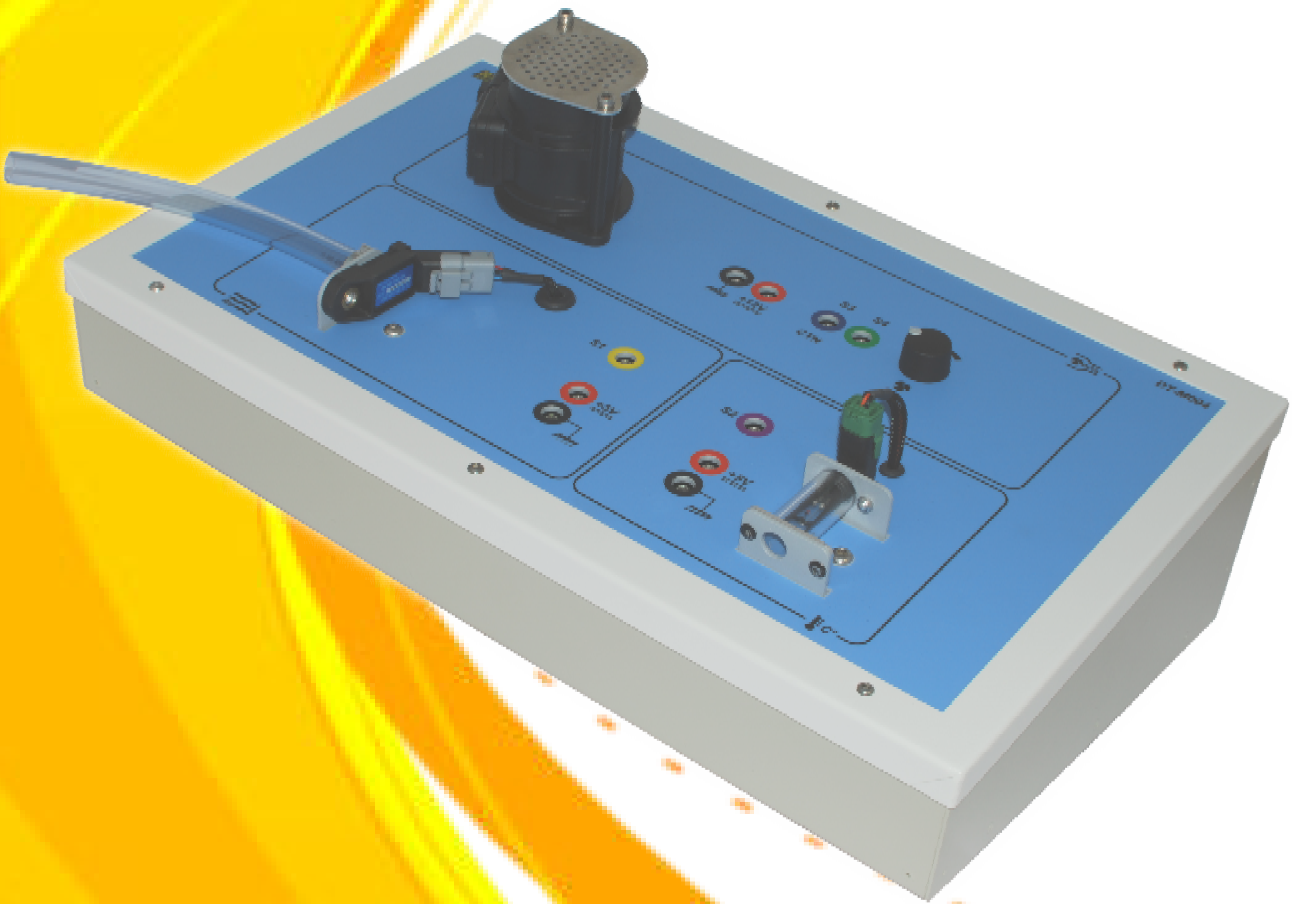
# User's guide for DT-M004



# Air Characteristics

EXXOTEST® EDUCATION

Document No. 00308621-v1

# 1. Introduction

## Models DT-XXXX

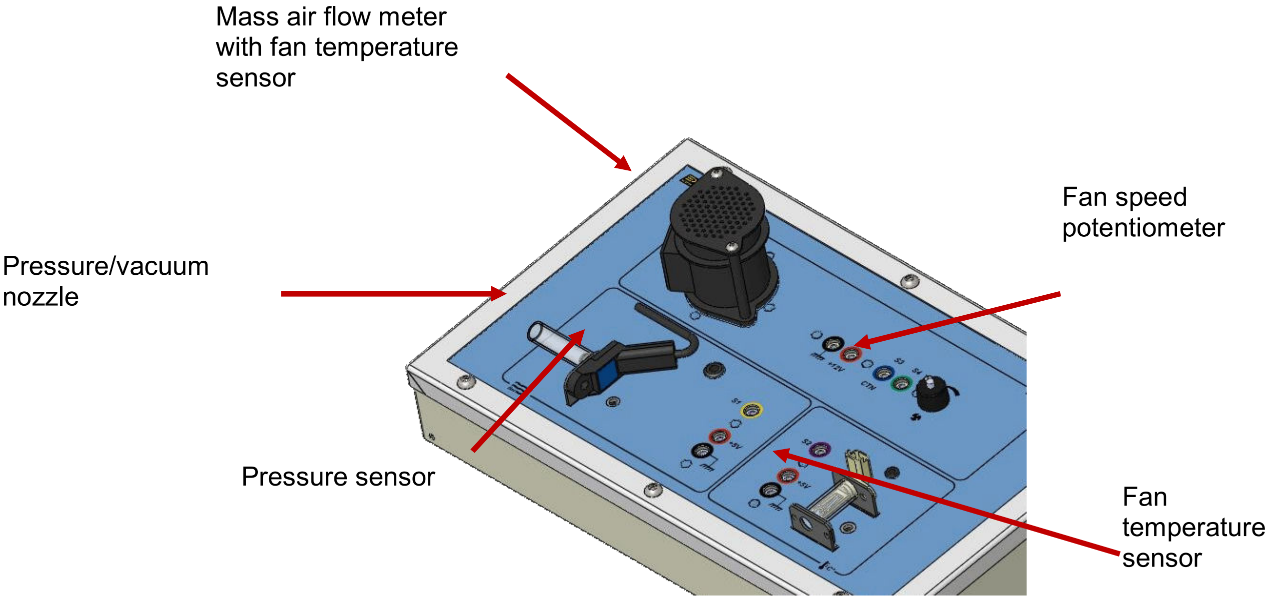
Models DT-MXXX consist of a number of benchtop learning modules, which together cover all the sensors (DT-M where M stands for Measure) and actuators (DT-C where C stands for Control). These components correspond to the latest models in production within the automotive industry.

## Module DT-M004

Module DT-M004 is designed for trainees to acquire skills and expertise in measuring the characteristics of air.

We have grouped together an air temperature sensor, an air pressure sensor and a mass air flow meter for this purpose. These three sensors originate from the parts bank for PSA Peugeot Citroën engines.

## 1.1 Using the module



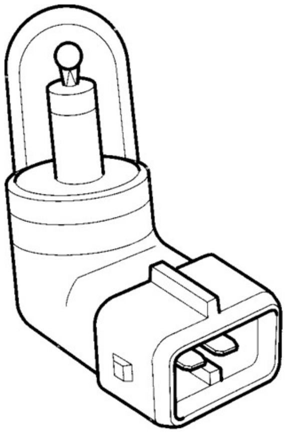

The sensors will be powered from an external 5 or 12 V supply (depending on the sensors) via the red and black sockets. Their signals will be retrieved via the green and purple sockets in the following order:

- S1 = air pressure
- S2 = air temperature
- S3 = air temperature (integrated into the mass air flow meter)
- S4 = air flow rate

# 2 Resources File

## 2.1 Temperature sensor

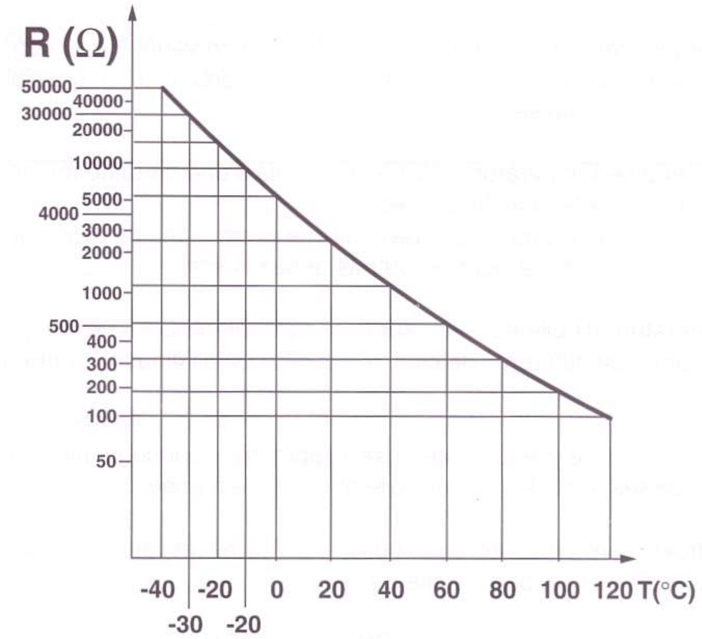
Temperature is measured in today's motor vehicles by thermistors. Thermistors offer the advantage of being ten times more sensitive than resistance thermometers, but exhibit an exponential response – rising in the case of PTC (Positive Temperature Coefficient) thermistors, or falling in the case of the more frequently used NTC (Negative Temperature Coefficient) thermistors. Due to their sensitivity, they are used over a measurement range limited to approximately 200 degrees for sintered ceramics (sufficient for intake air temperature).



Electrical resistance is most often converted to analog voltage in a voltage divider-type setup (linearisation effect) with a second, temperature-independent or beta-curve resistor.

The measurement resistor is part of a voltage divider circuit powered by a 5 V supply. The voltage measured across the terminals of this resistor therefore depends on the temperature. It is read via an analog/digital converter (ADC) and represents the temperature on the sensor. A characteristic curve, memorised in the engine ECU, indicates the correspondence between voltage and temperature.

Temperature vs. sensor output resistance curve:



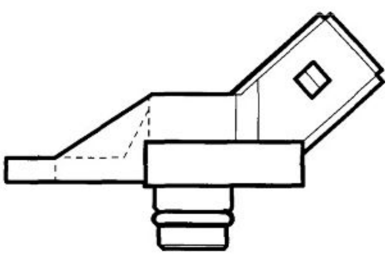

## 2.2 Pressure sensor

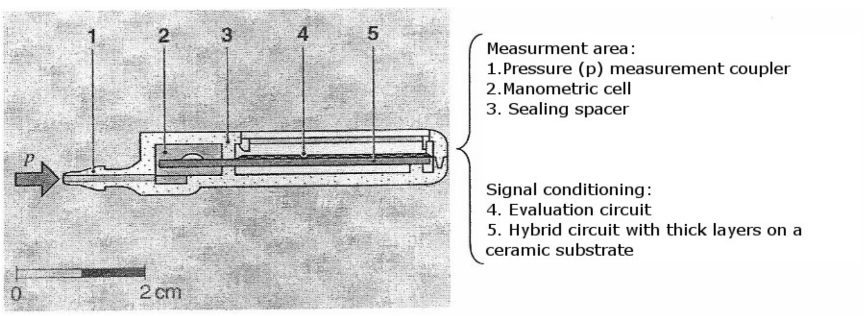
**Definition:** pressure is a value derived from the International System (SI). It is defined as the quotient of a force acting perpendicularly to a flat surface, to the area of that surface.

**<u>P = F/A</u>** where

- P = Pressure in pascals
- F = Force in newtons
- A = Area in square metres

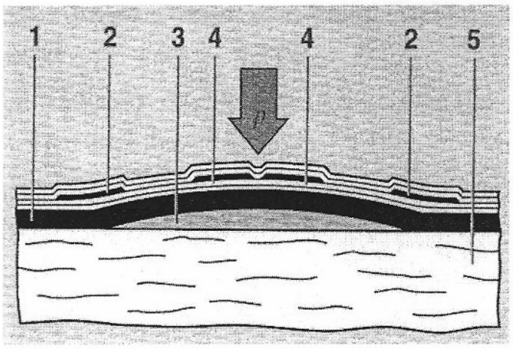
This sensor is divided into a pressure measuring cell and a compartment containing the evaluation circuit. These two elements are mounted on a ceramic substrate.






It is subdivided into pressure cells with two sensing elements and space for the evaluation circuit. The sensing elements and the evaluation circuit are positioned on a ceramic substrate. The sensing element of the pressure sensor comprises a thick, bell-shaped layer which includes a reference pressure chamber with a specific internal pressure.

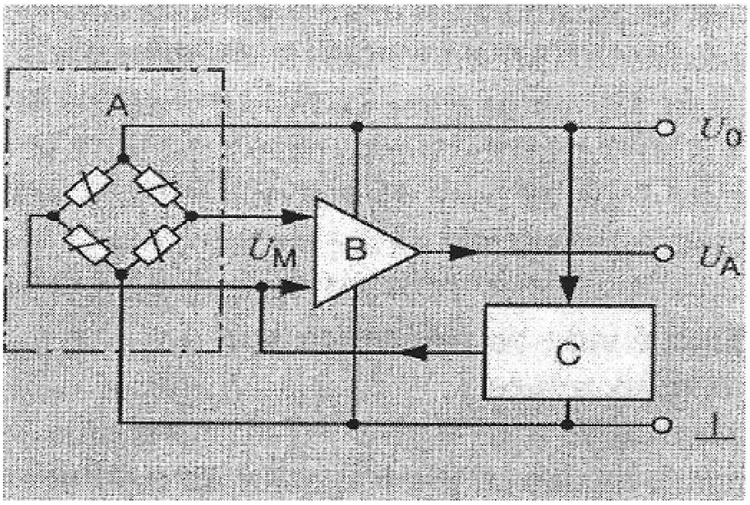
Manometric cell of a thick-film pressure sensor




1. Thick-film membrane
2. Reference passive strain gauge
3. Manometric reference bubble
4. Active strain gauge
5. Ceramic substrate

p: measurement pressure

The resistance values of the piezoresistors on the membrane change according to the elongation of the membrane as the pressure varies in the intake manifold. This change in resistance generates a variable-voltage signal depending on the pressure in the intake manifold. The voltage signal is processed and linearised in the evaluation circuit and transmitted to the ECU.

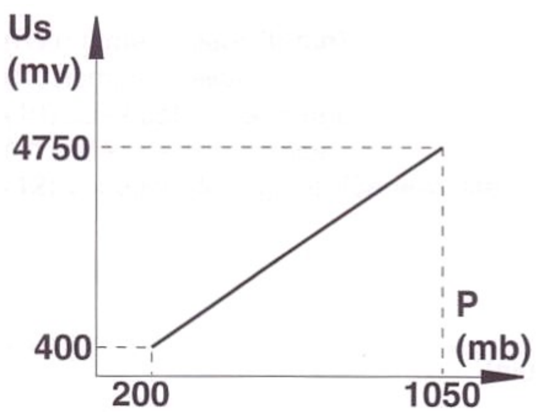



A Strain gauges cell

B Amplifier
C Temperature compensation circuit
$U_0$ Power supply voltage
$U_m$ Measurement voltage
$U_A$ Output voltage

The characteristic of the intake pressure sensor gives a voltage of 0.4 V on idling, rising to 4.75 V under full load. The linear working field of the sensor lies between these two values.
The ECU evaluation circuit uses the signal to determine the proportions of the mix. This physical value is therefore a reference variable in petrol injection systems.

Signal emitted by the sensor:




(Us) output voltage
(P) absolute pressure

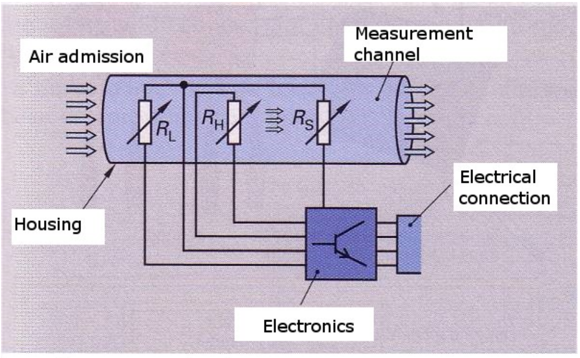
## 2.3 Hot-film mass air flow meter

This device measures the air flow into the engine in order to determine the optimum air/fuel mix. The maximum mass air flow ranges from 400 to 1000 kg/h depending on engine displacement. On modern engines, the ratio between the mass air flow on idling and the maximum mass air flow is of the order of 1 to 100.

A hot-film air sensor is located in a parallel measuring channel of the interior tube. The air drawn in by the engine flows through the mass air flow meter and thus affects the hot film temperature.

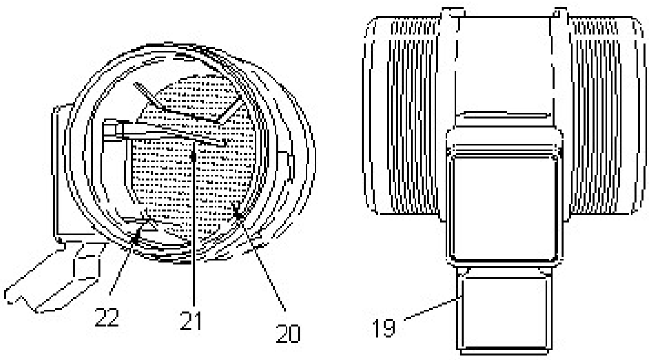
The sensor comprises three electric resistors:

- Heating resistor RH (platinum film resistor)
- Sensor resistor RS
- Thermal resistor RL (intake air temperature)



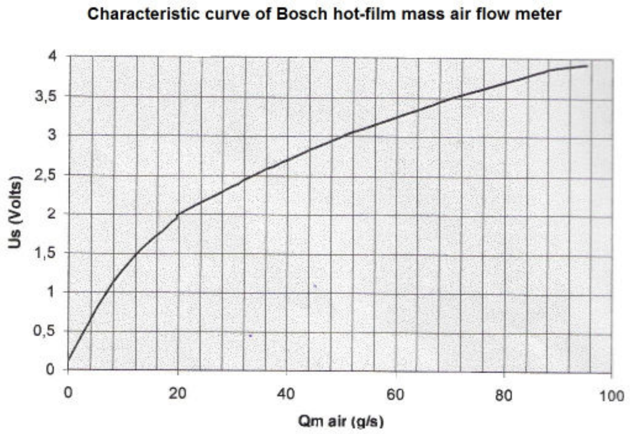
Hot film sensor bridge circuit

The electrical bridge circuit comprises thin film resistors on a ceramic substrate.
The electronics in the mass air flow meter adjust the heating resistor RH temperature by a variable voltage so that it is 160°C above the intake air temperature. This intake temperature is picked up by the thermal resistor RL. The heating resistor temperature is determined by the sensor resistor RS. The heating resistor is cooled to a greater or lesser extent by a variation in the air flow. The electronics adapt the voltage of the heating resistor RH via sensor resistor RS to maintain the 160°C temperature differential. This electronic control voltage generates a signal corresponding to the air flow rate which will be interpreted by the injection ECU.



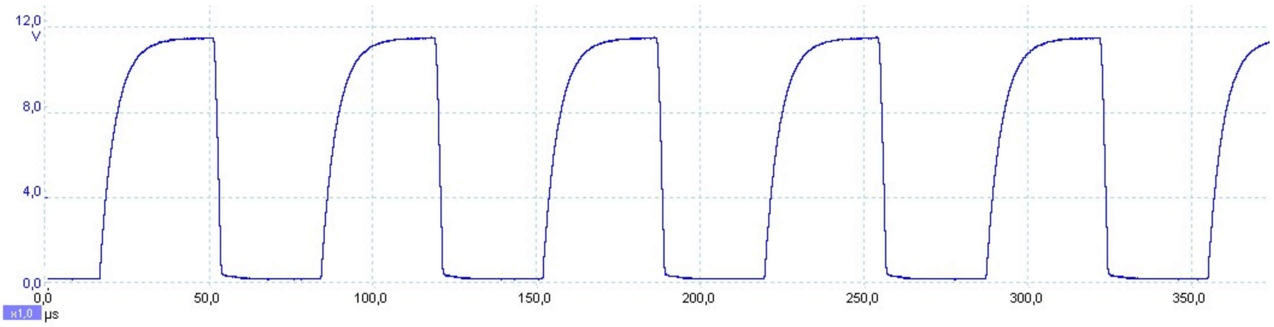

19 - Electrical connector
20 - Protective mesh screen
21 - Hot film
22 - Air temperature probe

This is the conventional signal from a hot-film mass air flow meter:

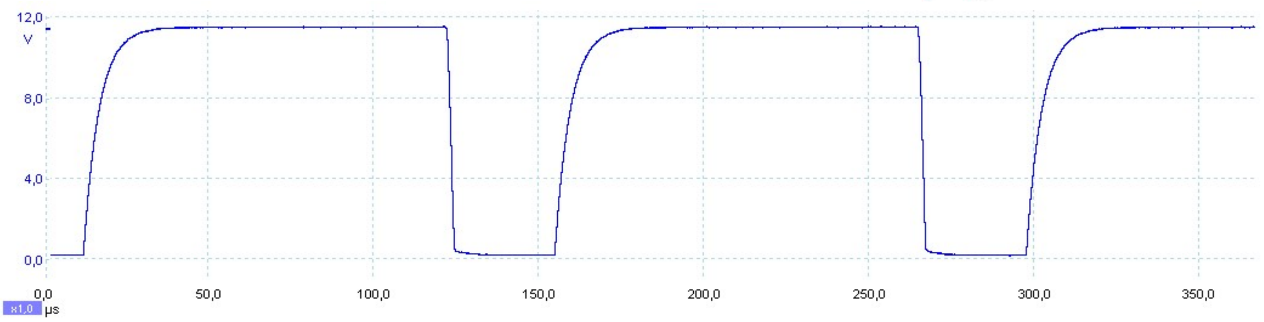



On more recent systems (such as the one in the model), resistor RH is supplied by variable-frequency voltage. To keep RH at constant temperature, the frequency of the power supply will vary (the greater the increase in air flow, the more the frequency will increase as more energy is required to keep RH at a constant temperature). This frequency is then analysed by the engine ECU which deduces an air flow and then adjusts the quantity of petrol for injection.
Comment: A pull-up resistor must be added between the power supply and the signal to “pull up” the signal.
Note that there is also a pull-up resistor between the temperature sensor signal and the power supply in order to view the temperature signal integrated into the mass air flow meter.

Zero flow rate:




Maximum flow rate:



# 3 Exercises

## 3.1 Pressure sensor

What is the main application of a pressure sensor?

The pressure sensor plays a major role in calculating the air/fuel mix.

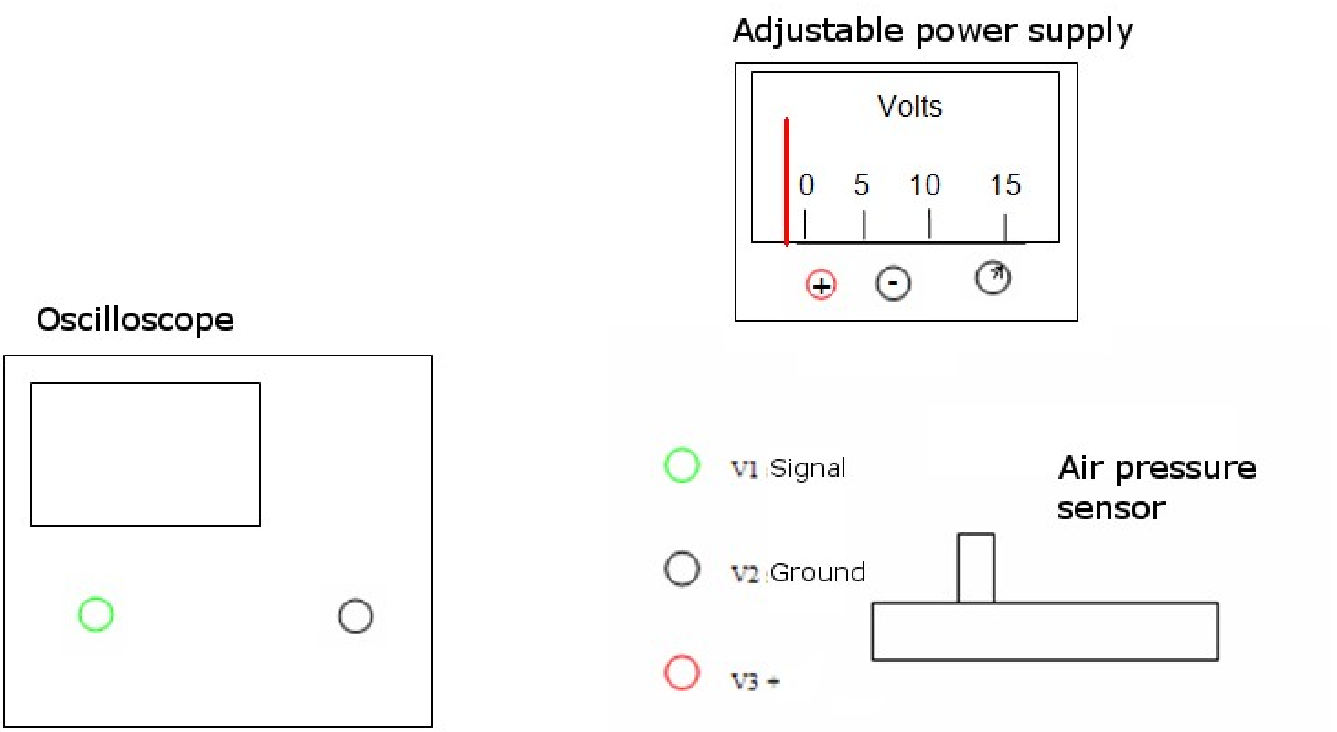
Indicate its main locations.

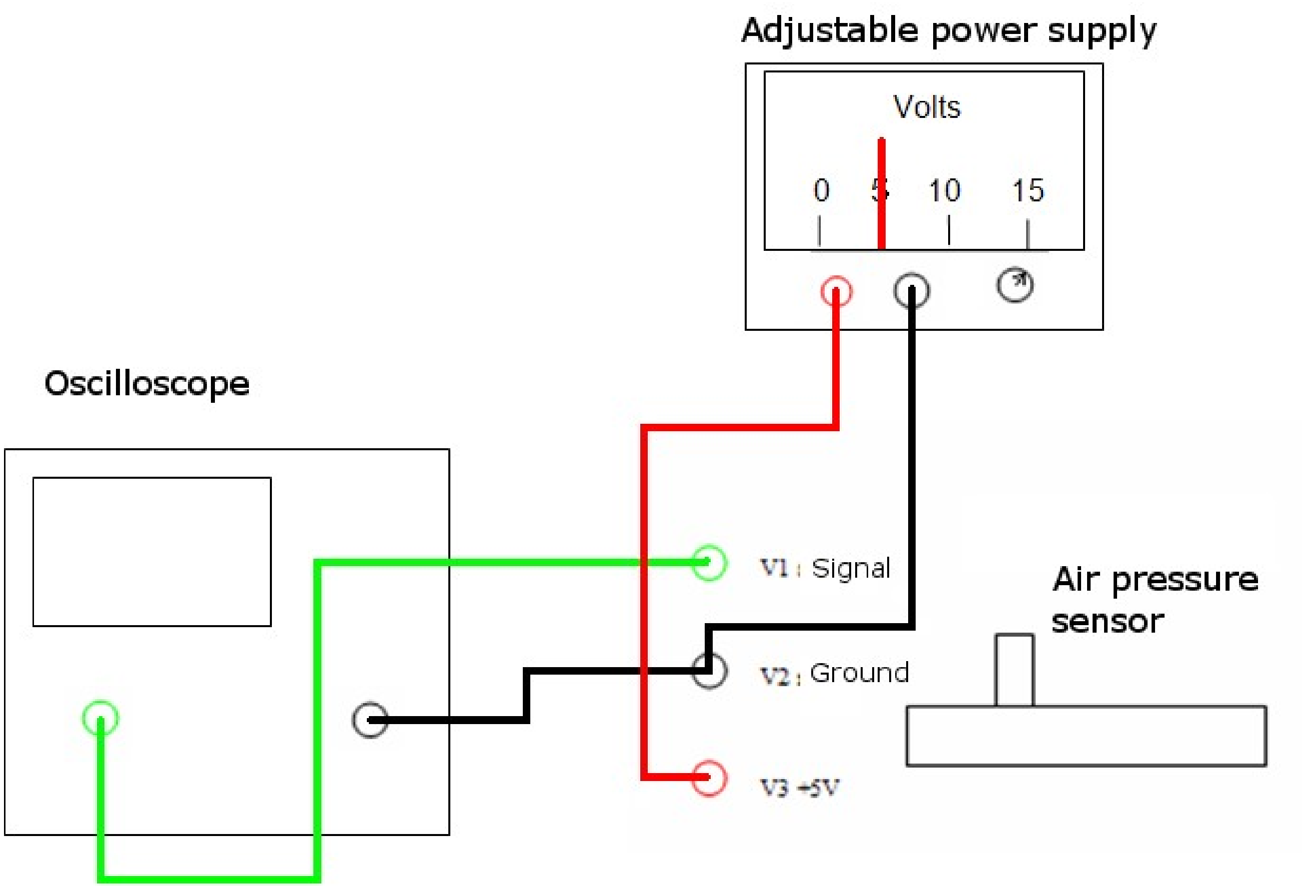
In the intake manifold (behind the throttle for petrol engines).

What is the supply voltage?

5 V.

Read the pressure sensor signal with an oscilloscope. Complete the wiring diagram below. Move the power supply indicator.






Give the oscilloscope calibration:

Create a vacuum with a vacuum gun. What does the oscilloscope show?

Conclude:

## 3.2 The hot-film mass air flow meter

What is the role of the mass air flow meter?

To measure the quantity of air admitted in order to adjust the air/fuel mix.

Briefly indicate its operating principle:

The air flows through a variable-frequency hot-film sensor. The greater the air flow, the more the film temperature drops. The aim is to keep the hot film at a constant temperature. A variable-frequency voltage is applied for this purpose. The frequency required to maintain the film temperature will be interpreted by the engine ECU to determine the quantity of air admitted.

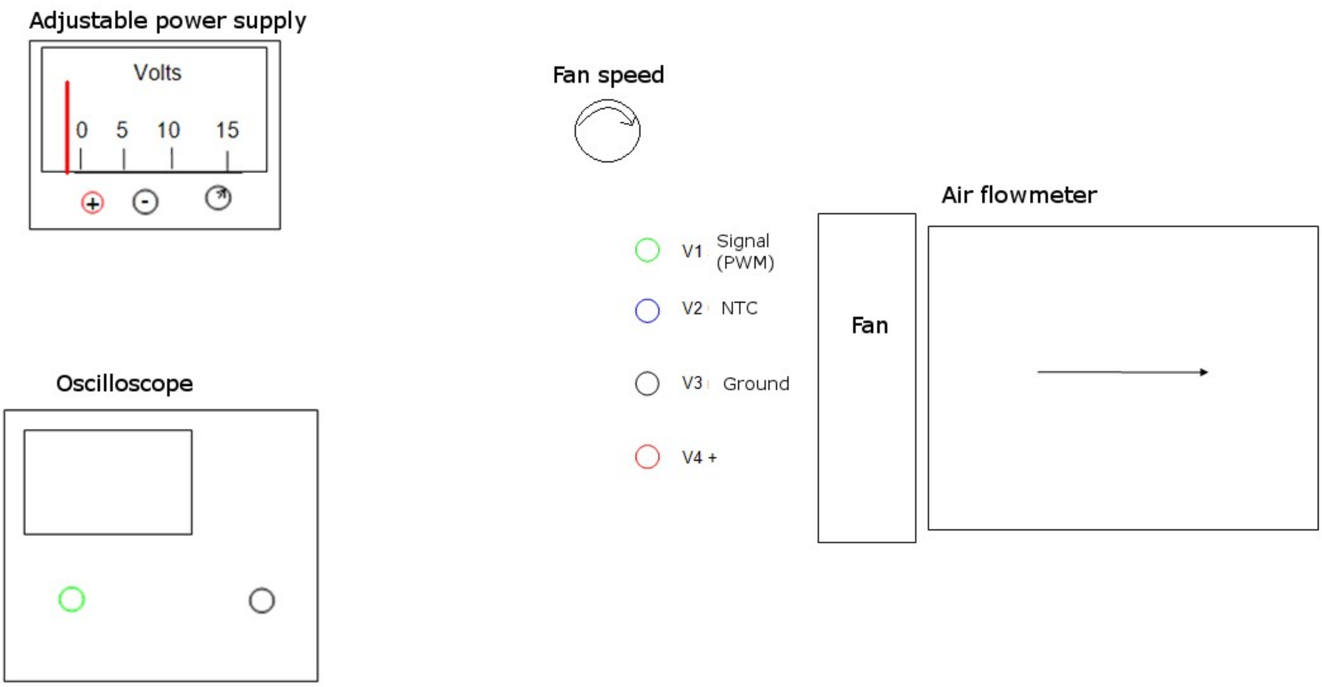
Indicate the sensor supply voltage:

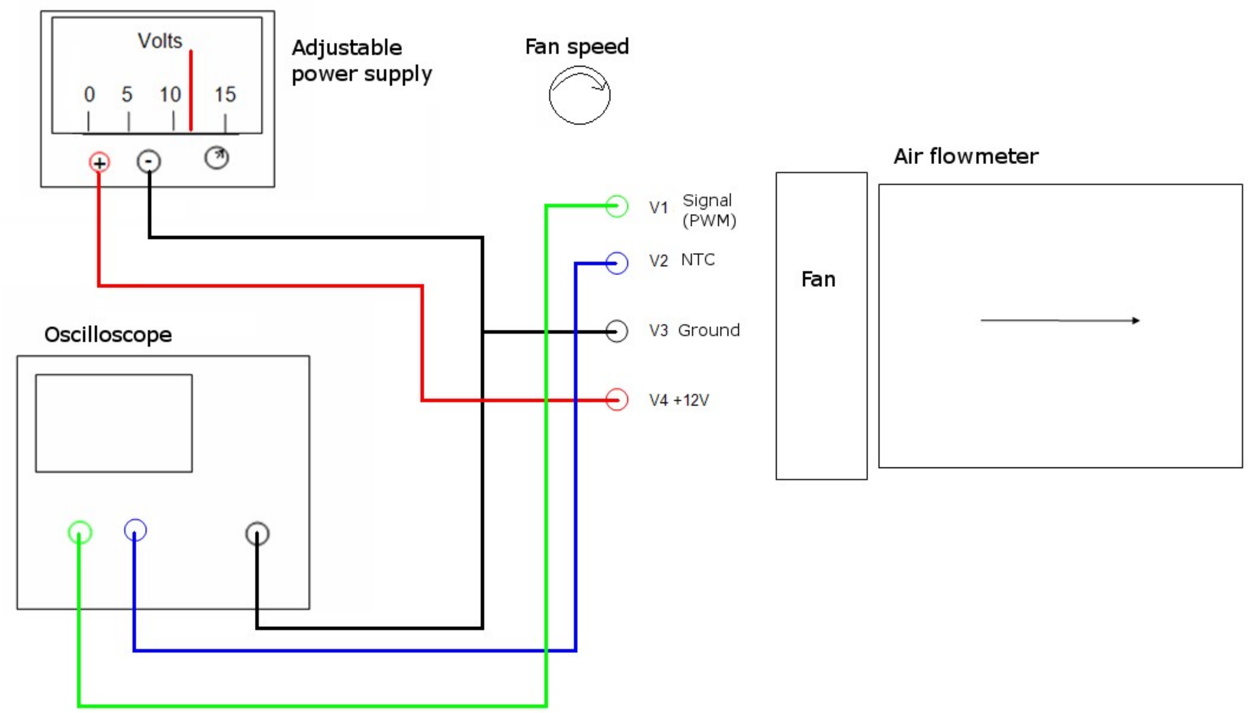
12 V.

Explain the presence of an NTC thermistor in the mass air flow meter.

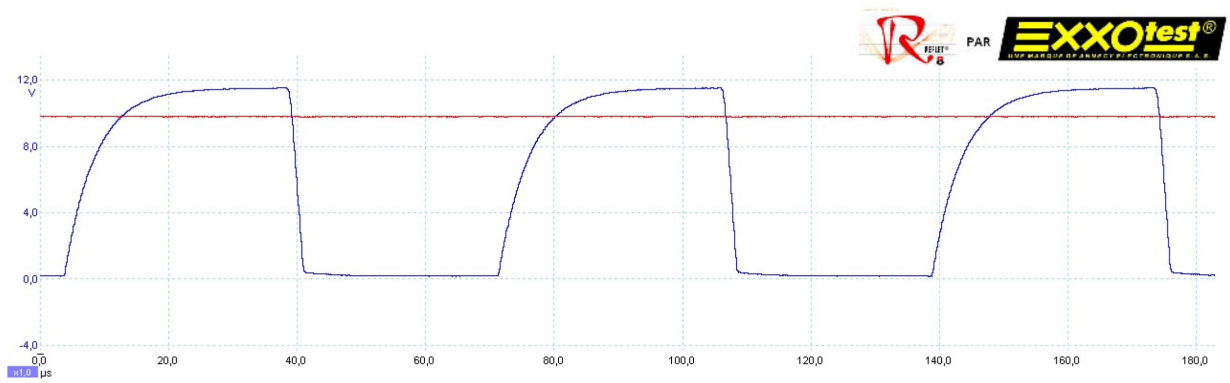
The air flow is measured while maintaining the hot film at a specific temperature. To improve measurement accuracy, it is important to know the actual temperature of the air flowing through the mass air flow meter as air density depends partly on its temperature.

To understand the control function, record the air flow signals and the air temperature at zero fan rotation speed and then at maximum speed.
Complete the wiring diagram below.

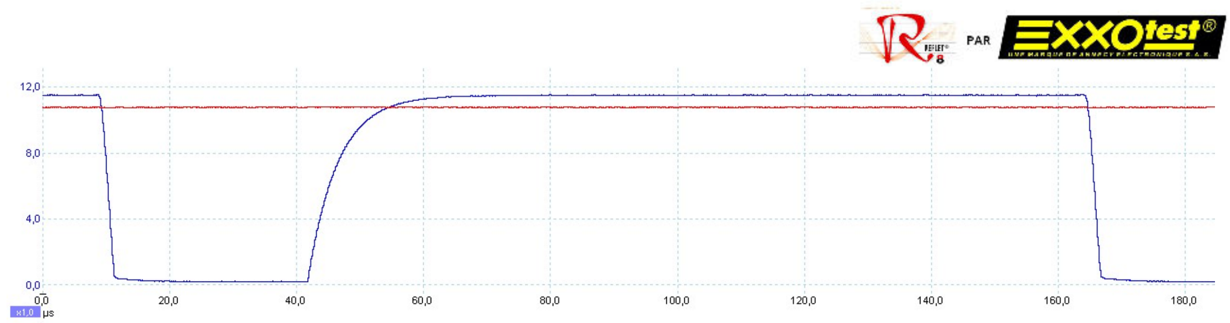





Record the two signals at zero speed:




Record the two signals at maximum speed:




Give the oscilloscope calibration on reading.

Comment on the curves and give the driving frequency of the minimum and maximum resistance:

Explain and indicate the difference between a variable-frequency drive (as is the case in our mass air flow meter) and an Open Cycle Ratio (OCR) or Pulse Width Modulation (PWM) drive (as may be the case for a canister solenoid valve, an air conditioning compressor, an electric fan unit control, an alternator charge information system or a pilot-controlled thermostat on the recent EP (Prince) range of engines).

To explain this, you can reuse the signals recorded previously and map what you do not have.

A Pulse Width Modulation (PWM) signal is a fixed-period signal. The period comprises a high edge and a low edge. The pulses have a fixed, set height. It is therefore the width of these pulses that varies within a given fixed period. PWM is often expressed as a percentage using the following formula:

$$PWM = \frac{Control\_time}{Period\_time} * 100$$

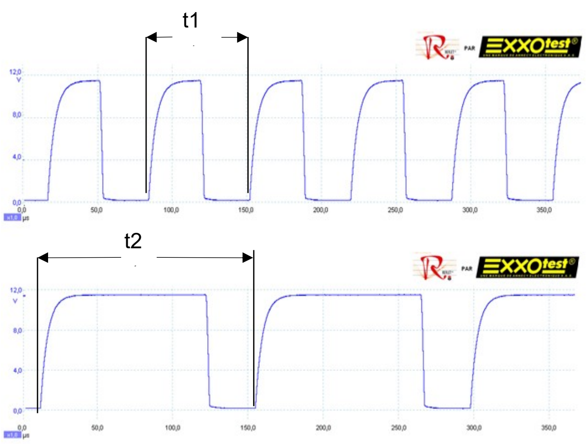
The average voltage of the signal will depend on this percentage.

In the case of a variable-frequency signal (as in our example of a mass air flow meter), it is the period time that changes. The signal will repeat identically within a variable lapse of time. The frequency is calculated as follows:

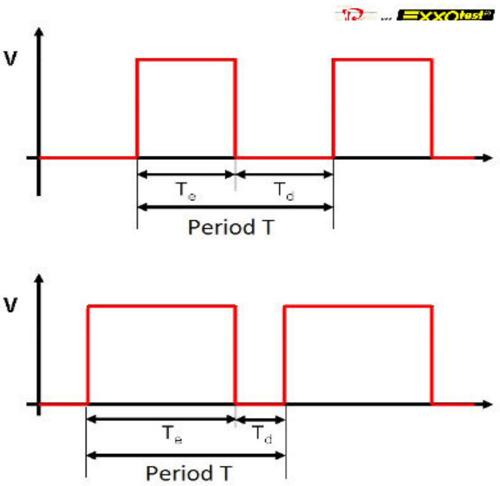
$$F = \frac{1}{t}$$

Where F is the frequency in hertz and t the period time in seconds.
The variation of the average signal voltage depends on this frequency (expressed in hertz).

Variable frequency




Variable PWM




Give the signal frequency (by calculation or using Reflet) for a zero air flow and for a maximum air flow.

$$F = \frac{1}{T}$$

$$\Rightarrow FD\min = \frac{1}{TD\min} = \frac{1}{0.75} = 1.33Hz$$

*and*

$$FD\max = \frac{1}{TD\max} = \frac{1}{0.145} = 6.9Hz$$

## 3.3 The intake air temperature sensor

Indicate the supply voltage of this sensor:
5 V.

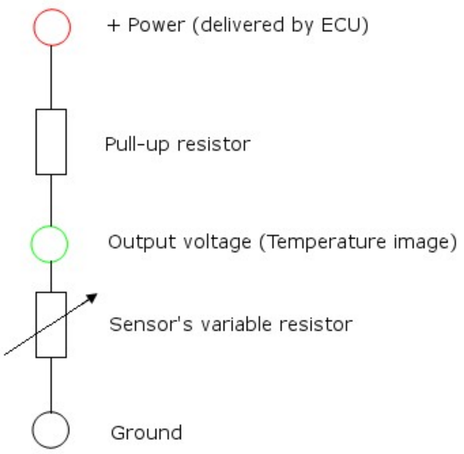
Explain the principle used for this sensor:

Given that, on recent engines, the temperature sensor is integrated into the mass air flow meter (diesel) or into the pressure sensor (petrol), find where the sensor you are viewing comes from and explain its utility:

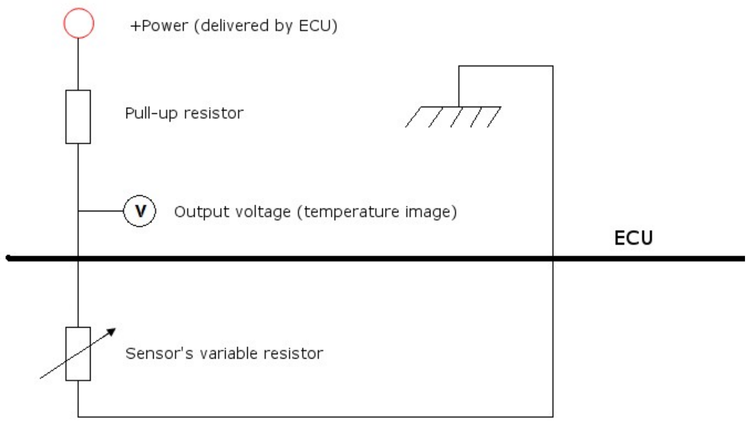
The sensor present on the model is a temperature sensor positioned at the turbo output. To finely adjust the mix on turbo engines, the ECU needs the intake air temperature and the turbo output temperature. By compressing the intake air, the turbo increases the temperature of the air that will enter the cylinders and thereby modifies its density.

The wiring diagram of the air temperature sensor is provided:

On the model:




On the vehicle:




Explain temperature sensor operation:

Which electrical principle is used?
Voltage divider bridge

Pull-up resistance is given as 10 kΩ.
It is admitted that sensor resistance takes the following three values according to temperature:
Sensor R1 = 5 kΩ
Sensor R2 = 10 kΩ
Sensor R3 = 20 kΩ

For these three values, calculate the voltage V and complete the table below:

| ***PULL-UP R*** | ***SENSOR R*** | ***V*** | ***TEMPERATURE*** |
|---|---|---|---|
| 10 kΩ | Sensor R1 = 5 kΩ | V1 = 1.667 V | Hot |
| 10 kΩ | Sensor R2 = 10 kΩ | V2 = 2.5 V | |
| 10 kΩ | Sensor R3 = 20 kΩ | V3 = 3.33 V | Cold |

The calculation must be detailed for at least one of the examples:

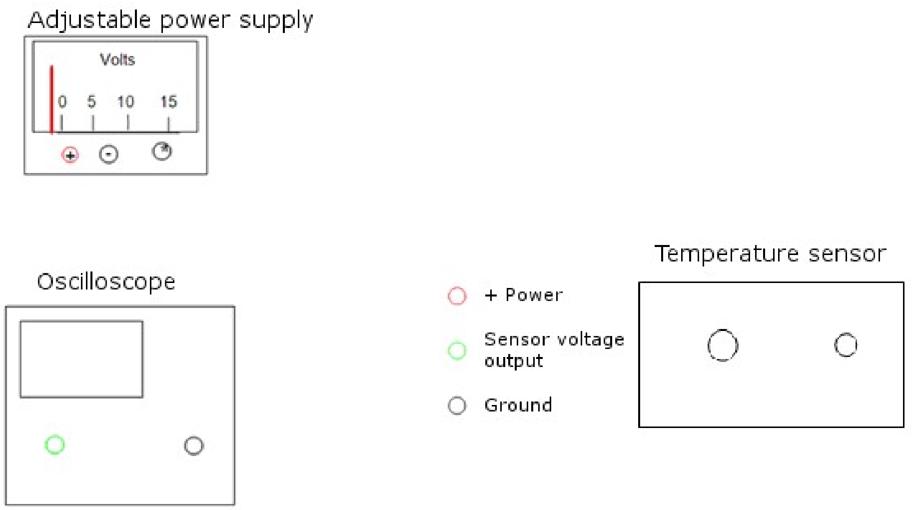
$$V = V\sup ply * \frac{Rsensor}{Rpullup + Rsensor}$$

$$\rightarrow V2 = 5 * \frac{10k\Omega}{10k\Omega + 10k\Omega} = 5 * \frac{1}{2}$$
$$\Leftrightarrow V2 = 2.5V$$

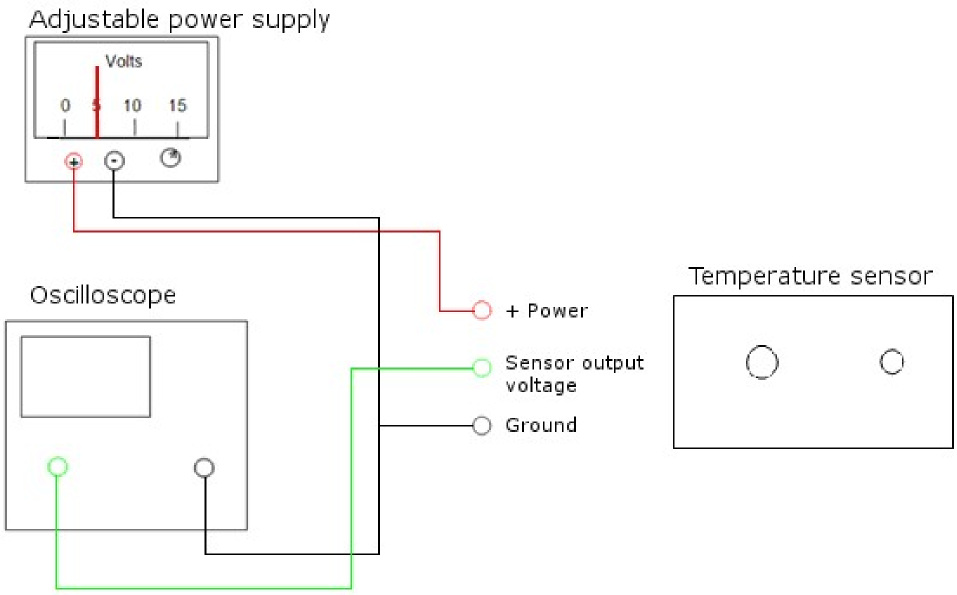
$$\Leftrightarrow V1 = 5 * \frac{5k\Omega}{10k\Omega + 5k\Omega} = 5 * \frac{1}{3}$$
$$\Leftrightarrow V1 \approx 1.667V$$

$$\rightarrow V3 = 5 * \frac{20k\Omega}{10k\Omega + 20k\Omega} = 5 * \frac{2}{3}$$
$$\Leftrightarrow V3 = 3.3V$$

Record the voltage levels (either using the oscilloscope or the voltmeter). Complete the diagram below:




Correction:




A hot-air gun can be used briefly to heat the sensor and alter the temperature.

Based on the tuition component and your measurements, is this an NTC or a PTC thermistor? Note Hot or Cold opposite sensor R1 and sensor R3 in the temperature column.

Based on the readings, it is an NTC (Negative Temperature Coefficient) thermistor as the voltage drops when the sensor is heated.

Give the voltage thresholds reached during your operations.

# CE DECLARATION OF CONFORMITY

By this declaration of conformity under the terms of Electromagnetic Compatibility Directive 2004/108/EC:

**ANNECY ELECTRONIQUE S.A.S**
**Parc Altaïs - 1 rue Callisto**
**F-74650 CHAVANOD**

Declares that the following product:

| Make | Model | Description |
|---|---|---|
| **EXXOTEST** | **DT-M004** | **Benchtop learning module** for measuring the characteristics of air |

**I - has been manufactured in accordance with the requirements of the following European directives:**

- Low Voltage Directive 73/23/EEC of 19 February 1973
- Machinery Directive 98/37/EC of 22 June 1998
- Electromagnetic Compatibility Directive 2004/108/EC of 15 December 2004

*and complies with the requirements of standard:*

- EN 61326-1:1997 + A1:1998 + A2:2001
  Electrical equipment for measurement, control and laboratory use. EMC requirements.

**II - has been manufactured in accordance with the requirements of European directives relating to the design of Electrical & Electronic Equipment (EEE) and the management of Waste Electrical & Electronic Equipment (WEEE) in the EU:**

- Directive 2002/96/EC of 27 January 2003 on waste electrical and electronic equipment
- Directive 2002/95/EC of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment.

Signed in Saint-Jorioz on 24 July 2007

Stéphane Sorlin, Chairman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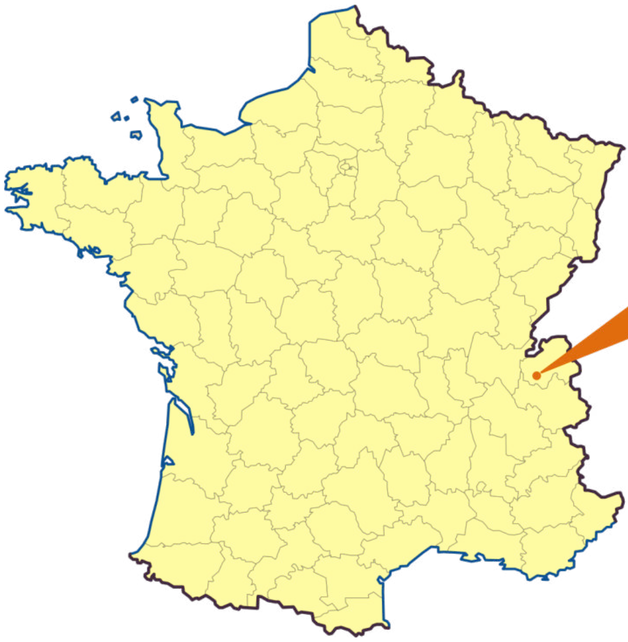


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Parc Altaïs - 1 rue Callisto - F 74650 CHAVANOD – Tel. +33 (0)4 50 02 34 34 - Fax: +33 (0)4 50 68 58 93
S.A.S. with capital of €276,000 - RC ANNECY 80 B 243 - SIRET 320 140 619 00042 - APE 2651B - VAT No. FR 37 320 140 619
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