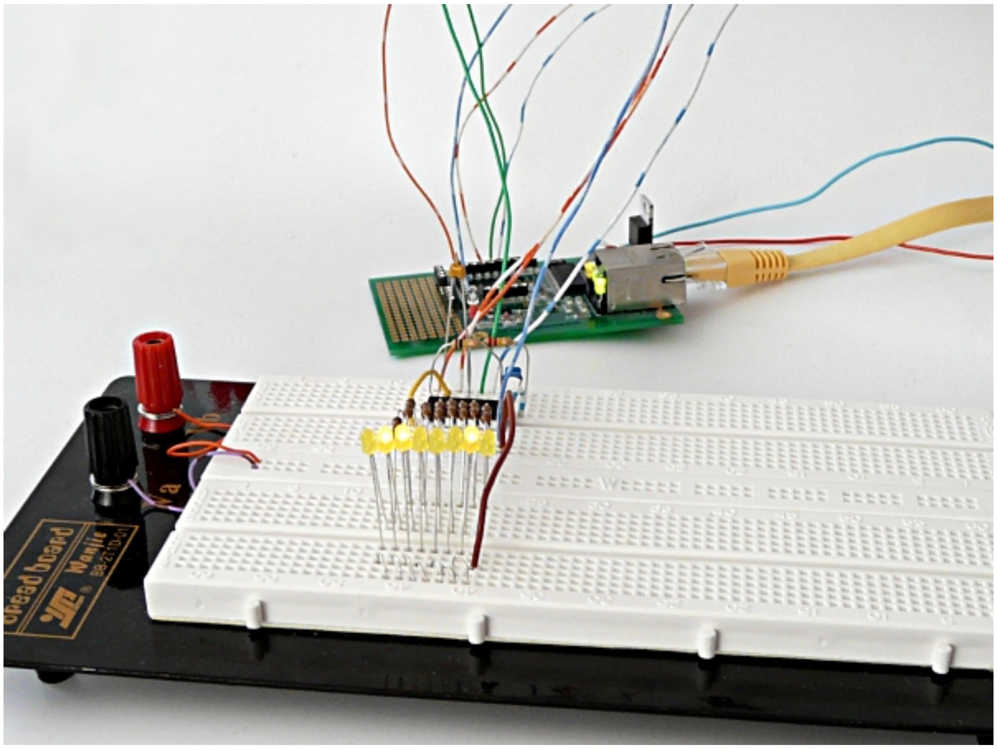
AVR I/O-web server with additional output pins via a 74hc595 port expander



Abstract:

The tuxgraphics web server is not a normal web server. It is an IO-web server. It reads sensor values or IO-pins and it controls digital output lines or relays. It is as well possible to have analog output lines providing arbitary voltages between 0V and 3.3V by using a R2R-ladder DAC.

Sometimes you want to have more digital output pins than the microcontroller you are using provides. You can either switch to a bigger microcontroller chip or use a 74hc595 port expander. This article focuses on the 74hc595. Using multiple 74hc595 chips you could in theory have an infinite amount of output lines on a single ethernet board.

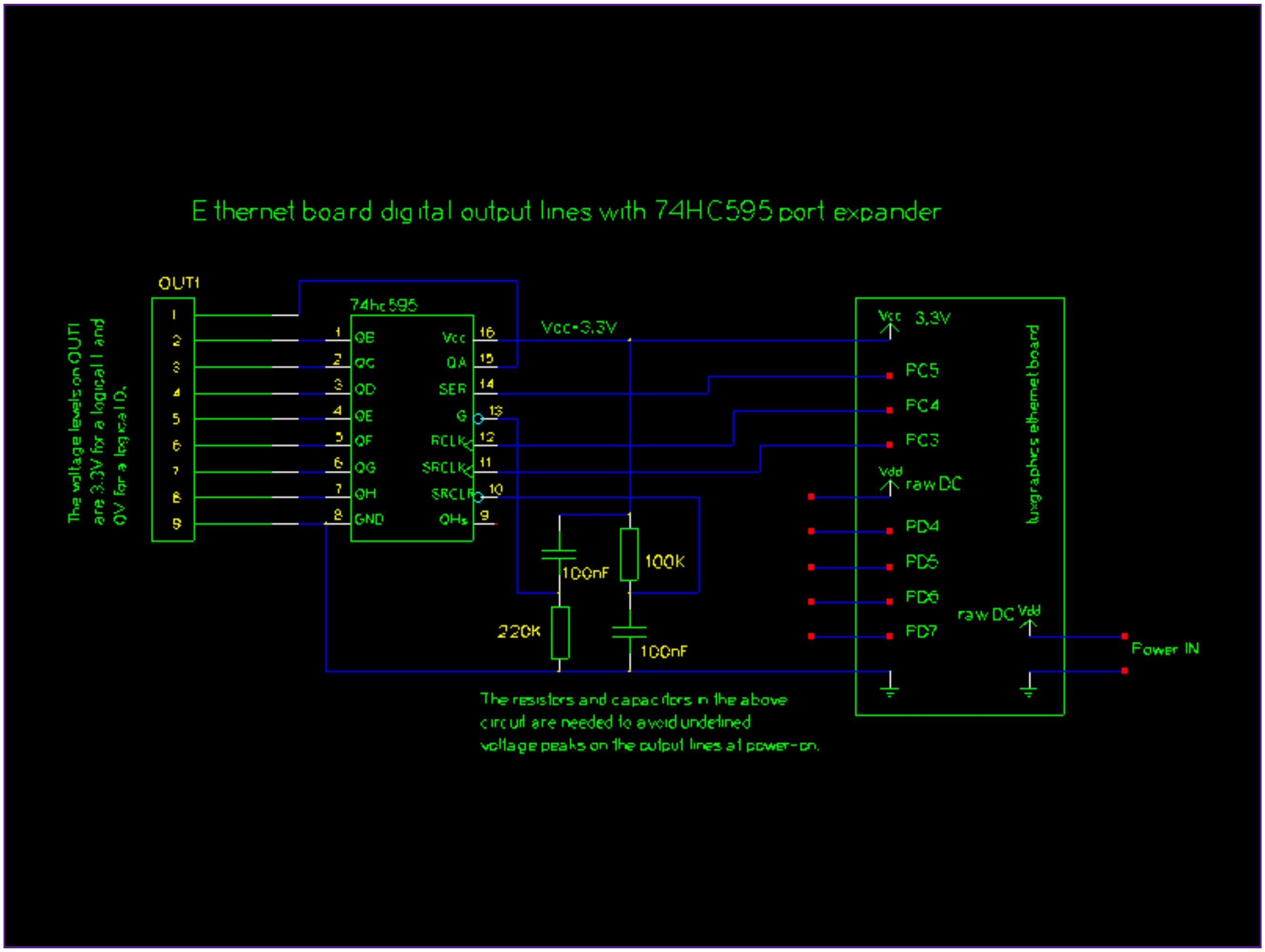
The advantage of the 74hc595 is that you save on wires if you want to have the 8 additional output pins in a different place. There is a serial connrection between microcontroller and 74hc595. The cable lenght of that connection should however not be longer than a meter (3ft).

The 74hc595 chips can be chained to provide 16 bit output ports or more without occupying any further output lines on the atmage.

For another article on IO-web servers which provide digital and analog input lines together with digital output lines see "Using the tuxgraphics embedded web server to control scientific equipment".

The 74hc595

The 74hc595 consists internally of two 8-bit registers. Those two registers are called shift register and storage register. The eight output lines are connected to the storage register. It is possible to fill the shift register in serial bit by bit and move the content of the shift register into the storage register with a single pulse on the RCK line (74hc595 pin 12).


Ethernet board digital output lines with 74HC595 port expander
OUT1
1
2
3
4
5
6
7
8
9
The voltage levels on OUT1 are 3.3V for a logical 1 and 0V for a logical 0.
74hc595
1 QB
2 QC
3 QD
4 QE
5 QF
6 QG
7 QH
8 GND
Vcc 16
QA 15
SER 14
G 13
RCLK 12
SRCLK 11
SRCLR 10
QHs 9
Vcc=3.3V
100nF
100K
220K
100nF
Vcc 3.3V
PC5
PC4
PC3
Vdd raw DC
PD4
PD5
PD6
PD7
raw DC Vdd
tuxgraphics ethernet board
Power IN
The resistors and capacitors in the above circuit are needed to avoid undefined voltage peaks on the output lines at power-on.

[click on the picture for a PDF version]

Connecting the 74hc595 to the tuxgraphics AVR web server. The software in the download section of this article provides as well 4 traditional digital output lines directly at the atmega chip on pins PD4, PD5, PD6 and PD7. They are as well shown in the above drawing.

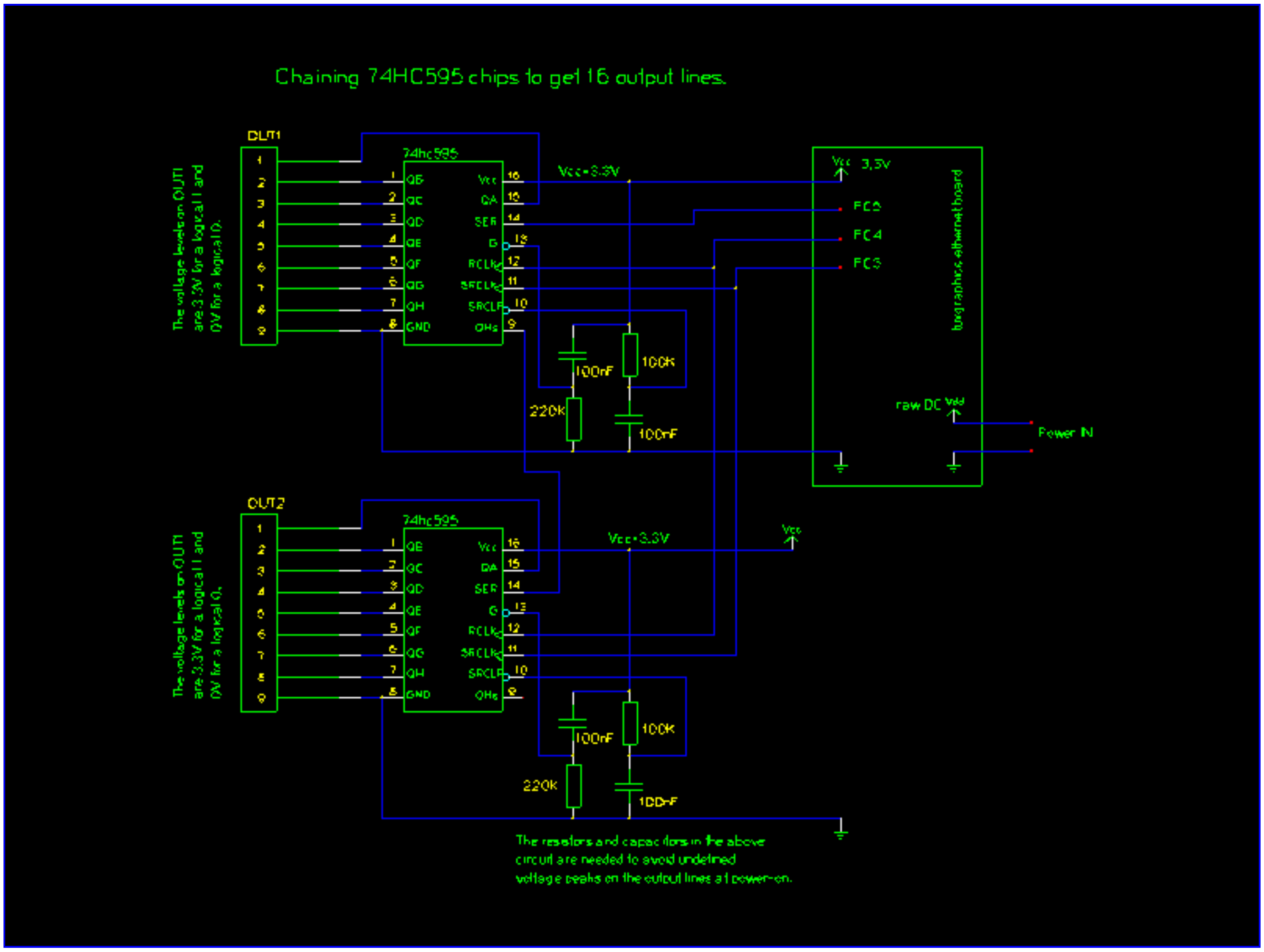
Power-on behavior

For many applications it is important to have a defined behaviour during power on. You don't want to have random blinking or other strange patterns even if you connect just LEDs to the output lines.

The 74hc595 has therefore a pin to clear the shift register (SRCLR, pin 10) and to disable the output (G, pin 13) during power on. Simple circuits hardwire those lines often to just Vcc and GND and then you might get undefined pulses on the output at power on.

A good way to avoid undefined behaviour and not use any additional pins on the microcontroller is to use a simple RC-timer. This RC-combination can be used to hold the pins just for a few µS during power on and then tie them to Vcc or GND respectively.

Chaining chips to get 16 or more output lines


Chaining 74HC595 chips to get 16 output lines.
OUT1
The voltage levels on OUT1 are 3.3V for a logical 1 and 0V for a logical 0.
74hc595
QB
QC
QD
QE
QF
QG
QH
GND
Vcc
QA
SER
G
RCLK
SRCLK
SRCLR
QHs
Vcc=3.3V
Vcc 3.3V
PC5
PC4
PC3
tuxgraphics ethernet board
raw DC Vdd
Power IN
100nF
100K
220K
100nF
OUT2
The voltage levels on OUT1 are 3.3V for a logical 1 and 0V for a logical 0.
74hc595
Vcc=3.3V
Vcc
100nF
100K
220K
100nF
The resistors and capacitors in the above circuit are needed to avoid undefined voltage peaks on the output lines at power-on.

[click on the picture for a PDF version]

Chaining two 74hc595 chips to get 16 digital output lines.

Note that the software which you find in the download section is currently written only for 8 additional output lines. If you want to chain two 74hc595 chips then you will have to modify the software just a little bit.

The Software

There are two functions defined in main.c :

```
init74595(void)

set74595(uint8_t val)
```

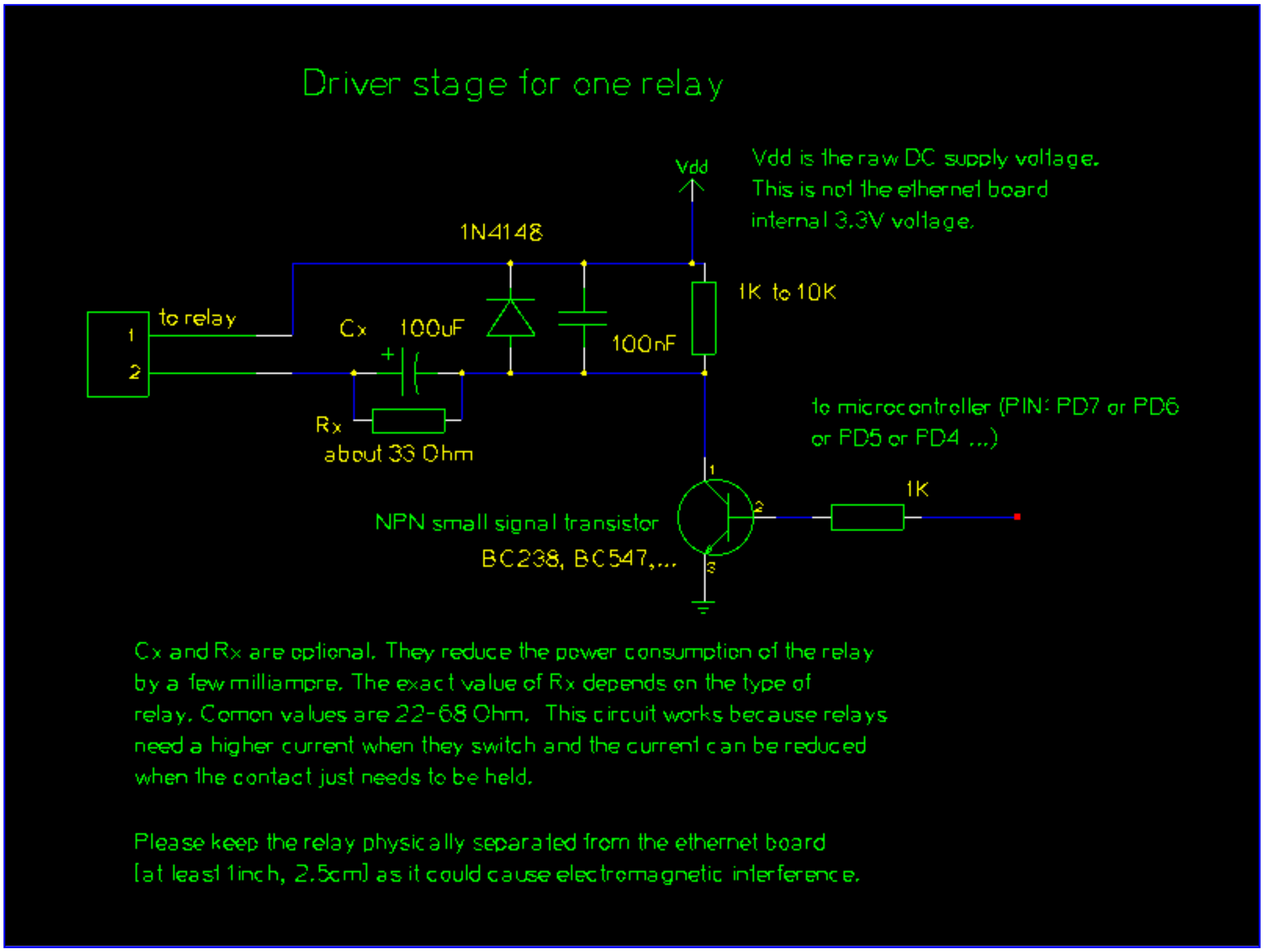
You call init74595 at startup and then you can set any of the output lines of the 74hc595 using set74595(val). A one in a certain bit position corresponds to output-on and a zero corresponds output-off. E.g 10000000 = dec 128 = hex 80 sets the output QH on the 74hc595 to 3.3V. If you want to change just one output and not set all at once then just define a variable that holds the current output bit pattern and use binary-AND or binary-OR to modify individual bits:

```
static uint8_t e74595val=0;
...

  i=3; // the third output pin (possible values 0..7)
  set74595(e74595val|(1<<i));// on
  ...

  i=3;
  set74595(e74595val&~(1<<i));// off
```

Connecting a relay

To switch on/off heavier loads it is a good idea to use a relay. It offers a galvanic separation and protects the microcontroller.

A relay itself causes however induced voltages at the driver when the relay is switched off. For this a fly-back diode is absolutly needed. I recommend to use the following driver stage for each relay that you want to connect. The capacitor and resistor parallel to the fly-back diode supress additional noise that might come in via the relay coil. You connect this driver to the 74hc595 output lines or the microcontroller.


Driver stage for one relay
Vdd
1N4148
1K to 10K
to relay
1
2
Cx 100uF
+
100nF
Rx
about 33 Ohm
to microcontroller (PIN: PD7 or PD6 or PD5 or PD4 ...)
1K
1
2
3
NPN small signal transistor
BC238, BC547,...

Vdd is the raw DC supply voltage. This is not the ethernet board internal 3.3V voltage.

Cx and Rx are optional. They reduce the power consumption of the relay by a few milliampre. The exact value of Rx depends on the type of relay. Comon values are 22-68 Ohm. This circuit works because relays need a higher current when they switch and the current can be reduced when the contact just needs to be held.

Please keep the relay physically separated from the ethernet board (at least 1inch, 2.5cm) as it could cause electromagnetic interference.

[click for a PDF version]

A relay driver stage as needed for each relay.

Keep in mind that a normal relay consumes about 50-100mA at 6V. To build e.g a circuit which controls 12 relays one would need a power supply that delivers 1.4A at 5V-6V. The tuxgraphics ethernet board consumes about 180mA.

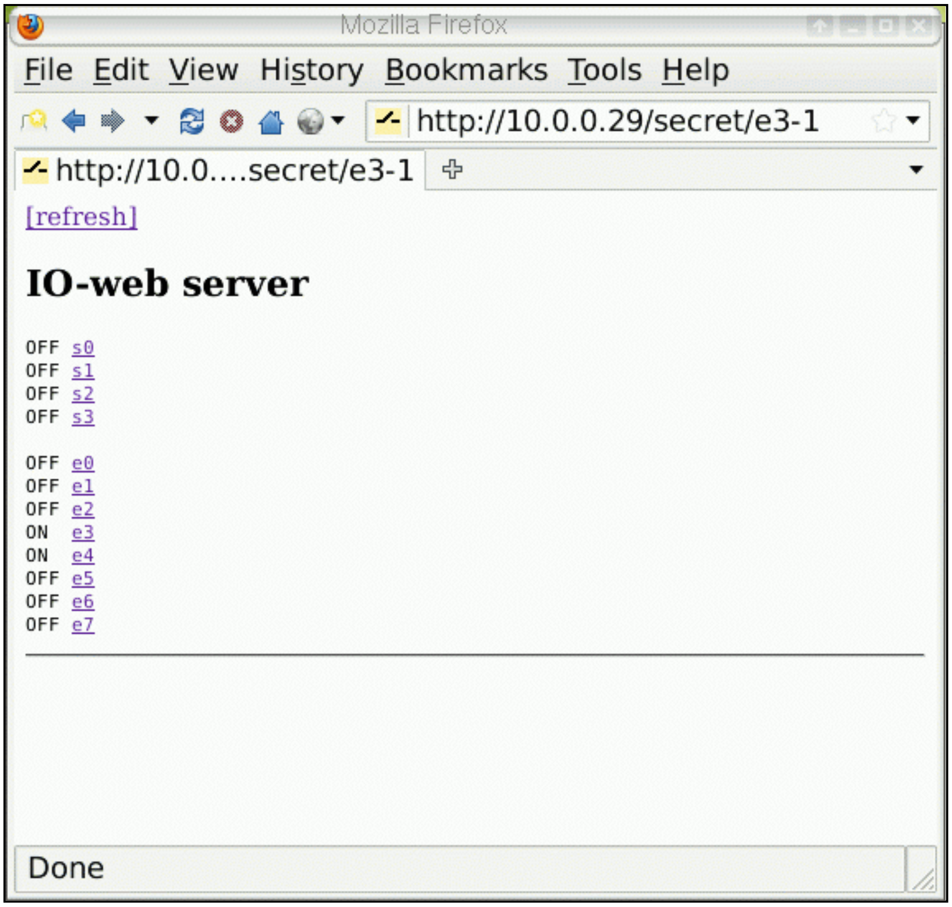
You can lower the power consumption a bit using the capacitor Cx and the resistor Rx as shown in the above circuit diagram. This works because relays need a higher current to switch than they need to just hold the contacts together. This is because they have a metal plate moving towards a magnet. When the plate is very close to the magnet then the magnetic field is stronger and you can lower the current a bit. The strength of a magnetic field is proportional to distance^3 (distance to the power of three). The hold current is determinted by the resistor Rx. When the relay is switched on then the 100µF capacitor is charged up and that causes the current peak needed for the relay to switch.

Do not choose a too high value for Rx. The relay contact need as well be pressed together a bit.

The user interface

The user interface is a web page. The s0 to s3 are the standard output lines on the microcontroller and the e0 to e7 are the eight additional output lines available via the 74hc595 port expander.

To change a value from on to off or vice versa you just click on the name and it toggles between on and off. There is a basic but convenient access protection available. The URL contains a shared secret. It is set to "secret" in the below screenshot.


Mozilla Firefox
File Edit View History Bookmarks Tools Help
http://10.0.0.29/secret/e3-1
http://10.0....secret/e3-1
Done

[refresh]

IO-web server

```
OFF s0
OFF s1
OFF s2
OFF s3

OFF e0
OFF e1
OFF e2
ON  e3
ON  e4
OFF e5
OFF e6
OFF e7
```

Screenshot of the user interface.

References/Download

- Download section
- The avr ethernet board and the 74hc595 is available in our online shop: shop.tuxgraphics.org

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