Raspberry Pi 40-Pin GPIO Pinout & Linux Cheat Sheet

40-Pin Header, vcgencmd, Watchdog, OverlayFS, ZRAM & PCIe Gen 3 Recipe (2026)

1. 40-Pin GPIO Color Pinout & Power Map

40-Pin Header

3.3V Pin 1 (3V3 PWR)	Pin 2 (5V0 PWR) 5V0
I2C Pin 3 (GPIO 2 / SDA1)	Pin 4 (5V0 PWR) 5V0
I2C Pin 5 (GPIO 3 / SCL1)	Pin 6 (GND Ground) GND
GP Pin 7 (GPIO 4 / GPCLK0)	Pin 8 (GPIO 14 / TXD0) UART
GND Pin 9 (GND Ground)	Pin 10 (GPIO 15 / RXD0) UART
GP Pin 11 (GPIO 17)	Pin 12 (GPIO 18 / PWM0) PWM
GP Pin 13 (GPIO 27)	Pin 14 (GND Ground) GND
GP Pin 15 (GPIO 22)	Pin 16 (GPIO 23) GP
3.3V Pin 17 (3V3 PWR)	Pin 18 (GPIO 24) GP
SPI Pin 19 (GPIO 10 / MOSI)	Pin 20 (GND Ground) GND
SPI Pin 21 (GPIO 9 / MISO)	Pin 22 (GPIO 25) GP
SPI Pin 23 (GPIO 11 / SCLK)	Pin 24 (GPIO 8 / CE0) SPI
GND Pin 25 (GND Ground)	Pin 26 (GPIO 7 / CE1) SPI
ID Pin 27 (ID_SD / EEPROM)	Pin 28 (ID_SC / EEPROM) ID
GP Pin 29 (GPIO 5)	Pin 30 (GND Ground) GND
GP Pin 31 (GPIO 6)	Pin 32 (GPIO 12 / PWM0) PWM
PWM Pin 33 (GPIO 13 / PWM1)	Pin 34 (GND Ground) GND
PCM Pin 35 (GPIO 19 / PCM_FS)	Pin 36 (GPIO 16) GP
GP Pin 37 (GPIO 26)	Pin 38 (GPIO 20 / PCM_DIN) PCM
GND Pin 39 (GND Ground)	Pin 40 (GPIO 21 / PCM_DOUT) PCM

CRITICAL WARNING: GPIO pins operate strictly at **3.3V LVTTL**! Direct 5V signal input will permanently destroy the Broadcom SoC. Use a level shifter.

2. Vital vcgencmd Diagnostic Commands

Diagnostic

Command	Description	Expected Value / Output
`vcgencmd measure_temp`	Core Temperature	`temp=48.2'C` (Max 80°C)
`vcgencmd measure_volts`	SoC Core Voltage	`volt=0.8500V` (<4.63V)
`vcgencmd measure_clock arm`	Active CPU Frequency	`frequency(48)=2400000000`
`vcgencmd get_mem arm/gpu`	RAM Allocation	`arm=3968M gpu=128M`
`vcgencmd get_throttled`	Voltage & Thermal Health	`throttled=0x0` (Perfect)

```
# get_throttled Bit Mask Analysis:
0x1: Active Under-Voltage (<4.63V!) | 0x2: Active CPU Throttling
0x4: Active Thermal Throttling (>80°C) | 0x50000: Past Under-Voltage Occurred
```

3. OverlayFS Read-Only Root Filesystem

Zero Corruption

```
# 1. Enable Overlay Root Filesystem via raspi-config:
sudo raspi-config
# -> Performance Options -> Overlay File System -> Enable -> Yes
# -> Boot partition read-only -> Yes -> Reboot
mount | grep "overlay on /" # (Zero SD card corruption even if power is yanked!)
```

4. ZRAM In-Memory Compression (Disk Swap Killer)

RAM Boost

```
# 1. Disable disk-thrashing dphys-swapfile:
sudo dphys-swapfile swapoff && sudo systemctl disable dphys-swapfile
# 2. Install zram-tools and edit /etc/default/zramswap:
sudo apt update && sudo apt install -y zram-tools
PERCENTAGE=60 # 60% of RAM as compressed swap
ALGO=lz4 # Ultra-fast lz4 algorithm (Zero CPU bottleneck)
sudo systemctl restart zramswap && zramctl
```

5. Hardware Watchdog Timer (Crash-Proof System)

Broadcom Hardware

```
# 1. Add to /boot/firmware/config.txt:
dtparam=watchdog=on
# 2. Enable in /etc/systemd/system.conf:
RuntimeWatchdogSec=14s   RebootWatchdogSec=10min
# 3. Test: Hardware fires cold reset in 15s if kernel hangs!
echo 1 | sudo tee /proc/sys/kernel/sysrq && echo c | sudo tee /proc/sysrq-trigger
```

6. USB OTG Gadget Mode (Ethernet over USB)

Headless

```
# Pi Zero / Zero 2W / Pi 4 (Single-Cable Headless SSH without Wi-Fi):
1. boot/config.txt: dtoverlay=dwc2
2. boot/cmdline.txt: modules-load=dwc2,g_ether
3. Create empty 'ssh' and 'userconf.txt' in boot.
ssh pi@raspberrypi.local # (Direct terminal access over single USB cable!)
```

7. Raspberry Pi 5 PCIe Gen 3 & NVMe SSD Boot

870+ MB/s

```
# 1. Add to /boot/firmware/config.txt:
dtparam=pciex1
dtparam=pciex1_gen=3 # Force PCIe Gen 3.0 (870+ MB/sec)
# 2. Configure EEPROM Boot priority: (6=NVMe, 1=SD Card)
sudo rpi-eeprom-config --edit # BOOT_ORDER=0xf416
```

8. GPIO Electrical Safety & Current Limits

Electrical Limits

Parameter	Safe Limit	Description & Precaution
Input Voltage	`4.85V - 5.25V`	Below 4.63V causes clock throttling or brownouts.
Single Pin Current	`16 mA (Max)`	Recommended safe operating current is 3 - 8 mA.
Total GPIO Budget	`50 mA (Total)`	Relays and motors must be driven via external transistors.
Internal Resistors	`~50 kΩ`	Software pull-up / pull-down resistance value.