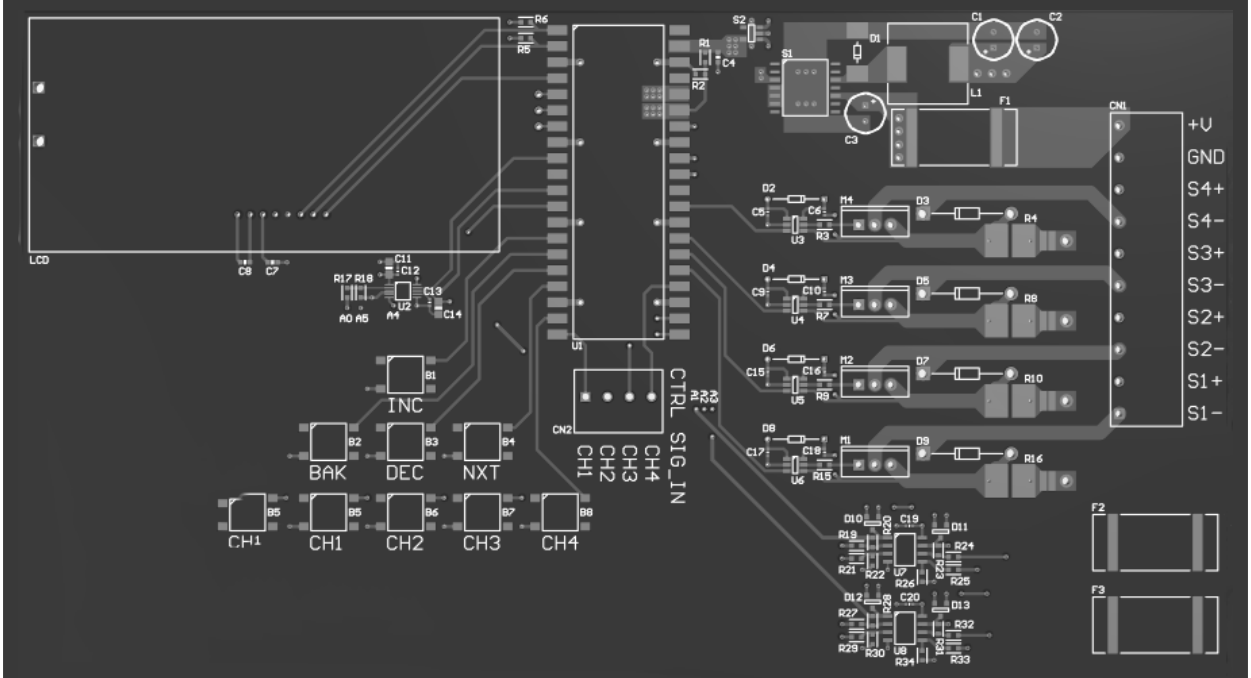
JOHNSON ELECTRIC

Solenoid Demonstration Board

User Manual



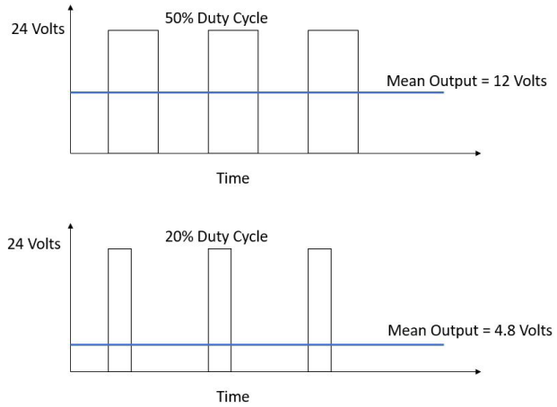
CONTENTS

The Solenoid Demonstration Board is designed to give customers the ability to test a variety of solenoid control schemes in a user-friendly sandbox environment.

Pulse-Width Modulation

Pulse-Width Modulation (PWM) is an essential control method for solenoid actuation. PWM uses a nominal DC input voltage and produces a reduced average output voltage. This is achieved by rapidly switching the voltage to the solenoid on and off through a transistor. The duty cycle (on time / (on time + off time) of the switching determines the output voltage. This average output voltage is equal to the nominal input voltage multiplied by the duty cycle ratio. This process is sometimes referred to as 'chopping,' as demonstrated in Figure 1:

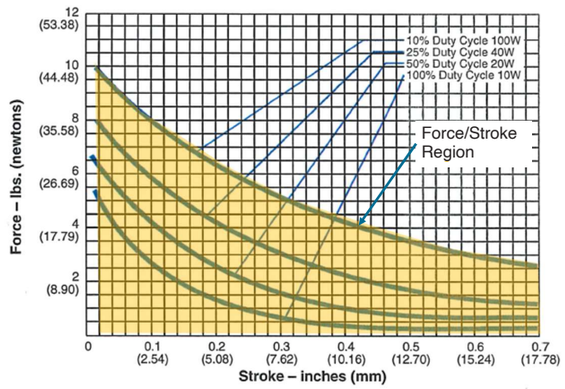
FIGURE 1: Examples of PWM duty cycles



The average power consumed by the solenoid can be decreased by reducing the average voltage. With PWM the system uses the level of power associated with the level of required force or torque. This ensures no unnecessary power is delivered to the solenoid. Since power consumption is directly related to heat, PWM can be used to reduce both the operating temperature and the overall energy consumed.

The force created by a linear solenoid increases with increasing current and decreases with increasing stroke, the distance from a fully seated position. A simple application of PWM is to deliver nominal voltage to the solenoid until it has fully actuated, then a reduced voltage to hold the solenoid in its actuated position. Reducing the voltage is possible because the force of the solenoid is at its peak at the fully seated position. This is a very common control scheme called 'Pick & Hold' and is pre-installed on the demo board.

FIGURE 2: PWM force/stroke region



In more advanced applications, PWM allows adjustments to a solenoid's force/stroke profile. Instead of operating along a single force/stroke profile based on a fixed voltage, PWM allows the solenoid to operate within a force/stroke region. At any given stroke point, a range of forces can operate between a maximum force, corresponding to the maximum input voltage, and zero force, corresponding to zero voltage. Figure 2 illustrates this difference.

How To Use The Board

Powering Up

The board supports a range of input voltages from 12-48V. If using a variable power supply, follow these steps before connecting to the demo board:

1. Turn on the power supply
2. Set the voltage to the desired level
3. Turn off the power supply
4. Connect the power supply's terminals to "+V" and "GND" positions on the terminal block, *(pictured below)*

Be certain that the "+V" is connected to the positive terminal of the power supply and "GND" is connected to the negative or ground terminal on the power supply.

The internal power system is fused, allowing a maximum of 10A.

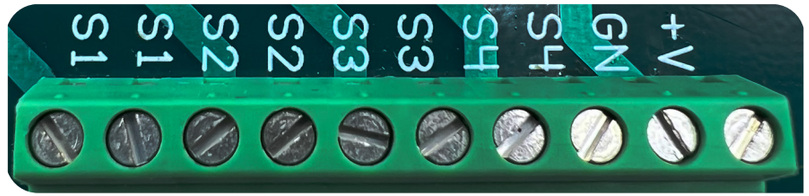
Connecting Your Solenoids

Solenoid channels are labeled from S1 to S4, with positive and negative sides for each. These numbers correspond to the channel numbers within the GUI. When attaching solenoids to the demo board, begin with S1, then continue towards S4 until the desired number of solenoids have been attached. When using a standard Johnson Electric solenoid without a polarity sensitive internal transient suppressor, there is no need to pay attention to the positive and negative of each solenoid channel. However, if using a solenoid with a polarity sensitive integral transient suppressor, it is critical to properly connect the leads to the required positive or negative terminals.

IMPORTANT

When connecting the solenoids, do not skip channels. Start with S1, then S2, and continue as needed. If a new solenoid is added, the board *MUST* be power cycled to ensure proper operation.

FIGURE 3:
Solenoid and Power Supply Connection Terminal



Temperature and Current Sensing

The demo board continuously measures solenoid current during operation. The board's code uses this measured current to calculate changes in resistance, which are correlated to changes in temperature inside the solenoid. The primary function of this is to ensure temperatures stay within the product specifications and interrupt actuation when those bounds are exceeded. For this feature to be accurate, the solenoid must be at room-temperature when the actuation cycling begins. The pre-programmed limit is 100˚C which is within specification for Johnson Electric solenoids. Be cautious when using any other solenoid products as this may surpass their limit and cause permanent damage. The advanced user can edit the Python code to use current sensing and temperature feedback for other purposes.

If the solenoid is hot, run the system at a lower duty cycle, effectively stepping down the voltage, reducing current (and force), and dropping temperature. This allows the solenoid to cool.

GUI Basics

Once you have connected your solenoids and power supply as directed above you are ready to begin using the demo board. As soon as the board is supplied with 12-48V, a prompt will display on the LCD screen. The prompt will read: “To begin setup, press any GUI key…” At this point, the board is ready to use. Begin by pressing any of the four GUI buttons to start the prompting process.

The GUI Buttons

INC (Increase)
increases the digit next to the cursor.

DEC (Decrease)
decreases the digit next to the cursor.

NOTE: Both the INC and DEC buttons can wrap around digits from 9 to 0 or vice versa.

BAK (Back)
moves the cursor to the left. If the cursor is already pointing to the leftmost digit, pressing the BAK key will change prompts to the previous prompt (if possible).

NXT (Next)
moves the cursor to the right. If the cursor is pointing to the last digit on the prompt, pressing NXT acts like an enter button, and forwards to the next prompt.

The Channel Prompts

The number in the lower right-hand corner of the screen represents the current channel for which you are entering criteria.

1. Number of Solenoids: enter the number of solenoids attached to the board.
2. PWM Freq: enter the desired PWM frequency for the current solenoid, this input is restricted to values at/or between 2kHz and 40kHz. Values outside the range are set to the nearest endpoint of the acceptable range.

   Note: Selection in the bottom half of this range can impact the audible sound produced by the solenoid during operation.
3. Pick Volts: specify the cycle’s pick voltage - the first component of the pick and hold cycle.
4. Pick Duration: specify the cycle’s pick duration in milliseconds.
5. Hold Volts: specify the cycle’s holding voltage.
6. Hold Duration: specify the cycle’s holding duration in seconds.
7. Wait: enter the wait duration for the pick and hold cycle in seconds. This is the time between solenoid actuation cycles during which no voltage is applied to the solenoid.

   Note: Steps 2-7 will repeat for the number of solenoids being used as specified in step 1.
8. Press NXT to begin cycling.

After moving through the above steps, the solenoid(s) will begin actuating.

Channel Overview

The demo board is equipped with the ability to display the number of completed cycles and current temperature (in degrees Celsius) of the solenoid attached to channel one. This will be shown once the user is finished with the GUI.

Channel Preset Buttons CH1 – CH4

These buttons toggle between a built-in output cycle. The built-in output cycle has a PWM frequency of:

20kHz with a 96.1% duty cycle for 100ms

then a **93.1%** duty cycle for 2 seconds

then it turns off for 2 seconds before **cycling again**

To use the preset cycle, and skip most of the GUI, enter the number of solenoids attached and press the preset buttons for each of the solenoids.

Stopping Output

Once the output from the first channel is available, then stopping everything is as simple as pressing the NXT button. To change the criteria without power cycling the board, press BAK at the output details screen which starts the prompts over again.

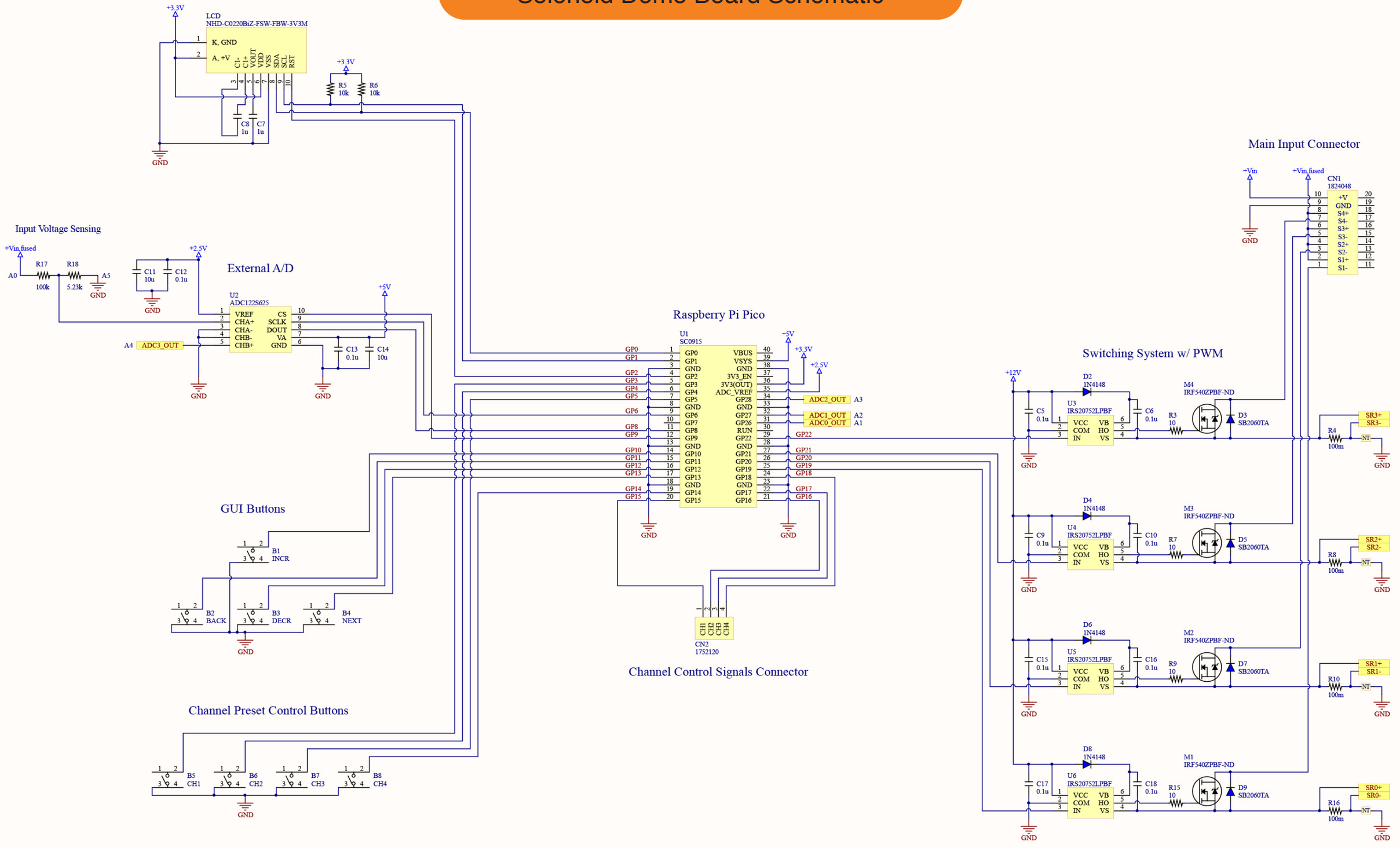
If you decided to skip entering the cycle information, and instead went immediately to one of the channel preset buttons (CH1 – CH4), pressing the preset button stops the output.

Channel Control Signal Inputs (CTRL SIG_IN)

The channel control signal inputs serve as leader control signals for the board. This allows the demo board to act as a follower to the controller of your choice. To achieve this functionality, the demo board monitors the digital value at each CTRL SIG_IN terminal. These inputs tell the board to restart the corresponding channel’s output cycle when the line is driven from low to high, or to stop the channel’s output completely if the line is driven from high to low.

FIGURE 4: CTRL SIG_IN Terminal Block

Solenoid Demo Board Schematic



Microcontroller

The demo board uses a Raspberry Pi® Pico microcontroller. It was chosen for the following reasons:

1. Uses MicroPython®, a rigorously documented Python library.
2. Is compatible with Thonny as an integrated development environment, which is free and open source.
3. Includes a board mounted micro-USB port.

Flashing

The basic procedure for flashing the Raspberry Pi Pico can be found on Raspberry Pi's website (https://datasheets.raspberrypi.com/pico/raspberry-pi-pico-python-sdk.pdf). It lists all the features of the Pico and serves as a good introduction to microcontrollers. We encourage users to download the Thonny environment (www.thonny.org), which enables the user to upload the python code from the demo board and customize as desired.

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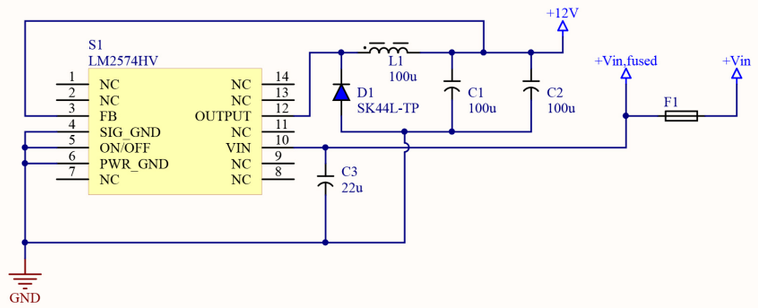
Python is a registered trademark of the PSF

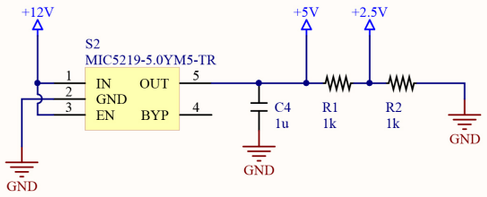
Power Subsystem

12-48V to 12V SMPS

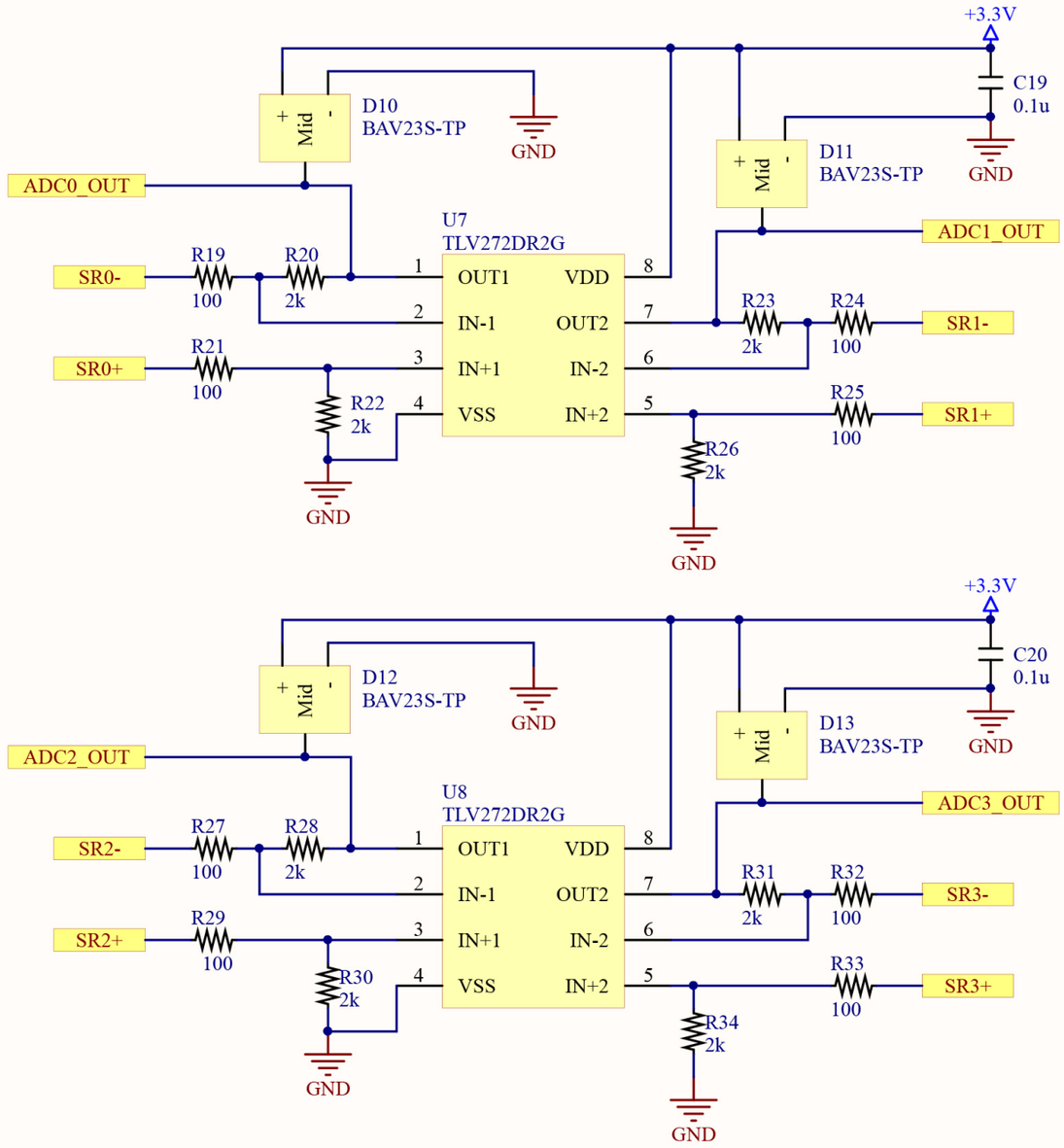


Extra Fuses

12V to 5V Linear Regulator



Sense Resistor Op-amps



Item #	Reference Designator	Quantity	Description	Mfg	Mfg Part Number
1	R4, R8, R10, R16	4	RES 0.02 OHM 1% 7W 2818	Vishay Dale	WSHM2818R0200FEA
2	R3, R7, R9, R15	4	RES 10 OHM 1% 1/10W 0603	YAGEO	RC0603FR-0710RL
3	R19, R21, R24, R25, R27, R29, R32, R33	8	RES 100 OHM 1% 1/10W 0603	Stackpole Electronics Inc	RMCF0603FT100R
4	R1, R2	2	RES 1K OHM 1% 1/10W 0603	Stackpole Electronics Inc	RMCF0603FT1K00
5	R20, R22, R23, R26, R28, R30, R31, R34	8	RES 2K OHM 1% 1/10W 0603	Stackpole Electronics Inc	RMCF0603FT2K00
6	R18	1	RES 5.23K OHM 1% 1/10W 0603	Stackpole Electronics Inc	RMCF0603FT5K23
7	R5, R6	2	RES 10K OHM 1% 1/10W 0603	Stackpole Electronics Inc	RMCF0603FT10K0
8	R17	1	RES 100K OHM 1% 1/10W 0603	Stackpole Electronics Inc	RMCF0603FT100K
9	C5, C6, C9, C10, C12, C13, C15, C16, C17, C18, C19, C20	12	CAP CER 0.1UF 25V X5R 0402	Samsung Electro-Mechanics	CL05A104KA5NNNC
10	C4, C7, C8	3	CAP CER 1UF 10V X7R 0603	YAGEO	CC0603KRX7R6BB105
11	C11, C14	2	CAP CER 10UF 10V X5R 0805	Samsung Electro-Mechanics	CL21A106KPCLQNC
12	C3	1	CAP ALUM 22UF 20% 100V RADIAL	KEMET	ESK226M100AE3AA
13	C1, C2	2	CAP ALUM 100UF 20% 25V RADIAL	KEMET	ESK107M025AE3EA
14	D2, D4, D6, D8	4	DIODE GEN PURP 100V 200MA DO35	onsemi	1N4148TA
15	D1	1	DIODE SCHOTTKY 4A 40V SMC	Micro Commercial Co	SK44L-TP
16	D10, D11, D12, D13	4	DIODE ARRAY GP 200V 225MA SOT23	Micro Commercial Co	BAV23S-TP
17	D3, D5, D7, D9	DNP	DIODE SCHOTTKY 60V 20A DO201AD	SMC Diode Solutions	SB2060TA
18	L1	1	FIXED IND 100UH 1.9A 140MOHM SMD	Würth Elektronik	7447706101
19	U7, U8	2	OPERATIONAL AMPLIFIER, 3MHZ, LOW	onsemi	TLV272DR2G
20	Fuses in F1, F2, F3	3	FUSE AUTO 10A 58VDC BLADE MINI	Littelfuse Inc.	0891010.NXS
21	F1, F2, F3	3	FUSE HOLDER BLADE 20A SMD (SMT)	Keystone Electronics	3587-20
22	CN1	1	TERM BLK 10P SIDE ENT 5.08MM PCB	Phoenix Contact	1729209
23	CN2	1	TERM BLOCK 4POS 25DEG 3.5MM PCB	Phoenix Contact	1752120
24	U1	1	RASPBERRY PI PICO MICROCONTROLLER	Raspberry Pi	SC0915
25	M1, M2, M3, M4	4	MOSFET N-CH 200V 56A TO220AB	Infineon Technologies	IRFB260NPBF
26	U3, U4, U5, U6	4	IC GATE DRVR HIGH-SIDE SOT23-6	Infineon Technologies	IRS20752LTRPBF
27	LCD	1	LCD MOD 40DIG 20X2 TRANSFLCT WHT	Newhaven Display Intl	NHD-C0220BIZ-FSW-FBW-3V3M
28	U2	1	IC ADC 12BIT SAR 10VSSOP	Texas Instruments	ADC122S625CIMM/NOPB
29	S2	1	IC REG LINEAR 5V 500MA SOT23-5	Microchip Technology	MIC5219-5.0YM5-TR
30	S1	1	IC REG BUCK 12V 500MA 14SOIC	Texas Instruments	LM2574HVMX-12/NOPB
31	B1, B2, B3, B4, B5, B6, B7, B8	8	SWITCH TACTILE SPST-NO 0.05A 12V	C&K	PTS645SK50SMTR92 LFS
32	Square bumpers (feet)	4	BUMPER SQUARE 0.5"L X 0.5"W BLK	3M	SJ-5008-BLACK

Notes

Notes

COMPLETE SOLUTIONS FROM ONE DOMESTIC PARTNER

Our Ohio-based engineering team has the largest portfolio of reliable motion solutions in the industry at their fingertips. Comprehensive design and manufacturing resources are also available to support unique needs, including alternative shafts and mounting features. Special plunger configurations, springs, cable harnesses, or other customizations can also be developed to your exact performance and unit cost objectives, with fast prototype turnarounds or custom models. Contact us to discuss your specialized requirements.

WHY JOHNSON ELECTRIC?

Johnson Electric invented the rotary solenoid and still knows it best, with an ongoing foundation of innovation spanning more than 80 years.

Today, Johnson Electric is the leader in motion subsystems. Technological leadership, application expertise, and a global footprint make Johnson Electric your ideal solution partner for differentiated product development projects and supply chain excellence.

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Sell Sheet PP-110-01-01

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