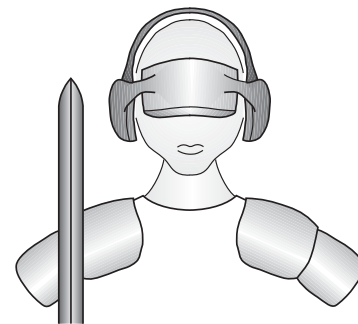# IO-Warrior28

Generic universal I/O Controller for USB

Code Mercenaries

1.0 Features
- USB interface
- USB V2.0 compliant full speed device
- USB HID 1.1 compliant
- 19 general purpose I/O pins
- 1000 Hz polling rate for I/O
- IIC master up to 1 MHz
- 4 channel 12 bit A/D converter up to 30 kHz sample rate
- Internal bandgap reference for absolute voltage measurement
- Supports HD44780 compatible display modules and several graphic display modules
- No USB knowledge necessary to use
- Single +3.3V power supply
- Available in QFN28 package, or as DIL28 module
- Easy to use evaluation kit
- Legacy support version for replacement of IOW24 in SO24 module (IOW28L-S24)

1.1 Variants
IO-Warrior is available in a couple standard package options as chip or module.

IO-Warrior28
- 19 general purpose I/O pins, typ. 1 kHz read
- IIC master up to 1 MHz
- 4 channel 12 bit A/D converter
- LCD module support
- Minimal external component count
- Identifies as either low power (100 mA) or high power (500 mA) bus powered device. Pin selectable
- Easy to use evaluation kit for immediate access
- QFN28 package, or DIL28 module

IO-Warrior28L
- Legacy replacement for IOW24-S
- 17 general purpose I/O pins, typ. 1 kHz read
- IIC master at 100 kHz
- LCD module support
- Minimal external component count
- Identifies as either low power (100 mA) or high power (500 mA) bus powered device. Pin selectable
- SO24 legacy module to replace IOW24-S
- **Available only for legacy applications where IOW24-S needs to be replaced!**

IO-Warrior40 & IO-Warrior56
Please check the respective data sheets for those chips.

IO-Warrior24 & IO-Warrior24PV
The IO-Warrior24 family has been discontinued. In some applications the IOW24-S may be replaced by IOW28L-S24.

1.2 Custom variants
Custom adaptions are available on request. If necessary complex functions can be added to the standard chips to directly control specific circuits.

2.0 Functional overview
IO-Warrior offers a simple access to the USB. Many projects that formerly used the parallel port or some other kind of direct I/O interface today face the problem that getting simple things to work on the USB is quite complex.

With a serial or parallel port you needed only a simple circuit to control an external relay or read a single switch. With USB you need a microcontroller that handles all the protocol work to do the same thing. Several standard commands need to be supported to get a device accepted as a USB device, let alone implementing any real function.

IO-Warrior brings simplicity to the USB. The protocol is encapsulated in the IO-Warrior Chip. You only have to care about the I/O pins and have to only write a few simple lines of code to access them.

IO-Warrior also supports a range of industrial standard interfaces to simplify interfacing to certain chips or modules. These interfaces are handled internally in IO-Warrior removing the bandwith wasting controlling of individual pins.
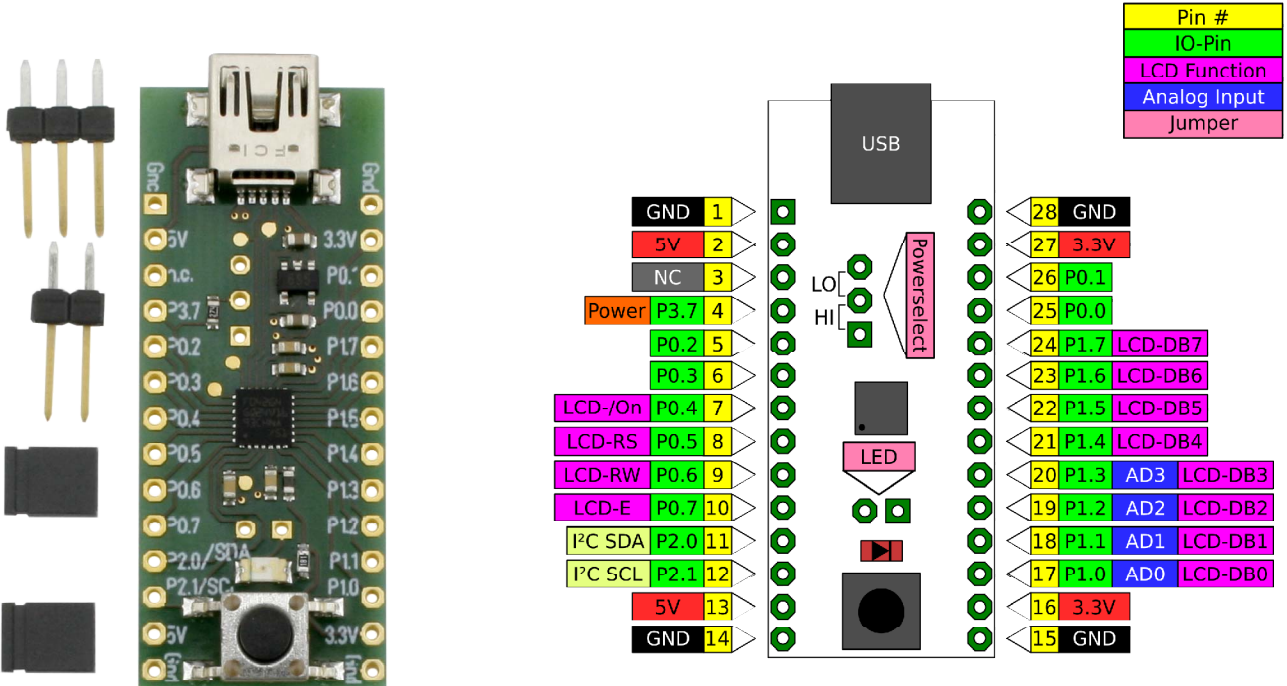
2.1 Product selection matrix

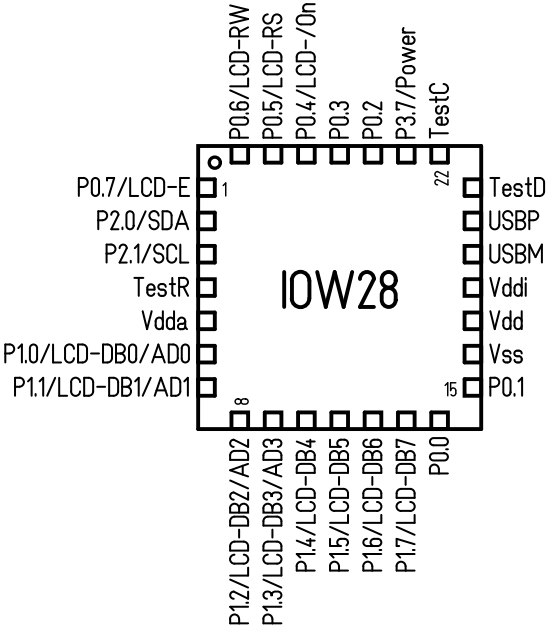| Type	I/O Pins	LCD	IIC	SPI	RC5 IR	Keys	LEDs	Timer	ADC	SSOP48	DIL	QFN	SOIC24	Starter Kit
IO-Warrior24 (obsolete)	16	√	√	√	√		√	√			√		√	√
IO-Warrior24PV (obsolete)	12		√	√							√	√		
IO-Warrior40 (end of life)	32	√	√		√		√			√	√			√
IO-Warrior28	19	√	√						√		√	√		√
IO-Warrior28L	17	√	√										√	
IO-Warrior56	50	√	√	√		√	√		√					√

2.2 Evaluation Kit

The IOW28 EvalKit has a form factor that allows to put it on a DIL28 (wide) socket or onto a breadboard. Pins are not supplied.

A two pin and a three pin header and jumpers are provided that need to be soldered into the board. The three pin jumper allows to set the power, placing the jumper next to the USB plug selects low power.

With the two pin jumper a LED can be connected to P2.0 for testing. The button connects to P2.1 and pulls to ground. LED and button are intended for simple testing of the I/O operations.

The power supply layout on the EvalKit has been carefully designed to allow good performance of the A/D converter.
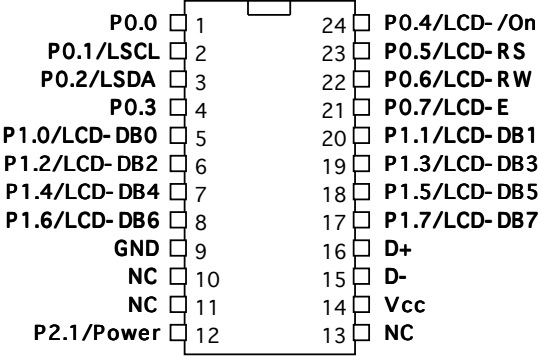
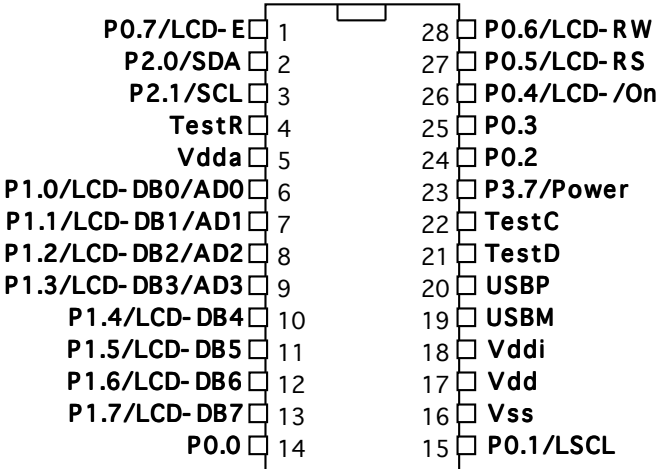# IO-Warrior28

3.0 Pin configurations
IO-Warrior28-Q28
QFN28 Chip

Top pins (left to right): P0.6/LCD-RW, P0.5/LCD-RS, P0.4/LCD-/On, P0.3, P0.2, P3.7/Power, TestC

Left pins (top to bottom): P0.7/LCD-E (1), P2.0/SDA, P2.1/SCL, TestR, Vdda, P1.0/LCD-DB0/AD0, P1.1/LCD-DB1/AD1

Bottom pins (left to right): P1.2/LCD-DB2/AD2 (8), P1.3/LCD-DB3/AD3, P1.4/LCD-DB4, P1.5/LCD-DB5, P1.6/LCD-DB6, P1.7/LCD-DB7, P0.0

Right pins (top to bottom): TestD (22), USBP, USBM, Vddi, Vdd, Vss, P0.1 (15)

Center: IOW28

IO-Warrior28L-S24
SOIC24 replacement module
(IOW28L only)

Pin	Left		Right	Pin
1	P0.0		P0.4/LCD-/On	24
2	P0.1/LSCL		P0.5/LCD-RS	23
3	P0.2/LSDA		P0.6/LCD-RW	22
4	P0.3		P0.7/LCD-E	21
5	P1.0/LCD-DB0		P1.1/LCD-DB1	20
6	P1.2/LCD-DB2		P1.3/LCD-DB3	19
7	P1.4/LCD-DB4		P1.5/LCD-DB5	18
8	P1.6/LCD-DB6		P1.7/LCD-DB7	17
9	GND		D+	16
10	NC		D-	15
11	NC		Vcc	14
12	P2.1/Power		NC	13

All drawings: TOP VIEW!

IO-Warrior28-DIL28
DIL28 module

Pin	Left		Right	Pin
1	P0.7/LCD-E		P0.6/LCD-RW	28
2	P2.0/SDA		P0.5/LCD-RS	27
3	P2.1/SCL		P0.4/LCD-/On	26
4	TestR		P0.3	25
5	Vdda		P0.2	24
6	P1.0/LCD-DB0/AD0		P3.7/Power	23
7	P1.1/LCD-DB1/AD1		TestC	22
8	P1.2/LCD-DB2/AD2		TestD	21
9	P1.3/LCD-DB3/AD3		USBP	20
10	P1.4/LCD-DB4		USBM	19
11	P1.5/LCD-DB5		Vddi	18
12	P1.6/LCD-DB6		Vdd	17
13	P1.7/LCD-DB7		Vss	16
14	P0.0		P0.1/LSCL	15

IO-Warrior28

4.0 Pin descriptions IO-Warrior28-Q28/-DIL28

Name	I/O	Type	Pins	Description
USBP, USBM	I/O	special	20, 19	USB differential data lines
P0.0, P0.1, P0.2, P0.3, P0.4, P0.5, P0.6, P0.7	I/O	I/O open drain, internal pullup	14, 15, 24, 25, 26, 27, 28, 1	First I/O port.
P1.0, P1.1, P1.2, P1.3, P1.4, P1.5, P1.6, P1.7	I/O	I/O open drain, internal pullup	6, 7, 8, 9, 10, 11, 12, 13	Second I/O port
P2.0, P2.1	I/O	I/O open drain, internal pullup	2, 3	Third I/O port. Also fast IIC port.
P3.7/Power	I/O	I/O open drain, internal pullup	23	Fourth I/O port P3.7 is used to determine power setting at power up.
Vss		power supply	16	Ground
Vdd, Vdda, Vddi		power supply	17, 5, 18	Supply voltage, connect to 3.3 V
TestR, TestD, TestC		special	4, 21, 22	Used during manufacturing, do not connect

4.1 Pin descriptions IO-Warrior28L-S24

Name	I/O	Type	Pins	Description
D+, D-	I/O	special	16, 15	USB differential data lines
P0.0, P0.1, P0.2, P0.3, P0.4, P0.5, P0.6, P0.7	I/O	I/O open drain, internal pullup	1, 2, 3, 4, 24, 23, 22, 21	First I/O Port.
P1.0, P1.1, P1.2, P1.3, P1.4, P1.5, P1.6, P1.7	I/O	I/O open drain, internal pullup	5, 20, 6, 19, 7, 18, 8, 17	Second I/O Port
P2.1/Power	I/O	I/O open drain, internal pullup	12	Third I/O Port. also used to determine power setting during power up
GND		Power supply	9	Ground
Vcc		Power supply	14	Supply voltage, 5 V
NC	-	no connection	10, 11, 13	No internal connection, don't care

4.2 Pin descriptions

USBP, USBM / D+, D-
Differential data lines of USB. Connect these signals direct to a USB cable. ESD protection may be added.

P0.0...P0.7
First I/O port of the chip. These pins correspond with the lowest 8 bits of the input or output (bits 0..7).

P1.0...P1.7
Second I/O port. Corresponds to the bits 8..15.

P2.0...P2.1 (IOW28 only)
Third I/O port. Corresponds to the bits 16..17.
P2.0 is not available on IOW28L-S24.

P2.1/Power (IOW28L only)
On IOW28L-S24 P2.1 is used to determine the power setting at power up. A weak pull up should be used to set high power (500 mA) mode and it may be left floating for low power mode (100 mA). This determines how much power the IOW28L will demand from the host. Checking the power setting happens during reset while shortly enabling an internal pull down resistor.
The pin may be used as a normal I/O pin at runtime.

P3.7/Power (IOW28 only)
Fourth I/O port. Corresponds to bit 31.
IOW28 uses P3.7 to determine the power setting. The pin is checked at reset before enabling internal pull-up resistors. A weak pull up should be used to set high power (500 mA) mode and a weak pull down for low power mode (100 mA). This determines how much power the IOW28L will demand from the host.

Vss
Power supply ground.

Vdd, Vddi, Vdda
Supply voltage. Requires 3.3 V.
Vdda is the supply for the ADC and also used as the reference for A/D conversion. When using the ADC it is recommended that the power to this pins is additionally filtered and screened from interference.

Vcc, GND (IOW28L-S24)
Power supply pins for SOIC24 replacement module. Vcc is 5 V.

TestC, TestD, TestR
These pins are used during production of the IO–Warrior chips, do not connect.

4.3 Special mode pin functions

IO-Warrior supports driving IIC compatible chips and HD44780 compatible display modules and some other display modules direct. Handling IIC via the normal generic I/O would be very slow as each edge of data and clock would have to be transmitted separately. At a rate of 1000 such transactions per second (which is the maximum IO-Warrior is allowed by USB specifications) the maximum bit rate would be around 500 bits/sec.

To make IIC and other devices usable, IO-Warrior implements the special mode functions. By handling the IIC inside IO-Warrior the actual data rate is increased by some orders of magnitude.

When any of the special mode functions is activated a couple pins will no longer respond as generic I/O pins but are under control of the activated special mode function.

4.3.1 IIC mode pins

IO-Warrior28 can act as an IIC master.

IOW28L has a legacy IIC port implemented in software to allow direct pin compatibility with some IOW24-S applications. This legacy IIC should be used only for existing designs where pin compatibility is required.

For new applications use the native IIC port of IO-Warrior28. It offers speeds from 10 kBit/s to 1000 kBit/s. The native IIC port has been optimized for maximum performance, allowing transfers of > 60 kByte/s without interfering with other functions of the IOW28. This allows to get close to the theoretical maximum of IIC data transfer except for the fastest speed at 1 MBit/s, where about 60% of the theoretical throughput is possible.

The following pins get reassigned when the IIC function is enabled:

Function	IOW28L	IOW28
SCL	P0.1	P2.1
SDA	P0.2	P2.0

These pins will no longer be affected by the data sent via the normal port setting command. Both pins have internal pull up resistors and can be connected direct to IIC compatible chips.

For IO-Warrior28 external 1 kΩ pull-up resistors to 3.3 V are recommended. Without them the IIC performance may be significantly reduced.

IO-Warrior28 monitors its IIC lines and can adapt to relatively high parasitic capacitance on the bus, but this will reduce the effective data rate by slowing down SCL.

4.3.2 LCD mode pins

IO-Warrior28 has support for controlling alpha-numeric display modules based on or compatible with HD44780 as well as some graphic displays which use the same interface.

For simplicity the function is refered to as the LCD function, but there are also OLED and vacuum fluorescence displays that are compatible with this interface.

The following pins get reassigned when the LCD function is enabled:

Function	IOW28
/On	P0.4
RS	P0.5
R/W	P0.6
E	P0.7
Data0	P1.0
Data1	P1.1
Data2	P1.2
Data3	P1.3
Data4	P1.4
Data5	P1.5
Data6	P1.6
Data7	P1.7

When the LCD function is enabled these pins will no longer be affected by the normal port setting command.

/On should be used to enable power supply to LCD modules that have high current demand or backlighting. The /On signal is low when the LCD function is enabled, it does go high when IO-Warrior enters suspend mode or when the LCD function is disabled.

The LCD function requires displays that work with 3.3 V power supply at least for the logic part.

4.3.3 ADC mode pins

Up to four analog input channels are available on IO-Warrior28. The internal ADC has a resolution of 12 bits and a calibrated internal voltage reference. This allows absolute voltage measurement.

It also has an internal temperature sensor with good linearity, but a rather poor absolute accuracy. It may be calibrated for absolute measurements but is fine as it is for measuring temperature difference.

The following pins get reassigned when the ADC function is enabled:

Function	IOW28
AD0	P1.0
AD1	P1.1
AD2	P1.2
AD3	P1.3

Either 0, 1, 2, or 4 channels may be selected. Zero channels is for using the internal temperature sensor, or measuring the Vdda voltage only.

The ADC works relative to the voltage on the Vdda power pin.

IO-Warrior28

5.0 Device operation

Due to the fact that all current operating systems offer an especially easy access to devices in the HID class, IO-Warrior was designed as a generic HID device. While this does not exactly fit the device it makes using it a lot easier.

By identifying as a generic HID class device IO-Warrior avoids being controlled by any of the higher level system drivers, which makes it possible to access IO-Warrior from application level.

5.1 Accessing IO-Warrior

A common misconception with people new to the USB is that they think they can "talk to the USB port". The truth is that you do that as likely as you are going to directly talk to your Ethernet port.

Communication on the USB is always with a specific device attached to the USB. The USB itself is only the medium through which you communicate.

To get access to a certain device you have to look for the VendorID and ProductID of that device. The specific mechanisms for doing so depend on the individual operating system.

For details refer to our sample code.

5.2 IO-Warrior communication

IO-Warrior28 has 8 USB endpoints for the I/O communication. Endpoints are like virtual communication ports into or out of the device.

An endpoint can be assigned to an interface. Interfaces are like virtual devices or subsystems within a device. IO-Warrior28 uses interface 0 to talk to the pins directly, interface 1 to talk to the special mode functions, interface 2 for the native IIC function, and interface 3 for the ADC.

A SetReport request sending a four byte output report to interface 0 sets the port pins. SetReport requests to interface 1, 2, and 3 with a length of 64 bytes are used to control the special mode functions.

For input data IO-Warrior is using endpoint 1 as an interrupt-in endpoint. Interrupt in this case is a bit misleading. For USB interrupt means that data is sent when there is new data available, the host computer is periodically asking the device for new data, the device itself can not initiate the data transfer. IO-Warrior sends a new report any time it detects a change to the input pin status.

Reactions to commands to the special mode functions are sent via endpoint 2, 3, or 4, also in interrupt transfer mode.

5.3 IO-Warrior input behaviour

IO-Warrior scans the status of all pins once every millisecond. If it detects a change from the last status a new report via endpoint 1 is issued. Pins which are currently used by a special mode function are not checked and are always reported as being high.

5.4 IO-Warrior output behaviour

Upon receiving a SetReport request IO-Warrior writes the new data to the output pins. There is a small timing offset between the ports getting their new status, which is about $1/4\,\mu$s.

5.5 Using pins as inputs or outputs

All I/O pins on IO-Warrior can be used as input or output pins.

Basically all pins act as inputs all of the time. When receiving an input report from IO-Warrior you always get the current status on the pins.

Writing a 0 as output value to any pin causes it to drive the pin low with an open drain driver. Usually this will result in this pin being read as a zero input as well, unless so much current has to be drained by the pin that the voltage at it gets above the threshold level.

Writing a 1 to a pin causes the open drain driver to be turned off. The pin will be pulled high by an internal pull up resistor. Now the pin acts either as an output with a high level, or can be used as an input.

5.6 Power supply

USB does allow a device to be "Bus Powered". This means the device does get its power off the USB port. To avoid overloading on the USB ports devices need to advertise their power requirements. There are two power classes for devices: Low power and high power. Low power devices may draw up to 100 mA off the USB, high power devices up to 500 mA.

Likewise there are high power and low power ports. Usually high power ports are those on the motherboard and on hubs with external power supply or hubs in a monitor. Low power ports are typically on hubs that get their power off the USB, like hubs in keyboards.

If the system decides that there is not sufficient power to supply a high power decive that device does not get enabled.

IO-Warrior can operate either as a high power or low power device. The power setting is determined

by checking the status of the P3.7/Power pin (IOW28) or the P2.1/Power pin (IOW28L) on powering up the IO-Warrior. Since the pin is also used as a I/O pin a relatively high resistor value should be used to pull the pin high or low. 270 kΩ or more is recommended.

5.7 Suspend
All devices on the USB port need to support the suspended state. When the host computer stops to periodically access the USB, like when it goes to sleep, all devices need to enter the suspended state and drop their power draw to less than 500 μA for low power devices or less than 2.5 mA for high power devices.
When entering suspended state IO-Warrior pulls all pins high. Care must be taken in designing external circuits so that they will draw no more than the allowed suspend power rating while all pins of IO-Warrior are high.

5.8 Remote Wakeup
IO-Warrior28 does not support remote wakeup.

5.9 Special mode I/O

To enable IO-Warrior to talk to devices that have more complex demands we have added the special mode functions. When any of these functions is enabled a couple pins of IO-Warrior turn into special function pins.

Talking to the special mode functions is handeled via the USB interface 1, which is also configured as generic HID compliant.

Commands to the functions are sent via endpoint 2 to interface 1. Replies from the functions are returned as interrupt in reports via endpoint 2.

To talk to these functions and to handle different requests ReportIDs are used which enable multiple functions to use the same endpoint. All reports to and from special mode interfaces are always 64 bytes long, including the ReportID.

The following chapters describe the individual special mode functions.

5.9.1 Legacy IIC Special mode function (IOW28L only)

Use the legacy IIC function only in applications where a replacement of the IOW24 is required. For any new designs use the fast IIC function of IO-Warrior28 which offers a superior performance while interfering less with other functions. The legacy IIC is only intended for backwards compatibility.

The legacy IIC function is enabled and disabled by sending a report with the following structure with ReportID = 1 to interface 1:

ReportID	1	2	3	4	…	62	63
$01 out	enable	flags	timeout	$00	$00	$00	$00

enable = $01 enables the IIC function, $00 disables it. Other values are reserved for future use.

Upon enabling IIC the SDA and SCL pins are pulled high and are no longer under control of SetReport requests to interface 0. Disabling IIC does return the pins under control of interface 0 and pulls them high initially.

"flags" is a legacy from IOW24 and not used on IOW28, the content of this byte is "don't care". Disabling internal pullups and the Sensibus protocol are not available on IOW28.

The timeout byte sets the maximum time IOW waits for SCL to be released by the slave when clock stretching handshake is used. Time is timeout x 500 μsec, writing a zero sets timeout to 256 x 500 μsec.

If the timeout expires due to the slave pulling down SCL too long, IO-Warrior will return an error, just like when the slave generates no Ack signal.

A write request to the IIC is sent with ReportID=2 and has the following format:

ReportID	1	2	3	4	…	62	63
$02 out	flags	data	data	data	data	data	data

flags contains the following bits:
7 - Generate Start
6 - Generate Stop
5 - unused, zero
4 - unused, zero
3 - unused, zero
2 - data count MSB
1 - data count
0 - data count LSB

If bit 7 - "Generate Start" is set a start signal (SDA falling edge while SCL is high) is generated on the IIC prior to sending out the first data byte.

Bit 6 - "Generate Stop" causes a stop signal (SDA goes high while SCL is high) to be generated after sending the last valid data byte of this report.

"data count" gives the number of valid data bytes in the report. The number may range from zero to six, higher values cause the report to be ignored.

To do write transactions that are longer than six bytes, send the first report with just the "Generate Start" bit set, then send additional reports with neither bit 6 or 7 set until the report with the last bytes is send which has the "Generate Stop" bit set.

Any write transactions are acknowledged by a report via interrupt-in endpoint 2:

ReportID	1	2	3	4	…	62	63
$02 in	flags	$00	$00	$00	$00	$00	$00

flags contains the following bits:
7 - Error bit, 1=error
6 - unused, zero
5 - unused, zero
4 - unused, zero
3 - unused, zero
2 - data count MSB
1 - data count
0 - data count LSB

"data count" indicates the last byte that was successfully transfered and acknowledged by the slave (if any). An error is indicated when the slave does not acknowledge a transfer.

Reading data off the IIC is initiated with a ReportID=3. The initiating report has the following format:

ReportID	1		2	3	4	…	62	63
$03 out	count	command	$00	$00	$00	$00	$00

"command" holds the command byte to be send to the IIC. "count" is the number of bytes that should be read off the IIC after sending the command byte, values 1 to 62 are valid.

A start signal is automatically generated before sending the command byte and a stop is generated after the last data byte is received.

Data is returned in an input report with ID=3 (which is different from the output ReportID=3 used to initiate the read transaction) via endpoint 2. This restricts a read to fewer bytes than on IOW24.

ReportID	1	2	3	4	…	62	63
$03 in	flags	data	data	data	data	data	data

flags contains the following bits:
7 - error, set if slave does not ack command byte
6 - unused, zero
5 - data count MSB
4 - data count
3 - data count
2 - data count
1 - data count
0 - data count LSB

Should the IIC slave fail to acknowledge the command byte the error flag will be set and the transaction aborted. IIC does not have an error condition during the actual reading of data after the command byte was sent.

IO-Warrior28

5.9.2 LCD special mode function
The LCD special mode function supports display modules that are compatible with the HD44780 controller and several graphic display controllers that use a compatible interface. This controller is made by Hitachi and has set the de-facto standard for alphanumeric LCD modules. There are also OLED and vacuum fluorescence displays that use this type of interface.
The display modules come in various configurations with up to 80 characters total in any kind of arrangement from single line to four lines. Displays with more than 80 characters typically use more than one HD44780. IO-Warrior28 does not directly support modules with more than a single HD44780, some additional hardware may be required for this.
It is recommended to read the HD44780 manual for using the LCD function. Also have a look at our application note AN5: Driving Display Modules with IO-Warrior.

The LCD function is enabled by sending an output report with ID 4 to the USB interface 1:

ReportID	1	2	3	4	…	62	63
$04 out	enable	$00	$00	$00	$00	$00	$00

enable = $00 disables the LCD function. enable = $01 enables the LCD function, other values are reserved.
Upon enabling the LCD function the Pins are put under control of the LCD function and can no longer be controlled by interface 0.
The /On pin is pulled low when the LCD function is enabled, it will go high when the IO-Warrior enters suspend state.
To write data to the connected LCD module an output report with ReportID=5 is written with the following format:

ReportID	1	2	3	4	…	62	63
$05 out	flags	data	data	data	data	data	data

"flags" contains the following bits:
7 - RS, Register Select bit
6 - unused, zero
5 - data count MSB
4 - data count
3 - data count
2 - data count
1 - data count
0 - data count LSB

The status of the RS bit is used to set the RS line to the LCD module. This allows access to the Instruction register (RS=0) or Data Register (RS= 1) of the LCD module.
With "data count" the number of bytes to be written is specified. IO-Warrior will write up to 62 data bytes to the register specified by the RS bit. The Busy bit of the LCD module is automatically checked and data written only when the LCD module is ready to accept it. There is a 16 ms timeout when waiting for the Busy bit, if this time has passed the transaction is cancled, no special feedback is provided.

To read data from the LCD module an output report with ReportID=6 is sent to interface 1:

ReportID	1	2	3	4	…	62	63
$06 out	flags	$00	$00	$00	$00	$00	$00

"flags" contains the following bits:
7 - RS, Register Select bit
6 - unused, zero
5 - data count MSB
4 - data count
3 - data count
2 - data count
1 - data count
0 - data count LSB

"RS" specifies which register is to be accessed. Data count sets the number of bytes to be read off the LCD (will be ignored if RS=0, only a single read will be done then).
Up to 62 bytes can be read with one request. The data read from the LCD module is returned in input reports with ID 6:

ReportID	1	2	3	4	…	62	63
$06 in	count	data	data	data	data	data	data

"count" specifies the number of bytes returned in this report.

5.9.3 Fast IIC special mode function (IOW28 only)

The fast IIC function of IO-Warrior28 offers a much higher performance than the legacy function. It uses a separate interface, so the bandwith of the two endpoints is not shared with any other functions.

Fast mode and fast mode plus are supported, allowing data rates up to 1 MBit/s and a throughput of > 60.000 bytes/s.

The native IIC function is enabled and disabled by sending a report with the following structure with ReportID=1 to interface 2:

ReportID	1	2	3	4	…	62	63
$01 out	enable	flags	timeout	$00	$00	$00	$00

enable=$01 enables the IIC function, $00 disables it. Other values are reserved for future use.

Upon enabling IIC the SDA and SCL pins are pulled high and are no longer under control of SetReport requests to interface 0. Disabling IIC does return the pins under control of interface 0 and pulls them high initially.

flags selects the speed of the IIC interface and sets the drivers on the SCL/SDA pins accordingly.

The values for flags are as follows:
0 - 100 kbit/s
1 - 400 kbit/s
2 - 50 kbit/s
3 - 10 kbit/s
4 - 1000 kbit/s

timeout is not yet implemented.

A write request to the IIC is sent with ReportID=2 and has the following format:

ReportID	1	2	3	4	…	62	63
$02 out	flags	data	data	data	data	data	data

flags contains the following bits:
7 - Generate Start
6 - Generate Stop
5 - data count MSB
4 - data count
3 - data count
2 - data count
1 - data count
0 - data count LSB

If bit 7 - "Generate Start" is set a start signal (SDA falling edge while SCL is high) is generated on the IIC prior to sending out the first data byte.

Bit 6 - "Generate Stop" causes a stop signal (SDA goes high while SCL is high) to be generated after sending the last valid data byte of this report.

"data count" gives the number of valid data bytes in the report. The number may range from one to 62, other values cause an error to be returned.

To do write transactions that are longer than 62 bytes, send the first report with just the "Generate Start" bit set, then send additional reports with neither bit 6 or 7 set until the report with the last bytes is send which has the "Generate Stop" bit set.

Any write transactions are acknowledged by a report via interrupt-in endpoint 3:

ReportID	1	2	3	4	…	62	63
$02 in	flags	code	$00	$00	$00	$00	$00

flags contains the following bits:
7 - Error bit, 1=error
6 - Arb Loss, 1 = lost arbitration
5 - data count MSB
4 - data count
3 - data count
2 - data count
1 - data count
0 - data count LSB

"data count" indicates the last byte that was successfully transfered and acknowledged by the slave (if any). An error is indicated when the slave does not acknowledge a transfer.

"code" contains an additional error code to indicate what happend. The following values are defined:
0 - no special code
1 - wrong number of bytes requested
2 - transaction without Start requested
3 - NACK received
4 - Bus Error

Reading data off the IIC is initiated with a ReportID=3. The initiating report has the following format:

ReportID	1	2	3	4	…	62	63
$03 out	count	addr	Mcount	$00	$00	$00	$00

"addr" holds the slave address to be send to the IIC.

"count" is the number of bytes that should be read off the IIC after sending the command byte, "Mcount" is the most significant byte for the count. The maximum number of bytes that may be requested at once is 65535.

A start signal is automatically generated before sending the command byte and a stop is generated after the last data byte is received.

Data is returned in input reports with ReportID=3 (which is different from the output ReportID=3 used to initiate the read transaction) via endpoint 3. If more than 62 bytes are requested the data is returned in multiple reports.

ReportID	1	2	3	4	…	62	63
$03 in	flags	data	data	data	data	data	data

flags contains the following bits:
7 - error, set if slave does not ack command byte
6 - unused, zero
5 - data count MSB
4 - data count
3 - data count
2 - data count
1 - data count
0 - data count LSB

Should the IIC slave fail to acknowledge the command byte the error flag will be set and the transaction aborted. IIC does not have an error condition during the actual reading of data after the command byte was sent.

5.9.4 ADC special mode (IOW28 only)
IO-Warrior28 has an internal 12 bit ADC with up to 4 input channels, a calibrated band gap reference, and a temperature sensor.

The ADC function has its own interface and endpoints to allow a high sampling rate without interfering with the other functions. Controlling the ADC and receiving data is done via interface 3.

Enabling and disabling the ADC is done by sending a report with ReportID=$1C to interface 3:

ReportID	1	2	3	4	5	6	…	63
$1C out	en	chan	$00	$00	mod	samp	$00	$00

"en" = $01 enables the ADC function
"en" = $00 disables it again.
"chan" is the number of channels to use, i.e. chan = 1 enables just AD0, chan = 2 enables AD0 and AD1, chan = 4 enables AD0…3, chan = 0 enables the temperature sensor only. All other values are invalid.
"mod" selects between single shot and continuos mode, 0 = single shot, 1 = continuous
"samp" specifies the sample rate:
0 - 1 kHz
1 - 2 kHz
2 - 3 kHz

3 - 4 kHz
4 - 6 kHz
5 - 8 kHz
6 - 10 kHz
7 - 12 kHz
8 - 15 kHz
9 - 16 kHz
10 - 20 kHz
11 - 24 kHz
13 - 30 kHz

For four channels the sample rate is limited to a maximum of 6000 Hz, for two channels at 15000 Hz, and for one channel at 30000 Hz. The 15000Hz for two channels and 30000 Hz for a single channel may not work on all computer setups as they generate the maximum number of reports allowed for this type of USB data transfer.

In continuous mode IO-Warrior28 continuously samples the selected ADC channels and sends reports with ReportID=$1D via interface 3 with the data.

The first byte of a data report is a sequence number that is counted up for each report transmitted. This allows to detect if there is a packet lost.

The sampling rate depends on the number of channels selected:
1 channel - 30 kHz
2 channels - 15 kHz
4 channels - 6 kHz
Data is reported with the lower byte first. For multiple channels the individual channels are sampled with an offset of about 1 μs.
For a single channel each report contains 30 samples from AD0:

ReportID	1	2, 3	…	60, 61	62	63
$1D in	seq	data0	…	data29	$00	$00

If two channels are selected each report contains 15 pairs fo AD0 and AD1 data:

ReportID	1	2, 3	4,5	…	60, 61	62	63
$1D in	seq	AD0	AD1	…	AD1	$00	$00

For four channels each report contains 7 sets of data for the four channels:

ReportID	1	2, 3	4,5	6,7	8,9	…	54.55	…
$1D in	seq	AD0	AD1	AD2	AD3	…	AD3	0

ADC data is 12 bit unsigned. The ADC input range is GND to Vdda. Vdda serves as the high reference for the data conversion. If Vdda is known with sufficient precision it may be used to calculate the absolute voltage. Though if Vdda is not known or

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can vary, the actual voltage can be calculated using the internal bandgap reference.

IO-Warrior28 has a bandgap reference for which the ADC value at Vdda = 3.3 V ±10 mV is stored internally.

The calibration data as well as the temperature sensor data can be read in single shot mode. If continuous mode is enabled all single shot commands will be ignored.

ReportID		1	2	3	…	63
$1E out	command	$00	$00	$00		$00

"command" = 0 requests the calibration and temperature data.
"command" = 1 reads the analog inputs.
For command = 0 the following data is returned:

RepID	1	2,3	4,5	6,7	8,9	10,11	…
$1E in	0	VrefCal	TCal1	TCal2	Vref	Temp	$00

To calculate the actual input voltage of an ADC channel the calibration data is used with the following formula:

$$Vin = 3.3\ V * VrefCal * ADn / Vref / 4095$$

The chip temperature can be calculated as follows:

$$t = 80°C / (TempCal2 - TempCal1) * (Temp * VrefCal / Vref - TempCal1) + 30$$

Absolute precision of the temperature sensor is limited since the TempCal1 and TempCal2 values are measured with just ±5°C accuracy. For more precise results the calibration may be done externally.

"command" = 1 returns the data from the enabled ADC channels:

RepID	1	2,3	4,5	6,7	8,9	…	63
$1E in	$01	AD0	AD1	AD2	AD3	$00	$00

Not active channels return zero. If no channel is selected there will be no reply report.

5.9.5 Reading special mode function status

To get the information which special modes are currently in use, send a report with ReportID=$FE to interface 1:

ReportID	1	2	3	4	...	62	63
$FE out	$00	$00	$00	$00	$00	$00	$00

This will immediately return an input report with ID $FE that contains flags for the special mode functions. Non zero means the function is active:

RepID	1	2	3	4	5	6	7	…
$FE in	IIC	LCD	$00	$00	$00	ADC	$00	$00

5.9.6 Getting current pin status

Due to the way Windows implements HID support IO-Warrior is unable to continuously send its status. HID class devices do have a function that allows the host to set the rate at which reports should be repeated if there is no change to the data. Windows does this rate to zero for IO-Warrior, which means IO-Warrior may send data only if there are changes.

To be able to get the current status from IO-Warrior it does support a special mode function that always returns the current status of all pins.

To get the port status just send a report with ID $FF to interface 1:

ReportID	1	2	3	4	5	6	7
$FF out	$00	$00	$00	$00	$00	$00	$00

This will result in the current pin status to be returned immediately in an input report with ID $FF with the following format:

ReportID	1	2	3	4	5	6	7
$FF in	Port0	Port1	Port2	Port3	$00	$00	$00

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6.0 Absolute maximum ratings

Storage Temperature ....-65°C to +150°C
Ambient Temperature with power applied...-40°C to +85°C
Supply voltage on Vdd, Vdda, Vddi relative to Vss ....-0.3 V to +4 V
Supply voltage on Vcc relative to Gnd (IOW28L) ....-0.3 V to +6.5 V
DC input voltage ....-0.3 V to +4 V
Maximum current into all ports...80 mA
Power Dissipation..max. 170 mW
Static discharge voltage..>2000 V
Latch-up current ....>200 mA

6.1 DC Characteristics

	Parameter	Min	Max	Units	Remarks
V_{dd}	Operating Voltage	2.0	3.6	V	typ. 3.3 V
V_{cc}	Operating Voltage	3.6	5.5	V	for IOW28L module only
I_{dd}	Operating Supply Current		25	mA	
I_{sb}	Suspend mode current		350	μA	internally active
I_{ol}	Sink current on port pins		25	mA	max. combined all pins 80 mA
V_{ol8}	Output low voltage		0.4	V	I = 8 mA
V_{oh8}	Output high voltage	V_{ddi}-0.4		V	I = 8 mA
V_{ol20}	Output low voltage		1.3	V	I =20 mA
V_{oh20}	Output high voltage	V_{ddi}-1.3		V	I =20 mA
R_{up}	Pull up/down resistors	25	55	kΩ	typ. 40 kΩ
V_{ith}	Input Threshold Voltage	0.7 x V_{ddi}		V	

6.2 ADC Characteristics

	Parameter	Min	Max	Units	Remarks
V_{dda}	Analog Operating Voltage	2.4	3.6	V	typ. 3.3 V
I_{cca}	Analog Operating Supply Current		1	mA	typ. < 0.9 mA
V_{ain}	Input Conversion Range	0	V_{dda}	V	
V_{ref}	Internal Reference Voltage	1.2	1.25	V	typ. 1.23 V
V_{refCal}	Accuracy of Calibration Value		± 10	mV	bandgap calibrated at 3.3 Vdda
$V_{refTemp}$	Reference Voltage Temperature Offset	-100	100	ppm	over full operating temperature
R_{ains}	Input Impedance, slow measurement		50	kΩ	for single shot mode
R_{ainf}	Input Impedance, fast measurement		5.9	kΩ	for continous mode
AD_{et}	ADC Total Unadjusted Error		±2	LSB	typ. ±1.3
AD_{eo}	ADC Offset Error		±1.5	LSB	typ. ±1
AD_{eg}	ADC Gain Error		±1.5	LSB	typ. ±0.5
AD_{et}	ADC Differential Linearity Error		±1	LSB	typ. ±0.7
AD_{el}	ADC Integral Linearity Error		±1.5	LSB	typ. ±0.8
T_{cal1}	Temperature Calibration Value 1	25	35	°C	tested value
T_{cal2}	Temperature Calibration Value 2	105	115	°C	tested value
T_{lin}	Temperature Sensor Linearity Error		±2	°C	typ. ±1°C

7.0 Ordering information

Partname	Order Code	Description	Package
IO-Warrior28	IOW28-Q28	IO-Warrior 19 I/O	QFN28
IO-Warrior28	IOW28-DIL28	IO-Warrior 19 I/O, pinned module	DIL28
IO-Warrior28L	IOW28L-S24	IO-Warrior module for partial backward compatibility to IOW24	SOIC24
IO-Warrior28-DG	IOW28-DG	I2C ongle, using IOW28	USB Dongle
IO-Warrior28 Eval kit	IOW28KIT	Evaluation kit for the IOW28	PCB

The chips listed here are standard products. Customized chips are available on request.

7.1 Packaging info
QFN28 chips come in trays - TBD
DIP28 modules - TBD
SOIC24 replacement modules - TBD

7.2 USB VendorID and ProductID
By default all IO-Warrior chips are shipped with the USB VendorID of Code Mercenaries ($7C0 or decimal 1984) and a fixed ProductID.
On request chips can be equipped with the customers VendorID and ProductID. VendorIDs can be obtained from the USB Implementers Forum www.usb.org
Customized chips may be subject to minimum order quantities, contact sales@codemercs.com for details.

Following are the ProductIDs for the IO-Warrior controllers:
IO-Warrior28 $1504
IO-Warrior28L $1505

ProductIDs are independent of the package type.

7.3 Serial numbers
All IO-Warrior28 chips have unique serial numbers in their device descriptors. These serial numbers can be used to simplify programming for multiple IO-Warriors connected to a single computer.

The serial numbers are factory programmed and can not be changed. Serial numbers are 8 digit hexadecimal numbers. No two chips of a type will be produced with identical serial numbers.
It is not possible to order chips with a specific serial number unless they are ordered as custom chips which are subject to minimum order volumes and setup charges.
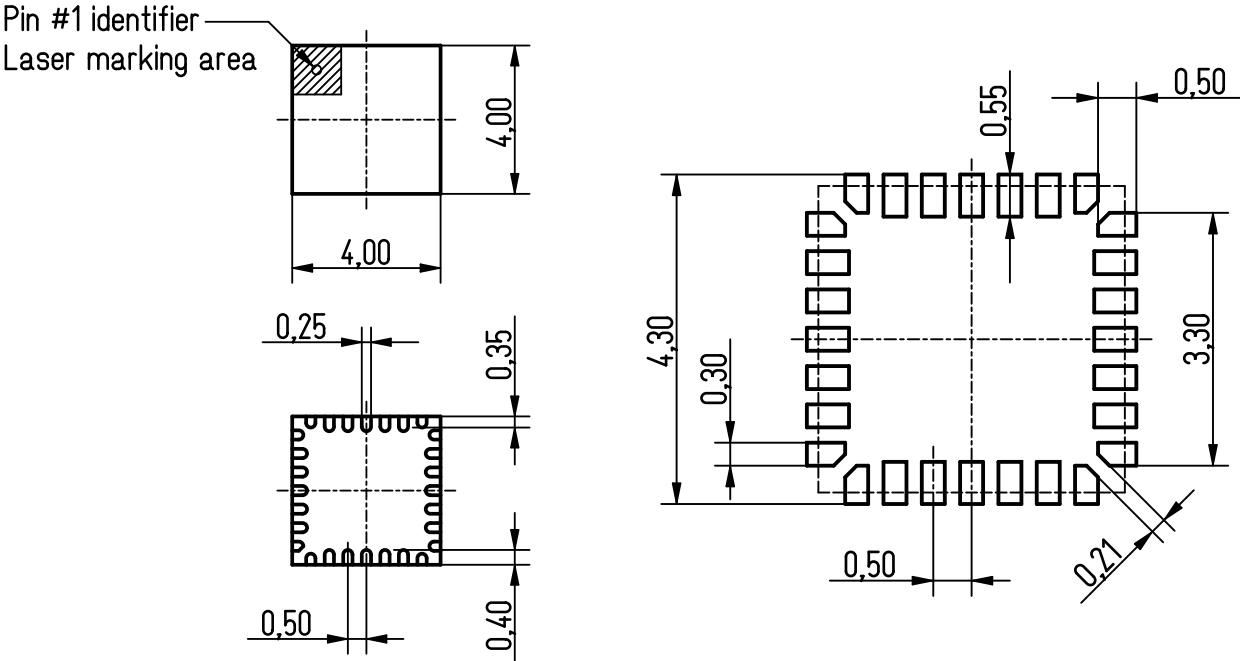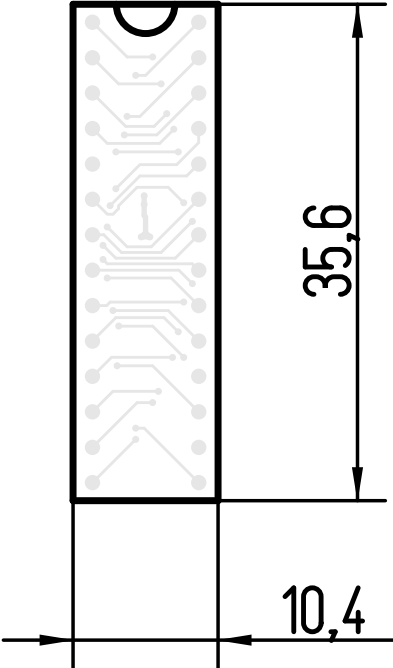
IO-Warrior28

Code Mercenaries

8.0 IO-Warrior28 basic circuit
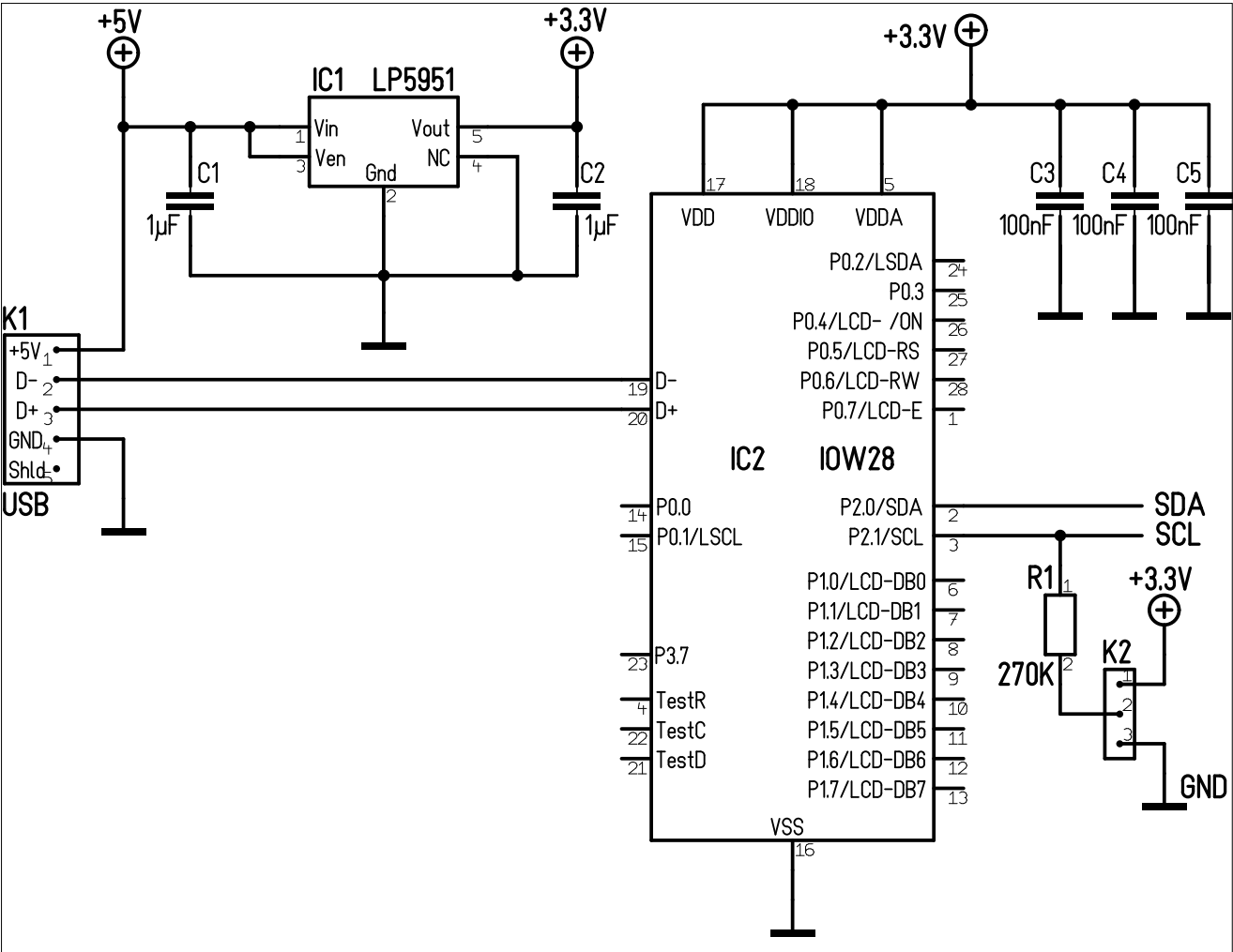
IO-Warrior28

9.0 Package dimensions
28 Pin QFN - UQFPN28 - 4x4 mm with 0.5 mm pitch
and recommended footprint

Pin #1 identifier
Laser marking area

4,00

4,00

0,25

0,35

0,50

0,40

0,55

0,50

4,30

3,30

0,30

0,50

0,21

Package thickness: 0.55 mm ±0.05 mm
Outer contour tolerance: ±0.1 mm

28 Pin DIL module

35,6

10,4

All dimensions: mm

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24 Pin SO24 replacement module (IOW28L only)

15,4

10,6
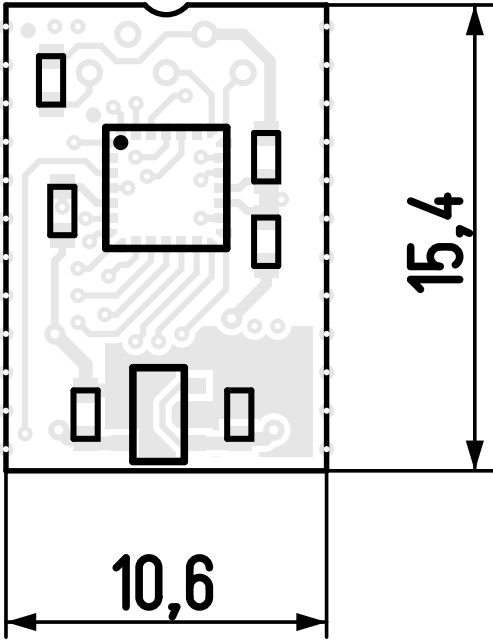
Height at thickest point: max. 2.2 mm

10.0 ESD considerations

IO-Warrior has an internal ESD protection to withstand discharges of more than 2000 V without permanent damage. However ESD may disrupt normal operation of the chip and cause it to exhibit erratic behaviour.

For the typical office environment the 2000 V protection is normally sufficient. Though for industrial use additional measures may be necessary.

When adding ESD protection to the signals special care must be taken on the USB signal lines. The USB has very low tolerance for additional resistance or capacitance introduced on the USB differential signals.

10.1 EMC considerations

IO-Warrior uses relatively low power levels and so it causes few EMC problems.

To avoid any EMC problems the following rules should followed:

- Put the 100 nF ceramic capacitors right next to the power supply pins of the chip and make sure the PCB traces between the chips power pins and the capacitor are as short as possible.
- Run the power supply lines first to the capacitor, then to the chip.
- Make the matrix lines only as long as absolutely necessary.
- Keep the two USB signal lines close to each other, route no other signal between them. USB uses differential signalling so the best signal quality with lowest RF emission is achieved by putting these lines very close to each other.

11.0 Revision history

Current shipping version of IO-Warrior28 is V1.0.0.9.

V1.0.0.9 - Pins were not set to idle high in suspend mode.

V1.0.0.8 - Initial release version

11.1 Document revision history

V1.0.0.1 - Minor corrections
V1.0.0.0 - initial release version

12. RoHS compatibility

IO-Warrior28 conforms to the requirements that are necessary to use it in a RoHS compliant device.

Legal stuff