THE CANSAT TECHNICAL GUIDE

CanSat Competition 2020-2021

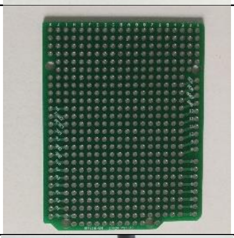
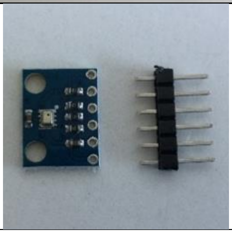
Introduction

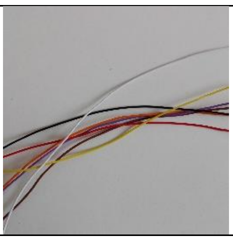
This guide shows how to build a basic CanSat from scratch, using the ESERO Lux CanSat-kit.
First we describe how to get the Arduino board up and running.
Then we discuss the primary mission and how to make sure that you extract the necessary data.

Electronics components

A typical primary mission CanSat kit consists of an Arduino Uno R3 board and a universal prototyping shield.

Here is the list of components used in this guide

Arduino Uno R3 (2x) The core of the Arduino system, which contains the microcontroller, I/O ports, etc.	
Universal prototyping shield The prototyping shield serves as the backbone of the system. It connects and holds all parts together.	
APC220 Radio transmitter/receiver (transceiver) The transceiver is used to transmit/receive radiosignals between between the ground station and the CanSat.	
BMP 280 Module Barometric pressure and temperature sensor module.	
Male header	
Female header	

Battery connector	
Several different colour wires	

The full list of components included in the Luxembourg CanSat kit can be found here:
https://www.esero.lu/wp-content/uploads/2021/02/Cansat_kit_2020-2021-v2.pdf

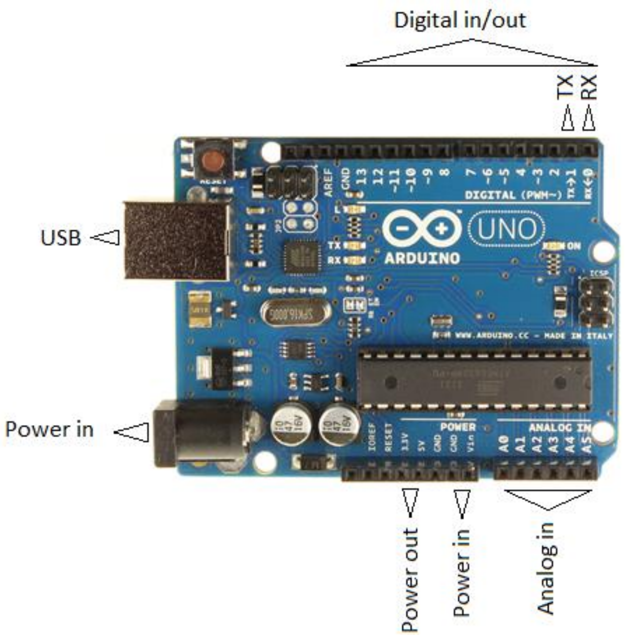
Arduino

To carry out the primary mission during descent, the CanSat has to measure barometric air pressure and temperature. The relevant sensors must be connected to an Arduino board. The Arduino board processes the sensor signals. The data Arduino produces is sent by radio signals to a ground station .

The core of the CanSat is the Arduino Uno R3.

Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards are able to read inputs from a sensor and turn them into an output. You can instruct your board on what to do by sending a set of instructions to the microcontroller on the board.

To get started with Arduino, follow the next steps.



First take a close look to the Arduino R3:

USB: The USB connection can do two things. Firstly, it can provide power to the Arduino from the computer. Secondly, it can communicate with the computer.

TX/RX: If uploading and communicating are not effected through USB, pins D0 and D1 can be used.

Power in: If the USB is not used as a power supply, the power jack (5.5mm-2.1mm) or the power pins Vin and GND can be used. Arduino can manage power with a range of 5-20V.

Power out: Powering the external components can be effected with the power pins 5V and 3.3V. The maximum current is 1A.

Analog in: Arduino can read analog voltage from 0V to 5V.

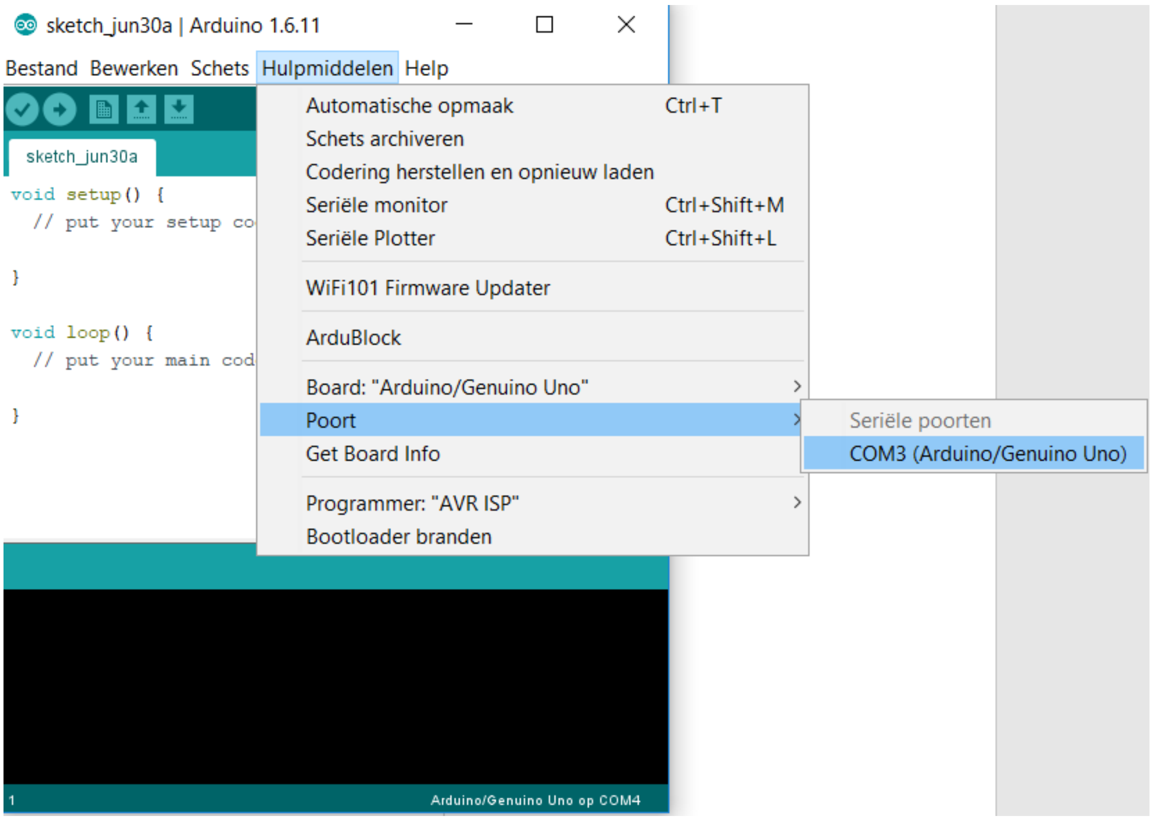
Digital in/out: These pins can be declared as input pins or output pins. As input pin, it can read input voltage: <2.5V is LOW, >2.5V is HIGH. As output pin, LOW is 0V, HIGH is 5V. Pin 3, 5, 6, 9, 10 and 11 can provide a PWM signal.

You can program the Arduino with Arduino IDE. You can download Arduino IDE at www.arduino.cc/en/Main/Software

Connecting the Arduino

Make sure you installed Arduino IDE properly. Open Arduino IDE and connect the Arduino UNO by USB. If drivers are properly installed, the computer recognises the Arduino board.

Go to ‘Tools’ and connect the COM-port of the Arduino board by clicking.



sketch_jun30a | Arduino 1.6.11

Bestand Bewerken Schets Hulpmiddelen Help

sketch_jun30a

```
void setup() {
  // put your setup co

}

void loop() {
  // put your main cod

}
```

Automatische opmaak	Ctrl+T
Schets archiveren	
Codering herstellen en opnieuw laden	
Seriële monitor	Ctrl+Shift+M
Seriële Plotter	Ctrl+Shift+L
WiFi101 Firmware Updater	
ArduBlock	
Board: "Arduino/Genuino Uno"	›
Poort	›
Get Board Info	
Programmer: "AVR ISP"	›
Bootloader branden	

Seriële poorten

COM3 (Arduino/Genuino Uno)

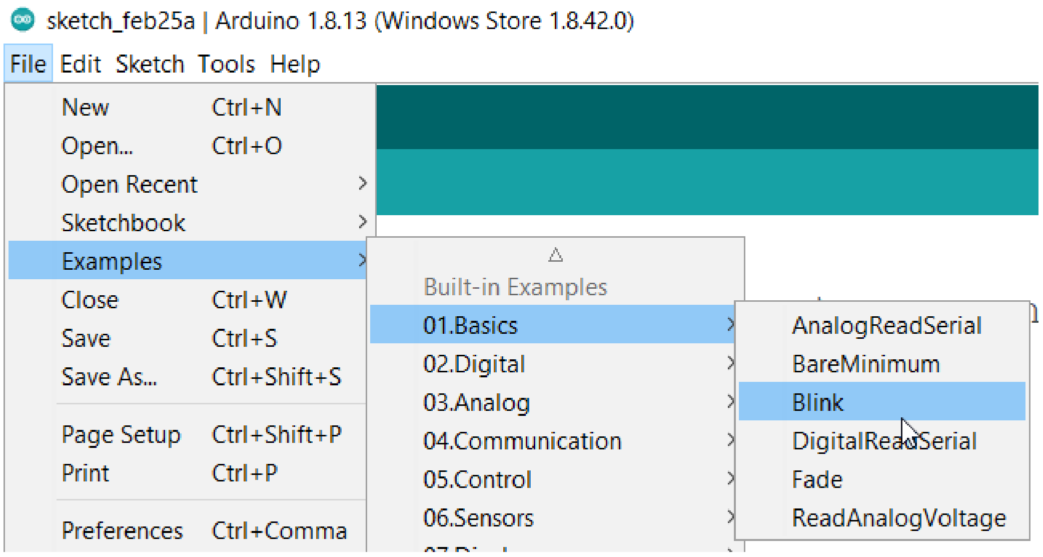
1 Arduino/Genuino Uno op COM4

In this example, it is COM3.

Programming the Arduino

The first sketch in Arduino is ‘Blink’.

You can find ‘Blink’ on ‘Bestand > Voorbeelden > Basic > Blink’.



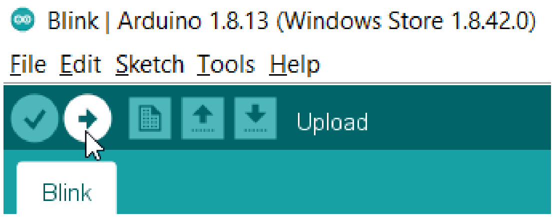
Read the text from this sketch.

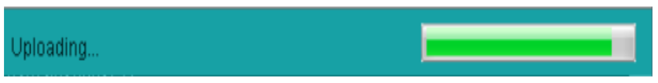
1. Blink

Turns on an LED for one second, then off for one second, repeatedly. Most Arduinos have an on-board LED you can control. On the Uno, it is attached to digital pin 13.

```
// the setup function runs once when you press reset or power the board
void setup() {
  // initialize digital pin 13 as an output.
  pinMode(13, OUTPUT);
}
// the loop function runs over and over again forever
void loop() {
  digitalWrite(13, HIGH);   // turn the LED on (HIGH is the voltage level)
  delay(1000);              // wait for a second
  digitalWrite(13, LOW);    // turn the LED off by making the voltage LOW
  delay(1000);              // wait for a second
}
```

When pressing Upload, you can see the upload progress at the bottom.

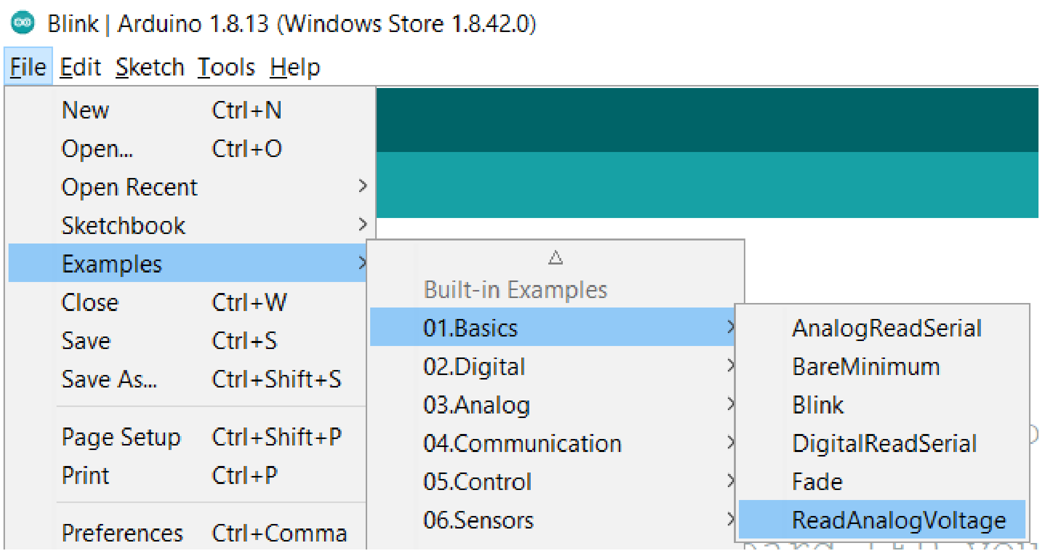

Blink | Arduino 1.8.13 (Windows Store 1.8.42.0)
File Edit Sketch Tools Help
Upload
Blink



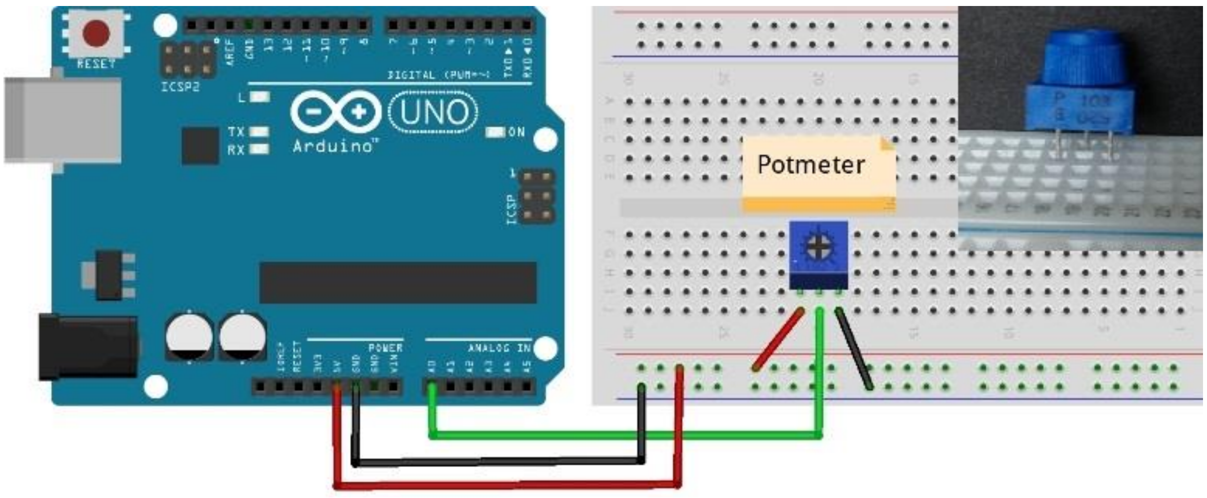
Try to speed up the blinking LED. Each time you make a change to the code, do not forget to upload the new code. The new code overwrites the old code in the Arduino.

2. measuring analog voltage with Arduino

The second sketch is ‘ReadAnalogVoltage’. The illustration shows you how to find this sketch:



For this sketch, you need to apply external components. In an experimental setting, you can use a breadboard and jumper wires. Most components can be placed directly on the breadboard. To generate a variable voltage, you have to use a 10KΩ potentiometer. See picture below.



Let’s take a look at this sketch:

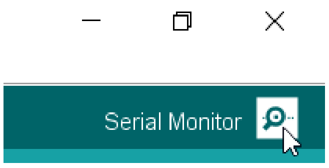
ReadAnalogVoltage

Reads an analog input on pin 0, converts it into voltage and prints the result to the serial monitor. Graphical representation is available using serial plotter (Tools > Serial Plotter menu).

Attach the centre pin of a potentiometer to pin A0 and the outside pins to +5V and ground.

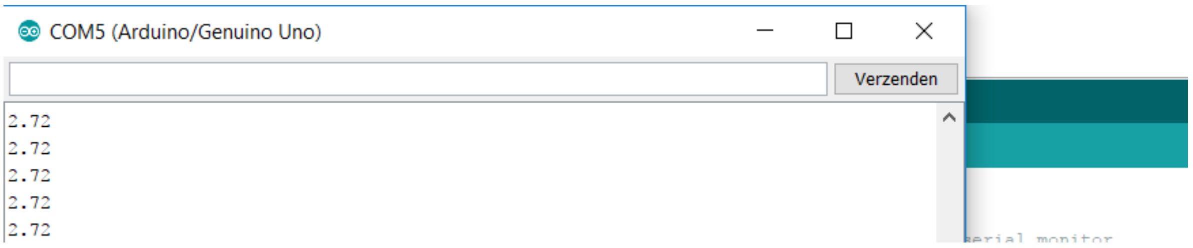
```
// the setup routine runs once when you press reset:
void setup() {
  // initialize serial communication at 9600 bits per second:
  Serial.begin(9600);
}

// the loop routine runs over and over again forever:
void loop() {
  // read the input on analog pin 0:
  int sensorValue = analogRead(A0);
  // Convert the analog reading (which goes from 0 - 1023) to a voltage (0 - 5V):
  float voltage = sensorValue * (5.0 / 1023.0);
  // print out the value you read:
  Serial.println(voltage);
}
```

Do not forget to turn on the serial monitor (button on the top-right).



When you are running this sketch on the Arduino, you can read the voltage on the serial monitor. Try to change the speed of measuring the values on A0. Create a delay of 1000 milliseconds.

You can see the values in the serial monitor.



```
2.72
2.72
2.72
2.72
2.72
```

Using the potentiometer, you can make any voltage on the centre pin between 0 – 5V. The main resistor of 10KΩ is cut into two pieces, the ratio of these two pieces can be adjusted by turning the potentiometer. In this way, you can provide a voltage between 0 – 5 V on the centre pin.

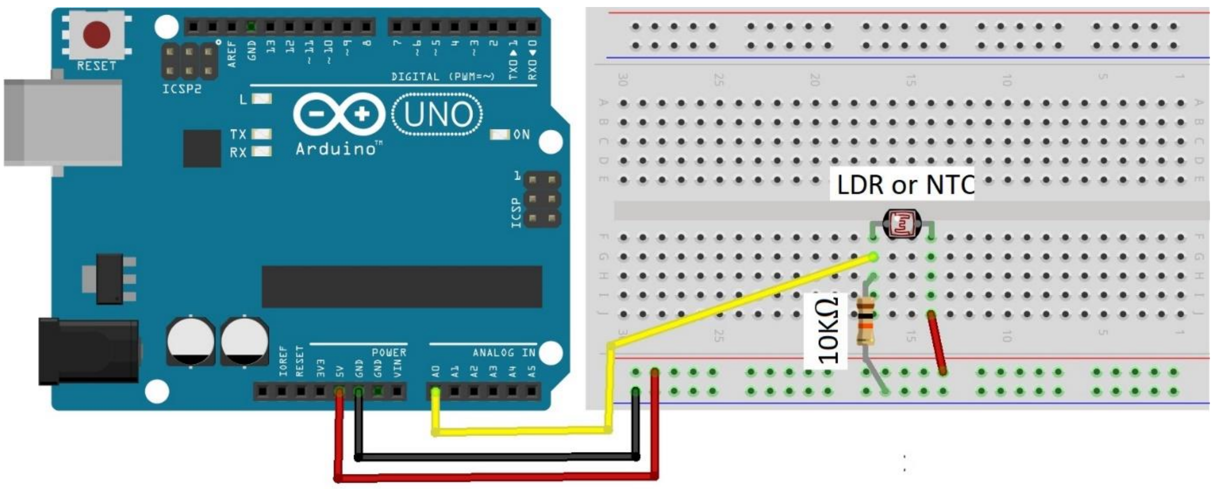
Learn more about a voltage divider at: https://en.wikipedia.org/wiki/Voltage_divider

We can do more with this knowledge.

3. *Measuring light intensity and temperature*

If we use one fixed resistor and one variable resistor, we can make a variable voltage. With a LDR (light depending resistor), we can measure light intensity and with a NTC or PTC, we can measure temperature.

Keep the same code (ReadAnalogVoltage) and make a new circuit with the LDR and NTC.

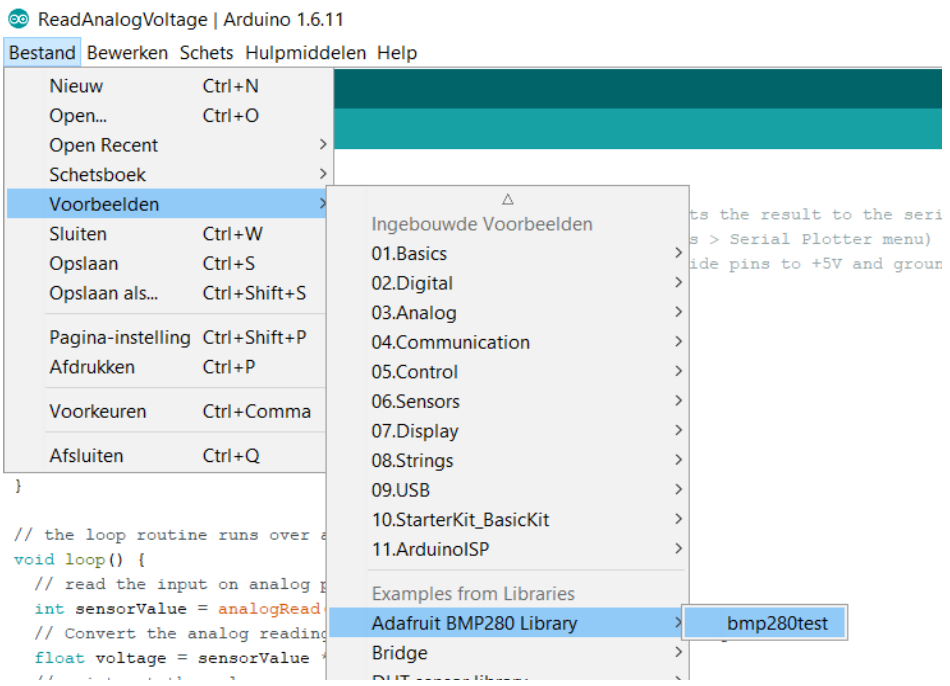


Measure light intensity and temperature. Try to change the code to adapt the values in the serial monitor.

4. Measuring barometric air pressure and temperature with BMP280 module

(in case you add a SD card to the CanSat, please refer to page 48)

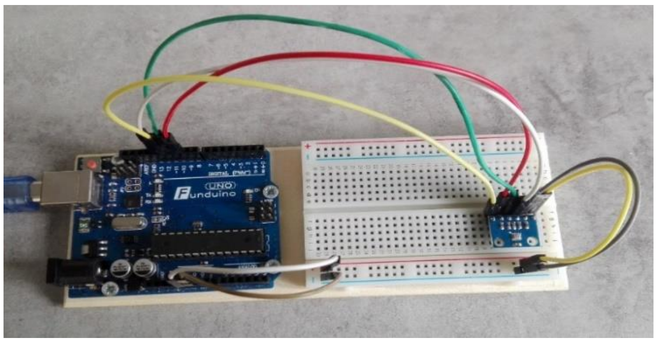
In the primary mission, you have to measure barometric air pressure and temperature. The CanSat kit contains a module, the BMP280. This module can measure pressure and temperature. The working voltage of this module is 3.3 V. Check this in the wiring diagram. If you want to use it with the Arduino IDE, you will need a library. The Arduino IDE can be extended through the use of libraries to provide extra functionality to your sketches. Most libraries come with example sketches. You can find the libraries in the CanSat download files. Copy the folder “Adafruit_BMP280” and “Adafruit_Sensor-master” into the “libraries” folder in “Arduino” – “My Documents”, Exit and restart Arduino IDE.
You can now find the example sketch *bmp280test*:

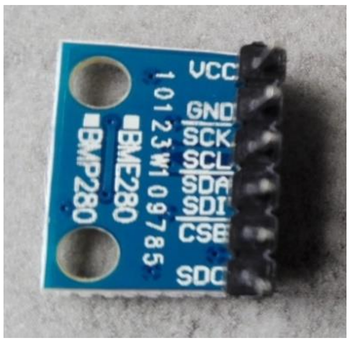


```
ts the result to the seri
s > Serial Plotter menu)
ide pins to +5V and groun
}

// the loop routine runs over a
void loop() {
  // read the input on analog p
  int sensorValue = analogRead(
  // Convert the analog reading
  float voltage = sensorValue *
```

Wire the BMP280 module:

1.	VCC	3.3V
2.	GND	GND
3.	SCK/SCL	D13
4.	SDA/SDI	D11
5.	CSB	D10
6.	SDO	D12





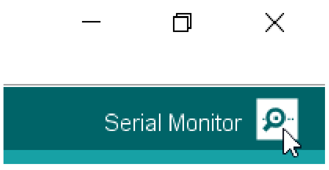
In the sketch, you have to 'double forward slash' and 'unslash' some lines.

```
#define BMP_CS 10

Adafruit_BMP280 bmp; // I2C
//Adafruit_BMP280 bmp(BMP_CS); // hardware SPI
//Adafruit_BMP280 bmp(BMP_CS, BMP_MOSI, BMP_MISO,  BMP_SCK);

void setup() {
```

To:

```
#define BMP_CS 10

//Adafruit_BMP280 bmp; // I2C
//Adafruit_BMP280 bmp(BMP_CS); // hardware SPI
Adafruit_BMP280 bmp(BMP_CS, BMP_MOSI, BMP_MISO,  BMP_SCK);

void setup() {
```

Now you can upload the sketch and open the serial port.



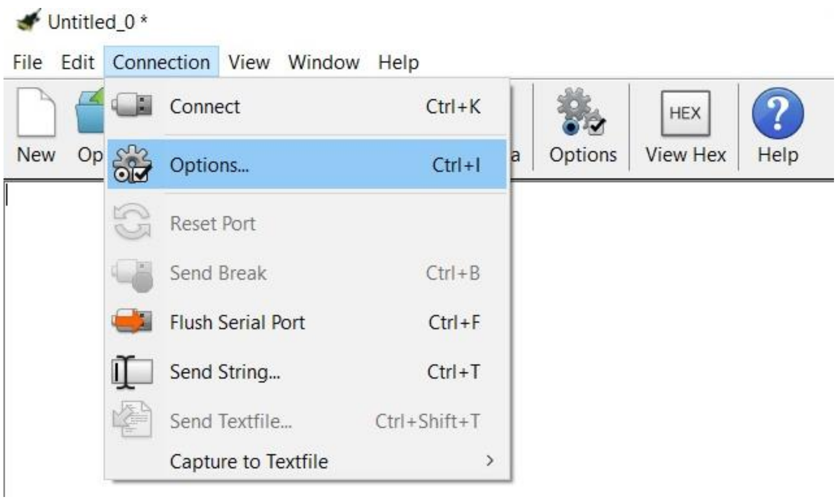
5. Gathering data from the serial port

If you want to use the data from the serial port, you can gather the data by using "CoolTerm". CoolTerm is a simple serial port terminal application that is able to exchange data with hardware connected to serial ports such as microcontrollers (Arduino Uno).

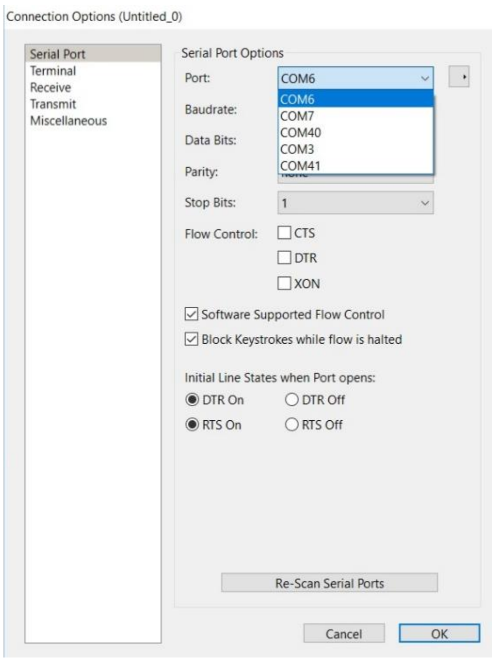
You can download it at freeware.the-meiers.org/. You can choose the download file for your operating system.

If you connect the Arduino Uno with the BMP280 sensor and example sketch, you can get the data via CoolTerm. First you must set the properties for the connection.

Go to: Connection > Options.



Press the button "Re-Scan Serial Ports". In the dropdown menu "Port", choose the com-port of your Arduino Uno and click OK. You can now hit the button "Connect" in the main dashboard.



Port: COM6

COM6
COM7
COM40
COM3
COM41

Baudrate:

Data Bits:

Parity:

Stop Bits: 1

Flow Control: ☐ CTS ☐ DTR ☐ XON

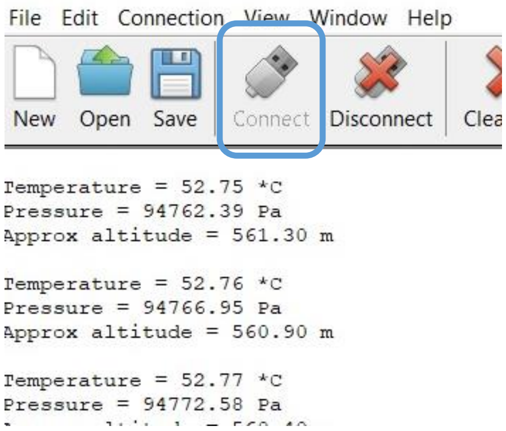
☑ Software Supported Flow Control

☑ Block Keystrokes while flow is halted

Initial Line States when Port opens:

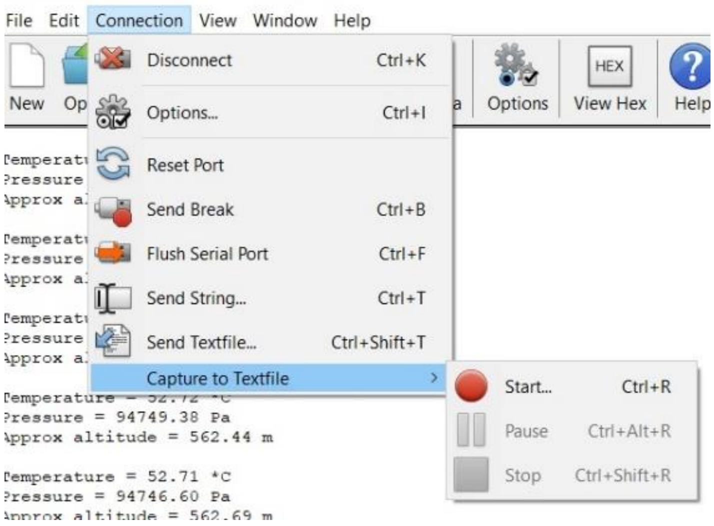
◉ DTR On ○ DTR Off

◉ RTS On ○ RTS Off



```
Temperature = 52.75 *C
Pressure = 94762.39 Pa
Approx altitude = 561.30 m

Temperature = 52.76 *C
Pressure = 94766.95 Pa
Approx altitude = 560.90 m

Temperature = 52.77 *C
Pressure = 94772.58 Pa
```

You can save the data received to a text file. Go to: Connection > Capture to Textfile > Start. The text file can be imported in Excel or other spreadsheet software. If you want to use the data in an easy way, you can change the code in the sketch first.



```
Pressure = 94749.38 Pa
Approx altitude = 562.44 m

Temperature = 52.71 *C
Pressure = 94746.60 Pa
Approx altitude = 562.69 m
```

Note: If you want to use “CoolTerm”, you have to close the serial monitor on the Arduino IDE, because only one program can listen to a serial port at one time.

Assembly

By following these guidelines, you can assemble the prototyping shield. This shield keeps the main components together. For the primary mission you will need:

1. External power
2. Power switch
3. Radio transmitter
4. Temperature sensor
5. Pressure sensor

Tools and requirements

The tools required to assemble are those required for soldering hobby electronics. We recommend that you have the following equipment with you during the assembly process:

- Pliers
- Soldering iron and solder. It is important that the solder contains a flux core (this will facilitate the soldering).
- Optional but recommended: flux remover (to clean flux residue).
- Optional: a third hand, which is very convenient if you are alone while doing the assembly.
- Optional: a solder wick remover in case you make a mistake and want to unsolder the components.
- Optional: extra flux (e.g. in a pen dispenser). This element is optional but can help soldering the voltage regulator, which is surface mounted.

Third hand

Note: The assembly requires basic soldering skills. However, you are working with quite delicate electronics. If you do not have much experience with soldering microelectronics, you should practice first before you start soldering the CanSat components to the prototyping shield. Consult these suggested tutorials to familiarise yourself with soldering if needed:

Short but very informative soldering tutorial: www.youtube.com/watch?v=f95i88OSWB4

Extended soldering tutorial:

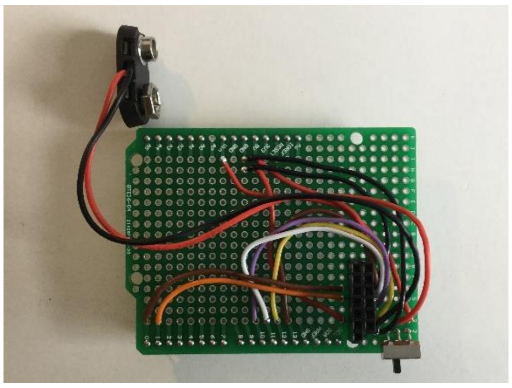
Part 1 - Tools: www.youtube.com/watch?v=J5Sb21qbpEQ&feature=youtu.be

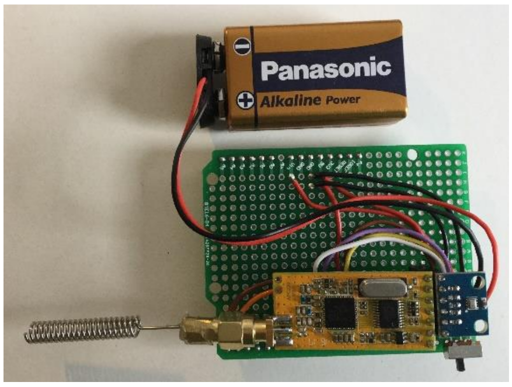
Part 2 - Basic techniques: www.youtube.com/watch?v=fYz5nIHH0iY&feature=youtu.be

Part 3 - Surface Mount: www.youtube.com/watch?v=b9FC9fAlfQE&feature=youtu.be

The shield

The final product we will be working towards will look like this:

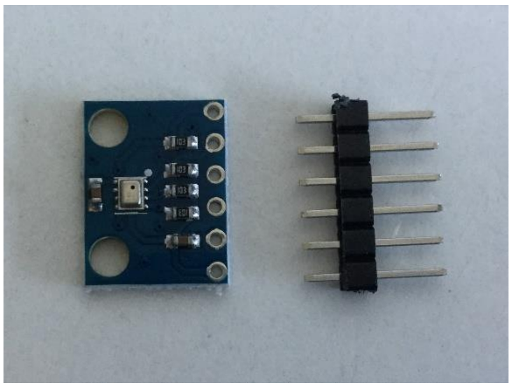


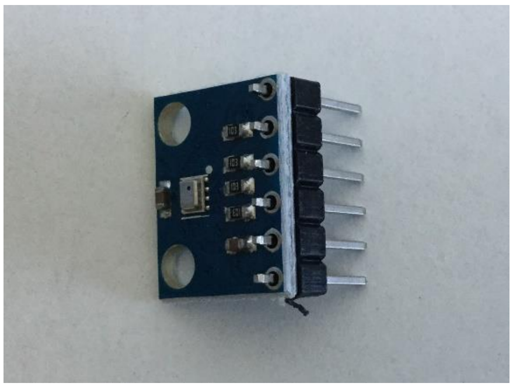


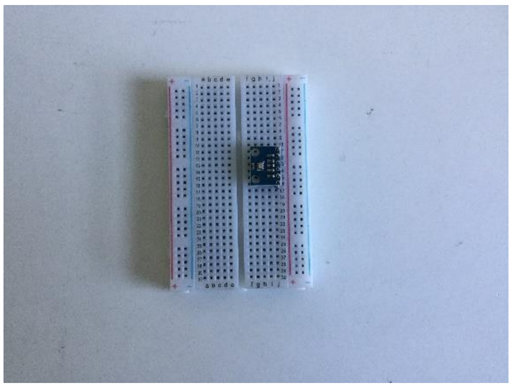
The shield is mounted on top of the Arduino UNO board. The battery holder, power switch, the transceiver (APC220) and the pressure/temperature sensor (BMP280) are mounted on top of the shield.

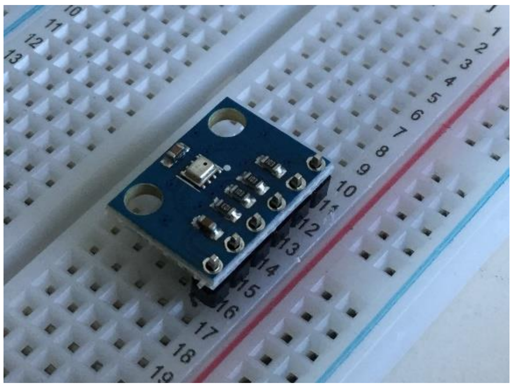
1. Solder the pin headers onto the BMP280 sensor

We will be soldering the headers to the BMP280 sensor. Use the male pin headers included in the plastic bag. Place the shorter ends of the headers through the holes.

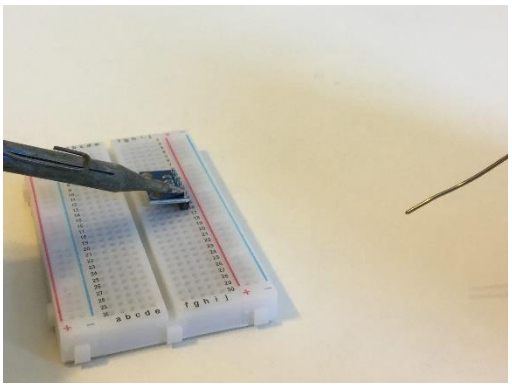


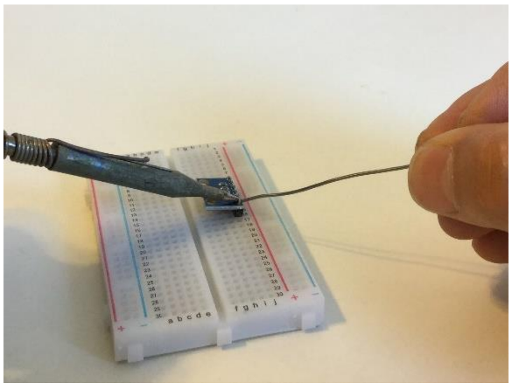


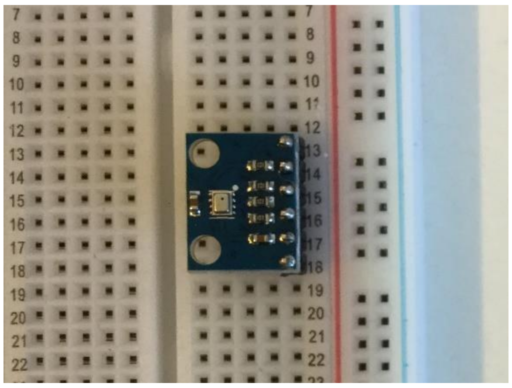




Place the pinheaders and the BMP280 on a breadboard.

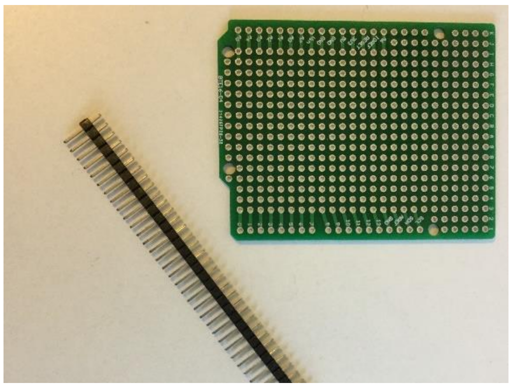
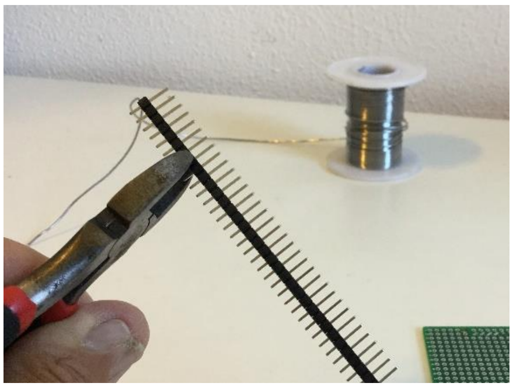
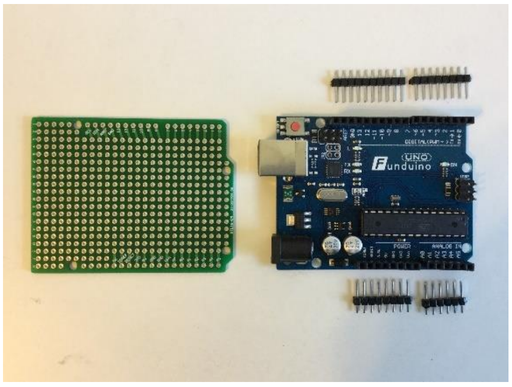
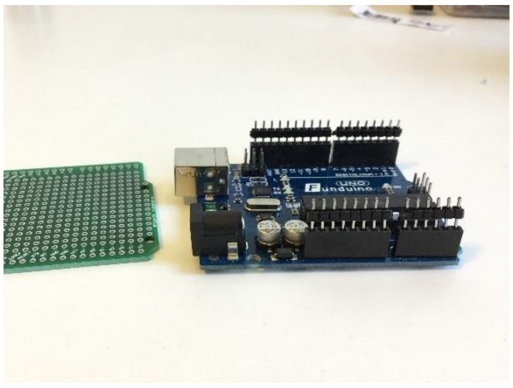

Preheat the two components briefly


Add a small amount of solder

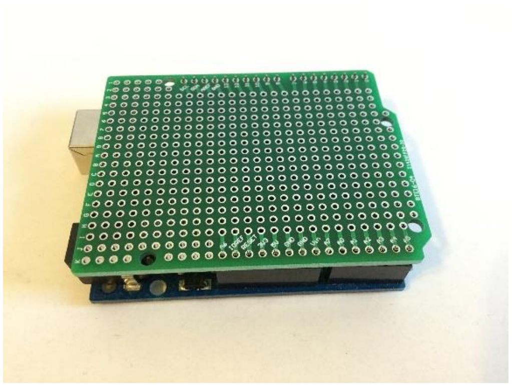
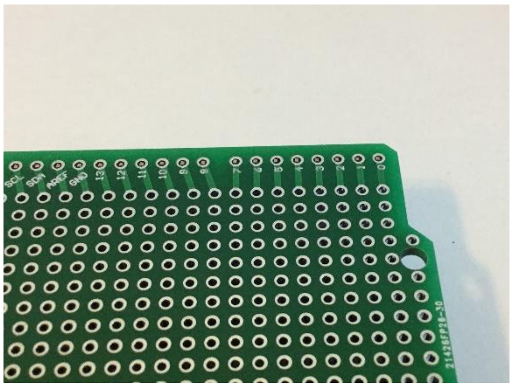

Done!

2. *Solder pin headers to the prototyping shield*

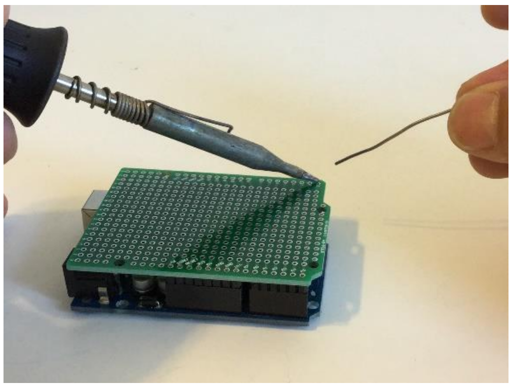
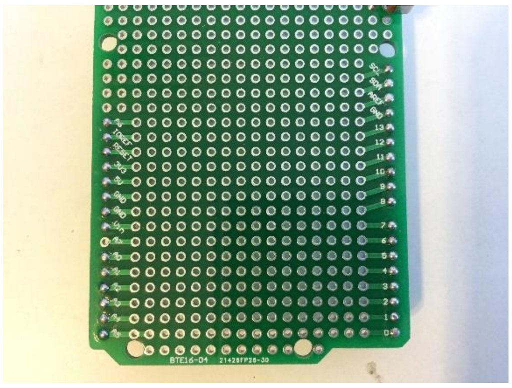
Now that you have had some practice in soldering headers, solder the headers of the prototyping shield. Use the male headers. These have to be cut apart in 4 blocks; 1 x 6 pins, 2 x 8 pins and 1 x 10 pins.

The long part of the pins needs to be placed through the Arduino UNO board.

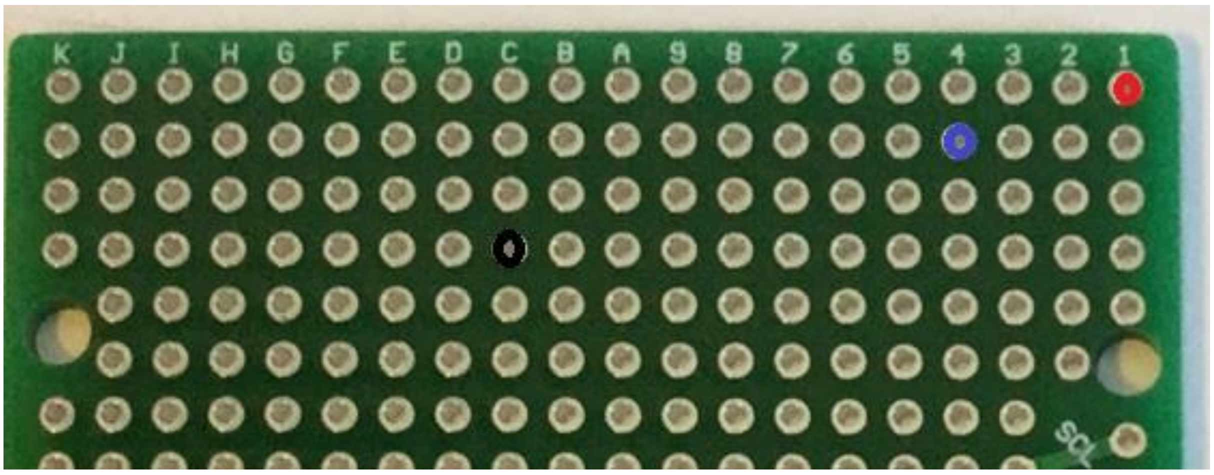
Place the shield on top of it. Note that the text printed on the shield is on top. Adjust the top of the pins so that they are aligned with the top of the shield.

Solder the pins and the final results should look like this.

The pins on the Arduino are now attached to the shield. You can see through the shield which pins are connected to which holes. The rest of the holes are not connected to other holes. If you want, you have to wire it yourself.

Take a look at the shield. The holes are placed in a grid of 0.1” (2.45mm).

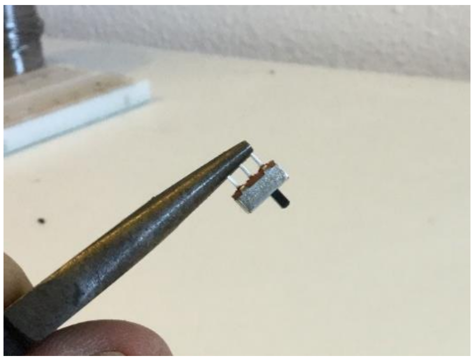


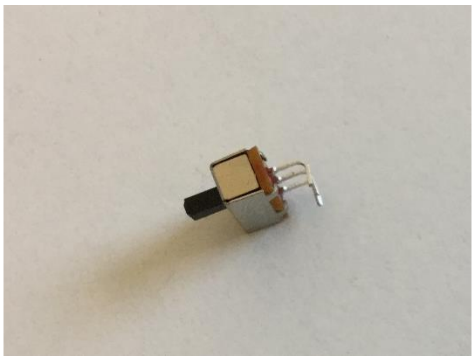
The red hole is on position (1,1), blue (4,2) and black (C,4).

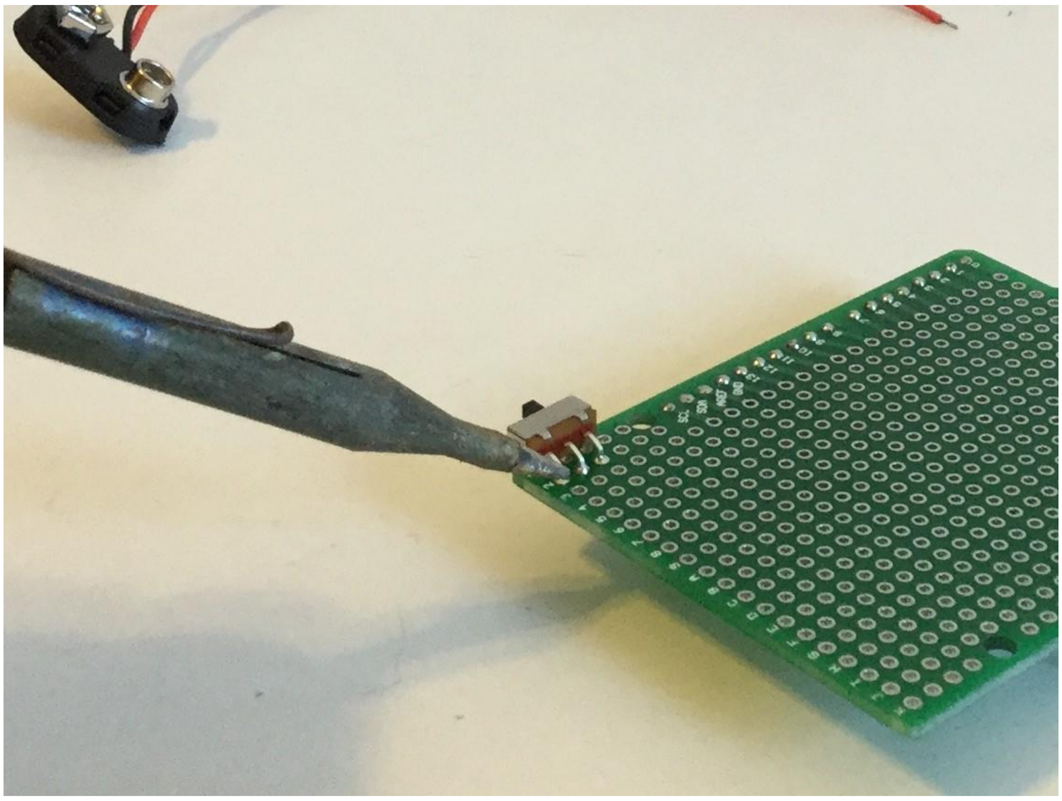
3. Solder the power switch to the shield

The next step is the power switch.

You have to solder the power switch on holes (2,1), (2,2) and (2,3). First, you must bend the pins of the switch. Then you can solder the switch on top of the shield.

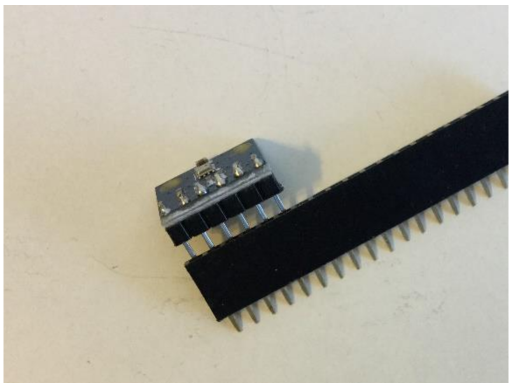
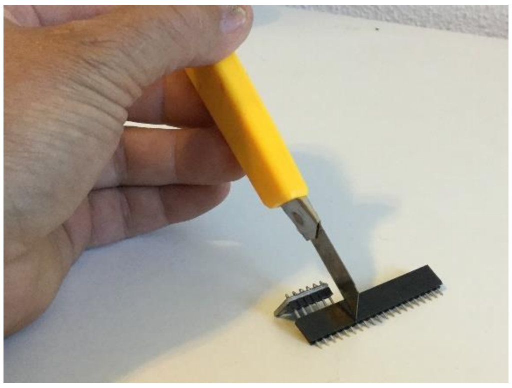
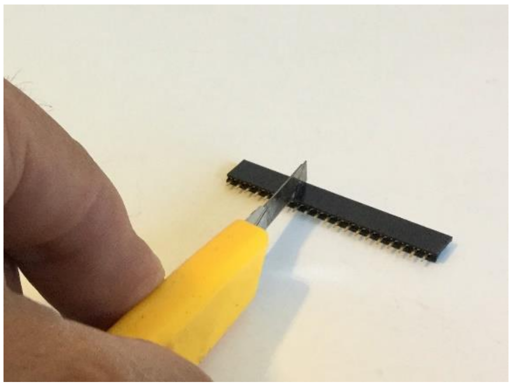
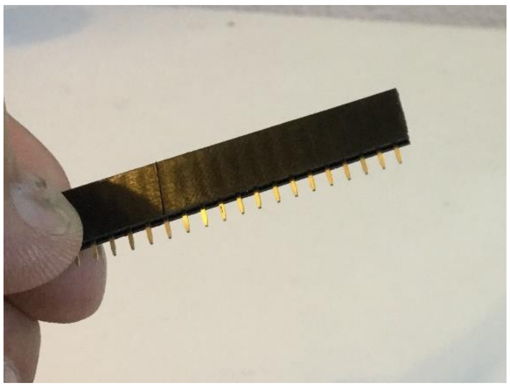
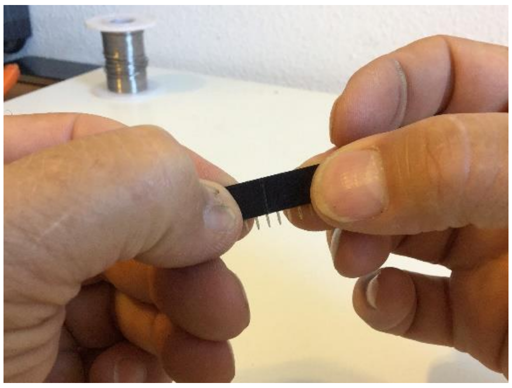
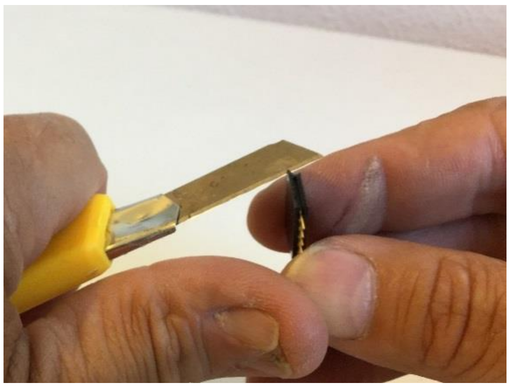






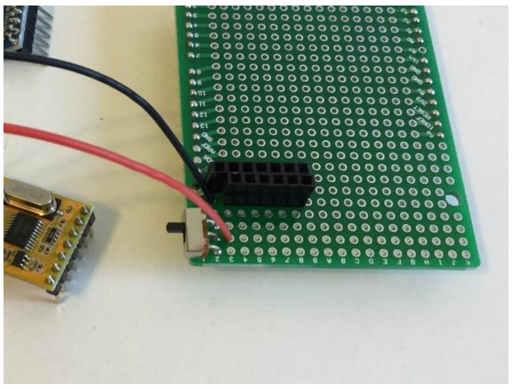
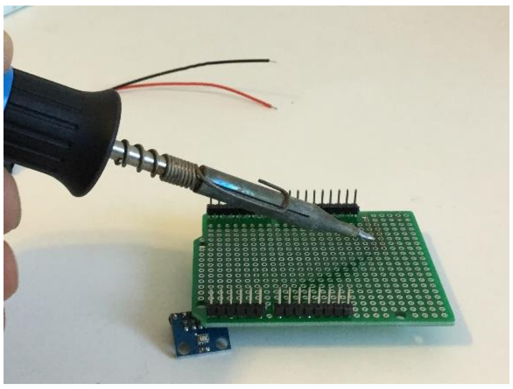
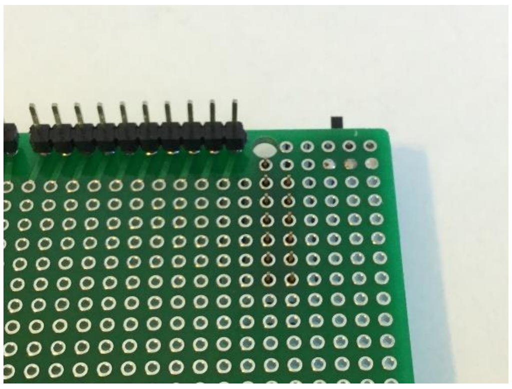
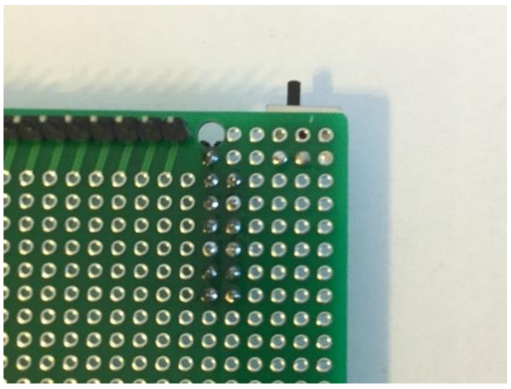
4. Make the female headers to attach APC220 and BMP280 to the shield

To attach the transceiver APC 220 and the BMP280, you need to solder two female pinheaders: 1 x 6 pins and 1 x 7 pins. First you have to cut/break the pinheaders. Before you can break the pinheaders, you have to make a cut, so it breaks at the right place. Note that you lose one pin by breaking the header. You can make the cut with a sharp knife. Cut the header on both sides before breaking. Clean the edge with the same knife.

5. Solder the female pinheader to the shield

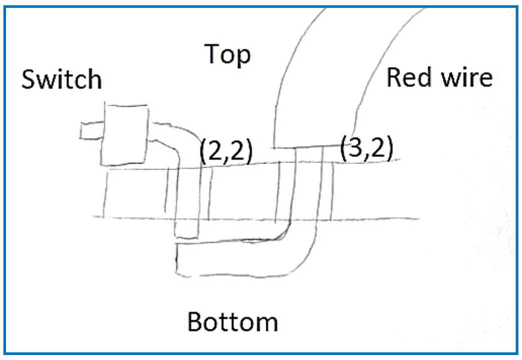
The positioning of the headers is very important and the layout of the shield is tight. The 7 pinheader is for the APC220. Its position is from (2,6) to (8,6). The 6 pinheader is for the BMP280. Its position is from (3,5) to (8,5). You can place the headers on top of the shield and solder it on the bottom side.

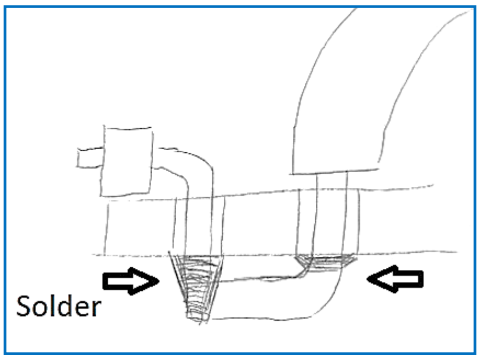





6. Solder the battery connector to the shield

The next component to be soldered to the board is the battery connector. This is also a tricky step since the board hole is bigger than the battery connector metal conductor. Use a third hand (or ask somebody to help you) so that you are able to place everything in the right position and solder. Be careful not to burn your assistant with the soldering iron!

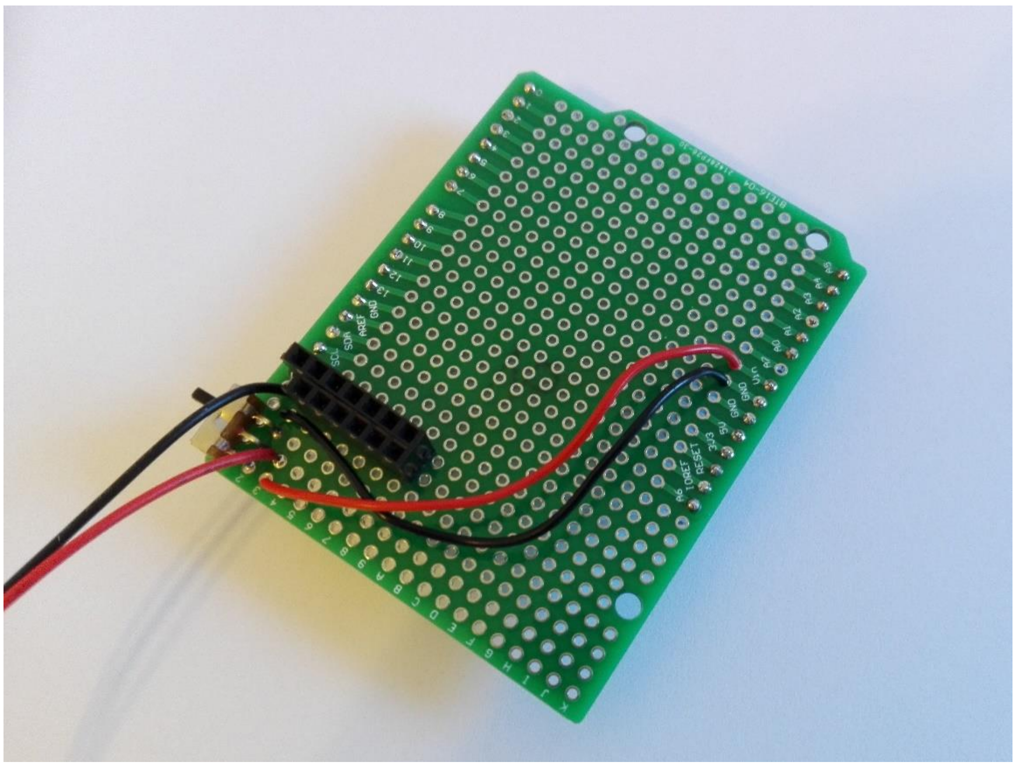
The red wire has to be positioned in (3,2). At the bottom side you have to connect the same wire with (2,2)! The black wire is positioned in (2,5). At the bottom side you have to connect the same wire with (2,6)!





7. *Powering Arduino*

The power switch on the shield can turn on and off the power from the battery to Arduino. Arduino is powered by two pins. Vin and GND. You have to solder two wires. One red wire from the power switch ((3,1) top, (2,1) bottom) to Vin ((I,18) top). One black wire from ((2,4) top, (2,5) bottom) to GND ((I,17) top).

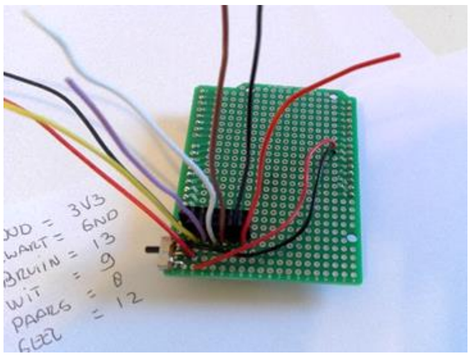
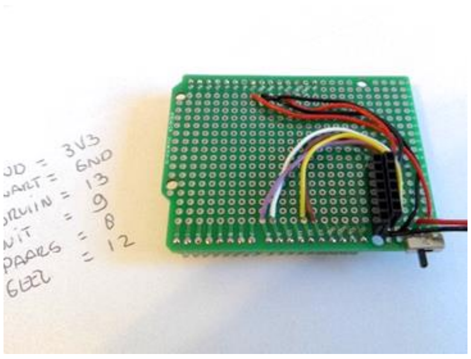


8. *Connect the BMP280 to the shield*

(in case you add a SD card to the CanSat, please refer to page 43)

You already used the sample code for BMP280. You can wire the BMP280 at the same pins. You can use 6 different colour wires.

BMP280	wire colour	top	down	Arduino	top	down
VCC	red	(8,4)	(8,5)	3.3V	(I,14)	N/A
GND	black	(7,4)	(7,5)	GND	(H,17)	(I,17)
SCK/SCL	brown	(6,4)	(6,5)	D13	(3,12)	N/A
SDA/SDI	white	(5,4)	(5,5)	D9	(3,16)	N/A
CSB	purple	(4,4)	(4,5)	D8	(3,17)	N/A
SDO	yellow	(3,4)	(3,5)	D12	(3,13)	N/A

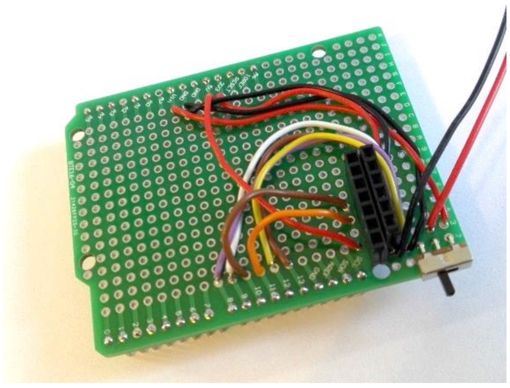
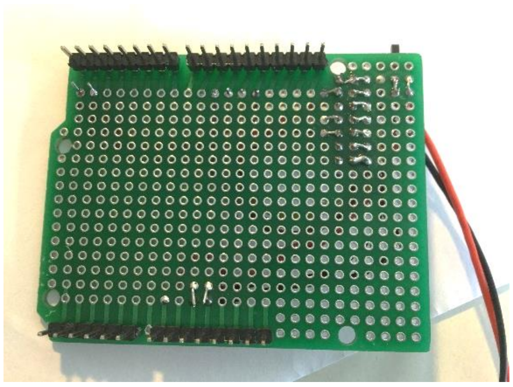



9. *Connect the APC220 to the shield*

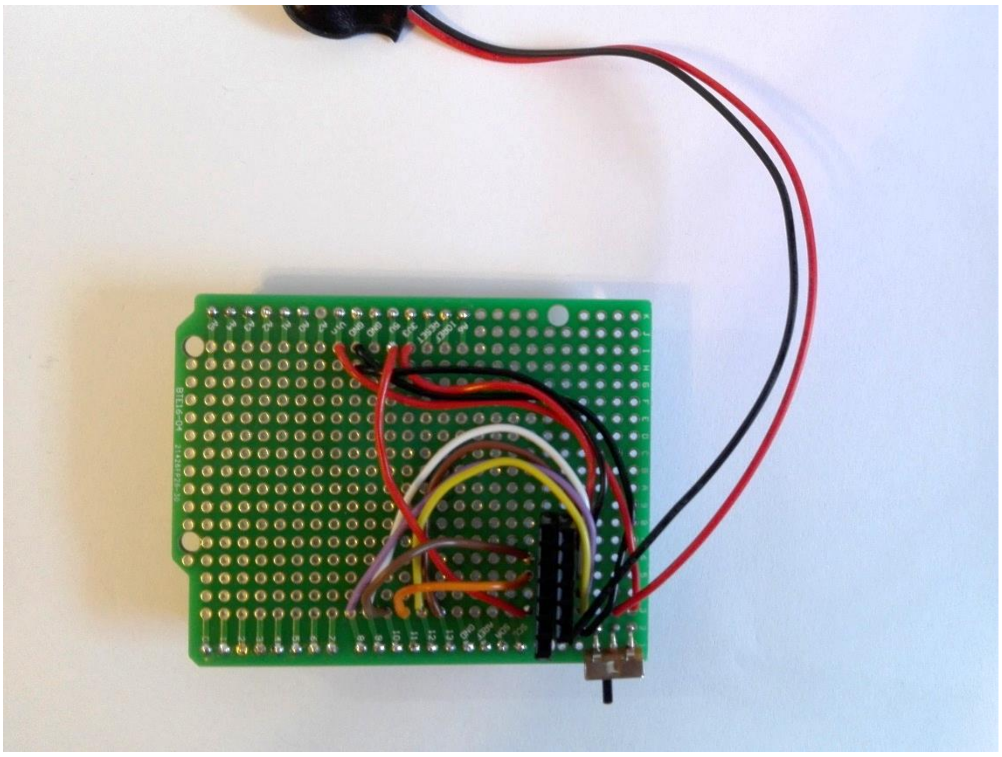
(in case you add a SD card to the CanSat, please refer to page 43)

The 7 pin female header is only to be wired with 4 wires, 3 pins are not wired. You can use 4 different colour wires.

APC220	wire colour	top	down	Arduino	top	down
SET	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx
AUX	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx
TXD	brown	(6,7)	(6,6)	RX/D10	(3,15)	N/A
RXD	orange	(5,7)	(5,6)	TX/D11	(3,14)	N/A
EN	xxxxx	xxxxx	xxxxx	xxxxx	xxxx	xxxxx
VCC	red	(3,7)	(3,6)	5V	(I,15)	N/A
GND	black	This wiring is combined with black wire battery holder				

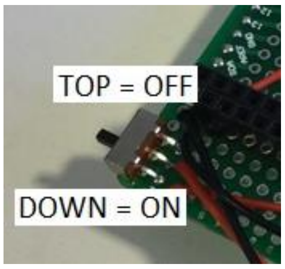



The shield is finished!



10. Connect the shield to the Arduino board
(in case you add a SD card to the CanSat, please refer to page 51)

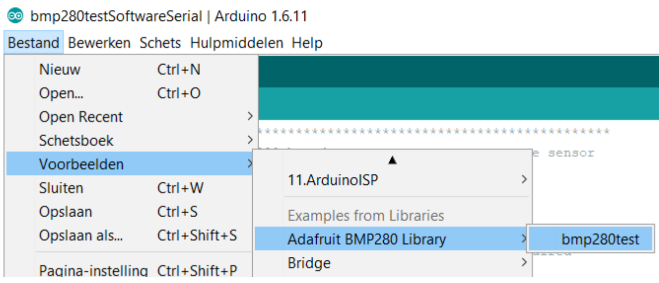
Before you can connect the shield to the top of the Arduino board, you have to check all connections. If you are sure everything is OK, you can place the shield on the Arduino. You can then place the BMP280 module on it. Do not place the APC220 and a battery on it! If you place a battery on it, make sure the power switch is in the top position.



Testing Arduino/BMP280

(in case you add a SD card to the CanSat, please refer to page 43)

Open in Arduino IDE bmp280test:



First we make some changes to this sample file. We change the pin connections of D10 to D8 and D11 to D9:

```
#include <Adafruit_Sensor.h>
#include <Adafruit_BMP280.h>

#define BMP_SCK 13
#define BMP_MISO 12
#define BMP_MOSI 11
#define BMP_CS 10

Adafruit_BMP280 bmp; // I2C
```

To:

```
#include <Adafruit_Sensor.h>
#include <Adafruit_BMP280.h>

#define BMP_SCK 13
#define BMP_MISO 12
#define BMP_MOSI 9
#define BMP_CS 8

Adafruit_BMP280 bmp; // I2C
```

In the sketch, you also have to 'double forward slash' and 'unslash' lines.

```
#define BMP_CS 10

Adafruit_BMP280 bmp; // I2C
//Adafruit_BMP280 bmp(BMP_CS); // hardware SPI
//Adafruit_BMP280 bmp(BMP_CS, BMP_MOSI, BMP_MISO,  BMP_SCK);

void setup() {
```

To:

```
#define BMP_CS 10

//Adafruit_BMP280 bmp; // I2C
//Adafruit_BMP280 bmp(BMP_CS); // hardware SPI
Adafruit_BMP280 bmp(BMP_CS, BMP_MOSI, BMP_MISO,  BMP_SCK);

void setup() {
```

With the APC220 disconnected and the power switch in the off position, you can upload the BMP280 sample file to test a measurement in the serial monitor. If you close the serial monitor, you can also test the data in 'CoolTerm'.

Set up the APC220

Telemetry is a technology that allows transmission of data from remote measurement devices. Telemetry is an essential part of satellite technology. Information is transmitted wirelessly using radio waves. On the ground, these signals are collected by radio receivers.

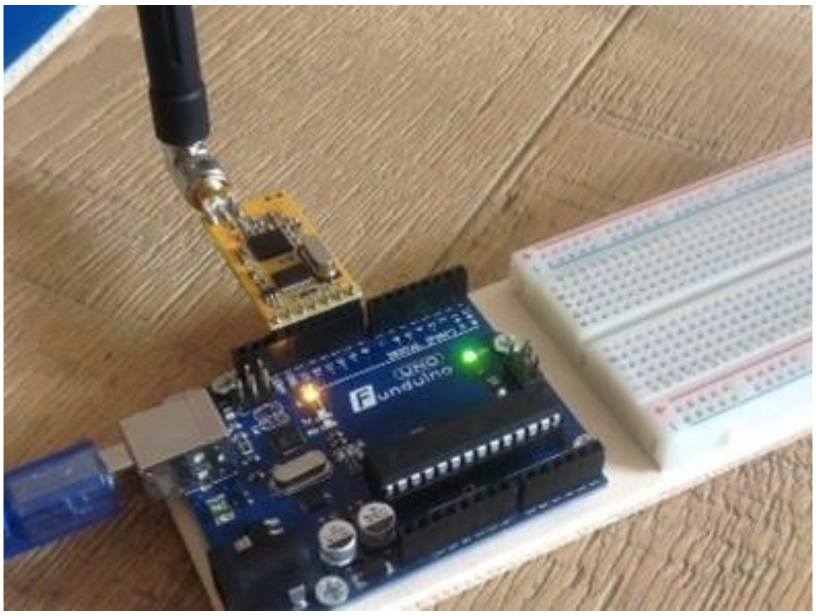
A transceiver is a device comprising both a transmitter and a receiver that are combined in a single housing.

In the CanSat kit, we are using APC220, which is a transceiver with a highly versatile low power radio solution that is easy to set up and integrate into any project requiring a wireless RF link.

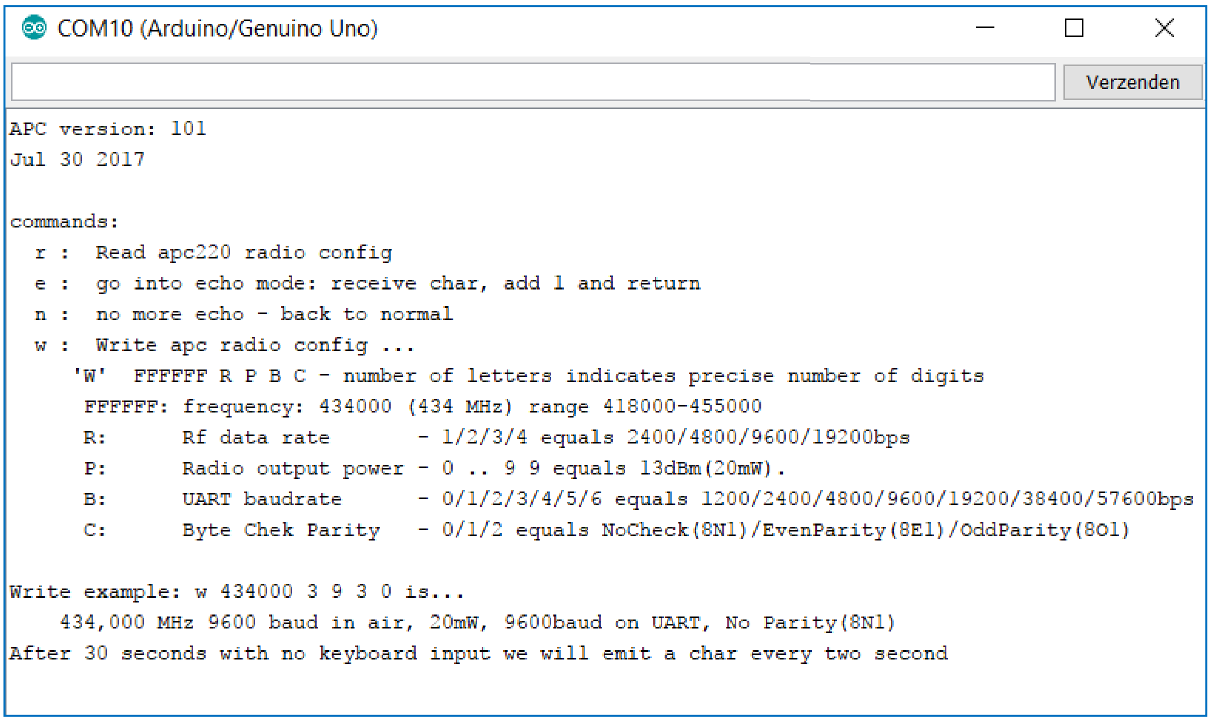
You can connect one of these modules with your microcontroller on the CanSat. And you can connect your “ground station” APC220 module with a second microcontroller. The second microcontroller is connected with your PC/Laptop.

Programming the transceivers with Arduino

Set up the APC220: Connect the Arduino board to the computer and upload the program “apc220cfg.ino”. Make sure you upload the program before you try to connect the transceiver to the Arduino board. Disconnect the USB cable from the Arduino board and connect the transceiver to the Arduino as shown in the figure.



The transceiver will be connected to the pins labelled GND, 8,9,10,11,12 and 13 on the Arduino. Reconnect the Arduino board through the USB cable and open the Serial Monitor. In the command line at the top, type in ‘m’ and hit enter. This will bring up the menu shown in the figure.



```
APC version: 101
Jul 30 2017

commands:
  r :  Read apc220 radio config
  e :  go into echo mode: receive char, add 1 and return
  n :  no more echo - back to normal
  w :  Write apc radio config ...
     'W'  FFFFFF R P B C - number of letters indicates precise number of digits
      FFFFFF: frequency: 434000 (434 MHz) range 418000-455000
      R:      Rf data rate       - 1/2/3/4 equals 2400/4800/9600/19200bps
      P:      Radio output power - 0 .. 9 9 equals 13dBm(20mW).
      B:      UART baudrate      - 0/1/2/3/4/5/6 equals 1200/2400/4800/9600/19200/38400/57600bps
      C:      Byte Chek Parity   - 0/1/2 equals NoCheck(8N1)/EvenParity(8E1)/OddParity(8O1)

Write example: w 434000 3 9 3 0 is...
    434,000 MHz 9600 baud in air, 20mW, 9600baud on UART, No Parity(8N1)
After 30 seconds with no keyboard input we will emit a char every two second
```

If you type ‘r’ and hit enter, the program will return the current configuration for the transceiver. To reconfigure the radio, type ‘w’ and the 5 parameters needed, with space between each parameter.

The first parameter is frequency, range 418000 – 455000. For your CanSat, you will get your team frequency from the CanSat organisation. The figure shows an example list of frequencies.

The second parameter is RF data rate: 1/2/3/4 equals 2400/4800/9600/19200bps. The lower RF data rate increases the transmission range.

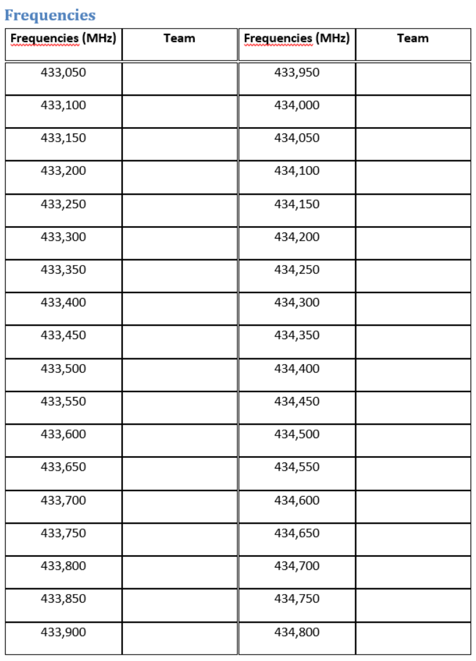
The third parameter is Radio output power: 0 .. 9. 9 Equals 13dBm(20mW). 9 is max power.

The fourth parameter is UART baudrate: 0/1/2/3/4/5/6 equals 1200/2400/4800/9600/19200/38400/57600bps. The baudrate should be set to 9600 bps.

The last parameter is Byte Chek Parity: 0/1/2 equals NoCheck(8N1) / EvenParity(8E1) / OddParity(8O1).

Note that you have to configure both transceivers with the same settings to be able to use them together.

Example entry: w 433100 3 9 3 0



Frequencies

Frequencies (MHz)	Team	Frequencies (MHz)	Team
433,050		433,950	
433,100		434,000	
433,150		434,050	
433,200		434,100	
433,250		434,150	
433,300		434,200	
433,350		434,250	
433,400		434,300	
433,450		434,350	
433,500		434,400	
433,550		434,450	
433,600		434,500	
433,650		434,550	
433,700		434,600	
433,750		434,650	
433,800		434,700	
433,850		434,750	
433,900		434,800	

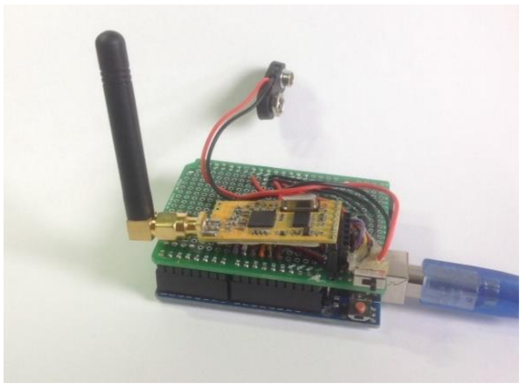
Testing APC220

(in case you add a SD card to the CanSat, please refer to page 53)

Finally, you can test the last electronic component of the CanSat kit: the APC220.

APC220 on CanSat:

Connect the shield to the Arduino and connect the APC220 to the shield.



Open ‘APC220_test’ sketch. Let’s take a look at this sketch.

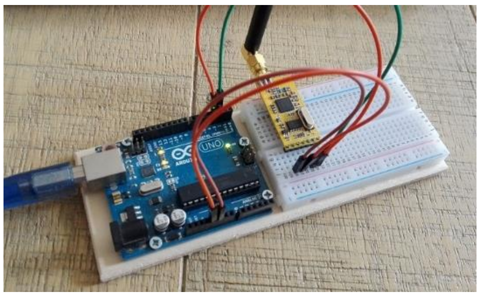
```
#include <SoftwareSerial.h>
SoftwareSerial mySerial(10,11);//RX, TX
int number = 0;

void setup() {

Serial.begin(9600);
  mySerial.begin(9600);

}

void loop() {
(number ++);
Serial.print ("APC220 test   ");
Serial.println (number);
mySerial.print ("APC220 test   ");
mySerial.println (number);
delay (1000);
}
```

Using Software serial, we can make a virtual serial port on pins we can choose. It is now possible to upload and check the serial monitor with the APC220 connected. Arduino communicates with pin 10 and 11 with APC220. It is even possible to display in the serial monitor information other than wireless. The sketch displays ‘APC220 test’ and an increasing number. This data is sent to the serial monitor by USB (Serial), the same data is sent by APC220 (mySerial).

Upload the code and open the serial monitor and see that your text and numbers are displayed. Close the serial monitor, disconnect the Arduino USB connection and power the Arduino by battery. With the power switch in the ‘ON’ position, the sketch will run again on the Arduino and APC220 will be transmitting text and numbers.

APC220 on ground station:
Connect the second APC220 to the second Uno, this will be the "ground station-Uno", and connect it to your computer.

Open the sketch "APC220_groundstation_UNO". Connect the APC220 as described in the sketch. Upload the sketch. If you are running the CanSat APC220 on battery, you can receive the test-data in the serial monitor of the ground station-Uno.

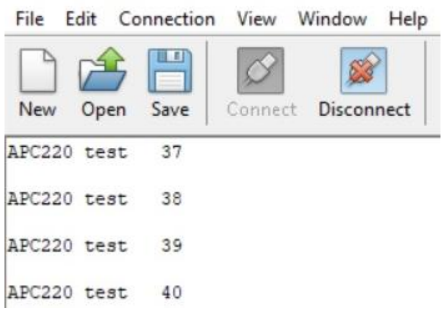


Gathering data at your ground station:
Close the serial monitor in Arduino IDE.

Open CoolTerm, select the right serial port and connect.

If your CanSat is transmitting and your second APC220 is connected, your ground station will receive data from it. In this case increasing numbers. Note that Coolterm can store data to a text file.

If you receive increasing numbers, the test has succeeded!



```
APC220 test   37

APC220 test   38

APC220 test   39

APC220 test   40
```

How to make an Arduino code for your missions

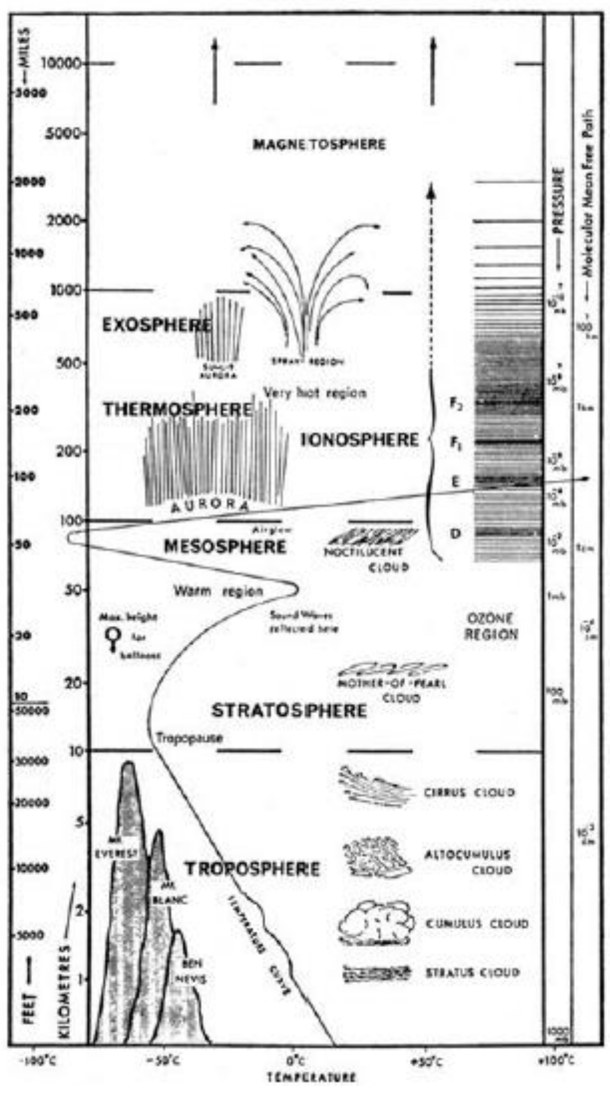
You have completed the electronic components of the CanSat for your primary mission. This handbook does not provide the proper Arduino code for carrying out this mission. You have to make your own code by combining pieces of code you used earlier. Try to decrease the transmitting data to a minimum and try to prepare these data to import in Excel or other spreadsheet software. For instance: Use 'comma' or 'space' and 'new line' (println) in the data strings.

Finally: Note that several Arduino pins are not connected. If you add more missions, you can use these pins. You can add the connections by soldering them to the shield.

Back Ground Information

Altitude calculations

The atmosphere is all around us. It is a thin gaseous layer surrounding our planet. The atmosphere is composed primarily of nitrogen (78%) and oxygen (21%). The remaining 1% consists of water vapour, CO_2 and other trace gasses. The Earth's atmosphere consists of different layers, each one having different properties (temperatures, pressure, composition, etc…).



The different layers are represented along with various human and weather activities seen in these layers.

Unlike our CanSat, most satellites operate in the exosphere. Here, the density of the atmosphere is very low. The CanSat, however, operates in the troposphere, which is the bottom layer of the atmosphere. This layer contains about 80% of the total mass of the atmosphere and stretches to about 10 kilometers altitude. A great deal of the "weather" we observe on a day-to-day basis (e.g. wind and clouds) occurs within this layer.

The temperature and pressure of the atmosphere vary with altitude. Although the ambient temperature can rise and fall as you move through the different layers of the atmosphere. Within the troposphere, there is a linear relation between the temperature and altitude. On average, ascending one kilometer from sea level will result in a temperature drop of 6.5 degrees Celsius.

The equation below provides the relation between temperature and altitude:

$$T = T_1 + a(h - h_1)$$

T	Temperature in Kelvin
T_1	Starting temperature at h_1 altitude
h	Altitude in metres
h_1	Starting altitude
a	Temperature gradient: -0.0065 K/m.

The relation between the pressure and the altitude is somewhat more complicated. The pressure not only depends on the altitude but also on the temperature. Let's start with the relation of pressure to temperature:

$$\frac{p}{p_1} = \left(\frac{T}{T_1}\right)^{-\frac{g_0}{\alpha R}}$$

p	Pressure in Pascal
p_1	Start pressure in Pascal
g_0	Gravitational acceleration: 9.81$\frac{m}{s^2}$
R	Specific gas constant: 287.06 J/kg*K

Inserting this formula into the temperature-altitude relationship, we achieve the following expression for altitude as a function of temperature and pressure:

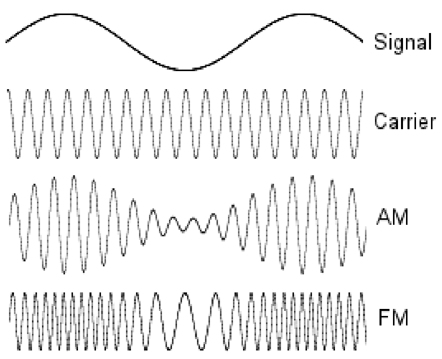
$$h = \frac{T_1}{\alpha}\left(\left(\frac{p}{p_1}\right)^{-\frac{\alpha R}{g_0}} - 1\right) + h_1$$

Antenna design

Modulation

Radio communication involves sending information from one place to another, using electromagnetic waves, also called radio waves. Electromagnetic waves are generated at an antenna when an alternating electric current is connected to it. The antenna transforms the electric current in electromagnetic waves. At the receiving end of the communication, the waves are transformed back into electric current by an antenna.

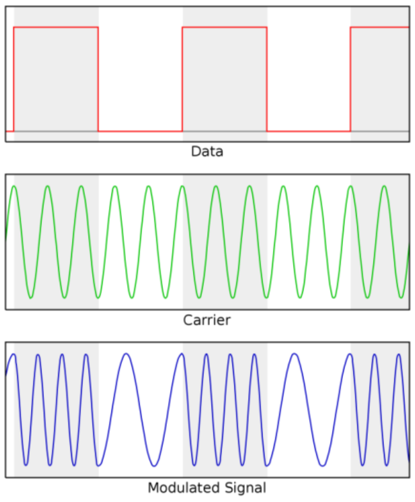
Using the radio waves to transfer information means that the information needs to be added to the radio frequency used. Adding this information is called *modulation* and can be obtained in several ways. The most basic form is to transmit a (*carrier*) frequency. This is called continuous wave (CW) communication. The most common form of CW is Morse code. The biggest drawback is that the information transfer rate or *baud rate* is very low.



There are many other forms of modulation, such as AM and FM. These are used by radio stations. With AM (amplitude modulation), the information is made to change the *amplitude* of the carrier frequency. In FM (frequency modulation), the *frequency* of the carrier is changed. The advantage of FM over AM is that the signal strength does not interfere with reception.

APC220

The APC220 transceiver in the CanSat supports various types of digital modulation. We are going to use Gaussian Frequency Shift Keying (GFSK). This means that it is transmitting a frequency if a logic 0 is transmitted and a different frequency if a logic 1 is transmitted.



The quality of the radio link mainly depends on three aspects: the transmission power, the receiver sensitivity and the antennas used. The only aspect that can be influenced by the CanSat team is the antenna. The other aspects can be influenced, but that requires a different transmitter and receiver, which is beyond the scope of this document.

Antennas

There are two antennas used in receiving information from the CanSat: the first is the antenna on board the CanSat, the second is the antenna used at the ground station. The antennas need to be made with different requirements, although the frequency of operation is similar for both antennas. The antenna on board the CanSat needs to be isotropic (or as much as possible), which means that it transmits the same amount of power in all directions. The antenna connected to the ground station can be pointed towards the CanSat, and it can therefore be made as a high-gain directional antenna, which receives more electromagnetic waves from one direction than from another.

CanSat Antenna

The CanSat antenna needs to be sufficiently robust to survive a rocket launch. For the CanSat, a quarter-wave wire antenna works very well. The quarter-wave describes the length of the antenna in reference to the operation frequency. The CanSat kit transmitter works at around 433 MHz. The precise frequency will depend somewhat on what team you are in. You will get your team frequency from the CanSat organisation. This is done to protect the teams from interference. The required length of the antenna can be calculated using the following equation:

$$L = \frac{c}{4f} = \frac{(3 * 10^8)}{(4 * 433 * 10^6)} = 0.173m$$

in which

L is the required antenna length (1/4 wavelength) in metres

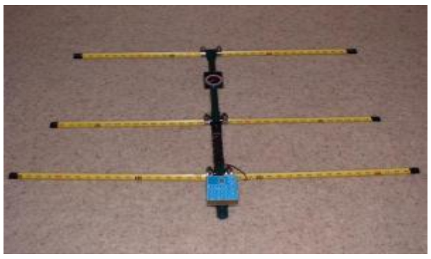
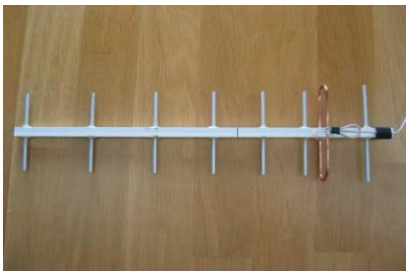
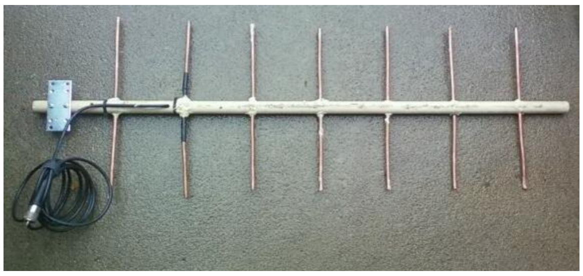
c is the speed of light (300,000 km/s) in metres per second

f is the operating frequency in Hertz

The formula shows that the length of the antenna for 433 MHz should be around 17.3 cm. The wire antenna that came with the CanSat kit should be this length exactly.

Ground station antenna

The ground station antenna can be pointed at the CanSat during flight. This means that it can be a high gain directional antenna. The most popular antenna design of this type is the Yagi antenna. These are versatile, powerful and can be bought cheaply. For your CanSat, building a Yagi antenna is a good option. They can be constructed relative easily, using wood and copper tubes. There is plenty of information on the internet on building a Yagi antenna.

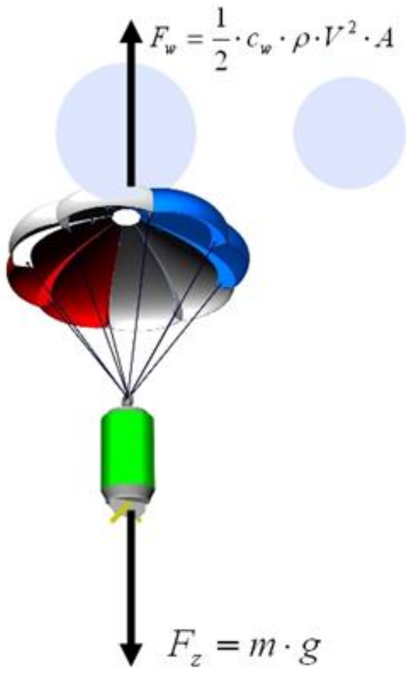
Parachute design

Satellites normally do not return to Earth on a parachute. At the end of its useful life, a satellite will be put into a different orbit. For satellites orbiting at a low altitude, this could result in burning up in the atmosphere. Satellites further away will end up in a much more distant “parking” orbit. They will circle our planet forever. Sometimes, however, a spacecraft has to return to earth with samples or astronauts. One of the solutions for a safe descend is to make use of a parachute.

When the CanSat is deployed it must have a device to slow it down, otherwise it will crash. Using a parachute will also help to keep the CanSat in an upright position.This is particularly important because it helps to maintain proper antenna orientation, which maximises the chances of receiving telemetry. This chapter will guide you through the different steps needed to design and build your parachute.

Parachute production

When the design of the parachute is finished, you can start the production process. There are, however, a few important issues to keep in mind. Deployment of the parachute will be relatively violent, so the fabric and fibres you use need to be strong. You can usually obtain nylon cord and ripstop fabric at a kite shop. These materials are ideally suited to the parachute.



When cutting the fabric, remember that some of the fabrics need to be cast double in order to sew it.

More handy tips on parachute production can be found at:
www.nakka-rocketry.net/paracon.html

When the parachute has been completed, the best way to check if it works is to test it.

Example assignments

The following assignments can be performed when working on the parachute.

- Calculate the impact speed of the can without a parachute (when released from 1 kilometer altitude).
- Calculate the minimum required area for your parachute when you use a cross parachute. What size should the squares be on the chute?
- Perform the same calculation for a spherical parachute. What is the radius?
- Test the descent velocity of your parachute with a soft drinks can.
- Try out different solutions for the parachute. A parachute with holes in it or perhaps multiple small parachutes could provide a solution. Both will enhance the stability of the CanSat.

Descent physics

Before we can start making the parachute, we will have to figure out how big it should be. More specifically, we need to calculate how much surface area the parachute will need in order to fulfil the requirements.

Logic suggests that the bigger the parachute, the slower the object’s descent velocity. This principle is shown below with some basic equations. Although it would be very beneficial for the CanSat to have a very low descent rate, a limit has been set to ensure that the CanSat will land near the launch area. If the descent rate is too slow, the CanSat may drift kilometers away along with the wind, which is neither allowed nor desired. Therefore a minimum descent rate has been set:

On lift-off, the launcher will reach 900 to 1000 metres within 13 seconds. Here, it will deploy all CanSats. Starting from lift-off, touch-down has to be within 90 seconds. This only leaves 77 seconds for your CanSat to descend 1000 metres. This is the most critical boundary of your recovery system. If your CanSat cannot meet this limit, it will not fly!

To design the parachute, we will use some basic physics. We use a simplified model to estimate the area of the parachute, after which we can start the construction.

During the descent, two forces will be acting on the CanSat. Gravity will pull on the can and accelerate it towards the ground and the drag force on the parachute will pull the CanSat in the opposite direction and slow down the descent rate. The two forces are shown in this image.

When the CanSat is deployed, the force of gravity will cause it to accelerate. After a few seconds, the drag force from the parachute will reach equilibrium with the force of gravity. From that point on, the acceleration will be zero and the CanSat will descend at a constant velocity. This constant velocity has to be greater than the minimum descent velocity specified in the requirements. For the following calculations, we can use this minimum value as the constant velocity of the CanSat.

The gravity force is equal to:

$$F_g = m * g$$

In this equation

m is the mass of the CanSat in kilograms
g is the acceleration of gravity, equal to 9.81 $\frac{m}{s^2}$

The drag force of the parachute is equal to:

$$F_D = 0.5 * C_D * \rho * A * V^2$$

In this equation:

A is the total area of the parachute (not just the frontal area)
C_D is the drag coefficient of the parachute. This value depends on the shape of the parachute.
ρ is the local density of the air, assumed to be constant at 1.225 $\frac{kg}{m^3}$.
V is the descent velocity of the CanSat

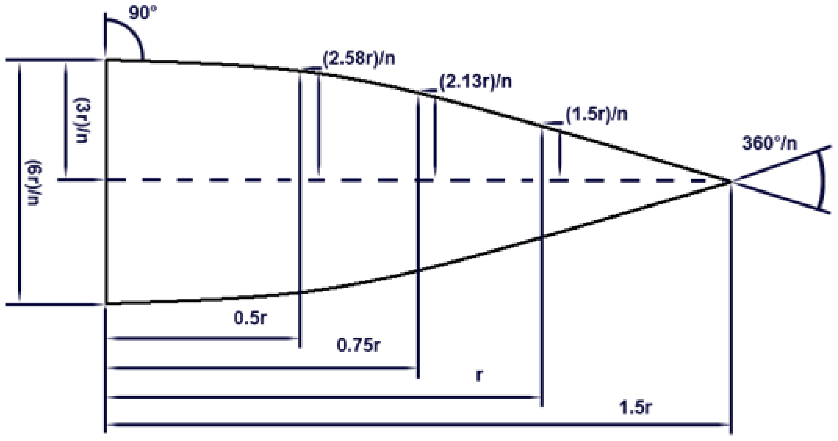
Given a desired velocity, you can easily rewrite these equations to calculate the area needed for the parachute.

Required descent parameters

Maximal descent Velocity:	12 m/s
Maximum allowed mass:	0.350 kilograms
Drag coefficient:	When designing the size of your parachute, you can assume the drag coefficient to be 0.4.

For the area calculations of the parachute, you have to take the full production area of your parachute. For instance, if you are making a cross parachute, you have to use the area of the full cross laid flat. Not the area seen when a parachute is inflated.

Semi-spherical parachute design
A semi-spherical appearance is the most common shape for a parachute. Although it is not hard to make one, it can be quite time-consuming to get the right shape. The figure below should help.



n	stands for the number of parts needed
r	stands for the radius of the parachute.

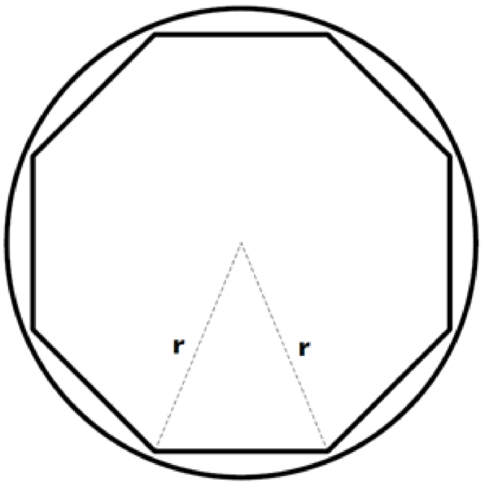
Cross parachute design
Instead of using a semi-spherical-shaped parachute, you can also choose a cross shape. The advantage of this shape is that it's easy to make. If you want to know more about cross-shaped parachutes, you can check the following link:

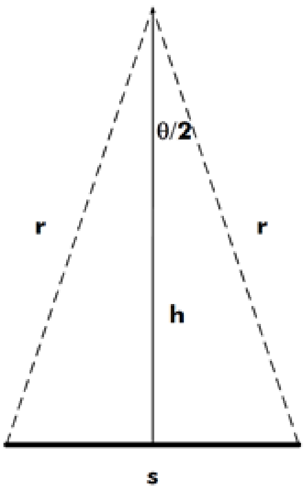
www.nakka-rocketry.net/xchute1.html

Parapent
A parapent shaped parachute acts rather like a wing. Because of its shape you can use it to steer. The design of a parapent is more complex than that of the other shapes mentioned. You will have to do some more research if you wish to use this type of parachute.

Flat parachute design

The most commonly available parachutes are in fact created from standard two-dimensional flat geometric figures, such as hexagons or octagons.



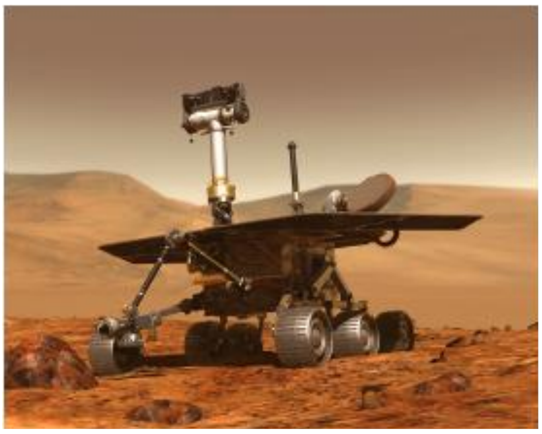


From above, you can see that the parachute consists of 8 equal triangles. Hence, the total area for the parachute would be $A = 8 * AT,$ where the area of one triangle is $AT = s * \frac{h}{2}$. By combining these two equations, we get $A = \frac{8*s*h}{2}$. You can read more about how to calculate the area of a flat parachute at: www.sunward1.com/imagespara/The%20Mathematics%20of%20Parachutes%28Rev2%29.pdf

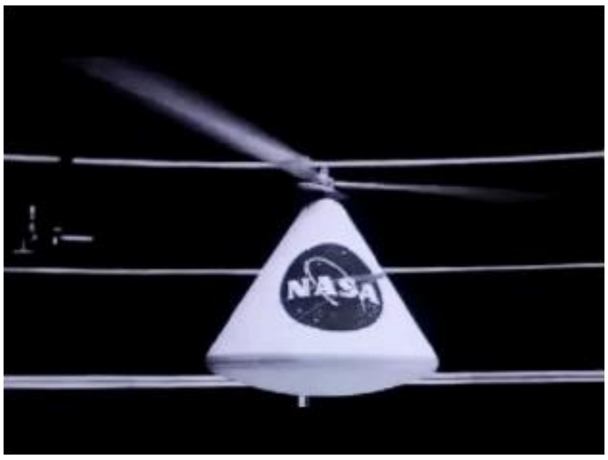
As soon as you know the total area (A) together with the drag coefficient (C_D), you can easily determine the descent rate for your CanSat. Perform some drop tests to check if your calculations are accurate and to find the terminal velocity.

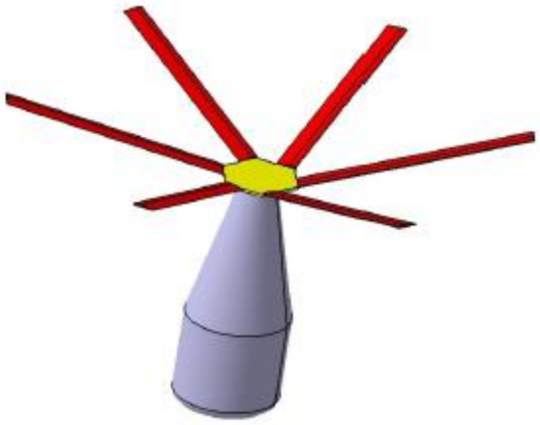
Other recovery systems

There are also different options when recovering an object. Opportunity (Mars exploration rover B) used airbags for its landing on Mars (see below). This is based on the same principle as a parachute, namely increasing area to increase drag and therefore slow down the vehicle. Airbags have the additional advantage that they soften the landing.



Apart from these systems, there are also recovery systems that use lift-induced drag. This type of drag is used in airplanes and helicopters. Auto rotation, a recovery system researched by many including NASA, is based on the movement of helicopter blades. One big advantage of this system would be that it is steerable to a certain location. An example of these blades is shown in the figure below.





CanSat Competition tips

Based on experiences of teams competing in other CanSat competitions, we would like to offer you some extra tips and tricks to get you well prepared for the CanSat competition.

Tips on your CanSat design:

- The temperature sensor for your primary mission must measure the air temperature *outside the CanSat*. If the sensor is hidden away too much within your CanSat, the measuring results may be impacted negatively, so that no proper analysis can be performed. Take this into account in your CanSat design.
- During previous launching events, it became clear that the CanSats are difficult to trace in the heathland when trying to recover them after launch. As a result, the CanSats of several teams were never recovered. Using a sound signal (e.g. a beeper) as a recovery system increases the likelihood of recovery. The CanSat teams won't recovery their CanSats themselves. This will be done by the military personnel.
- Use a bright colour for your parachute that contrasts sharply with the background. This improves your chance of being able to see your CanSat easily during the flight and being able to follow it with your Yagi antenna.

Tips from participants in earlier competitions:

- The most important tip: prepare well, start on time, make a good planning! Keep in mind that you need a lot of time. Manage your time well. Be organised and work hard.
- Make a good division of tasks within your team. Make sure everybody knows his or her task and responsibilities.
- Communicate: talk to each other regularly about how things are going and have the courage to talk to each other when things are not going well.
- Research well before you choose a secondary mission. Check if it is realistic and feasible.
- Test, test, test. Test everything thoroughly and often (under different circumstances): test and check your design. Make sure it meets the requirements.
- If you encounter a problem that you cannot solve, ask for help in time, for example from your teacher.
- Bring your tools to the test and launch days (e.g. last minute soldering of wires).
- Giving up is not an option. If you experience any setbacks, always continue. Think in terms of solutions instead of problems. Persevere and you will succeed!
- And very important: have fun!

Addendum: adding a SD card

Why an addendum?

Due to possible corona measures, we have to take into account that the launch cannot go ahead as planned.

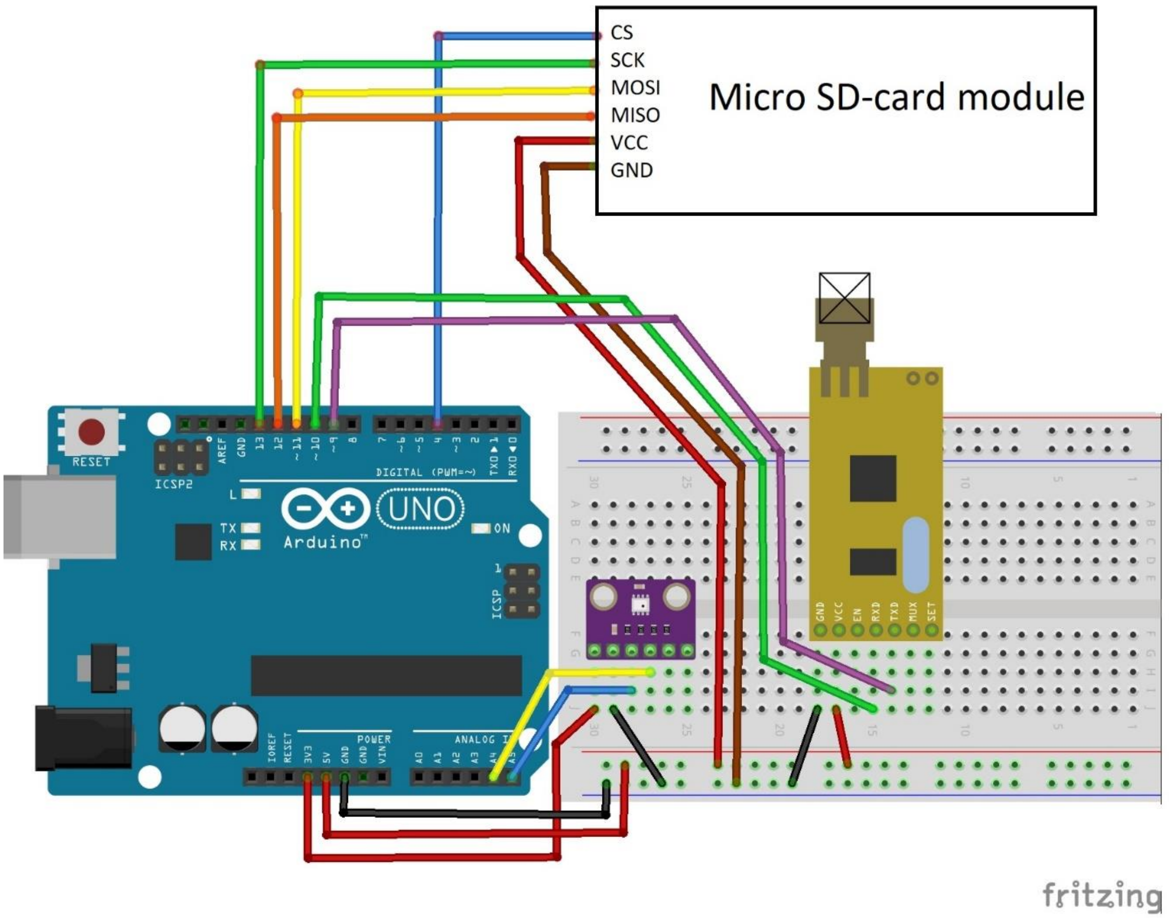
In a worst case scenario, the rocket launch will unfortunately have to take place without the teams being present. In that case, no data can be collected via telemetry. The CanSat will have to be able to collect the data on a SD card.

The winner will get the chance to participate in the European Competition. For this competition it has already been decided that teams cannot be present at the launch. Please check the extra requirements at the website.

What has to be changed?

The BMP280 is no longer connected with SPI (Serial Peripheral Interface), but with I2C. The micro SD card module is connected with SPI and on the designated pins. The connection of the APC220 module has also been slightly changed in the new design.

As a breadboard setup it will look like this.



Wiring tabel:

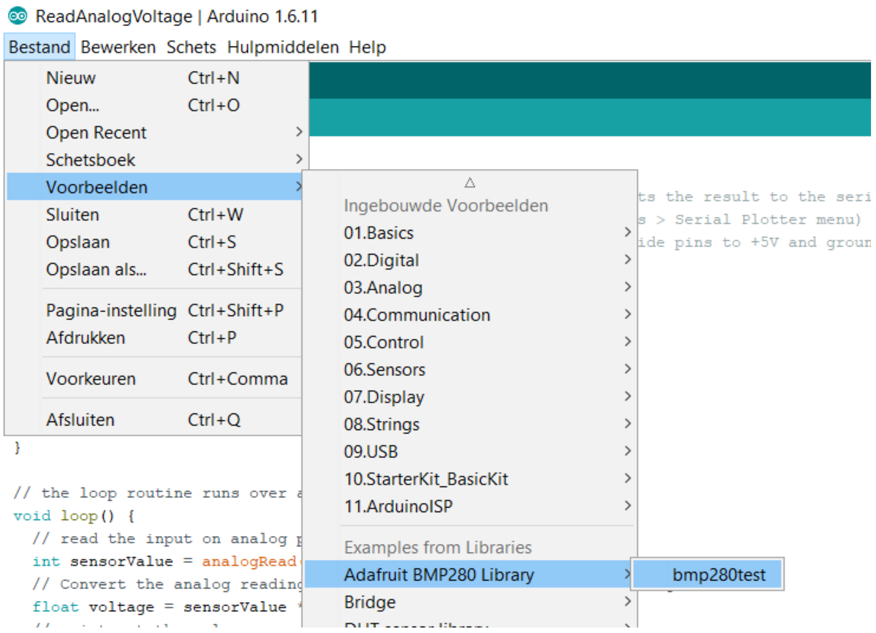
BMP280	**Arduino**
VCC	3.3V
GND	GND
SCL	A5
SDA	A4
CSB	na
SDO	na
Micro SD	**Arduino**
CS	D4
SCK	D13
MOSI	D11
MISO	D12
VCC	5V
GND	GND
APC220	**Arduino**
GND	GND
VCC	5V
EN	na
RXD	D10
TXD	D9
AUX	na
SET	na

CanSat Tech Guide page 14 – 15:

Measuring barometric air pressure and temperature with BMP280 module:

In the primary mission, you have to measure barometric air pressure and temperature. The CanSat kit contains a module, the BMP280. This module can measure pressure and temperature. **The working voltage of this module is 3.3 V. Check this in the wiring diagram.** If you want to use it with the Arduino IDE, you will need a library. The Arduino IDE can be extended through the use of libraries to provide extra functionality to your sketches. Most libraries come with example sketches. You can find the libraries in the CanSat download files. Copy the folder “Adafruit_BMP280” and “Adafruit_Sensor-master” into the “libraries” folder in “Arduino” – “My Documents”, Exit and restart Arduino IDE.

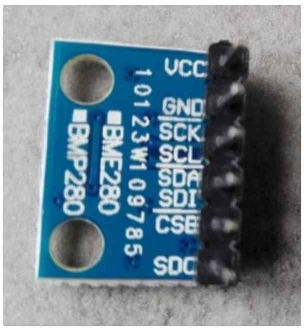
You can now find the example sketch *bmp280test*:

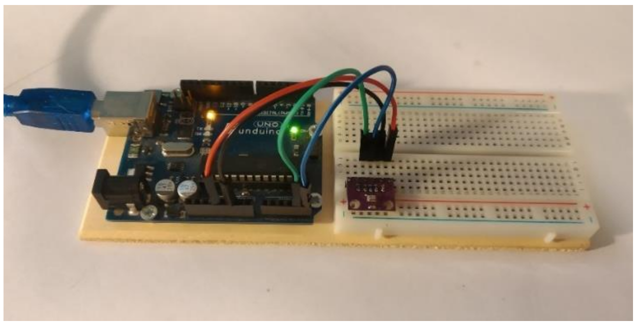


```
ts the result to the seri
s > Serial Plotter menu)
ide pins to +5V and groun
}

// the loop routine runs over a
void loop() {
  // read the input on analog p
  int sensorValue = analogRead(
  // Convert the analog reading
  float voltage = sensorValue *
```

Wire the BMP280 module:

7.	VCC	3.3V
8.	GND	GND
9.	SCK/SCL	A5
10.	SDA/SDI	A4
11.	CSB	
12.	SDO	





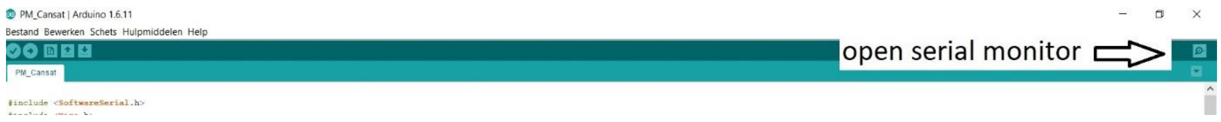
In the sketch, you have add the BMP address, bmp begin-code and check-code:

```
Adafruit_BMP280 bmp; // I2C
//Adafruit_BMP280 bmp(BMP_CS); // hardware SPI
//Adafruit_BMP280 bmp(BMP_CS, BMP_MOSI, BMP_MISO,  BMP_SCK);

void setup() {
  Serial.begin(9600);
  Serial.println(F("BMP280 test"));

  if (!bmp.begin()) {
```

To:

```
Adafruit_BMP280 bmp; // I2C
//Adafruit_BMP280 bmp(BMP_CS); // hardware SPI
//Adafruit_BMP280 bmp(BMP_CS, BMP_MOSI, BMP_MISO,  BMP_SCK);
const int BMP_address = 0x76;

void setup() {
  Serial.begin(9600);
  Serial.println(F("BMP280 test"));
  bmp.begin (BMP_address));

  if (!bmp.begin(BMP_address)) {
```

Now you can upload the sketch and open the serial port.


PM_Cansat | Arduino 1.6.11
Bestand Bewerken Schets Hulpmiddelen Help
PM_Cansat
open serial monitor

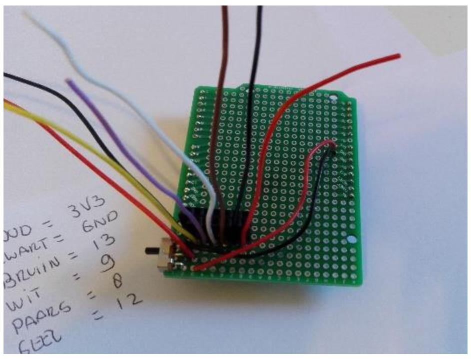
```
#include <SoftwareSerial.h>
```

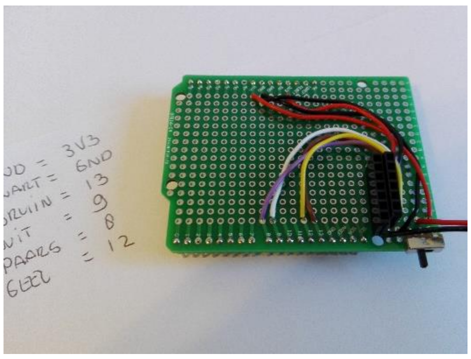
CanSat Tech Guide page 26 – 27:

Connect the BMP280 to the shield

You already used the sample code for BMP280. You can wire the BMP280 at the same pins. You can use 6 different colour wires.

BMP280	wire colour	top	down	Arduino	top	down
VCC	red	(8,4)	(8,5)	3.3V	(I,14)	N/A
GND	black	(7,4)	(7,5)	GND	(H,17)	(I,17)
SCK/SCL	brown	(6,4)	(6,5)	A5	(I,25)	N/A
SDA/SDI	white	(5,4)	(5,5)	A4	(I,24)	N/A
CSB						
SDO						

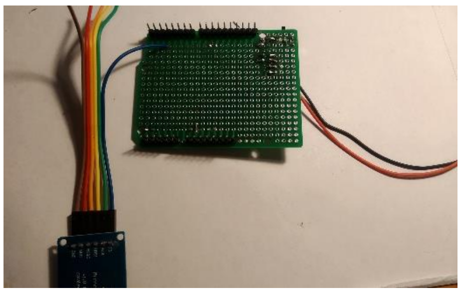


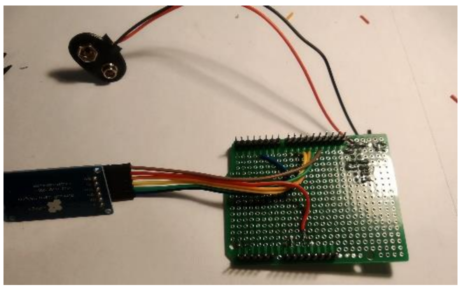


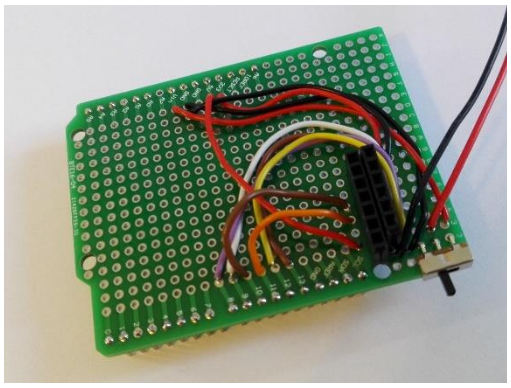
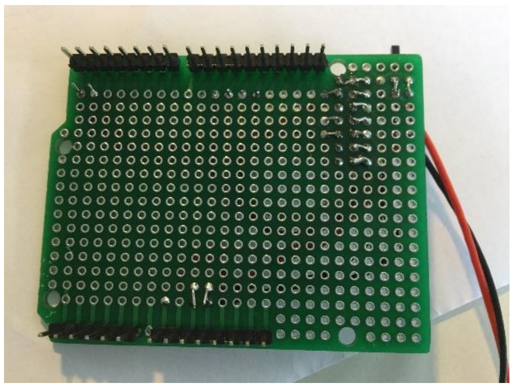
Connect the APC220 to the shield

The 7 pin female header is only to be wired with 4 wires, 3 pins are not wired. You can use 4 different colour wires.

APC220	wire color	top	down	Arduino	top	down
SET	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx
AUX	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx
TXD	brown	(6,7)	(6,6)	RX/D9	(3,16)	N/A
RXD	orange	(5,7)	(5,6)	TX/D10	(3,15)	N/A
EN	xxxxx	xxxxx	xxxxx	xxxxx	xxxx	xxxxx
VCC	red	(3,7)	(3,6)	5V	(i,15)	N/A
GND	black	This wiring is combined with black wire battery holder				



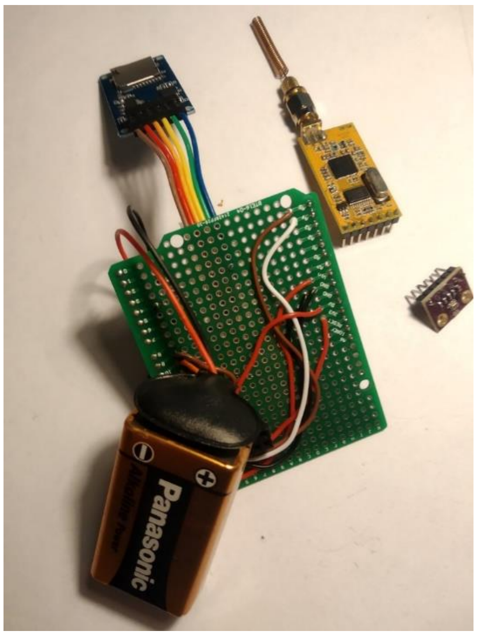


Connect the Micro SD-card module to the shield

We connect the Micro SD-Card module with female-jumper wires, length 10 cm. We do not solder the end of the jumper wires on the top, but on the bottom of the prototyping shield. It is recommended to tin the ends of the copper wires (1cm.) first.

SD card module	Wire color	Arduino	down
CS	Blue	D4	(3,21)
SCK	Green	D13	(3,12)
MOSI	Yellow	D11	(3,14)
MISO	Orange	D12	(3,13)
VCC	Red	5V	(i,15)
GND	Brown	GND	(3,11)

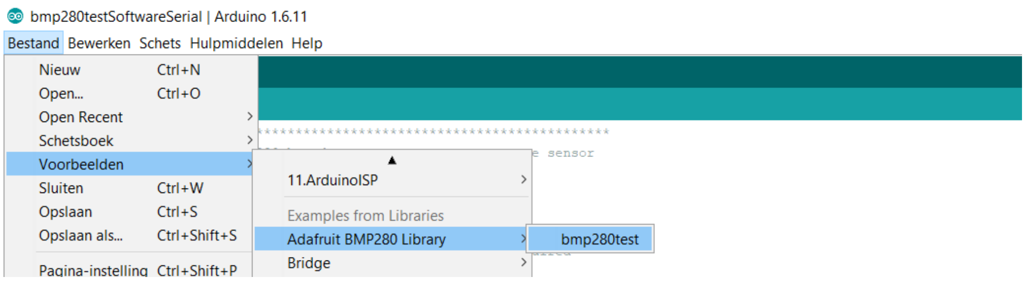


The shield is finished!

CanSat Tech Guide page 29:

Testing Arduino/BMP280

Open in Arduino IDE bmp280test:



With the APC220 disconnected and the power switch in the off position, you can upload the BMP280 sample file to test a measurement in the serial monitor. If you close the serial monitor, you can also test the data in ‘CoolTerm’. You have to make the same changes to the sketch as in page 15 of this CanSat Tech Guide.

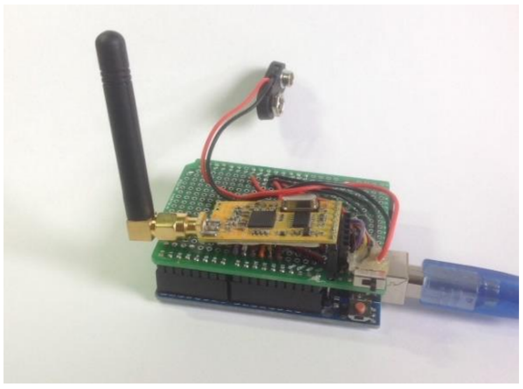
CanSat Tech Guide page 32:

Testing APC220

Finally, you can test the last electronic component of the CanSat kit: the APC220.

APC220 on CanSat:

Connect the shield to the Arduino and connect the APC220 to the shield.



Open 'APC220Test' sketch. Let's take a look at this sketch.

```
#include <SoftwareSerial.h>
SoftwareSerial mySerial(9,10);
int number = 0;

void setup() {

Serial.begin(9600);
  mySerial.begin(9600);

}

void loop() {
(number ++);
Serial.print ("APC220 test   ");
Serial.println (number);
mySerial.print ("APC220 test   ");
mySerial.println (number);
delay (1000);
}
```

Using Software serial, we can make a virtual serial port on pins we can choose. It is now possible to upload and check the serial monitor with the APC220 connected. Arduino communicates with pin 10 and 11 with APC220. It is even possible to display in the serial monitor information other than wireless. The sketch displays 'APC220 test' and an increasing number. This data is sent to the serial monitor by USB (Serial), the same data is sent by APC220 (mySerial).

Upload the code and open the serial monitor and see that your text and numbers are displayed. Close the serial monitor, disconnect the Arduino USB connection and power the Arduino by battery. With the power switch in the 'ON' position, the sketch will run again on the Arduino and APC220 will be transmitting text and numbers.

Credits

The CanSat Tech Guide has been written by Frank Hagenaars on behalf of ESERO NL. It is based on the work of Thomas Gansmoe, Stian Vik Mathisen and Jøran Grande from NAROM, together with Jens F. Dalsgaard Nielsen from Aalborg University and Nils Kristian Rossing from the Norwegian University of Science and Technology published at: esero.no/wp-content/uploads/2015/11/The-CanSat-Book-R2.12.compressed.pdf

The CanSat kit used in this book has been developed by Fun met Electronica and is based on the NAROM CanSat Kit.

Photography cover: DigiDaan.