PRELIMINARY
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USB100
Programmable Low-Cost USB Machine (PLUM)
Single Chip Controller for Mouse, Trackball, Joystick and Gamepad Applications

General Description

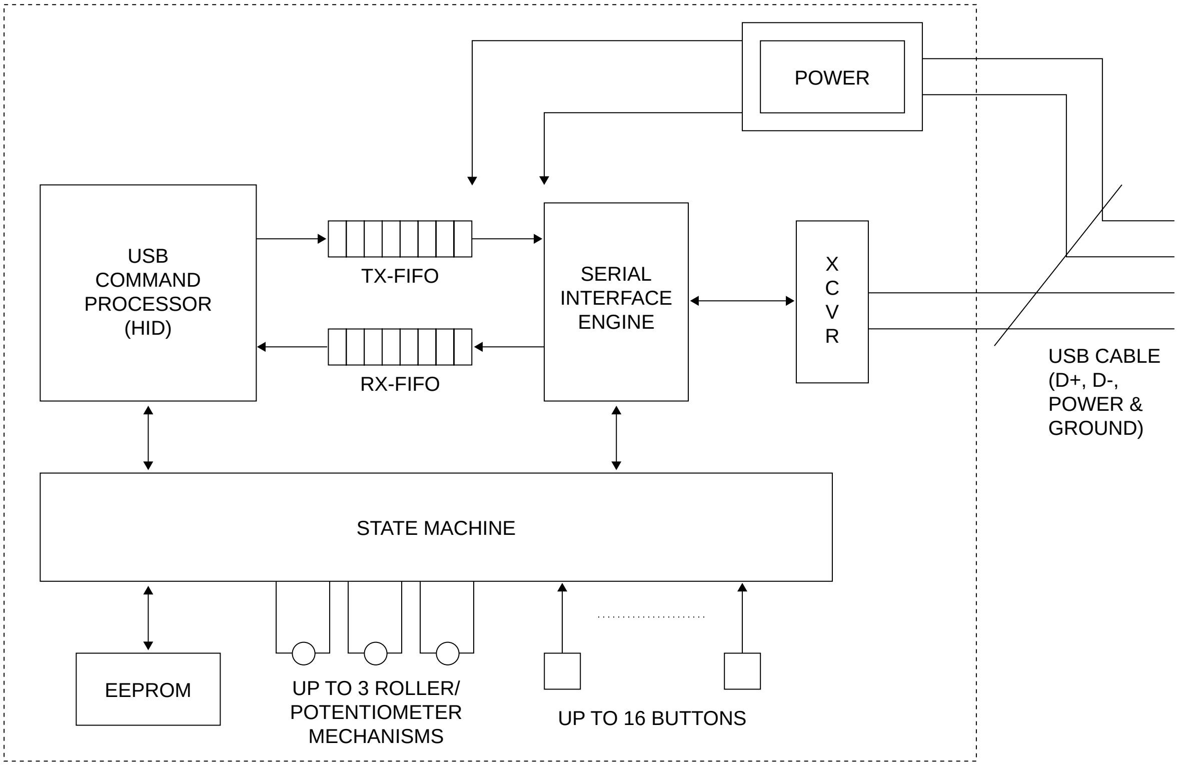
The USB100 is a Low cost, fully customizable controller for USB HID-class pointing devices. It is in full compliance with REV 1.0 of the USB standard and implements the HID class specification for mice, trackballs, joysticks and gamepads. This device interprets the commands specified in the HID class document and provides appropriate responses from an On-Chip EEPROM. It also provides ability to customize the device according to individual needs of the designers. Programming utilities supplied with this device allow HID manufacturers to easily create the necessary data to be programmed into the device.

The device includes the necessary transceiver for USB operation and meets all of the active and standby current specifications for a bus-powered device.

Features

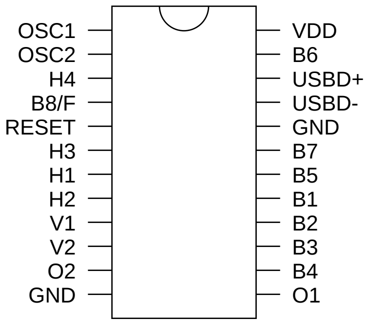
- ■ USB 1.0 standard compliant
- ■ Has the necessary on-chip transceivers
- ■ Support for 2D and 3D mice with 2, 3 or more buttons
- ■ Supports 3 potentiometer mechanisms for joysticks
- ■ Up to 16 buttons for digital gamepads
- ■ Choice of 18-pin and 24-pin packages
- ■ Choice of 2Kbit and 4Kbit EEPROM densities

Block Diagram

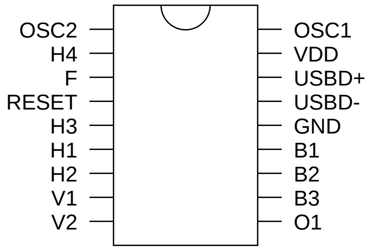


Pinout

24 Pin Package



18 Pin 3D Package



Pin Description

Pin	Type	Description
H4	I	Roller/Button/Joystick input.
H3	I	Roller/Button/Joystick input.
O2	I/O	Register output pin / Button input.
OSC1	I	Crystal input number 1.
OSC2	I	Crystal input number 2
B4	I	Button input
Reset	I	Active high reset pin
H1	I	Roller/Button/Joystick input.
H2	I	Roller/Button/Joystick input.
V1	I	Roller/Button/Joystick input.
V2	I	Roller/Button/Joystick input.
GND	I	Ground
B7	I	Button input
B6	I	Button input
B5	I	Button input
VDD	I	Positive power supply
USBD+	O	USB D + line
USBD-	O	USB D – line
GND	I	Ground
B8/F	I/O	Button input / LED driver
B1/CS	I	Button input and chip select to internal EEPROM.*
B2/SK	I	Button input and system clock to internal EEPROM.*
B3/DI	I	Button input and data in to internal EEPROM.*
O1/DO	O	Button input and data out to read from internal EEPROM.*

* See Programming internal EEPROM section

Absolute Maximum Ratings

Ambient Storage Temperatures	-65°C to + 150°C
All Input or Output Voltages with respect to ground	V_{CC} + 1 to – 0.3V
Lead Temperature (Soldering, 10 seconds)	+300%
ESD Rating	2000V

Operating Conditions

Ambient Operating Temperature	0°C to +70°C
Power Supply (V_{CC}) Range	4.4V to 5.5V

DC and AC Electrical Characteristics 4.4V $\leq V_{CC} \leq$ 5.5V

Symbol	Parameter	Conditions	Min	Max	Units
I_{CCA}	Operating Current	USB interface in active mode		40	mA
I_{CCS}	Standby Current	USB interface in suspend		500	µA
V_{IL}	Input Low Voltage			0.8	V
V_{IH}	Input High Voltage		2		V
V_{OL}	Output Low Voltage			0.4	V
V_{OH}	Output High Voltage		2.4		V
I_{IL}	Input Leakage Current			2.5	µA
I_{OL}	Output Leakage Current			2.5	µA
F_{SK}	SK Clock Frequency	Note 3	0	1	MHz
T_{SKH}	SK High Time		250		ns
T_{SKL}	SK Low Time		250		ns
T_{CS}	Minimum CS Low Time	Note 4	250		ns
T_{CSS}	CS Setup Time		50		ns
T_{DH}	DO Hold Time		70		ns
T_{DIS}	DI Setup Time		100		ns
T_{CSH}	CS Hold Time		0		ns
T_{DIH}	DI Hold Time		20		ns
T_{PD1}	Output Delay to “1”			500	ns
T_{PD0}	Output Delay to “0”			500	ns
T_{SY}	CS to Status Valid			500	ns
T_{DF}	CS to DO in TRI-STATE			100	ns
T_{WP}	Write Cycle Time			10	ms

AC Test Conditions

Output Load	1 TTL Gate
Input Pulse Levels	0.4V and 2.4V

Timing Measurements Reference Level

Input	1V and 2V
Output	0.8V and 2.0V

Note 1: Stress ratings above those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and operation of the device at these or any other conditions above those indicated in the operational sections of the specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Note 2: The shortest allowable S clock period = $1/f_{SK}$ (as shown under the f_{SK} parameter). Maximum SK clock speed (minimum SK period) is determined by the interaction of several AC parameters stated in the datasheet. Within this SK period, both t_{SKH} and t_{SKL} limits must be observed. Therefore, it is not allowable to set $1/f_{SK} = t_{SKH}$(minimum) + t_{SKL}(minimum) for shorter SK cycle time operation.

Note 3: CS (Chip Select) must be brought low (to V_{IL}) for an interval of t_{CS} in order to reset all internal device registers (device reset) prior to beginning another opcode cycle. (This is shown in the opcode diagrams in the following pages.)

Interface Pin Descriptions

H1, H2, H3, H4, V1, V2 (Roller/Joystick inputs)

When configured as roller inputs these pins function in pairs, H1 and H2, H3 and H4, V1 and V2 to allow photo diodes to be attached in a mouse or trackball application. See the section “Roller Movement Reporting” for a more detailed description. When configured for a joystick only one of the inputs pairs is used. A potentiometer is attached to track the movements of a joystick lever. When these inputs are configured as buttons they all act independently as active low button inputs. All of them have internal pull-ups and debounce circuitry which can be programmed using the ICB registers. These inputs also contain current sink features so no external resistor is needed to sink current from the photo diode.

B1, B2, B3, B4, B5, B6, B7, B8/F (Button inputs)

The button inputs to the USB100 have internal pull up resistors, with active low inputs to the chip. These inputs also contain debounce circuitry which can be programmed by the ICB registers.

Key Debounce Select Table (ICB register3[3:2])

KD[1:0]	
00	15 ms
01	30 ms
10	45 ms
11	60 ms

USBD -, USBD +

These inputs are the serial bus lines which USB data is communicated. These bi – directional lines connect to the host, through a USB type A or type B connector, and are used to communicate all USB information to and from the host. The two lines must both be wired through a 27 ohm resistor before being attached to the USB connector. See Recommended Configuration for a detailed diagram.

Reset

This pin is used to reset the entire chip. It must be held high for more than 10ns, to reset the chip and then brought low for the reset of normal chip operation.

O1, O2

These two pins are wired to internal registers which can be programmed with either a “1” or a “0” by a USB request. If this command is sent to the USB100. INSERT COMMAND FROM INSPECTOR. Then the O1 and O2 pins will be programmed with the values that are in the second data package. These two pins can also be configured as standard button inputs by one of the ICB registers.

O1, O2 Functionality. ICB register 1[3:2]

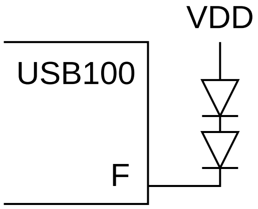
IOM[1:0]	Function
00	Both O1 and O2 function as programmable outputs.
01	O1 is a programmable output but O2 is a standard button input.
11	Both O1 and O2 are standard inputs.

In case these are selected as outputs, their state (1 or 0) can be set using the USB set_report command. These outputs are open-collector. A typical use of these outputs is using them to drive LEDs (for example, a drag-lock function in a trackball). These pins have a programmable current sink capability.

B8/F

When this pin is configured as an input it will behave as a standard button input. But if the pin is disabled in the ICB registers then this pin can be used to control the roller LEDS in powersave mode.

Using the B8/F pin to control the LEDs



This allows the LEDs to be shut off during powersave mode which allows the USB100 to draw very little current. The official name for powersave mode on a USB device is known as suspend mode which is discussed in the section labeled Suspend Mode Operation.

OSC1, OSC2

These two pins are the clock inputs into the USB100. The speed at which the chip runs at is 6MHz. The clock sign can be generated two ways. The first is to use a parallel resonant, fundamental mode crystal circuit or a ceramic resonator circuit connected to the OSC1 and OSC2 inputs. The other method is to use a crystal oscillator connected to the OSC2 input and leaving the OSC1 input unconnected

USB modes of operation

The USB100 loads up its configuration from the EEPROM on power-on reset, or when a USB reset command is issued. Upon completion of reset, the device is in a operational mode, and responds correctly to the various commands described in the USB spec rev 1.0. The USB100 supports two endpoints – the default endpoint (endpoint 0) and the interrupt endpoint (endpoint 1). The supported packet size on both endpoints is 8 bytes. The endpoint 1 is an “IN” endpoint.

Standard Requests

The USB100 supports all of the required standard requests. These requests are sent to the device using control transfers to endpoint 0.

In USB terminology, the data transmitted by the mouse when movement is detected is called a report. The reports are generated by the USB100 device in accordance to the USB HID spec 1.0 Final.

Programming the EEPROM

The on-chip EEPROM can be programmed in a special mode which defines some of the button inputs/output as a microwire port.. In this mode, these inputs behave as a conventional Microwire serial port. Data can be easily programmed and verified, by executing simple EEPROM programming commands.

Initial Configuration Bytes (ICB) register description

The first five bytes in the EEPROM are used to configure the physical characteristics of the USB100 device, and are called the Initial configuration Byte registers. Some of the bits in these registers are reserved, and are referred to as RFU (reserved for future use) in the following section.

Roller Configuration Byte (Address 0)

D7	D6	D5	D4	D3	D2	D1	D0
IS3	IS2	IS1	IS0	IOM1	IOM0	R1	R0

R[1:0]: No of roller pairs. This pair of bits configure the functionality of the three roller pair inputs – <H1, H2>, <V1,V2> and <H3, H4>.

00: No rollers on this device, all roller inputs are available as general purpose inputs

01: H1, H2 are the only roller mechanism active. The other roller inputs are available as general purpose inputs.

10: H1, H2 and V1 and V2 are defined as roller mechanism pairs. The other pair is still available as general purpose inputs.

11: All the three pairs of roller inputs function as roller inputs.

It must be noted that the reassignment of the rollers must be done only as follows: If the application needs to use only one roller – use H1 and H2. Two rollers – use H1, H2 and V1, V2, Three rollers – use H1, H2, V1, V2 and H3, H4. Any other choice for roller use is illegal and results in unpredictable device behavior.

IOM[1:0]: I/O functionality of the O0 and O1 pins. When IOM0 is set to ‘0’, the O0 bit functions as an output. When set to ‘1’ it becomes an input. . When IOM1 is set to ‘0’, the O1 bit functions as an output. When set to ‘1’ it becomes an input. The only valid combinations for these bits are 00, 01 and 11 respectively.

IS[3:0]: This 4-bit value is to set the amount of current that an external device can sink into the H1, H2, V1, V2 and H3 and H4 inputs When these bits are set to 0000 the current sink is set to 0.1 mA on each of the inputs. In can be varied in steps of 0.1mA up to a max of 1 mA.

IS[3:0]	Current
0000	0.1 mA
0001	0.2 mA
0010	0.3 mA
0011	0.4 mA
0100	0.5 mA
0101	0.6 mA
0110	0.7 mA
0111	0.8 mA
1000	0.9mA
1001	1.0mA

Input Pin Configuration Byte 0 (ICB0) (Address 1)

D7	D6	D5	D4	D3	D2	D1	D0
B8	B7	B6	B5	B4	B3	B2	B1

B[7:0]: Input Pin Report Generator. A ‘1’ causes this bit to be reported in the corresponding report generated when the device is polled for the status. The device accepts only the following bit patterns as valid. B[7:0] control the functionality for pin inputs B[8:1] respectively.

00000000
00000001
00000011
00000111
00001111
00011111
00111111
01111111
11111111

Input Pin Configuration Byte 1 (ICB1) (Address 2)

D7	D6	D5	D4	D3	D2	D1	D0
IO1	IO0	EB5	EB4	EB3	EB2	EB1	EB0

EB[5:0]: Input Pin Report Generator, Extended byte. The functionality of this register is influenced by the roller configuration byte. A ‘1’ causes this bit to be reported in the corresponding report generated when the device is polled for the status. EB0 corresponds to H3 and EB1 corresponds to H4. EB2 corresponds to V1 and EB3 corresponds to V2. EB4 corresponds to H1 and EB5 corresponds to H2.

00000000
00000001
00000011
00000111
00001111
00011111
00111111

RFU: Reserved for future use, must be set to 0.

IO[1:0]: When the IO pins are reconfigured as inputs, a ‘1’ in the corresponding bit position will cause the input to be included in the report generator.

Application Configuration Byte (Address 3)

D7	D6	D5	D4	D3	D2	D1	D0
FIS3	FIS2	FIS1	FIS0	KD1	KD0	F1	F0

F[1:0]: Function Select. Selects between the following

00 : Mouse operation
01: RFU
10: Joystick Operation.
11: Digital Gamepad operation

KD[1:0]: Key Debounce Select:

00: 15 Ms
01: 30 Ms
10: 45 Ms
11: 60 Ms

FIS[3:0]: These bits select the amount of current that the ‘F’ pin can sink, in 1 mA increments. When FIS[3:0] = “0000” The current sink is set at 2 mA. Incrementing this count by 1 will cause the current to be increased by 1mA The maximum value is 10 mA.

Remote Resume Config Byte (Address 4)

D7	D6	D5	D4	D3	D2	D1	D0
RFU	RFU	RFU	RFU	RRES_EN	RRES2	RRES1	RRES0

RRES_EN: Remote_resume enable. This bit, when set, enables remote resume operation.

RRES[2:0]: Duration Select. When the device has entered in suspend mode, these bits select the duration after which an internal “momentary wakeup” is done to check whether there has been any movement on the rollers in the mouse mode or the potentiometers in the joystick mode. The RRES_EN bit must be set to 1 to enable this feature.

000: 15 ms
001: 30 ms
010: 45 ms
011: 60 ms
100: 75 ms
101: 90 ms
110: 105 ms
111: Reserved for future use (do not use this combination, unpredictable operation could result)

Descriptor Setup

The EEPROM stores a Descriptor Description Table (DDT) followed by the actual descriptors (DES). The DDT begins at byte address 8 in the EEPROM. It consists of 14 Words. Each Word consists of two bytes – The first byte is a byte indicating the type of descriptor (these byte values are indicated in the USB specification). The second byte is an address. This address indicates the first byte of this descriptor in the EEPROM. An unimplemented descriptor table entry begins with a 00. The following table shows a possible configuration.

Address Map

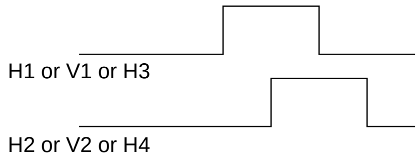
Memory AddressRange	Data type
08-35	Descriptor Description Table
36-53	Device Descriptor
54-62	Config Descriptor
63-71	Interface Descriptor
72-78	Mouse HID Class Descriptor
79-86	Endpoint Descriptor
87-118	String Descriptor

Descriptor Description Table (for above example)

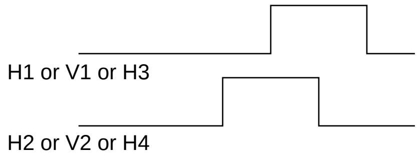
Address	Descriptor type	Memory Offset
08	Device	36
10	Config	54
12	Interface	63
14	Mouse-HID	72
16	Endpoint	78
18	String	87
20	00	00
22	00	00
24	00	00
26	00	00
28	00	00
30	00	00
32	00	00
34	00	00

Roller Movement Reporting

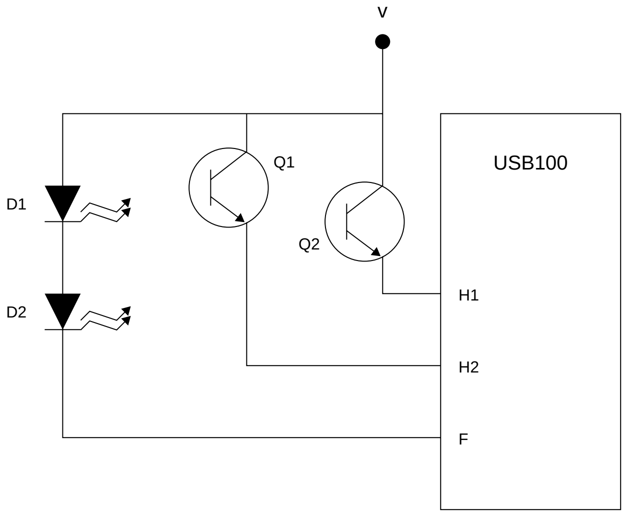
The roller mechanism built on the USB100 is capable of interfacing either to a LED-chopper wheel-Phototransistor system or a mechanical system using a commutator with wiper contacts.



Negative Counting



Positive Counting



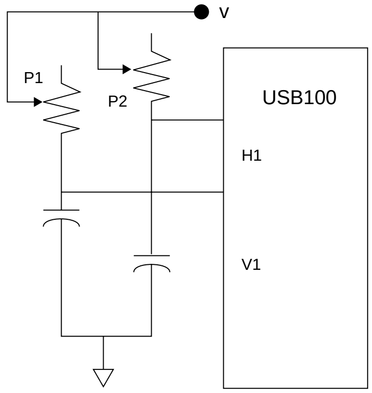
Schematic 1: Roller Mode of Operation

When the Roller configuration register is used to define an input pair as roller inputs, the corresponding roller movement reporting is enabled. In this case, internally, the roller wheel pulses are counted and registered into an 8 bit register. One register is available per input pair. A total of three rollers movement registers (RMRs) are available, corresponding to the three roller mechanisms available. On all the input pairs (H1, H2 or V1, V2 or H3, H4) the positive counting sequence is defined as (0,0), (0,1), (1,1) and (0,0) and the same sequence repeating over again. Negative counting sequence is defined as (0,0), (1,0), (1,1) and (0,1) and the same sequence repeating again. Each of the above transitions will result in the counter incrementing or decrementing by one depending on whether the rollers are moving in the positive or negative direction. Each time an IN query is sent on endpoint 1, the counter contents are transferred to a temporary holding register and queued for transmission on the USB. When an ACK is received for the current transaction, the counter is cleared.

Hardware Features

Roller / Potentiometer Interface

One of the key differences between the mouse and joystick hardware implementation is that themouse uses optical encoding

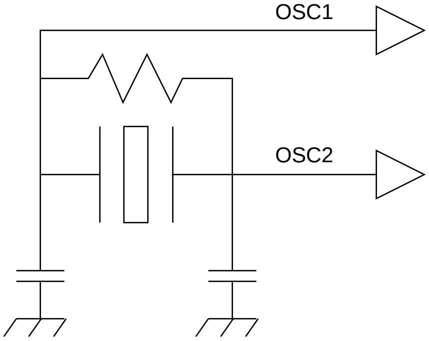


Schematic 2 : Potentiometer Mode of Operation for Joystick and a roller wheel to detect mouse movement. In contrast, joystick uses a potentiometer to detect angular motion. The function select bits [F1:0] allow the designer

to set the bits. In a mouse mode, the H1, H2, V1,V2 and H3 & H4 inputs are selected for the roller mechanism decode.In the joystick mode, it selects the potentiometer interface. The state machine uses a different algorithm for interpreting the inputs to the chip. This function selection also affects the format of the report that is generated.The roller mode is shown in schematic 1 and the potentiometer mode is shown in schematic 2.

In case of the roller mode of operation (mouse/trackball), the transitions on the Hx and Vx pairs are used in the counting process to generate a digital estimate of the motion of the ball. In the joystick mode of operation, the RC timing constant changes the width of an internal digital pulse whose width is measured and reported back. All of the buttons feature an internal pullup. The actual switches used is a push button switch with one terminal connected to a button input and the second terminal connected to ground.

Crystal / Crystal Oscillator combination



The above configuration is the recommended configuration for use with a crystal or a ceramic resonator. The capacitors are optional and if used, must be in the 10-30pf range. The resistor is necessary and its value is 1MΩ. A metal-can oscillator may be used too. In this case, the output of the oscillator must be connected to OSC1 and OSC2 must be left unconnected.

Suspend mode operation

When the PLUM device determines that the necessary conditions (laid down in the USB standard), it goes into the suspend mode. It wakes up on USB bus activity, or when any of the buttons are depressed. There exists an internal timer, whose timing operation could be selected via bits 3 through 0 in ICB register 5. The PLUM device wakes up on the expiration of the timer. It senses the roller/potentiometer interface to determine if these inputs have changed since the last poll. It does a remote wakeup, when such a movement has occurred.

Remote Wakeup Support

This device supports the remote wakeup feature. This is indicated to the host via the corresponding descriptor. Internally, the state machine uses the values of the RRES_EN and RRES[2:0] bits in the Remote Resume configuration byte to enable this feature, and the amount of time between the “polls” to the roller/potentiometer ports to determine whether the necessary conditions for wakeup have been met.

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