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Title VARIABLE VOLUME PUMP DRIVER QUICK START GUIDE

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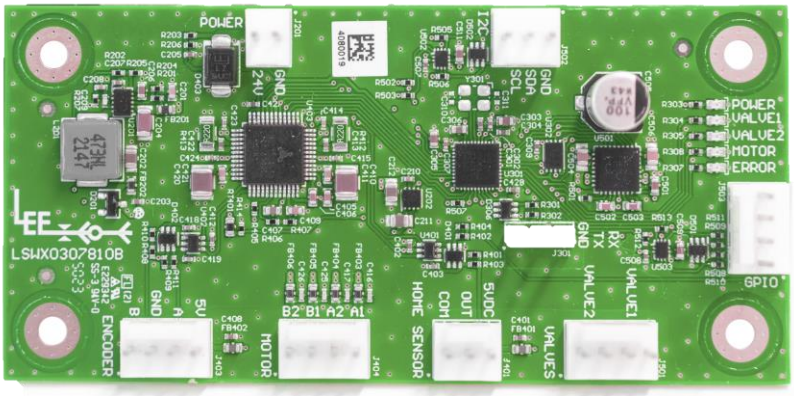
Abstract:

Quick Start Guide for setting up and operating the variable volume pump driver.



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LSOC0002338 A1

Contents

1. INTRODUCTION

1.1. Variable Volume Pumps

The Lee Company's variable volume pumps (VVPs) are stepper motor-driven positive displacement pumps that allow for extremely precise and accurate dispenses with reliable performance. Pump volumes range from 50µL to 3000µL and can be customized based on your system's needs. Our variable volume pumps have low full-step resolutions, going as low as 0.04 µL/step for our single seal LPD series, or 0.47 µL/step for our dual seal LPV series. If even smoother flow is desired, these pumps can perform micro-stepping up to 256 micro-steps per full step. Both the LPD and LPV series will last several million cycles on water while maintaining a dispense accuracy of around ±0.5% at 100% volume.

Figure 1. LPD pumps are available as standards and/or customized options.

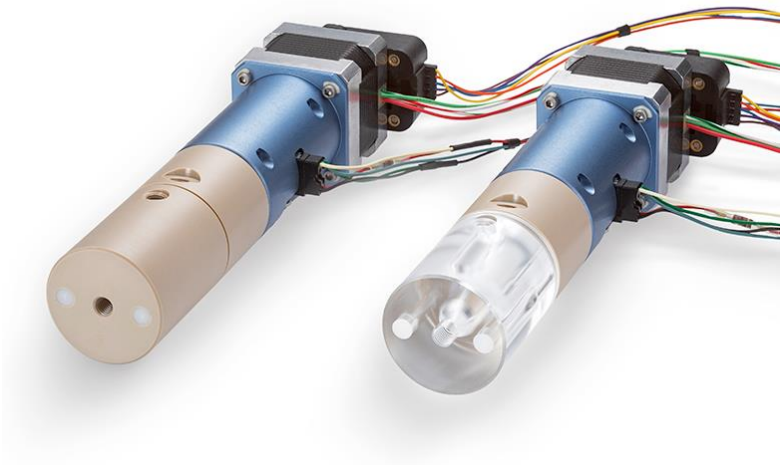

Figure 2. Dual Seal pumps are available as standards and/or customized options.

1.2. Variable Volume Pump Driver

The Lee Company has collaborated with ADI Trinamic to develop a stepper motor driver module specially designed to operate our variable volume pumps. The module is driven by the powerful ADI Trinamic TMC5130 motion controller and motor driver, along with two ADI Trinamic MAX22200 solenoid drivers. This comprehensive setup enables the driver to manage every aspect of the pumping system, from the precise control of the bipolar stepper motor, home sensor, and encoder, to the easy addition of two solenoid valves. The driver's I2C and UART comms are optimal for streamlining system development by expediting benchtop testing of Lee pumps and valves. Crafting custom scripts and subroutines is effortless with the TMCL-IDE, allowing users to easily upload code to the driver for standalone operation. Moreover, the driver can function as a peripheral device, seamlessly receiving direct motion commands from another controller. For new users, a library of starter scripts is readily available on our website to assist with simple pumping routines. For more information about advanced control options, detailed hardware and firmware manuals are available to get the best performance in your application.

2. REQUIRED MATERIALS

2.1. Solenoid Valves

The Lee Company variable volume pumps require external valves to move fluid. The driver can drive up to two valves along with the pump. The MAX22200 solenoid drivers on this pump driver employ PWM to allow a range of voltage outputs as well as spike and hold operation. The drivers allow usage of either 24V valves via the main 24V power supply input, or 12V valves via the optional 12V supply input. The power supply voltage input ranges from +10Vdc to +30Vdc.

For even faster response times, these valves can be spiked above nominal voltage with this driver. To ensure you do not overheat your valves when performing spike and hold, please consult our handbook or your local sales engineer for more information.

2.1.1. 2-way Inert Solenoid Valves

The Lee Company specializes in high-quality inert valves. The following 2-way valves are ideal for use in a fluidic system with our VVPs. If using 2-way valves, two are required per pump. For more details on fluidic system setup, please refer to Section 3 of this guide. Below are some recommended 2-way valve part numbers to get started. Additional part numbers can be found in our Technical Fluid Control Handbook for Health & Science or our website's Product Finder filtered to "2-Way Isolation Solenoid Valves".

Table 1. Recommended part numbers for LFV Series 2-way inert isolation valves.

PART NUMBER	FLUIDIC PORTS	VOLTAGE (VDC)	OPERATING PRESSURES (PSIG)	LOHM RATE (CV)	SEAL MATERIAL	ELECTRICAL CONNECTION
LFVA2430213H	¼-28	24	Vacuum – 30	1300 Lohms (0.015)	EPDM	Lead wires
LFVA2430113H	¼-28	24	Vacuum – 30	1300 Lohms (0.015)	FKM	Lead wires
LFVA2430413H	¼-28	24	Vacuum – 30	1300 Lohms (0.015)	FFKM	Lead wires

2.1.2.3-way Inert Solenoid Valves

Instead of two 2-way valves, it is also possible to use a single 3-way valve with any of our variable volume pumps. Reference Section 3 for more fluidic system details. Below are some recommended 3-way valve part numbers to get started. Additional part numbers can be found in our Technical Fluid Control Handbook for Health & Science or our website's Product Finder filtered to "3-Way Isolation Solenoid Valves".

Table 2. Recommended part numbers for 3-way inert isolation valves.

SERIES	PART NUMBER	FLUIDIC PORTS	VOLTAGE (VDC)	OPERATING PRESSURES (PSIG)	LOHM RATE (CV)	SEAL MATERIAL	ELECTRICAL CONNECTION
Xover	**LXRA2405000B**	¼-28	24	Vacuum – 30	1000 Lohms (0.02)	FKM	TE connector
LFR	**LFRA2430210H**	¼-28	24	Vacuum – 30	1000 Lohms (0.02)	EPDM	Lead wire
LFR	**LFRA2430110H**	¼-28	24	Vacuum – 30	1000 Lohms (0.02)	FKM	Lead wire
LFR	**LFRA2430310H**	¼-28	24	Vacuum – 30	1000 Lohms (0.02)	FFKM	Lead wire

2.2. Tubing and Adapters

The Lee Company offers various types of tubing and inert adapters to handle aggressive fluids in our MINSTAC® product line. This Miniature Inert System of Tubing and Components includes tubing assemblies optimized for low shear and low volume, as well as inert (PEEK) check valves, safety screens, filters, adapters, and unions. These adapters and tubing can help port any valves or other components to your pump. For part numbers and more information, reference our Technical Fluid Control Handbook for Health & Science or our website's Product Finder filtered to "Additional Products".

2.3. Wire-to-Board Mating Connectors

This board utilizes pin connectors. To connect the power source, UART or I/O communications, pump, and valves to the driver board, you will need mating connectors for the board's pins. Below are the recommended part numbers for these connectors. Please reference ADI Trinamic's "TMCM-1247 Hardware Manual" for more information on the board's connectors.

Table 3. Recommended Molex part numbers for mating connectors to connect lead wires to the driver board.

CONNECTOR	MANUFACTURER	MPN	DESCRIPTION
Crimp Terminals	Molex	16020069	Series KK254 / 6373, Cat ear crimp terminal, tin (Sn); to be used for all wire connections
Pump Home Sensor	Molex	0022012047	Series KK254 / 6373, Housing, lock, 4 pins, 2.54mm
Pump Motor	Molex	0022012047	Series KK254 / 6373, Housing, lock, 4 pins, 2.54mm
Pump Encoder	Molex	0022012047	Series KK254 / 6373, Housing, lock, 4 pins, 2.54mm
Valve(s)	Molex	0022012027	Series KK254 / 6373, Housing, lock, 2 pins, 2.54mm
Power Mating Connector	Molex	0022012027	Series KK254 / 6373, Housing, lock, 2 pins, 2.54mm
I/O Mating Connector	Molex	0022012047	Series KK254 / 6373, Housing, lock, 4 pins, 2.54mm

2.4. USB to UART Cable

This will be required to connect the driver board to your computer to access the driver program. The Lee Company has qualified an FTDI cable, part number TTl-232R-RPi, but any equivalent cable will work.

3. SETUP

3.1. Fluidic Connections

The variable volume pumps require valves for proper operation and performance. The Lee Company offers various types of valves which include 2-way normally closed (NC) valves and 3-way valves. This section will provide a couple options when connecting valves to your pump, but for further detail, please refer to the variable volume dispense pump technical guide available by request on our website.

3.1.1. Two 2-way Valves

The Lee Company offers various types of 2-way isolation solenoid valves. It is recommended to use our LFV Series valves, which are chemically inert NC diaphragm-style valves and work well with the pumps.

The below image depicts a simple setup for dispensing from a reagent supply using two LFVs connected to an LPD.

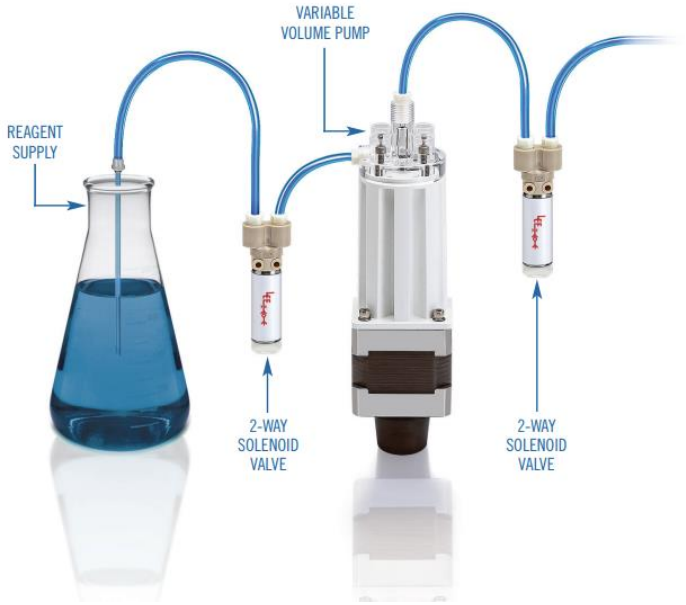

Figure 3. Two 2-way LFV valves, one connected to the reagent supply and inlet of an LPD pump, the second connected to the outlet of the pump.

3.1.2. One 3-way Valve

The Lee Company offers several 3-way inert solenoid valves, but we recommend the Xover or LFR when driving alongside a VVP. The Xover is an internal pinch-tube style valve optimized for low carryover volume, zero dead volume, laminar flow and excellent flushability. The LFR is a diaphragm rocker valve suited for higher pressures and higher flow rates.

Figure 4 below shows a common fluidic setup with a 3-way Xover connected to an LPD, which allows aspiration from one source and a dispense through a different point in the fluid system.

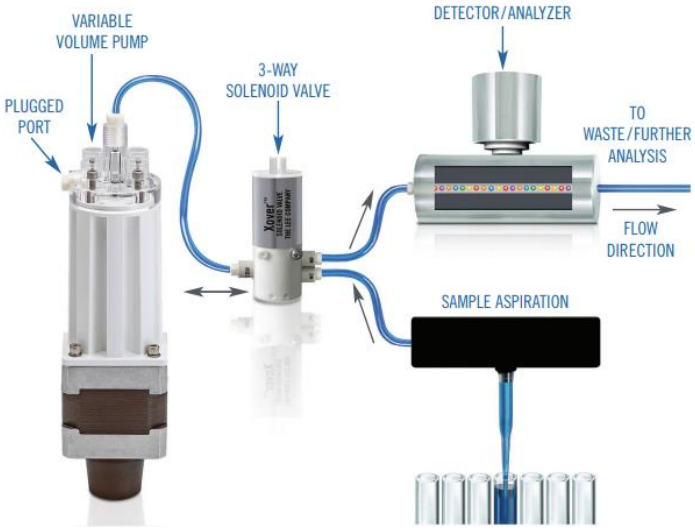

Figure 4. One Xover 3-way valve with an LPD pump. Common port of the valve is connected to the pump's outlet port, while the normally closed and normally open ports are connected to system inlet and outlet. The inlet port of the LPD pump is plugged.

3.2. Board Hardware Connections

Once the fluidic connections are established, the driver must also be connected electrically. Since this board utilizes pin connections, mating connectors are required. The required mating connectors are listed in Table 3 in Section 2.4. For more information on the connectors, please reference ADI Trinamic's "TMCM-1247 Hardware Manual."

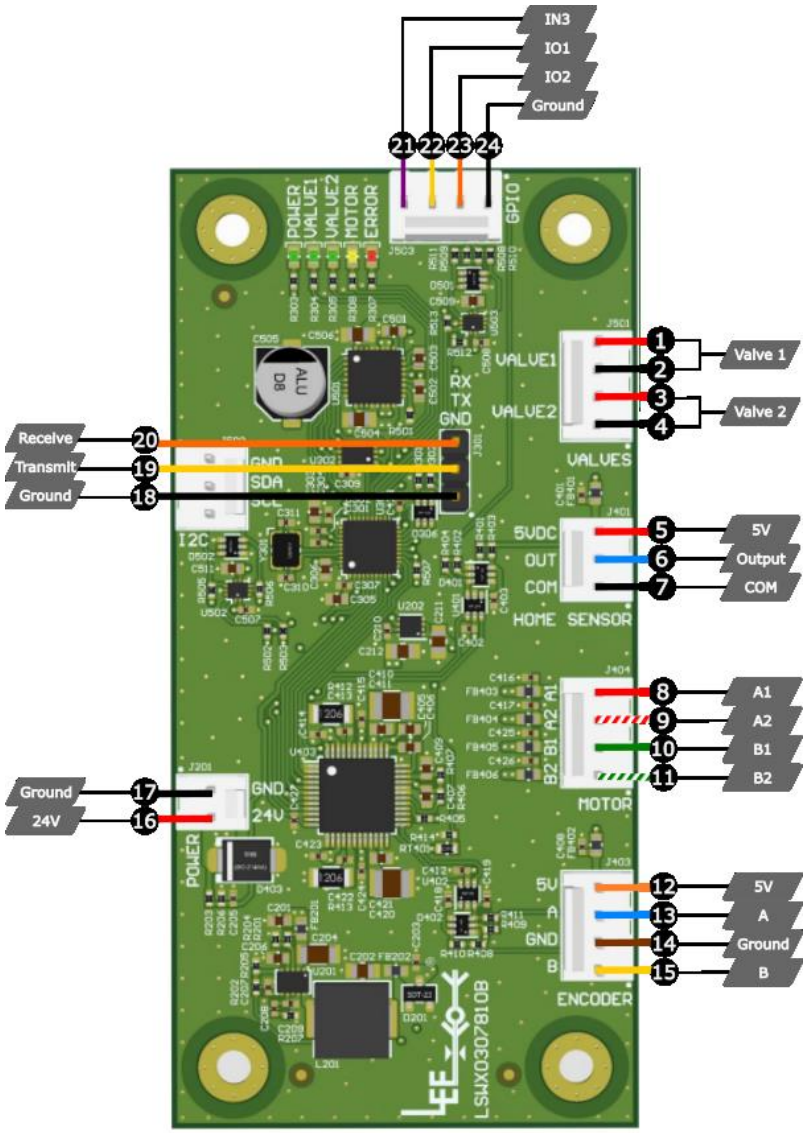

Figure 5. Pin-out diagram of the LSWX0307810B (TMCM-1247) driver board. Colored lines coming from each pi represent the colored wires that connect to their respective pins.

3.2.1. Pump and Valve Hardware

The below pin table outlines the connections between the VVP's colored wires and the board's pins. Please refer to your pump's inspection drawing for more information on the wire connections, as well as the above pinout diagram of the board (Figure 5). The lead wires on the solenoid valves are not polarized; therefore, the 2-pin valve connections are not sensitive to which exact pins the valve's lead wires connect to.

Table 4. Pin numbers on the driver board from Figure 5 and their corresponding connections.

PIN #	WIRE CONNECTION
1 – 2	Valve 1
3 – 4	Valve 2
5 – 7	Home sensor
8 – 11	Pump motor
12 – 15	Encoder (high performance pumps only)
16 – 17	Power source
18 – 20	UART controller (FTDI cable)
21 – 24	General-Purpose Input/Output

To add the mating connectors to your lead wires, please follow these instructions:

Step 1. Strip the end of your 26 AWG lead wires so that about 3-4 mm of the wire are exposed from the insulation.

Step 2. Insert the lead wire into the crimp terminal.

Step 3. Using a hand crimper, crimp the front wings then the back wings of the terminal onto the wire. The front wings should be in contact with the wire, and the back wings should only be in contact with the wire's insulation.

Step 4. Add the proper mating connector housing over the terminal connection. Refer to Table 3 or ADI Trinamic's hardware manual for mating connectors.

3.2.2. Board Hardware Connections

Mating connectors are also required for the board's power supply and I/O connections. Recommended part numbers can be found in Section 2.4. To add these connectors to your lead wires, please follow the instructions listed in the section above.

The UART connection will be via the FTDI cable that is included in this driver kit. The part number can be found in Section 2.5.

3.3. Connecting Driver Board to PC

Necessary materials:

- FTDI cable

3.3.1. Installing the TMCL-IDE Software

The TMCL-IDE program is the program used to write scripts and control the driver. The program is available for download on ADI Trinamic's download page. Make sure that the most updated version is being used.

Step 1. Launch the .exe setup file after downloading the latest version of the TMCL-IDE.

Step 2. Launch the TMCL-IDE program.

Step 3. Connect the driver board to the computer using the FTDI cable on pins 18-20.

Step 4. Connect the driver board to the 24V power source. The driver should start flashing an orange light. For more details about the board's power requirements please refer to the TMCM-1247 Hardware Manual.

3.3.2. Updating the VVP Driver Firmware

The VVP Driver firmware is automatically installed onto the driver. However, it may occasionally be updated to patch bugs and improve overall user experience. Please ensure you have the latest version downloaded. This version can be found on The Lee Company's website on our Variable Volume Pump's Get Started tab.

Once the latest firmware is on the board, it must then be uploaded into the driver module using the following steps:

Step 5. Open the TMCL-IDE program and go to "Tools" in the upper left corner.

Step 6. Select "Firmware Update" in the dropdown menu.

Step 7. Click the refresh button. This should make Module TMCM-1247 appear in the module list.

Step 8. Click "Browse" and select the .hex file.

Step 9. Hit "Update". The IDE will confirm when the update is complete.

3.3.3. Recognizing the Driver

Step 10. Disconnect the FTDI cable from your computer.

Step 11. Cycle power to the driver board.

Step 12. Reconnect the FTDI cable to the computer.

Step 13. Select the COM port and ensure the baud rate is set to the default of 9600.

Step 14. Click “Connect”.

These last steps allow the software to recognize the hardware automatically. These steps should be followed in case the software has difficulty recognizing the driver at any point.

4. PROGRAM INTERFACE

The TMCL-IDE has a beginner-friendly interface and allows for seamless control of the connected pump and valves. It contains different modules within the program which utilize user inputs.

The TMCL program has several different sections that you can explore to further customize the performance of your pump.

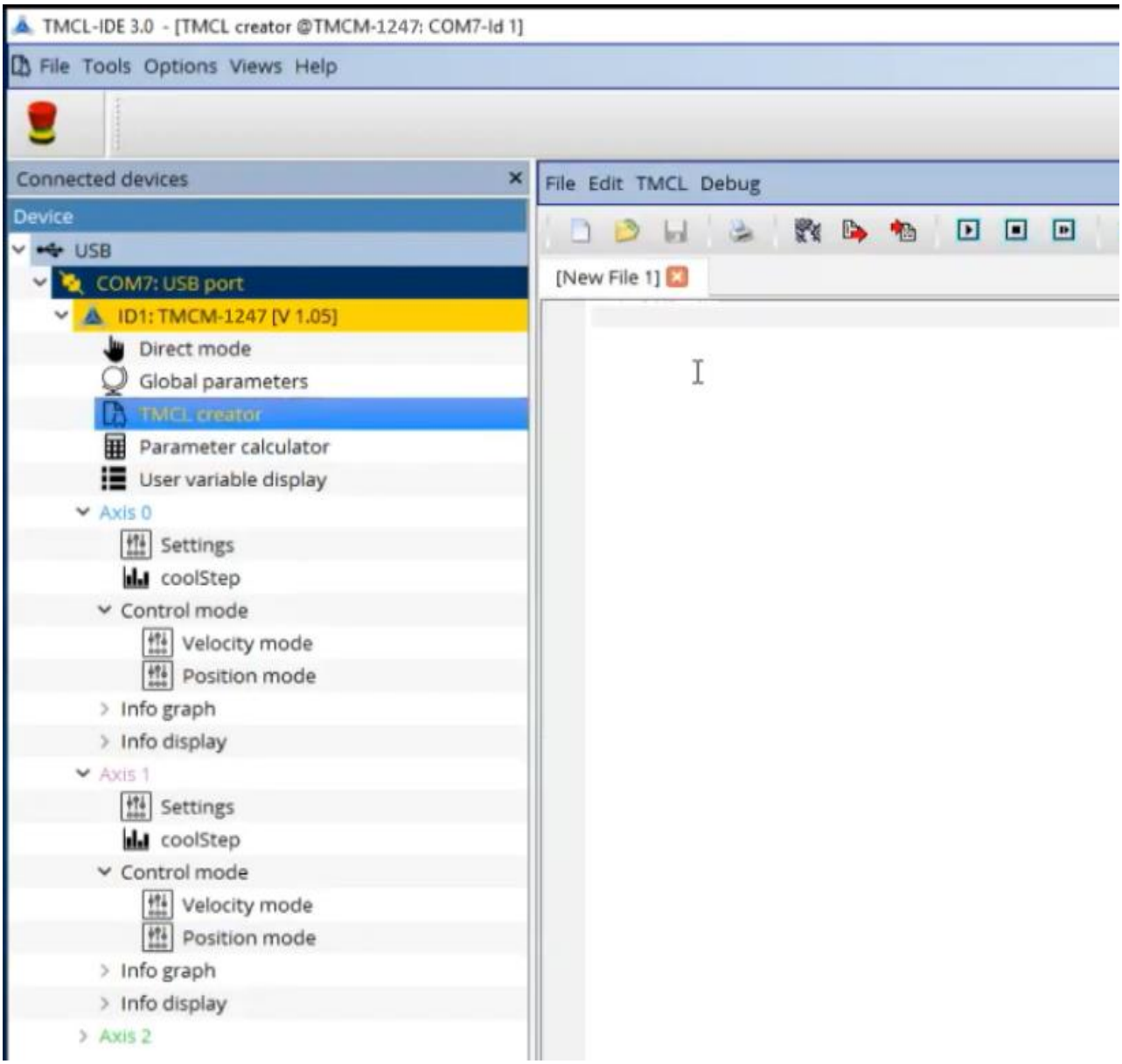

Figure 6. TMCL-IDE program interface after connecting all components and updating firmware.

4.1. Direct Mode

Direct mode offers users the ability to execute functions without the need to write and run a script. It's particularly handy for tasks such as testing specific movement functions before initiating new scripts, troubleshooting, and restoring factory defaults.

4.2. TMCL Creator

TMCL Creator serves as the platform for script creation and execution. Users can write and run scripts to automate motor control tasks efficiently. Please refer to TMCM-1247 Firmware Manual for instructions on the code.

4.3. User Variable Display

This feature displays all designated user variables within the scripts, providing an easily viewable list of all variables and their values.

4.4. Axis Parameter Display

The Axis Parameter Display feature allows users to monitor axis parameters in real time as scripts are executed. This live update capability expedites any troubleshooting process.

4.5. Velocity Mode

Velocity Mode enables users to quickly start testing the pump directly with velocity and acceleration inputs. It provides control over the motor direction using intuitive arrow controls.

However, it is not recommended that this mode be used with our pumps. This is because there is a risk of driving the piston into the hard stops at both ends and potentially jamming the pump.

4.6. Positioning Mode

Similar to Velocity Mode, Positioning Mode allows the users to test out the pump without needing to write a script first, but this mode focuses on moving the motor to specific positions. It offers options for both absolute positioning, which moves the motor to a predetermined coordinate regardless of its current position, and relative positioning, which moves the motor a specified number of steps from its current position.

4.7. stallGuard & CoolStep

stallGuard is a sensorless way of detecting stalls in the motor and can help prevent them. CoolStep allows the motor to run on less energy and reduces the amount of heat produced by the motor.

This tab provides real-time visualization of motor position, stallGuard value, and motor current while the pump is running. CoolStep is invaluable for controlling the power consumption of the pump and can be used during current titration to evaluate the pump's wear over time. The stallGuard values can also be easily input here, and the live graph will help with detecting stalls in the motor.

5. DRIVER CODE EXAMPLE SCRIPTS

The Lee Company has developed several example scripts that are great starting points to test out the pump and driver's performance. This reduces the time required to learn the code in-depth and write out scripts from scratch. Below are descriptions of each example script.

5.1. Homing Cycle

Most VVPs have a home sensor which is useful for determining the location of the piston. The sensor is placed at the full dispense position. On system startup, the piston's position may not be known. A homing cycle will move the piston until the home position is reached and define this as absolute position zero. The homing feature helps with maintaining accurate positioning throughout the pump's operation as well.

5.2. Full Dispense Cycle

This makes the pump perform an aspirate and dispense cycle with its full dispense volume. This can be used for priming the pump or during normal operation.

Adjustable inputs: Number of cycles, pump volume, motor speed, motor acceleration(s), micro-step resolution.

5.3. Multi-Dispense Cycle

This script allows for a full-volume aspiration followed by multiple small dispenses. The number and volumes of dispenses can be customized to your application. This function is useful for aliquoting a sample to allow multiple tests to be conducted.

Adjustable inputs: Number of dispenses, number of cycles, pump volume, motor speed, motor acceleration(s), micro-step resolution.

5.4. Current Titration

The Lee Company's variable volume pumps are generally rated to 10 million cycles on water. During these 10 million cycles, the pumps will continue to meet the rated precision and accuracy specifications. Towards the end of the pump's life, the gradual wear of its components will cause the performance to drift outside the rated specifications. One way to monitor the health of a stepper motor pump is through a current titration test. This test measures the minimum drive current required to move the motor. Typically, the minimum drive current will increase over time. Periodically monitoring the minimum drive current can help as an indicator of pump wear. Increased drive current does not necessarily indicate product failure.

The current titration script provided runs the piston back and forth starting at the max rated current. With each cycle of the piston, the drive current is decreased. Eventually, the motor will stall which can be detected through feedback from the encoder or stallGuard. An increase in the minimum drive current may indicate a pump is nearing the end of its cycle life.

Adjustable inputs: Pump volume, motor speeds, motor acceleration(s).

6. SUPPORTING DOCUMENTS

The Lee Company's website contains several helpful documents about this driver and its accessories. These are available for download to help answer any FAQs:

- "TMCM-1247 Hardware Manual"
- "TMCM-1247 Firmware Manual"
- "Variable Volume Dispense Pump Technical Guide"
- "Dispense Pump Solutions"
- "Key Considerations for Selecting a Medical Pump"
- "Dispense Pumps Enable Designers to Meet Fluidic Challenges of Evolving IVD Instruments"
- "LPD Precision Dispense Pump Technical Data Sheet"

If you have any additional questions not addressed in the above documents, please contact your local sales engineer for assistance.

7. REVISION HISTORY

REVISION	DATE	DETAILS
A1		Initial release.