Sistemas Operacionais Embarcados

GPIOs do Raspberry Pi

Hardware da placa*

SoCs Broadcom (CPU + GPU + RAM)

- RPi 1, RPi0 e RPi 0W - BCM2835
  - Processador ARM1176JZF-S de 32 bits @ 700 MHz (mesmo do 1o iPhone)
- RPi 2 V1.1 - BCM2836
  - Processador quad-core ARM Cortex-A7 de 32 bits a 900 MHz
- RPi2 V1.2 - BCM2837
  - Processador quad-core ARM Cortex-A53 de 64 bits a 900 MHz
- RPi3 - BCM2837
  - Processador quad-core ARM Cortex-A53 de 64 bits a 1.2 GHz
- RPi 3A+ e 3B+ - BCM2837B0
  - Processador quad-core ARM Cortex-A53 de 64 bits a 1.4 GHz
- RPi 4B - BCM2711
  - Processador quad-core ARM Cortex-A72 de 64 bits a 1.5 GHz

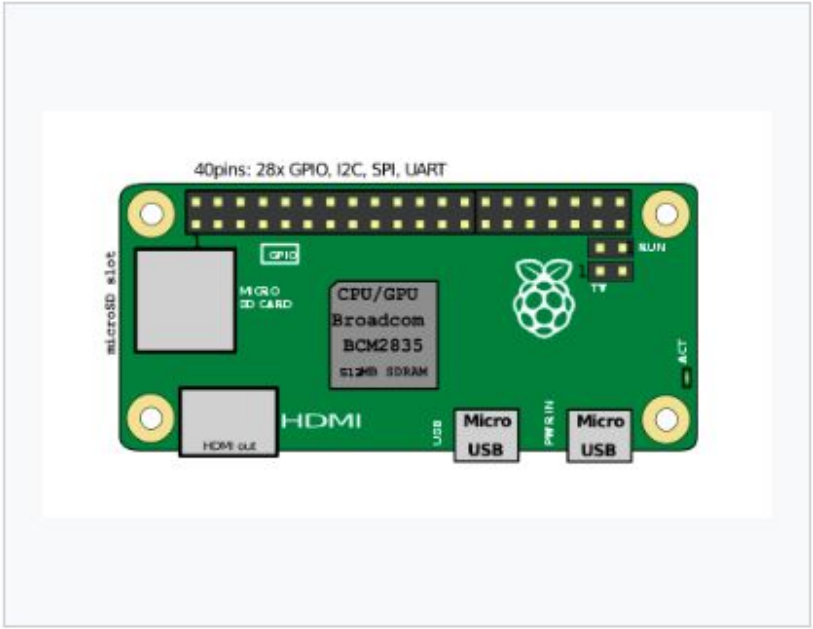
GPU VideoCore IV @ 250 MHz - RPis 0, 0W, 1, 2 V1.1, 2 V1.2, 3, 3A+ e 3B+

GPU VideoCore VI @ 250 MHz - RPi 4B

* https://www.raspberrypi.org/documentation/hardware/raspberrypi/ e https://en.wikipedia.org/wiki/Raspberry_Pi#Processor

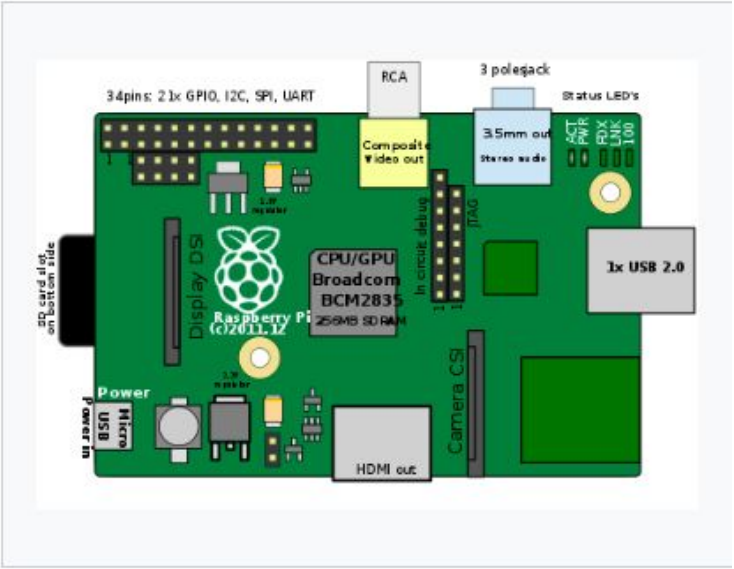
Conectores*

Pi Zero [edit]

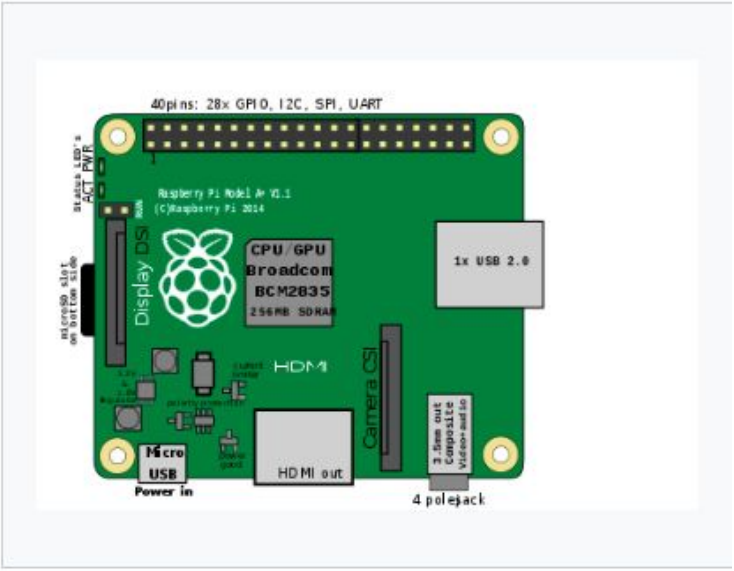


Location of connectors and main ICs

Model A [edit]



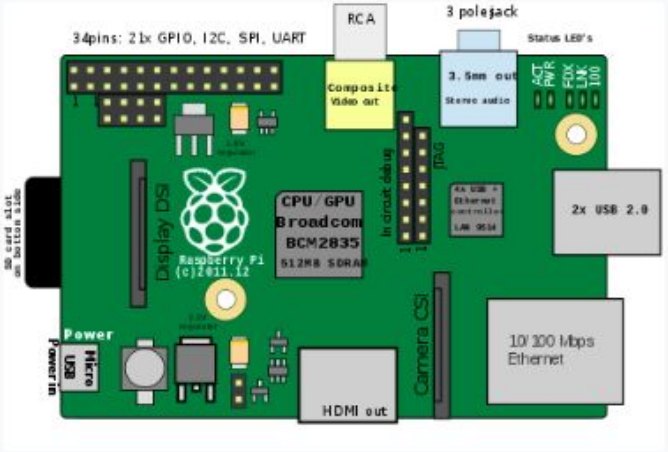
Location of connectors and main ICs on Raspberry Pi 1 Model A



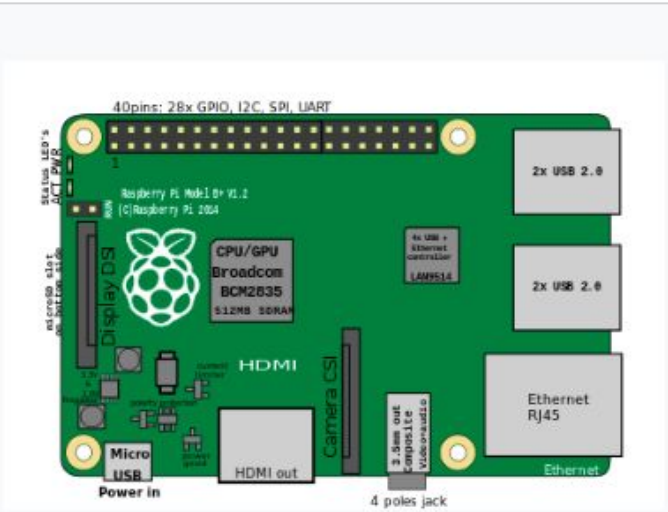
Location of connectors and main ICs on Raspberry Pi 1 Model A+ revision 1.1

* https://en.wikipedia.org/wiki/Raspberry_Pi#Connectors

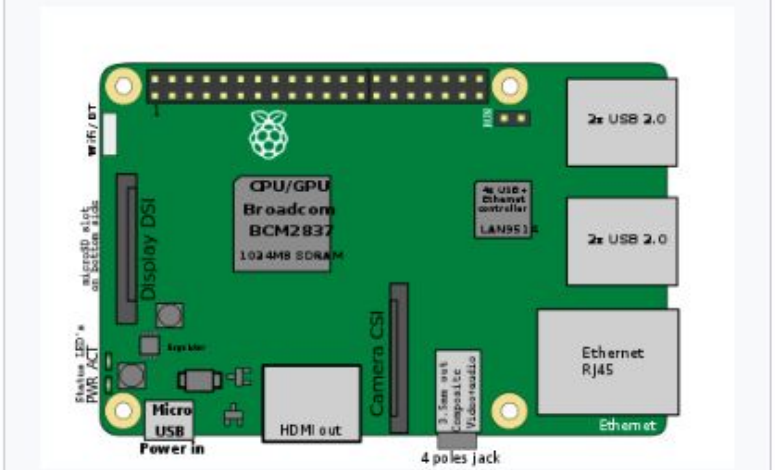
Model B [edit]



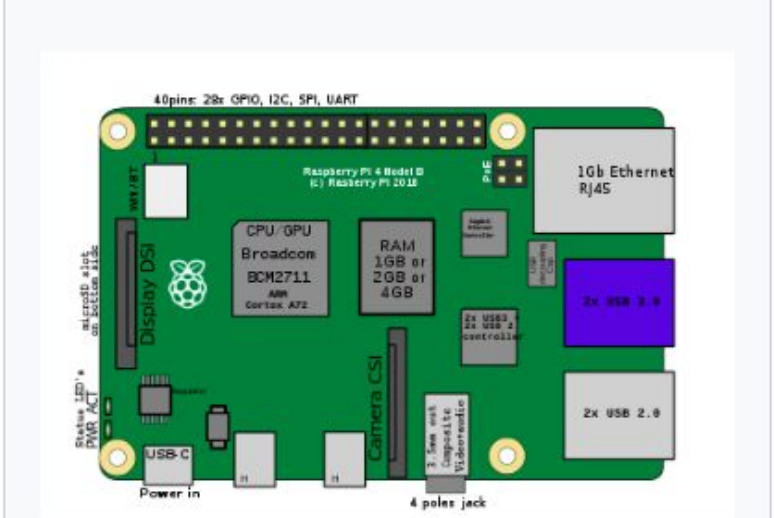
Location of connectors and main ICs on Raspberry Pi 1 Model B revision 1.2



Location of connectors and main ICs on Raspberry Pi 1 Model B+ revision 1.2 and Raspberry Pi 2

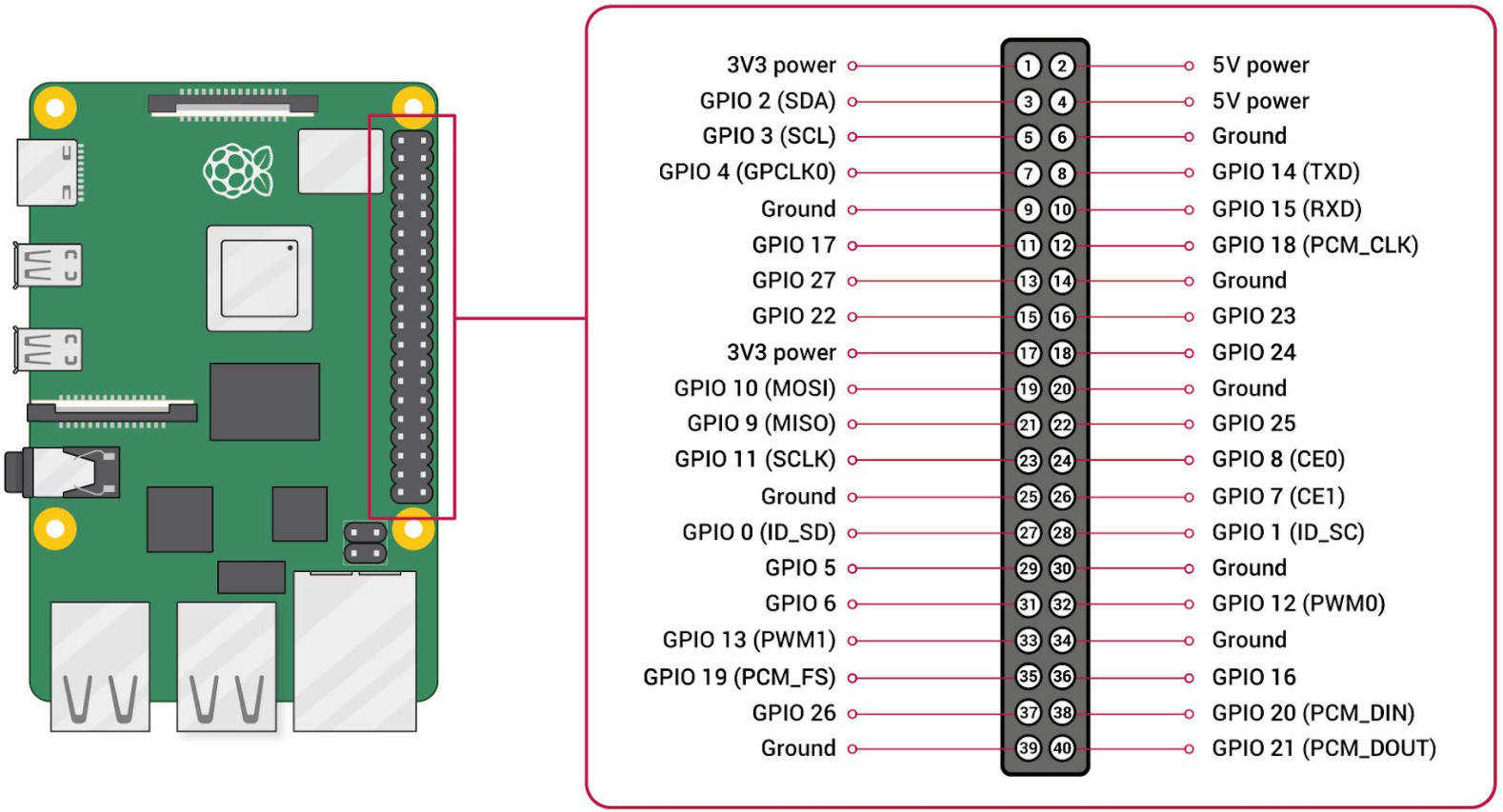


Location of connectors and main ICs on Raspberry Pi 3



Location of connectors and main ICs on Raspberry Pi 4

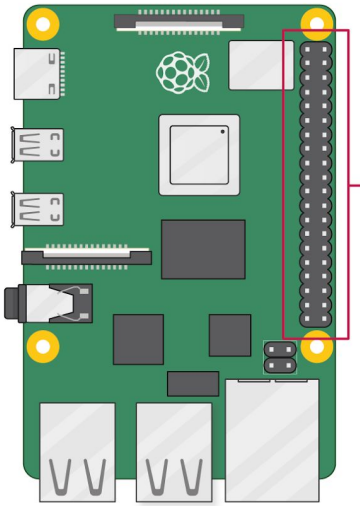
Pinos GPIO

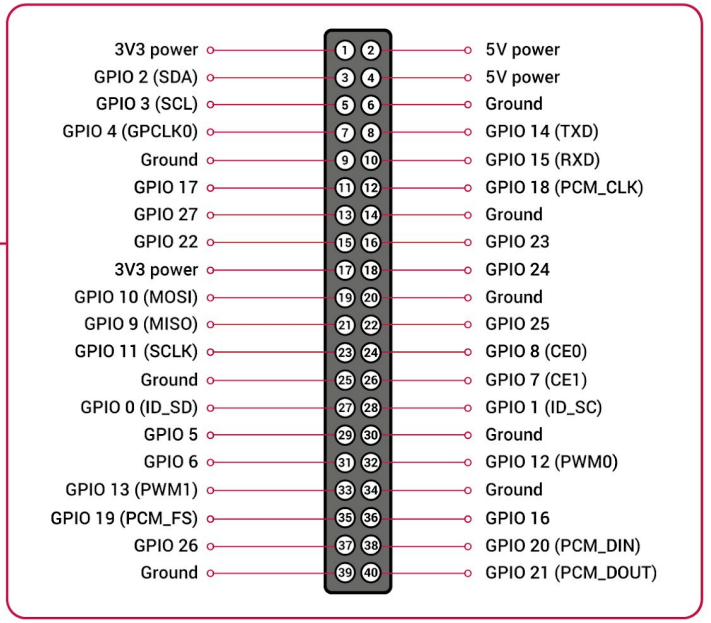


- Pinos GPIO trabalham em 3,3V
- RPis 1A e 1B têm somente os 26 pinos superiores da lista
- Legendas em parênteses indicam funções alternativas para o mesmo pino

Pinos GPIO

- Resistores internos de pull-up/pull-down
  - Fixos em GPIO2 e GPIO3 (pull-up), configuráveis por software nos outros
- PWM (pulse-width modulation)
  - PWM em software disponível em todos os pinos
  - PWM em hardware disponível em GPIO12, GPIO13, GPIO18 e GPIO19
- SPI
  - SPI0: MOSI (GPIO10); MISO (GPIO9); SCLK (GPIO11); CE0 (GPIO8), CE1 (GPIO7)
  - SPI1: MOSI (GPIO20); MISO (GPIO19); SCLK (GPIO21); CE0 (GPIO18); CE1 (GPIO17); CE2 (GPIO16)
- I2C
  - Data: (GPIO2)
  - Clock (GPIO3)
  - EEPROM Data: (GPIO0)
  - EEPROM Clock (GPIO1)
- Serial
  - TX (GPIO14); RX (GPIO15)





Programação para GPIO

O Raspberry Pi possui diversas ferramentas para controlar pinos GPIO:

- Sistema sysfs
  - Escrita em arquivos especiais
- Acesso direto a registradores
  - Escrita em espaços fixos de memória
- Biblioteca WiringPi
- Biblioteca pigpio

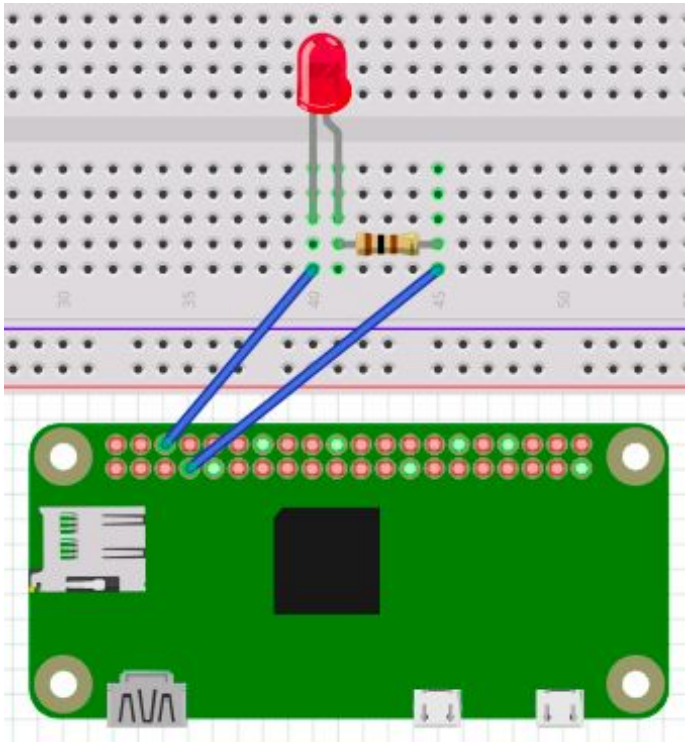
Sistema sysfs

- Acesso a hardware usando arquivos virtuais em pastas especiais:
  - `/sys/block`: subdiretórios para cada dispositivo do sistema
  - `/sys/bus`: vários tipos de barramento do kernel presentes no processador:
    - devices (links simbólicos)
    - drivers
  - `/sys/devices`: árvore de dispositivos
  - `/sys/firmware`: atributos e objetos específicos do firmware
  - `/sys/module`: módulos do kernel
  - `/sys/class`: dispositivos conhecidos pelo kernel

```
pi@raspberrypi:/sys $ pwd
/sys
pi@raspberrypi:/sys $ ls -la
total 4
dr-xr-xr-x 12 root root    0 Nov 25 11:37 .
drwxr-xr-x 21 root root 4096 Sep 13 03:08 ..
drwxr-xr-x  2 root root    0 Nov 25 12:48 block
drwxr-xr-x 18 root root    0 Nov 25 12:48 bus
drwxr-xr-x 48 root root    0 Nov 25 11:37 class
drwxr-xr-x  4 root root    0 Nov 25 12:48 dev
drwxr-xr-x  9 root root    0 Nov 25 12:48 devices
drwxr-xr-x  3 root root    0 Nov 25 12:48 firmware
drwxr-xr-x  5 root root    0 Nov 25 12:48 fs
drwxr-xr-x  8 root root    0 Nov 25 12:48 kernel
drwxr-xr-x 62 root root    0 Nov 25 12:48 module
drwxr-xr-x  2 root root    0 Nov 25 12:48 power
```

Sistema sysfs

- Acesso a hardware usando arquivos virtuais em pastas especiais:
  - `/sys/class/gpio/export`: escreva neste arquivo o valor numérico do pino GPIO para controla-lo
  - `/sys/class/gpio/unexport`: escreva nele o valor numérico do pino GPIO para libera-lo
  - `/sys/class/gpio/gpioN/direction`: escreva “in” ou “out” para definir se o pino GPIO**N** é de entrada ou de saída
  - `/sys/class/gpio/gpioN/value`:
    - leitura: indica o valor atual do pino GPIO**N** (“0” ou “1”)
    - escrita: leva o pino GPIO**N** para nível baixo ou alto (“0” ou “1”)
  - `/sys/class/gpio/gpioN/edge`: permite verificar bordas de subida, descida ou ambas
  - `/sys/class/gpio/gpioN/active_low`: permite a inversão dos níveis lógicos de leitura e/ou gravação



Circuito para Ex1.sh, Ex2.c e Ex3.c

Acesso direto a registradores*

Acesso a hardware através de memória mapeada

Address	Field Name	Description	Size	Read/ Write
0x 7E20 0000	GPFSEL0	GPIO Function Select 0	32	R/W
0x 7E20 0000	GPFSEL0	GPIO Function Select 0	32	R/W
0x 7E20 0004	GPFSEL1	GPIO Function Select 1	32	R/W
0x 7E20 0008	GPFSEL2	GPIO Function Select 2	32	R/W
0x 7E20 000C	GPFSEL3	GPIO Function Select 3	32	R/W
0x 7E20 0010	GPFSEL4	GPIO Function Select 4	32	R/W
0x 7E20 0014	GPFSEL5	GPIO Function Select 5	32	R/W
0x 7E20 0018	-	Reserved	-	-
0x 7E20 001C	GPSET0	GPIO Pin Output Set 0	32	W
0x 7E20 0020	GPSET1	GPIO Pin Output Set 1	32	W
0x 7E20 0024	-	Reserved	-	-
0x 7E20 0028	GPCLR0	GPIO Pin Output Clear 0	32	W
0x 7E20 002C	GPCLR1	GPIO Pin Output Clear 1	32	W
0x 7E20 0030	-	Reserved	-	-
0x 7E20 0034	GPLEV0	GPIO Pin Level 0	32	R
0x 7E20 0038	GPLEV1	GPIO Pin Level 1	32	R
0x 7E20 003C	-	Reserved	-	-
0x 7E20 0040	GPEDS0	GPIO Pin Event Detect Status 0	32	R/W
0x 7E20 0044	GPEDS1	GPIO Pin Event Detect Status 1	32	R/W
0x 7E20 0048	-	Reserved	-	-
0x 7E20 004C	GPREN0	GPIO Pin Rising Edge Detect Enable 0	32	R/W
0x 7E20 0050	GPREN1	GPIO Pin Rising Edge Detect Enable 1	32	R/W
0x 7E20 0054	-	Reserved	-	-
0x 7E20 0058	GPFEN0	GPIO Pin Falling Edge Detect Enable 0	32	R/W
0x 7E20 005C	GPFEN1	GPIO Pin Falling Edge Detect Enable 1	32	R/W

Address	Field Name	Description	Size	Read/ Write
0x 7E20 0060	-	Reserved	-	-
0x 7E20 0064	GPHEN0	GPIO Pin High Detect Enable 0	32	R/W
0x 7E20 0068	GPHEN1	GPIO Pin High Detect Enable 1	32	R/W
0x 7E20 006C	-	Reserved	-	-
0x 7E20 0070	GPLEN0	GPIO Pin Low Detect Enable 0	32	R/W
0x 7E20 0074	GPLEN1	GPIO Pin Low Detect Enable 1	32	R/W
0x 7E20 0078	-	Reserved	-	-
0x 7E20 007C	GPAREN0	GPIO Pin Async. Rising Edge Detect 0	32	R/W
0x 7E20 0080	GPAREN1	GPIO Pin Async. Rising Edge Detect 1	32	R/W
0x 7E20 0084	-	Reserved	-	-
0x 7E20 0088	GPAFEN0	GPIO Pin Async. Falling Edge Detect 0	32	R/W
0x 7E20 008C	GPAFEN1	GPIO Pin Async. Falling Edge Detect 1	32	R/W
0x 7E20 0090	-	Reserved	-	-
0x 7E20 0094	GPPUD	GPIO Pin Pull-up/down Enable	32	R/W
0x 7E20 0098	GPPUDCLK0	GPIO Pin Pull-up/down Enable Clock 0	32	R/W
0x 7E20 009C	GPPUDCLK1	GPIO Pin Pull-up/down Enable Clock 1	32	R/W
0x 7E20 00A0	-	Reserved	-	-
0x 7E20 00B0	-	Test	4	R/W

*https://www.raspberrypi.org/app/uploads/2012/02/BCM2835-ARM-Peripherals.pdf

Acesso direto a registradores*

Acesso a hardware através de memória mapeada

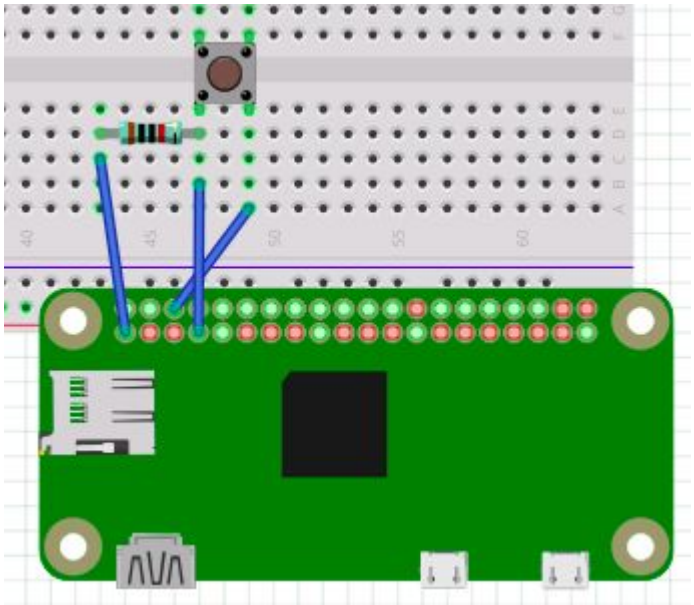
GPIO Function Select Registers (GPFSELn)

SYNOPSIS The function select registers are used to define the operation of the general-purpose I/O pins. Each of the 54 GPIO pins has at least two alternative functions as defined in section 16.2. The FSEL{n} field determines the functionality of the nth GPIO pin. All unused alternative function lines are tied to ground and will output a "0" if selected. All pins reset to normal GPIO input operation.

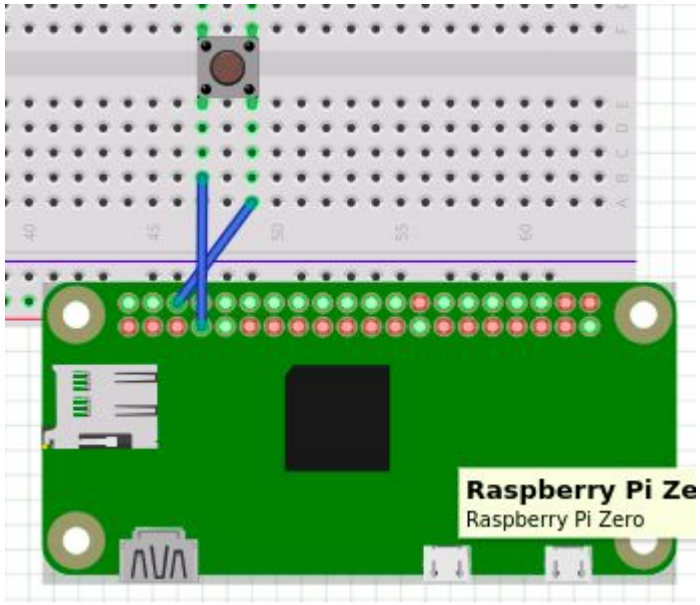
Bit(s)	Field Name	Description	Type	Reset
31-30	---	Reserved	R	0

BROADCOM. **BCM2835 ARM Peripherals**

29-27	FSEL9	FSEL9 - Function Select 9 000 = GPIO Pin 9 is an input 001 = GPIO Pin 9 is an output 100 = GPIO Pin 9 takes alternate function 0 101 = GPIO Pin 9 takes alternate function 1 110 = GPIO Pin 9 takes alternate function 2 111 = GPIO Pin 9 takes alternate function 3 011 = GPIO Pin 9 takes alternate function 4 010 = GPIO Pin 9 takes alternate function 5	R/W	0
26-24	FSEL8	FSEL8 - Function Select 8	R/W	0
23-21	FSEL7	FSEL7 - Function Select 7	R/W	0
20-18	FSEL6	FSEL6 - Function Select 6	R/W	0
17-15	FSEL5	FSEL5 - Function Select 5	R/W	0
14-12	FSEL4	FSEL4 - Function Select 4	R/W	0
11-9	FSEL3	FSEL3 - Function Select 3	R/W	0
8-6	FSEL2	FSEL2 - Function Select 2	R/W	0
5-3	FSEL1	FSEL1 - Function Select 1	R/W	0
2-0	FSEL0	FSEL0 - Function Select 0	R/W	0



Circuito para Ex4.c e Ex5.c



Circuito para Ex6.c