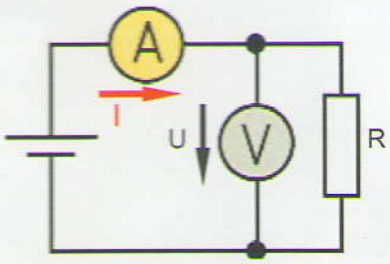
UW 01 - Fundamentals of electricity

$$I = \frac{U}{R}$$

Unit: $A = \frac{V}{\Omega}$



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1. Introduction to electricity / electronics

1.1 Definitions

1.1.1 Voltage

An electrical voltage is produced between two points (e.g. the terminals on a battery) if there are a different number of electrons at each of these points.
The magnitude of this difference in electrons determines the size of the voltage.

Charge separation in the voltage source (fig 1) results in the generation of an electrical voltage. For example, the chemical reaction inside a charging battery causes negatively charged electrons to migrate to the negative terminal.
This means there is a shortage and surplus of electrons at the positive and negative terminals respectively. This results in a voltage difference between the two poles. The higher the charge differential, the higher the difference in voltage (potential difference).

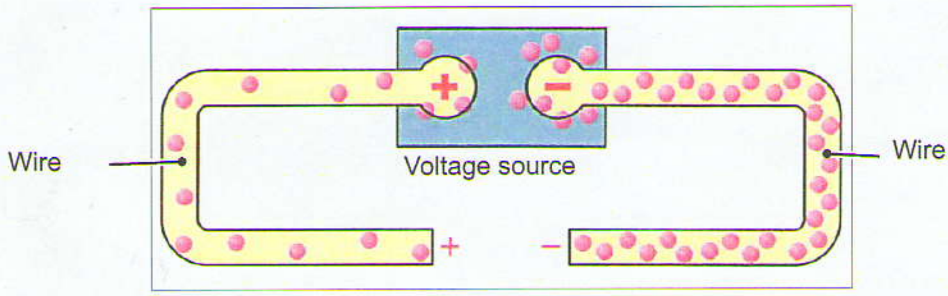


Fig. 1: Voltage generated by charge separation

Electrical voltage is produced in an attempt to compensate these different-sized charges.
Voltage causes current to flow.
The unit of voltage *U* is given in Volt (V).

▶1.1.2 Current

Electrons attempt to compensate voltage differences.
Current can only flow in closed circuits. Voltage causes electrical current to flow.

Electrical current is the directional movement of free electrons.
Closing a circuit by applying a voltage forces all free electrons to move in a certain direction. This causes electrical current to flow from the negative terminal through the loads and wires to the positive terminal. Electrons perform electrical work.

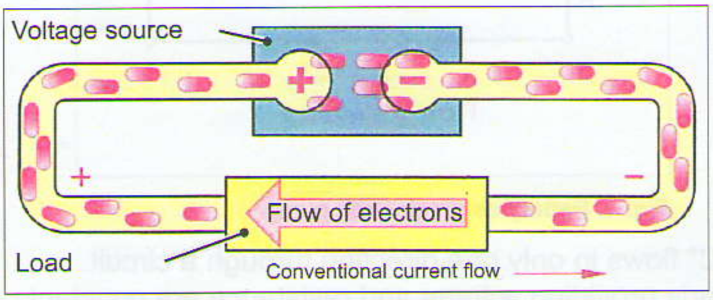


Fig. 2: Flow of electrons in an electrical circuit

Every electrical circuit must have:
- Voltage generator
- Load
- Wires

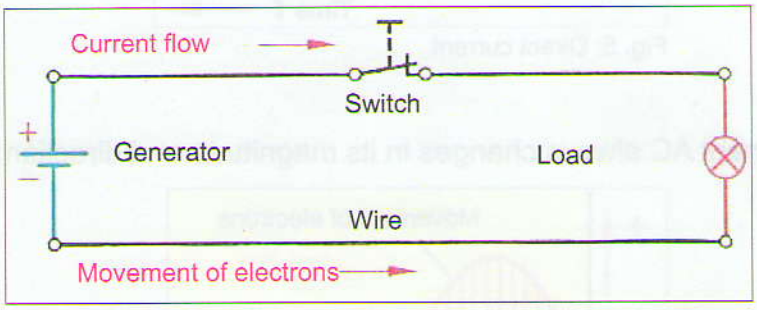


Fig. 3: Electrical circuit

Note:
Other components such as switches, relays or fuses might also be included.
Switches are drawn in their non-actuated state.
Fuses are fitted to protect electrical circuits against short-circuits and overload.

According to the definition of "conventional current", current flows from the positive to the negative terminal.
The unit of current strength I is given in Ampere (A).

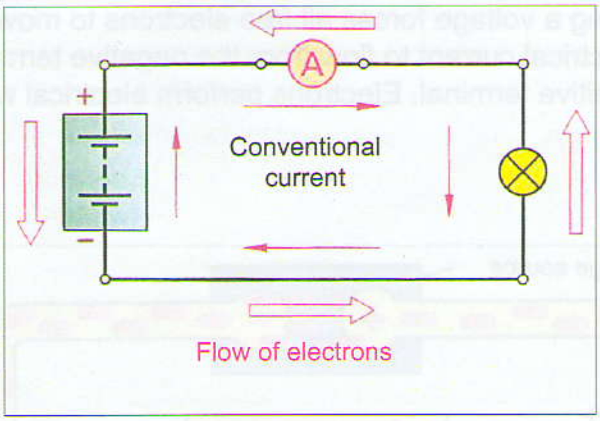


Fig. 4: Battery as an electron pump

Direct Current "DC" flows in only one direction through a circuit.
The current is steady providing voltage and resistance are constant:

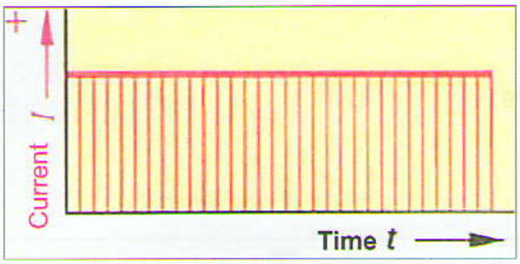


Fig. 5: Direct current

Alternating current AC always changes in its magnitude and direction:

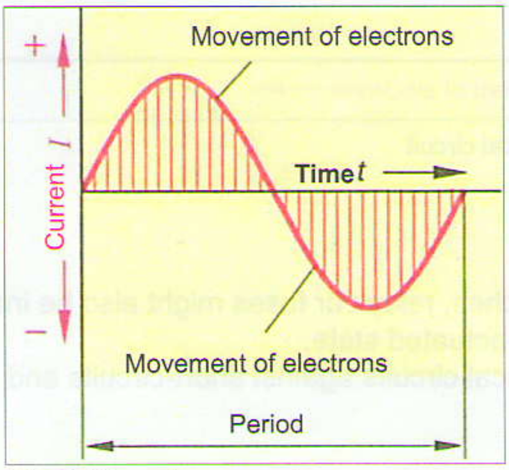


Fig. 6: Alternating current

▶1.1.3 Electrical resistance

Electrons do not flow freely when a voltage is applied to an electrical conductor. Depending on their composition, materials have different numbers of free electrons. Consequently these materials provide different levels of resistance which oppose the current. The movement of electrons is therefore slowed down at different rates.

> Obstruction of the flow of electrons is referred to as electrical resistance.
> The unit of resistance *R* is given in Ohm (Ω).
> (1 Ohm = 1 Ω = 1 Volt Ampere = 1VA).

There are different types of resistors:

- Fixed resistors
- Variable resistors
- Potentiometers (resistors with a sliding contact)

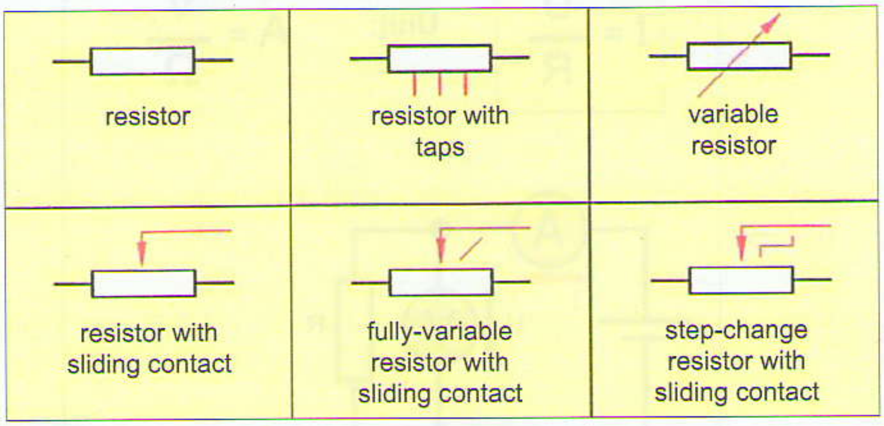


Fig. 7: Resistor symbols

Unwanted resistance:

- Poorly soldered connections
- Bad plugged contacts
- Faulty wires and connections
- Rusted ground connections (corrosion resistance)

Resistance designations:

500R	=	500Ω
0R5	=	0.5Ω
20K	=	20000Ω
1K5	=	1,5KΩ = 1500KΩ

▶1.1.3 Ohm's law

The applied voltage *U* in a closed circuit will cause a current I to flow through resistor *R* (fig1).
The ratio of voltage *U* to current I determines the resistance *R*.
This law is named after its discoverer Georg Simon Ohm, namely "Ohm's law".

Derivation:
For a constant resistance, current will increase as the voltage increases.
This means that current I and voltage *U* are proportional to one another (U ~ I).
For a constant voltage U, current will decrease as resistance R increases.
This means that currentl and resistance R are inversely proportional to one another (I ~ 1/R).
Combining the above results in the definition of Ohm's law (U=R*I).

$$I = \frac{U}{R}$$

Unit: $$A = \frac{V}{\Omega}$$

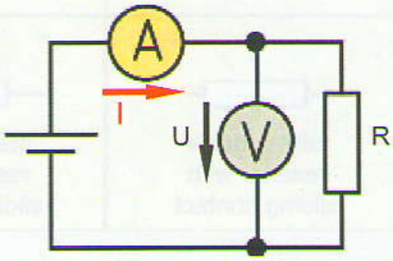


Fig. 8: Variables in an electrical circuit

The following aid can be used to remember the equation:

Note:
Simply use your finger to cover the desired symbol!

Measurement examples:

Resist-ance	U in V	0	2	4	6	8	10
$R_1 = 2\Omega$	I_1 in A	0	1	2	3	4	5
$R_2 = 1\Omega$	I_2 in A	0	2	4	6	8	10

Fig. 9: Current versus voltage

Voltage	R in Ω	0	2	4	6	8	10
U_1=5V	I_1 in A	Short-circuit	2,5	1,25	0,83	0,675	0,5
U_2=10V	I_2 in A	Short-circuit	5	2,5	1,66	1,35	1,0

Fig. 10: Current versus resistance

▶1.1.4 Resistor networks

Series resistors:

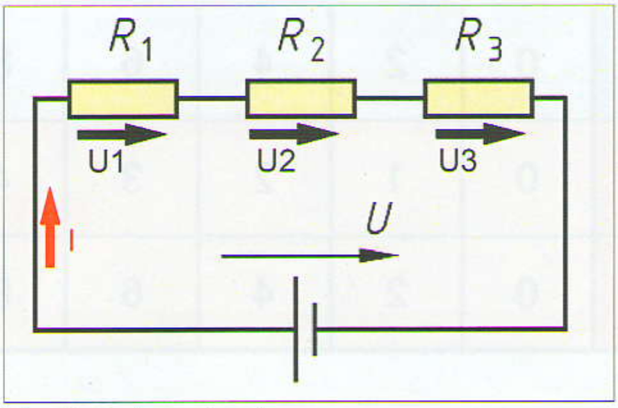


Fig. 11: Series network

Series networks serve as voltage dividers.
Pre-resistors are required when connecting LEDs (e.g. with a nominal voltage of 2.4V) to the 24V on-board supply on mobile cranes.

The following laws apply:

$I_{tot.} = I_1 = I_2 = ...$	The same current flows through all the resistors.
$U_{tot.} = U_1 + U_2 + ...$	The total voltage is the sum of all partial voltages.
$R_{tot.} = R_1 + R_2 + ...$	The total resistance is the sum of all partial resistances.

Parallel resistors:

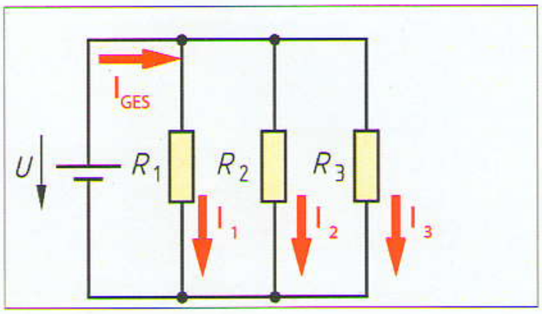


Fig. 12: Parallel network

Parallel networks serve to divide the current.

The following laws apply:

$I_{tot.} = I_1 + I_2 + ...$	All the resistors have the same voltage.
$U_{tot.} = U_1 = U_2 = ...$	The total current is the sum of all partial currents.
$1/R_{tot.} = 1/R_1 + 1/R_2 + ...$	The reciprocal of the total resistance is the sum of all reciprocated partial resistances.

1.2 Measurement technology

▶1.2.1 Types of measurement instruments

There are two types of measurement instruments:
- Analogue multimeter
- Digital multimeter

Analogue multimeter:

Fig. 13: Analogue multimeter

Connections:

COM:	ground connection
V/Ω:	voltage and resistance measurement
A:	current measurement in Ampere-range
mA:	current measurement in milli-Ampere range

Advantages:
- Rapid changes in measured vari ables are easily seen.
- If correctly used, often more accurate.

Disadvantages:
- When using moving coil mechanisms, it is only possible to measure DC voltage and current.
- Measurement range must always be manually selected.

Note:
The measurement leads must be re-plugged depending on the variable being measured. Always select the highest measurement range when measuring an unknown variable. Then select the measurement range where the needle is in the upper third of the scale.

1.2.1 Types of measurement instruments

Digital multimeter:

Fig. 14: Metrix MX22

Fig. 15: Chauvin Arnoux MAX3000

Fig. 16: Chauvin Arnoux Conpa2010

Connections:

COM:	ground connection
V/Ω:	voltage and resistance measurement
A:	current measurement in Ampere-range
mA:	current measurement in milli-Ampere range

Advantages:

- Rapid indication of measured values
- The measurement range is often automatically selected by the measurement instrument.
- On some instruments the measured values can be stored or transferred to a PC for further analysis.

Disadvantages:

- Difficult to notice measurement range changes.

Note:
The measurement leads must be re-plugged depending on the variable being measured.

1.2.2 Using measurement instruments

Measuring electrical voltages:

The electrical voltage is measured using a voltmeter. The voltmeter (fig 1) is switched in parallel to the voltage source or load. A voltmeter always measures the voltage difference between two measurement points. The type of voltage AC ~ or DC must ⎓ be selected.

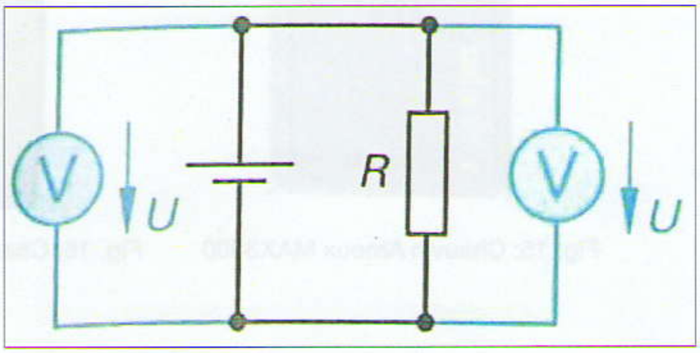


Fig. 17: Voltage measurement

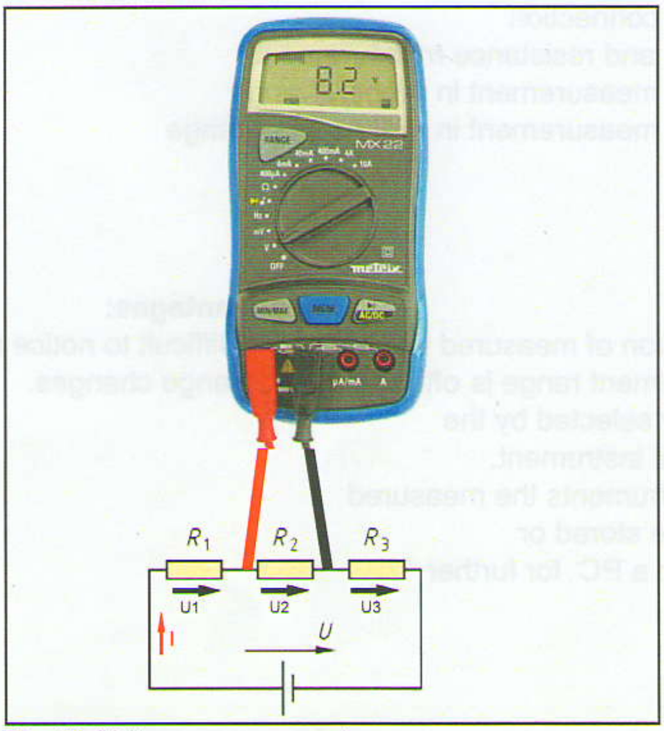


Fig. 18: Voltage measurement

Note:
The voltage across each load can be individually measured. The measurement probes must be applied directly in front of and behind the loads (fig 2).

Caution:
The red and black leads must be connected to V and COM respectively when making voltage measurements.

Measuring electrical currents:

Electrical current is measured using an ammeter. The ammeter is placed in the circuit, i.e. it is switched in series in either the supply or return line to the load.

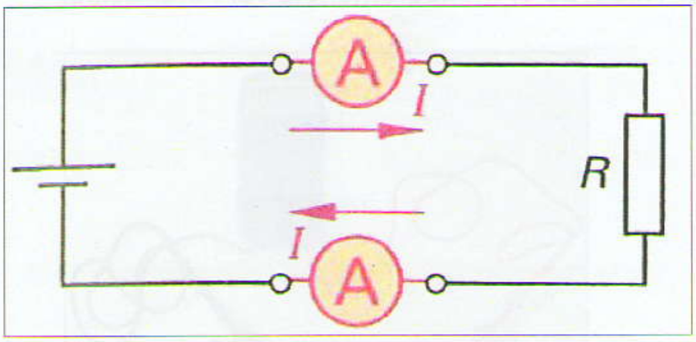


Fig. 19: Current measurement

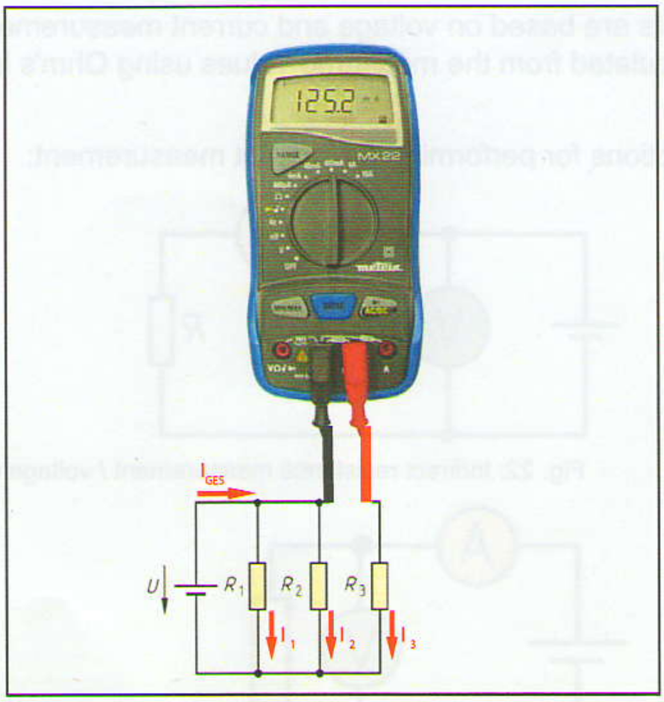


Fig. 20: Current measurement

Caution:
The red and black leads must be connected to mA (or A) and COM respectively when making current measurements.

Resistance measurements:

The resistance value is determined using a direct or indirect measurement.

Direct resistance measurements either require the circuit to be interrupted or the component to be removed. This type of measurement is very imprecise.

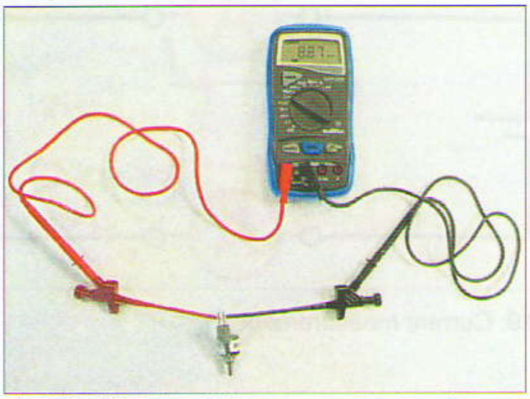


Fig. 21: Direct resistance measurement

Indirect measurements are based on voltage and current measurements at the resistor. The resistance is calculated from the measured values using Ohm's law.

There are different options for performing an indirect measurement:

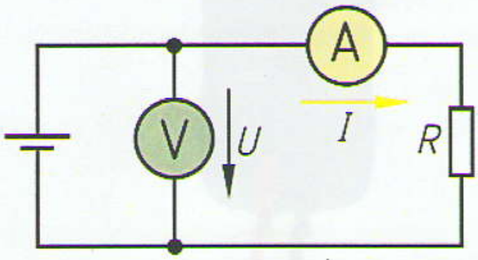


Fig. 22: Indirect resistance measurement / voltage error circuit

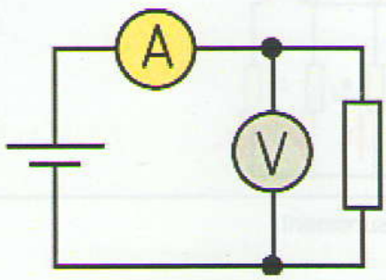
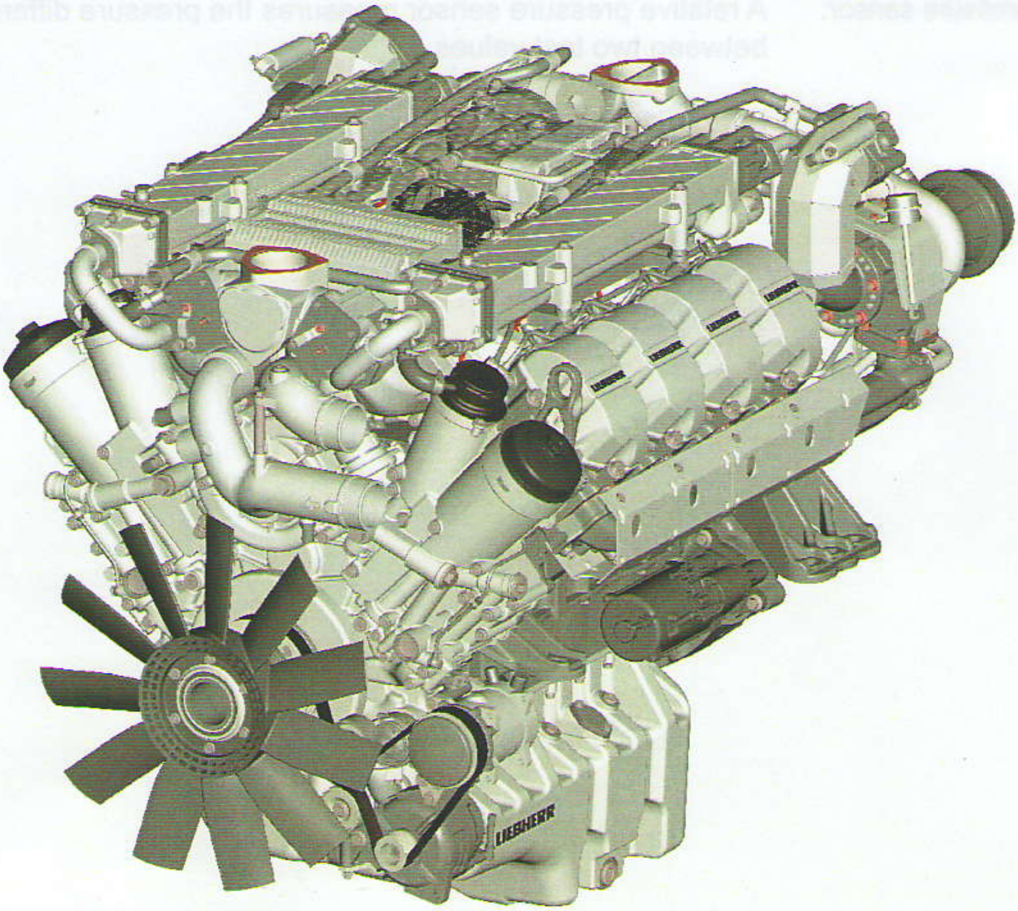


Fig. 23: Indirect resistance measurement / current error circuit

Caution:
The red and black leads must be connected to R and COM respectively when making resistance measurements.

Component description

UW04 - Drive unit / diesel engine



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Glossary:

Absolute pressure sensor:	The absolute pressure sensor always relates its measurement to a reference point
AGR:	Exhaust return
ECU:	Electronic Control Unit (engine control unit)
EDC:	Electronic Diesel Control (injection system for Diesel engines)
OT:	Top dead center
PLD:	Pump line nozzle
Relative pressure sensor:	A relative pressure sensor measures the pressure difference between two test values
UT:	Bottom dead center
ZME:	Unit to be measured

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