RPi Low-level peripherals

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Hardware & Peripherals:

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Contents

Introduction

In addition to the familiar USB, Ethernet and HDMI ports, the Raspberry Pi offers the ability to connect directly to a variety of electronic devices. These include:

- Digital outputs: turn lights, motors, or other devices on or off
- Digital inputs: read an on or off state from a button, switch, or other sensor
- Communication with chips or modules using low-level protocols: SPI (http://www.corelis.com/education/SPI_Tutorial.htm), I²C (http://i2c.info/), or serial UART (https://learn.sparkfun.com/tutorials/serial-communication)

Connections are made using GPIO ("General Purpose Input/Output" (https://en.wikipedia.org/wiki/General-purpose_input/output)) pins. Unlike USB, etc., these interfaces are not "plug and play" and require care to avoid miswiring. The Raspberry PI GPIOs use 3.3V logic levels (https://learn.sparkfun.com/tutorials/logic-levels/all), and can be damaged if connected directly to 5V levels (as found in many older digital systems) without level-conversion circuitry.

Note that no analogue input or output is available. However, add-on boards such as the Rpi Gertboard provide this capability.

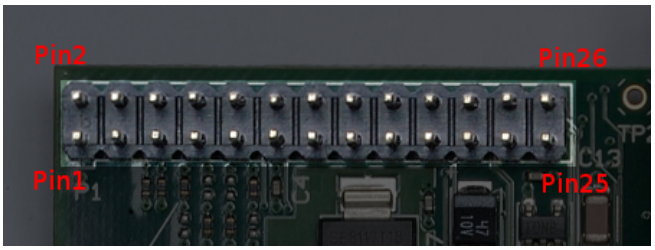
Links

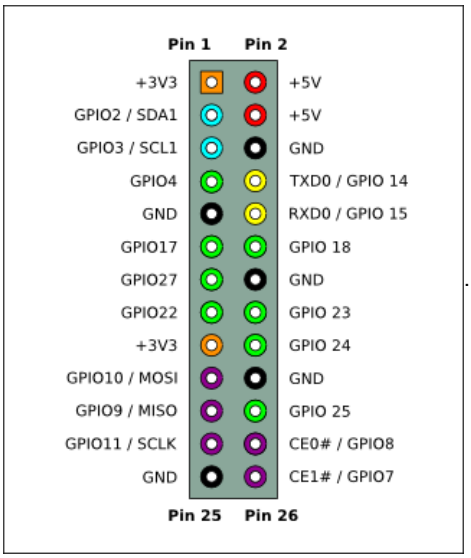
- For further specific information about the Raspberry Pi's BCM2835 GPIOs, see: RPi BCM2835 GPIOs.
- For further specific information about the Raspberry Pi4's BCM2711 GPIOs, see: RPi BCM2711 GPIOs.
- Sample code in many different languages is on the RPi GPIO Code Samples page
- To connect devices to the serial port (UART), see the RPi Serial Connection page.
- Sample circuits for interfacing the GPIOs with other electronics are shown on the RPi GPIO Interface Circuits page.

General Purpose Input/Output (GPIO)

Model A and B (Original)

P1 Header





The Raspberry Pi Model A and B boards have a 26-pin 2.54 mm (100 mil)[1] expansion header, marked as P1, arranged in a 2x13 strip. They provide 8 GPIO pins plus access to I²C, SPI, UART), as well as +3.3 V, +5 V and GND supply lines. Pin one is the pin in the first column and on the bottom row. [2]

Revision 1 PCBs: Raspberry Pis with a revision 1 PCB (September 2012 or earlier) have a different pin assignment on the P1 connector:

- P1 pin 3 is GPIO 0 / SDA0 (not GPIO 2)
- P1 pin 5 is GPIO 1 / SCL0 (not GPIO 3)
- P1 pin 13 is GPIO 21 (not GPIO 27)

Revision 1 PCBs also do not have the P5 header (see below). See this discussion (http://www.raspberrypi.org/archives/1929#comment-31646) for more details of the changes between Rev 1 and Rev 2 PCBs.

P2 header

The P2 header is the VideoCore JTAG and used only during the production of the board. It cannot be used as the ARM JTAG [3]. This connector is unpopulated in Rev 2.0 boards.

Useful P2 pins:

- Pin 1 - 3.3V (same as P1-01, 50 mA max current draw across both of them)
- Pin 7 - GND
- Pin 8 - GND

P3 header

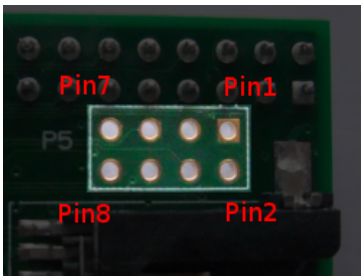
The P3 header, unpopulated, is the LAN9512 JTAG [4].

Useful P3 pins:

- Pin 7 - GND

P5 header

The P5 header was added with the release of the Revision 2.0 PCB design.



P5 Header pinout, top row

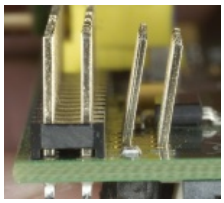
As seen from the back of the board:

Pin Number	Pin Name Rev2	Hardware Notes	Alt 0 Function	Other Alternative Functions
P5-01	5V0	Supply through input poly fuse		
P5-03	GPIO28		I2C0_SDA	ALT2 = PCM_CLK
P5-05	GPIO30			ALT2 = PCM_DIN ALT3 = UART0_CTS ALT5 = UART1_CTS
P5-07	GND			

P5 Header pinout, bottom row

As seen from the back of the board:

Pin Number	Pin Name Rev2	Hardware Notes	Alt 0 Function	Other Alternative Functions
P5-02	3.3 V	50 mA max (combined with P1)		
P5-04	GPIO29		I2C0_SCL	ALT2 = PCM_FS
P5-06	GPIO31			ALT2 = PCM_DOUT ALT3 = UART0_RTS ALT5 = UART1_RTS
P5-08	GND			


Slanted P5 header

Note that the connector is intended to be mounted on the bottom of the PCB, so that for those who put the connector on the top side, the pin numbers are mirrored. Pin 1 and pin 2 are swapped, pin 3 and 4, etc.

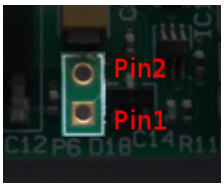
An alternative way to attach this header is on top, at a slant away from the P1 header. (http://raspi.tv/2013/the-leaning-header-of-pi5a-how-best-to-solder-a-header-on-p5)

The new header can provide a second I²C channel (SDA + SCL) and handshake lines for the existing UART (TxD and RxD), or it can be used for an I2S (audio codec chip) interface using the PCM signals CLK, FS (Frame Sync), Din and Dout.

Note that the connector is placed JUST off-grid with respect to the P1 connector.

P6 header

The P6 header was added with the release of the Revision 2.0 PCB design.



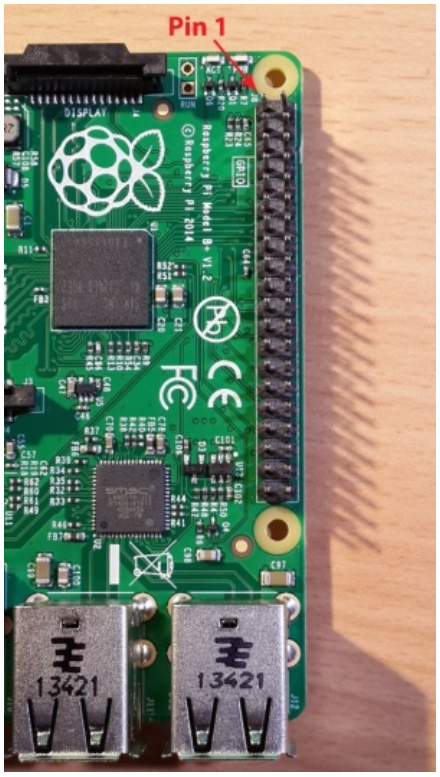
P6 Pinout

Pin Number	Pin Name Rev2	Hardware Notes
P6-01	RUN	Short to ground to reset the BCM2835
P6-02	GND	

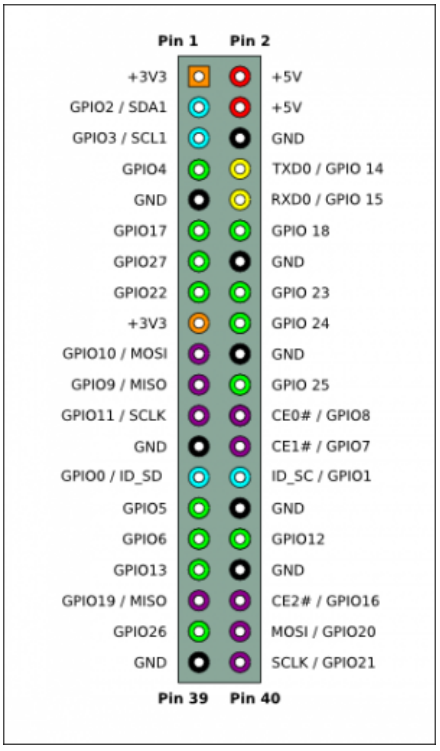
A reset button can be attached to the P6 header.[5] Momentarily shorting the two pins of P6 together will cause a soft reset of the CPU (which can also 'wake' the Pi from halt/shutdown state).

Model A+, B+ and B2

Model A+



Models B+, B2



Connector pinout

The Raspberry Pi Model A+ and B+ boards, and the Pi 2 Model B, have a 40-pin header marked J8, arranged as 2x20 pins. The first 26 pins are the same as P1 on the A/B boards, with the remaining 14 pins providing additional GPIO and ground pins, and an EEPROM ID feature for auto-configuration with add-on "HAT" boards.[6]

Interfacing with GPIO pins

GPIO voltage levels are 3.3 V and are not 5 V tolerant. There is no over-voltage protection on the board - the intention is that people interested in serious interfacing will use an external board with buffers, level conversion and analog I/O rather than soldering directly onto the main board.

All the GPIO pins can be reconfigured to provide alternate functions, SPI, PWM (http://en.wikipedia.org/wiki/Pulse-width_modulation), I²C and so. At reset only pins GPIO 14 & 15 are assigned to the alternate function UART, these two can be switched back to GPIO to provide a total of 17 GPIO pins[7]. Each of their functions and full details of how to access are detailed in the chipset datasheet [8].

Each GPIO can interrupt, high/low/rise/fall/change.[9][10] There is currently no support for GPIO interrupts in the official kernel, however a patch exists, requiring compilation of modified source tree.[11] The 'Raspbian "wheezy"' [12] version that is currently recommended for starters already includes GPIO interrupts.

GPIO input hysteresis (Schmitt trigger) can be on or off, output slew rate can be fast or limited, and source and sink current is configurable from 2 mA up to 16 mA. Note that chipset GPIO pins 0-27 are in the same block and these properties are set per block, not per pin. See GPIO Datasheet Addendum - GPIO Pads Control (http://www.scribd.com/doc/101830961/GPIO-Pads-Control2). Particular attention should be applied to the note regarding SSO (Simultaneous Switching Outputs): to avoid interference, driving currents should be kept as low as possible.

The available alternative functions and their corresponding pins are detailed below. These numbers are in reference to the chipset documentation and may not match the numbers exposed in Linux. Only fully usable functions are detailed, for some alternative functions not all the necessary pins are available for the funtionality to be actually used.

There is also some information on the Tutorial on Easy GPIO Hardware & Software.

Kernel boot messages go to the UART at 115200 bit/s - there are more details on the serial port page.

P1 Header pinout, top row

Pin Number	Pin Name Rev1	Pin Name Rev2	Hardware Notes	Alt 0 Function	Other Alternative Functions
P1-02	5V0		Supply through input poly fuse		
P1-04	5V0		Supply through input poly fuse		
P1-06	GND				
P1-08	GPIO 14		Boot to Alt 0 ->	UART0_TXD	ALT5 = UART1_TXD
P1-10	GPIO 15		Boot to Alt 0 ->	UART0_RXD	ALT5 = UART1_RXD
P1-12	GPIO 18			PCM_CLK	ALT4 = SPI1_CE0_N ALT5 = PWM0
P1-14	GND				
P1-16	GPIO23				ALT3 = SD1_CMD ALT4 = ARM_RTCK
P1-18	GPIO24				ALT3 = SD1_DAT0 ALT4 = ARM_TDO
P1-20	GND				
P1-22	GPIO25				ALT3 = SD1_DAT1 ALT4 = ARM_TCK
P1-24	GPIO08			SPI0_CE0_N	
P1-26	GPIO07			SPI0_CE1_N	

P1 Header pinout, bottom row

Pin Number	Pin Name Rev1	Pin Name Rev2	Hardware Notes	Alt 0 Function	Other Alternative Functions
P1-01	3.3 V		50 mA max (01 & 17)		
P1-03	GPIO 0	**GPIO 2**	1K8 pull up resistor	I2C0_SDA / **I2C1_SDA**	
P1-05	GPIO 1	**GPIO 3**	1K8 pull up resistor	I2C0_SCL / **I2C1_SCL**	
P1-07	GPIO 4			GPCLK0	ALT5 = ARM_TDI
P1-09	GND				
P1-11	GPIO17				ALT3 = UART0_RTS ALT4 = SPI1_CE1_N ALT5 = UART1_RTS
P1-13	GPIO21	**GPIO27**		PCM_DOUT / **reserved**	ALT4 = SPI1_SCLK ALT5 = GPCLK1 / **ALT3 = SD1_DAT3 ALT4 = ARM_TMS**
P1-15	GPIO22				ALT3 = SD1_CLK ALT4 = ARM_TRST
P1-17	3.3 V		50 mA max (01 & 17)		
P1-19	GPIO10			SPI0_MOSI	
P1-21	GPIO9			SPI0_MISO	
P1-23	GPIO11			SPI0_SCLK	
P1-25	GND				

Colour legend
+5 V
+3.3 V
Ground, 0V
UART

GPIO
SPI
I²C

KiCad symbol: File:Conn-raspberry.lib[13]

Pin 3 (SDA0) and Pin 5 (SCL0) are preset to be used as an I²C interface. So there are 1.8 kohm pulls up resistors on the board for these pins.[14]

Pin 12 supports PWM (http://en.wikipedia.org/wiki/Pulse-width_modulation).

It is also possible to reconfigure GPIO connector pins P1-7, 15, 16, 18, 22 (chipset GPIOs 4 and 22 to 25) to provide an ARM JTAG interface.[15] However ARM_TMS is not available on the GPIO connector (chipset pin 12 or 27 is needed). Chipset pin 27 is available on S5, the CSI camera interface however.

It is also possible to reconfigure GPIO connector pins P1-12 and 13 (chipset GPIO 18 and 21) to provide an I2S (a hardware modification may be required[16]) or PCM interface.[17] However, PCM_FS and PCM_DIN (chipset pins 19 and 20) are needed for I2S or PCM.

A second I²C interface (GPIO02_ALT0 is SDA1 and GPIO03_ALT0 is SCL1) and two further GPIOs (GPIO05_ALT0 is GPCLK1, and GPIO27) are available on S5, the CSI camera interface.

Referring to pins on the Expansion header

The header is referred to as "The GPIO Connector (P1)". To avoid nomenclature confusion between Broadcom signal names on the SoC and pin names on the expansion header, the following naming is highly recommended:

- The expansion header is referred to as "Expansion Header" or "GPIO Connector (P1)"
- Pins on the GPIO connector (P1) are referred to as P1-01, etc.
- Names GPIO0, GPIO1, GPIOx-ALTy, etc. refer to the signal names on the SoC as enumerated in the Broadcom datasheet, where "x" matches BCM2835 number (without leading zero) and "y" is the alternate number column 0 to 5 on page 102-103 of the Broadcom document. For example, depending on what you are describing, use either "GPIO7" to refer to a row of the table, and "GPIO7-ALT0" would refer to a specific cell of the table.
- When refering to signal names, the Broadcom name should be modified slightly to minimize confusion. The Broadcom SPI bus pin names are fine, such as "SPI0_*" and "SPI1_*", but they did not do the same on the I²C and UART pins. Instead of using "SDA0" and "SCL0", "I2C0_SDA" and "I2C0_SCL" should be used; and "UART0_TXD" and "UART0_RXD" instead of "TX" or "TXD" and "RX" or "RXD".

Power pins

The maximum permitted current draw from the 3.3 V pins is 50 mA.

Maximum permitted current draw from the 5 V pin is the USB input current (usually 1 A) minus any current draw from the rest of the board.[18]

- Model A: 1000 mA - 500 mA -> max current draw: 500 mA
- Model B: 1000 mA - 700 mA -> max current draw: 300 mA

Be very careful with the 5 V pins P1-02 and P1-04, because if you short 5 V to any other P1 pin you may permanently damage your RasPi. Before probing P1, it is a good idea to strip short pieces of insulation off a wire and push them over the 5 V pins are not accidentally shorted with a probe.

GPIO hardware hacking

The complete list of chipset GPIO pins which are available on the GPIO connector is:

> 0, 1, 4, 7, 8, 9, 10, 11, 14, 15, 17, 18, 21, 22, 23, 24, 25

(on the Revision2.0 RaspberryPis, this list changes to: 2, 3, 4, 7, 8, 9, 10, 11, 14, 15, 17, 18, 22, 23, 24, 25, 27, with 28, 29, 30, 31 additionally available on the P5 header)

As noted above, P1-03 and P1-05 (SDA0 and SCL0 / SDA1 and SCL1) have 1.8 kohm pull-up resistors to 3.3 V.

If 17 GPIOs are not sufficient for a project, there are a few other signals potentially available, with varying levels of software and hardware (soldering iron) hackery skills:

GPIO02, 03, 05 and 27 are available on S5 (the CSI interface) when a camera peripheral is not connected to that socket, and are configured by default to provide the functions SDA1, SCL1, CAM_CLK and CAM_GPIO respectively. SDA1 and SCL1 have 1K6 pull-up resistors to 3.3 V.

GPIO06 is LAN_RUN and is available on pad 12 of the footprint for IC3 on the Model A. On Model B, it is in use for the Ethernet function.

There are a few other chipset GPIO pins accessible on the PCB but are in use:

- GPIO16 drives status LED D5 (usually SD card access indicator)
- GPIO28-31 are used by the board ID and are connected to resistors R3 to R10 (only on Rev1.0 boards).
- GPIO40 and 45 are used by analogue audio and support PWM (http://en.wikipedia.org/wiki/Pulse-width_modulation). They connect to the analogue audio circuitry via R21 and R27 respectively.
- GPIO46 is HDMI hotplug detect (goes to pin 6 of IC1).
- GPIO47 to 53 are used by the SD card interface. In particular, GPIO47 is SD card detect (this would seem to be a good candidate for re-use). GPIO47 is connected to the SD card interface card detect switch; GPIO48 to 53 are connected to the SD card interface via resistors R45 to R50.

Internal Pull-Ups & Pull-Downs

The GPIO ports include the ability to enable and disable internal pull-up or pull-down resistors (see below for code examples/support of this):

- Pull-up is 50 kOhm - 65 kOhm
- Pull-down is 50 kOhm - 60 kOhm

Driver support

The Foundation will not include a GPIO driver in the initial release, standard Linux GPIO drivers should work with minimal modification.[19]

The community implemented SPI and I²C drivers [20], which will be integrated with the new Linux pinctrl concept in a later version of the kernel. (On Oct. 14 2012, it was already included in the latest raspbian image.) A first compiled version as Linux modules is available to install on the 19/04/2012 Debian image, including 1-wire support[21]. The I²C and SPI driver uses the hardware modules of the microcontroller and interrupts for low CPU usage, the 1-wire support uses bitbanging on the GPIO ports, which results in higher CPU usage.

GordonH[22] wrote a (mostly) Arduino compatible/style WiringPi library (https://projects.drogon.net/raspberry-pi/wiringpi/) in C for controlling the GPIO pins.

A useful tutorial on setting up I²C driver support can be found at Robot Electronics (http://www.robot-electronics.co.uk/htm/raspberry_pi_examples.htm) - look for the downloadable document rpi_i2c_setup.doc

SPI

There are two SPI bus brought out to the header: RPi_SPI

I²C

There are two I²C-buses on the Raspberry Pi: One on P1, and one on P5.

Note that there's a bug concerning I²C-clock-stretching, so don't use I²C-devices which use clock-stretching directly with the Raspberry Pi, or use a workaround. Details about this bug can be found at:

- http://www.raspberrypi.org/phpBB3/viewtopic.php?f=44&t=13771
- http://www.advamation.com/knowhow/raspberrypi/rpi-i2c-bug.html

MIPI CSI-2

On the production board[23], the Raspberry Pi Foundation design brings out the MIPI CSI-2 (Camera Serial Interface[24]) to a 15-way flat flex connector S5, between the Ethernet and HDMI connectors. A compatible camera[25] with 5 Megapixels and 1080p video resolution was released in May 2013.

DSI

On the production board, the Raspberry Pi Foundation design brings out the DSI (Display Serial Interface[26]) to a 15-way flat flex connector labelled S2, next to Raspberry Pi logo. It has two data lanes and a clock lane, to drive a possible future LCD screen device. Some smart phone screens use DSI[27].

CEC

HDMI-CEC (Consumer Electronics Control for HDMI) is supported by hardware but some driver work will be needed and currently isn't exposed into Linux userland. Eben notes that he has seen CEC demos on the Broadcom SoC they are using.

libCEC with Raspberry Pi support has been included in OpenELEC and will be included in Raspbmc RC4.[28]

For more information about HDMI-CEC and what you could do with it on the Raspberry Pi please see the CEC (Consumer Electronics Control) over HDMI article.

References

1. raspberrypi.org (http://www.raspberrypi.org/forum/features-and-requests/easy-gpio-hardware-software/page-3/#p31907)
2. raspberrypi.org (http://www.raspberrypi.org/archives/384)
3. http://www.raspberrypi.org/phpBB3/viewtopic.php?f=24&t=5894
4. http://www.raspberrypi.org/phpBB3/viewtopic.php?f=24&t=5894
5. raspi.tv (http://raspi.tv/2012/making-a-reset-switch-for-your-rev-2-raspberry-pi)
6. raspberrypi.org (http://www.raspberrypi.org/wp-content/uploads/2014/04/bplus-gpio.png)
7. raspberrypi.org (http://www.raspberrypi.org/archives/384)
8. raspberrypi.org (http://www.raspberrypi.org/wp-content/uploads/2012/02/BCM2835-ARM-Peripherals.pdf)
9. http://www.raspberrypi.org/archives/384#comment-5217
10. http://www.raspberrypi.org/wp-content/uploads/2012/02/BCM2835-ARM-Peripherals.pdf
11. http://www.raspberrypi.org/phpBB3/viewtopic.php?f=44&t=7509
12. http://www.raspberrypi.org/downloads
13. http://www.raspberrypi.org/forum/projects-and-collaboration-general/gpio-header-pinout-clarification/page-2
14. http://www.raspberrypi.org/forum/features-and-requests/easy-gpio-hardware-software/page-6/#p56480
15. http://www.raspberrypi.org/forum?mingleforumaction=viewtopic&t=1288.1
16. Forum:Sad about removal of I2S. Why was this change made? (http://www.raspberrypi.org/forum/features-and-requests/sad-about-removal-of-i2s-why-was-this-change-made)
17. http://www.raspberrypi.org/forum?mingleforumaction=viewtopic&t=1288.2
18. http://www.raspberrypi.org/forum?mingleforumaction=viewtopic&t=1536#postid-21841
19. http://www.raspberrypi.org/forum?mingleforumaction=viewtopic&t=1278.0
20. http://www.bootc.net/projects/raspberry-pi-kernel/

21. http://www.raspberrypi.org/phpBB3/viewtopic.php?p=86172#p86172
22. http://www.raspberrypi.org/forum/general-discussion/wiring-for-the-raspberry-pis-gpio
23. http://www.raspberrypi.org/wp-content/uploads/2012/04/Raspberry-Pi-Schematics-R1.0.pdf
24. http://www.mipi.org/specifications/camera-interface
25. http://elinux.org/Rpi_Camera_Module
26. http://www.mipi.org/specifications/display-interface
27. http://en.wikipedia.org/wiki/Display_Serial_Interface
28. http://blog.pulse-eight.com/2012/08/01/libcec-1-8-0-a-firmware-upgrade-and-raspberry-pi-support/

Raspberry Pi

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- E (https://elinux.org/index.php?title=Template:Raspberry_Pi&action=edit)

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