VEX U – Reverse Engineering Challenge

Sponsored by Texas Instruments

Raider Robotics – MSOE1 Presents

From Milwaukee, Wisconsin

Pneumatic Solenoid Driver Cable

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Pneumatic Solenoid Driver Cable

Introduction:

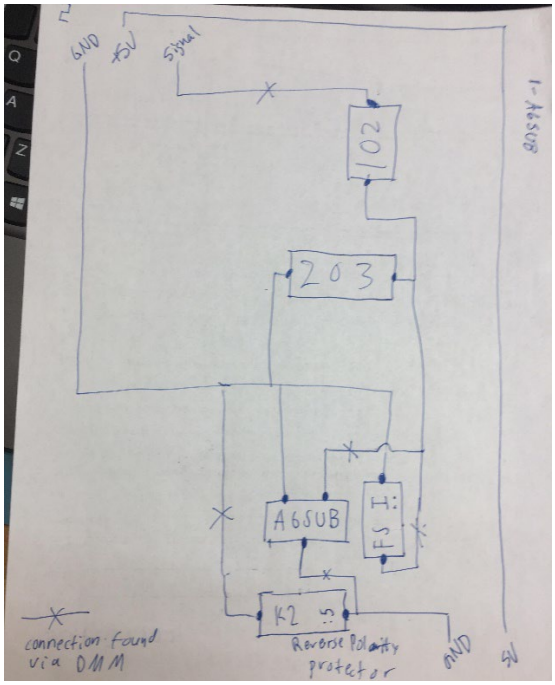
The VEX Solenoid Driver Cable (275-0277) is utilized to control the pneumatic solenoids (SY113-SMO-PM3-F or SYJ3120-SMO-M3-F) by converting the 5V PWM from the V5 Brain (276-4810) to 5V digital. We selected this device to better understand of how the VEX system operates so we could improve upon and develop our own for testing and eventually utilize standard pneumatic solenoids that do not run on 5V (pending Q and A).

VEX Solenoid Driver Cable

Solenoid Driver Cable Base Functionality

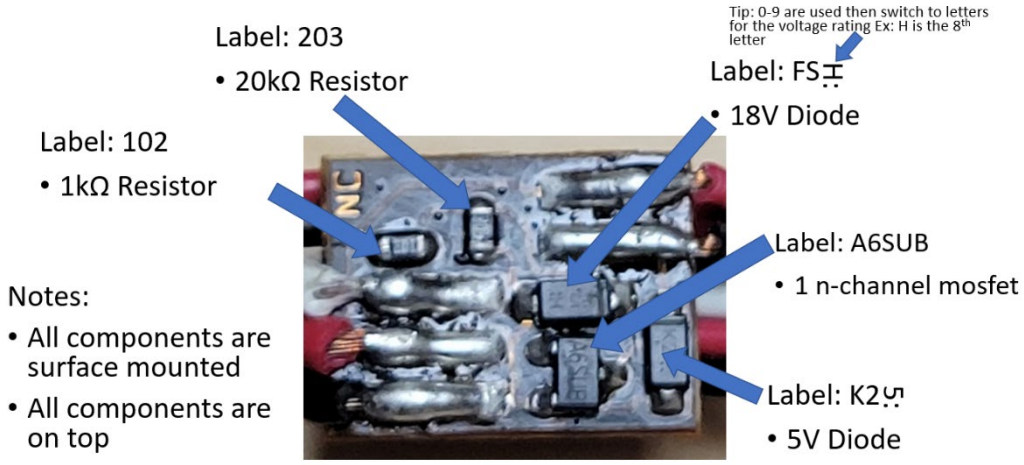
Reverse Engineering Process:

We removed the heat-shrink wrapped PCB, identified the components, and traced the paths of the 5V input, ground, and signal from the PWM contacts to the 5V and ground output under a microscope and with a digital multimeter.



Initial Drawn Schematic of the VEX Solenoid Driver

Components:



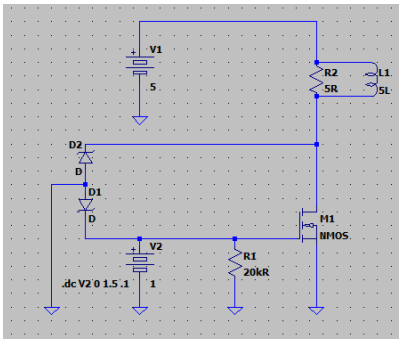
Component Locations on VEX Solenoid Driver

Note: A6SUB Datasheet

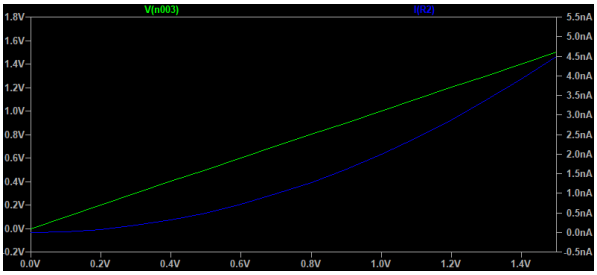
Simulation and Operation:

The circuit takes the signal from PWM to the gate of the MOSFET, which opens a path between drain and source allowing the 5V on the solenoid to flow to ground. The 20kΩ resistor is a pull-down resistor for the gate when power isn't applied and the other regulates the current. The two reverse-biased Zener Diodes are connected to the solenoid's ground and signal to provide transient voltage suppression as spikes in voltage caused by external sources or the inductive load of the solenoid could damage the MOSFET.

These specific functions were found and validated by LTSpice simulations, utilizing known information about the power draw and approximate inductive load from the pneumatic solenoid.



LTSpice Simulation



Relationship between the voltage on the MOSFET gate (green) and current allowed to flow through the load(blue)

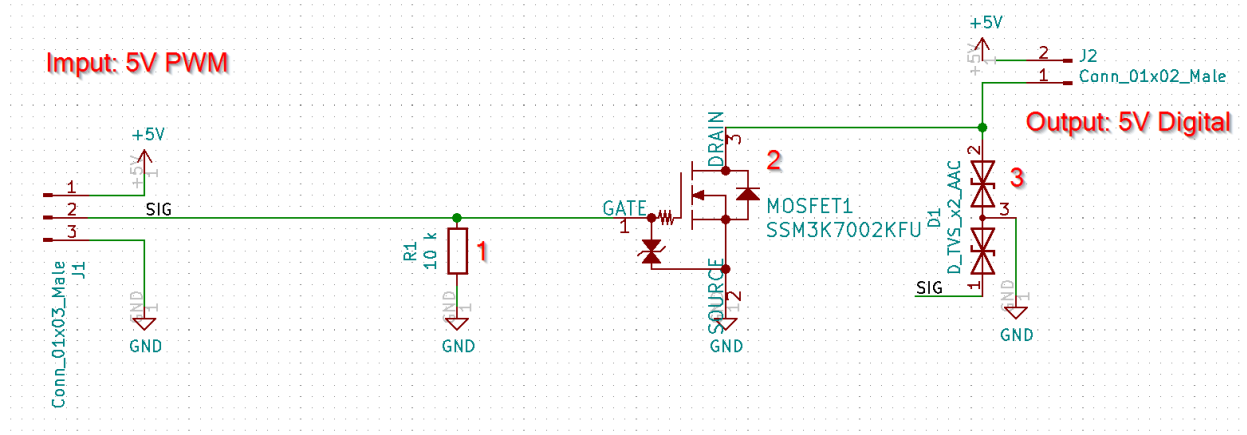
Improvement and Redesign:

We significantly reduced the complexity of the PCB (now only 3 components instead of 5) while maintaining the same functionality. We verified this via LTSpice simulations, and the protective diodes for ESD and TVS remained.

The three components we selected are:

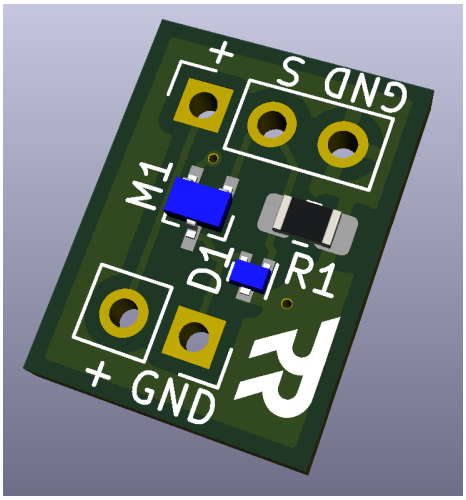
1. RC2012F1782CS – 10KΩ resistor – Replaces the 20kΩ pull-down resistor in the original with a more standard resistance value for this application (negligible change in simulation).
2. SSM3K7002KFU,LF - 1 n-channel MOSFET - with a built-in resistor and similar RDS_{On}, $VGS_{Threshold}$, and rated for above 5V.
3. MAZW082H0L - Double 5V Zener Diode – Replaces both diodes in the original while providing the same if not increased protection from ESD or reverse polarity.

These components were arranged in the following schematic in KiCad:

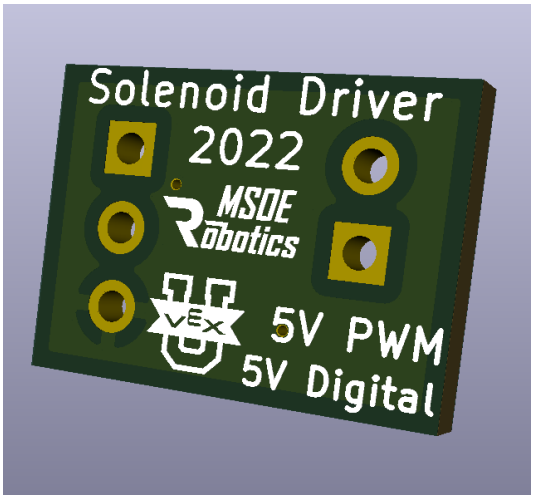


KiCad Schematic and Physical PCB for the Redesigned Solenoid Driver

From this schematic, we developed a PCB:

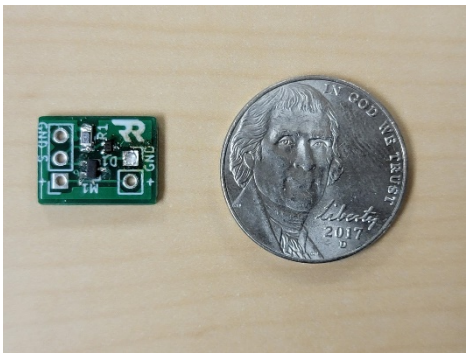


Top Layer of the Redesigned PCB

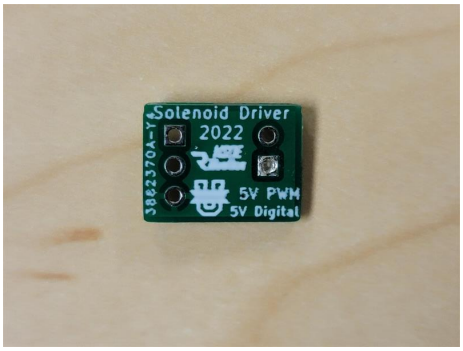


Bottom Layer of the Redesigned PCB

Which was manufactured by JLC PCB and surface mount soldered by our members:



PCB Front (with quarter for scale)



PCB Back

Conclusion:

Through undertaking this project, our team not only expanded our knowledge of how this circuit operates and how to utilize Zener diodes as transient voltage suppression devices, but also gained a better understanding of circuit analysis tools (LTSpice) as well as circuit design tools (KiCAD). Overall, this has allowed us to gain more confidence in these skillsets, and we look to utilize what we learned in designing more custom PCBs for our robot.

Bill of Materials:

PART NUMBER	DESCRIPTION	VENDOR	PRICE FOR 25 UNITS
MAZW082H0L	Double 5V Zener Diode	**Digi-Key**	**$4.50**
SSM3K7002KFU,LF	1 n-channel mosfet	**Digi-Key**	**$5.25**
RC2012F1782CS	10K Ohm Resistor	**Digi-Key**	**$0.33**
	25 PCBs	**JLC PCB**	**$4.30**
SYJ3120-SM-M3-F	Solenoid connectors (included in purchase of solenoids)	**SMC**	
	PWM Cable or Extensions		
	Heatshrink tubing		
		TOTAL:	**$14.38**
		Price/Board	**$0.58 (3.5% of the original cost)**

Credits

Reverse Engineering Resources:

- VEX Robotics Solenoid Driver Cable (275-0277)
- MSOE University Electrical Engineering and Computer Science Lab

Software Used:

- LTSpice
- KiCAD

Component Suppliers:

- Digi-Key
- JLC PCB
- SMC USA