User's guide for DT-M008

Benchtop Learning Module

MOTOR VEHICLE ALTERNATOR

EXXOTEST EDUCATION

DM No. 00308623-v1

1. THE ALTERNATOR

1.1. History

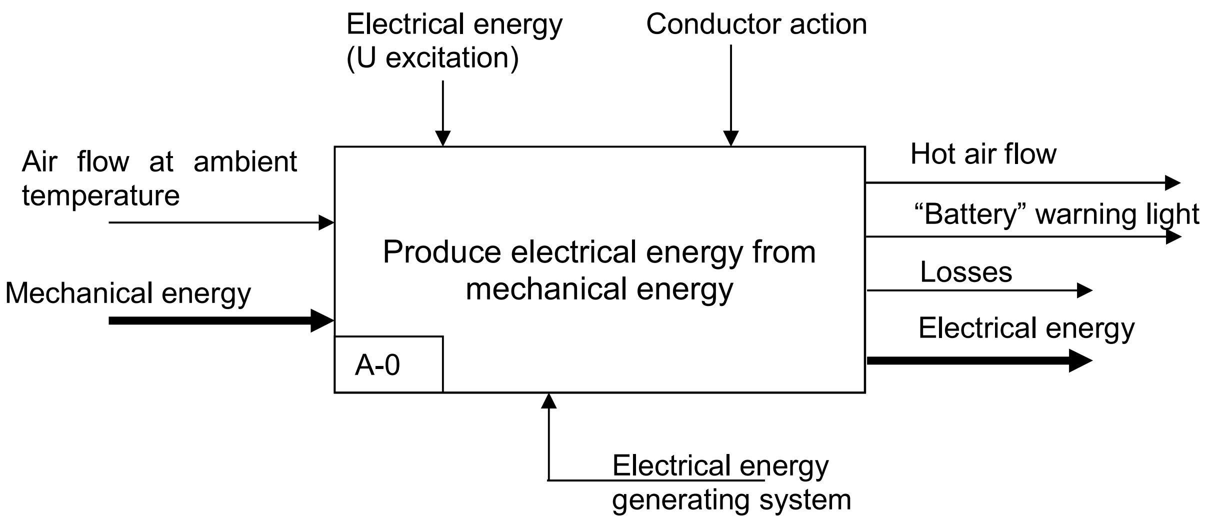
Batteries came into general use with the introduction of electric starting motors on cars. For more than fifty years, the automotive industry relied on dynamos to recharge the batteries with direct current.
The alternator system was already widespread in heavy-duty industrial applications. However, adapting the technology to the technical constraints of motor cars in an era when electrical energy requirements were relatively low proved to be too complicated. Indeed, converting the alternating current supplied by the alternator to the direct current required by the battery posed a real problem.
However, with the introduction of new electrical consumers such as double headlamps, radios, electric windows and passenger compartment fans in the 1960s, the dynamos of the day soon reached their limits. They barely managed to produce 400 watts from an engine speed of 1500 rpm, a situation that was especially problematic in towns. The solution lay in adapting the alternator to the demands of the motor car.
This technical transformation was made possible by the use of new conductive materials resulting in reliable current rectification within a smaller footprint.
Chrysler was the first carmaker to market a production vehicle with an alternator when the new Valiant appeared in 1961. The Europeans soon followed suit with the support of Bosch and Ducati, a manufacturer of electrical accessories at the time. In 1963, Fiat introduced the 2300Luxe and Mercedes the new 600, both equipped with alternators. The move to the new technology was under way.

1.2. Role

The purpose of the alternator is to generate DC voltage in excess of 14 volts.
When the engine is running, it supplies electrical energy to:

- ✓ the vehicle's electric circuit (all consumers)
- ✓ the battery (recharging and holding the charge)

In normal operation (engine running), the alternator is capable of energising all the consumers and can do without the battery.
In reality, apart from providing the power for the starting motor drive, the battery acts as a "buffer" and helps maintain constant voltage throughout the electrical system.
<u>General function</u>

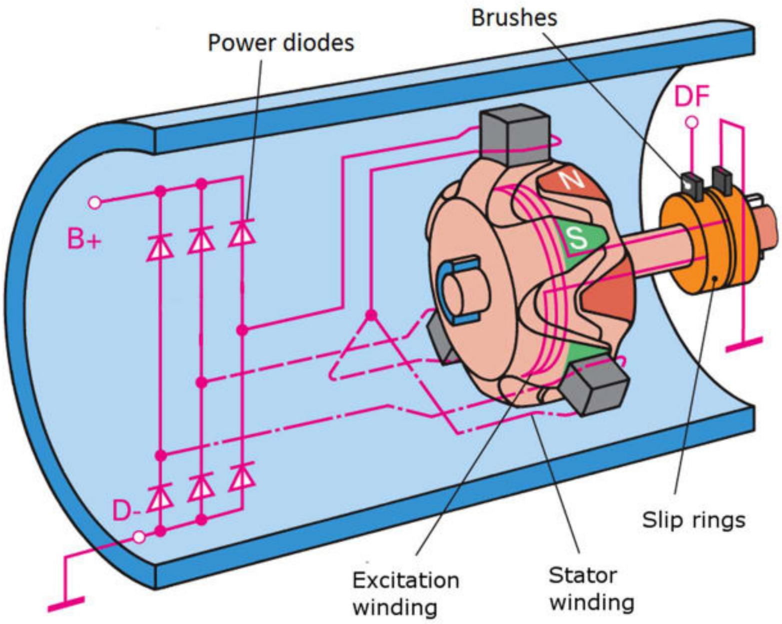


1.3. Basics of electromagnetism

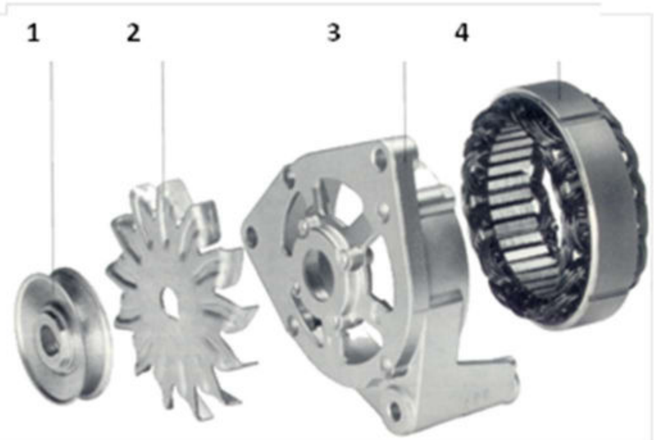
Principle

When a magnetic field varies in the presence of a winding, a voltage is induced across the winding terminals.

In a motor vehicle alternator, the magnetic field is generated by the ***rotor*** (rotated by the engine), and voltage is produced in the ***stator*** (fixed to the alternator body and therefore "static"). This current is then rectified by the rectifying diodes or diode bridge.



1.4. System components

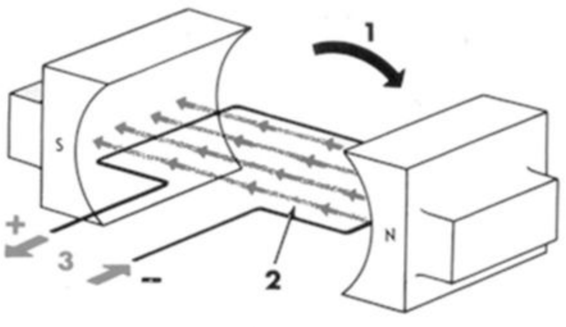


Number	Description	Number	Description
1	Drive pulley	5	Rotor
2	Centrifugal fan	6	Rectifier
3	Front housing	7	Rear housing
4	Stator	8	Brush holder/regulator

Number	Description
1	The pulley transmits mechanical power to the rotor and adjusts the alternator's rotational speed to that of the engine. The step-up ratio varies from 2 to 3, depending on the setup, to produce a higher alternator speed and thus allow sufficient current to be generated even at low engine speed.
2	The fan ventilates the alternator to counter the rise in temperature that occurs on high current flows. Its peculiarity is that it is a centrifugal fan (the air enters through the rear and is forced out from the centre).
3	The front housing forms the alternator casing and supports the assembly.
4	The stator is the actual source of current. It generally comprises three star- or delta-connected windings which, when subjected to the rotating field of the rotor, deliver AC voltage.
5	The purpose of the rotor is to subject the stator to a rotating magnetic field. It comprises a field winding with the function of creating a polarity. This field winding is surrounded by two claw-type finger poles that slot together alternately around the rotor.
6	The rectifier bridge converts the three-phase output current into direct current.
7	The rear housing has a connector to which the outputs of the stator windings and the two alternator outputs are connected. It supports the six rectifier diodes and the three excitation diodes (for mono-function regulators).
8	The brush holder/regulator supplies an excitation current to the rotor that depends the output voltage of the alternator. It varies the field produced by the rotor by modulating the current flowing through it and must control the activation of the warning light in the event of a malfunction.

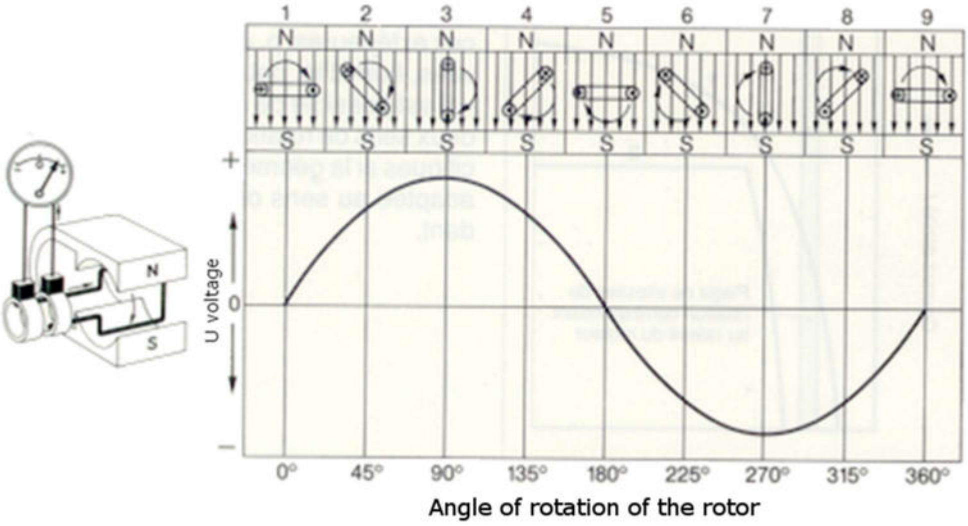
1.5. Conversion of mechanical energy into electrical energy

The alternator principle is based on the fact that the displacement of a conductor in relation to a magnetic field generates a voltage across its terminals. In this case, the conductor rotates in a magnetic field.

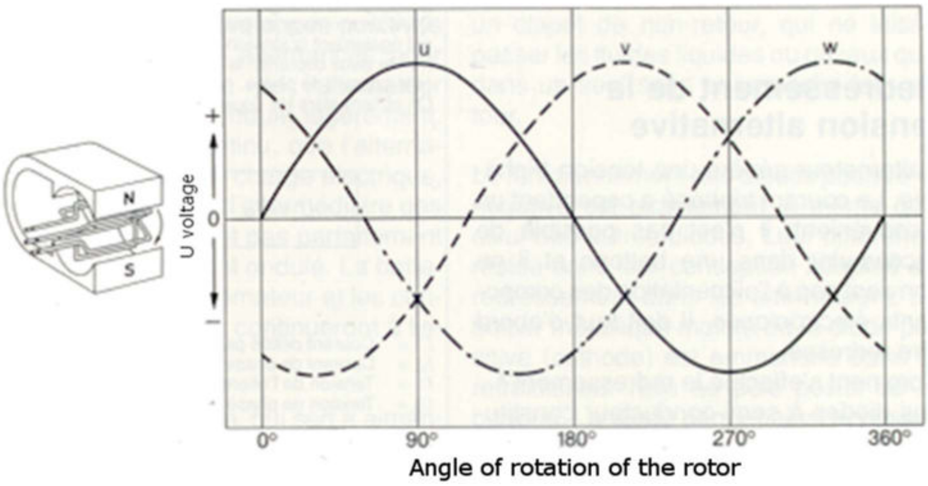


Number	Description
1	Loop rotation
2	Field line
3	Induced voltage

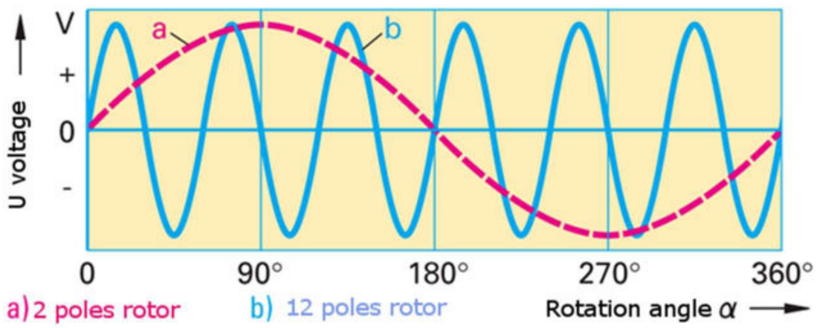
Change in voltage according to conductor position.



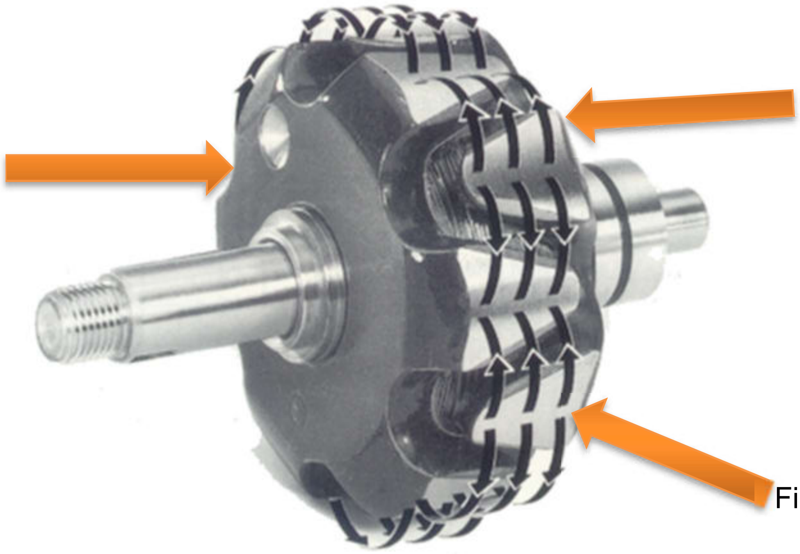
The conductor position illustrated on the left corresponds to the third scenario in the table.
Below, three conductors (U,V,W) rotate within the same magnetic field but offset by 120° in relation to each other:



The cycle defined above corresponds to a three-phase winding rotating in a two-pole magnetic field. However, an alternator rotor comprises between twelve and sixteen poles, multiplying the number of waves per revolution.

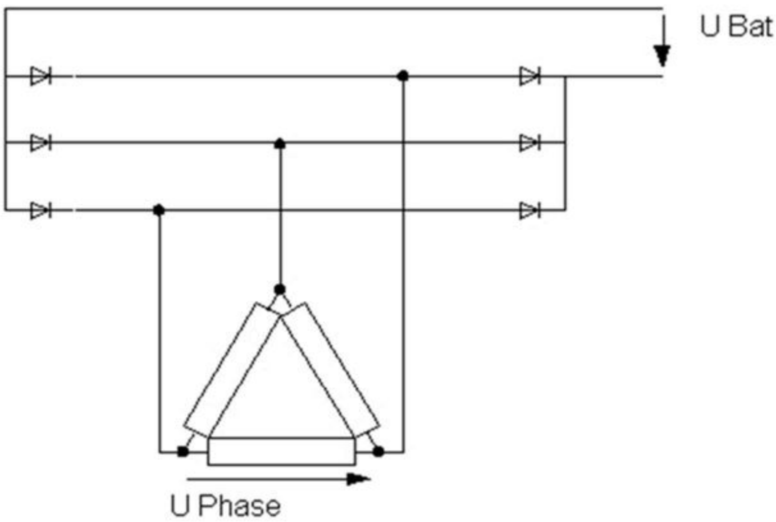


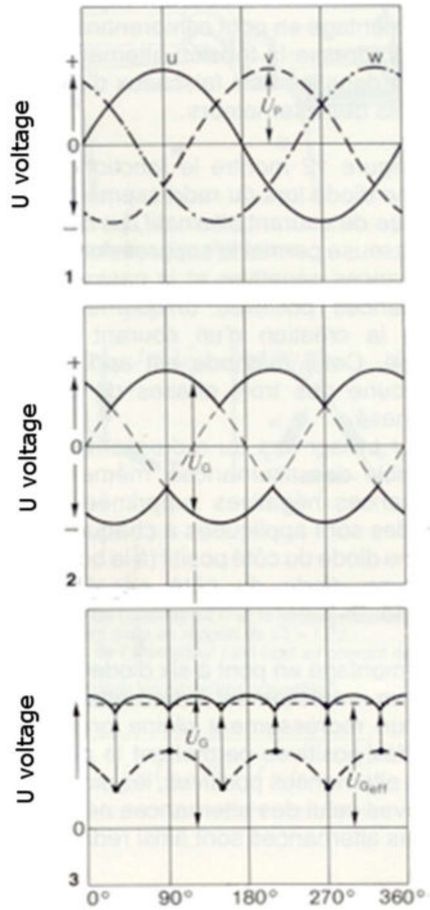
Detail of rotor field lines



1.6. Conversion of alternating current into direct current

This operation consists in rectifying the negative half-waves of the three-phase current. The result is not a perfectly flat current. It is slightly rippled. The battery absorbs these ripples and the current becomes usable. The diagrams below show the rectifier bridge mounted at the stator output and the transformations on the negative ripples.

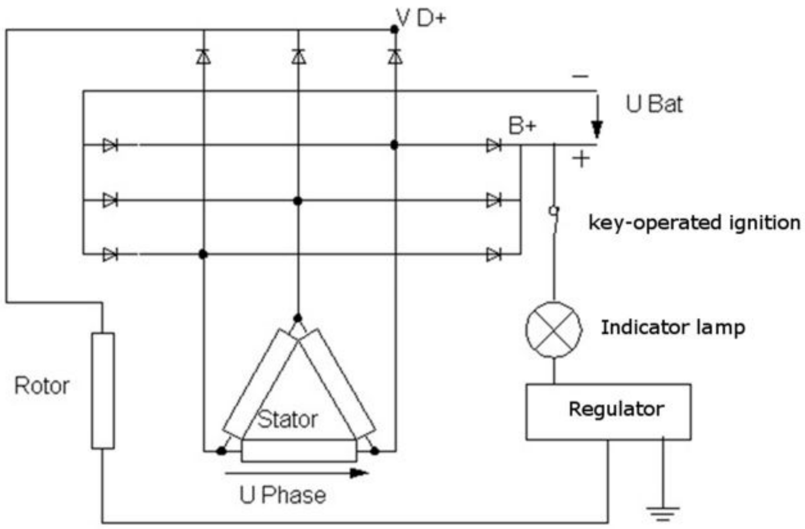




1.7. Charge voltage regulation

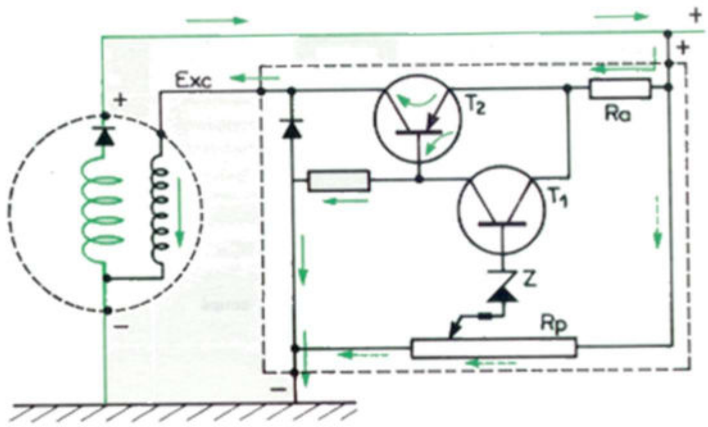
The alternator regulator adjusts the current output by the alternator to consumer needs by holding its output voltage at a setpoint value. To do this, it measures the alternator output voltage and compares it to a reference value.
Current consumption induces a drop in voltage across the battery terminals and, therefore, across the alternator terminals. The regulator then commands the current required to maintain a correct voltage level. This regulates the voltage applied to the rotor. The alternator output is therefore under constant voltage, thus guaranteeing a current output that is equal to the requirement.
Mechanical regulators have been replaced by electronic regulators that offer numerous advantages including reliability, shock resistance, footprint, wear and response time.

Regulation involves controlling the rotor ground. The rotor current is taken at the stator output and rectified. It receives only positive half-waves as there are no negative diodes.



Operating principle of an electronic regulator

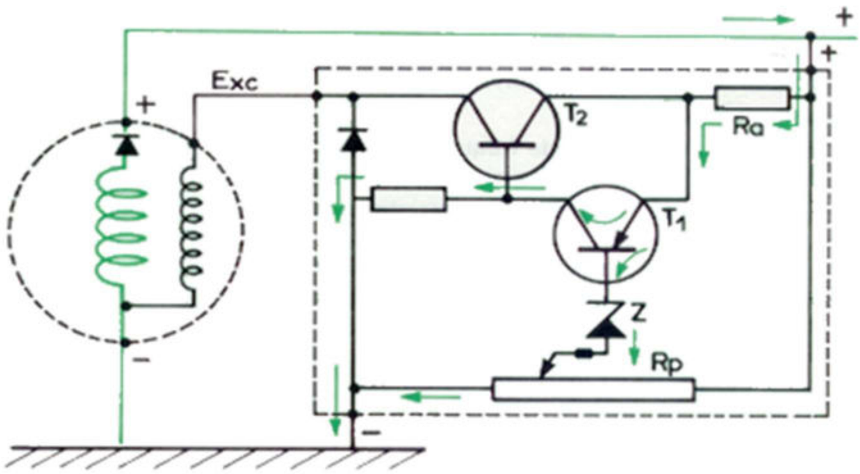
The following diagrams indicate the simplified operation of a basic regulator. The illustration below shows a conducting regulator, and the one on the next page a non-conducting regulator.



CONDUCTING REGULATOR

In this configuration, the battery voltage is below the normal threshold, the Zener diode is non-conducting, T1 is non-conducting and the T2 base is grounded. T2 is conducting and the rotor is energised.

No.	Description
T1	PNP transistor (conducting when the base is negative)
T2	PNP power transistor
Ra	Input resistor (short circuit protection)
Rp and RA	Voltage divider with the purpose of adjusting the setpoint voltage to the Zener voltage

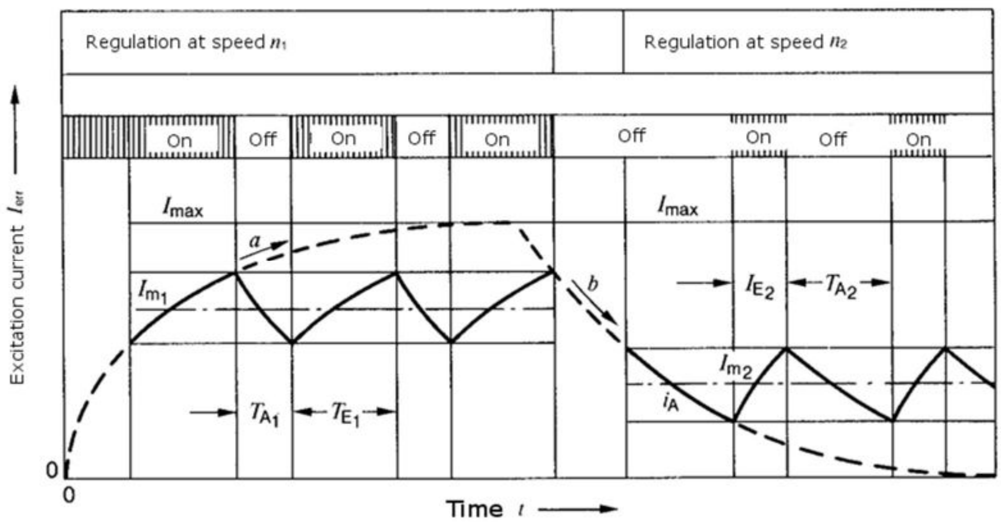


NON-CONDUCTING REGULATOR

The voltage threshold is reached, the Zener diode is conducting in the inverse direction, T1 is conducting and the base is (+). It is therefore non-conducting and excitation is nil.

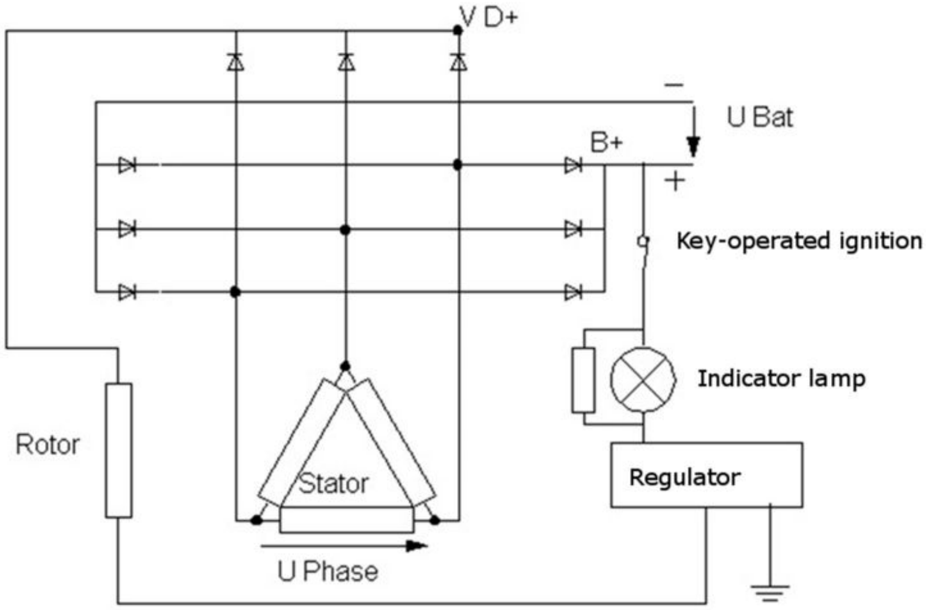
The excitation voltage has a chopped voltage pattern when operating conditions are "normal" (the alternator is able to fulfil the current demand). If this excitation voltage is constant, the alternator is full-fielded and produces maximum output. This phase can occur after starting (especially at low rpm) but must not last long.

Excitation current pattern at two different speeds



The pattern of this current is due to the fact that the current flows through a winding and is not instantly established. The current increase is represented by curve A, and the current decrease by curve B.
Imax is the maximum excitation current; the maximum current curve follows the dashed lines.
The solid line corresponds to alternator output regulation; it is the current flowing through the rotor. This is illustrated for two speeds and it can be seen that, for the same load, at higher rpm, the excitation current falls as the alternator output increases with speed.
Various types of electronic regulator can be found. Mono-function regulators are the most widespread and are recognisable from their wiring illustrated below.

Mono-function regulator setup

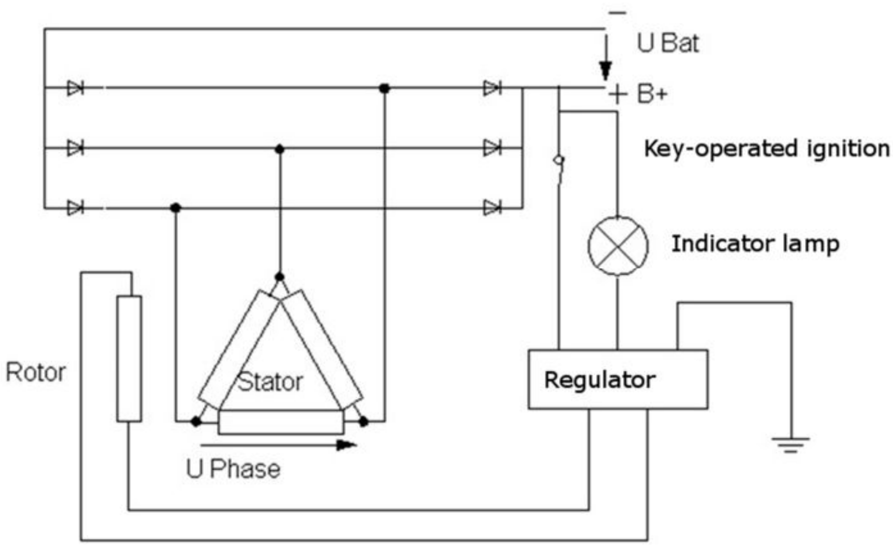


On this type of setup, the warning light is lit when there is a potential difference between V+ and B+:

- When the alternator is not running
- If the rotor is grounded
- If the alternator output is insufficient

In most cases, the warning light is mounted with a resistor in parallel. This starts the rotor on ignition.

Multifunction regulator setup



In this case, the regulator is subject to an ignition positive and controls rotor energisation and warning light activation.

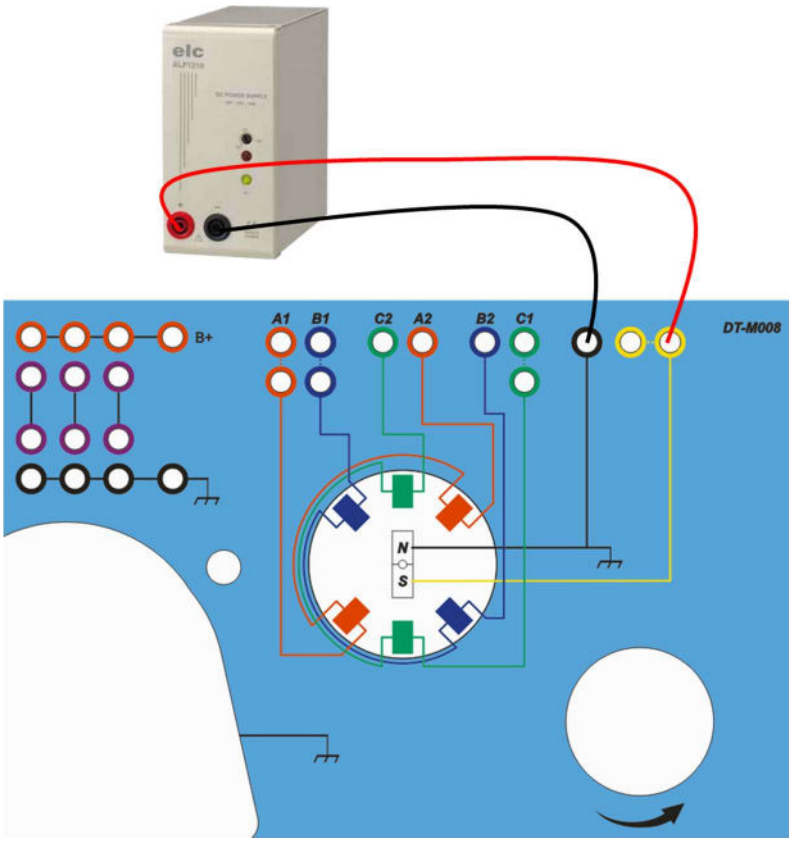
2. USER FILE

2.1. Benchtop learning module DT-M008

This module is designed for detailed study of alternator operation. Trainees can use this module to analyse the transformation of mechanical energy into electrical energy, measure AC voltage and then rectified voltage (removable diode bridge), and study the wiring of star and delta arrangements.
Sockets are provided on the module upper panel for the various wiring configurations. The user can simulate engine rotation using the handle (manual alternator drive) and read the various measurements across the components' terminals.

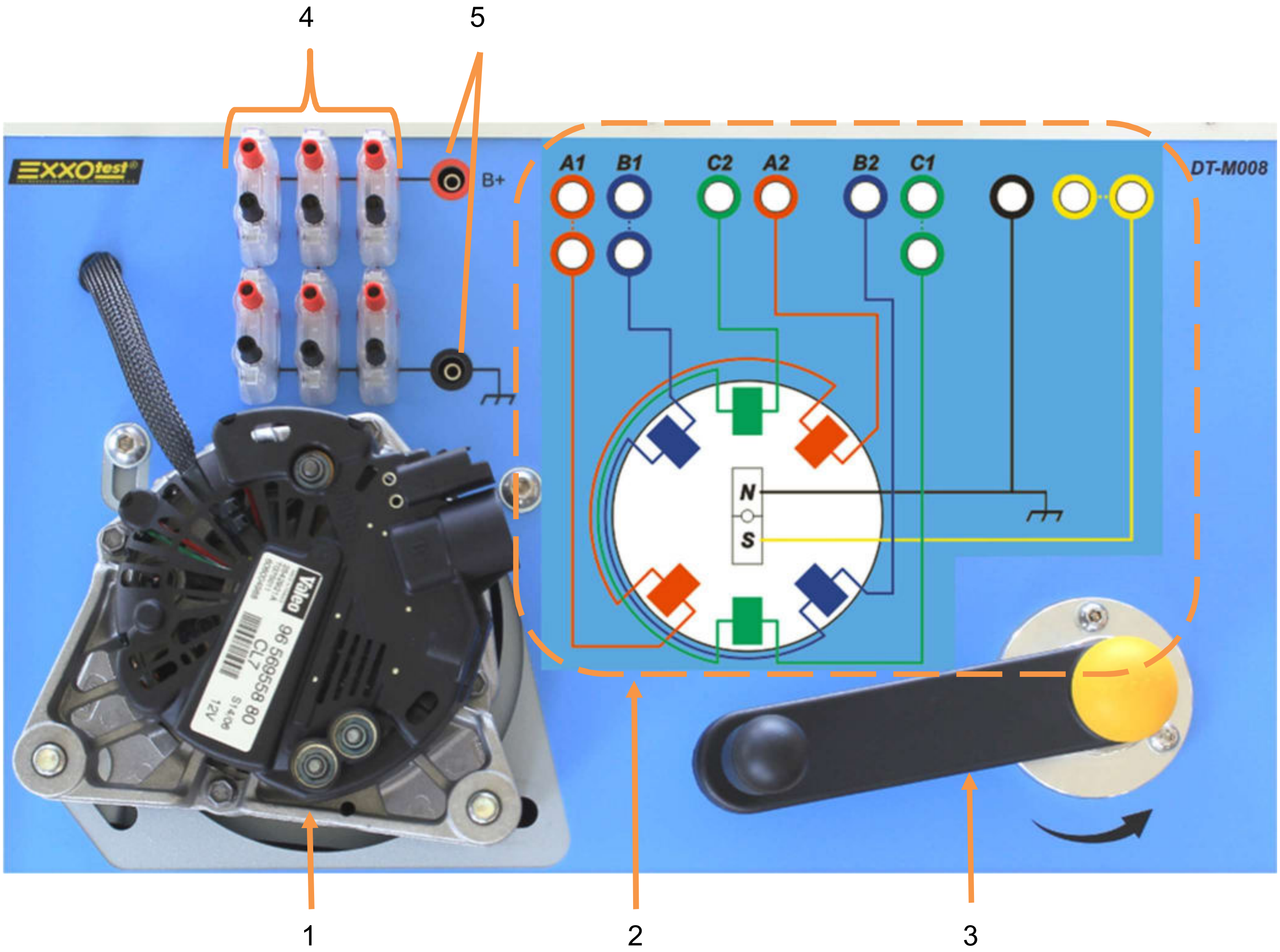
2.2. Using the module

<u>Installation and operation</u>
Use the ELC ALF1210 (12 V – 10 A) power supply unit provided. Connect the power supply unit to the 230 V mains supply. Check the switch position (0) and voltage selector (12 V).
Connect the power supply + and GND outputs to module DT-M008 using the two cables provided.
Proceed with wiring the module, then switch on the power supply unit (switch to position 1).



2.3. Wiring the module

Description

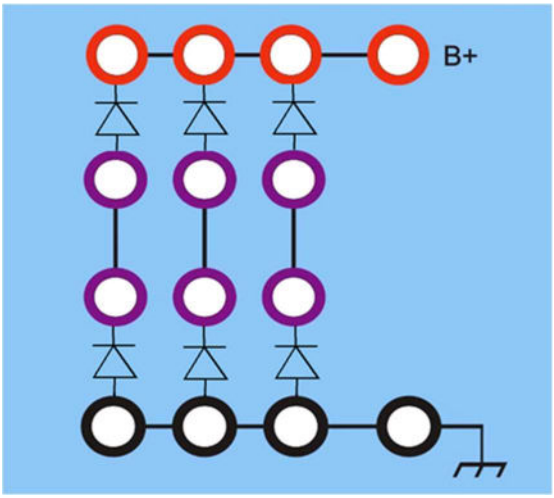


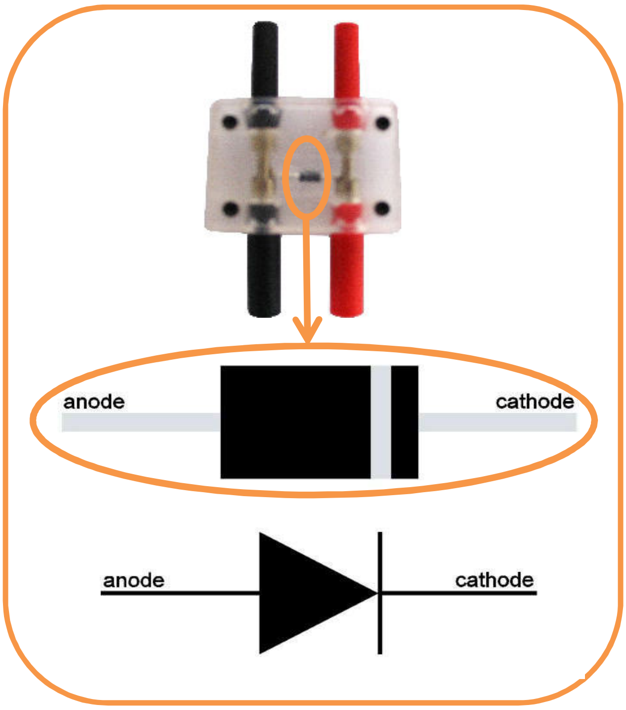
Number	Description
1	**Alternator**: initially a delta arrangement with the regulator removed.
2	Schematic of the **rotor** (magnet in the centre) and **stator** (blue, green and red windings). **A1**, **B1** and **C1** identify the "input" of each winding, while **A2**, **B2** and **C2** indicate the "output". The two top right sockets are used to connect the rotor power supply.
3	**Handle** to rotate the alternator drive
4	**Diode bridge**
5	**Alternator output** (rectified voltage)

Caution: the sockets linked in the schematic by dashes are not connected electrically. They are initially provided for the use of an ammeter.

2.4. The rectifier diodes

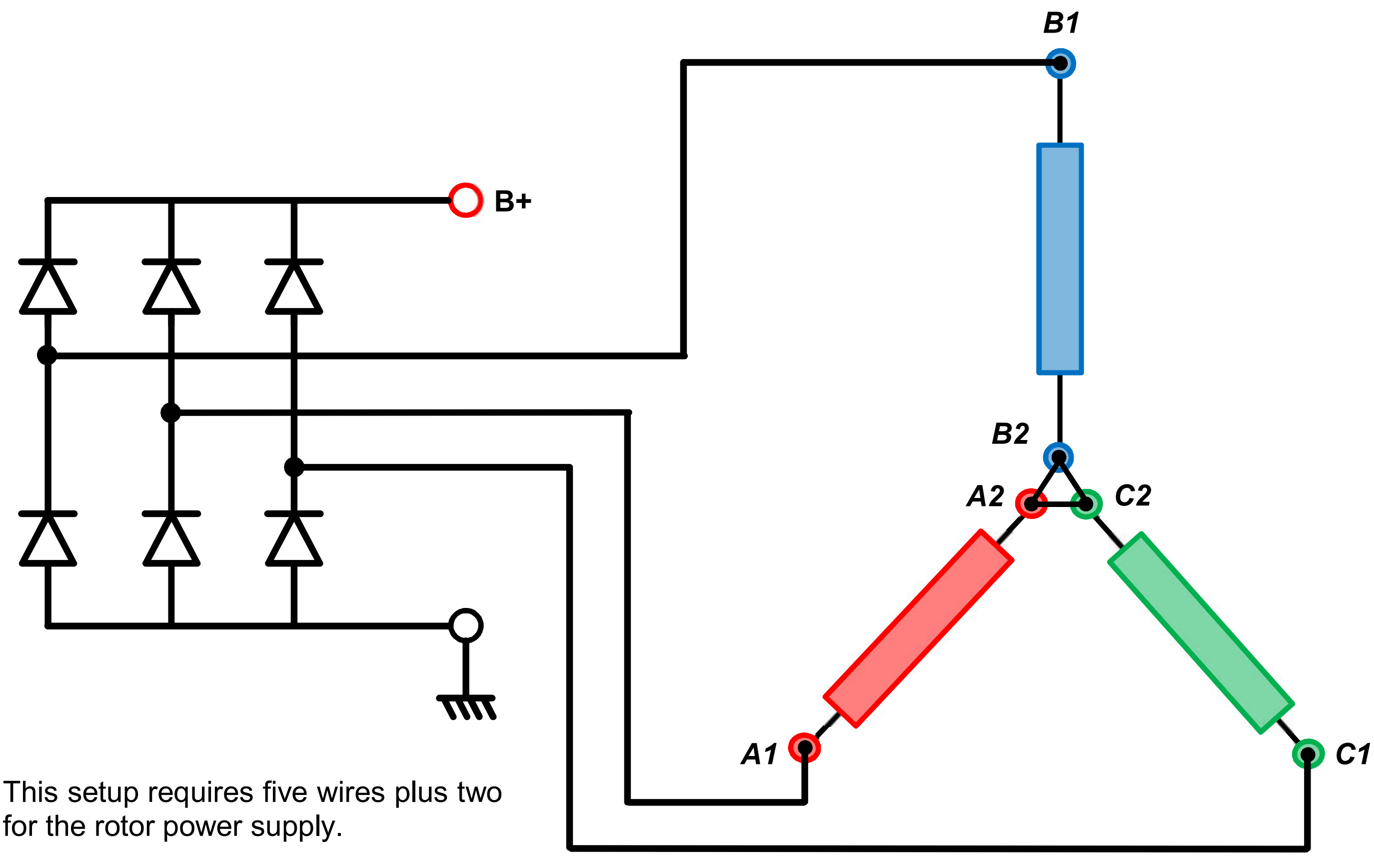
When setting up the diode bridge, pay attention to the polarity of the diodes.





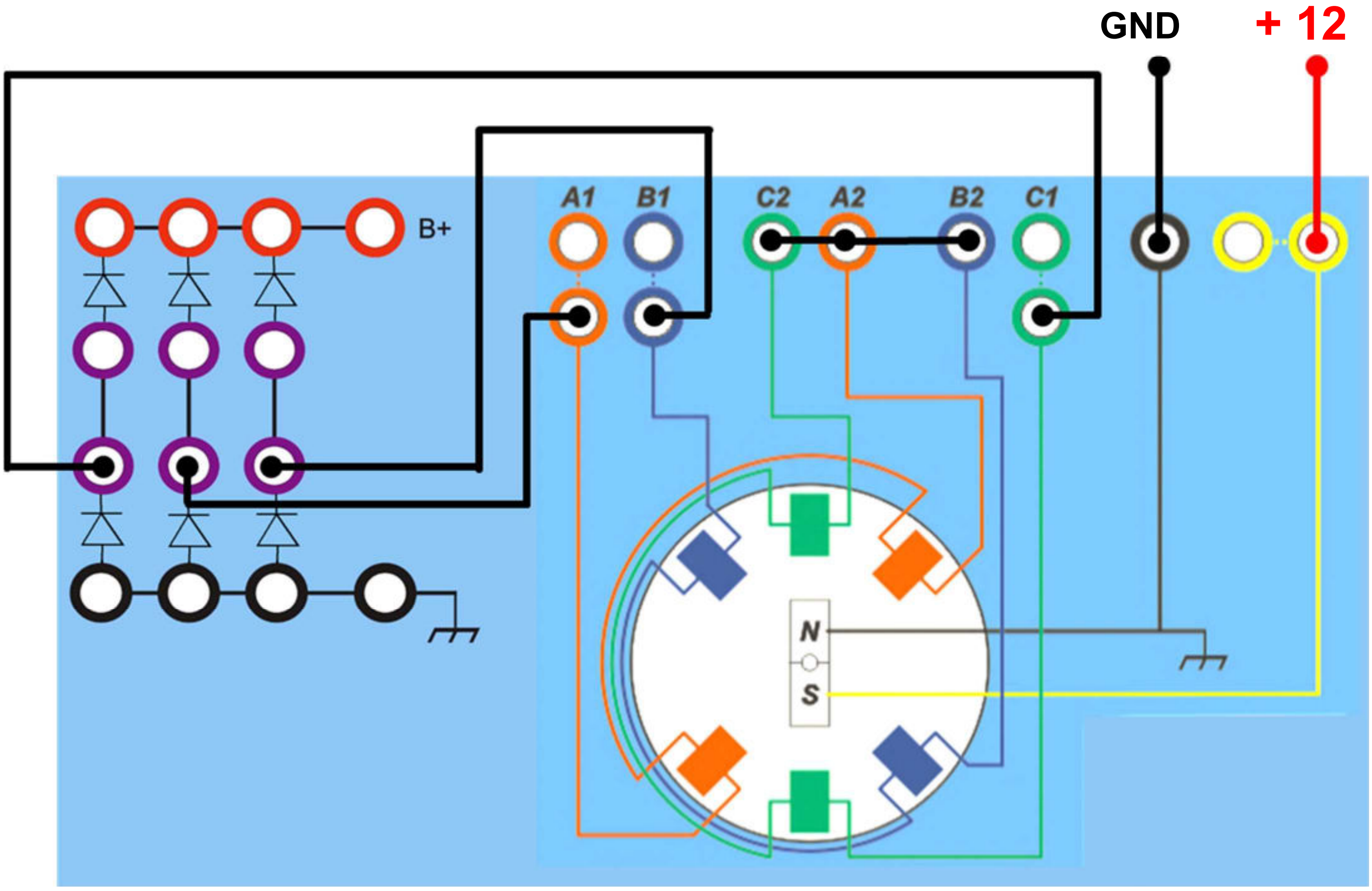
The red terminal of the diode is oriented to terminal B+, and the black terminal to ground.

2.5. Star arrangement of the stator windings



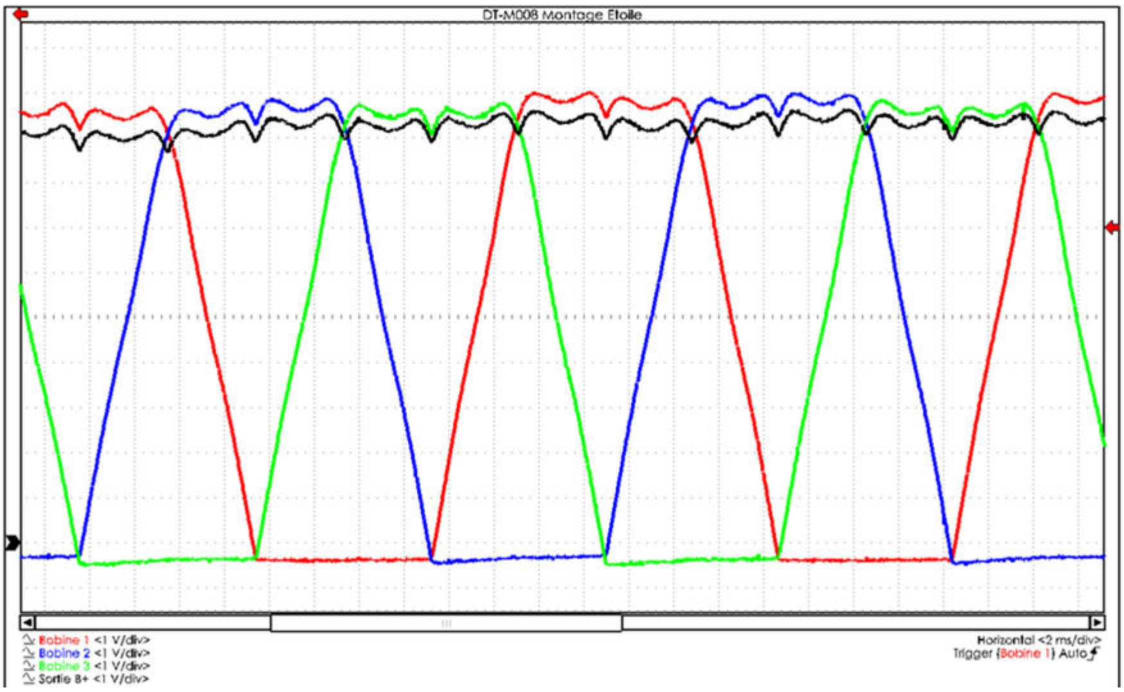
This setup requires five wires plus two for the rotor power supply.

The three terminals linked together form a mid point. The other three terminals are wired with the three phase conductors.

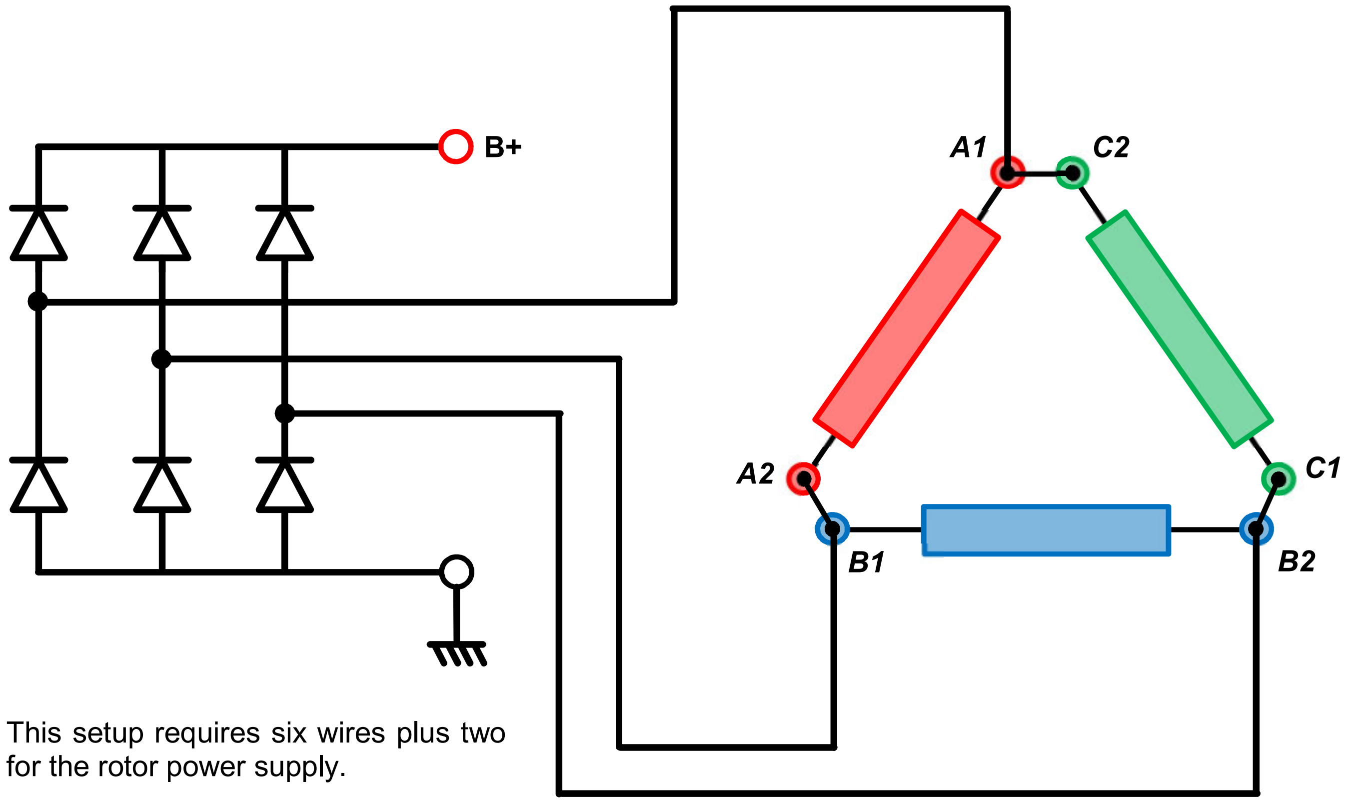


Example of an oscilloscope reading of the star arrangement using Reflet software.

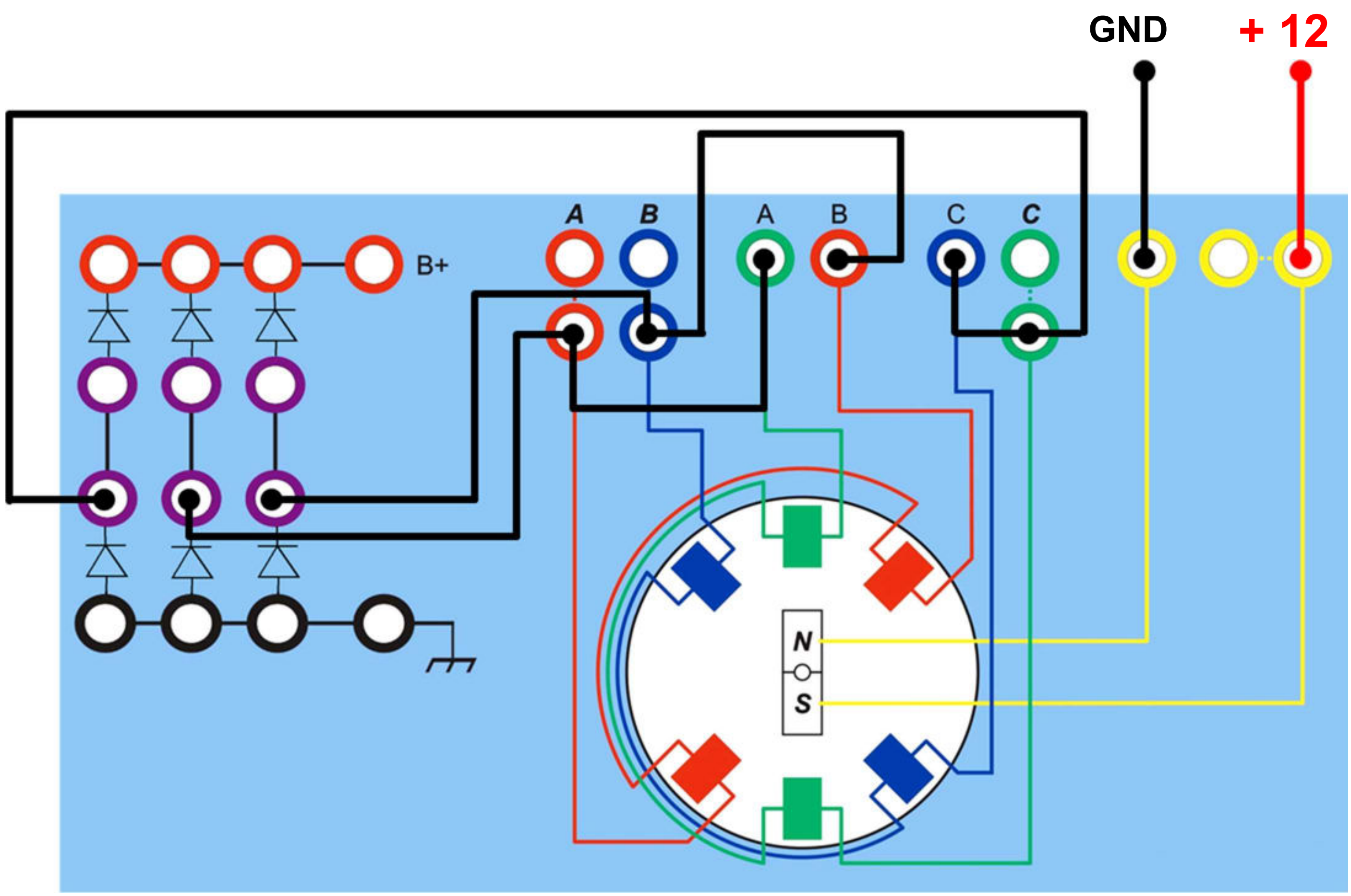
Oscilloscope channels 1, 2 and 3 are connected to each of the three phases (terminals A1, B1 and C1) and channel 4 is connected to diode bridge output B+.



2.6. Delta arrangement of the stator windings

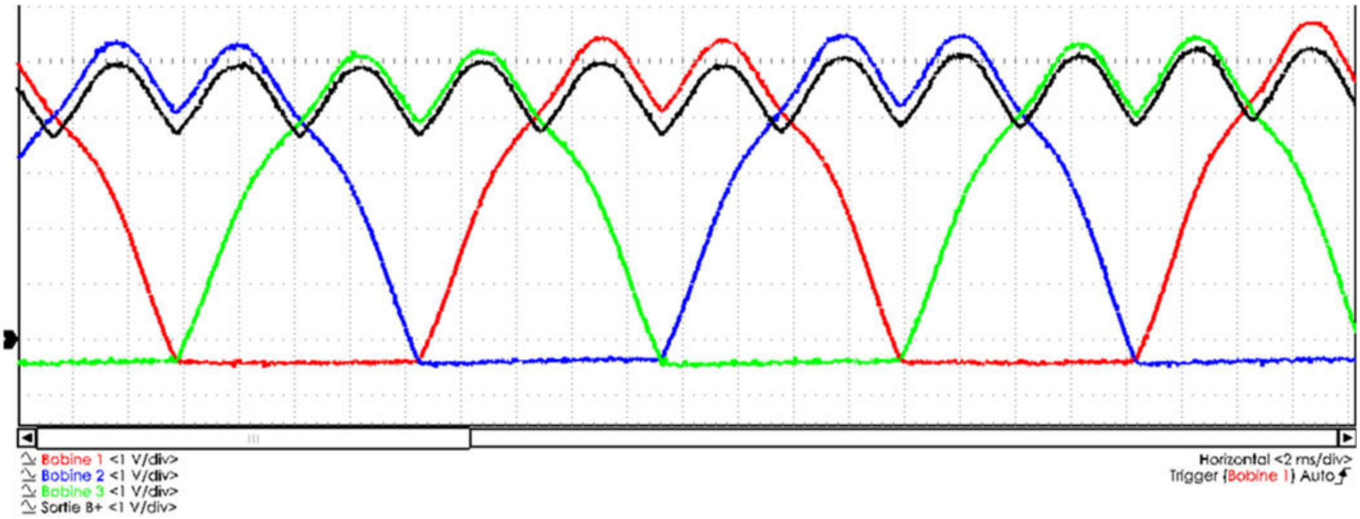


This setup requires six wires plus two for the rotor power supply.



Example of an oscilloscope reading of the delta arrangement using Reflet software.

Oscilloscope channels 1, 2 and 3 are connected to each of the three phases (terminals A1, B1 and C1) and channel 4 is connected to diode bridge output B+.



CE DECLARATION OF CONFORMITY

Manufacturer	Name:	**ANNECY ELECTRONIQUE SAS**
	Street:	**1, rue Callisto - Parc Altaïs**
	Town:	**74650 CHAVANOD**
	Country:	**FRANCE**

Represented by the signatory below, declares that the following product:

Product reference	Description	Make
DT-M008	**"Motor vehicle alternator" benchtop leaning module: star or delta wiring arrangement, diode bridge setup**	EXXOTEST

complies with all 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 2012/19/EU of the European Parliament and of the Council of 4 July 2012 on waste electrical and electronic equipment (WEEE)

- Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (ROHS)

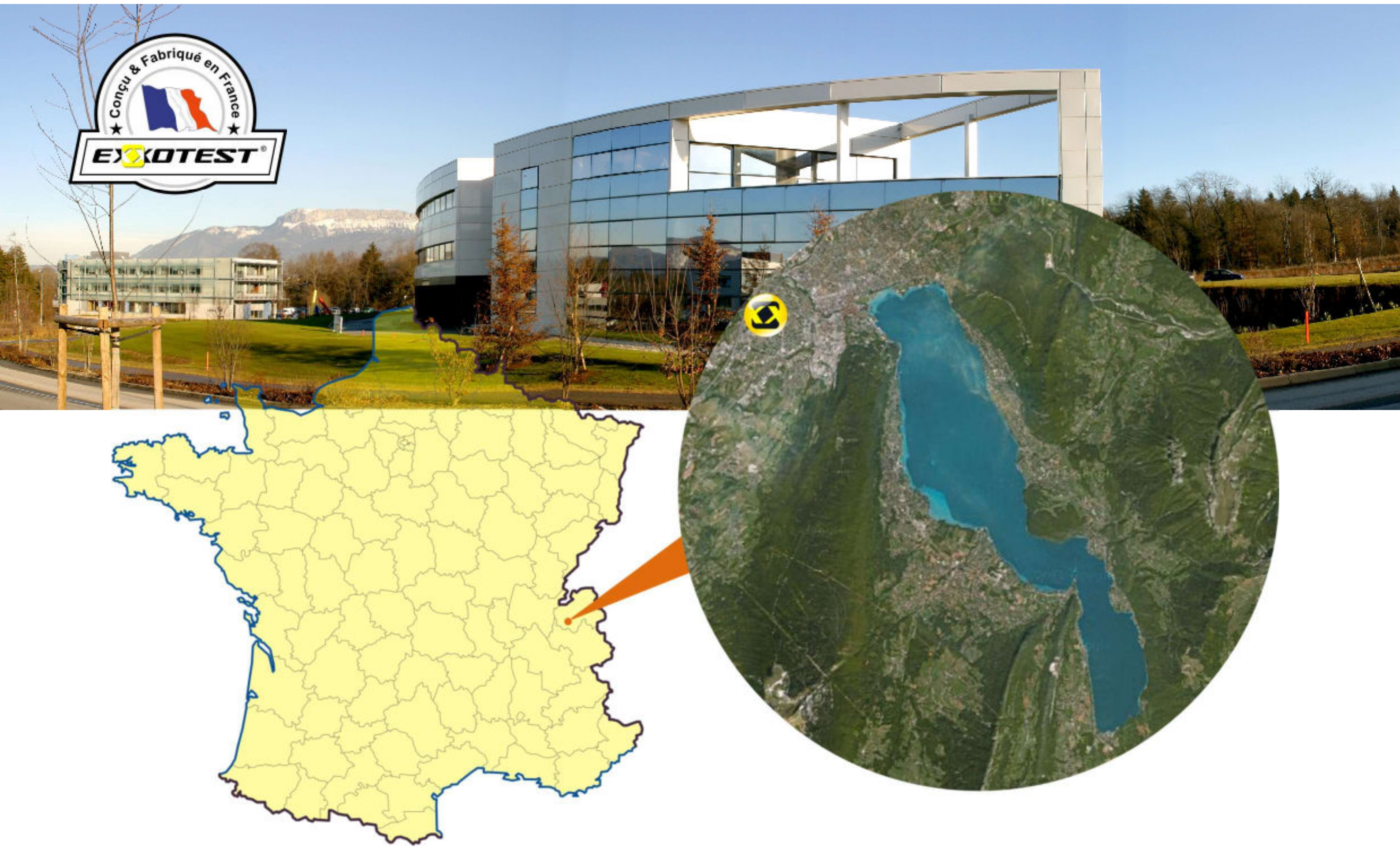
- Electromagnetic Compatibility Directive 2004/108/EC of the European Parliament and of the Council of 15 December 2004.

The product has been manufactured in accordance with the requirements of European directive:

- Directive 2006/95/EC of the European Parliament and of the Council of 12 December 2006 on the harmonisation of the laws of Member States relating to electrical equipment designed for use within certain voltage limits.

Signed in Chavanod on 09/07/2015

Stéphane Sorlin, Chairman



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