PLATYPUS

IoT Monitoring and Control

This suite of hardware comprises a Raspberry Pi Pico W-based ESPHome main board and a set of stacking daughter boards that support a range of sensor inputs and control outputs appropriate for the monitoring and control of remote equipment, such as a community radio station's control room or transmitter site.

One or more ESPHome stacks can be connected to a HomeAssistant IoT management base station.

The design is modular and individual boards are stackable.

An Extender board is provided so that stacks can be split into two parts. Alternately, split stacks can be joined with an IDC cable. Cabling to boards using SPI should be kept as short as possible and the SPI frequency kept modest (1MHz) for reliable operation.

While all required sensor and control boards may be stacked on one ESPHome main board, creating several stacks for specific purposes may make more sense for power supply, redundancy, maintenance or operational reasons.

Specific monitoring hardware is included for RVR radio transmission equipment, specifically the TEX150 series of FM transmitters and the PRTL-LCD/RXRL-LCD series of RF studio transmitter links.

The information in this manual is current for:

- Raspberry Pi Pico W – only versions with the CYW43455 WiFi chip are currently supported (Nov 2025).
  The Pico 2 W has no formal support at the time of writing (Nov 2025).
- HomeAssistant 2025.11 (HAOS 16.3)
- ESPHome Builder 2025.11

As both HomeAssistant and ESPHome have rapid update cycles, with bug correction based on user feedback, updates should be carefully considered and tested before being applied to the production platform.

Implementation and operation instructions for HomeAssistant and ESPHome are not duplicated in this documentation and community support are available at:

- https://www.home-assistant.io/ and https://community.home-assistant.io/
- https://esphome.io/ and https://community.home-assistant.io/

The repository for this project is: https://github.com/palmerr23/ESPhomeMonitor

- Schematics and board layouts
- Gerber files
- Documentation

V1.0 Nov 2025

Contents

Base Station and Satellite

The following components are used in this implementation from among the many available on the ESPHome and HomeAssistant platforms.

- Raspberry Pi running HomeAssistant (HAOS) OS.
- Remote control, monitoring, configuration and updating of HA and ESPHome devices.
- TailScale VPN for remote access.

- Raspberry Pi RP2040 Pico W running ESPHome firmware (Pico 2 W is untested).

Sensors and Actuators

- See ESPHome.io for all supported devices.
  - Analogue – Pico ADC pins and MCP3008 SPI ADCs.
  - Digital input and output – PCA9554 series I2C bus expanders.
  - SHT4x temperature and humidity sensors (I2C).

- See HomeAssistant.io for all supported devices
  - USB webcams (FFMPEG).
  - Some IP cameras with ONVIF compatibility (some cameras advertising ONVIF compatibility have failed to register).
  - Remote access using TailScale VPN

ESPHome Stack Overview

General

- Flexible configuration to suit different needs
- Multiple stacks supported by one HomeAssistant hub on each wireless LAN.
- Flexible connector options:
  3.81mm pitch pluggable terminals (Kefa KF2EDG or compatible)
  IDC cable
  D-sub (for RVR equipment) connectors.
- Single 5V @ 1A supply.

Main Board

- Pico W running ESPHome OS.
- WiFi connection to HomeAssistant base station.
- 3 channels of peak indicating analogue inputs 400mV p-p, or greater, FSD. Single-ended or pseudo-differential inputs.
- QWIIC connector and pin header for I2C_0.
- Analogue (filtered PWM) 5V output.
- Expansion connector for stacking or daisy-chaining boards.

Analogue Input Boards

- Eight single-ended analogue channels 3.3V, or higher, FSD.
- Two connector options:
  - Pluggable 3.81 terminals
  - 12-pin IDC header (3.3V and 5V power)
- QWIIC connectors and pin headers for primary and secondary I2C buses (I2C_0 & I2C_1).
- Four analogue boards (including RVR) maximum, in each stack.

Analogue Input Board (RVR-specific)

- Eight analogue channels 3.3V, or higher, FSD (set to 4V FSD).
- 6 connected to RVR-compatible DB-15 female connector.
- Jumper from Pin 12 to A1 analogue input for STL MPX signal.
- QWIIC connectors and pin headers for primary and secondary I2C buses (I2C_0 & I2C_1).
- Four analogue boards (all types) maximum, in each stack.

Digital Boards

- Digital input and output boards use PCA9554 or PCA9554A chips.
- Up to a total of four boards of each chip type can be used in a single stack.

Digital Input Board - Isolated

- Eight opto-isolated AC inputs (3.3V-12V) with low drive current requirement.
  Higher input voltages supported with external current-limiting resistors.
- Two connector options:
    - Individual 3.81mm pluggable terminal pairs
    - 16-pin IDC connector (with optional isolated 5V power).
- QWIIC connectors and pin headers for primary and secondary I2C buses (I2C_0 & I2C_1).
- I2C addresses vary across the compatible chips.
- Four digital boards of a chip type supported in each stack.

Digital Input Board (non-isolated)

- High impedance (10k) inputs (3.3V-12V).
- QWIIC connectors and pin headers for primary and secondary I2C buses (I2C_0 & I2C_1).
- I2C addresses vary across the compatible chips.
- Four digital boards of a chip type supported in each stack.

Digital Output Board

- Four SPDT relay outputs (G5V: 1A @ 24VDC), with bypass for external power relays.
- Four opto-isolated outputs.
- Relays and optos may be bypassed if non-isolated connections are acceptable.
- QWIIC connectors and pin headers for I2C_0 & I2C_1.
- Four digital boards of each chip type supported in a stack (I2C addresses vary across the compatible chips).

Extender Board

- Two back-to-back stacks.
- Alternate 5V supply input.
- Alternate 3.3V regulator for B-connector.
- I2C connectors for I2C_0 & I2C_1.

* The Mains Power Board and Serial Board have not been extensively tested.

Case

- The modular 3D-printed case comprises
    - Base with cable management bar and mounting flanges (4mm screws).
    - One middle section per module
    - Top section for Main Board (with extra clearance)
    - 3mm laser-cut lid with SHT40 environmental sensor mount

Cover plates

- Each module has a 2mm laser-cut side cover plate.
- The cover plates fit into slots in the case.

Warnings

- Updates should be carefully considered before being applied to HomeAssistant or ESPHome as breaking changes may have been introduced.
    - ESPHome Builder and HA updates should only be applied when full testing of the results is convenient.
    - A HA backup should be performed before any HA update.
    - It is recommended that auto-updates are NOT enabled for add-ons.
- While some inputs and outputs are opto- or relay-isolated, potentials more than 48V different from the board's ground plane should be avoided.
- Beware fouling the board above if the main (CPU) board is not mounted at the top of a stack.
- When connecting multiple stacks using an IDC cable, care should be taken to ensure correct orientation. Incorrect orientation will connect 5V to GND (pins2 & 4, 27 & 29).
- When selecting *output* components, consider the start-up behaviour of the ESPHome controller and the RP2040 for connected devices that should receive a known signal at power on.
- Excessive capacitance on the 3.3V supply rail can prevent the Pico starting up correctly. Four boards with 1uF each has proven reliable.

Earthing

Lack of a consistent 'technical ground' potential across studio or transmission equipment can cause issues when monitoring is introduced.

- Use opto-isolated digital inputs when ground potentials differ.
- Capacitor couple the ground (unbalanced) or negative (balanced) pin of audio signals being monitored.
- Consider using a separate stack, run from a different 5V supply, if issues persist.

Table 1: Function Matrix

Board	Inputs or Outputs	I2C	Other
Main (CPU)	3 x peak detectors (DB9-F) [ADC_0-2] 5V PWM outputs [GPIO 22]	I2C_0 (QWIIC + Header) [GPIO 4 & 5]	5V power(pluggable) 3.3V @ 250mA supply for other boards
Analogue Input (SPI) 4 boards	8 x inputs with gain control 12-pin IDC (with +3.3V +55 power) or 3.81mm pluggable terminal options	I2C_0 (QWIIC + Header) I2C_1 (QWIIC + Header) [GPIO 6 &7]	4 analogue boards maximum per satellite. MCP3008 ADC
Analogue Input (SPI) (RVR adapted) 4 boards	5 x inputs (DB15-F) 1 x input (pluggable) 2 x peak detectors (2 pin pluggable)		
Digital Input (I2C) 4 boards	8 x direct inputs 14_pin IDC or pluggable terminal options	I2C_0 (QWIIC + Header)	4 digital boards (input + output) per satellite. May be increased to 8 if PCA9554 and PCA9554A variants are both used.
Isolated Digital Input (I2C) 4 boards	8 x AC-input opto-isolated 14_pin IDC or pluggable terminal options Optional isolated 5V supply	I2C_0 (QWIIC + Header)	

Isolated Digital Output (I2C) 4 boards	4 x SPDT relay (3 pin pluggable) 4 x opto-isolated (2 pin pluggable)	I2C_0 QWIIC + Header	
Non-isolated Digital Output (I2C) 4 boards	8 x 3.3V digital outputs. 14_pin IDC or pluggable terminal options	I2C_0 QWIIC + Header	
Extender		I2C_0 (QWIIC) I2C_1 (QWIIC + Header)	Alt 5V power input (header or wired) Additional 3.3V regulator option for second stack.

Stacking PCBs

Stacking PCBs is enabled by mounting 30-pin female headers with long pins on the Expansion connectors of each board. The gap between boards is 12mm (13.6mm including the PCB), which is sufficient to clear the PCB-mounted D-SUB connectors but not the Pico when it is mounted in a header.

When stacking boards, the CPU board should be at the top so that WiFi transmission is unimpeded and so that the top of the Pico does not foul the board above when mounted on a header.

Metal enclosures or lids should be avoided.

Power consumption should be taken into account when stacking boards. The Isolated Digital Out board, particularly, has significant power consumption (480mA @ 5V) with all outputs engaged. If one or more Isolated Digital Output boards are used, the pluggable socket on the Main or Extended board should be used to supply power to the system.

The Pico is capable of supplying 250mA to other boards. If greater current is required, the Extender Board has an optional 3.3V regulator which can supply a second stack.

Boards using the SPI bus should be kept as close to the CPU as practical. The SPI clock speed can be reduced if this is not feasible.

Multiple stacks, sharing a CPU, can be joined using the Extender Board or a 30-pin IDC cable (male or female). Ensure that pin 1 on each stack correctly aligned.

3D printable case

The 3D printable case is designed for a single stack, not using the Extender board.

The bottom-most module should have short pins on the expansion header.

Modules are stacked using 3mm x 12+6mm tapped spacers.

The bottom module is mounted from below the case with 3mm x 8mm metric round head screws and uses a 3mm x 12mm spacer tapped at both ends.

The top module uses a 3mm x 15 + 6mm spacer and the lid is screwed to this, securing the case. It has sufficient clearance for the Main module with the Pico W mounted on headers.

Part substitution

- Main board pp amps are rail-to-rail, 5V single rail devices with low input currents. Gain-bandwidth product is not critical except in the peak detector circuits where the slew rate contributes to the rise time. Op amps with internal protection diodes protection should be used.
- Either PCA9554 and PCA9554A I2C Bus Expanders may be used in the digital input and output boards. Note that they have different I2C address ranges.
- Pico W: Pico 2 W microcontroller modules are not yet fully tested under ESPHome.

ESPHome Configuration

Information in the ESPHome documentation is referenced, but not repeated here.

Startup and Restart Behaviour

During the ESPHome power-on sequence the state of various peripherals is determined by the RP2040 startup behaviour:

- All GPIOs are reset to pull-down state (~50k ohms to GND).
- Soft pull-ups will not be operating on inputs.
- Opto-isolated outputs will be set to open-circuit.
- Peripherals (I2C, SPI, etc) are inactive.
- Analogue outputs (PWM) will be at 0V, although a start-up spike may occur.
- Analogue inputs will have undefined values until the input offset voltage has settled. (~20mS)

After an ESPHome software restart, until the firmware becomes active:

- The ESPHome documentation is unclear on the value of GPIO outputs (GPIO Switch) during start-up.
- Analogue outputs (PWM) will temporarily sink towards 0V.
- Peripherals (I2C, SPI, etc) are inactive and will be reset.

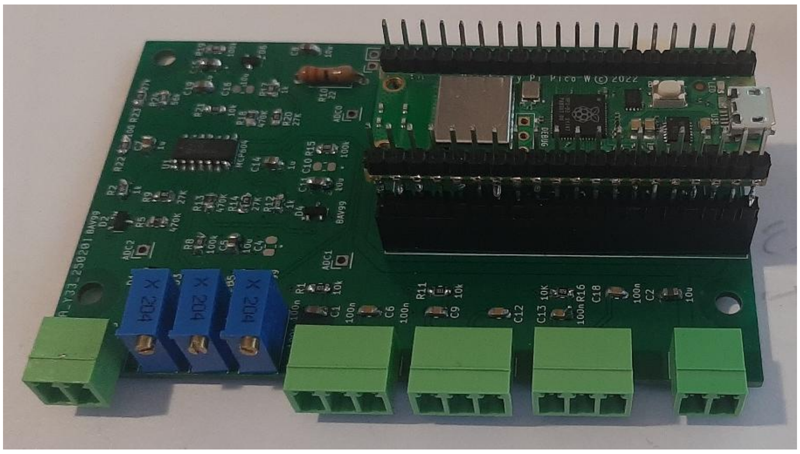
When HomeAssistant is unavailable:

- All ESPHome output states remain stable as there are no local ESPHome automations.
- Local ESPHome lambda code continues to run (e.g., serial port logging).
- ESPHome display devices will not be updated if the values are supplied by HomeAssistant.

ESPHome Main Board

This board should be placed at the top of the stack if the Pico W is mounted on top of the board. WiFi coverage is improved and the Pico, when mounted on headers, can foul the underside of the board above it on the stack.

Alternately, the headers can be placed on the rear of the board, and the pins mounted on the top of the Pico instead of underneath. This configuration is particularly useful for testing daughter boards.



Boards using SPI should be in the same stack (e.g., power and analogue input) as the CPU board or on a very short IDC extender cable. The default SPI data rate is 1MHz, which can be slowed down further if these boards behave erratically.

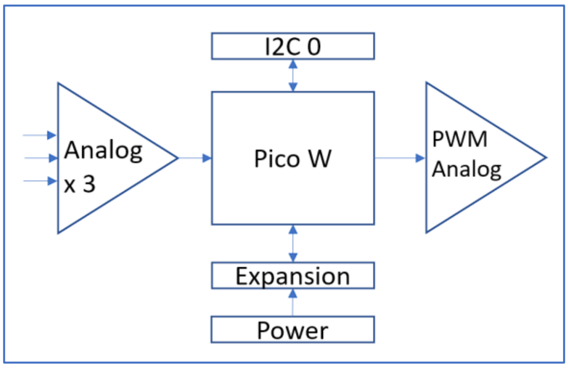
The main board hosts the Raspberry Pi Pico W as well as three overvoltage protected, pseudo-differential, peak detecting analogue inputs broken out to a 3-pin 3.81mm pluggable terminals. Their FSD is trimmable via potentiometers from 400mV p-p to more than 12V.

Voltages > 48V should not be applied.

A PWM signal is available via the 2-pin 3.81mm pluggable terminal next to the pots.

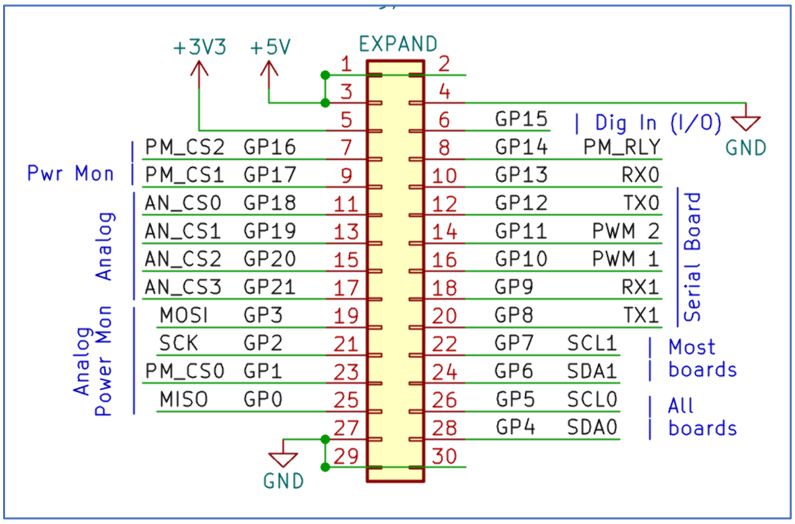
Power can be supplied via the Pico's USB connector or through the 2-pin 3.81mm pluggable terminal at the same end of the board as the Pico's USB connector.

The Pico W can provide 3.3V up to 250mA to power logic on other boards in the stack. If more current is required, the Expansion board offers a second 3.3V regulator to power a second stack of daughter boards.



Main Board Block Diagram

Expansion Header



Expansion header

Table 2: Expansion Header Pins

Pin	Signal	Uses	Pin	Signal	Uses
1	+5V Power		2	+5V Power	
3	+5V Power		4	GND	
5	+3.3V (250mA tot)		6	GP15*	Dig In I/O
7	GP16*	Pwr Mon CS2*	8	GP14*	Power Monitor Relay
9	GP17*	Pwr Mon CS1*	10	GP13, UART0 RX*	Serial
11	GP18	Analog Board SEL0	12	GP12, UART0 TX*	Serial
13	GP19	Analog Board SEL1	14	GP11	Opt. Serial PWM 1
15	GP20	Analog Board SEL2	16	GP10	Opt. Serial PWM 2
17	GP21	Analog Board SEL3	18	GP9, UART1 RX*	Serial
19	GP3, SPI0 MOSI	Analog, Power Mon	20	GP8, UART1 TX*	Serial
21	GP2, SPI0 SCK	Analog, Power Mon	22	GP7, SCL1	Analog, Extender
23	GP1	Power Monitor SEL0	24	GP6, SDA1	Analog, Extender
25	GP0, SPI0 MISO	Analog, Power Mon	26	GP5, SCL0	Digital In and Out,
27	GND		28	GP4, SDA0	Digital In and Out
29	GND		30	GND	

* GPIO 15 is uncommitted in this design.

* GP 0, 1, 8, 9, 12, 13, 14, 16 & 17 may be used for other purposes if the Serial and Power Monitor boards (planned developments) are not used.

Inputs and Outputs

I2C

Pin assignments are:

SDA 0 GP4
SCL 0 GP5

SDA 1 GP6
SCL 1 GP7

Pull-ups are present on the main board for both I2C buses.

I2C 0 is available on the main board both as a QWIIC (STEMMA QT / Grove / PiicoDev / etc) four-pin JST-SH 1.0mm connector and a four pin 0.1” header.

I2C 1 signals are available via the expansion header on the analogue and digital input boards and the extender board.

SPI

SPI0 is available via the expansion header. CS pins are managed via software.

The Analogue Input boards and Power Monitor boards use SPI.

GP0 MISO
GP2 SCK
GP3 MOSI
GP18-21 are allocated to CS signals for up to four analogue input boards.
GP1 is allocated to CS for the (future) power monitor board.

All SPI pins may be reallocated if not required.

UARTS
Both UARTS are presented to the expansion header. They are configurable to any modes and data rates supported by the Pico.

GP8 TX1
GP9 RX1

GP12 TX0
GP13 RX0

The pins may be re-allocated if UARTS are not required.

GPIO
GPIOs 15 is available on the expansion header and not used by any of the existing daughter boards – see Table 3.

Any other *uncommitted* pins on the expansion header may also be used as GPIO inputs or outputs. The constructor needs to take responsibility for protecting the Pico against excessive and reverse voltages. While the Pico's inputs do include some protection, it is strongly advised not to rely solely on this.

The digital input and output boards include protection as well as providing options for opto-isolation of inputs and relay or opto-isolation of outputs.

Analogue Inputs

Three peak-detecting analogue inputs are available using the Pico's ADC 0-2 (GPIO 26-28) with a basic FSD of 400mV, trimmable by on-board pots. These inputs translate to 0.0 – 1.0 in HomeAssistant. While the maximum count is 4095 (12 bits), the accuracy (ENOB) is around 9 bits (~512 counts, or 0.2% accuracy).

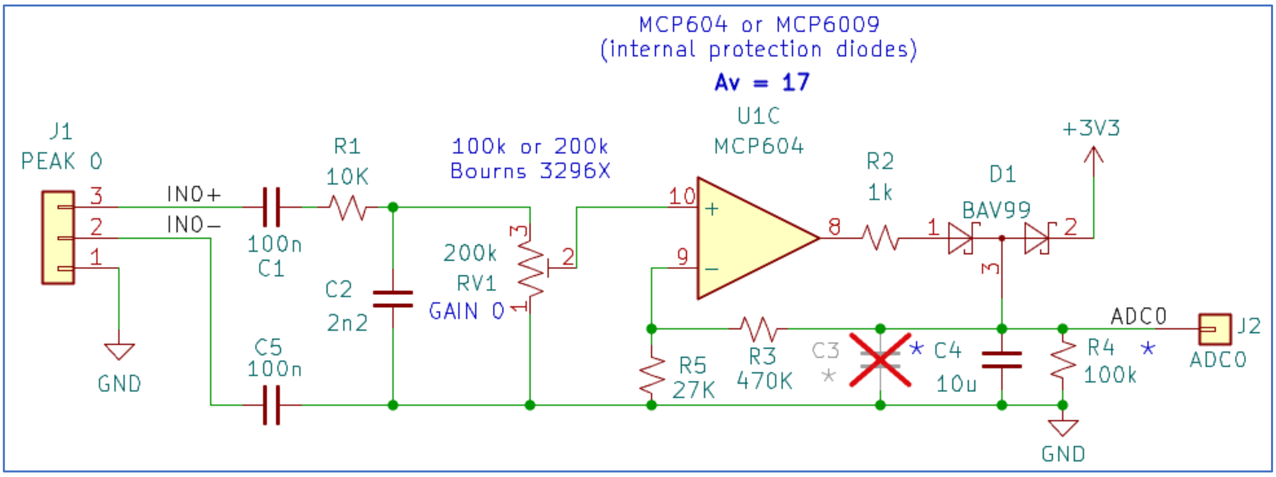
The inputs are pseudo-balanced and the sensitivity is controlled by the trim pot. The opamp gain is 17 which translates an un-trimmed 390 mV p-p op-amp input to 3.3V output.

If any channel is overdriven erroneous results may occur on other channels, particularly those with small input signals.

If single ended inputs are required, the remote device ground may be connected to the INx— pins or board ground, as desired.

The attack time constant is short (20mS) and the decay time constant is long (2 seconds). They can be changed by varying R2/C4+C5/R8, etc. The Pico's analogue inputs have ~100k ohm input resistance, so increasing R8 will have limited effect on the time constant.

R1/C1/C2 tailor the frequency response is tailored to an extended speech band: 200Hz to 5kHz.



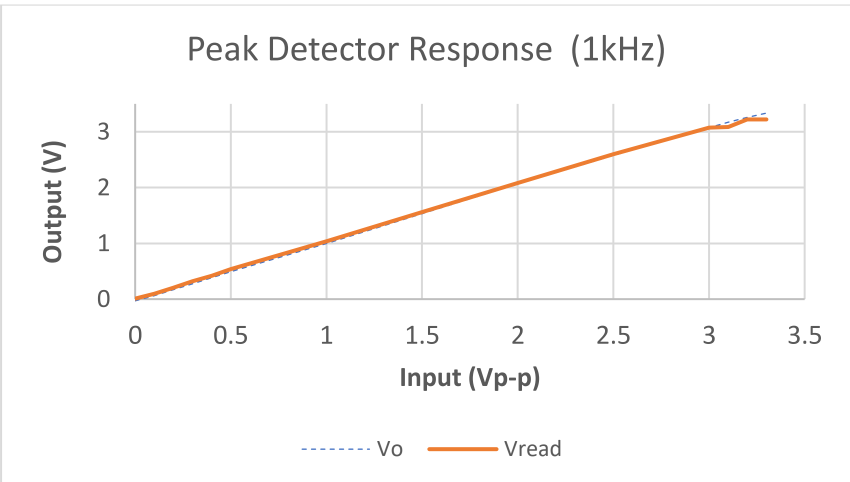
Example peak detector. C3 may be added to extend the decay time.

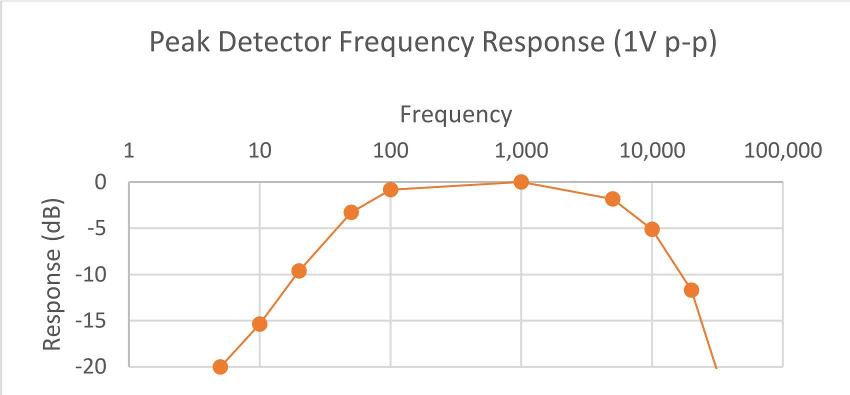
The op amps are rail-to-rail, 5V devices with low input currents. The slew rate (GBP) contributes to the rise time. The recommended MCP604 or MCP6009 op amps have internal protection diodes.

ESPHome documentation recommends that digital filtering is applied to all analogue inputs to avoid start-up misreads and signal noise. Specifically, the ‘sliding window moving average’ and ‘skip initial’ filters are recommended and included in their example configuration code.
https://esphome.io/components/sensor/#skip-initial

```
# Place in sensor: block
# Pico inbuilt ADC - Main board
  - platform: adc
    pin: 26
    name: "ADC0"
    update_interval: 10s
  - platform: adc
    pin: 27
    name: "ADC1"
    update_interval: 10s
  - platform: adc
    pin: 28
    name: "ADC2"
    update_interval: 10s
```

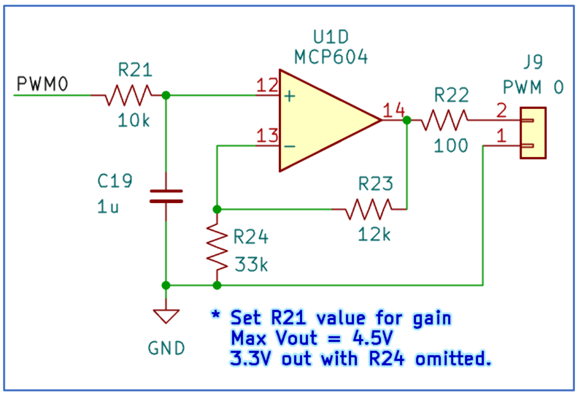
Peak Detector Response
The frequency response of the peak detector has been tailored to the speech band, approximating C-weighting.





Analogue Output

A smoothed PWM output is available from GPIO22 using a simple RC filter and amplifying buffer.



PWM output buffer

The maximum output level is 4.7V (VCC – 0.3V) with the values indicated for R32/R24 the output is 4.5V @ 100%. Omitting R24 sets the maximum output to 3.3V.

Setting the PWM frequency to 64kHz will provide 10 bits of accuracy and minimise output ripple.
At 64kHz and 50% duty cycle, the ripple is < 10mV p-p.

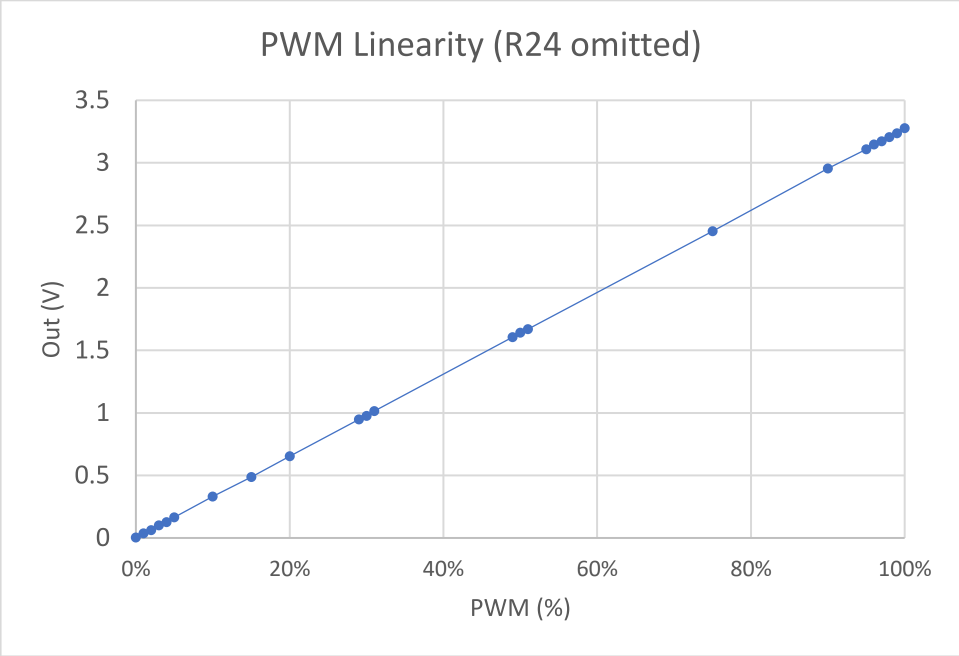
If lower ripple is required a 100n capacitor may be soldered across R15, providing a second filter pole.

The standard 'monochromatic light' platform is configured for linear LED brightness, so Gamma correction needs to be re-set to linear (1.0).

At start-up and restart, the signal will fall to zero.

```
# PWM output - Main board
output:
  - platform: rp2040_pwm
    pin: 22
    id: PWM_22
    frequency: 64000Hz
light:
  - platform: monochromatic
    output: PWM_22
    gamma_correct: 1.0 # align output with pwm %
    name: "PWM"
    id: pwm
```

PWM Performance



Deviation from linear response is < 7mV with a 3.3V FSD output.

WiFi

The WiFi interface is reserved for communicating with the HomeAssistant base platform.

WiFi credentials are set in the 'Secrets' section of the ESPHome Builder tab on HomeAssistant. No additional configuration is required.

Powering

The Main board consumes less than 20mA, excluding any consumption by devices attached to the I2C interface.

While the unit can be powered via the Pico USB socket for testing, it is recommended that an external regulated 5V supply be connected to the board PWR terminals. The required current can be determined from Table 3. There are additional 5V terminals on the Extender board.

The Pico is capable of providing 3.3V @ 250mA to other boards. If more current is required, a 3.3V regulator is available on the Extender Board which powers the second (B) stack.

Configuration

The Pico should be configured as described in the ESPHome online documentation. A straightforward approach is to follow the instructions at https://esphome.io/guides/getting_started_hassio which allows firmware loading and configuration of the Pico W from the HomeAssistant browser window.

After the board has been configured and installed using ESPhome Builder, it must be brought on line from the HA Integrations screen.

Table 3: Daughter Board Current Consumption

Board	**3.3V** * excluding connected devices	**5V** * excluding connected devices
Main	Can source 250mA	20mA
Analogue In	1mA	5mA
Digital In	5mA plus 10mA (all 8 optos active)	-
Digital Out	5mA	480mA (all 4 relays and 4 optos active)

* Add current drawn by I2C and other connected devices.

Extender Board

If side by side operation is required, the extender board has two expansion connectors rotated 180º and offset so that the two sets of boards are correctly aligned.

The board has additional 5V input pads.

An optional 3.3V regulator may be mounted on the expander board to power the ‘B’ stack. If this is configured, the Pico should be mounted on the ‘A’ connector and the links on the underside of the board adjusted.

Analogue Boards

A-D Conversion is provided by an MCP3008 8-input 10-bit SPI ADC.
https://esphome.io/components/sensor/mcp3008.html

Three versions are offered with different input connectors:

- 3.81mm pluggable terminals (trimmable on all channels)
- 12-pin IDC cable which also carries 3.3V and 5V power (trimmable on all channels)
- RVR equipment-specific with a DE-15 connector (trimmable peak detectors on channels 0 and 1)

SPI data rates are kept low (200kHz, default is 1MHz) to increase the effective ADC input impedance from 1k ohm to 10k ohm.

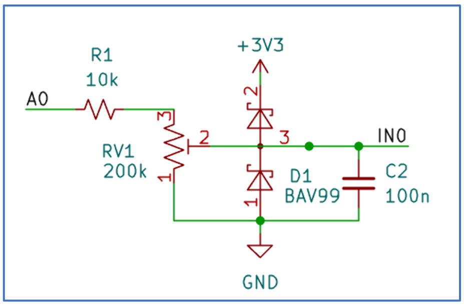
A-D Conversion is provided by an MCP3008 8-input 10-bit SPI ADC with 3.3v FSD.

CS jumpers are provided for up to four analogue input boards in a stack.

The native sensitivity of 3.0 V full-scale is decreased by the trimpot, and the 100n capacitor reduces transient sensitivity and provides a charge reservoir for the ADC sample and hold.

The ADC's internal diodes protect from under and over voltage. R1 keeps the protection diodes within their 250mA current limit for up to 25V when the potentiometers are at their maximum setting.

The maximum recommended input voltage (with reduced gain) is -5V to +48V.

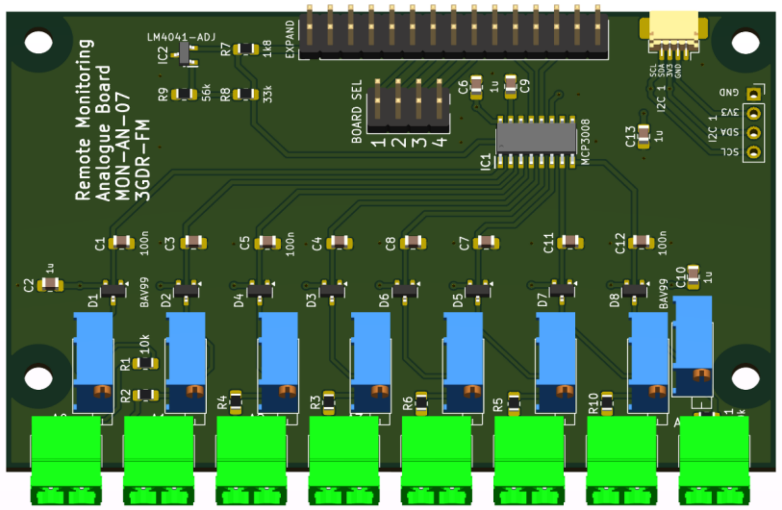


The LM4041-derived ADC voltage reference is set to 3.3V by resistors R10/R11.

Up to four analogue boards may be used in a stack, by jumpering CS to one of the dedicated expansion pins GP18-21 on the BOARD_SEL header.

Analogue Input Board (pluggable terminals)

This board has eight single-ended analogue inputs. The ESPHome implementation does not support MCP3008 pseudo-differential mode, as of November 2025.



All inputs have configurable voltage dividers, with a basic sensitivity of 3.3V FSD.

The 100nF capacitors provide a low impedance source for the ADC sample and hold and reduce sensitivity to transients.

The inputs have gain trimmer potentiometers accessible between the input connectors.

CS jumpers are provided for up to four analogue input boards in a stack.

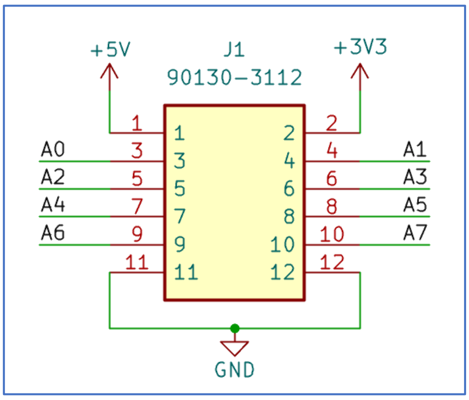
The inputs are presented as 2 x 3.81mm pitch, pluggable terminal blocks.

I2C
QWIIC connectors and pin headers are provided for I2C 1.

Configuration
See configuration for the RVR Analogue Input Board.

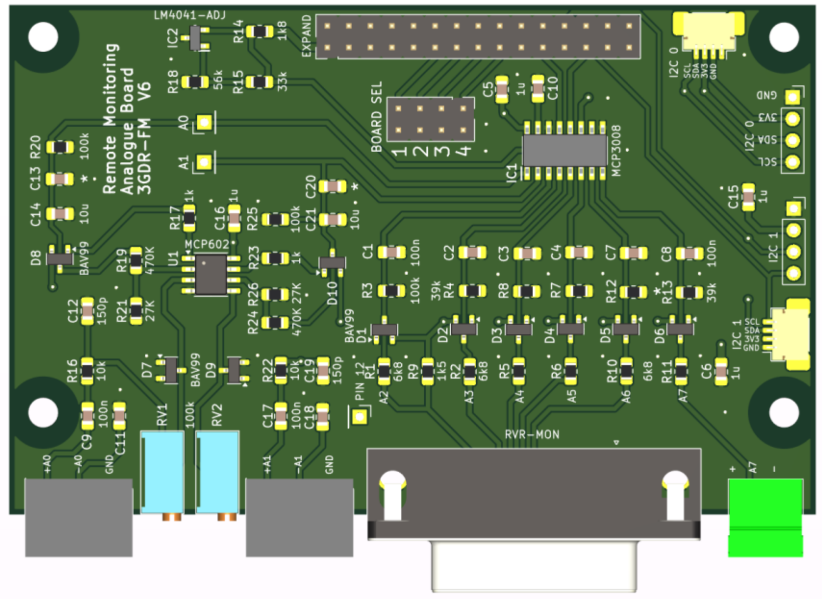
Analogue Input Board (IDC)
This board has the same circuit and configuration as the pluggable terminal option, with the inputs presented as a 12-pin IDC header.

3.3V and 5V supplies are provided to power any signal conditioning circuitry on the daughter boards.



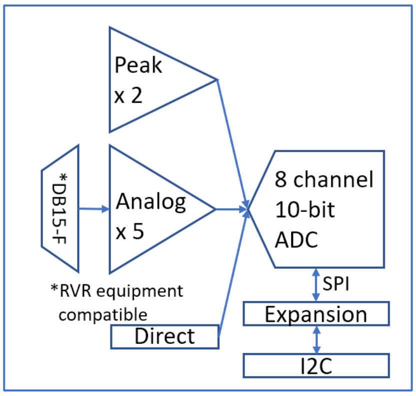
The IDC connector pin-out is compatible with the non-isolated digital input board.

RVR Analogue Input Board



This board has been designed specifically to interface with RVR broadcast equipment which has a fairly standard monitoring and control interface, presented as a DB-15F connector.

It has five direct-reading inputs tied to specific pins of a DB-15F connector. The remaining DB-15 pins are left unconnected as they have other functions on RVR equipment.



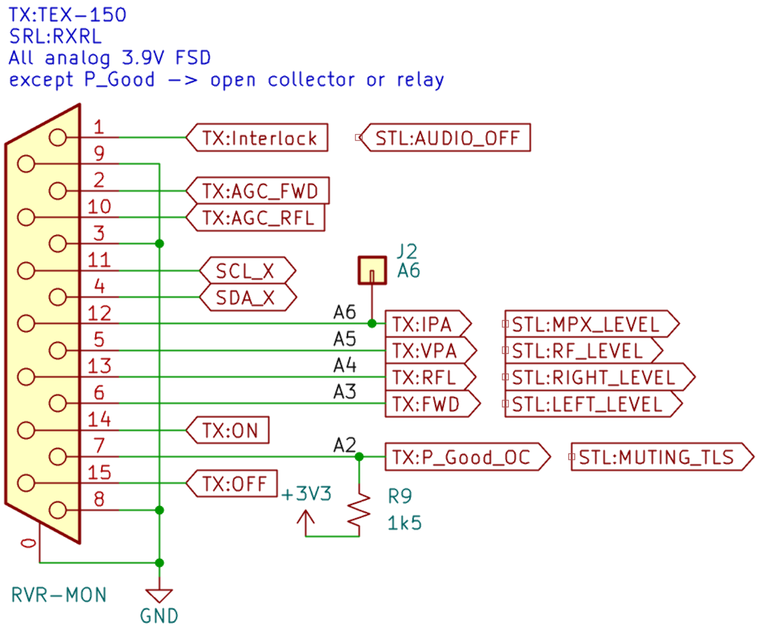
All inputs have voltage dividers with the default 22k gain resistors providing 3.9V FSD, compatible with RVR analogue monitoring outputs. The 100nF capacitors provide a low impedance source for the ADC sample and hold, and form a low-pass filter (F_0 = 250Hz) with the 6.8k input resistors

RVR devices provide an open collector output (PWR_GOOD on transmitters and MUTING_TLS on STLs) on Pin 7 on the DB-15 connector. A pull-up resistor is provided to the 3.3V rail.

Pin 6 is a static analogue signal (PA_CURRENT) on transmitters and a dynamic signal (MPX_LEVEL) on STLs. A patch point to is provided for this signal to be connected to the A0 or A1 peak detectors, if desired.

Of the remaining three inputs, A0 and A1 are peak-reading – with the same configuration as the Main Board.

A0, A1(peak reading) and A7 are presented as 3.81mm pitch, pluggable terminal blocks.



RVR equipment DB15 pinouts

Pin	RVR FM & STL Transmitter	RVR STL Receiver	Pin	RVR FM & STL Transmitter	RVR STL Receiver
1	Interlock (control)	Audio Off (control)	9	GND	GND
2	AGC FWD (control)	-	10	AGC RFL (control)	
3	GND	GND	11	SCL	SCL
4	SDA	SDA	12	IPA	MPX LEVEL
5	VPA	RF LEVEL	13	RFL	RIGHT LEVEL
6	FWD	LEFT LEVEL	14	TX On (control)	-
7	PWR_Good (OC)	MUTING (OC)	15	TX Off (control)	-
8	GND	GND			

- Signals in red are not connected.
- Analogue signals are 3.9V FSD, which represents 100% of the unit's set value in most cases.
- Pin 7 signals are OC, active low. On-board pull-ups are provided.

The ESPHome documentation recommends that digital filtering is applied to analogue inputs.
https://esphome.io/components/sensor/#skip-initial

Configuration

```
# Place in sensor: block
# Analogue input board
  # Channel 0 of the MCP3008.
  - platform: mcp3008
    unit_of_measurement: "%"
    reference_voltage: 3.0
    update_interval: 5s
    mcp3008_id: mcp0
    name: "AD_B0_V1"
    accuracy_decimals: 1
    id: v1
    number: 0
    # scale to 100% from 3.3V ref
    filters:
      - multiply: !lambda return 30;
 # Channel 1
  - platform: mcp3008
    reference_voltage: 3.0
    update_interval: 5s
    mcp3008_id: mcp0
    accuracy_decimals: 2
    name: "AD_B0_V2"
    id: v2
    number: 1
```

Auxiliary

QWIIC connectors and pin headers are provided for I2C_0 and I2C_1.

Digital Boards

The digital input and output boards are compatible with the PCA9554 (and PCA9554A) series of I2C bus expander chips. I2C addresses vary across the range. Four chips sharing the same base address may be used in any stack.

Each board has eight inputs or outputs numbered 0 .. 7.

Inputs or outputs may be logically inverted by code.

https://esphome.io/components/pca9554.html

Platform Configuration – all digital boards

```
pca9554:
  - id: dig_in_0
    i2c_id: i2c_a #I2C bus previously defined
    address: 0x38         // 0x38 .. 0x3F for Board 0 PCA9554A; 0x20 .. 0x27 for PCA9554
# additional input or output boards are added here:
```

Digital Input Boards

Input Configuration

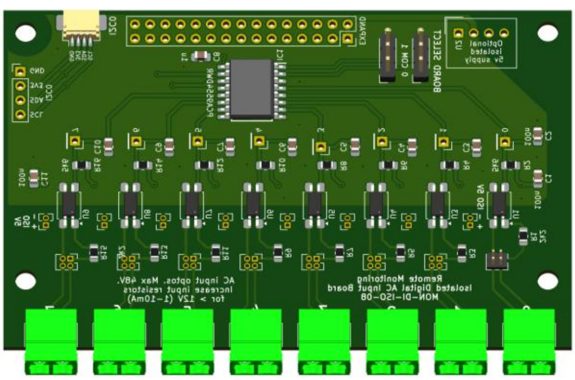
https://esphome.io/components/binary_sensor/

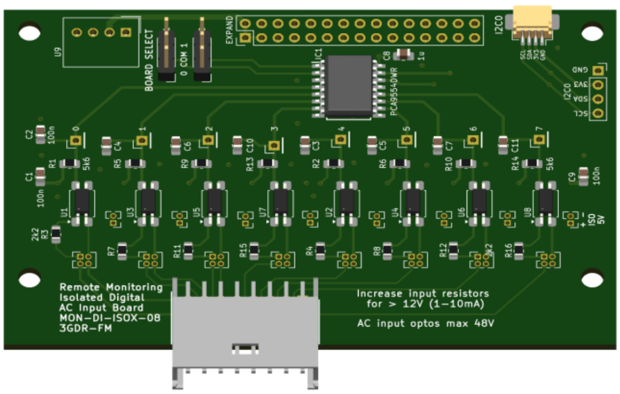
```
binary_sensor:
# on digital input board 0
  - platform: gpio
    name: "Input 0"
    id: in_0_0
    pin:
      pca9554: dig_in_0
      number: 0         # 0 .. 7
      mode:
        input: true
      inverted: false   # (as required)
  # additional inputs or outputs are added here
```

The ESPHome documentation recommends that digital filtering is applied to all inputs to avoid start-up misreads and signal noise. https://esphome.io/components/sensor/#sensor-filters

Digital Input Board (opto-isolated)

The digital input board has eight opto-isolated inputs which are presented as 2-pin 3.81mm pluggable terminal blocks or a single 16-pin IDC connector.





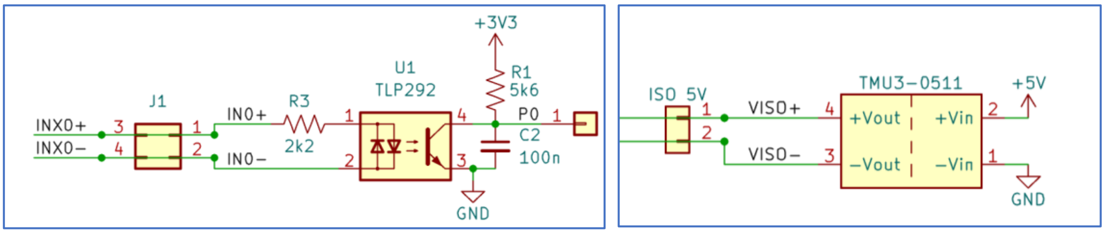
While the inputs are opto-isolated, potentials of more than 48V difference from the board's ground should be avoided.

Opto-isolated inputs accept either polarity at a source current of 1mA or more, using AC input opto-couplers with a high (> 100% @ 1mA input) CTR (TLP292, TLP180GB or similar). The PCB footprints have wide pads that can accept either 1.27 or 2.54mm pin spacings.

Jumper blocks are provided to allow flexible configuration of the inputs, along with an access to an optional isolated 5V supply on the IDC variant. The input jumper blocks are linked by default, using fine tracks on the top of the board.

For instance, these jumpers and the isolated power supply may be used to sense a pulled-up switch-to-ground signal. 2.2k pullup resistor is inserted from Viso+ to pin 1 & 3; and Viso- connected to pins 2 & 4.

Both rails of the isolated supply need to be connected to some point in the sensed circuit.



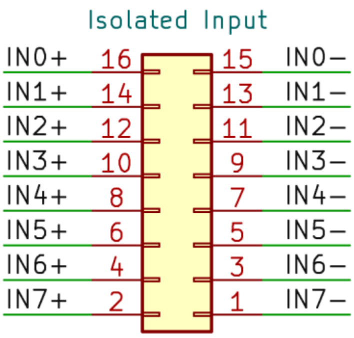
A representative opto-isolated input. The left panel is the default configuration.
The jumpers 1-3 &/or 2-4 may be broken to connect the isolated 5V supply to either pin.
Both rails of the isolated supply need to be connected to some point in the sensed circuit.

If an isolated 5V supply is not required this board may be used with input resistors up to 22k for 48V input.

TLP180GB (high CTR) optos reliably trigger with a LED current of 1mA. With the default 1K ohm input current-limiting resistors the inputs reliably trigger at 1.5V with either polarity inputs, compatible with 3.3 – 5V CMOS logic levels. Above 5V, the series resistance should be increased (either by changing the on-board resistors or by adding eternal series resistors) to ensure the opto's input current remains in the range 1-20mA.

Input	**Trigger voltage**	**Recommended input resistor (R3+ external) for 4-5 mA operating current**
3.3V or 5V CMOS logic	1.5V	1k
	3.3V – 5V	2.2k
12V		3.3k
24V		6.8k
48V		12k

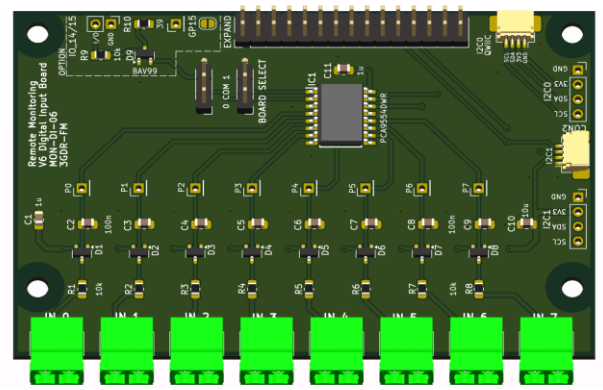
IDC Header

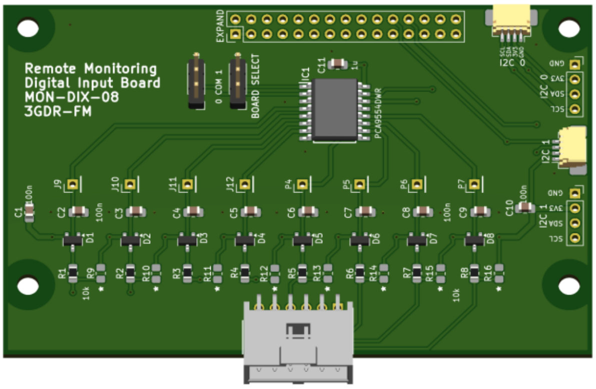


Digital Input Board (non-isolated)

The digital input board has eight diode-protected inputs and a direct GPIO connector mappable to GPIO 14/15.

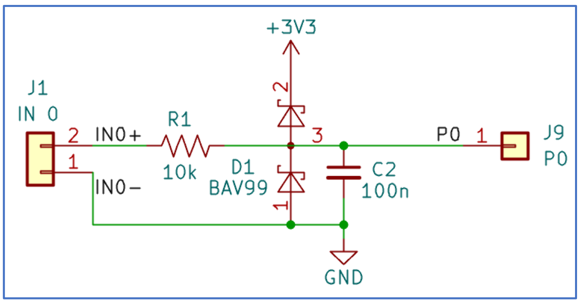
It comes with two connector options – individual 3.81mm pluggable terminals or a 12-pin IDC header with the same pinouts as the analogue input board.





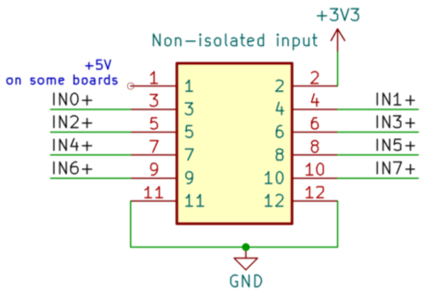
With the standard 1k ohm current-limiting resistors on the inputs, the inputs reliably trigger at 2V, and are compatible with 3.3V or greater logic levels. While the inputs are current limited and over-voltage protected, potentials of more than 48V difference from the board's ground should be avoided.

If reduced current inputs are required, the input resistors may be raised to 47k or greater, as the bus expander has CMOS inputs draw less than 100uA and trigger at 1V and 2.7V (0.3 and 0.8 Vcc).



A representative direct digital input.

IDC Header



The IDC connector pin-out is compatible with the analogue input board

Digital Output Board (Isolated)

The PCA9554 (or PCA9554A) is used for the digital output boards.

It is recommended that the ESPHome GPIO Switch platform is used instead of the bare GPIO Output.

https://esphome.io/components/switch/gpio

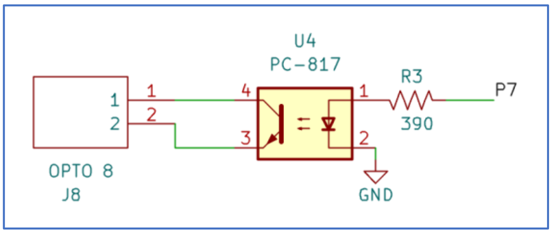
Eight digital outputs are provided, four as SPDT relay contacts and four as opto-coupler OC outputs.

The SPDT relays are Omron G5V-2_H1 (low current coil) equivalents, rated at 24V DC @ 1A or 0.5A @125V AC.

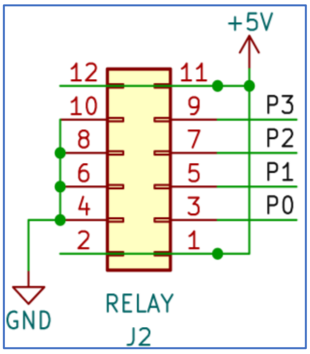
The open collector opto-coupler outputs are active low, and require current limiting resistors which should limit the sunk current to less than 20mA. The maximum V_{CE0} is 35V.

Voltages of more than 48V above or below the board's ground plane should not be applied to any terminal.

Outputs are presented as 2-pin x 3.81mm pluggable terminal blocks.



A pin header is also provided to directly drive more substantial relays or SSRs, from outputs 0 to 3. No driver transistor is used, so drive currents should be limited to 5mA. 5V power is available at pins 1, 2, 11 & 12.



Connector: 2x6 x 0.1" pin header

Specifications

Item	Specification	
All boards		
Connectors Digital, analogue & 5V power	3.81 mm pluggable terminals Two and three pin Kefa KF2EDG, Amphenol TJ, etc. 12 and 14-pin IDC sockets	
RVR equipment	DB-15F (2-row)	
Main		
Power supply	Micro USB or 3.81mm pluggable header 5V 50mA + daughter boards	
Pico 3.3V supply	Supply: Use Extender Board for greater current.	250mA max (all boards)
Peak-detecting analogue inputs	FSD: Linearity Rise time: Fall time:	400mV(p-p) or greater 1% of FSD or better 20mS 2Sec
PWM output	Range: Output: Ripple: Linearity;	0-100% 4.5V @ 100% 7mV p-p < 7mV deviation (3.3V output)
Expansion connectors	I2C_0 QWIIC and header pins 30 pin Expansion header	
Analogue Input (pluggable terminal or IDC)		
Number	A maximum of four analogue boards in a stack	
Purpose	General purpose analogue inputs.	
Connectors	Eight 2-pin pluggable connectors Or 12-pin IDC connector.	
Inputs	A0-A7	3.5V (p-p) FSD or greater. Max 50V p-p. 10k ohms or greater. Transient suppression capacitor Input level controls 10-bit resolution, < 0.5 bit INL/DNL
Expansion	I2C_0 I2C_1	QWIIC and pin header QWIIC and pin header
Power supply	5V ADC 3.3V supply	< 10mA (3.3V reference) LM4041 regulator (<1mA) from 5V rail
Analogue Input (RVR)		
Number	A maximum of four analogue boards in a stack	
Purpose	Optimised for RVR RF equipment (TEX-150 transmitter or RXRL STL)	
ADC Sensitivity Linearity	ADC	3.3V FSD 10-bit resolution, < 0.5 bit INL/DNL
Analogue Inputs	A0-A1 A2-A7 A2 A6	Peak detector. See main board specification. 3.9V FSD with specified gain resistors 6.8k ohms, 250 Hz LPF Pullup resistor (3.3V) for OC input. Additional patch point near A0/A1
Expansion	I2C_0 I2C_1	QWIIC and pin header QWIIC and pin header
Power supply	5V ADC 3.3V supply	< 10mA LM4041 regulator (<1mA) from 5V rail

Digital Input and Output Boards	
Number	A maximum of four Digital Input + Output boards in a stack Eight if a mix of PCA9554 and PCA9554A ICs are used.
Digital Input – Isolated (pluggable terminal or IDC)	
Connectors	Eight 2-pin 3.81mm pluggable connectors or 16-pin IDC connector.
Digital inputs	Opto-isolated (PC-817) Trigger: 1-20mA 3.3V - 12V compatible with specified (2.2k) input resistors.
Expansion	I2C_0 QWIIC and pin header I2C_1 QWIIC and pin header
Power supply	3.3V < 10mA
Digital Input – Non-isolated (pluggable terminal or IDC)	
Connectors	Eight 2-pin 3.81mm pluggable connectors or 14-pin IDC connector (includes 5V and 3.3V power)
Digital inputs	3.3V - 12V input (optional 10k pull-up resistors).
Expansion	I2C_0 QWIIC and pin header I2C_1 QWIIC and pin header
Power supply	3.3V < 10mA
Digital Output	
Relay outputs	SPDT Omron G5V-2_H1 (low power coil) 24v @ 1A
Expansion	I2C_0 QWIIC and pin header I2C_1 QWIIC and pin header
Power supply	5V < 150mA (all outputs active) 3.3V < 5mA
Extender Board	
Power	Alternate 5V input Alternate 3.3V (500mA) supply for EXPAND_B connector.
Expansion	I2C_0 QWIIC and pin header I2C_1 QWIIC and pin header

Tested I2C Devices

While any SPI or I2C-based sensors and control devices supported by ESPHome may be used, the design has been successfully tested with the following devices.

Temperature and Humidity Sensor (SHT40)

- The standard configuration is a SHT40 on I2C_0.
- A different ESPHome-compatible sensor, such as the BME680, could be used for a second sensor.
- Alternately, a second SHT40 could be connected on I2C_1.

BME680 Temperature, Humidity, Barometric Pressure and Gas Sensor

- Temperature, Humidity, Barometric Pressure and Gas Sensor
- Will detect Volatile Organic Compound (VOC) gases such as ethanol, acetone or ethane at moderate concentrations.

VEML7700 Ambient Light Sensor

- I2C

https://esphome.io/components/sensor/veml7700/

AM312 PIR Motion Sensor

- GPIO

https://omarghader.github.io/esp32-am312-pir-motion-sensor/

```
# AM312 connected to a GPIO pin and +5V
binary_sensor:
  - platform: gpio
    pin: 15  # Pin may be changed
    name: "PIR Sensor"
    device_class: motion
```

WiFi Webcams

Several ONVIF-compatible webcams were tested (with and without PTZ controls).

Some worked and some didn't!

https://www.home-assistant.io/integrations/onvif/

Troubleshooting

The HomeAssistant community forum is a useful place to search for problem resolutions on both platforms.

https://community.home-assistant.io/

The documentation is regularly updated for both platforms:

https://www.home-assistant.io/

https://esphome.io/

ESPHome

Symptom	**Cause**	**Resolution**
SPI bus function behaving erratically	Two devices sharing a CS pin	Board jumpers or CS pin definitions.
	SPI bus too long	SPI devices on same stack as CPU board. Slow the SPI data rate.
Poor WiFi coverage	Shielding from boards or enclosure	CPU board to top of stack. Use a plastic enclosure.
Device not appearing in HA Devices or Dashboards after compile and install.	Not enabled	Enable ESPHome device in Settings > Devices > HACS

Home Assistant

Issue	**Likely cause**	**Solution**
Dashboard does not update after changing device config or restarting device.	60 second delay for HA to update entities list.	Reload dashboard page in browser.
New ESPHome device not showing on dashboard or devices list.	Not enabled	Enable ESPHome device Settings > Devices > HACS
New entity not showing on dashboard after refresh.	Not enabled.	Enable on Entities screen menu
Digital input not reading reliably.	Opto current too low.	Reduce input resistance or increase voltage.
Analog peak not reading reliably.	Peak decays before reading.	Add config software filter to read more often and calculate max value over time. Increase C in peak detector circuit. 100uF is a practical maximum.
PWM not linear.	Gamma is set to default (2.8).	Set gamma_correct to 1.0