Swiss Pi Extensions

Hardware extensions

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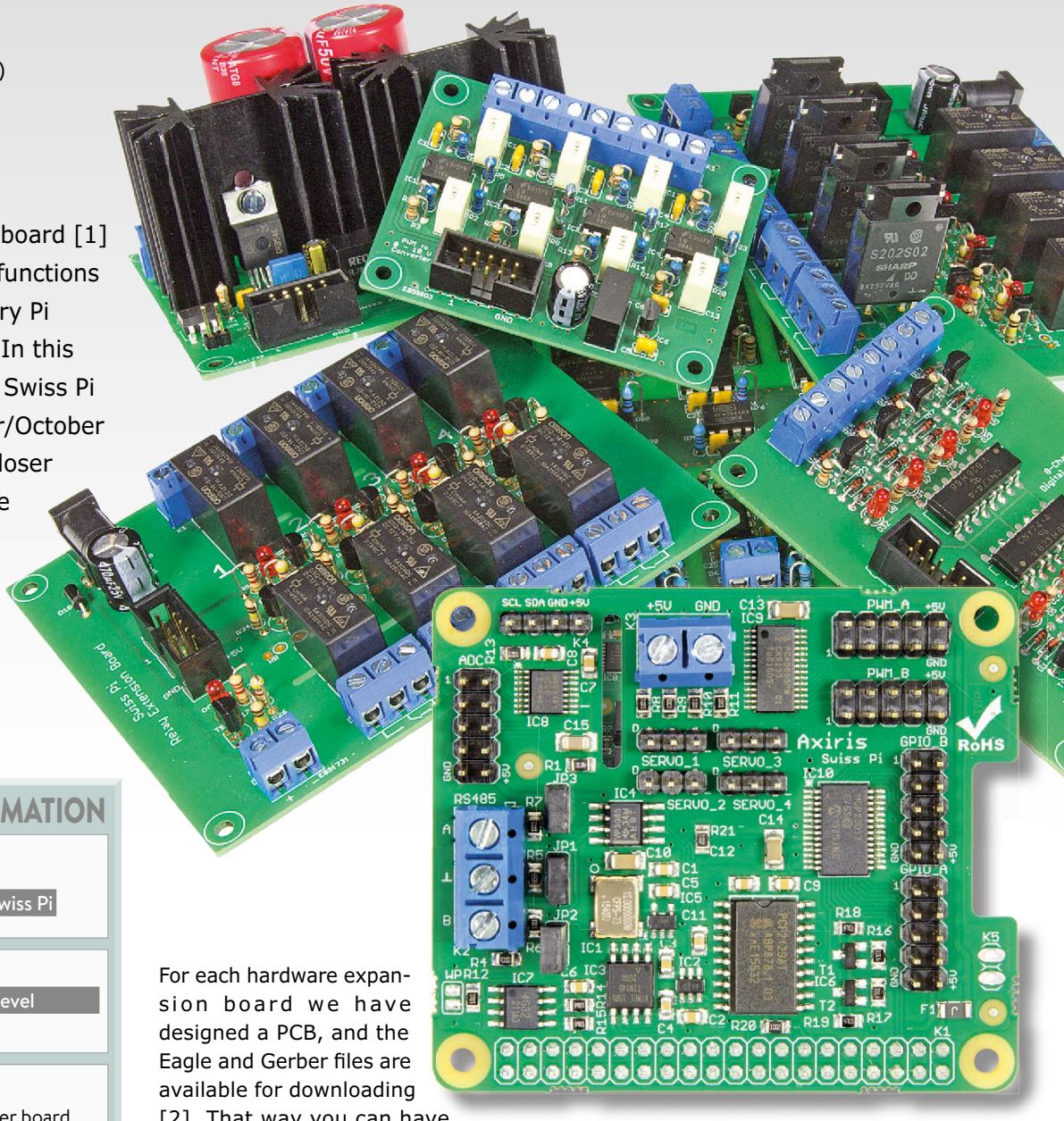


The Swiss Pi expansion board [1] provides a lot of useful functions for the popular Raspberry Pi single-board computer. In this second follow-up to the Swiss Pi article in the September/October 2016 issue, we take a closer look at several hardware extensions developed specifically for the Swiss Pi board.

PROJECT INFORMATION

Microcontrollers
Raspberry Pi | Swiss Pi

entry level
➡ intermediate level
expert level

0.5 to 1.5 hours per board

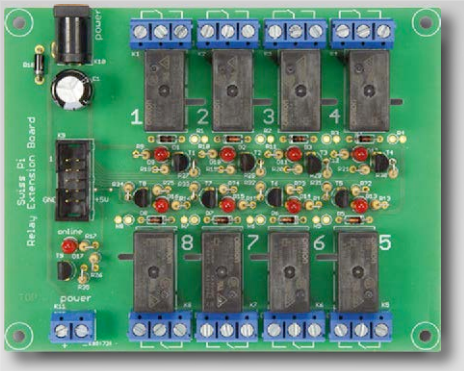
Soldering station with suitable solder tip

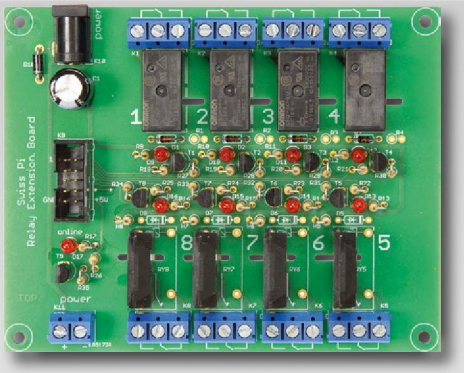
€25/£20/$30 to €50/£40/$60 per board

For each hardware expansion board we have designed a PCB, and the Eagle and Gerber files are available for downloading [2]. That way you can have the boards made by a PCB manufacturer of your choice. We have avoided the use of SMD components as much as possible, to make it easy to build the boards. If you want to go a step further and design something yourself, you can draw on these circuits for suitable inspiration. Naturally, these boards are not limited to use with the Swiss Pi; they can be used in a wide variety of environments. There is nothing to stop you from using them with your own microcontroller circuits or with an Arduino board.

Eight-channel relay board

The eight-channel relay board (**Figure 1**) uses relays from the Omron G5Q series. Sharp S202S02 solid-state relays can also be mounted on the board in place of conventional relays. Unfortunately those





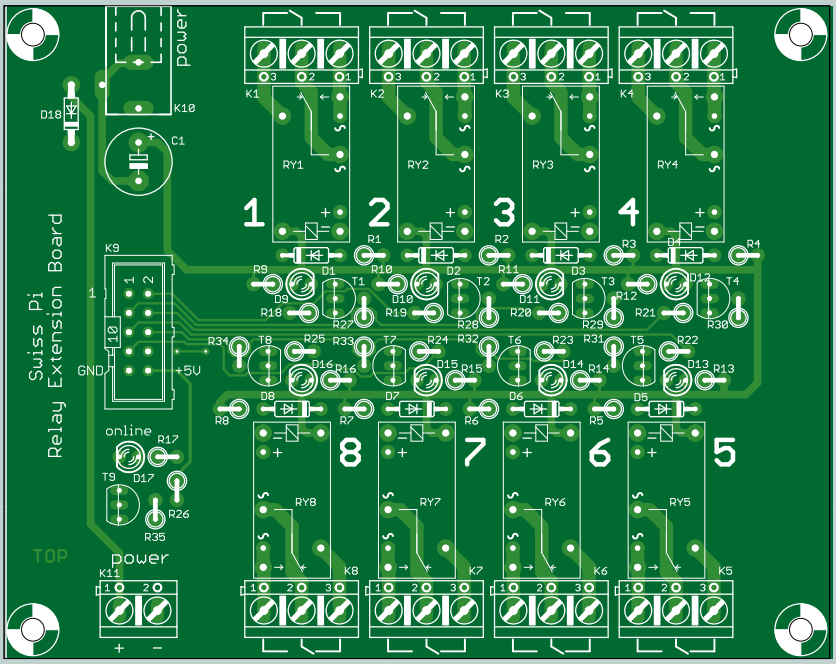
relays are no longer being made, but for now they are still readily available on eBay. There is no other direct alternative because the S202S02 is by far the only solid-state relay that fits within the footprint of a G5Q relay. The S202S02 only has an LED at the input, so a series resistor is necessary.

Despite their compact dimensions, the G5Q relays fulfill all requirements with regard to isolation distances and clearances for use with AC line voltage. By contrast, the pins of the solid-state relays are closer together, so we provided slots in the PCB to fulfill the clearance distance requirements despite this limitation. Although the G5Q relays can switch a maximum of 10 A, the actual current has to be limited to about 5 A due to the width of the PCB tracks.

The relays are driven by standard NPN transistors, and there is a status LED for each relay. There is also a power indicator LED on the relay board, which is lit

Figure 1. The eight-channel relay board is suitable for both conventional G5Q-SPDT relays and S202S02 solid-state relays.

COMPONENT LIST FOR RELAY BOARD



Resistors

R1–R8 = 560Ω*
R9–R17 = 2.2kΩ
R18–R26 = 4.7kΩ
R27–R35 = 100kΩ

Capacitors

C1 = 100µF/16V

Semiconductors

D1–D8 = 1N4148**
D9–D17 = LED, 3mm, red
D18 = 1N4007
T1–T9 = BC547B

Miscellaneous

RY1–RY8 = G5Q-14-EU 12DC or S202S02***
K1–K8 = 3-way PCB screw terminal block, 0.2" pitch
K9 = 10-pin boxheader
K10 = DC power connector, coaxial
K11 = 2-way PCB screw terminal block, 0.2" pitch

*Mount when using an S202S02 solid state relay
**Mount when using a G5Q relay
***Mount per channel as desired; for the G5Q relays a different supply voltage can be chosen if necessary. In that case it may be necessary to alter the values of R1–R17 and C1.

when the supply voltage is present on the Swiss Pi board.
If desired, you can also use G5Q relays with a different supply voltage rating, such as 24 V. However, in that case a number of resistor values will have to be changed.

Eight-channel digital input board

This extension provides eight galvanically isolated inputs with an input volt-

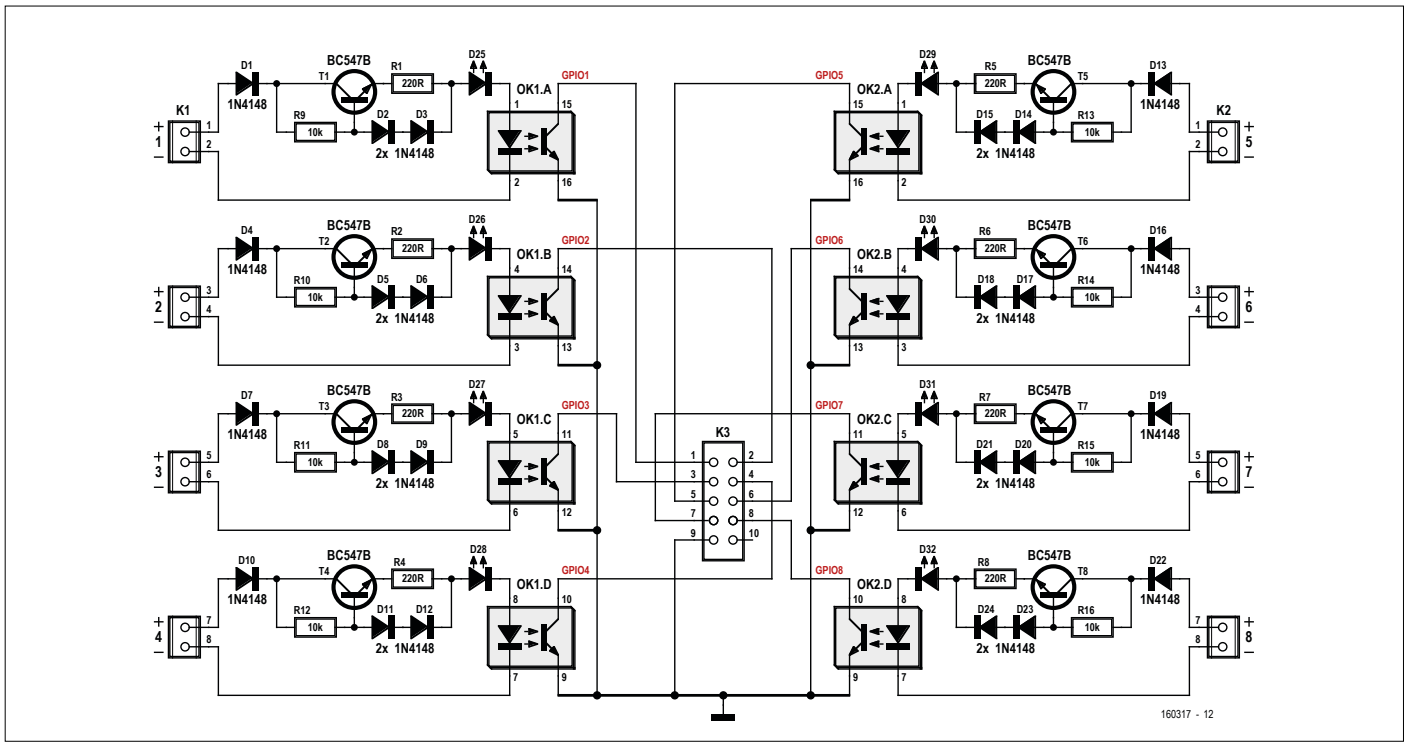


Figure 2. Eight galvanically isolated digital inputs are implemented with optocouplers.

age range of 5 to 45 V (see **Figure 2**). Galvanic isolation is provided by optocouplers. On the input side the current sources built around the BC547 transistors keep the current through the LEDs of the optocouplers and the indicator LEDs more or less constant, regardless of the input voltage. This current is equal to the forward voltage drop of two 1N4148 diodes minus the base-emitter junction voltage of the transistor, divided by 220 (the resistance value of R1–R8). The current through the 1N4148 diodes ranges from a few microamps to several milliamps over the input voltage range of 5 to 45 V. If you look at the characteristic curve of the 1N4148, you can see that this is precisely the region where the forward voltage is most strongly dependent on the forward current. As a result, the current supplied by the current sources is not truly constant over the entire input voltage range. In practice it ranges from 3 to 6 mA, depending on the input voltage.

If the voltage over the current source is reversed, the collector-emitter voltage of the transistor will be negative. However, the transistor will continue to operate as a low-grade NPN transistor with very low gain and a low reverse breakdown voltage. If the magnitude of the negative collector-emitter voltage rises above 6 V, the

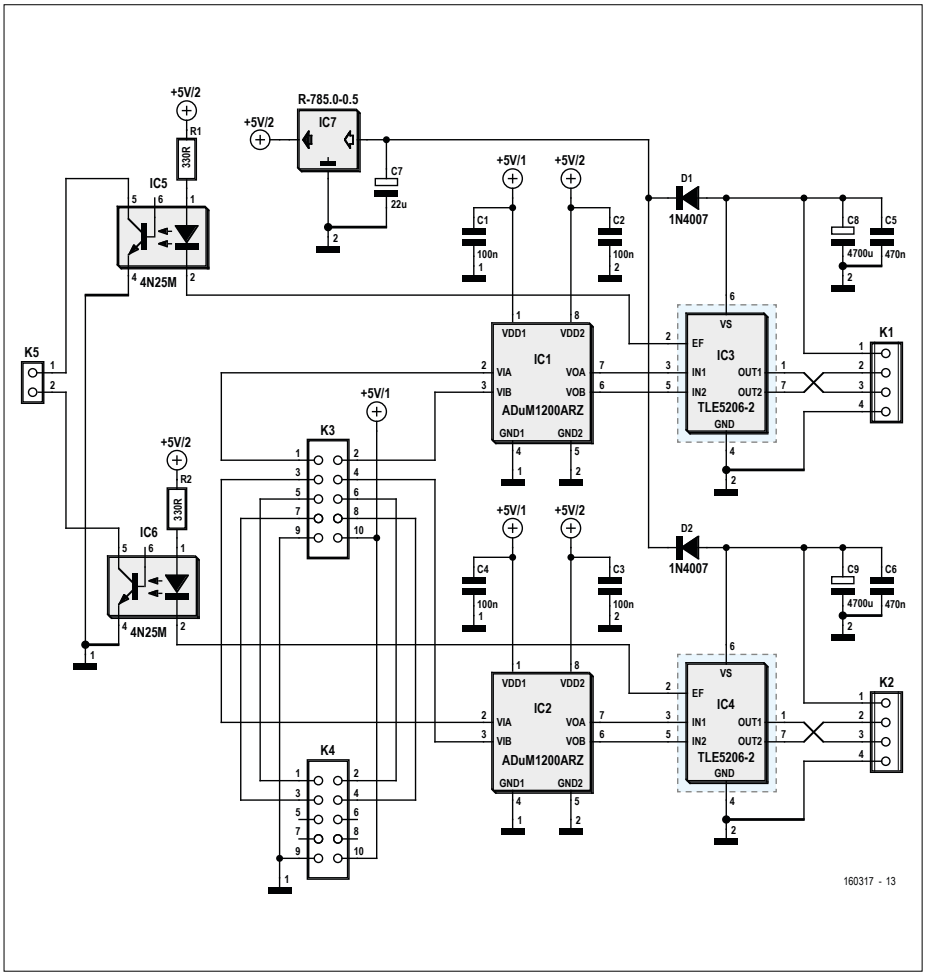


Figure 3. The galvanically isolated motor controller boards can be daisy-chained to drive up to eight DC motors (two per board).

COMPONENT LIST FOR DIGITAL INPUT BOARD

resistors

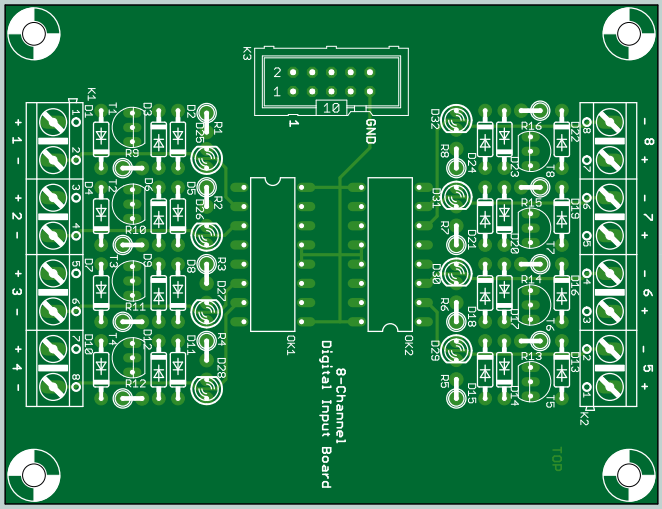
R1–R8 = 220Ω
R9–R16 = 10kΩ

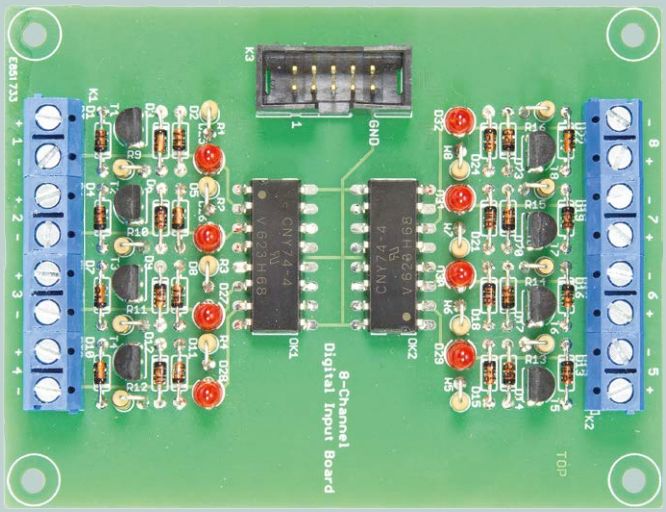
Semiconductors

D1–D24 = 1N4148
D25–D32 = LED, 3mm, red
T1–T8 = BC547B
OK1,OK2 = CNY74-4

Miscellaneous

K1,K2 = 8-way PCB screw terminal block, 0.2" pitch
K3 = 10-pin boxheader





transistor will start conducting and the current will only be limited by the 220 Ω resistors and the leakage currents of the indicator and optocoupler LEDs. To avoid potential damage to the LEDs, particularly with relatively high input voltages, an additional 1N4148 diode is included to provide reverse-polarity protection.
In the prototype we used red LEDs as indicators, but you can also use other colors. Bear in mind that this will have some effect on the input voltage range, especially the minimum input voltage.
On the Swiss Pi side the optocouplers have open-collector outputs. This means that the GPIO pins must be configured as inputs with pull-up resistors. When a voltage is applied to an input on the extension board, the corresponding GPIO input is pulled low (inverse logic).

DC motor controller

The DC motor controller board (**Figure 3**) can drive two DC motors independently, with a maximum operating voltage of 40 V and a maximum current of 5 A. The output stage of this board consists of two TLE5206-2 MOSFET H-bridge ICs. These ICs are especially easy to control and are protected against overcurrent and shorted outputs. The drain-source resistance $RDS_{(on)}$ is 0.2 Ω, so the power dissipation remains within reasonable limits. A drawback of this IC is that the switching time ("source on" time) can be as much as 15 µs, which is fairly slow. However, that is not a significant problem because the PWM controller of the Swiss Pi has a maximum upper frequency of about 1.5 kHz. This also means that the drive frequency is audible on the DC motor, especially at low PWM values.

To prevent noise and harmonics on the motor supply voltage rails from reaching the Swiss Pi and the Raspberry Pi, galvanic isolation is provided between the H-bridges and the Swiss Pi. For the PWM signals this is done using type ADUM1200ARZ digital isolators. These devices have two channels and much wider bandwidth than optocouplers. Unfortunately, they are not available in a through-hole version, but the 8-pin SOIC package is relatively easy to solder by hand. Conventional optocouplers are used for the optional feedback of error flag signals from the H-bridges.

The dual motor controller boards can

COMPONENT LIST FOR DC MOTOR CONTROLLER

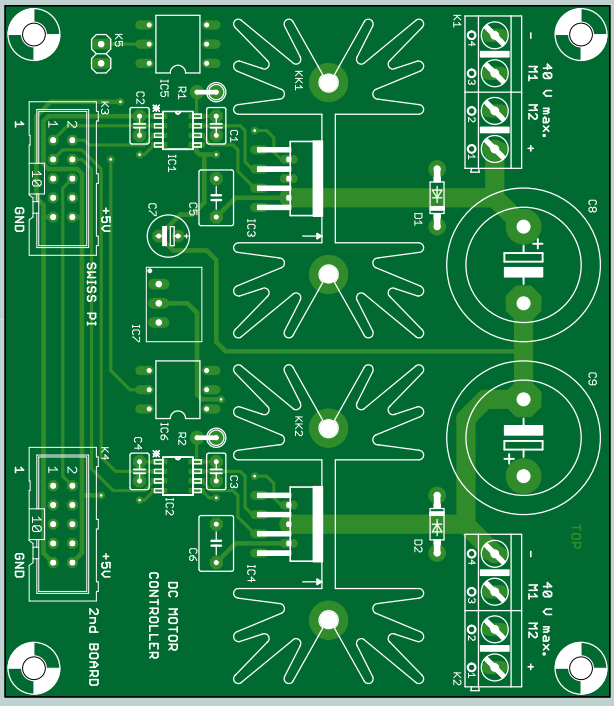
Resistors
R1,R2 = 330Ω

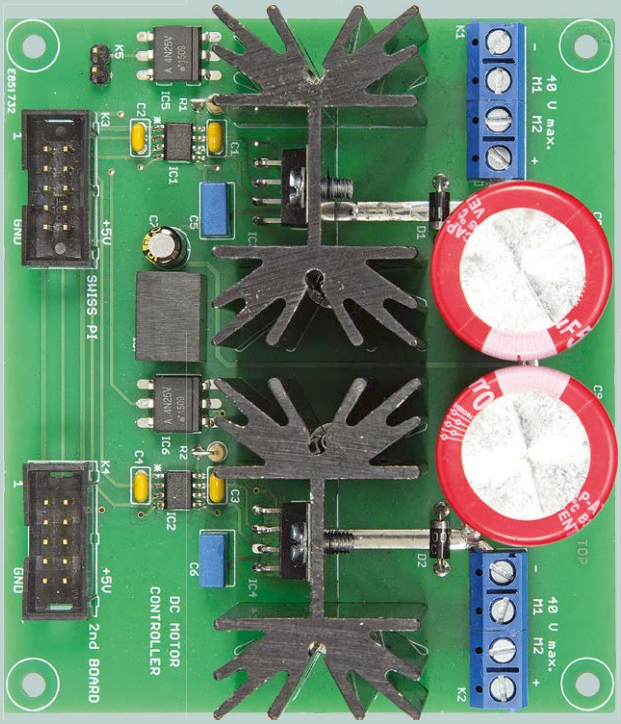
Capacitors
C1–C4 = 100nF
C5,C6 = 470nF/63V*
C7 = 22µF/50V*
C8,C9 = 4700µF/50V*

Semiconductors
D1,D2 = 1N4007
IC1,IC2 = ADUM1200ARZ
IC3,IC4 = TLE5206-2
IC5,IC6 = 4N25
IC7 = DC/DC converter SIP3, 5V/1A, 40Vin (e.g. Würth 173010542)*

Miscellaneous
K1,K2 = 4-way PCB screw terminal block, 0.2" pitch
K3,K4 = 10-pin boxheader
KK1,KK2 = heatsink, e.g. SK 129 38,1 STS from Fischer Elektronik (38.1 x 42 x 25 mm)

*These component values can be adjusted if the motor controller is used with voltages lower than 40 V. IC7 does not need to supply 1 A, but all available DC/DC converters with a relatively high input voltage rating (over 28 V) are 1 A types.





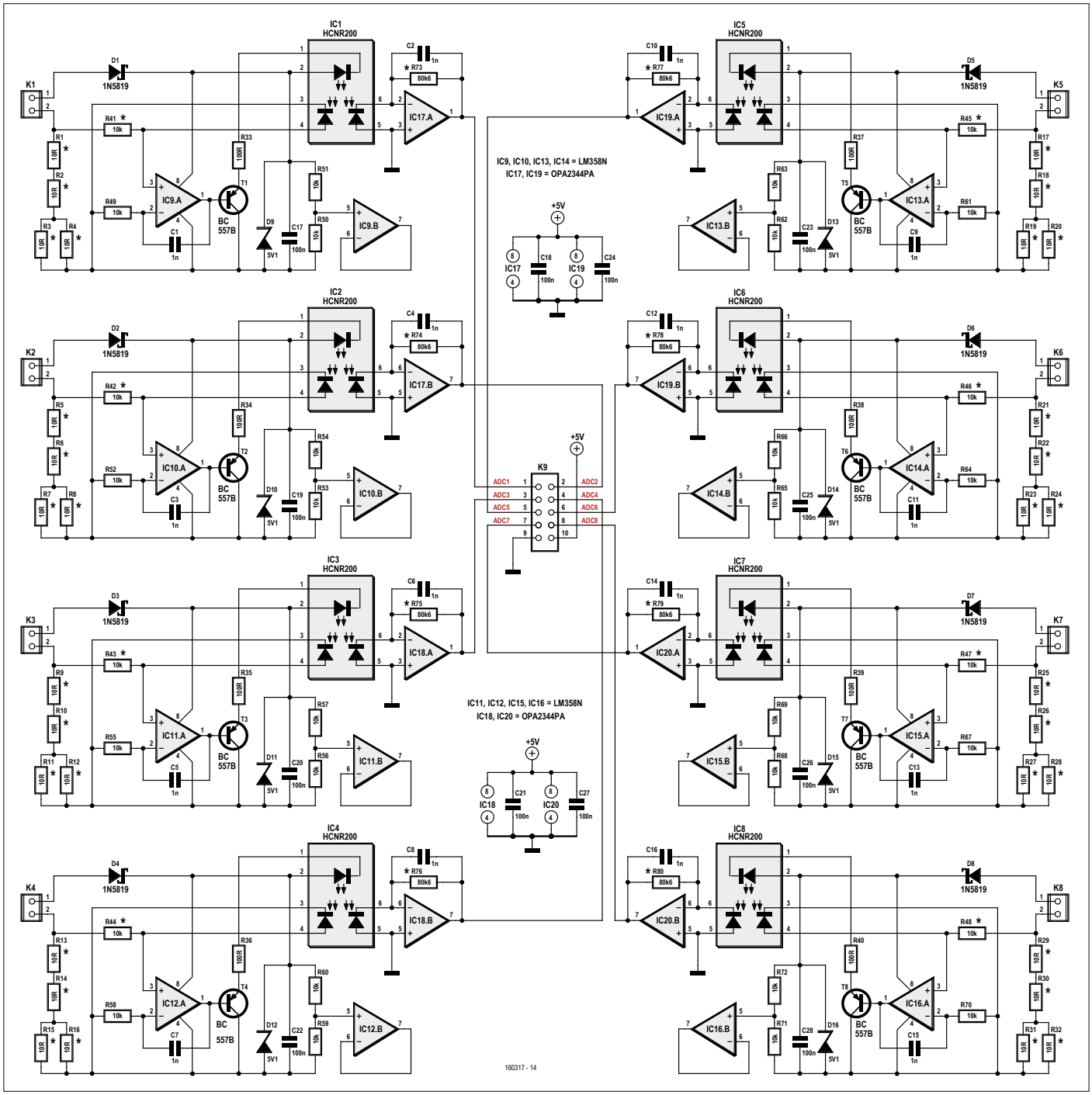


Figure 4. The schematic of the current loop interface board looks fairly large, but it actually consists of eight identical circuits.

be daisy-chained to enable a total of eight DC motors to be controlled with the Swiss Pi.

Finally, a DC/DC converter provides the 5 V supply voltage for the logic circuitry on the H-bridge side. If you want to use relatively high supply voltages, it is essential to choose a DC/DC converter that can withstand a 40 V input voltage.

Current loop interface

Current loop interfaces are still widely used in the industrial sector for reading sensors, despite the advent of digital alternatives. Current loops are simple and robust, and they have a long working range. Consequently, there are a lot of sensors available which use this technology.

The interface described here (see **Figure 4**) is built around HCNR200 linear optocouplers from Avago. The internal structure of these devices consists of two matched photodiodes and an LED. At the transmit end, one photodiode is used to provide feedback from the power emitted by the LED. The overall transmission characteristic is virtually linear because the current through the photodiode at the receive end is nearly the same as the current through the photodiode at the transmit end.

For this circuit we used a fairly direct copy of the typical application circuit on the Avago data sheet, with only a few minor changes. For instance, we replaced the LM158 opamps at the transmit end

COMPONENT LIST FOR CURRENT LOOP INTERFACE

Resistors

R1–R32 = 10Ω*
R33–R40 = 100Ω
R41–R48 = 10kΩ*
R49–R72 = 10kΩ
R73–R80 = 80.6kΩ*

Capacitors

C1–C16 = 1nF
C17–C28 = 100nF

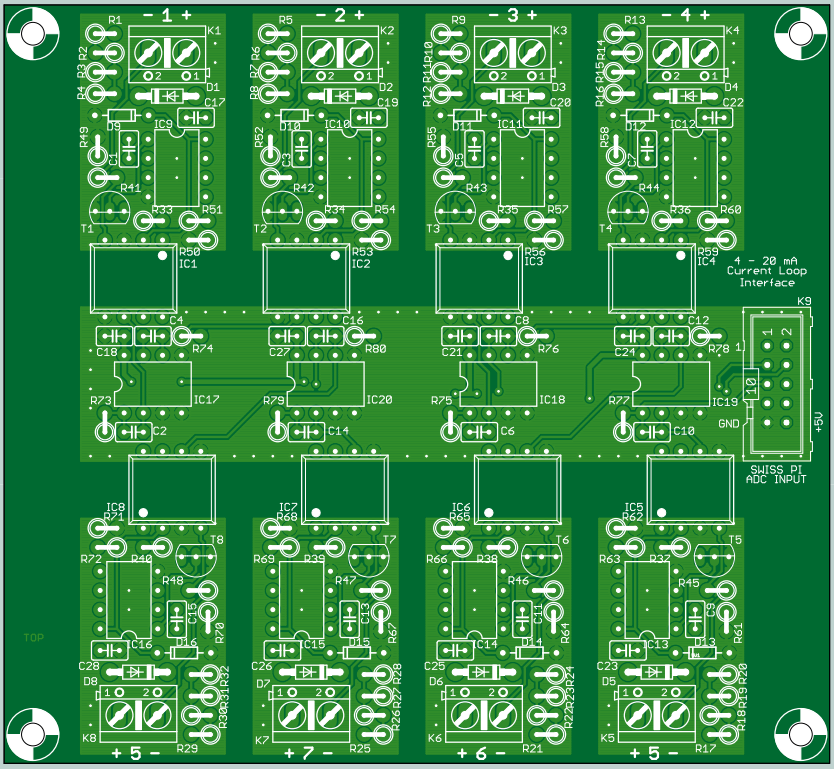
Semiconductors

D1–D8 = 1N5819
D9–D16 = Zener diode 5.1V, 400mW
IC1–IC8 = HCNR200
IC9–IC16 = LM358N
IC17–IC20 = OPA2344PA (LM6142BIN/NOPB)

Miscellaneous

K1–K8 = 2-way PCB screw terminal block, 0.2" pitch
K9 = 10-pin boxheader

*1% metal film or better



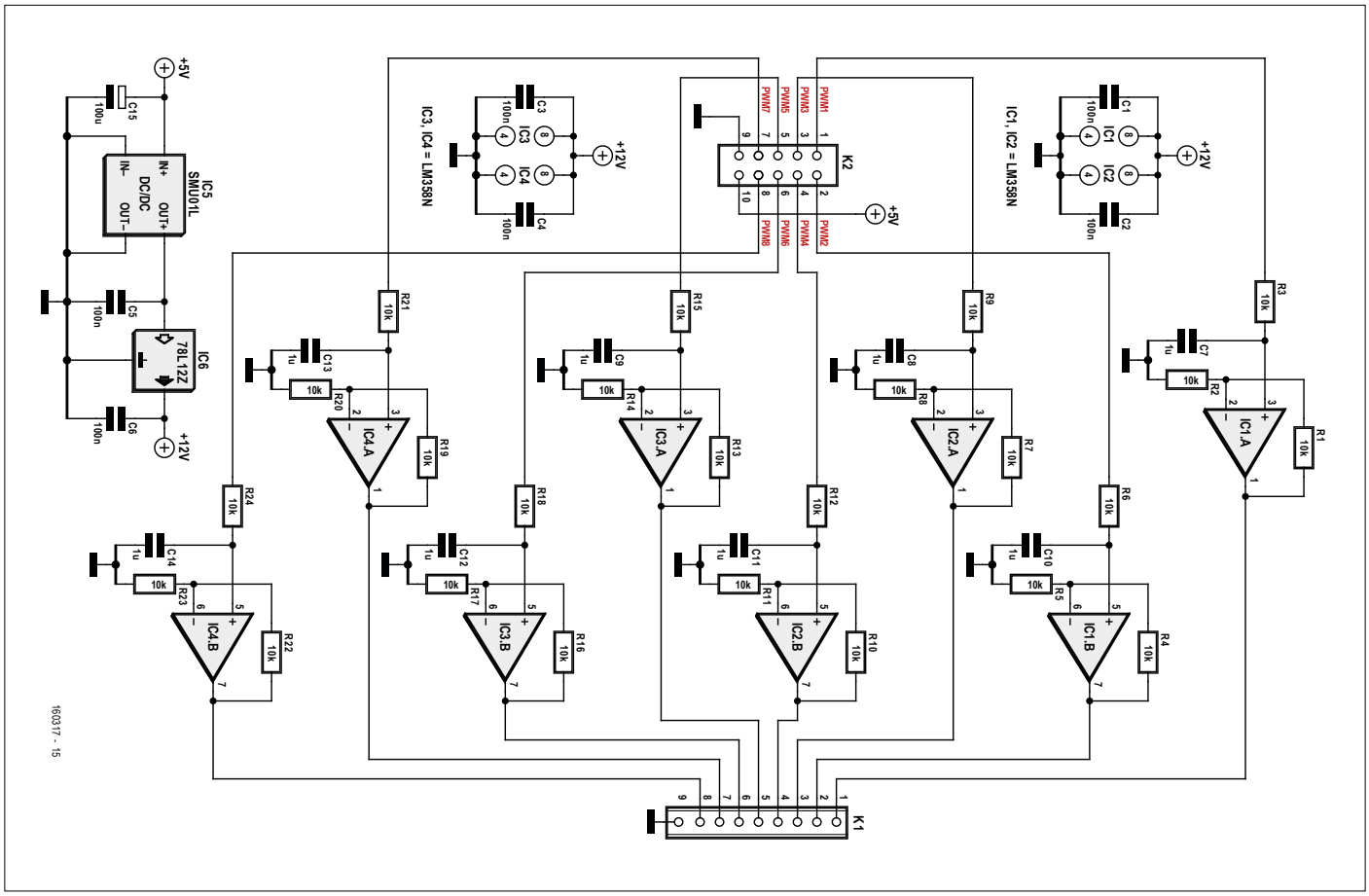
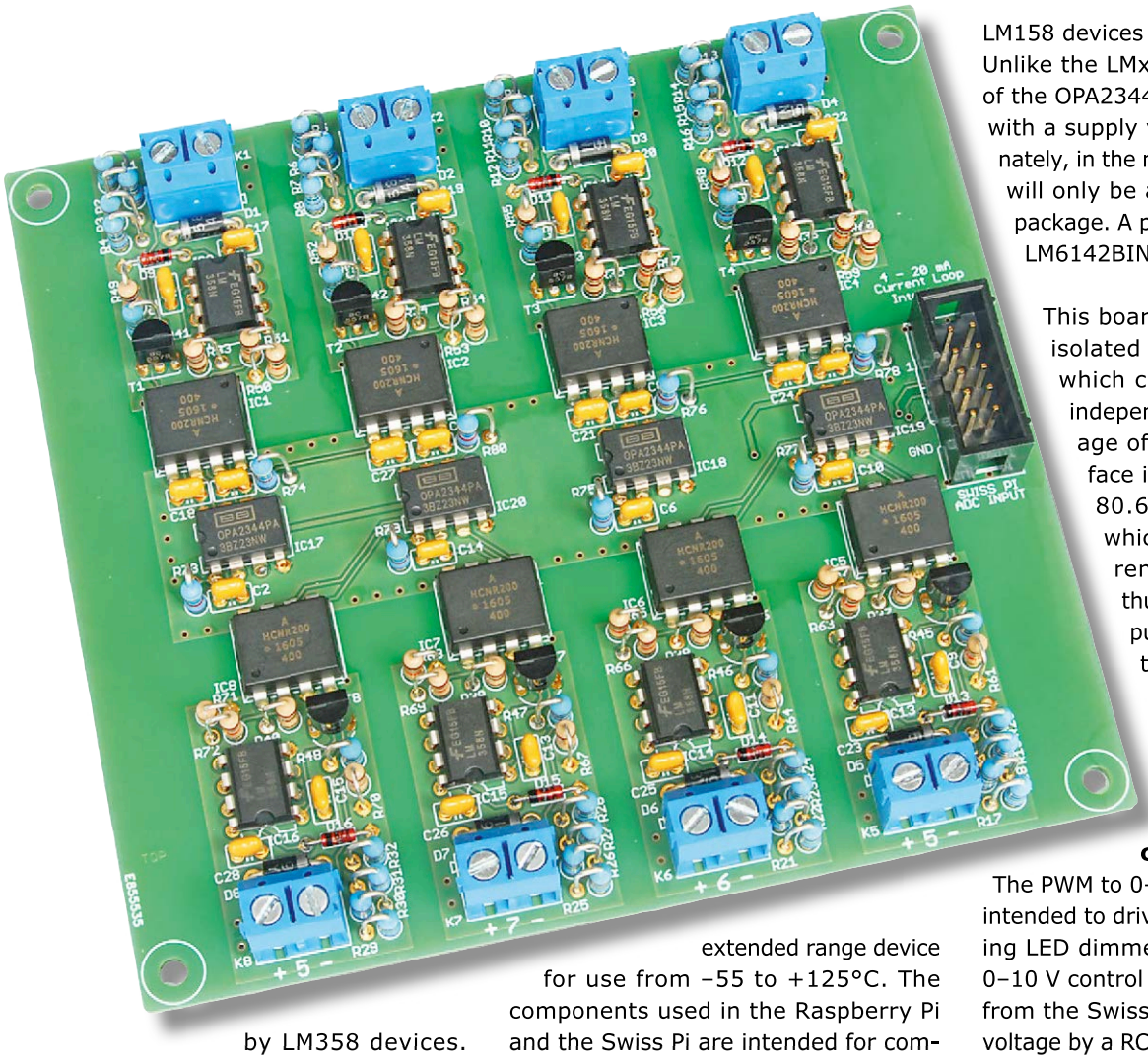


Figure 5. The PWM to voltage converter board generates 0 to 10 V voltage outputs from PWM signals.



by LM358 devices. They cost a lot less and are more readily available than the LM158. The main difference is in the rated temperature range of the opamps: the LM158 is an extended range device for use from –55 to +125°C. The components used in the Raspberry Pi and the Swiss Pi are intended for commercial use with a temperature range of 0 to 70°C. In that situation there is not much reason to use the LM158.

At the receive end we replaced the LM158 devices by OPA2344PA opamps. Unlike the LMx58 opamps, the output of the OPA2344PA can easily reach 4 V with a supply voltage of 5 V. Unfortunately, in the near future these opamps will only be available in the SOIC-8 package. A possible alternative is the LM6142BIN/NOPB.

This board provides galvanically isolated current loop interfaces which can be used completely independently. The output voltage of the current loop interface is equal to $I_{in} \times (25\ \Omega \times 80.6\ k\Omega)/(10\ k\Omega + 25\ \Omega)$, which is $I_{in} \times 201$. The current range of 4 to 20 mA thus corresponds to an output voltage range of 0.804 to 4.02 V, which is within the A/D conversion range of the Swiss Pi.

PWM to voltage converter

The PWM to 0–10 V converter board is intended to drive light dimmers (including LED dimmers), most of which use 0–10 V control signals. The PWM signal from the Swiss Pi is converted to a DC voltage by a RC filter, and this voltage is then buffered and doubled by the opamps (see **Figure 5**).

The current consumption of the opamps

COMPONENT LIST FOR PWM TO VOLTAGE CONVERTER

Resistors

R1–R24 = 10kΩ

Capacitors

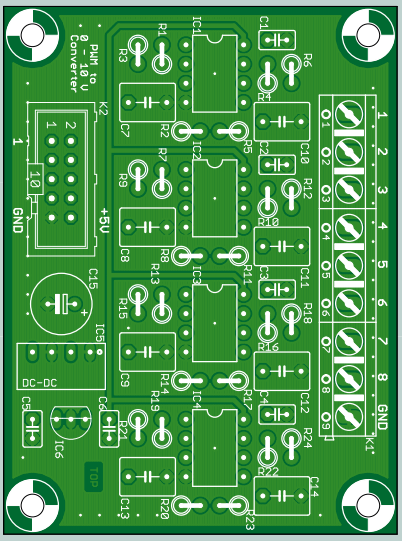
C1–C6 = 100nF
C7–C14 = 1µF
C15 = 100µF

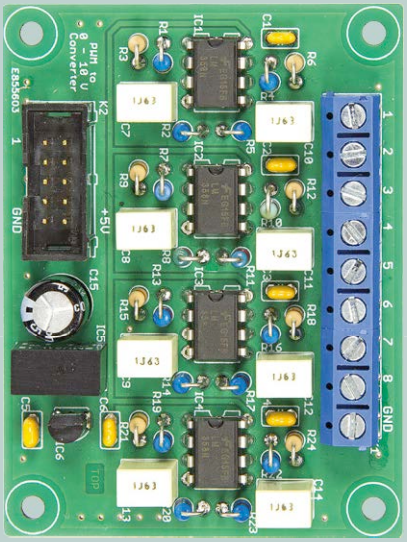
Semiconductors

IC1–IC4 = LM358N
IC5 = SMU01L-15
IC6 = 78L12Z

Miscellaneous

K1 = 9-way PCB screw terminal block, 0.2” pitch
K2 = 10-pin boxheader





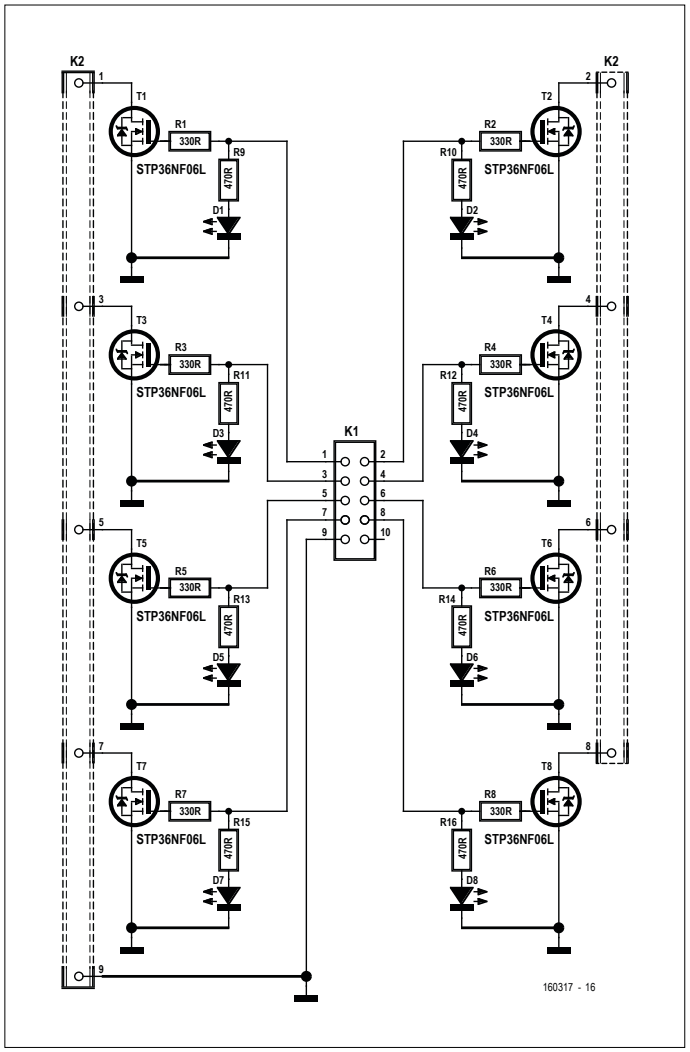


Figure 6. The MOSFET board is populated with STP36NF06L devices, which can handle 30 A and a maximum voltage of 60 V.

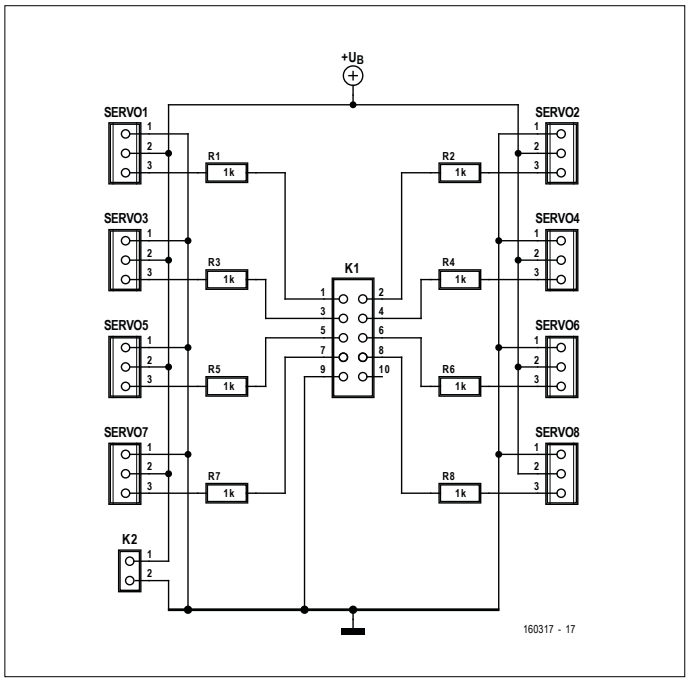


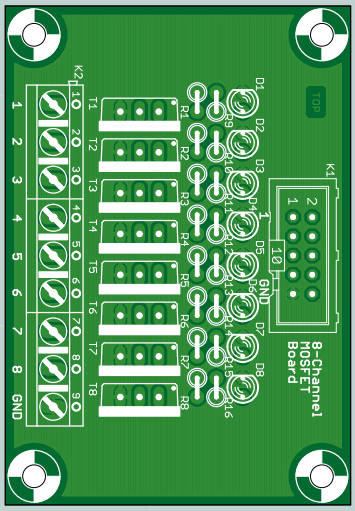
Figure 7. With this simple servo motor board you can control up to eight servo motors from the Swiss Pi.

COMPONENT LIST FOR MOSFET BOARD

Resistors
R1–R8 = 330Ω
R9–R16 = 470Ω

Semiconductors
D1–D8 = LED, 3mm, red
T1–T8 = STP36NF06L

Miscellaneous
K1 = 10-pin boxheader
K2 = 9-way PCB screw terminal block, 0.2” pitch



is low and the load on the 0–10 V signals is usually low, so a simple DC/DC converter is used to provide the higher supply voltage for the opamps. It converts the 5 V supply voltage from the Swiss Pi to 15 V, which is then reduced to a regulated 12 V by a 78L12. That eliminates the need for an external power source.
You should bear in mind that the output voltage range may not be exactly 0 to10 V — in practice it extends from 0 V to twice the supply voltage of the PWM IC on the Swiss Pi board.

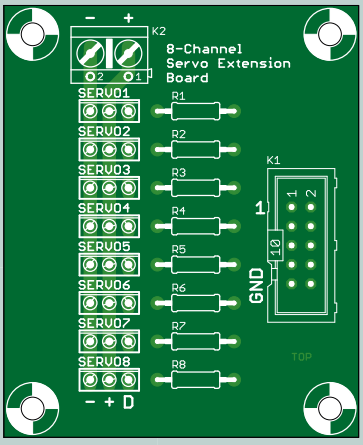
MOSFET board

The MOSFET board (**Figure 6**) can be used to switch DC loads. The normal GPIO lines of the Swiss Pi or the PWM channels can be used for this purpose. Driving RGB LED strips is a typical application.

COMPONENT LIST FOR SERVO MOTOR BOARD

Resistors
R1–R8 = 1kΩ

Miscellaneous
K1 = 10-pin boxheader
K2 = 2-way PCB screw terminal block, 0.2” pitch
K3–K10 = 3-pin header, 0.1” pitch



For the MOSFETs we chose type STP36NF06L devices. That is an N-channel MOSFET which is suitable for voltages up to 60 V with a rated current of 30 A ($R_{DS(on)}$ = 0.032 Ω at V_{GS} 10 V / 15 A). The STP36NF06L is a logic-level MOSFET, which means it can be driven fully on even with a gate voltage less than 5 V. With a V_{GS} of 5 V the on resistance $R_{DS(on)}$ is 0.045 Ω, which in practice means that you can switch about 5 A per channel without needing a heat sink for the MOSFET. Each channel also has an indicator LED.

Servo motor extension

With the servo motor extension board (**Figure 7**) you can connect more servo motors to the Swiss Pi than the four supported directly. With two of these boards you can control a maximum of sixteen servo motors.

The resistors protect the Swiss Pi in the event that the three-pin plug of a servo motor is accidentally connected the wrong way.

In combination with the previous article and the many software examples described there [3], you now have an arsenal of tools to tackle a wide range of applications with the Swiss Pi / Raspberry Pi duo.

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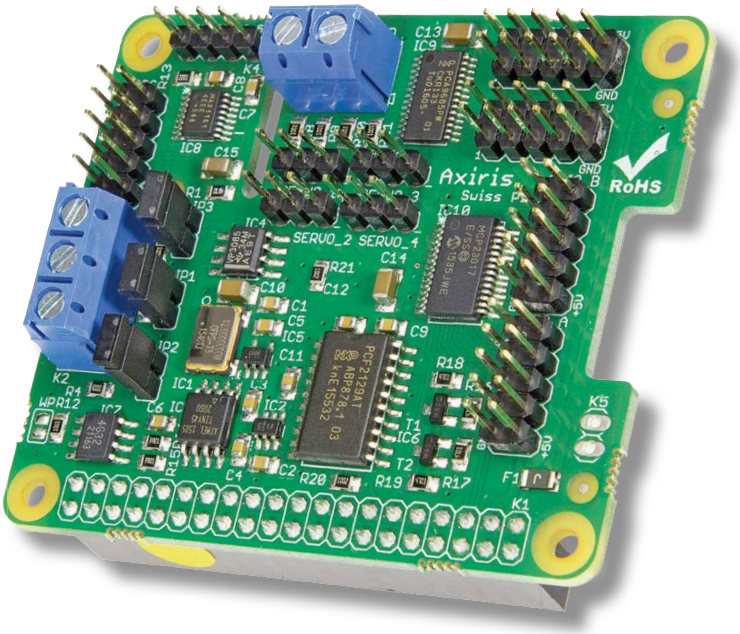

Web Links

[1] www.elektormagazine.com/150584

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