Meetjestad! station repair instruction

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1 Introduction

1.1 Purpose

When you have a broken Meetjestad! station, this document lists possible actions for repair.

1.2 PCB version

PCB = Printed Circuit Board, on which all electronic components are placed.
At https://github.com/meetjestad/mjs_pcb/releases you can see which version of the PCB you have.
In short, there are v1 PCBs (with the 28-pin IC) and v2 PCBs (with tiny SMD conponents).

1.3 Tools

The tools that can be used for troubleshooting are listed in chapter 5.

1.4 Contact

Meetjestad repair contact: Diana Wildschut, meedoen@meetjestad.nl

1.5 Github

This document is stored on Github at https://github.com/Peter-dM/repairs/Meetjestad_repair_checklist.odt.

2 Check operation history

2.1 Check the meetjestad website

Check URL e.g.: https://meetjestad.nl/data/sensors_recent.php?sensor=2000&limit=50 if the station ID is 2000.
Column “Time” shows when a measurement was received from the station the last time.
Column “Voltage” shows the most recent (battery and) supply voltage.
Nodes 1-1999 are v1, should have a battery voltage of around 4.0 V and a (supply) voltage of 3.3 V.
Nodes 2000++ are v2, should have a battery voltage of around 4.0 V and a (supply) voltage of 3.0 V.
Note:
Some v2 stations (station ID 2000++) also have a web page showing graphs of the voltages over time, e.g. https://meetjestad.nl/static/graphs/batt/index_batt_2002.html for station with ID 2002.
If the station has a solar panel these graphs also show the solar panel voltage (dark orange).
They also show the solar activity (vague light orange).

3 Unboxing

- remove the top from the holder (nl: weerhut) (if you have a light sensor (white half-sphere) or a solar panel, note the wire connecting it),
- at the bottom, gently shift the PCB up, rotate it a quarter, and take it down.
- remove any spider webs, or accumulated dust
- allow any spiders or ladybugs (lieveheersbeestjes) to run away

4 Supply testing

4.1 Unloaded (onbelast) battery testing

Measure the unloaded battery voltage with a multi-meter.

v1 Stations have discharge-only batteries, their voltage should be between 4.5 and 3.6 V.
If the voltage is lower then 4.0 V, replace the batteries (with discharge-only's).

v2 Stations have rechargeable batteries, this voltage should be between 4.2 and 3.6 V.
If the voltage is lower then 4.0 V, check the solar panel.
In daylight or when you shine a bright light on it, it should charge the batteries with at least some mA.

Rechargeable batteries can be revived by discharging and charging them several times in a battery charger.
Some battery chargers support discharge-charge cycles.

All batteries for a station should be of the same type, brand and capacity (mAh).

4.2 Battery testing under load

Take out the batteries from the container and measure each of their voltages with a battery tester that applies a current load to a battery.
Each voltage should be at least 1.20 V or 80% of full scale.
Also the voltages of all 3 batteries should be approximately equal.
Replace all 3 batteries if necessary.

4.3 Test voltages under load

Shortly load the batteries combined with a 33 Ohm 1W resistor.
Note: when applied longer, the resistor may become hot.
For a v1 station, under load, their combined voltage should be at least 3.3 V.
For a v2 station, under load, their combined voltage should be at least 3.0 V.
If the voltage is too low:

- Check the battery container's contacts for corrosion. They might be not shiny enough.
- Check the battery's contacts.
  - If they are covered with white powder, remove the white powder carefully (= chemical waste) and replace the batteries and the battery container (details below).
  - If they are corroded (rusty), polish them or replace the complete battery container.
- Check that the the batteries make good electrical contact with the container's springs.
- In case you fear the batteries might flip out of the holder, you can bind a binder or wire around the container so that the battery contacts are firmly attached to the holder contacts or even better replace the battery container with a better one.

4.4 Operational voltages - explanation

Every 15-16 minutes the station awakes from sleep.
It gathers measurement data and uploads the data to the Meetjestad! website.
The station's components use the following amounts of current:

- GPS: ca 50 mA for a few to maximally 120 secs, once per 24 hours
- PM-sensor: 80 mA for ~ 10 secs each time
- LoRa: 120 mA, for ~ .3 secs each time

This is a substantial amount of current to be delivered by 3 small batteries.
Due to the current, the battery voltage can drop to such a low voltage that the station may stop to function[1].
Note:
A simple multimeter might be unable to show the battery voltage during short times.

1 Recently the firmware has been adjusted, so that no PM-sensor and GPS measurements are done below a certain battery voltage.

5 Connection testing

5.1 Connectors

Check the following connectors:

- **Si7021 temperature sensor**
  Check that the Si7021 was placed correctly.
  Seen at the front, the (-) pin should be on the right-hand side
  Take the sensor out from its holder and check for corroded contacts.
- **SPS30 PM-sensor**[2]
  The connector cable for the SPS30 PM sensor is very fragile.
  Check with a bright light and magnifying glasses if all wires are firmly connected.
  Spare connector cables are available; to re-solder one or more contacts is quite a challenge.
- **6-pin and USB-C**[3] **programming connector**
  The 6-pin programming connector can also get corroded.
  This can make re-programming error-prone or even impossible.
  Note: The contact between the programmer and the PCB is made in between the pins (at the pins' sides, not at the side of the pin strip)

Antenna:

- Check the length of the antenna; it should be 8.2 cm, measured from the solder on the PCB.
- When the station has been working without antenna, the radio transceiver might have become disfunctional.

Notes:

- Make sure you have a proper antenna when you power up or reboot the station !
- I suggest that, when you place the station in the field again, you cover the 6-pin connector with a dummy, resp. the USB-C connector with a small stretch of duct tape, to prevent corrosion.

5.2 Soldering

Check the solder points, especially those of the FETs (small blocks) and voltage stabilizer (small cylinder) and the radio transceiver, for corrosion.
If there is, you can remove solder with a tin sucker (tinzuiger) and apply new heat and/or new solder.
If the solder can not be melted anymore, try to apply some new solder first.

Electronic circuit diagrams can be found at https://github.com/meetjestad/mjs_pcb/releases

2 v2 only
3 v2 only

6 Tools

6.1 Hand tools

Recommended tools:

- **Web browser**
  URL e.g.: https://meetjestad.net/data/sensors_recent.php?sensor=2000&limit=50 if your station ID is 2000.

- **2.54 mm female pin jumper**
  To bridge the reset pins when you need to enforce a reset and to switch between supply from the programmer or supply from the batteries

- **Multimeter (nl: universeelmeter)**
  To measure power supply and other voltages (no load)
  ~~To measure solar panel charge current~~

- **Battery tester**
  To measure a battery's voltage under load
  Also some multimeters have this option.

- **Connection wires with hooks**
  E.g. to connect the load resistor with the battery case connections.

- **Resistor 33 Ohm 1 W** (orange, orange, black)
  To load (belasten) the batteries

- **Bright light**
  To inspect possibly moisted and corroded contacts and soldering

- **+3 Magnifying spectacles (bril) or glass (loupe)**
  To inspect possible moisted or corroded contacts.
  @NL magnifying glasses are sold at a.o. Etos

- **Binding wire or straps/tie-wraps (opt.)**
  To contain batteries firmly in their holder

6.2 Status indicator light

The v1 station has a small red light that blinks shortly at reboot.

The v2 station has a light indicating what the station is doing at the moment.
Colors are in order of occurrence[4]:

- **red,** while waiting for USB/Serial (max 10s)
- **orange,** while doing initial sensor readings
- **yellow,** while waiting for TTN activation
- **cyan,** while waiting for a GPS fix
- **purple,** while reading the SPS030 sensor
- **blue,** when doing LoRaWAN transmission

In all other situations (including when sleeping, which will be most of the time), the LED is off to save power.

6.3 IT tools

Recommended IT tools are:

Cables needed for v1 stations:

- USB-A to USB-A extension cable
- USB-A-to-serial (TTL) dongle, e.g. CP2102, use 5V setting
  RX and TX indicator lights would be nice

4 Listed on https://github.com/meetjestad/mjs_firmware#board-status-through-led-color-mjs2020-only

- 6-pin F-F adapter (preferred) or 6-wire F-F Dupont cable[5], typically straight
  note that the serial connection is swapped:
  dongle-RX connects to PCB-TX and dongle-TX to PCB-RX.
- Use colored cables! E.g. red for battery, yellow for +5V, green for 3.3 V, black for ground.

Cable needed for for v2 stations:

- USB-A to USB-C extension cable

Install on your laptop:

- Since library setups for v1 and v2 slightly differ, I recommend creating separate login users for
  - v1 (stations 1-1999), e.g. ardmjs1
  - v2 (stations 2000++) , e.g. ardmjs2 or any other suitable user name
- the Arduino IDE[6], most recent version 1.8.16 is working OK for this
- the Meetjestad firmware zipfile[7], it contains the libraries.
- **DON'T** upgrade any libraries after that !, in Preferences untick "notify for updates".
- get familiar how to use the Arduino IDE, how to get the controller into programming mode, and how to reset the controller and replace the firmware.

Note:

- Usually first time things go wrong, so be patient.
- Once an environment is running OK, **DON'T** make any unnecessary changes to it anymore !

6.4 Programming tools

The v1 Meetjestad! stations follow the Arduino IDE conventions closely.
@Linux, the serial dongle port = e.g. /dev/ttyUSB0, and your ardmjs1 and ardmjs2 users must be a member of the dialout group.
@Linux, lsusb lists the serial dongle e.g. as "CP210x UART bridge"

The v2 Meetjestad! stations can be programmed as follows:

- press "Boot"; the USB (@Linux e.g. /dev/ttyACM0) should reactivate
- connect the programming jumper (near the "Boot" button)
- press "Boot" again
- @Linux, lsusb should now show: "STMicro electronics STMdevice in DFU mode"
- start the Arduino IDE compiler, followed by upload
- when that is uploading, gently remove the jumper
- you might need to press "Boot" again

6.5 Program debugging

The v1 stations have the Arduino Serial via the 6-pin connector. You can use a USB-to-serial dongle (e.g. CP2102) for debugging; set DEBUG to true.
Some ATMEGA328Ps give issues when being programmed serially.
This might be caused by a deviation of the internal clock oscillator frequency.
On a USB-serial dongle that shows serial traffic, one can see that they TX to the serial, but that is not shown in the serial monitor.
In that case, the ATMEGA328P can be programmed via SPI using e.g. an USBasp.
Note:
When the controller is flashed (by Meetjestad staff), the controller's oscillator is calibrated for LoRa timings.
TO DO: question: does the calibration apply to the LoRa timings only or to the serial speed as well ?

In case the station doesn't respond to a reset, the reset can be applied to ATMEGA328P pin 1 directly,
In case the station seems to hang e.g. after listing EEPROM contents, check the sensors.
A broken sensor might hang the station.

The v2 stations use the USC-C port, some have a Serial1, a separate 6-p pin connector.
Using either USB-C or Serial1 can be set in the Arduino IDE.

6.6 Library debugging

If you would wish to write debug code to the libraries, be aware that they can be located in the ~/Arduino/libraries directory, in directory ~/.arduino15 or at your laptop's generic Arduino install directory.

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5 I recommend using an adapter, my experience is that Dupont connectors wear out very quickly when applied to corroded pins.
6 https://www.arduino.cc/en/Tutorial/getting-started-with-ide-v2/ide-v2-downloading-and-installing
7 https://www.meetjestad.net/meten/files/arduino-bundle-v5.zip
Detailed install instructions can be found at https://github.com/meetjestad/mjs_firmware.

Also libraries might (multiple) include other libraries in an order of that might not be straightforward.
Note: When you restore original libraries, make sure you touch their files or they might not be re-compiled and re-linked again !

6.7 Electronic tools

The following electronic tools can be used for troubleshooting:

- Arduino Uno SPS30 PM sensor test unit
- Arduino Mini Pro Si7021 temperature sensor test unit
- USB UART dongle with connector matching the v1 GPS

and the following optionally:

- Arduino Mini Pro 3.3V + Meetjestad ATmega328p programmer[8]
  for setting the ATmega328p fuses and EEPROM
- Arduino UNO + DIYMORE AVR ISP shield
  for setting ATmega328p fuses
- USBasp + DIYMORE AVR shield for writing the program code into flash via SPI, in case programming via serial would fail[9].
  You will need the compiled binary code for this, not the source code[10].

TODO:

- If things go wrong…. Where to give comments/improvements

8 https://github.com/meetjestad/mjs_programmer

9 https://forum.arduino.cc/t/avrdude-failing-to-program-a-barebones-atmega328p/559101
AVRDUDE failing to program a barebones atmega328p

10 On Ubuntu Linux, the command for this might look something like:
/opt/install/arduino-1.8.15/hardware/tools/avr/bin/avrdude
-C/opt/install/arduino-1.8.15/hardware/tools/avr/etc/avrdude.conf -v -patmega328p -cusbasp
-P/dev/bus/usb/003/018 -b57600 -D -e -Uflash:w:/tmp/arduino_build_633056/mjs_firmware.ino.hex:i

7 Refurbishing

While repairing, the following improvements can be made to the station:

7.1 Firmware backup (optional)

For a v1 station, when desired, a backup of the controller's fuses, EEPROM and firmware can be made.

7.2 Si7021 mounting

The sensitive side of the Si7021 Temperature sensor is the component side, the small white rectangle on it being the sensor area.

The Si7021 should be placed with the sensitive side facing sideways outside, so: not facing the PCB.

This has the result that the Si7021 can be placed in 2 ways:
- at the component side of the MJS PCB, pointing downwards
- at the solder side of the MJS PCB, pointing upwards. In this position, it has just enough room when a 3AA battery holder is mounted.

7.3 Cover pins with dummy sockets

While repairing, many times the 6-p, 3-p and 2-p connector pins had gotten corroded to such an extend, that they needed to be replaced.
Typically, a station with corroded pins can not be restarted and not be reprogrammed.

For a v1 PCB, the serial connector pins can be covered with a 6-p 0.1" dummy female pinheader.
For a v2 PCB, it is recommended to cover the USB-C female socket with a bit of duct tape; if that socket would ever corrode, the PCB might be lost.

7.4 GPS sensor fixation

In case the opening for the GPS sensor on top is too wide, the sensor can be fixated using 2 halve toothpicks.

7.5 Battery voltage measurement

Originally, on a v1 PCB, the supply voltage behind the voltage stabilizer is reported, which is 3.3 V almost all of the time. This is not very informative. Reporting the battery voltage too is more useful.

It can be done using a 470 kΩ/100kΩ voltage divider (1% recommended). Its input is connected to the middle of the 3-p supply jumper, its output to pin A0. In the firmware, it can be enabled in line 54:

```
float const BATTERY_DIVIDER_RATIO = (100.0 + 470.0) / 100.0;
```

7.6 Firmware improvements

There is firmware available that has the following improvements:
- Temporarily inhibits GPS and PM measurements when the battery voltage is too low
- Reports Temperature sensor (Si7021) serial number every 24 hours

It can be found at https://github.com/meetjestad/mjs_firmware/pull/23.

7.7 Removing the battery holder

If resoldering of the PCB is necessary, in most cases the battery container needs to be removed.

It can be removed by, inside the battery container, cutting the wires that connect it to the PCB.
The remaining wire ends can then be heated with the soldering iron and should ideally, while heated, slide down from their holes.
Please note that the (-) hole makes a connection between the front and the rear side of the PCB.

7.8 TO DO: replace AAA batteries with AA batteries

At the moment, AAA batteries are used.
AAA batteries have a capacity of ~ 800 mAh, whereas AA batteries have a capacity of ~ 2400 mAh.
AA batteries should therefor be able to last 2.5 times longer then AAA batteries.
Also the internal resistance of AA batteries is somewhat smaller, enabling supplying larger currents (e.g. 100 mA for the GPS) a bit longer, and rechargeable batteries should last longer in periode where there is not much sunlight.
In the future, AA batteries will be used; the cabinet has room for a 3 AA battery holder.

For v1 stations (ATMEGA28P controller in 28-p socket) the old strongwired 3AAA battery holder (soldered onto the PCB) can be replaced by a 3AA strongwired battery holder (see below) or by:
- a flexwire 3AA battery holder with a JST 2-p female connector and
- on the PCB a 2-p JST male socket.
Note: there is a ground connection between the front and the rear side of the PCB at the (-) pin. That connection needs to be continued.

The JST 2-p connector also enables using a standard LiPo battery instead.
The flexwire battery holder then needs to be attached to the PCB in an alternative way, e.g. with a tie-wrap around the controller IC.
Make sure the station ID (typically written onto the controller IC) must continue to be visible and might have to be written elsewhere on the PCB or on one of the the fixing plates.

For v2 stations (STM32 controller soldered in SMD), the 3AAA battery holder can be replaced with a firmwired 3AA battery holder.
Since the AA battery holder has a somewhat different pinout, the pins need to be Z-bent for that:
in a square angle sideways, and 4 mm further upright again.

Figure 1: Holder bottom view, circuit board rotated

Figure 2: Removing the circuit board from the holder

Figure 3: v1 circuit board without the ATmega328p controller

Figure 4: v2 circuit board with SPS30 PM-sensor

Figure 5: Multimeter

Figure 6: Multiple battery charger and -tester

Figure 7: Single battery tester with built-in load


Figure 8: 33 Ohm resistor

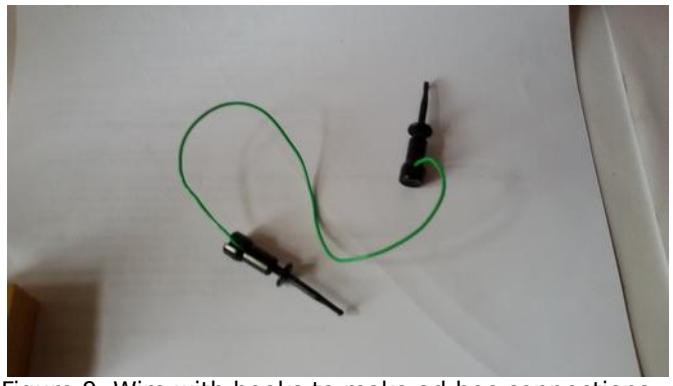


Figure 9: Wire with hooks to make ad-hoc connections

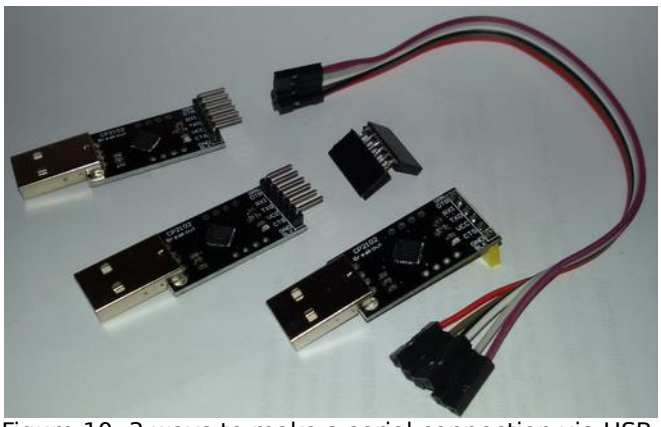
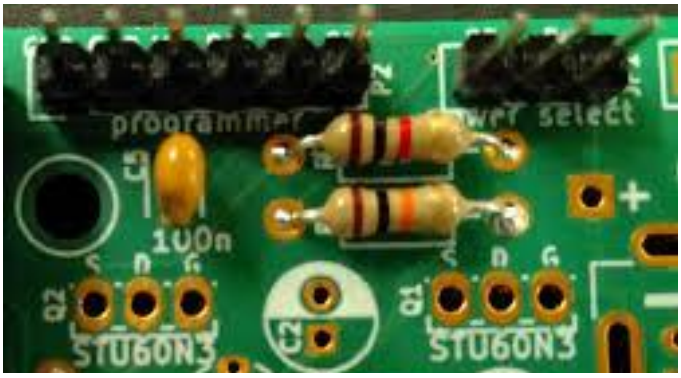


Figure 10: 3 ways to make a serial connection via USB

- CP2102 with 6-wire Dupont cable (not recommended)
- CP2102 with hand-made 6-pin female-to-female connector
- CP2102 with male pin connector replaced with female connector (yellow) (recommended)



v1 circuit board under construction (detail):
Figure 11: top: the serial and power select pins

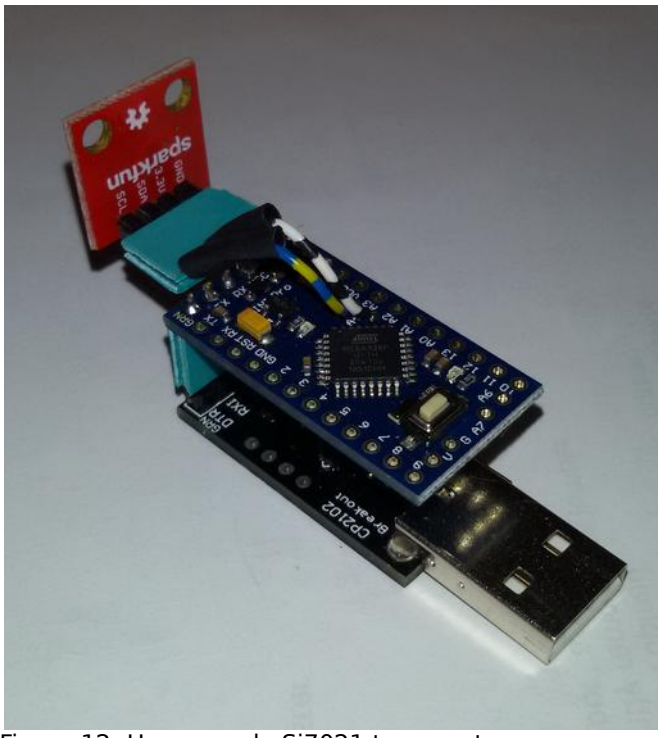


Figure 12: Home-made Si7021 temperature sensor tester

using CP2102 (below) and Arduino Mini Pro on 3.3 V

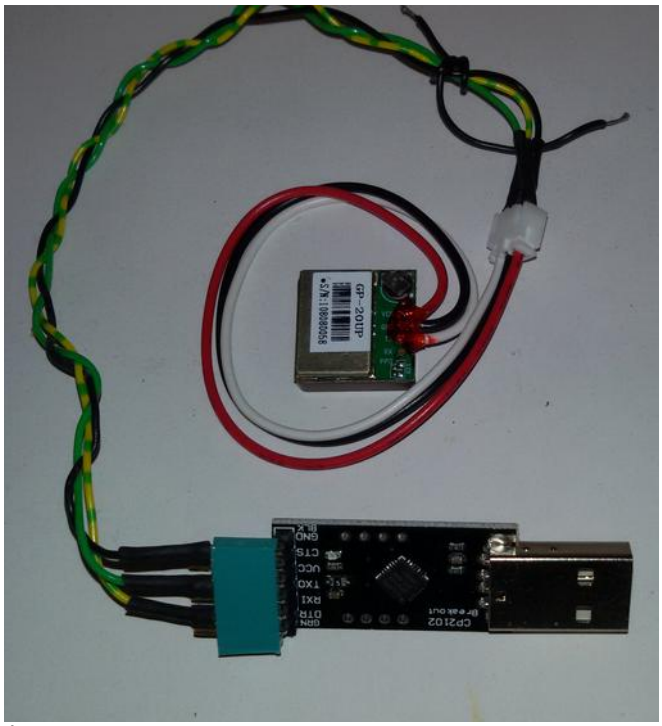


Figure 13: v1 GPS sensor tester

using CP2102 USB-to-serial and matching connector.
Note: On the v2 boards, the GPS sensor is attached to the board

Figure 14: Home-made SPS30 PM(fijnstof)-sensor tester

using Arduino Uno (not shown) with shield

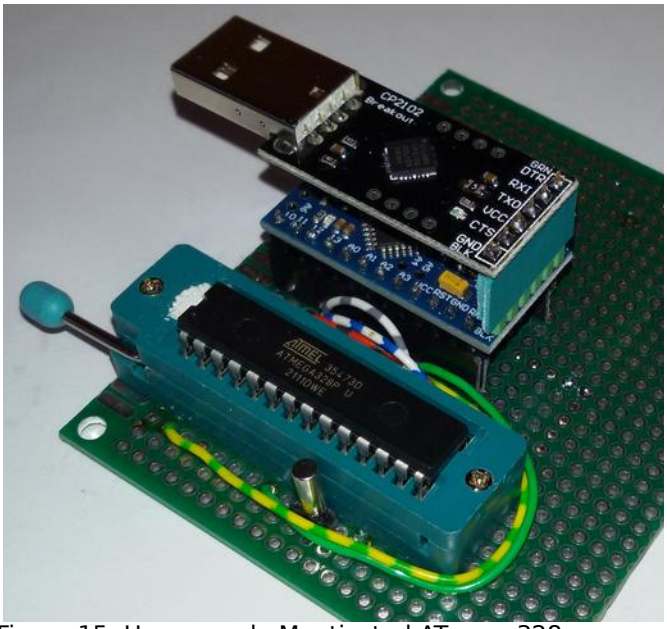


Figure 15: Home-made Meetjestad ATmega328p programmer

using CP2102 on 3.3V and Arduino Mini Pro
Ref: https://github.com/meetjestad/mjs_programmer
(optional)

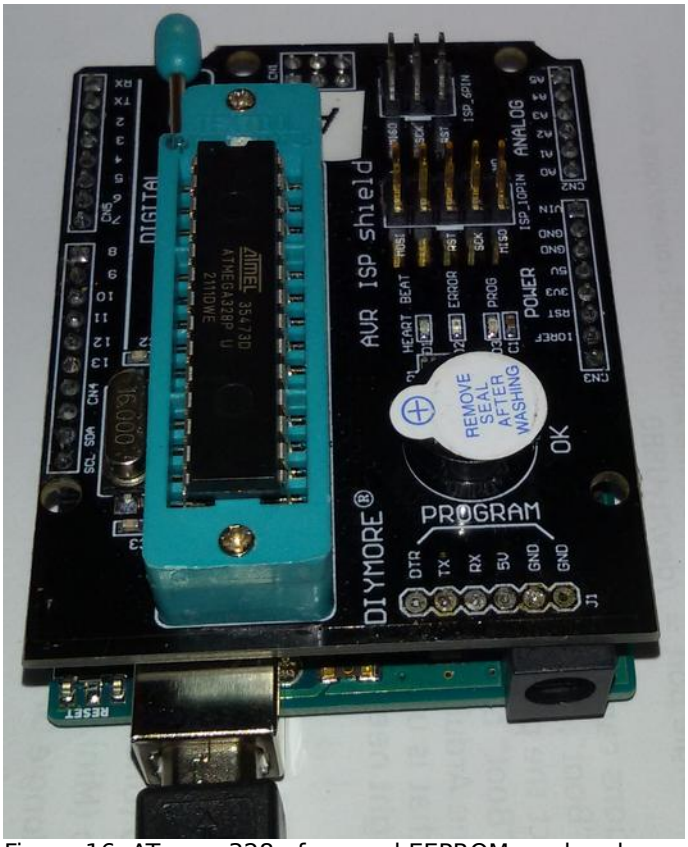


Figure 16: ATmega328p fuse and EEPROM read and write

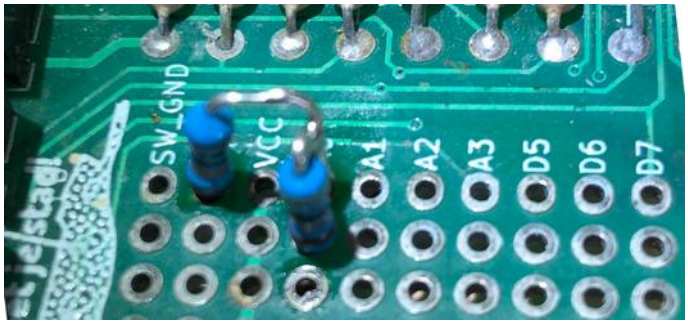
using Arduino Uno and DIYMORE AVR ISP shield
(optional)

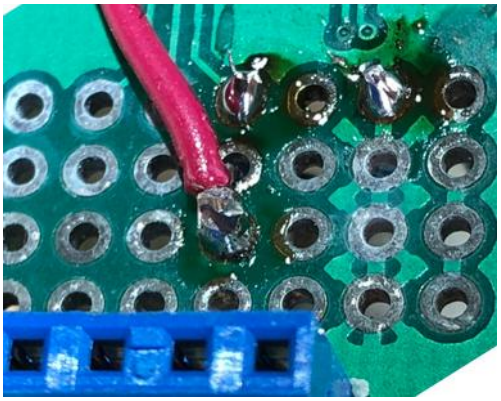
Figures 17: Battery voltage measurement

Right: Connection to the mid of the PROG/BATT selector, rear view

Bottom left: the 100 kOhm/470 kOhm voltage divider, front view

Below right: connection to the voltage divider, rear view


SW
GND
VCC
A1
A2
A3
D5
D6
D7



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