

# 108-Channel Programmable Solenoid Driver



## 1 Overview

This board is a portable programmable signal generator and solenoid driver with 108 digital channels. A sampling rate of 49.8kS/s is used for every channel. The channel configuration is performed via USB-Serial interface.

## 2 Application

This board is designed to generate 108 independent waveforms, each able to drive one or more micro-solenoids. Active flow control research with steady and pulsed microjets is a very promising field that possesses several potential applications in the transportation industry.

The circuit can be used for research investigations where the jet array pattern is not known or is not straightforward to assume without deep prior investigations. It also has potential industrial research applications where active flow control is being considered and physics-free studies are acceptable. The flexibility of the driver allows for optimization studies to be performed in wind tunnel experiments, enabling empiric micro-actuator placement by either a machine-learning algorithm or a human operator.

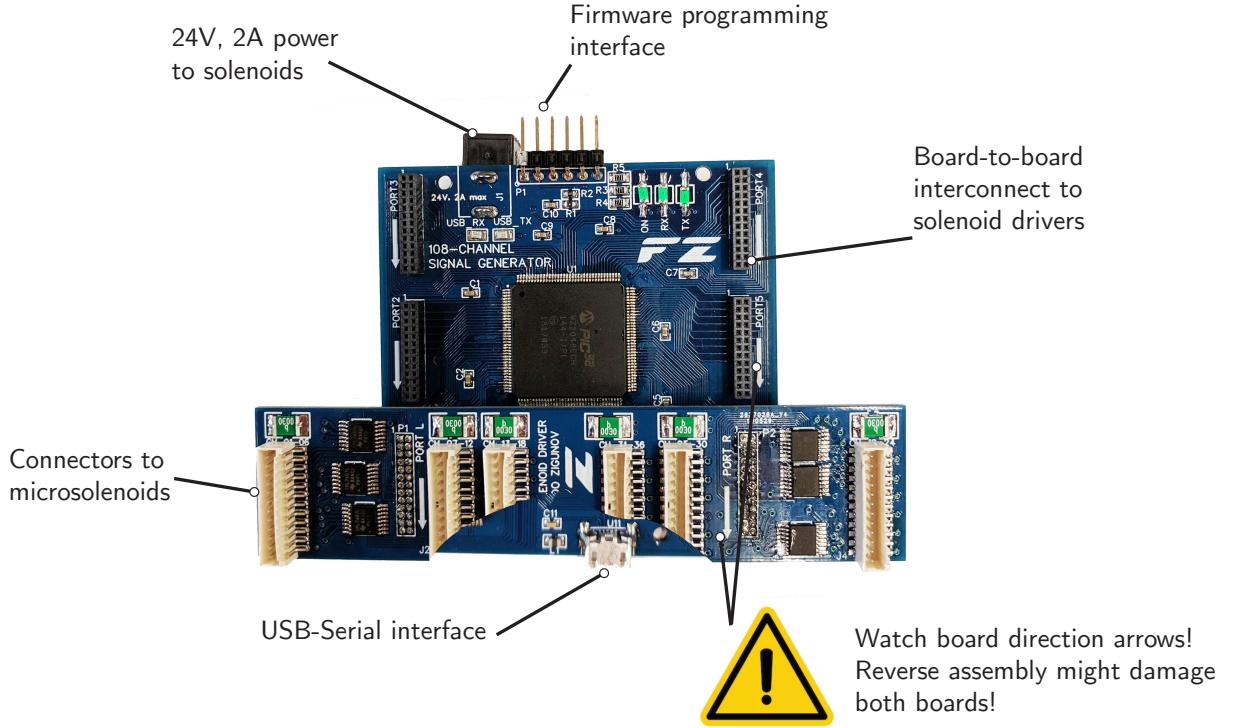
In the intended application, the aerodynamic model would have a number of jet array elements ("jixels"), which would be toggled on/off by this programmable signal generator. This jixel pattern can change in time, allowing for interesting dynamic behaviors. Extra hardware can be used to acquire data from a wind tunnel experiment and loop over hundreds or thousands of jixel configurations, associating the measured variable of interest (i.e., aerodynamic drag or others) to each configuration. Optimization approaches can be used to improve the jixel pattern experimentally and find best drag coefficients for a given jixel array.

## 3 Technical specifications

Name	Value
Maximum Current per Channel	50mA
Maximum Current per Port Pair	1.8A
Maximum Current, All Ports	2A
Maximum Voltage in Power Connector	30V
Signal Frequencies	DC-200Hz
Sampling Frequency	50kS/s
Number of Channels	108

## 4 Assembly Details

The solenoid driver was designed to be a simple interface between a computer and the solenoids. The driver consists of two boards: The signal generator board (Motherboard), which interfaces via USB-Serial to the computer, and the driver board, which contains the power transistors to toggle the solenoids on/off. The assembly is very simple as shown in the figure below: A 5.5mm power jack connects to a



switched-mode power supply (Digikey P/N 993-1120-ND, for example) and provides power to the solenoids. The black 26-pin header connectors in the motherboard provide a sturdy connection to the driver board while maintaining a low profile. The driver board possesses six 12-pin connectors that can drive 6 microsolenoids each. The pins are arranged in the following configuration: (C, D, C, D, C, D, ..., C, D), where C=common to fuse and D is the specific driver channel pin (goes to GND through a N-channel MOSFET). The MOSFET drivers possess a back-EMF diode for each channel, providing back-EMF protection to the system.

## 5 Communication Protocol

The USB interface shows in the computer as a COM port, which can be accessed through a serial terminal program (i.e., Termite). If it does not appear in the Device Manager, you might need to download and install the VCP drivers from FTDI, inc.

When connected to the USB port, the driver auto-initializes all 108 channels to the same 100Hz, 75% duty cycle waveform. This provides a means to the user to probe the channels in case troubleshooting is needed.

Serial port configuration:

Configuration	Value
Baud Rate	57600
End-of-Line character	LF
Data bits	8
Stop bits	1
Parity	none
Flow control	none

The CR character (in CR-LF) will be ignored by the interpreter.

The communication protocol consists of the following keywords:

## 5.1 ZERO

This command will reset all the channels to a duty cycle of 0%. The frequency and phase parameters will not be affected, however this will cause all channels to be turned off simultaneously. The command ZERO has no parameters and any string after the 4th character will be ignored by the interpreter. The interpreter will transmit the string "OK." if the command was successfully executed.

### 5.1.1 Prototype

**ZERO**

## 5.2 INIT

This command will initialize all the counters to the correct phase value and start the waveform generation. The command INIT has no parameters and any string after the 4th character will be ignored by the interpreter.

The interpreter will transmit the string "OK." if the command was successfully executed.

### 5.2.1 Prototype

*INIT*

## 5.3 STOP

The STOP command will turn all outputs OFF and stop waveform generation. It has no parameters and any string after the 4th character will be ignored by the interpreter.

The interpreter will transmit the string "OK." if the command was successfully executed.

### 5.3.1 Prototype

*STOP*

## 5.4 CONF

The CONF command configures a channel waveform. It is advisable to use the CONF command after STOP, to ensure the phase value is correct. If CONF is used while the waveforms are running, the phase value will be random (according to when the command arrives in the interpreter). Synchronization of the waveforms only occurs after INIT is executed.

### 5.4.1 Prototype

**CONF XYY FFF DDD PPP**

The CONF command has the following prototype, which must be followed in the exact order:

- **CONF**: String with command label, followed by a space character
- **X**: One character, from the list A, B, C, D, E, F, defining the port of the channel to be configured
- **YY**: Two numeric characters between 0 and 9 defining the channel number. Channel number must be between 00 and 17. Channel numbers lower than 10 must be padded with leading zeros (i.e., 08).
- **FFF**: Three numeric characters between 0 and 9 defining the frequency, in Hz, this channel will operate. Only integer frequency values are supported. Frequency will be rounded to nearest integer at the sampling rate of 49800 samples/s. Frequency values lower than 100 must be padded with leading zeros (i.e., 009, 035). Frequency must be between 0 and 200.
- **DDD**: Three numeric characters between 0 and 9 defining the duty cycle, in percent, of this channel. Only integer duty cycle values are supported. Duty cycle will be rounded to nearest integer at the sampling rate of 49800 samples/s. Duty values lower than 100 must be padded with leading zeros (i.e., 009, 035). Duty cycle must be between 0 and 100. A duty cycle of 0 corresponds to the channel always off, whereas a duty cycle of 100 corresponds to the channel always on.
- **PPP**: Three numeric characters between 0 and 9 defining the phase angle, in degrees, of this channel in relation to a zero-phase internal counter. This parameter must always be provided. Only integer phase angle values are supported. The phase angle will be rounded to nearest integer at the sampling rate of 49800 samples/s. Phase angles lower than 100 must be padded with leading zeros (i.e., 009, 035). The phase angle must be between 0 and 360. This parameter is only meaningful if two or more channels have the same frequency. In that case, the phase angle will make the channels lead/lag each other, allowing for interesting effects in a pulsed jet application.

### 5.4.2 Warnings

Any deviation from the prototype will cause the interpreter to ignore the command and send an error message. The error message will contain details on which parameter was incorrectly specified. Be extra careful to add the spaces between "CONF" and "XYY", "XYY" and "FFF", "FFF" and "DDD", "DDD" and "PPP", as these will cause the interpreter to read the numbers from incorrect locations. Also be careful to pad with leading zeros if the values do not fit the field lengths, otherwise a similar problem (reading from incorrect places) will occur.

### 5.4.3 Sample usage - correct use

**CONF D17 050 040 000** - Changes channel D17 to 50Hz frequency, 40% duty cycle, 0° phase angle. Channel D17 is the last pin the PORTD connector.

**CONF F00 001 000 000** - Changes channel F00 to 1Hz frequency, 0% duty cycle, 0° phase angle. This means the solenoid will be constantly off.

**CONF F00 010 100 000** - Changes channel F00 to 10Hz frequency, 0% duty cycle, 0° phase angle. This means the solenoid will be constantly on.

**CONF A09 010 050 000** - Changes channel A09 to 10Hz frequency, 50% duty cycle, 90° phase angle.

#### 5.4.4 Sample usage - incorrect use

**CONF D18 050 040 000** - Channel D18 does not exist in this implementation. Will throw an error.

**CONF G01 050 040 000** - Channel G01 does not exist in this implementation. Will throw an error.

**CONF A1 050 040 000** - Channel A01 misspelled as A1, will not interpret correctly. Will throw an error.

**CONF A01 10 0 0** - Frequency, duty and phase were not padded with zeros (correct spelling would be CONF A01 010 000 000). Will throw an error.