X1501 Pico SoM Datasheet

V1.0b

Features

- Ingenic X1501 SoC
  - 1GHz rated core frequency
  - Double precision FPU
  - 16KiB each L1 inst/data cache
  - 128KiB unified L2 cache
  - 8MiB LPDDR
  - 2MiB NOR flash
- Rich communication interfaces
  - One 4-wire SPI module (up to 50MHz)
  - Two USART modules (up to 1Mbaud)
  - Two I2C modules (up to 400kHz)
  - One 4-bit SDIO module (up to 50MHz)
  - One 8-bit parallel camera interface (up to 80MHz)
  - USB 2.0 High Speed On-The-Go (OTG) controller
  - One analog mono audio output
  - One PDM digital microphone input
- Secondary Core
  - 100MHz rated core frequency
  - 8KiB zero wait state TCSM
  - Realtime control
  - Programmable digital I/O
- High power efficiency and performance
  - 2200+ CoreMark
  - 333.3+ Double Precision WhetStone MWIPS
  - 0.018W suspend-to-RAM power consumption
- Advanced security features
  - Full featured MMU with execution disable bit
  - EFUSE for firmware protection
- Versatile power supply options
  - 2.5V to 6.0V power supply voltage
  - 3.3V 800mA buck regulated power output
- Easy integration
  - 16mm x 16mm x 2mm physical size, easily solderable by hand
  - As few as 3 external passive components required

Applications

- Portable instruments
- Flight computer
- IoT and home automation
- USB gadgets
- Intelligent industrial control
- Embedded computing
- Education

General Description

The X1501 Pico is a system-on-module (SoM) with a power efficient and high-performance processor in very small 16mm x 16mm x 2mm physical size. It incorporates the Ingenic X1501 SoC which contains 8MiB LPDDR and 2MiB NOR flash. Runs mainline Linux and supports wide voltage supply range from 2.5V to 6.0V.

1. Description

The X1501 Pico SoM is a high-performance System-On-Module based on the 32-bit MIPS32r2 RISC processor. X1501 Pico SoM is tested working within industrial operating conditions over a -40 to 85°C temperature range.

The system of the X1501 Pico SoM operates at a maximum rated CPU operating frequency of 1008 MHz. It features up to:

- 64 Mbit of LPDDR SDRAM memory
- 16 Mbit of QSPI NOR Flash memory

The X1501 processor offers high performance and power efficiency:

- 2200+ CoreMark at 1GHz
- 333.3 Double Precision WhetStone MWIPS at 1GHz
- 0.018W suspend-to-RAM power consumption at 5V supply voltage

The X1501 Pico SoM is a 52-pin, 1.0mm pad pitch module, 16mm x 16mm x 2mm in size. **There are no components on the back side.**

The X1501 Pico SoM offers an extensive peripheral set, including High-speed USB Host and Device, system control and up to 36 digital I/Os featuring:

- Up to 2 UARTs
- Up to 2 PWM channels
- Serial Interfaces such as SPI and I2C
- SD/MMC, eMMC, SDIO Interface
- Parallel CMOS Camera Interface
- Built-in audio codec with stereo PDMIC input and mono analog output
- Programmable digital I/O using the secondary core

TIP If operating between 0-70°C, it's typically possible to raise the CPU speed to 1.2GHz, optimizing performance without compromising stability. Nonetheless, it is advisable to perform tests prior to implementation in a production environment. Individuals undertaking overclocking should acknowledge and assume the responsibility associated with this process.

TIP Each digital I/O of the X1501 Pico SoM is configurable, as either a general-purpose I/O line only, or as an I/O line multiplexed with peripheral I/Os. As the multiplexing is hardware-defined, the hardware designer and programmer must carefully determine the configuration of the GPIO controller required by their application.

TIP The secondary core of X1501 can be used to create software-defined peripherals with GPIO bitbanging without slowing down the main core. On the main core, the maximum GPIO flipping speed is 2.3MHz[1]. On the secondary core, the maximum GPIO flipping speed is 9.48MHz[2].

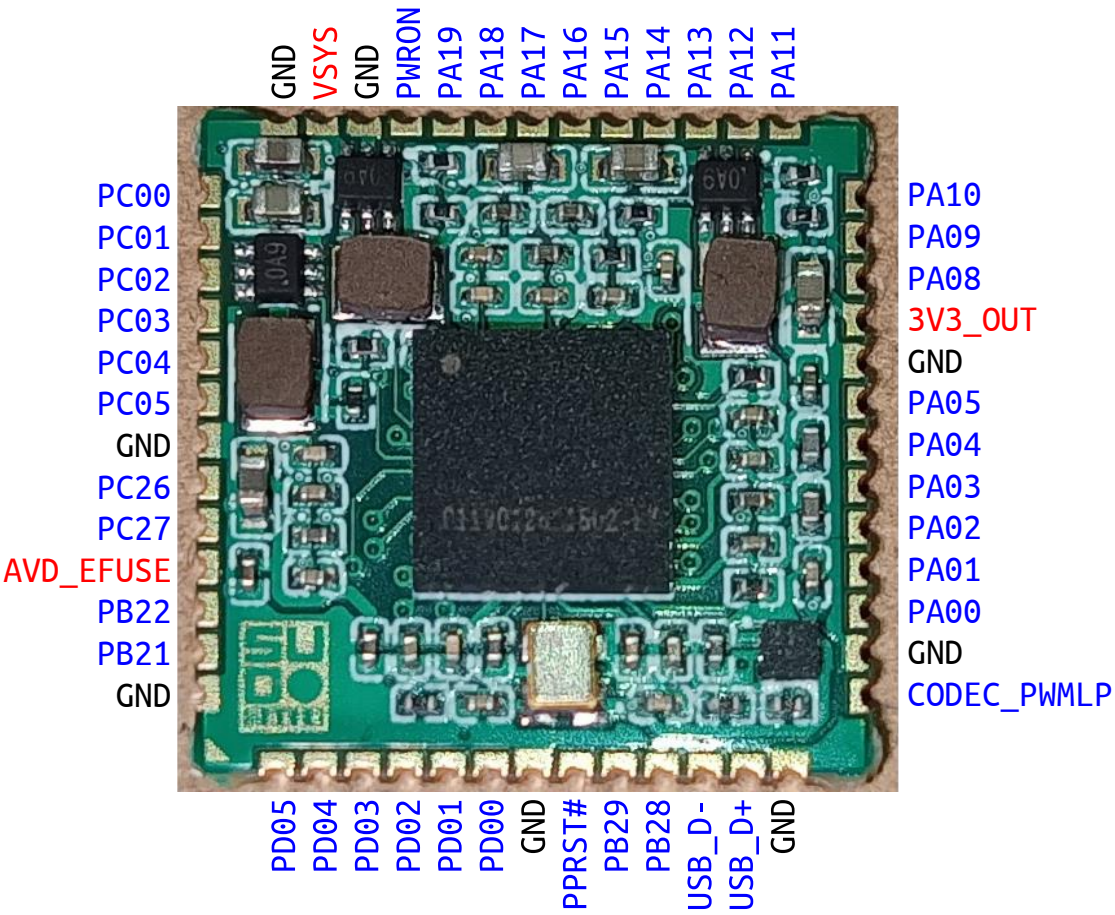
[1] At rated core frequencies, bare metal.
[2] At rated core frequencies. Up to 24MHz when PCLK is 150MHz.

2. Pinout

2.1 Pinout Overview

The categories of pins are listed below:

- Red: Power Supplies
- Blue: Signals
- Black: Ground



2.2 Pin List

The categories of pins are listed below:

- DIO: Digital I/O
- AIO: Analog I/O
- PWR: Power

Pin No.	Name	Type	Func 0	Func 1	Func 2
1	PD05	DIO	GPIO	UART2_RXD	UART1_RTS
2	PD04	DIO		UART2_TXD	UART1_CTS
3	PD03	DIO		SSI0_DR	UART1_TXD
4	PD02	DIO		SSI0_DT	UART1_RXD
5	PD01	DIO		SSI0_CE0	SMB2_SDA
6	PD00	DIO		SSI0_CLK	SMB2_SCK
7	GND	PWR			
8	PPRST#	DI			
9	PB29	DIO	GPIO	BOOTSEL1	
10	PB28	DIO	GPIO	BOOTSEL0	
11	USB_D-	AIO			
12	USB_D+	AIO			
13	GND	PWR			
14	CODEC_PWMLP	AO			
15	GND	PWR			
16	PA00	DIO	GPIO	SMB1_SCK	
17	PA01	DIO	GPIO	SMB1_SDA	
18	PA02	DIO	GPIO	UART2_RXD	
19	PA03	DIO	GPIO	UART2_TXD	
20	PA04	DIO	GPIO	UART1_RXD	
21	PA05	DIO	GPIO	UART1_TXD	
22	GND	PWR			
23	3V3_OUT	PWR			
24	PA08	DIO	GPIO	CIM_PCLK	
25	PA09	DIO	GPIO	CIM_HSYN	
26	PA10	DIO	GPIO	CIM_VSYN	
27	PA11	DIO	GPIO	CIM_MCLK	
28	PA12	DIO	GPIO	CIM_D7	
29	PA13	DIO	GPIO	CIM_D6	
30	PA14	DIO	GPIO	CIM_D5	
31	PA15	DIO	GPIO	CIM_D4	
32	PA16	DIO	GPIO	CIM_D3	
33	PA17	DIO	GPIO	CIM_D2	
34	PA18	DIO	GPIO	CIM_D1	

Pin No.	Name	Type	Func 0	Func 1	Func 2
35	PA19	DIO	GPIO	CIM_D0	
36	PWRON	DI			
37	GND	PWR			
38	VSYS	PWR			
39	GND	PWR			
40	PC00	DIO	GPIO	MSC1_CLK	
41	PC01	DIO	GPIO	MSC1_CMD	
42	PC02	DIO	GPIO	MSC1_D0	
43	PC03	DIO	GPIO	MSC1_D1	
44	PC04	DIO	GPIO	MSC1_D2	
45	PC05	DIO	GPIO	MSC1_D3	
46	GND	PWR			
47	PC26	DIO	GPIO	SMB1_SCK	PWM1
48	PC27	DIO	GPIO	SMB1_SDA	PWM2
49	AVD_EFUSE	PWR			
50	PB22	DIO	GPIO	DMIC_IN0	
51	PB21	DIO	GPIO	DMIC_CLK	
52	GND	PWR			

3. Functional Description

3.1 Ingenic X1501 SoC

The Ingenic X1501 SoC integrates the high-performance & ultra-low power MIPS32r2 based XBurst1 Core, 64Mbit (8MiB) LPDDR, and 16Mbit (2MiB) NOR flash in a single package.

The Ingenic X1501 is available in an 81-ball BGA package.

3.2 Power Supplies

The X1501 Pico SoM is supplied by an external 2.5V-6.0V power supply in the VSYS pin and generates its own internal supplies with 3 high efficiency DC-DC buck regulators and 1 LDO.

- DCDC1 set @ 1.25V supplies X1501 Core.
- DCDC2 set @ 1.8V supplies X1501 LPDDR.
- DCDC3 set @ 3.3V supplies X1501 VDDIO.
- LDO1 set @ 2.5V supplies X1501 USB PHY.

The X1501 Pico SoM also has a buck regulated 3.3V 800mA power output which is supplied by DCDC3. You can use it to power other on-board components conveniently.

TIP If the power supply voltage at the VSYS pin falls below 3.3V, the DCDC3 will act like a MOSFET with an on-resistance of approximately 170 mΩ. The module continues to operate at VSYS >= 2.5V, **however, components powered by 3V3_OUT on your board might not work as expected.**

3.3 System Control

The X1501 Pico SoM provides a processor reset (PPRST#) pin to the application board. This pin has an internal 330 KΩ pull-up. When this pin is pulled low, the X1501 processor will be rebooted forcibly.

The X1501 Pico SoM provides a global system power control (PWRON) pin to the application board. This pin has no internal pull resistors. When this pin is pulled high (at least 1.2V), the module will be powered on. When this pin is pulled low, the module will be powered off. If the power control functionality is not needed, please tie it to the VSYS pin.

4. Electrical Characteristics

This section provides an overview of the electrical characteristics of the X1501 Pico SoM module. Absolute maximum ratings for the X1501 Pico SoM module are listed below. Exposure to these maximum rating conditions for extended periods may affect device reliability. Functional operation of the module at these or any other conditions, above the parameters indicated in the operation listings of this specification, is not implied.

4.1 Absolute Maximum Ratings

Table 4-1: Absolute Maximum Ratings

Parameter	Conditions	Min.	Max.
Storage Temperature	-	-60°C	+150°C
Operating Temperature	-	-40°C	+85°C
Voltage on VSYS	With respect to ground	-0.3V	+6.2V
Voltage on 3V3_OUT	With respect to ground	-0.3V	+3.6V
Current on 3V3_OUT		-	1A
Voltage on I/O Pins	With respect to ground	-0.3V	3V3_OUT*1.15
Current on I/O Pins	-	-	15mA

4.2 Operational Characteristics

Table 4-2: Power Supplies Operating Conditions

Parameter	Conditions	Min.	Typ.	Max
Voltage on VSYS		2.5V	-	6.0V
Power drained from VSYS	3V3_OUT floating	-	-	0.5W
Current on 3V3_OUT		-	-	800mA

The above characteristics are applicable to the operating temperature range:

TA = -40°C to +85°C

unless otherwise specified.

For other operational characteristics, please consult the X1501 datasheet for more information.

5. Assembly and Production

5.1 Bake Information

The X1501 Pico SoM is rated MSL 3 and has a total thickness of 2.0mm according to the IPC/JEDEC J-STD-033 standard.

It's the users' responsibility to ensure their storage and assembly processes are compliant with the IPC/JEDEC J-STD-033 standard.

5.2 Hand Soldering

You can solder this module by hand in diverse ways. For example:

- Use a double-sided tape or your hand to fix the module at its intended position and use a solder iron.
- Scribble solder paste on the base board and put the module at its intended position carefully. Then use a heating plate or oven.

You are strongly recommended to make use of protective equipment properly and take adequate fire prevention measures during the process. Be careful not to burn yourself or inhale toxic gases.

5.3 Reflow Profile

The X1501 Pico SoM was assembled using standard lead-free reflow profile IPC/JEDEC J-STD-020E. We recommend a maximum of two soldering processes.

The X1501 Pico SoM can be soldered to the host PCB by using the standard and lead-free solder reflow profile. To avoid damage to the module, follow the JEDEC recommendations as well as those listed below:

- Do not exceed the peak temperature (Tp) of 245℃.
- Refer to the solder paste data sheet for specific reflow profile recommendations.
- Use no-clean flux solder paste.
- Use only one flow. If the PCB requires multiple flows, mount the module at the time of the final flow.

6. Hand on Designing

6.1 Hardware Designing

It is quite easy to integrate the X1501 Pico SoM into your project. This module only requires as few as 3 external components for correct operation:

- Pull resistors on PB28_BOOTSEL0 and PB29_BOOTSEL1.
  - Suggested value: 100KΩ.
- Pull-down resistor on AVD_EFUSE.
  - Suggested value: 1KΩ.

TIP You can always add more capacitance to VSYS and 3V3_OUT to reduce ripple and improve stability. You should do so if you have an unstable power supply or there are power-hungry components connected to 3V3_OUT.

The BOOTSEL pins decide the boot media after reset or power-on. Here SFC means the internal NOR flash, MSC1 means external SD/eMMC. For the detailed boot procedure, please consult the X1501 datasheet for more information.

Table 6-1: BOOTSEL Conditions

	Enter USB bootloader	Boot from SFC	Boot from MSC1
BOOTSEL0	0	1	1
BOOTSEL1	X	1	0

TIP If your product needs buttons, you can connect them to the BOOTSEL pins. These pins will behave as normal GPIO after boot. Doing so can also provide you an effortless way to enter the USB bootloader (i.e., holding the button connected to BOOTSEL0 and power cycle).

The AVD_EFUSE pin must be connected to ground during normal operation. When programming the EFUSE, 2.5V voltage needs to be applied to this pin for a short time. If you plan to make use of the EFUSE, you need another GPIO pin and a MOSFET to control the time of 2.5V voltage applied to this pin precisely. Please kindly reach out to us for detailed information about the EFUSE at this moment.

The CODEC_PWMLP is the mono analog audio output. The maximum load is 16Ω. It is advised to use an external amplifier if you are driving a speaker. Extra filtering is needed if the signal is fed to a high impedance input. Please consult the X1501 datasheet for more information.

More hardware designing resources can be found at:
https://github.com/SudoMaker/X1501_Pico/tree/master/Hardware

6.2 Firmware Flashing

Hold the BOOTSEL0 pin low and perform a reset to enter the USB bootloader.
You can download the PC software here:
https://github.com/Ingenic-community/Cloner

6.3 Software Development

The X1501 Pico SoM only supports running mainline Linux at this moment. There are plans to support NetBSD in the future.
More software development resources can be found at:
https://github.com/SudoMaker/X1501_Pico/tree/master/Software

Revision History

1. V1.0b – First release (2023/6/11)

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