Topic 12:
Design, implementation and programming of the **Motor Interface** for the Slow Control System MPD-NICA, on the NImyRIO and LabView platforms.[1]

Marek Jerzy PERYT

Faculty of Physics, Warsaw University of Technology
Koszykowa 75, 00-662 Warszawa, Poland
Joint Institute for Nuclear Research
Dubna, J. Curie 6

(Accepted June, 2018)

12 Motor

The low-voltage DC Motor pictured in Figure 12.1 provides sufficient mechanical power to drive small fans or to spin lightweight objects. While the voltage is relatively low at 1,5 to 4,5 volts, the current can get as high as several hundred milli Amps or even several Amps in stall (blocked rotor) conditions. For this reason a power MOS FET is used as a motor driver. Figure 12.1 shows the NImyRIO StarterKit DC motor.

Figure 12-1; NImyRIO StarterKit DC Motor

12.1 Learning Objectives:

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

[a] Describe the DC motor principle of operation,
[b] Size the power transistor to drive the motor under various load conditions,
[c] Protect the transistor from back-EMF voltage spikes when the transistor switches the motor current on and off,
[d] Design a voltage level-shifting circuit from 3,3 volts to 5 volts,

---

[1] Developed on the basis of educational materials: National Instruments, IBM, Reichle & De-Massari, Microsoft, Warsaw University of Technology, Joint Nuclear Institute Research

[e] Design the interface circuit to work with digital outputs that include either pull-up or pull-down resistors.

12.2 Component Demonstration

Follow these steps to demonstrate correct operation of the motor.

12.2.1 Select these parts from the NI myRIO Starter Kit:

[a] DC motor,

http://www.mabuchi-motor.co.jp/cgi-bin/catalog/e_catalog.cgi?CAT_ID=ff_180phsh

[b] 1N4001 general-purpose rectifier,

http://www.vishay.com/docs/88503/1n4001.pdf

[c] ZVN2110A n-channel enhancement-mode MOSFET,

http://www.diodes.com/datasheets/ZVN2110A.pdf

[d] ZVP2110A p-channel enhancement-modeMOSFET,

http://www.diodes.com/datasheets/ZVP2110A.pdf

[e] IRF510 n-channel enhancement-mode power MOSFET,

http://www.vishay.com/docs/91015/sihf510.pdf

[f] Breadboard
[g] Jumper wires, M-F (4x)

12.2.2 Build the interface circuit:

Refer to the schematic diagram and recommended breadboard layout shown in Figure 12.2 on the facing page. The interface circuit requires four connections to NImyRIO MXP Connector B (see Figure A.1 Appendix):

[a] 5-volt power supply → B/+5V (pin 1)
[b] 3,3-volt power supply → B/+3,3V (pin 33)
[c] Ground → B/GND (pin 30)
[d] Motor control → B/DIO8 (pin 27)

12.2.3 Run the demonstration VI:

[a] Download

http://www.ni.com/academic/myrio/project-guide-vis.zip

[b] if you have not done so previously and unpack the contents to a convenient location,
[c] Open the project Motor demo.lvproj contained in the subfolder Motor demo,
[d] Expand the hierarchy button (a plus sign) for the myRIO item and then open Main.vi by double-clicking,
[e] Confirm that NImyRIO is connected to your computer, and
[f] 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 of the project compiles and deploys (downloads) to NImyRIO before the VI starts running.

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

12.2.4 Expected results:

Click the DIO state button to set the digital output to its low state and your motor should spin at high speed, then click the button again to stop the motor. Note that the motor driver interface circuit is active low. Click the Stop button or press the escape key to stop the VI and to reset NImyRIO; a myRIO reset causes all of the digital I/O pins to revert to input mode.

12.2.5 Troubleshooting tips:

Not seeing the expected Results? Confirm the following points:

[a] Glowing power indicator LED on NImyRIO,
[b] Black Run button on the toolbar signifying that the VI is in runmode,
[c] Correct transistor orientation—carefully follow the pin diagrams for each transistor; especially note that the IRF 510 has the gate pin on the side rather than in the middle as do the lower-power MOSFETS,
[d] Correct rectifier orientation—when the rectifier is backwards the motor will never reach the voltage level necessary to turn on.

12.3 Interface Theory

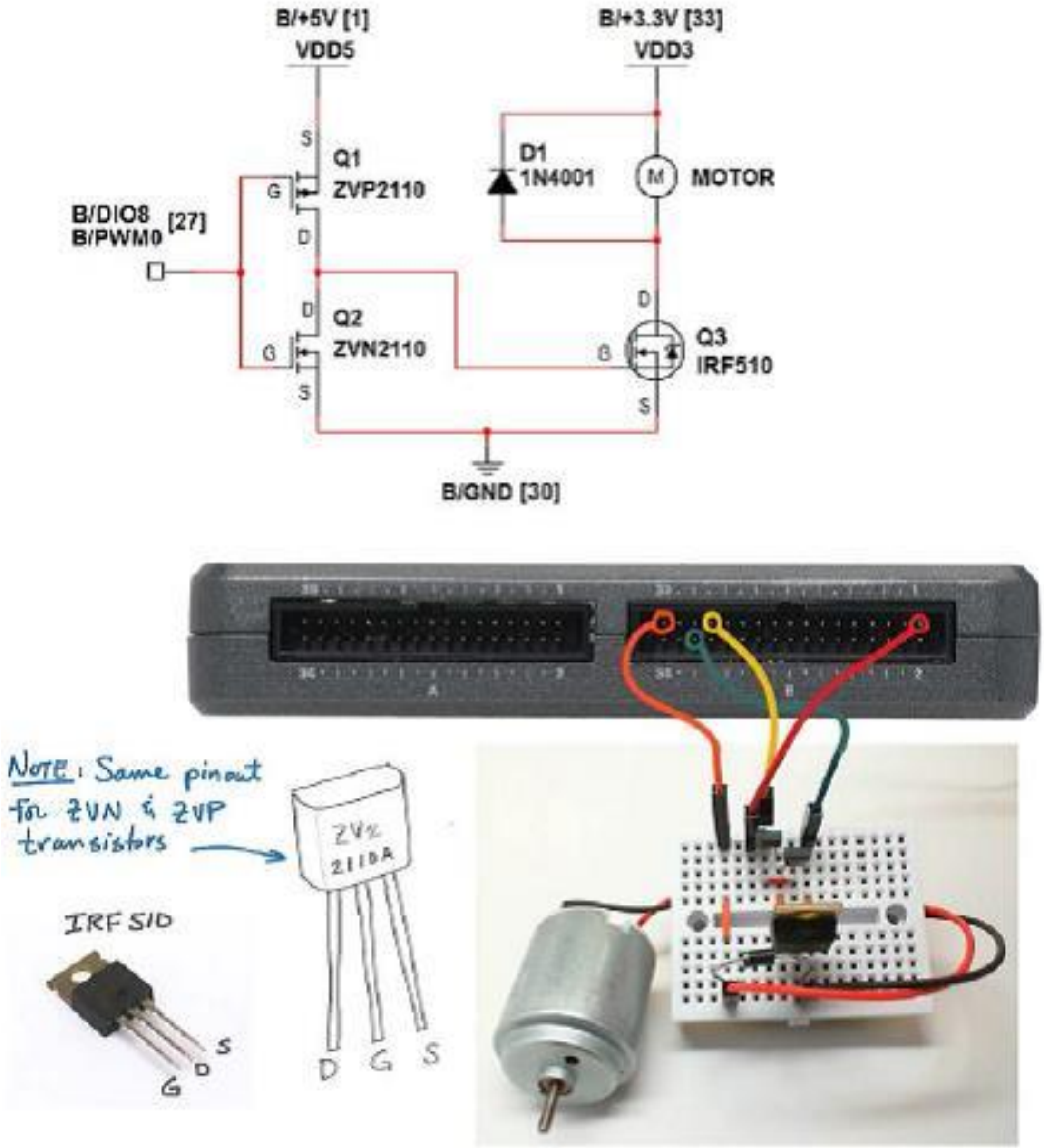

Figure 12-2; Demonstration circuit for DC motor: schematic diagram, recommended breadboard layout, and connection to NImyRIO MXP Connector B.

12.3.1 Interface circuit:

The motor requires approximately 180 mA (at 3,3 V) when unloaded and over 1000 mA when running at maximum efficiency, three times higher than the maximum available current from all three NImyRIO connectors combined. Stalling the motor due to excessive loading or blocking the rotor demands even higher current because effective resistance of the motor is less than 1Ω. For these reasons the IRF 510 n-channel enhancement power MOSFET serves as a high-current solid-state switch to operate the motor. Because the IRF 510 gate-to-source threshold voltage VGS(th) ranges from 2 to 4 V the NImyRIO DIO output voltage of 3,3 V is not sufficient to turn on the IRF 510. The two low-power MOSFETS arranged as a standard CMOS logic inverter supplied by the 5 V supply act as a 3,3-to-5 V level shifter to ensure that the IRF 510 gate voltage is either 0 V (off) or 5 V (on).

Study the video ***Motor Interfacing Theory*** (6:49)

https://www.youtube.com/watch?v=C_22XZaL5TM&feature=youtu.be

to learn more about the motor principles of operation and interface circuit design principles including: sizing the power transistor for motor current under various load conditions, importance of the rectifier to deal with back-EMF voltage spiking, level-shifting circuit for 3,3-to-5 V, and required modification to connect the interface to the MSP connector with integral pull-down resistors.

[a] LabView programming:

Study the video ***PWM Express VI*** (2:41)

https://www.youtube.com/watch?v=mVN9jfwXleI&feature=youtu.be

to learn how to use the PWM Express VI to create a pulse-width modulated square wave to provide variable-speed motor operation.

12.4 Basic Modifications

Study the video ***Motor Demo Walk-Through*** (1:56)

https://www.youtube.com/watch?v=UCqFck0CLpc&feature=youtu.be

to learn the design principles of Motor demo, and then try making these modifications to the block diagram of ***Main.vi***:

Create variable-speed motor operation as follows:

[a] Replace the existing Digital Output Express VI with the PWM Express VI. Choose the PWM channel as B/PWM0, the same connector pin as B/DIO8 (pin 27). Choose the remaining dialog box options so that both frequency and duty cycle are available as inputs,

[b] Create pointer slide front-panel controls for each; right-click on each control and choose “Visible items” and the “Digital display,”

[c] Right-click on the frequency control, select “Scale” and then “Mapping,” and choose “Logarithmic.” Also, double-click the upper limit of your frequency control and enter “40000” and then similarly set the lower limit to “40.”

Experiment with both the duty cycle and frequency. What frequency minimizes audible PWM noise and maximizes your ability to create very slow motor speeds? What do you notice about restarting the motor after it stops? If you have a DMM ammeter handy, you may wish to observe the motor current under various conditions including mechanical loading, free running, and start-up.

[a] Insert additional code to deal with the fact that the motor control interface is active-low. That is, you want 0 % duty cycle to turn the motor off rather than causing maximum speed as it does now.

[b] Add a Boolean front-panel control as a motor enable. Trying using a Select node under the Programming | Comparison subpalette to set the duty cycle either to 0 or to the value of the front-panel duty cycle control.

[c] Disconnect the motor control line and re-connect to C/PWM0 (pin 14) on MSP Connector C; adjust your VI to refer to this channel, too. You should observe that the motor is on due to the internal pull-down resistor. Now counter the effect of the internal pull-down with a 4,7 kΩ external pull-up resistor connected between the motor control line and the +5-volt supply. The motor should now remain off when the NImyRIO first powers on or after executing myRIO reset.

12.5 Integrated Project Ideas

Now that you know how to use the DC motor consider integrating it with other devices to create a complete system, for example:

[a] Tachometer (Topic 49)
[b] On-Off Control System (Topic 51)

12.6 For More Information

Brushed DC Motor Fundamentals by Microchips Learn about DC Motor principles of operation, drive circuits, direction control with an H-bridge, and speed control with Hall-effect sensors as feedback:

http://ww1.microchip.com/downloads/en/AppNotes/00905B.pdf

Bibliography:

---

[a] www.jinr.ru
[b] www.ni.com
[c] www.nica.if.pw.edu.pl
[d] The Multi-Purpose Detector – MPD to Study Heavy Ion Collisions at NICA; (CDR Conceptual Design Report) Version 1.4; Project leaders: A. N. Sissakian, A. S. Sorin, V. D. Kekelidze.
[e] http://www.mabuchi-motor.co.jp/cgi-bin/catalog/e_catalog.cgi?CAT_ID=ff_180phsh
[f] http://www.vishay.com/docs/88503/1n4001.pdf
[g] http://www.diodes.com/datasheets/ZVN2110A.pdf
[h] http://www.diodes.com/datasheets/ZVP2110A.pdf
[i] http://www.vishay.com/docs/91015/sihf510.pdf
[j] http://www.ni.com/academic/myrio/project-guide-vis.zip
[k] https://www.youtube.com/watch?v=C_22XZaL5TM&feature=youtu.be
[l] https://www.youtube.com/watch?v=mVN9jfwXleI&feature=youtu.be
[m] https://www.youtube.com/watch?v=UCqFck0CLpc&feature=youtu.be
[n] http://ww1.microchip.com/downloads/en/AppNotes/00905B.pdf