Chapter 5. Electrical and Mechanical

Looking for information on the Raspberry Pi Pico

See [using-the-chip] for information on the Raspberry Pi Pico board.

Physical and electrical details of the RP2040 chip.

5.1. Package

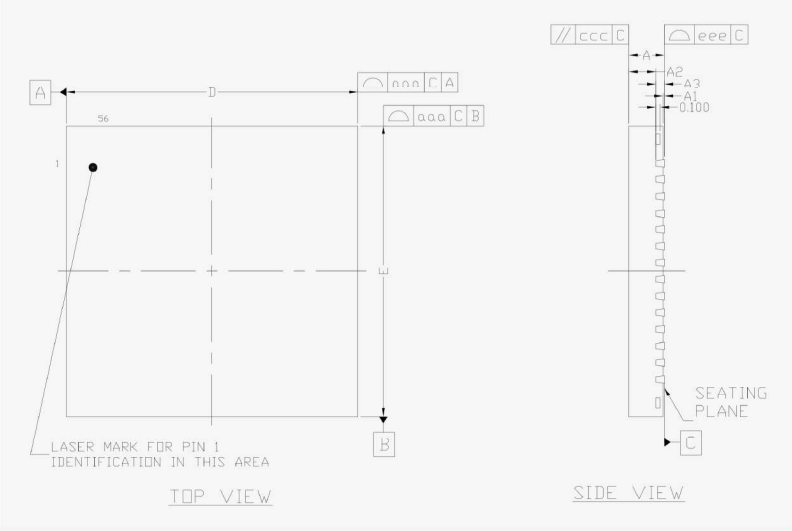


Figure 159. Top down view (left) and side view (right) of the RP2040 QFN-56 package

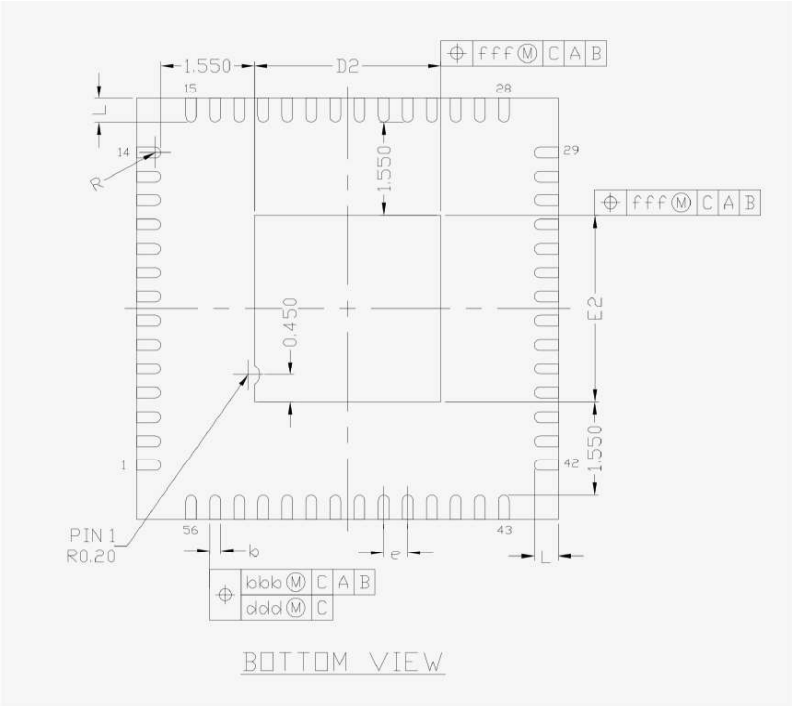


Figure 160. Bottom view of the RP2040 QFN-56 package

Dimensions and Tolerances can be found in the table Table 571

Table 571. Constraints for the RP2040 QFN-56 package

Symbol	Millimeter			Inch		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	-	-	0.900	-	-	0.035
A_1	0.000	-	0.050	0.000	-	0.002
A_2	-	0.650	0.700	-	0.026	0.028
A_3	0.203 REF.			0.008 REF.		
b	0.130	0.180	0.230	0.005	0.007	0.009
D	7 BSC			0.276 BSC		
D_2	3.00	3.100	3.200	0.118	0.122	0.126
E	7 BSC			0.276 BSC		
E_2	3.00	3.100	3.200	0.118	0.122	0.126
L	0.300	0.400	0.500	0.012	0.016	0.020
e	0.400 BSC			0.016 BSC		
R	0.065	-	-	0.003	-	-
Tolerances of form and position						
aaa	0.100			0.004		
bbb	0.070			0.003		
ccc	0.100			0.004		
ddd	0.050			0.002		
eee	0.080			0.003		
fff	0.100			0.004		

NOTE

There is no standard size for the central GND pad (or ePad) with QFNs. However, the one on RP2040 is smaller than most. This means that standard 0.4mm QFN-56 footprints provided with CAD tools may need adjusting. This gives the opportunity to route between the central pad and the ones on the periphery, which can help with maintaining power and ground integrity on cheaper PCBs. See [minimal-design-example] for an example.

5.1.1. Recommended PCB Footprint

Figure 161. Recommended PCB Footprint for the RP2040 QFN-56 package

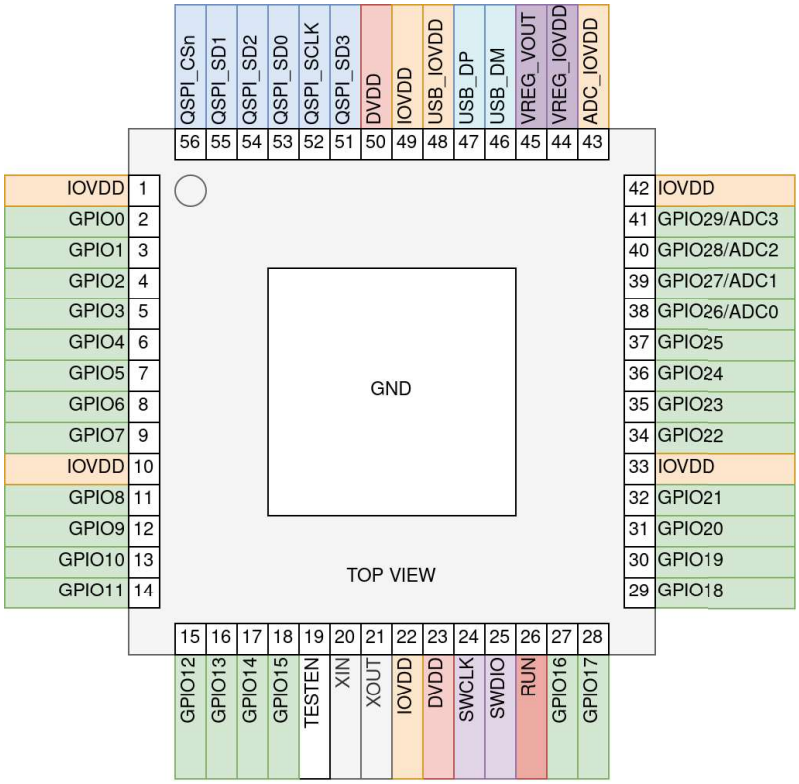
TO DO: JACK: Create an actual dimensioned drawing

TO DO: MIKE/JACK: each diagram should have relevant dimensions listed on the same page, otherwise this is a nightmare to use

5.2. Pinout

5.2.1. Pin Locations

Figure 162. RP2040 QFN-56 package pinout



5.2.2. Pin Definitions

5.2.2.1. Pin Types

In the following GPIO Pin table, the pin types are defined as shown below.

Table 572. Pin Types

Pin Type	Direction	Description
Digital In	Input only	**Standard Digital**. Programmable Pull-Up, Pull-Down, Slew Rate, Schmitt Trigger and Drive Strength. Default Drive Strength is 4mA.
Digital IO	Bi-directional	
Digital In (FT)	Input only	**Fault Tolerant Digital**. These pins are described as Fault Tolerant, which in this case means that very little current flows into the pin whilst it is below 3.63V and IOVDD is 0V. There is also enhanced ESD protection on these pins. Programmable Pull-Up, Pull-Down, Slew Rate, Schmitt Trigger and Drive Strength. Default Drive Strength is 4mA.
Digital IO (FT)	Bi-directional	
Digital IO / Analogue	Bi-directional (digital), Input (Analogue)	**Standard Digital and ADC input**. Programmable Pull-Up, Pull-Down, Slew Rate, Schmitt Trigger and Drive Strength. Default Drive Strength is 4mA.
USB IO	Bi-directional	These pins are for USB use, and contain internal pull-up and pull-down resistors, as per the USB specification. **Note** that external 27Ω series resistors are required for USB operation.
Analogue (XOSC)		Oscillator input pins for attaching a 12MHz crystal. Alternatively, XIN may be driven by a square wave.

5.2.2.2. Pin List

Table 573. GPIO pins

Name	Number	Type	Power Domain	Reset State	Description
GPIO0	2	Digital IO (FT)	IOVDD	Pull-Down	User IO
GPIO1	3	Digital IO (FT)	IOVDD	Pull-Down	User IO
GPIO2	4	Digital IO (FT)	IOVDD	Pull-Down	User IO
GPIO3	5	Digital IO (FT)	IOVDD	Pull-Down	User IO
GPIO4	6	Digital IO (FT)	IOVDD	Pull-Down	User IO
GPIO5	7	Digital IO (FT)	IOVDD	Pull-Down	User IO
GPIO6	8	Digital IO (FT)	IOVDD	Pull-Down	User IO
GPIO7	9	Digital IO (FT)	IOVDD	Pull-Down	User IO
GPIO8	11	Digital IO (FT)	IOVDD	Pull-Down	User IO
GPIO9	12	Digital IO (FT)	IOVDD	Pull-Down	User IO
GPIO10	13	Digital IO (FT)	IOVDD	Pull-Down	User IO
GPIO11	14	Digital IO (FT)	IOVDD	Pull-Down	User IO
GPIO12	15	Digital IO (FT)	IOVDD	Pull-Down	User IO
GPIO13	16	Digital IO (FT)	IOVDD	Pull-Down	User IO
GPIO14	17	Digital IO (FT)	IOVDD	Pull-Down	User IO
GPIO15	18	Digital IO (FT)	IOVDD	Pull-Down	User IO
GPIO16	27	Digital IO (FT)	IOVDD	Pull-Down	User IO
GPIO17	28	Digital IO (FT)	IOVDD	Pull-Down	User IO
GPIO18	29	Digital IO (FT)	IOVDD	Pull-Down	User IO
GPIO19	30	Digital IO (FT)	IOVDD	Pull-Down	User IO
GPIO20	31	Digital IO (FT)	IOVDD	Pull-Down	User IO
GPIO21	32	Digital IO (FT)	IOVDD	Pull-Down	User IO
GPIO22	34	Digital IO (FT)	IOVDD	Pull-Down	User IO
GPIO23	35	Digital IO (FT)	IOVDD	Pull-Down	User IO
GPIO24	36	Digital IO (FT)	IOVDD	Pull-Down	User IO
GPIO25	37	Digital IO (FT)	IOVDD	Pull-Down	User IO
GPIO26 / ADC0	38	Digital IO / Analogue	IOVDD / ADC_IOVDD	Pull-Down	User IO or ADC input
GPIO27 / ADC1	39	Digital IO / Analogue	IOVDD / ADC_IOVDD	Pull-Down	User IO or ADC input
GPIO28 / ADC2	40	Digital IO / Analogue	IOVDD / ADC_IOVDD	Pull-Down	User IO or ADC input
GPIO29 / ADC3	41	Digital IO / Analogue	IOVDD / ADC_IOVDD	Pull-Down	User IO or ADC input

Table 574. QSPI pins

Name	Number	Type	Power Domain	Reset State	Description
QSPI_SD3	51	Digital IO	IOVDD		QSPI data
QSPI_SCLK	52	Digital IO	IOVDD	Pull-Down	QSPI clock
QSPI_SD0	53	Digital IO	IOVDD		QSPI data
QSPI_SD2	54	Digital IO	IOVDD		QSPI data
QSPI_SD1	55	Digital IO	IOVDD		QSPI data
QSPI_CSn	56	Digital IO	IOVDD	Pull-Up	QSPI chip select

Table 575. Crystal oscillator pins

Name	Number	Type	Power Domain	Description
XIN	20	Analogue (XOSC)	IOVDD	Crystal oscillator differential signal. XIN may also be driven by a square wave.
XOUT	21	Analogue (XOSC)	IOVDD	Crystal oscillator differential signal.

Table 576. Serial wire debug pins

Name	Number	Type	Power Domain	Reset State	Description
SWCLK	24	Digital In (FT)	IOVDD	Pull-Up	debug clock
SWD	25	Digital IO (FT)	IOVDD	Pull-Up	debug data

Table 577. Miscellaneous pins

Name	Number	Type	Power Domain	Reset State	Description
RUN	26	Digital In (FT)	IOVDD	Pull-Up	chip enable / reset
TESTEN	19	Digital In	IOVDD	Pull-Down	test enable (connect to Gnd)

Table 578. USB pins

Name	Number	Type	Power Domain	Description
USB_DP	47	USB IO	USB_IOVDD	USB Data +ve. 27Ω series resistor required for USB operation
USB_DM	46	USB IO	USB_IOVDD	USB Data -ve. 27Ω series resistor required for USB operation

Table 579. Power supply pins

Name	Number(s)	Description
IOVDD	1, 10, 22, 33, 42, 49	IO supply
DVDD	23, 50	core supply
VREG_IOVDD	44	voltage regulator input supply
VREG_VOUT	45	voltage regulator output
USB_IOVDD	48	USB supply
ADC_IOVDD	43	ADC supply

Name	Number(s)	Description
GND	57	common ground connection via central pad

5.2.3. Pin Specifications

The following electrical specifications are obtained from characterisation over the specified temperature and voltage ranges, as well as process variation, unless the specification is marked as 'Simulated'. In this case, the data is for information purposes only, and is not guaranteed.

TO DO: MIKE: Revisit this section when characterisation results are available

5.2.3.1. Absolute Maximum Ratings

Table 580. Absolute maximum ratings for digital IO (Standard and Fault Tolerant)

Parameter	Symbol	Minimum	Maximum	Units	Comment
I/O Supply Voltage	IOVDD	-0.5	3.63	V	
Voltage at IO	V_{PIN}	-0.5	IOVDD + 0.5	V	

5.2.3.2. ESD Performance

Table 581. ESD performance for all pins, unless otherwise stated

Parameter	Symbol	Minimum	Maximum	Units	Comment
Human Body Model	HBM	2		kV	Compliant with JEDEC specification JS-001-2012 (April 2012)
Human Body Model ***Digital (FT) pins only***	HBM	4		kV	Compliant with JEDEC specification JS-001-2012 (April 2012)
Charged Device Model	CDM	500		V	Compliant with JESD22-C101E (December 2009)

5.2.3.3. Thermal Performance

Table 582. Thermal Performance

Parameter	Symbol	Minimum	Typical	Maximum	Units	Comment
Case Temperature	T_C	-20		85	°C	
Thermal Resistance - Junction to Ambient (0 m/s airflow)	Θ_{JA}		TBD		°C/W	Simulated. 4 layer PCB. As per JEDEC JESD51-9.

Parameter	Symbol	Minimum	Typical	Maximum	Units	Comment
Thermal Resistance - Junction to Ambient (1 m/s airflow)	Θ_{JA}		TBD		°C/W	Simulated. 4 layer PCB. As per JEDEC JESD51-9.
Thermal Resistance - Junction to Ambient (2 m/s airflow)	Θ_{JA}		TBD		°C/W	Simulated. 4 layer PCB. As per JEDEC JESD51-9.
Thermal Resistance - Junction to Case	Θ_{JC}		TBD		°C/W	Simulated. 4 layer PCB. As per JEDEC JESD51-9.
Thermal Resistance - Junction to Board	Θ_{JB}		TBD		°C/W	Simulated. 4 layer PCB. As per JEDEC JESD51-9.
Thermal Characterisation Parameter - Junction to Top	Ψ_{JT}		TBD		°C/W	Simulated. 4 layer PCB. As per JEDEC JESD51-9.

5.2.3.4. IO Electrical Characteristics

Table 583. Digital IO characteristics - Standard and FT unless otherwise stated

Parameter	Symbol	Minimum	Maximum	Units	Comment
Pin Input Leakage Current	I_{IN}		0.05	µA	
Pin Input Leakage Current - ADC pins (GPIO26:29)	I_{IN}		TBD	µA	Combined leakage of Digital IO and ADC input
Input Voltage High @ IOVDD=1.8V	V_{IH}	0.65 * IOVDD	IOVDD + 0.3	V	
Input Voltage High @ IOVDD=2.5V	V_{IH}	1.7	IOVDD + 0.3	V	
Input Voltage High @ IOVDD=3.3V	V_{IH}	2	IOVDD + 0.3	V	
Input Voltage Low @ IOVDD=1.8V	V_{IL}	-0.3	0.35 * IOVDD	V	
Input Voltage Low @ IOVDD=2.5V	V_{IL}	-0.3	0.7	V	
Input Voltage Low @ IOVDD=3.3V	V_{IL}	-0.3	0.8	V	
Input Hysteresis Voltage @ IOVDD=1.8V	V_{HYS}	0.1 * IOVDD		V	Schmitt Trigger enabled

Parameter	Symbol	Minimum	Maximum	Units	Comment
Input Hysteresis Voltage @ IOVDD=2.5V	V_{HYS}	0.2		V	Schmitt Trigger enabled
Input Hysteresis Voltage @ IOVDD=3.3V	V_{HYS}	0.2		V	Schmitt Trigger enabled
Output Voltage High @ IOVDD=1.8V	V_{OH}	1.24	IOVDD	V	I_{OH} = 2, 4, 8 or 16mA depending on setting
Output Voltage High @ IOVDD=2.5V	V_{OH}	1.78	IOVDD	V	I_{OH} = 2, 4, 8 or 16mA depending on setting
Output Voltage High @ IOVDD=3.3V	V_{OH}	2.62	IOVDD	V	I_{OH} = 2, 4, 8 or 16mA depending on setting
Output Voltage Low @ IOVDD=1.8V	V_{OL}	0	0.3	V	I_{OL} = 2, 4, 8 or 16mA depending on setting
Output Voltage Low @ IOVDD=2.5V	V_{OL}	0	0.39	V	I_{OL} = 2, 4, 8 or 16mA depending on setting
Output Voltage Low @ IOVDD=3.3V	V_{OL}	0	0.27	V	I_{OL} = 2, 4, 8 or 16mA depending on setting
Pull-Up Current @ IOVDD=1.8V	I_{PU}	16	62	µA	
Pull-Up Current @ IOVDD=2.5V	I_{PU}	18	65	µA	
Pull-Up Current @ IOVDD=3.3V	I_{PU}	34	111	µA	
Pull-Down Current @ IOVDD=1.8V	I_{PD}	9	56	µA	
Pull-Down Current @ IOVDD=2.5V	I_{PD}	12	58	µA	
Pull-Down Current @ IOVDD=3.3V	I_{PD}	26	103	µA	

Table 584. USB IO characteristics

Parameter	Symbol	Minimum	Maximum	Units	Comment
Pin Input Leakage Current	I_{IN}		0.05	µA	
Single Ended Input Voltage High	V_{IHSE}	TBD	TBD	V	
Single Ended Input Voltage Low	V_{ILSE}	TBD	TBD	V	

Parameter	Symbol	Minimum	Maximum	Units	Comment
Differential Input Voltage High	V_{IHDIFF}	TBD	TBD	V	
Differential Input Voltage Low	V_{ILDIFF}	TBD	TBD	V	
Output Voltage High	V_{OH}	TBD	TBD	V	I_{OH} = TBD
Output Voltage Low	V_{OL}	TBD	TBD	V	I_{OL} = TBD
Pull-Up Current - RPU1	R_{PU1}	TBD	TBD	kΩ	
Pull-Up Current - RPU1&2	$R_{PU1\&2}$	TBD	TBD	kΩ	
Pull-Down Current	R_{PD}	TBD	TBD	kΩ	

Table 585. ADC characteristics

Parameter	Symbol	Minimum	Maximum	Units	Comment
ADC Input Voltage Range	V_{PIN_ADC}	0	IOVDD	V	
Effective Number of Bits	ENOB	9.5		bits	Simulated
Resolved Bits			12	bits	
Integral Non Linearity	INL	TBD	TBD	V	
Differential Non Linearity	DNL	TBD	TBD	V	

Table 586. Oscillator pin characteristics when using a Square Wave input

Parameter	Symbol	Minimum	Maximum	Units	Comment
Input Voltage High	V_{IH}	0.5*IOVDD + TBD	IOVDD	V	XIN only. XOUT floating
Input Voltage Low	V_{IL}	0	0.5*IOVDD - TBD	V	XIN only. XOUT floating

See Crystal Oscillator for more details on the Oscillator, and [minimal-design-example] for information on crystal usage.

5.3. Power Supplies

Table 587. Power Supply Specifications

Power Supply	Supplies	Min	Typ	Max	Units
IOVDD[a]	digital IO	1.62	1.8 / 3.3	3.63	V
DVDD	digital core	0.99	1.1	1.21	V
VREG_IOVDD	voltage regulator	1.62	1.8 / 3.3	3.63	V
USB_IOVDD	USB PHY	3.135	3.3	3.63	V
ADC_IOVDD[b]	ADC	1.62	3.3	3.63	V

[a] If IOVDD <2.5V, GPIO VOLTAGE_SELECT registers should be adjusted accordingly. See Power Supplies for details.

[b] ADC performance will be compromised at voltages below 2.97V

5.4. Power Envelope

The following data shows the current consumption of various power supplies on 3 each of typical (`tt`), fast (`ff`) and slow (`ss`) corner RP2040 devices, with four different software use-cases.

NOTE

For power consumption of the Raspberry Pi Pico, please see the **Raspberry Pi Pico Datasheet**.

5.4.1. Popcorn

Firstly, 'Popcorn' (Media player demo) using the VGA, SD Card, and Audio board. This demo uses VGA video, I2S aduio and 4-bit SD Card access.

NOTE

For more details of the VGA board see the **Hardware Design with the RP2040 Microcontroller** book.

The 'Average' `IOVDD` data shows the mean current consumption over several seconds of video, with varying colour and intensity. The 'Maximum' data is obtained during periods of white video, when the current required is at it's highest. `DVDD` is shown as 'Average', as this does not vary greatly with video contents

5.4.2. USB Boot Mode

Secondly, the USB Boot mode of . These measurements are made both with and without USB activity on the bus, using a Raspberry Pi 4 as a host; `USB_IOVDD`, `IOVDD` and `DVDD` are shown.

5.4.3. DORMANT Mode

The third use-case uses the `hello_dormant` binary which puts RP2040 into a low power state, `DORMANT` mode

5.4.4. SLEEP Mode

The final use-case uses the `hello_sleep` binary code which puts RP2040 into a low power state, `SLEEP` mode