Instructions

My Electronics

Nixie Thermometer Shield for Arduino

V1.2

Safety Notes

This circuit design includes a switch-mode voltage converter which generates 170 VDC. You are responsible for the safety during the assembly and operation of this device. DO NOT USE IF YOU DON'T KNOW HOW TO HANDLE HIGH VOLTAGES. All assembly and safety instructions should be read carefully before the device is operated.

Disclaimer

The information in this document is provided "as is" without any warranty of any kind and is subject to change without notice. You are responsible for the safety during the assembly and operation of this device. “My Electronics” takes no responsibility for any damage to property, personal injury or death. In no event shall “My Electronics” be liable to you or any third parties for any special, indirect, or consequential, or any other damages resulting from assembly or operation of this kit. When you buy the kit you agree with the disclaimer.

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Product Description

The Nixie Thermometer Shield allows you to build a two-digit thermometer, including a minus sign, with your Arduino. It is a modular system consisting of a High Voltage (HV) Power Supply and a Socket Module depending on the Nixie tubes you want to use. The on-board temperature sensor and an optional external temperature sensor can be used to measure the in- and outside temperature. The kit can be used to getting started with Nixie tubes and 1-wire digital temperature sensors.

Features

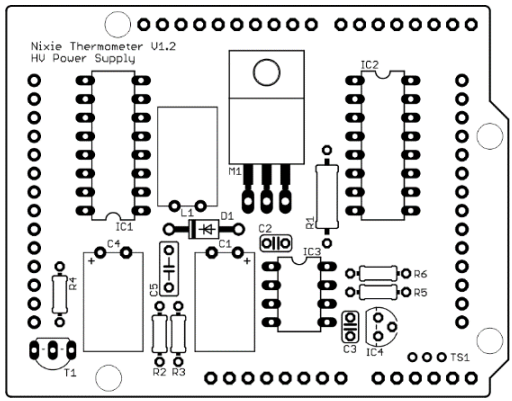
- Compatible with Arduino UNO and MEGA
- Modular system consisting of a HV Power Supply and a Socket Module for different types of Nixie tubes
- Neon lamp NE-2 as minus sign (Optional)
- On-board temperature sensor DS18B20 with a measuring range from -55°C to +85°C
- Connection for external DS18B20 temperature sensor (Up to 10 m length)
- Very high efficiency using the MAX1771 switch-mode controller
- Easy to build, no SMD parts
- Programmable using the Arduino IDE

Assembly Instructions

To build this kit, you should know how to solder. If you have never soldered before, we recommend the Soldering is Easy tutorial.

HV Power Supply

Board Layout



Parts List

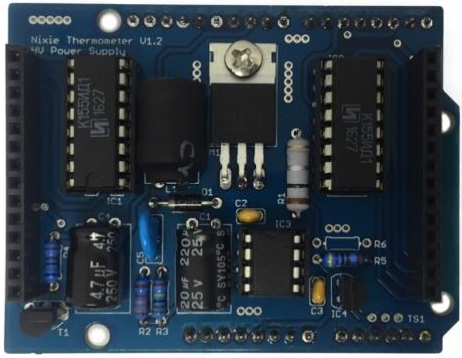
Qty.	Part	Value/Description
1	R1	0.1 Ω, 2 W
1	R2	13.3 kΩ
1	R3	1.5 MΩ
1	R4	68 kΩ
2	R5, R6	4.7 kΩ
1	D1	UF4004
1	M1	IRF630
1	L1	100 µH, 1 A
1	C1	220 µF, 25 V
2	C2, C3	100 nF
1	C4	4.7 µF, 250 V
1	C5	100 nF, 250 V
2	IC1, IC2	K155ID1
1	IC3	MAX1771
1	IC4	DS18B20
1	T1	MPSA42
1		IC Socket DIP 8
2		IC Socket DIP 16
1		Pin Header 1x6
2		Pin Header 1x8
1		Pin Header 1x10
2		Female Header 1x16
1		Pan Head Screw M3 + Lock Nut
1		Piece of Electric Tape
1		Connector + Crimp Contacts

First, check if all listed parts are included in your package. We recommend to begin soldering the components with the flattest design. Start with the resistors, followed by the capacitors C2, C3 and the diode D1. Then solder the MOSFET M1, the IC sockets, the transistor T1 and the temperature sensor IC4. Finally, solder the capacitors C1, C4, C5, the inductivity L1 and the headers.
Note that the diode D1, the capacitors C1, C4 and the ICs need to be soldered/mounted in the right direction.

The kit comes with 1x16 female headers instead of the 1x14 headers required for the socket module. We recommend using a utility knife or a side cutter to shorten the headers.
The table below lists the required resistors and their corresponding color codes:

Part	Value	1st Band	2nd Band	3rd Band	4th Band	5th Band
R1	0.1 Ω	Brown	Black	Silver	Gold	-
R2	13.3 kΩ	Brown	Orange	Orange	Red	Brown
R3	1.5 MΩ	Brown	Green	Black	Yellow	Brown
R4	68 kΩ	Blue	Gray	Black	Red	Brown
R5	4.7 kΩ	Yellow	Violet	Black	Brown	Brown

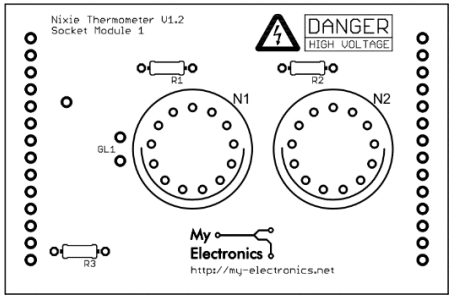
The assembled PCB is shown below:



To prevent shorts, cover the USB connector of the Arduino board with the piece of electrical tap included the kit.

Socket Module

Board Layout

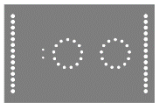
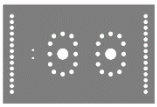


Parts List

Qty.	Part	Value/Description
2	R1-R2	See „List of Socket Modules“ on Page 6
1	R3	180 kΩ
2		Pin Header 1x16
1		Fuse Holder (Ø 5 mm) + Silver Plated Wire (50 mm)

The front side of the Nixie tubes are indicated by semicircles. To mount the Neon lamp, first cut the pins of the fuse holder with a side cutter. Then, solder a silver plated wire from the rear and bend the wires of the Neon lamp at a right angle. Finally, solder the three wires into the board (See the cover image for reference).

List of Socket Modules

Socket Module		Supported Nixie Tubes	Resistor
1		IN-14	10 kΩ
2		Z570/3/4M, Z5700/30/40M, ZM1080/2, ZM1134/5/6/8, B570M, F9080B, TAF1093A, TAF1317A	16 kΩ
3		IN-12, IN-12A/B, IN15A/B, ZM1180/81/82/83/86/88, ZM1162	8.2 kΩ
4		IN-8	8.2 kΩ
5		IN-16	16 kΩ
6		IN-8-2	8.2 kΩ

Value	1st Band	2nd Band	3rd Band	4th Band	5th Band
8.2 kΩ	Gray	Red	Black	Brown	Brown
10 kΩ	Brown	Black	Black	Red	Brown
16 kΩ	Brown	Blue	Black	Red	Brown
180 kΩ	Brown	Gray	Black	Orange	Brown

Operation

To use the shield, mount the HV Power Supply on top of an Arduino board and the Socket Module on top of the HV Power Supply.

IMPORTANT: Before operating the shield connect a 9 to 12 V external power supply to the Arduino board.

Then, connect the Arduino to your computer via USB as usual and open the sample sketch using the Arduino IDE. The sample sketch is available on our GitHub repository: Download Sample Sketch

If you are using the Arduino IDE for the first time, we recommend the Getting Started with Arduino guide.

The sample sketch requires the OneWire library to function. To install the library, in the Arduino IDE, open Sketch → Include Library → Manage Libraries… and search for “OneWire”.

If the sample sketch was uploaded without any error and the kit was assembled properly, the Nixie tubes should display the temperature measured by the on-board temperature sensor (IC4). If the kit does not operate as expected, see the Troubleshooting section. The function of the sample sketch is explained in detail in the Functional Description section.

Note that, due to the heat dissipation of the other components, the temperature reading of an on-board temperature sensor can up to 5°C higher than expected. A more precise temperature reading can be obtained by soldering 10 cm wires to the included temperature sensor pins or using wired temperature sensor as shown below.

Wired DS18B20 Temperature Sensor

The wired temperature sensor it not included and has to be purchased separately. There are many sources available, both on eBay and elsewhere online.

WARNING: The assembled kit generates HIGH VOLTAGES. If you buy the kit, you are fully responsible for the safety during the assembly and operation of this device.

Troubleshooting

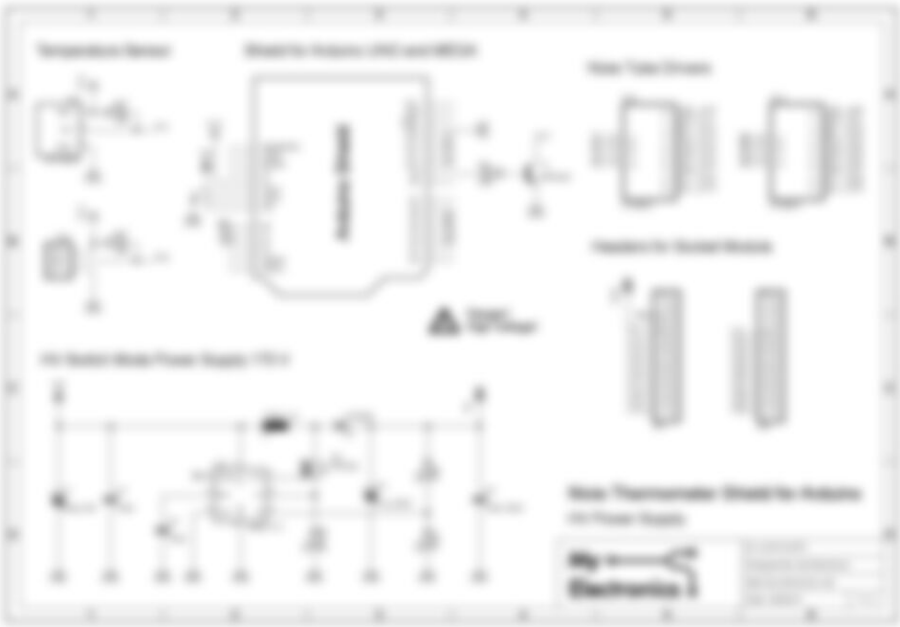
If the kit does not operate, please perform the following tests before sending a support request:

1. Check if all components are soldered properly and installed in the right position and direction
2. Check if the required external power supply is connected to your Arduino.
3. In the Arduino IDE, check if the sketch was uploaded properly.
4. In the Arduino IDE open Tools → Serial Monitor. Press the Reset button on your Arduino board and check the error messages and temperature readings.

Need help with the DIY Kit? Please send a support request with your order number or eBay ID: support@my-electronics.net

Schematics

HV Power Supply



Socket Module

Functional Description

The shield is based on a step-up switch-mode power supply which generates the 170 V required to drive Nixie tubes. There are a few ICs that can be used for step-up converters including the MC34063, MAX1771 and others. Here, the MAX1771 is used (IC3) because of its high efficiency. The IC is a step-up switching controller that uses a unique pulse-width modulation (PWM) scheme to get a high efficiency in a variety of configurations. The employed circuit is mainly adapted from the MAX1771 Datasheet. However, for a configuration like this, where the step-up is large, the component choice and board layout becomes important.

The key points are:

- M1 should be selected for low R_{DS} and Q_g
- D1 should be ultrafast recovery (t_r < 50 ns) and rated 1 A, > 170 V
- L1 should be rated 1 A
- C1 should be low ESR and close to IC3 as it must provide a high current for L1 and M1 very quickly
- The trace between the M1 and EXT pin needs to be short to allow the gate of M1 to be charged very quickly, directly effecting the efficiency
- The connection to the FB pin should be as short as possible as it is very sensitive to EMI interference
- R1 must be capable of handling at least 1 A
- C5 must be rated > 170 V
- C4, the output capacitor, should be low ESR (< 3 Ω) and rated > 170 V

From the MAX1771 Datasheet we get:

$$R3 = R2 \left(\frac{V_{OUT}}{1.5\ V} - 1 \right).$$

requiring R2 = 10 to 500 kΩ. To get V_{OUT} = 170 V the resistors are selected as R2 = 13.0 kΩ and R3 = 1.5 MΩ:

$$V_{OUT} = 1.5\ V \left(1 + \frac{R3}{R2} \right) = 1.5\ V \left(1 + \frac{1.5\ M\Omega}{13.3\ k\Omega} \right) = 170.7\ V.$$

The specification for, e.g., an IN-14 tube are as follows:

Supply Voltage	170 V
Operating Voltage	140 V
Cathode Current	2.5 mA

Therefore, using Ohm's law, the anode resistor should be:

$$R = \frac{170\ V - 140\ V}{2.5\ mA} = 10\ k\Omega.$$

See the "List of Socket Modules" for comparison.

To drive the Nixie tubes two K155ID1 Nixie drivers are used (IC1, IC2). The IC is a binary to decimal decoder with build in high voltage transistors. It takes a 5 V logic level input on D, C, B, A and outputs the corresponding digit of the Nixie tube.

The shield takes a binary input on the pins 13, 12, 11, 10 and 5, 4, 3, 2, connected to the D, C,B, A pins of the K155ID1 drivers. So, e.g., L, L, L, H on the pins 13, 12, 11, 10 will display "1" on the Nixie tube N1. Here, L stands for "LOW" (0 V) and H for "HIGH" (5 V). L, H, L, H on the pins 5, 4, 3, 2 will display "5" on the Nixie tube N2. The entire logic table is shown in below.

Logic Table for the Nixie Driver

Digit	D	C	B	A
0	L	L	L	L
1	L	L	L	H
2	L	L	H	L
3	L	L	H	H
4	L	H	L	L
5	L	H	L	H
6	L	H	H	L
7	L	H	H	H
8	H	L	L	L
9	H	L	L	H
OFF	X	X	X	X

With the A0 pin, defined as EN in the sample sketch, the HV Power Supply can be turned On or Off.

The sample sketch for the Nixie Thermometer Shield is available on our GitHub repository: Download Sample Sketch

The sample sketch is well-commented but some function will be described in detail in the following section.

The boolean array `nixieTable` resembles the logic table for the Nixie driver. The function `nixieWrite` takes the input pins of the Nixie driver and the digit to be displayed as input and writes the corresponding logic levels.

The transistor T1, driving the minus sign tube, is connected to pin 9 defined as SIGN. HIGH will turn the Neon tube On, LOW will turn it Off.

The DS18B20 (DQ) is 1-wire digital temperature sensor. It reports the temperature in degrees Celsius with a 9 to 12-bit precision, from -55 to 125 (±0.5) °C. The on-board temperature sensor is connected to A1.

The function `getTemperatureInCelsius()` returns the temperature from a DS18B20 in degree Celsius. First, it searches for the connected sensor and gets its address. Then it sends the convert command 0x44 and reads the scratch pad. To read the scratch pad, the command 0xBE is send and 9 bytes of data are received. The first two bytes corresponds to the LSB and MSB of the temperature data represented as a 16-bit two's complement binary. (See Fig. 9 and Page 6 in the DS18B20 Datasheet). The temperature in degree Celsius is then calculated as follows:

```
int value = data[1] << 8 | data[0];
float temperature = value*0.0625;
```

Suppose that MSB = 1111 1111 and LSB = 0110 0000. They will be combined to the 16-bit binary 1111 1111 0110 0000 by the bitwise left shift operator `<<` and the bitwise or operator `|` and converted to signed integer value -160 using two's complement. Finally, the factor 0.0625 converts between the sensor's internal 12-bit values and the temperature in degree Celsius leading to a temperature of -160*0.0625 = -10 °C.