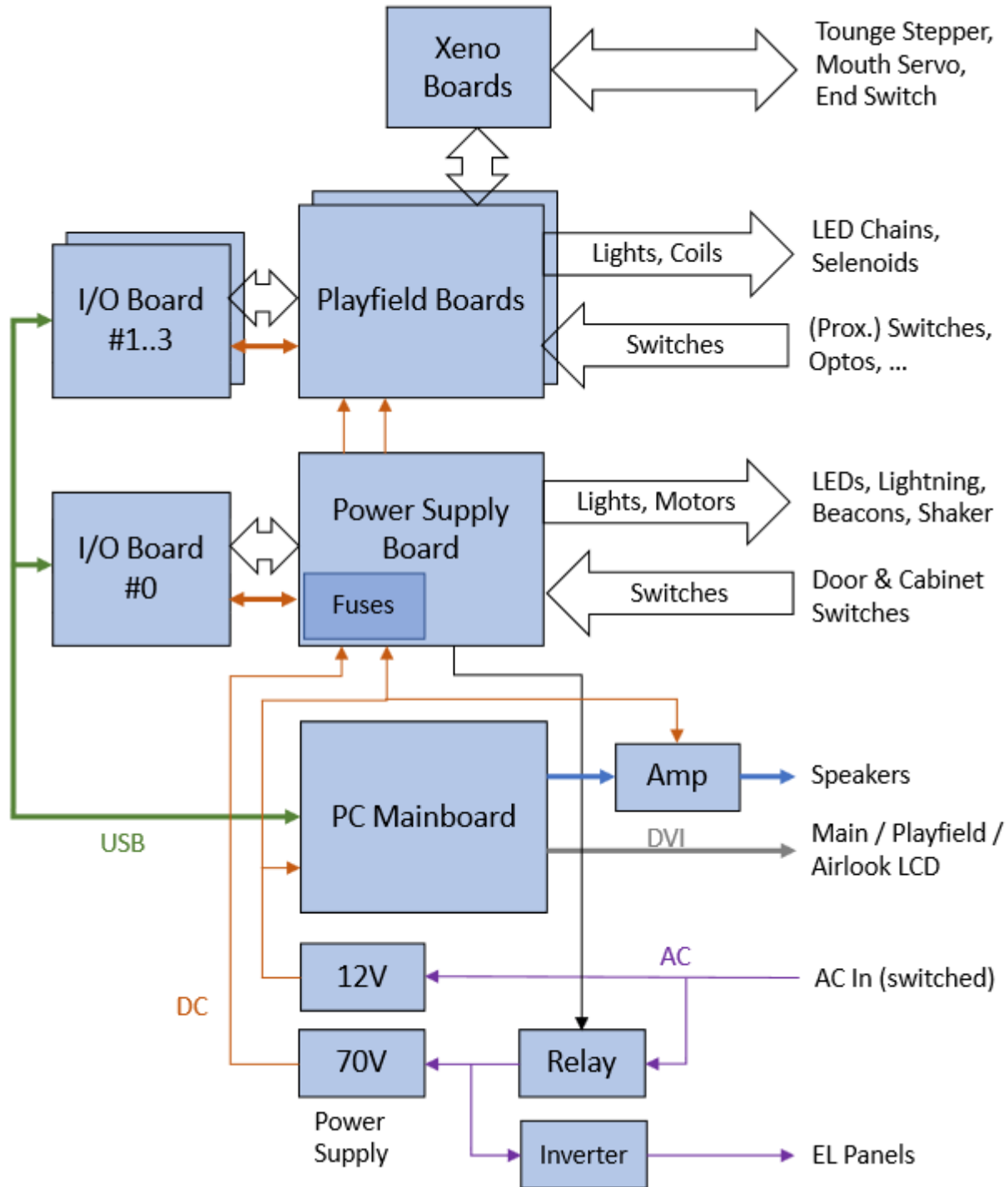# Alien I/O-Board

Version 1.1 created on 01/28/2019 by Per

The Heighway Alien pin uses 4 identical I/O-Boards to connect the PC mainboard with the pin hardware (coils, motors, lights, switches etc.) as shown in the following diagram of the Alien pinball electronics.
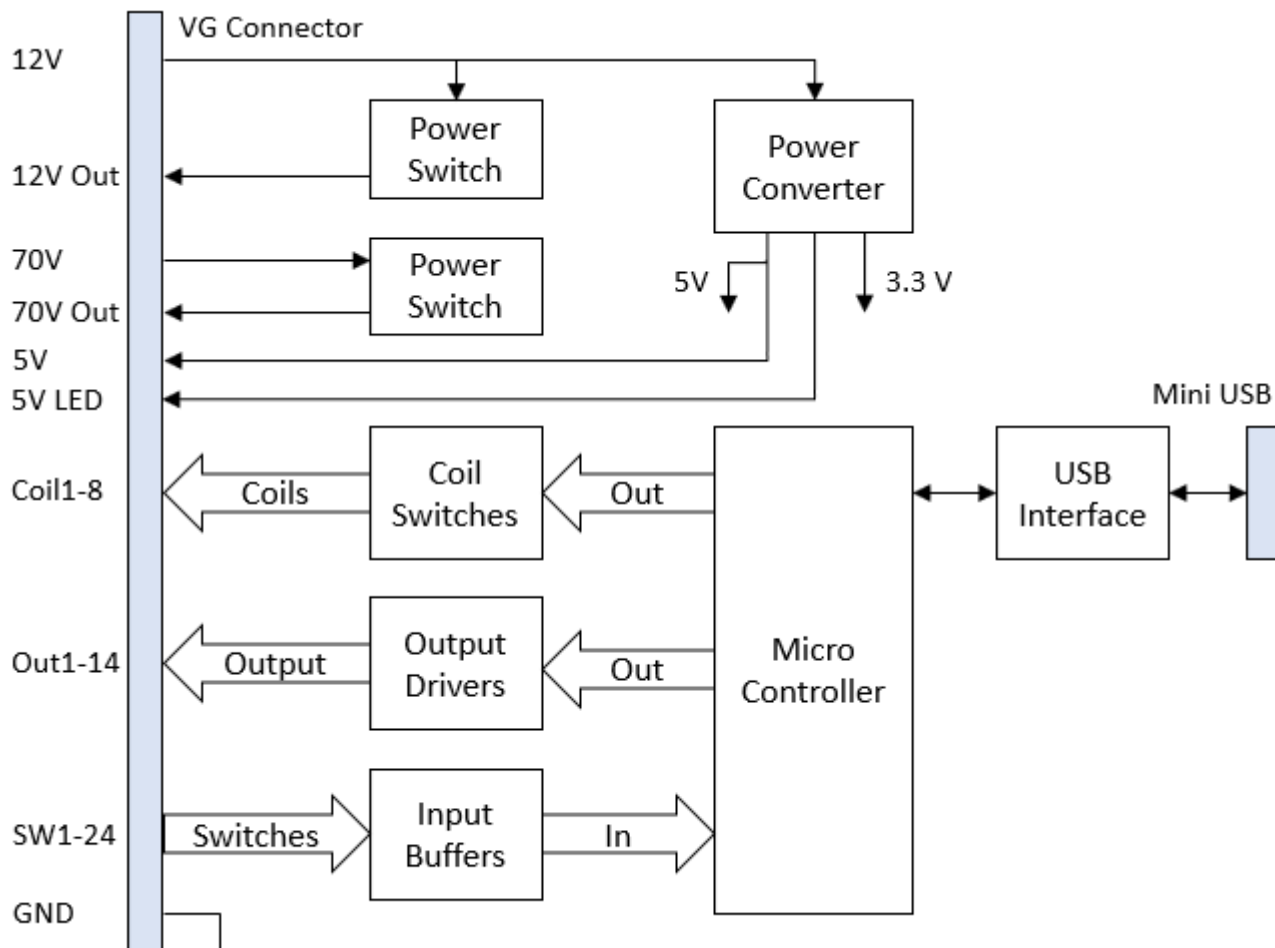

Unfortunately there are no schematics available for the I/O Board (as of Jan 2019) but it would be helpful to understand its functionality and circuitry for general maintenance as well as repair purposes. Therefore I inspected the boards for some time and here are my results.

Overview

The I/O-Board is a multilayer printed circuit (dimensions 10x15cm, close to euroboard size) with a VG connector. The electronic components – mostly SMD type – are placed on both sides of the board:
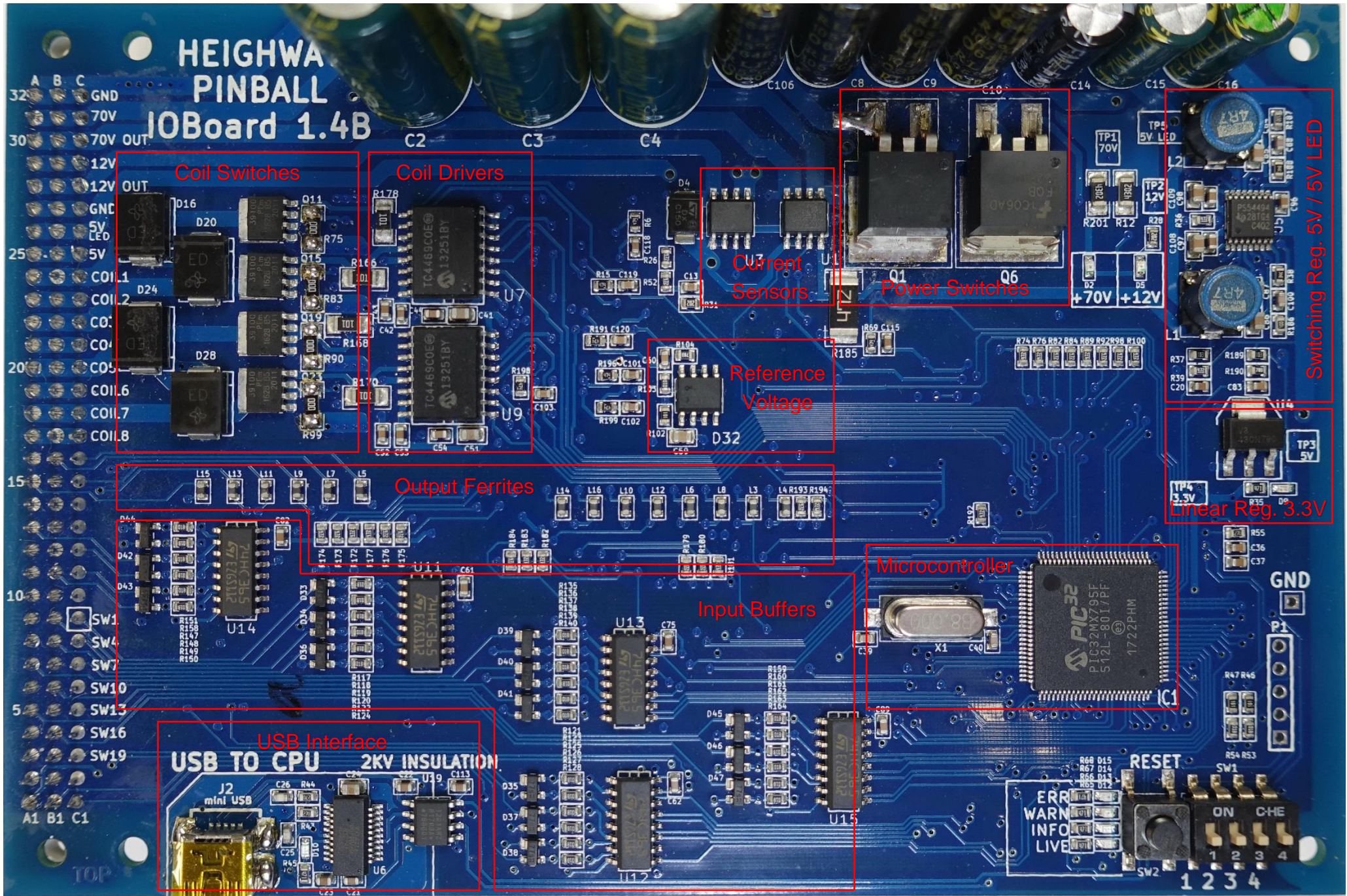
- The heart of every board is a PIC32 MX7 microcontroller (uC) including a CPU, memory and many I/O channels
- 8 I/O channels toggle the high current coil switches
- 14 more I/O channels are connected to 5 volt output drivers
- 24 I/O channels are used to detect closed switches via buffered inputs
- Each board has its own power supply circuits, converting the 12 volt input to 5 and 3,3 volt for integrated curcuits and additional 5 volt for the LEDs.
- There are also two power switches implemented, delivering 12 volt and 70 volt with over-current protection
- Finally there is a USB Interface to connect the uC with the PC mainboard

Component Map

The following pictures show both sides of the I/O-Board. The labeled red boxes indicate the locations of the main electronic devices.

Note: A few parts are missing on the pictures as I took the photos from a defect board.

HEIGHWAY PINBALL IOBoard 1.4B

Coil Switches

Coil Drivers

Current Sensors

Power Switches

Switching Reg. 5V / 5V LED
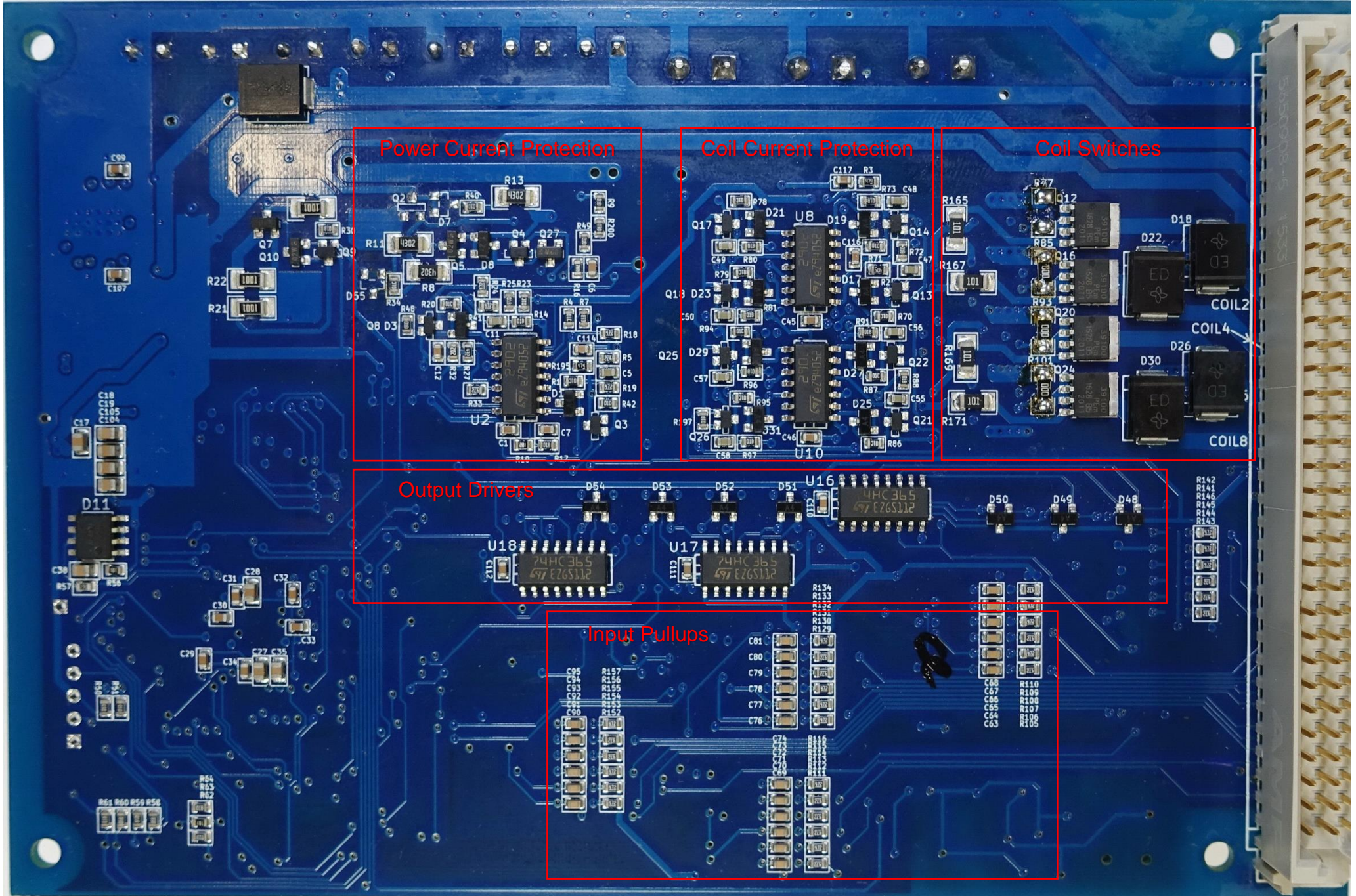
Reference Voltage

Linear Reg. 3.3V

Output Ferrites

Microcontroller

Input Buffers

USB Interface

USB TO CPU   2KV INSULATION

Microcontroller — PIC32 PIC32MX795F 512L-801/PF

3

Component details

The next sections provide schematic circuit diagrams for most components together with a short explanation and links to datasheets. Several circuits exist multiple times (see overview above) - part numbers in [..] are related to one example in these cases.
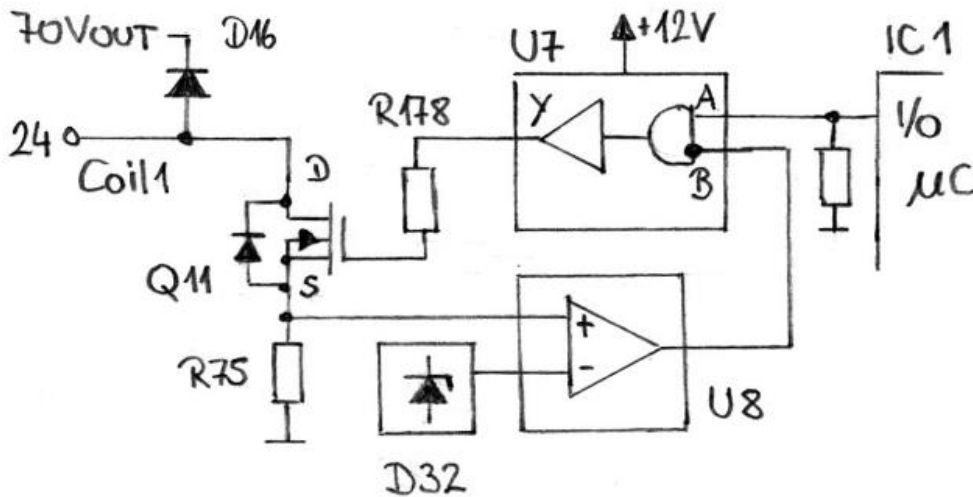
Microcontroller

The I/O-Board uses a quite powerful 80 MHz, 32bit microcontroller PIC32MX795F512L-80I/PF manufactured by Microchip [IC1]. Check the Datasheet for more information.

Coil Switch

There are 8 coil switches (4 on each side of the board). Each of them uses a n-channel MOSFET PSMN039-100YS (100V, 28A) [Q11, Datasheet] to connect the corresponding Coil x output to ground (GND). An ES3D diode [D16, Datasheet] protects the MOSFET against back current from the coil.

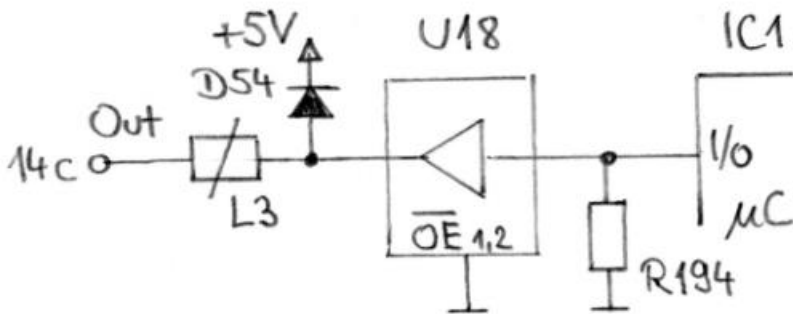TC4467 drivers [U7, Datasheet] are used to amplify the PIC32 output signal (12V, 1.2A). The drivers are also controlled by a LM 2902 op amp [U8, Datasheet] comparing the coil current related voltage drop at resistor [R75, 30mOhm] with a reference voltage [D32, Datasheet].

Note: The over current protection is disabled for all MOSFETs on current I/O-Boards by replacing all measuring resistors with 0 Ohm devices and additionally shorting them with a common wire. Obviously this circuitry caused problems, the additional wires could be a hint at some (unhealthy) oscillation tendency.
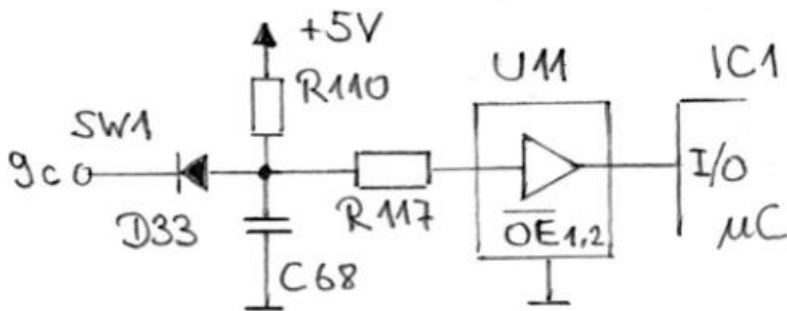
Output Driver

14 outputs are available for 5V logic devices, like the WS2812B LED chips [Datasheet]. They outputs are implemented with 74HC365 buffer devices [U18, Datasheet] (5V, 30mA) together with a protection diode [D54] and a ferrite bead [L3] for noise suppression.

Input Buffer

24 pins of the VG connector are attached to microcontroller inputs via 74HC365 buffer devices [U11, Datasheet]. A pull-up resistor [R110] signals 5V (logic high) for open inputs, connected switches should therefore close to ground when active. All other components protect the input [D33] and clean the signal [C68] (debouncing).
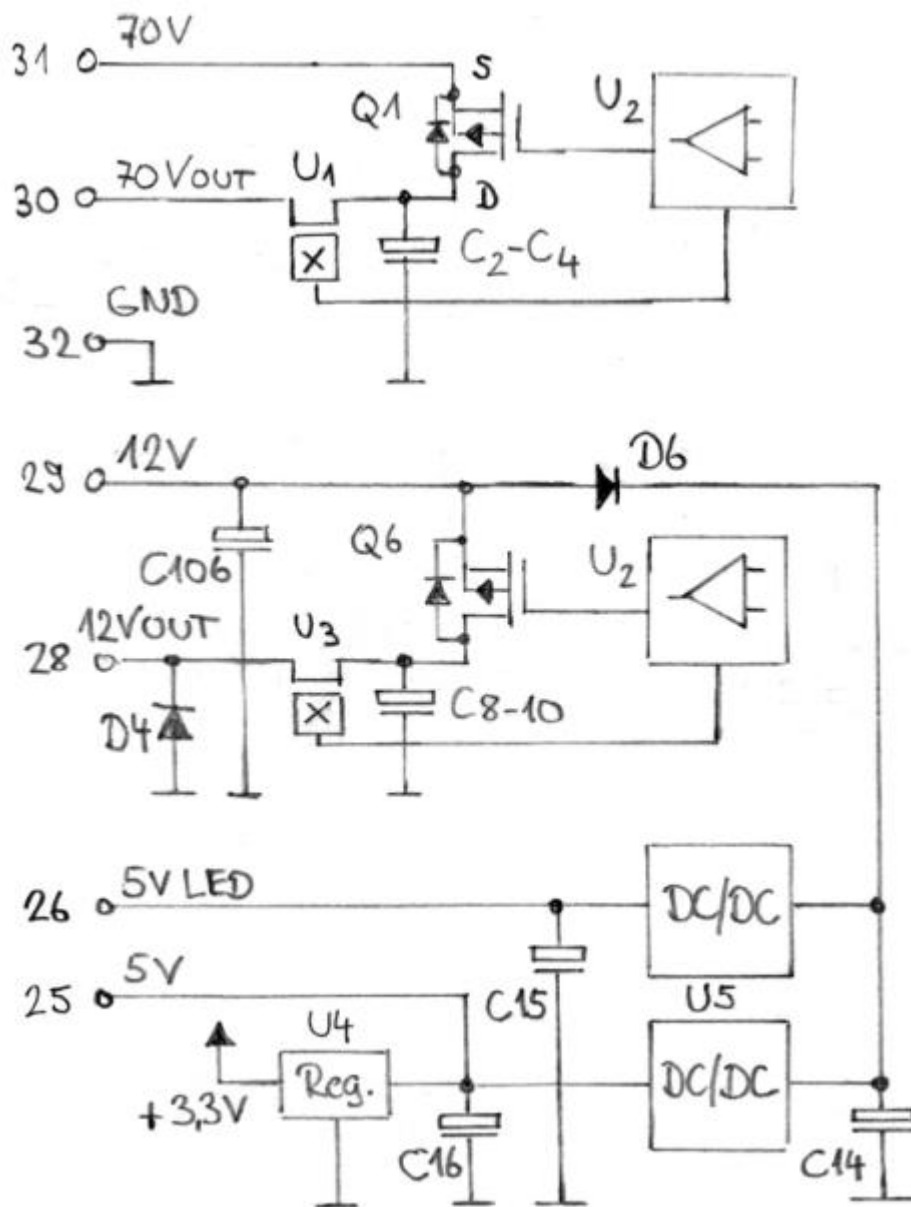

Power Supply / Switches

The board is working with 12V consuming about 150mA. There are two groups of components for the power supply of the board itself and the attached hardware.

The first group creates 5V and 3.3V operating voltages for the integrated circuits on the I/O-Board as well as for the LEDs and other attached devices. A TPS54494 dual DC/DC converter [U5, Datasheet] reduces the main 12V supply to 5V and 5V LED. A linear regulator [U4, like LM1117, Datasheet] provides 3.3V out of the 5V line. A series of capacitors smooth the voltages.
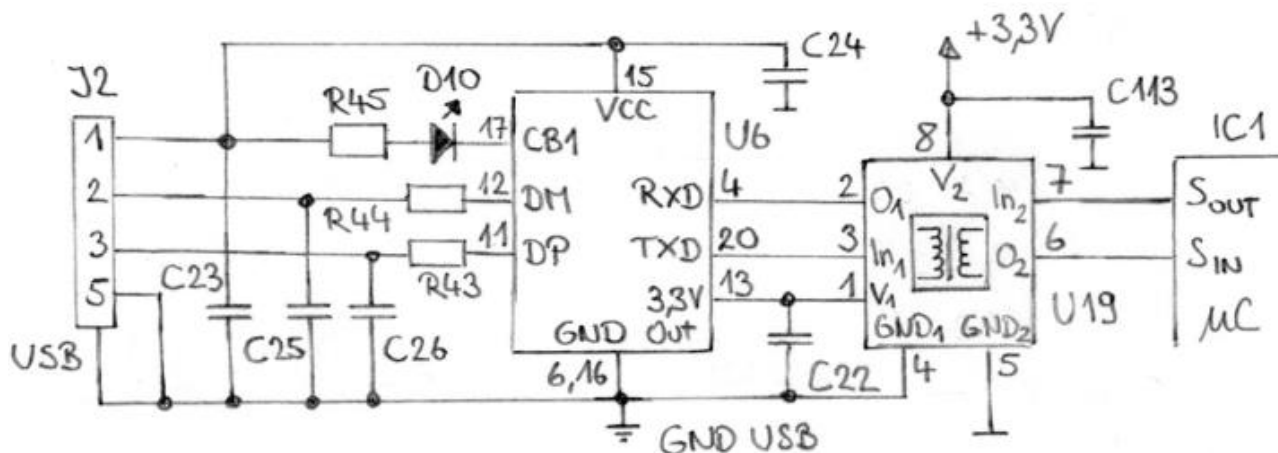
The second group implements 12V and 70V high current outputs with over-current protection. The incoming voltage is switched off with a FQB22P10TM p-channel MOSFET [Q1/Q6, Datasheet] if the current sensor ACS711 KLCTR-12AB [U1/U3, Datasheet] reaches a certain threshold. The current / voltage check is performed by a LM 2902 op amp [U2, Datasheet] and many additional parts (see component map).

Note: I saw some melted 70V MOSFETs (see pictures above). The reason is unclear to me and I ask myself, if a simple fuse could not replace those switches…

USB Interface

The USB interface uses a FT231X interface device [U6, Datasheet] with USB bus powered configuration. The serial signal and power separation is accomplished with an additional ADuM 1201 [U19, Datasheet]. All discrete parts follow exactly the vendor's application example.

VG Connector pinout

Heighway selected a male 96 pin VG Connector (DIN 41612, see [wikipedia](#)) to hook-up the I/O-Boards. The pins are arranged in 32 rows numbered 1 to 32 and three columns named A, B and C. The pin numbers and most signals are clearly marked on the I/O-Board, as visible in the component map picture above.

Pin	Signal	Input/Output
A1	GND	Output
B1	SW 24 / A2	Input
C1	SW 23 / A1	Input
A2	SW 22 / A0	Input
A3, B3, C3	SW 21, 20, 19	Input
B4, B4, C4	SW 18, 17, 16	Input
…	…	Input
A9, B9, C9	SW 3, 2, 1	Input
C10	Out 14	Output
A11	Out 13	Output
A12, B12	Out 12,11	Output
B13, C13	Out 10, 9	Output
B14, C14	Out 8, 7	Output
A15, B15, C15	Out 6, 5, 4	Output
A16, B16, C16	Out 3, 2, 1	Output
A17, B17, C17	Coil 8	Output
A18, B18, C18	Coil 7	Output
A19, B19, C19	Coil 6	Output
A20, B20, C20	Coil 5	Output
A21, B21, C21	Coil 4	Output
A22, B22, C22	Coil 3	Output
A23, B23, C23	Coil 2	Output
A24, B24, C24	Coil 1	Output
A25, B25, C25	5V	Output
A26, B26, C26	5V LED	Output
A27, B27, C27	GND	Input
A28, B28, C28	12V OUT	Output
A29, B29, C29	12V	Input
A30, B30, C30	70V Out	Output
A31, B31, C31	70V	Input
A32, B32, C32	GND	Input

Remarks:

- The address inputs A0..A2 are used to select the board, see next chapter
- The Out x signals are not labeled on the PCB
- The high current connections use 3 pins in parallel (max. 2A / pin allowed)
- Missing pins are unused
- Be careful, the numbering on the connector itself may be different (opposite)

Test Adapter

One reason for my analysis were several defect IO-Boards which I got from other Alien and Full Throttle owners. For detailed checks I liked to have a live test environment. I hoped for some I/O test modes in the firmware activated by the DIP switches. An insider told me that there is some test code included, "but nothing very useful". He also confirmed, that the Alien software only needs the cabinet I/O-Board to enter the settings menu.

I decided to set up a minimal system with a power supply, a mainboard, the cabinet I/O-Board and door switch "replicas". The following sections present some basics and the test adapter I build.

I/O-Board Selection

The 4 Alien I/O-Boards are numbered from 0 to 3. The location of a board is selected using the 3 address inputs A0..A2 of the VG connector. The following table shows the input settings per board:

Board Number	Location	A2 (Pin B1)	A1 (Pin C1)	A0 (Pin A2)
IO0	Cabinet	GND	GND	GND
IO1	Xeno	GND	GND	Open
IO2	Center Playfield	GND	Open	GND
IO3	Apron	GND	Open	Open

An open pin results in a high level input signal because of the internal pull-up resistor. The GND / low level is available at pin A1.

Cabinet I/O-Board Switch Inputs

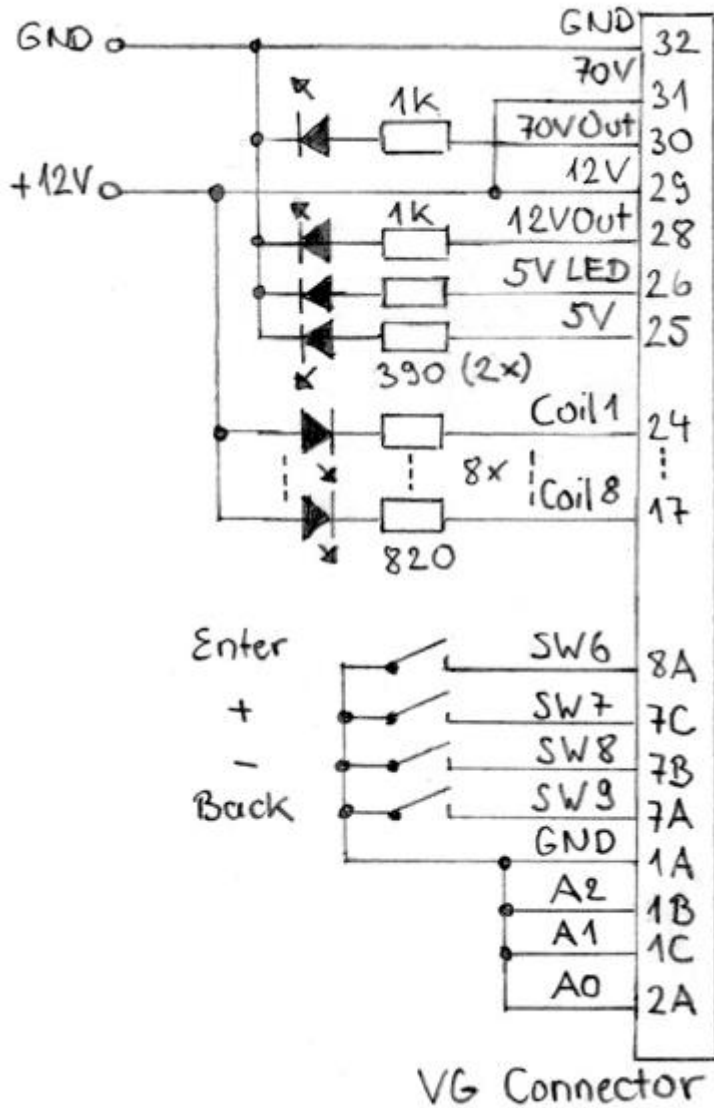Here is a list of selected inputs attached to the Cabinet I/O-Board:

Input	Pin	Switch
SW6	A8	Enter
SW7	C7	+
SW8	B7	-
SW9	A7	Back
SW1	C9	Flipper button left
SW17	B4	Flipper button right
SW4	C8	Start
SW5	B8	Extra ball
SW20	B3	Launch
SW11	B6	Tilt
SW12	A6	Door closed

All switches connect the input to GND when active.

Test circuit

The test adapter consists of a stripboard with

- a female 96 pin VG connector
- 12 Volt power supply, also attached to 70V to check the power switch
- 2 LEDs to monitor the two power switch outputs 12V Out and 70V Out
- 2 LEDs to check the 5V and 5V LED delivered by the DC/DC converter
- 8 LEDs signaling active (grounded) Coil outputs
- 4 switches to simulate the coin door switches (Enter, +, -, Back).
  I added some more switches for other inputs.
- GND connections to address the board #0

GND

GND 32
70V 31
70V Out 30
1K
12V 29
+12V
12V Out 28
1K
5V LED 26
5V 25
390 (2x)
Coil 1 24
8x Coil 8 17
820

Enter SW6 8A
+ SW7 7C
SW8 7B
- SW9 7A
Back GND 1A
A2 1B
A1 1C
A0 2A

VG Connector

The attached I/O-Board is connected via USB to a reserve Alien mainboard, also powered with 12V. After booting up, the cabinet board (IO0) should be detected and respond to the switch signals. It is possible to enter all settings and test menus, allowing coil, lamp, switch and sound tests as well as software updates.

The coil tests C-1 to C-8 are especially valuable, as the coil switches fail most often (C-4 is unfortunately missing).

The power switches are obviously not controlled by the uC as they are always on – even during a reset or with a (simulated) open coin door.