltage decreases as you increase the digital value.
2. Evaluate the linearity of the digital potentiometer: Change the while-loop structure to a for-loop, create an array of the analog voltage at each digital value, and then plot the analog voltage as a function of digital voltage.
3. Continue the linearity evaluation of the previous step by plotting the difference of the measured analog voltage and the ideal analog voltage. This difference plot makes it much easier to identify any trends of nonlinearity.

32.4 For More Information

- *PmodDPOT Reference Manual* by Digilent ∼ Reference manual for the digital potentiometer board: `http://digilentinc.com/Data/Products/PMOD-DPOT/PmodDPOT_rm.pdf`
- *PmodDPOT Schematics* by Digilent ∼ Schematic diagram of the digital potentiometer board: `http://digilentinc.com/Data/Products/PMOD-DPOT/PmodDPOT_sch.pdf`
- *AD5160 Data Sheet* by Analog Devices ∼ Complete information on the AD5160 that serves as the heart of the digital potentiometer board: `http://www.analog.com/ad5160`
- *M68HC11 Reference Manual* by Freescale Semiconductor ∼ Refer to Section 8 for a complete treatment of the SPI serial bus standard, including timing diagrams and multi-master systems: `http://www.freescale.com/files/microcontrollers/doc/ref_manual/M68HC11RM.pdf`