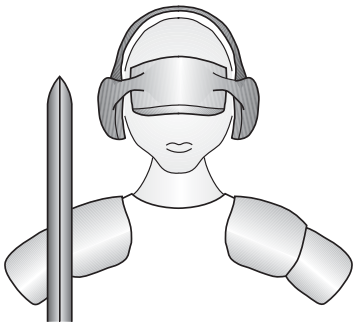
AN5: Driving Display Modules with IO-Warrior

Applicable for IOW24, IOW40, IOW56



Code Mercenaries

1. Overview

A wide variety of display modules at moderate prices is available in the market.
All IO-Warrior chips come with the ability to drive certain display modules. The IOW24 and IOW40 have been designed to drive HD44780 compatible alphanumeric displays, but there are a number of graphic modules that are compatible as well.
IOW56 has been designed with the goal of supporting as many display module families as possible. In addition to the HD44780 based modules it can drive the majority of the graphic display modules.
Since the LCD modules dominate the market of display modules we will talk about LCD modules throughout this document, though in many cases the same information applies to OLED and vaccum fluorescense displays (VFDs) as well.

1.1 Display Module Variants

LCD modules can be sorted into a number of categories. The two top level categories are modules with just drivers and modules with controllers. Modules that only have drivers need a special kind of digital video signal. IO-Warrior can not control this type of LCD module.
Modules with controllers have the logic and memory intergrated which produce the necessary signals internally. They usually have a 8 bit microcontroller bus interface. Some also support serial communications like SPI.
The LCD modules with controllers fall in three sub categories: Alphanumeric, graphic and hybrid.
Alphanumeric modules can display only characters and may have a few programmable characters.
Graphic modules display pixel graphics, any characters have to be generated by software.
Hybird displays can either switch between graphic and character or they can do both at the same time by overlaying character and graphic.
Further to that the display controllers can be grouped into families. There are many controllers that may differ in their hardware properties but use the same command set and bus interface. So the differences between some of the controllers are only of interest for the module manufacturer not for the user of the module.
In the following chapters we will outline the basic capabilities of the controller families and show how they can be used with the IO-Warrior chip family.

1.2 Alphanumeric modules

The alphanumeric modules are the most simple to use. They are dominated by the HD44780 controller and derivatives of it like the KS0073.
Very few alphanumeric modules use controllers that are not completely or mostly compatible with the HD44780.
Typically alphanumeric modules also require only a single 5V power supply.

1.3 Graphic and hybrid modules

While the alphanumeric displays are rather uniform the graphic and hybrid modules are a real mess. So far we have evaluated 28 different controllers and grouped them into 10 families that require specific handling from the software and /or hardware side.
Even modules that use the same controller chip and offer very similar features can have completely different pinouts. It is also not uncommon for graphic and hybrid modules to require a negative supply voltage in addition to 5V. Some even require a clock signal to be supplied.

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Alphanumeric:
HD44780
KS0073

Works with:
IOW24 (dual controller modules need extra circuit)
IOW40 (dual controller modules need extra circuit)
IOW56

Displays up to 80 characters arranged in 1, 2 or 4 lines (max. 40 chars per line)

The HD44780 is the oldest and most common controller. There are a number of variants that are manufactured by various companies, but generally the display module manufacturer will indicate compatibility with HD44780. The KS0073 is very similar with a few additional functions, a different assignment of memory to display lines, and the option to use SPI.
Both controllers can generate up to 80 characters arranged in 1, 2, or 4 lines. To display more than 80 chars (typically used for 4 lines of 40) a module may contain two chips which have their E lines separate to select which chip is addressed.
Using modules with one of these chips is supported by all IO-Warriors. IOW56 also directly supports to use modules with 2 chips. For IOW24 and IOW40 it is necessary to add a few logic gates and use a separate I/O line to control dual chip modules.
The pinout for the modules is pretty much standard, usually it varies just for the backlight (14 pins with separate backlight connector or 16 pins with backlight included) and the dual controller modules. The main difference is that the pins may be arranged as 2x8 or 16 in a row, 2x7 or 14 is usually found on older displays with no backlight.
Addressing the display memory in HD44780 is a bit odd when you don't know the hardware reasons for this. Due to the age of the chip there is not much flexibility in the circuit, the assignment of memory to display is following hardware restrictions of the 1970s.
So if you have a two line display the second line will start on memory address 40. On a four line display the lines are interlaced, the first starts on 0, second on 40, third on 20, fourth on 60. On a dual chip module the first two lines are controlled by one controller, the second two lines by the other.
The KS0073 has a linear memory to display line assignment.
There are also OLED and VFD modules that use HD44780 compatible protocol.

The mode byte for IOW56 is $00 for single controller modules and $01 for dual controller modules.

Connecting to IO-Warrior24, 40, 56:
Use the standard pins of the LCD function.
In case of dual chip modules extra circuitry is required for IOW24 and IOW40, see section 3.5

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Hybrid VFD module:
Noritake GU112X16 and family

Works with:
IOW24
IOW40
IOW56

Displays characters and graphics in various resolutions

This display family uses a superset of the HD44780 commands. Some additional commands are used to control character size, font, and access the graphic display memory.
The characters are drawn into a graphic memory by the display, which allows mixing various character sizes and graphics.

The mode byte for IOW56 is $00.

Connecting to IO-Warrior24, 40, 56:
Use the standard pins of the LCD function.

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Hybrid:
ST7920

Works with:
IOW24
IOW40
IOW56

Displays up to 128 characters arranged in 1or 2 lines (max. 64 chars per line) plus up to 256x64 pixels of graphic

The ST7920 is a superset of the HD44780. It can display up to 128 characters in two lines and it can overlay this with 256x64 pixel graphics.
Basic instructions are identical to the HD44780 but it uses a formerly undefined bit to switch to an extended command set for handling the graphics.

The start address for the second character line has moved to 64 and the characters are 16x8 pixels (which affects programmable characters and looks great!). Besides ASCII there is also a Chinese character set.
To our knowledge there are no modules with two ST7920 controllers. Typically the module connectors follow the same pinout as HD44780 based modules.
The bits of a byte in graphic mode are displayed horizontally with MSB left.
The ST7920 can be used with all IO-Warrior chips.

The mode byte for IOW56 is $00.

Connecting to IO-Warrior24, 40, 56:
Use the standard pins of the LCD function.

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Graphics:
KS0108
HD61202
S6B0108

Works with:
IOW24 (reset line required)
IOW40 (reset line required)
IOW56

Displays up to 64x64 pixels of graphic, modules with two chips for up to 64x128 pixels are common

For simplification we will call this family the KS0108 controllers.
The KS0108 is a plain graphics controller that can drive up to 64x64 pixels. Larger displays can use multiple chips but only modules with one or two controllers are common.
Addressing two controllers on a module is done via chip select lines. The chip select lines can be active high or active low, at least we have not found any modules that mix CS polarities.
After power up the controller needs a reset signal which is usually not generated on the module.
The hardware protocol is sufficiently similar to the HD44780 to allow IOW24 and IOW40 to drive the KS0108. Only a reset has to be generated after power up and if a dual chip module is used the chip selects need to be generated.
The reset signal can be generated by a I/O pin or by a RC circuit from either the power supply or the /On signal of IO-Warriors LCD function.
IOW56 does have a dedicated Reset pin for the LCD function that can be used. The chip select lines are not handeled by the LCD function.

The bits of a byte are displayed vertically with the LSB on top.

The mode byte for IOW56 is $02.

Connecting to IO-Warrior24 or 40:
Use the standard pins of the LCD function.
Generate a reset signal by either an additional IO pin or see section 3.1
In case of a dual chip module use two additional IO pins to generate the chip select signals or see section 3.4

Connecting to IO-Warrior56:
Use the standard pins of the LCD function including the Reset line and the CS lines.

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Graphics:
SED152x
S1S15xx
AX1520
NJU6450

Works with:
IOW24 (reset line required)
IOW40 (reset line required)
IOW56

Depending on the chip type display sizes can vary, typically one chip can drive 64x16 pixels but there are variants with other configurations. Modules with two chips are common to drive 64x32, or 96x32, or other display sizes.

For simplification we will call this family the SED1520 controllers.
The SED1520 is more or less a superset of the KS0108 with a different memory mapping and display size. The SED1520 and its derivatives can control varying numbers of pixels which leads to some funny arrangements in dual chip modules, like a 96x32 module where the left block of 61 pixels horizontal being controlled by one chip and the right block of 37 pixels by the second chip.
On dual chip modules the chip select lines are active low.
Some modules do not have on board clock generation, an external 18kHz clock may be required.
The reset line of the modules selects the bus mode between 8080 and 6800 protocol. For use with IO-Warrior the 6800 bus mode must be selected by leaving reset high during operation.
The hardware protocol is sufficiently similar to the HD44780 to allow IOW24 and IOW40 to drive the KS0108. Only a reset has to be generated after power up and if a dual chip module is used the chip selects need to be generated.
The reset signal can be generated by a I/O pin or by a RC circuit from either the power supply or the /On signal of IO-Warriors LCD function.
IOW56 does have a dedicated Reset pin for the LCD function that can be used. The chip select lines are not handeled by the LCD function.

The bits of a byte are displayed vertically with the LSB on top.

The mode byte for IOW56 is $02.

Connecting to IO-Warrior24 or 40:
Use the standard pins of the LCD function.
Generate a reset signal by either an additional IO pin or see section 3.1
In case of a dual chip module use two additional IO pins to generate the chip select signals or see section 3.4
An external clock may be required, see section 3.2.

Connecting to IO-Warrior56:
Use the standard pins of the LCD function including the Reset line and the CS lines.
An external clock may be required, see section 3.2.

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Graphic:
KS0713
S6B1713
S6B0724
UC1606
ST7565
SSD1815

Works with:
Not yet tested

Displays up to 132x65 pixels of graphic. Modules with multiple chips seem to be uncommon.

For simplification we will call this family the KS0713 controllers.
The KS0713 is a very close relative to the SED1520 but not compatible. With up to 132x65 pixels supported it generally makes dual chip modules unneccesary.
Usually the modules have flex layer connectors making them inconvenient for small volume applications and testing.
Not yet tested, likely to work with IOW24 and IOW40 as well as IOW56.

The bits of a byte are displayed vertically with the LSB on top.

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Hybrid:
LC7981
HD61830

Works with:
IOW56

Displays up to 512K pixels of graphic and/or 4096 characters

For simplification we will call this family the LC7981 controllers.
The LC7981 can run in either graphic or character mode. It can control displays with up to 512K pixels, though actual display sizes are typically much smaller (i.e. 80x80, 128x128, 240x128).

A reset is required and the busy flag handling is not compatible with HD44780, so it is not possible to use the LC7981 with IOW24 and IOW40.
IOW56 has a special mode for controlling the LC7981. The standard busy flag checking has to be disabled too.

The bits of a byte in graphic mode are displayed horizontally with the LSB left.

The mode byte for IOW56 is $16.

Connecting to IO-Warrior56:
Use the standard pins of the LCD function including the Reset line.

Hybrid:
SED133x
S1D133xx

Works with:
IOW56

Displays up to 640x256 pixels graphic and 5x7 or 8x16 pixel chars

For simplification we will call this family the SED1330 controllers.
The SED1330 is a family of its own, it has no resemblance to other families.
With the ability to drive up to 640x256 pixels there usually is no need for modules with multiple chips.
It can display graphics and text at the same time by combining up to three graphics layers and a text layer.
Quarter VGA displays with 320x240 pixels are quite common with the SED1330.
Initialisation is somewhat complex but the design of the commands is pretty straight forward and clean.
The bus protocol is not compatible with IOW24 or IOW40.
IOW56 can control the SED1330 direct, checking of the busy flag has to be disabled. The bus protocol of the SED 1330 has to be set to 6800. A reset signal is required.

The bits of a byte in graphic mode are displayed horizontally with the LSB left.

The mode byte for IOW56 is $06.

Connecting to IO-Warrior56:
Use the standard pins of the LCD function including the Reset line.

Hybrid:
T6963C

Works with:
IOW56

Displays up to 640 pixels horizontal or 256 pixels vertical graphic and 5x8 to 8x8 pixel chars

The T6963C is a good example of making things totally different without being any better. It has no relation to any of the other controllers, it supports only 8080 bus protocol, the instruction set is somwhat complicated, and it is in quite widespread use.
It can drive max. 640 pixels horizontally and max. 256 pixels vertically but the total number of pixels must be significantly lower than that. Typical resolutions are 128x128 or 240x128. Modules may or may not have a signal to select the font set.
Depending on the operation mode of the T6963C there are different busy bits that have to be checked before writing data to the controller.
Operation with IOW24 and IOW40 is not possible.
IOW56 has a special mode for the T6963C.

The bits of a byte in graphic mode are displayed horizontally with the LSB left.

The mode byte for IOW56 is $0A.

Connecting to IO-Warrior56:
Use the standard pins of the LCD function including the Reset line.
An extra line to select the character font may be required.

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Following are a couple more controller chips that are known to us but which we had no ocassion to test as of now

LH155BA5
UC1611
S6B0794
6125
T6B66
ST7522
SED1565
S1D13305
RA8804

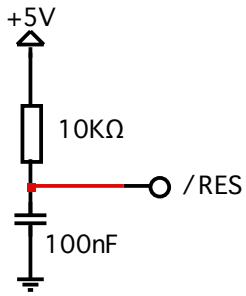
3.0 Backlight

Many modules have a backlight for better visibility. There are two basic technologies for backlight: LED and EL.
While LEDs need only a series resistor and a transistor to switch them on and off, EL (Electro Luminescence) needs relatively high voltages.
In any case it is necessary to put the backlight under control by the /On pin of IO-Warrior to make sure that the maximum current draw on the USB is not exeeded when the host computer enters sleep mode.

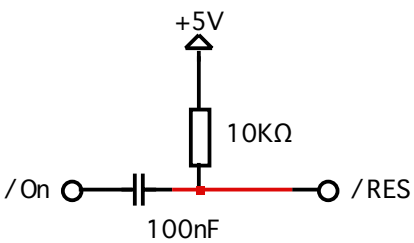
3.1 Generating Reset

The IOW56 does offer a pin that provides a reset signal as required for some modules. IOW24 and IOW40 do not have this signal.
To supply the reset on IOW24 and IOW40 either a dedicated pin can be used that is then pulled low and released again under software control, or the reset can be generated by hardware. This can be done either from the supply voltage or from the / On signal of the IO-Warrior LCD function. Either option just requires a simple RC combination.

Reset from power:



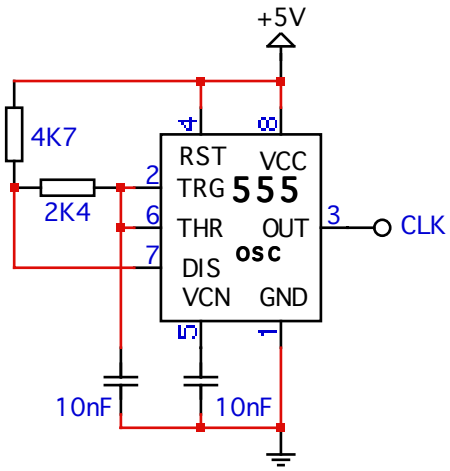
Reset from /On:



Using /On for the reset generation will of course reset the display every time the computer comes back from sleep mode.

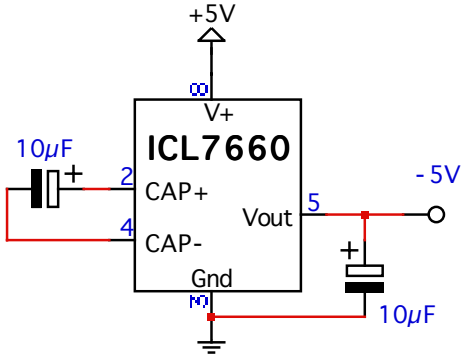
3.2 Generating a clock for SED1520

Some modules that use the SED1520 family of controllers do not generate their clock signal on the module. None of the IO-Warriors can generate this signal, though this can be easily done with a NE555 (example for 18kHz clock):



3.3 Generating a negative supply voltage

With graphic or hybrid modules it is quite common that they don't generate the negative supply voltage for the LCD on board. Refer to the module data sheet to find out if the module requires a negative supply and what voltage level. Usually the negative voltage is specified relative to Vcc and not relative to ground. Usually a negative voltage of -5V relative to ground is sufficient. This can be easily generated by a voltage inverter like the ICL7660 or MAX1044:

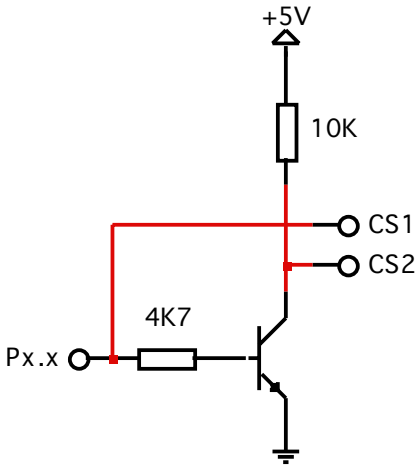


3.4 Generating chip select from a single line

The KS0108 and SED1520 based modules quite often use two controller chips. To drive these modules it is necessary to select which chip to talk to.

On the IOW56 two IO pins are defined for this use, though they are not driven by the LCD special mode function, instead they have to be directly controlled by your code.

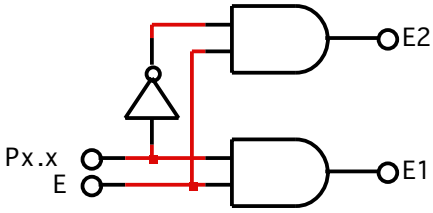
If I/O pins are a critical resource (like on the IOW24) it is also possible to drive both of these chip select lines with a single pin:



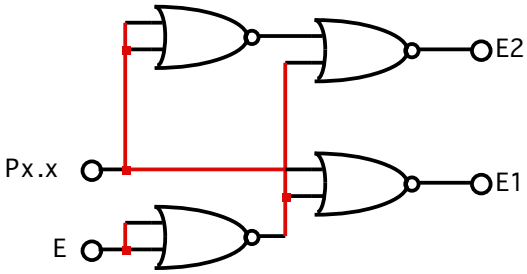
3.5 Driving dual HD44780 modules

IOW56 does have built in support for modules with two HD44780 controllers. To use these modules with IOW24 or IOW40 some additional circuitry is required. Since the selection of the two HD44780 chips is done via the E signals it is not possible to use a simple chip selection like with the KW0108 chips.

A logic circuit is reqiured which selects which of the two E inputs of a module gets the E signal generated by the IOW24 or IOW40:



Or if you want to use just a single type of gate:



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