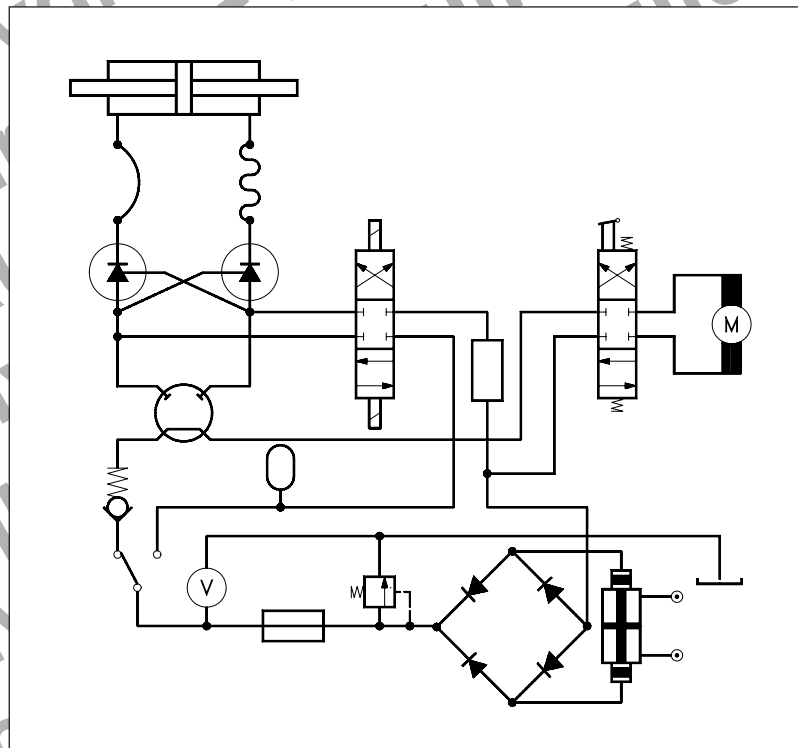


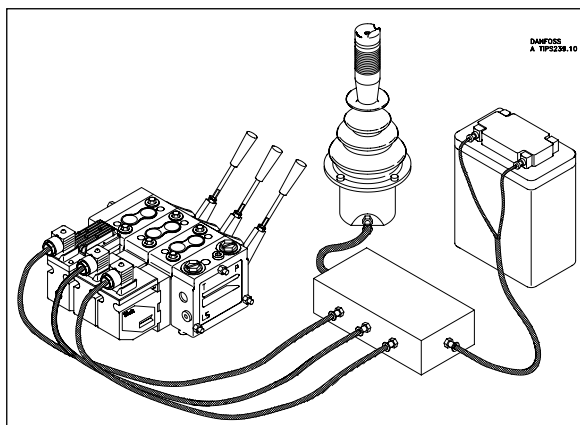
## Facts worth knowing about electronics for hydraulics



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## Contents

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## Danfoss Hydraulics

### Facts worth knowing about electronics for hydraulics

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## Purpose

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### Purpose

The purpose of this training booklet is to give hydraulics technicians in service centers and sales departments enough basic knowledge on electrical and electronic circuits and supplemented by some practical exercises to enable them to find and remedy failure in integrated hydraulic and electrical installations and systems of which Danfoss products are a constituent part and to perform replacement of a defective component.

It is thus not our intention to give anybody the belief that this booklet will enable you to go home and repair the colour television or even the hi-fi stereo set. They have the contact dangerous high volt area of 42 - 1000 volts.

It is our hope that the hydraulic technician's fear, if any, of touching leads, switches and terminals will disappear. The voltage area in the succeeding is the contact harmless from 0 to 42 volts, which means no electric shock. Well, there may be a few sparks if you are a bit awkward with tools or leads thus blowing a fuse, but the only thing which may give noticeable electric shocks in mobile installations is the ignition system of a petrol engine or the AC/DC power supply of an industrial plant.

Comparing what is going on in the circuit of a direct current (DC) circuit and in a hydraulic system and furthermore comparing the symbols with one another you will soon realize that there are quite logical similarities between the well-known and the new unknown.

This will facilitate reading electric diagrams which is a condition of understanding the function of the system as it is also the case with the hydraulic system.

In order also to understand what is roughly going on in the small electronic products used together with e.g. proportional valves, simple electronic circuits will also be explained. For this purpose we shall naturally mainly use the electric and electronic components contained in our sales programme and the illustrations figured in our catalogues and tech notes.

In the following chapter, comparisons will be made as far as possible between the electric and the hydraulic symbols which approximately have the same function.

Besides international standards there are also many national standards.

You will frequently come across small differences in the symbol for the same thing; well, some companies even apply their own "standards". As there are not symbols for everything either and since the variety of components and principles are rapidly increasing the degree of liberty for combining symbols and perhaps "inverting" new ones are extensive and there are also examples to that effect.

Sometimes, you will have to use your imagination a little when reading diagrams and drawing.

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## Basics

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Like the old chaps Pascal, Bramah, Reynold and other physicists found and defined natural laws and principles ruling for hydraulics, also electronics has its discoverers who have determined laws, principles and values ruling for the work with these things. Among the pioneers let's mention Volta, Ampère, Farady, Hertz, Ohm, Watt and Coulumb and others as well as the Dane Ørsted.

Each of these physicians lent their name to the units and laws they discovered and described.

Funny enough, most of them all lived from the middle of the 18th century to the middle of the 19th century!

Now, in order to know what we are talking about, let's take a closer look at the sizes we'll come across in the coming chapters:

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**Volt**, V, in formulae: U, unit of electrical voltage, measured with voltmeter. Defined by the Italian Alessandro Volta (1745-1827).

1 V is the potential difference between the ends in a lead yielding a resistance of 1 Ohm in which there is a current of 1 A.

**Ampère**, A, amp, in formulae: I, unit for measuring electric current, measured with ammeter. Defined by the Frenchman André Marie Ampère (1775-1836).

1 A is the current liberating 1,118 mg silver of a solution of silver nitrate.

**Ohm**, Ohm,  $\Omega$  (the Greek letter Omega), in formulae: R (Resistance), measured with an ohmmeter. Defined by the German Georg Simon Ohm (1787-1854).

1  $\Omega$  is the resistance at 0°C in a 106,3 cm long mercurial column with 1 mm<sup>2</sup> section.

**Watt**, W, in formulae: P, unit for measuring electric power, measured with wattmeter or calculated after the formula

$$P = U \times I$$

i.e. power = voltage multiplied by current. Defined by the Scotchman James Watt (1736-1819). Better known for the steam engine.

**Coulumb**, (pronounced coo-long) Coul, unit for measuring amount of electricity which is designated ampère-second or ampère-hour. Defined by the Frenchman Charles Coulumb (1736-1806).

1 coul is equal to the amount of electricity moving with a current intensity of 1 A in one second.

1 ampèretime (1Ah) = 3600 coulumb

**Farad**, F, in formulae: C, unit for measuring the capacitor capacity. To be calculated. Defined by the Englishman Michael Farady (1791-1867).

1 F is the capacity (charging) of a capacitor when the voltage is 1 V and the charge 1 coulumb.

**Hertz**, Hz, cycle, designation of the frequency of an electric alternating current. Defined by the German Heinrich Hertz (1857-1894).

1 Hz = 1 entire period per second.

**Ørsted**, unit for measuring electromagnetism. Defined by the Dane H.C. Ørsted (1777-1851) who discovered the electromagnetism.

## Electric units

Designation	Symbol	Unit of measurement	Abbreviation
Voltage	U (E), u	volt	V
Current	I i	ampère	A
Resistance	R r	ohm	$\Omega$
Power	P	watt	W (V · A)
Work (energy)	A	watt · hour	Wh (W · hour)
Designation	Unit of measurement	Abbreviation	Value
Voltage	mega volt	MV	1000.000 = $10^6$
	kilo volt	kV	1000 = $10^3$
	volt	V	1 = $10^0$
	milli volt	mV	$\frac{1}{1000}$ = $10^{-3}$
	micro volt	$\mu$ V	$\frac{1}{1000.000}$ = $10^{-6}$
Current	ampère	A	1
	milli ampère	mA	$\frac{1}{1000}$ = $10^{-3}$
	micro ampère	$\mu$ A	$\frac{1}{1000.000}$
Resistance	mega ohm	M $\Omega$	1000.000 = $10^6$
	kilo ohm	k $\Omega$	1000 = $10^3$
	ohm	$\Omega$	1
	milli ohm	m $\Omega$	$\frac{1}{1000}$ = $10^{-3}$
	micro ohm	$\mu\Omega$	$\frac{1}{1000.000}$ = $10^{-6}$
Capacitor	farad	F	1
	micro farad	$\mu$ F	$\frac{1}{1000.000}$ = $10^{-6}$
	nano farad	nF	$\frac{1}{1000.000.000}$ = $10^{-9}$
	pico farad	pF	$\frac{1}{1000.000.000.000}$ = $10^{-12}$


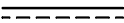




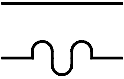
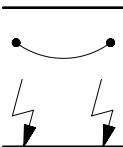








## Symbols

### References

Electrical signatures:  
IEC recommendations  
117-1 to 7.

Hydraulic signatures:  
Din 24300 sheet 1 to 8 and  
ISO.

CETOP:  
Comité Européen des Trans-  
missions Oléohydrauliques  
et Pneumatiques.

IEC 117 No.	Electrical symbols	Description	Hydraulic symbols if any	Comparative description
3		Alternating current. Changing polarity.		Pulsating flow, changing direction, few applications (hydraulic hammer)
1		Direct current. The current runs in one direction from plus to minus.		The oil flow runs in one direction, usually from pump to tank
19		Positive polarity. Plus Identification colour: red/black		Flow direction forward motion Identification colour: red
20		Negative polarity. Minus Identification colour: blue		Tank line  Identification colour: blue
43		Conductor Usually single conductor Flexible lead		Pipeline Hose Electric lead
65		Terminal Connection		Pressure source Connection
66		Branch Wire connection		Tube connection T-coupling
70		Branch Wire connection		Tube connection Cross coupling
72		Crossing conductors without electric connection		Crossing tubes without connection

## Symbols

### References

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117-1 to 7.

Hydraulic signatures:  
Din 24300 sheet 1 to 8 and  
ISO.

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missions Oléohydrauliques  
et Pneumatiques.

IEC 117 No.	Electrical symbols	Description	Hydraulic symbols if any	Comparative description
86		Earthing Identification colour: Green/Yellow		
87		Frame connection often common minus Identification colour: Green/Yellow		Tank connection  Identification colour: blue
92		Continuously variable size, see e.g. 512		Variable size, e.g. variable pump or orifice
502		Adjustment by means of tools		Adjustment by means of tools
243		Mechanical connection		Simplified connection CETOP symbol
251		Manual operation		Manual operation
112		Generator Alternating current		
113		Generator DC dynamo		Pump
173		Motor DC motor		Hydraulic motor Electric motor
		Dry cell or accumulator The long line is always + pole		Power pack

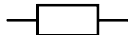
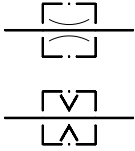
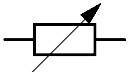
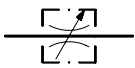
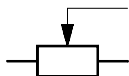
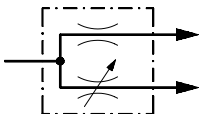



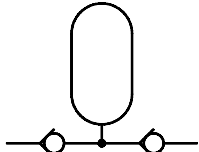

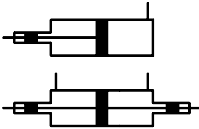
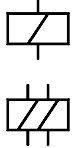

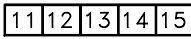
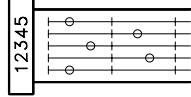

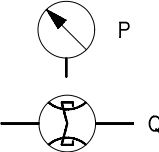


## Symbols

### References

Electrical symbols:  
IEC recommendations  
117-1 to 7.

Hydraulic symbols:  
Din 24300 sheet 1 to 8 and  
ISO.

CETOP:  
Comité Européen des Trans-  
missions Oléohydrauliques  
et Pneumatiques.

IEC 117 No.	Electrical symbols	Description	Hydraulic symbols if any	Comparative description
74		Resistance, fixed, size indicated in Ohm		Orifice, throttling Viscosity dependent Viscosity independent
512		Variable resistance Largest resistance indicated in Ohm,		Orifice variable throttling
519		Potentiometer Voltage divider, largest resistance in Ohm		Flow divider, one or both outlets often variable
84 639		Capacitor Electrolyte, unpolarized, stores electrical energy Capacity in Farad		Accumulator, stores oil under pressure = energy
641		Electrolytic capacitor, polarized Capacity in Farad		This is how the polarized electrolytic condensator works
157		Transformer changing an alternating voltage from one size to another upwards or downwards		Press. transf. single Press. transf. double Can increase or decrease pressure from one size to another
276 277		Relay coil, with one or several windings		Coil, usually a solenoid valve coil for electric- hydraulic control of directional valve
240		Terminal board Terminal		Manifold for distribution of flow and stacking of e.g. valves
300		Measuring instrument voltmeter, ammeter, wattmeter. Only with indication		Measuring instrument Pressure gauge, vacuum gauge. Flowmeter
230 234		Signal lamp Indicator		Lamp Indicator, rotating



## Symbols

### References

Electrical symbols:  
IEC recommendations  
117-1 to 7.

Hydraulic symbols:  
Din 24300 sheet 1 to 8 and  
ISO.

CETOP:  
Comité Européen des Trans-  
missions Oléohydrauliques  
et Pneumatiques.

IEC 117 No.	Electrical symbols	Description	Hydraulic symbols if any	Comparitive description
204		Closing switch		Closing valve, opens upon influence
205		Breaking switch		Closing valve, shuts off upon influence
206		Change-over switch breaks before closing		3/3 directional valve closes before opening Positive overlapping
208		Change-over switch closes before breaking		3/3 directional valve opens before opening Negative overlapping
207		Change-over switch with neutral position		3/3 directional valve Spring centered middle position
222		Fuse, ordinary safety fuse. Fuse with manual reset		Safety valve with manual reset Pressure relief valve
607	The use of circle symbols in the following is optional. May be omitted in places where mistakes are impossible.		The use of square symbols in the following is optional. May be omitted in places where mistakes are impossible.	
609		Diode, allows current in the direction of the arrow only. Unidirectional		Check valve, allows flow in the direction of the arrow only. Unidirectional
		Zener diode, normal diode in one direction, also in opposite direction, but at higher voltage.		Dual check valve, opens at low pressure in one direction, at a higher pressure in opposite direction.
616		Controlled diode Opens or closed at outside voltage signal.		Remote-controlled check valve. Opens or closes at outside pressure signal.

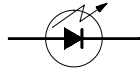
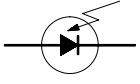


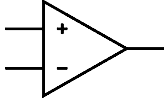
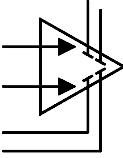
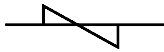
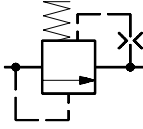

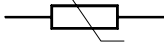

## Symbols

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et Pneumatiques.

IEC 117 No.	Electrical symbols	Description	Hydraulic symbols if any	Comparitive description
		LED, Check valve with low Light Emitting Diode Lights up when current is passing through.		Pressure cut-out with control lamp
		Photo diode, closed in the dark, open in daylight. Thus controlled from the outside by the light intensity.		Works as pilot-con- trolled check valve, the "pilot" is light
623		Transistor, PNP Amplifies an input signal by a factor to the output		Bears only just com- parison with the pressure converter page 8 item 157.
624		Transistor. NPN Amplifies an input signal by a factor to the output.		Bears only just com- parison with the pressure converter page 8, item 157.
		Operational amplifier OP-AMP		OSQ. Flow amplifier This valve contains a hydraulic Op-Amp, a proportional amplifier.
522		VDR-resistance. Voltage Dependable Resistor. Large resi- stance at low voltage Small resistance at high voltage.		Pressure control valve with delayed opening
		NTC-termistor. Negative Temperature Coefficient Large resistance at low temperature. -Small resistance in daylight.		
		PTC-termistor. Positive Temperature Coefficient. Large resistance at high temperature.		
617		LDR, photo-resistance Light Dependable Resistor. Large resistance in dark, small resi- stance in daylight		

## Passive and active components

### Passive and active components

Electronic “hardware” consists of passive and active components which in an intelligent way are coupled together in order to perform a certain task.

The basic elements of electronics are the **passive** components such as:

Resistors, capacitors and coils and the way in which they react to voltage and current.

The **active** components are those performing one or several functions if supplied with a voltage or a signal, like e.g. a voltage variation or the like. These components are among others:

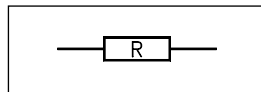
### Diodes, transistors, op-amp's gates etc.

We are now going to start little by little with the easiest part - the **passive** components and the terms **voltage** and **current** and how we measure them.

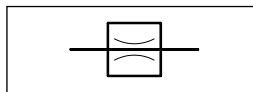
### Resistance, voltage, current and Ohm's law

#### Symbols

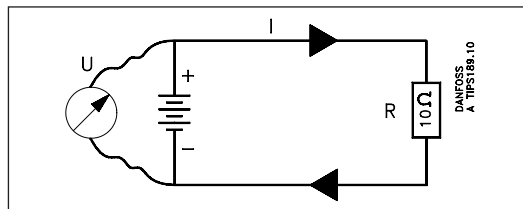
Resistor



Throttle valve



The voltage  $U$  is e.g. 12 V which forces a current  $i$  THROUGH the resistor  $R$  which is 10  $\Omega$ .



As earlier mentioned the size of resistance is indicated in

**Ohm,  $\Omega$**

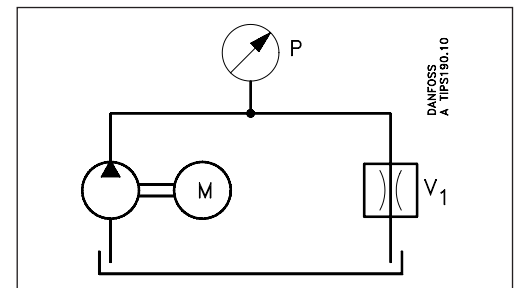
and depending on the size we normally use:

Ohm for resistance up to 999  $\Omega$

kohm, kilohm, from 1 k $\Omega$  (1000  $\Omega$ ) up to 999.999  $\Omega$

Mohm, Megohm, from 1 m $\Omega$  (1000 k $\Omega$ ) and up.

Let's connect a voltage to the resistor; this means that the voltage is across the resistor (always say ACROSS when talking about voltage, otherwise you will reveal yourself as a beginner. You also say: the pressure drop across  $V_1$  is P bar don't you?).



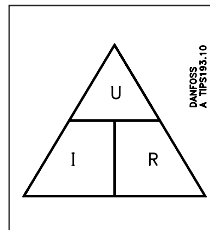
Here the differential pressure  $P$  across the relief valve is e.g. 12 bar and the flow through  $V_1$  is the pump displacement multiplied by the number of revolutions.

And now we come to **Ohm's law** saying that:

$$U = I \times R$$

which means that voltage is equal to current multiplied by resistance. If we are to calculate  $I$  or  $R$  we are going to use these formulars:

$$I = \frac{U}{R} \quad \text{or} \quad R = \frac{U}{I}$$



What is then the current  $I$  through our resistance in the circuit on the previous page?

$$I = \frac{U}{R} = \frac{12}{10} = 1,2 \text{ A}$$

If  $U$  and  $I$  are known, but not  $R$  we find it this way:

$$R = \frac{U}{I} = \frac{12}{1,2} = 10 \text{ } \Omega$$

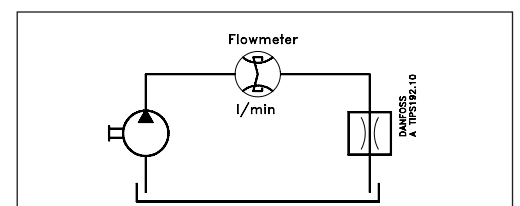
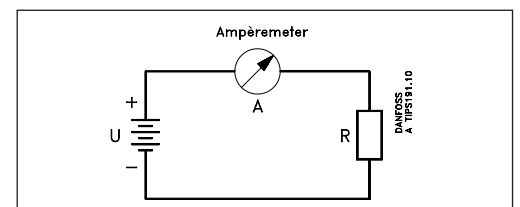
From the above mentioned it appears that if the voltage  $U$  is increased, the current  $I$  will **increase** proportionally, and if  $U$  is kept constant and the resistor  $R$  is **increased**, the current will **decrease** proportionally.

Try to change the figures yourself and “play” with the formulae.

As you will see, a voltage **across** a resistor is

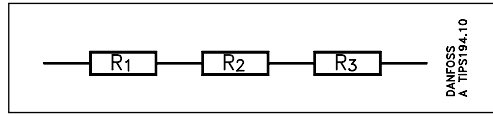
Current is actually often measured by means of a voltmeter which is connected across the resistor; the measuring result is then divided by the resistance value (we'll revert to that subject in a little while).

A real measurement of current by means of an ammeter would actually imply that we had to cut off the current path and insert an instrument in **SERIES** with the resistor to let the current run through it, just as we know it from hydraulics. It would be a bit inconvenient on a printed circuit, don't you think so?



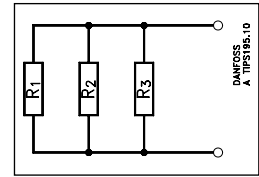
## Series and parallel connection

Total resistant  $R = R_1 + R_2 + R_3$  etc.,



thus the sum of all resistors, precisely as in a hydraulic circuit.

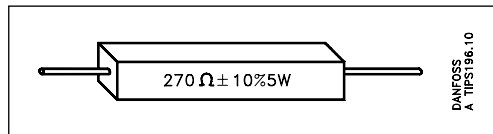
$$R = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}}$$



Total resistance in a parallel connection is found as follows:

## Marking of resistors

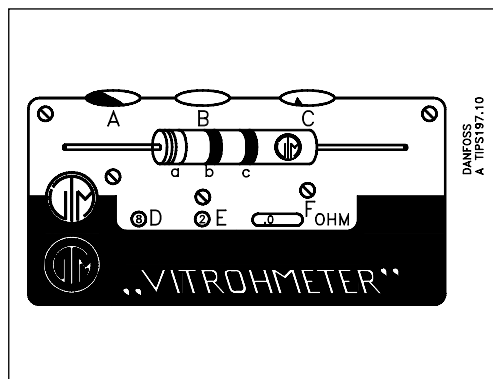
To make these calculations possible at all it is obviously a prior condition that we can determine the size of these resistors. It is not so difficult on physically large resistance as it is often printed in plain text like e.g.



This means that the rated resistance is 270 Ohm with a permissible tolerance of  $\pm 10\%$  and permissible continuous load of 5 Watt.

However, on physically small resistors there is no room for plain text. Here an international code marking consisting of 4-5 or 6 rings in different colours is used. When reading the colours you start with the ring closest to one end of the resistor. The first three rings indicated the resistance in Ohm and a 4th-5th or 6th ring, if any, indicated the tolerance in %. They are decoded by means of e.g. the VITROHMETER shown below which is published by the Danish company Vitrohm.

By means of 3 rotating discs A, B and C the colours of the resistor are sought in the squares a, b and c and the corresponding figure values are read in the 3 squares D, E and F.



The resistor sought in the example is Grey - Red - Black viz:  $82.0 \Omega \pm 20\%$

The 4th ring which is often found on resistors may be

or **red**, corresponding to  $\pm 2\%$   
or **yellow**, corresponding to  $\pm 5\%$   
or **silver**, corresponding to  $\pm 10\%$

If there is no 4th ring tolerance is  $\pm 20\%$ .

The colour code corresponds to the following values:

	1.Ring	2.Ring	3.Ring	4.Ring
Black		0	x1	
Brown	1	1	x10	
Red	2	2	x100	$\pm 2\%$
Orange	3	3	x1 k	
Yellow	4	4	x10 k	
Green	5	5	x100 M	
Blue	6	6	x1 M	
Violet	7	7		
Grey	8	9	:10	$\pm 5\%$
White	9	9	:100	

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Identification DIN IEC 62				
5-Ring Identification				
1.Ring	2.Ring	3.Ring	4.Ring	5.Ring
	0	0	x1	
1	1	1	x10	$\pm 1\%$
2	2	2	x100	$\pm 2\%$
3	3	3	x1 k	
4	4	4	x10 k	
5	5	5	x100 k	$\pm 0,5\%$
6	6	6	x1 M	$\pm 0,25\%$
7	7	7		$\pm 0,1\%$
8	8	9	:10	
9	9	9	:100	

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## Liberation of power

Just like throttling of an oil flow e.g. through a valve implies major or minor generation of heat a resistance will also develop more or less heat depending on the current passing through it.

In both cases, **power is liberated** in the form of heat because of the resistance against the current and power is the product of pressure multiplied by flow or (in electronics) **voltage multiplied by current**:

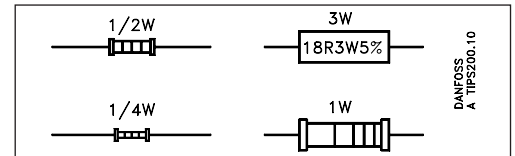
$$\text{Power, } P = U \times I \text{ (Watt, W)}$$

It can also be expressed by means of resistance:

$$P = I^2 \times R \text{ and } P = \frac{U^2}{R}$$

In order to avoid loss of power in a circuit the components must be available in different sizes to be able to select the correct one. This naturally applies to the same extent within hydraulics as well as electronics.

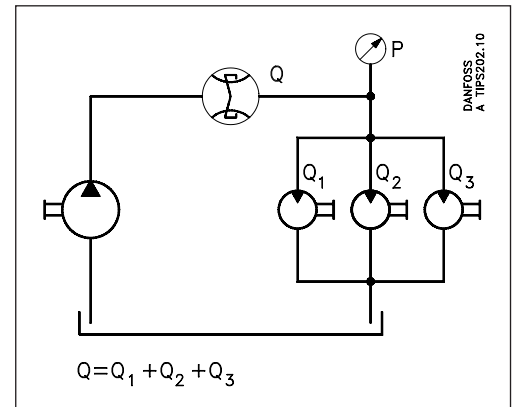
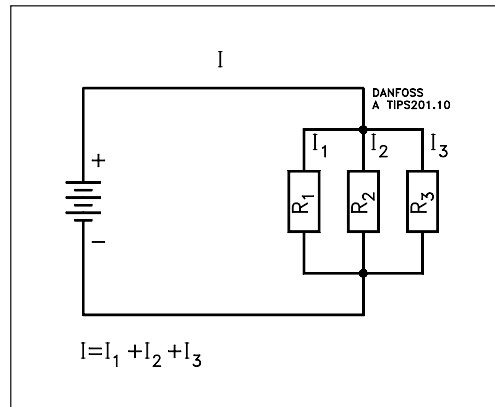
Therefore, all resistor sizes are available in several different power sizes of which the most frequently used are for 1/4 W, 1/2 W, 1 W and 3 W load corresponding to a throttle valve with e.g. 1/8", 1/4", 3/8" and 1/2" pipe thread connections.



This is the approximate size of these resistors.

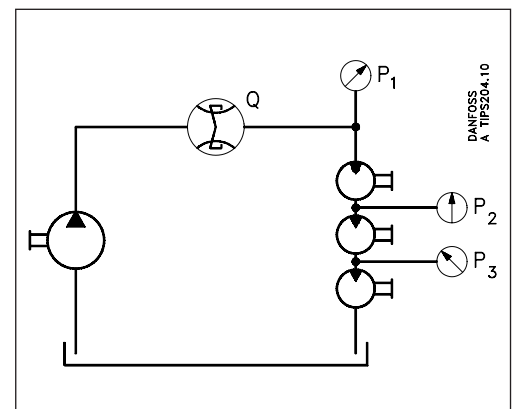
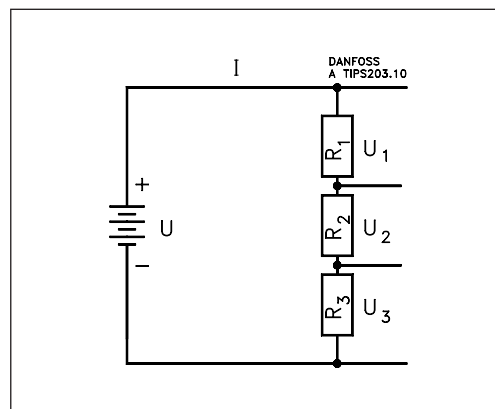
## Current and voltage divider

A **parallel circuit** is also a **current divider**.



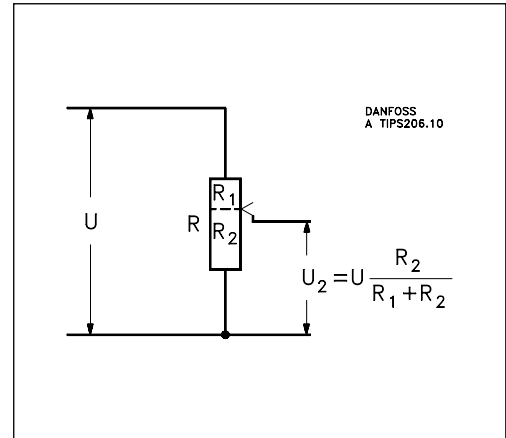
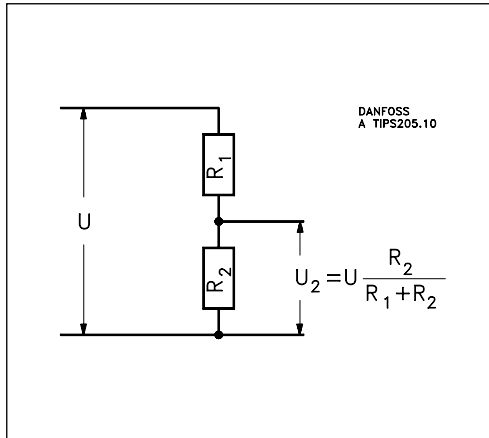
The voltage  $U$  (pressure  $P$ ) is common to all resistors (throttles), but the current is divided in  $I_1$ ,  $I_2$  and  $I_3$  ( $Q_1$ ,  $Q_2$  and  $Q_3$ ) according to the resistance values.

A **series circuit** is also a **voltage divider**.



The current  $I$  is common to all resistors and the voltage  $U$  is split in  $U_1$ ,  $U_2$  and  $U_3$ . The flow  $Q$  is common to all motors and the pressure is split up depending on the pressure drop across each motor.

A widely used voltage divider consists of either two resistors in series or a **potentiometer**.

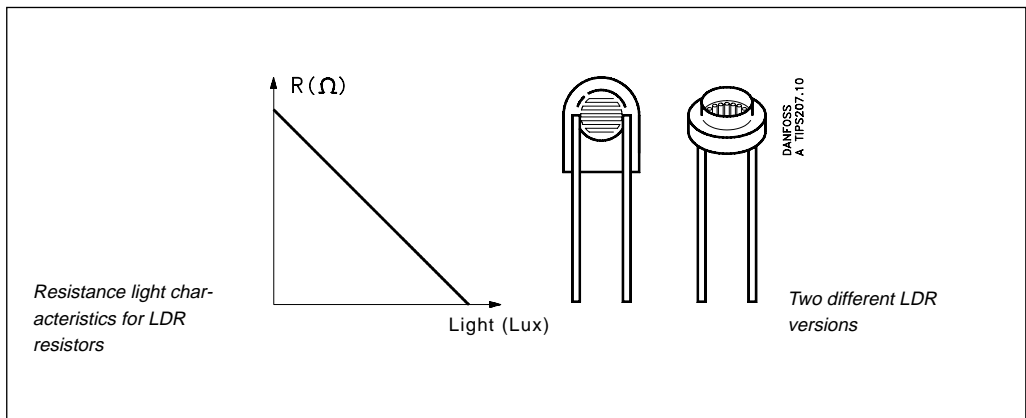


### Special resistors

Besides the ordinary resistors we have been looking at so far there are also resistors with quite special properties. We are not going to bury ourselves in their characteristics but merely have them presented.

One which undoubtedly is known to everybody from Danfoss' products programme is the **photo resistor**, the little "glass eye" which is placed in the burner tube of an oil burner watching whether the flame is ON or OFF. The official designation of this resistor is **LDR = Light Dependable Resistor**.

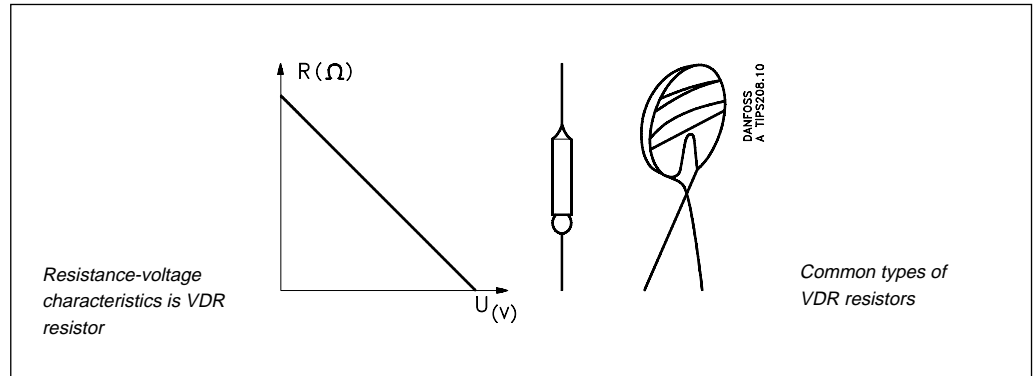
It is made of sintered cadmium sulphide, a material which changes its value of resistance depending on the amount of light to which it is exposed. The resistance value in the dark is usually 10 MOhm and at 1000 Lux it has decreased to between 75 and 300 Ohm.



Another special version is the VDR resistor i.e. (**V**oltage **D**ependable **R**esistor).

It is made of sintered silicium carbide, a material with the property that its resistance changes according to the voltage applied seeing that its resistance decreased when the voltage is increased.

In popular terms it is used to give a “soft start” to a circuit as its resistance is large right from the voltage starting at zero and decreasing as the voltage increases. The function almost corresponds to a check valve with damped opening.

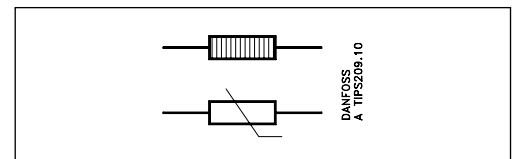


Finally we are going to mention two resistors which mutually have opposite functions viz. the **NTC** resistance and the **PTC** resistance, also called **thermistors**.

NTC = **N**egative **T**emperature **C**oefficient.  
PTC = **P**ositive **T**emperature **C**oefficient.

Both resistors are made of materials changing its resistance when its temperature changes, normally between 3 % and 5 % per °C.

The NTC has large resistance at **low** temperatures and the PTC has large resistance at **high** temperatures.



Both these special resistors are also being used in Danfoss' production, especially as temperature sensors in thermostats.

## Measuring

In this chapter we are going to talk a little about measuring with **voltmeter**, **ammeter** and **ohmmeter**.

For that purpose we have to distinguish between “good” and “bad” measuring instruments, especially when talking about measurements on

the electronic circuit.

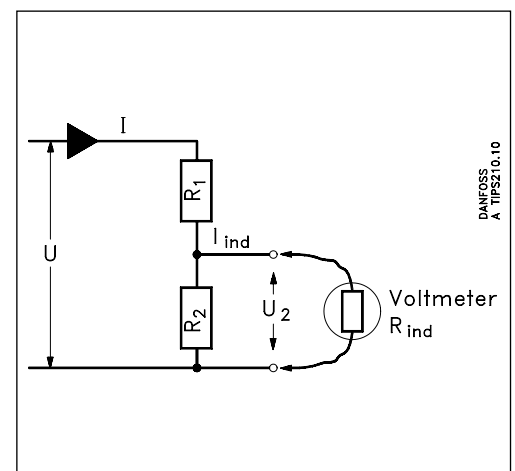
The reason is that the deflection of the indicating instrument is produced by means of a moving coil which is traversed by the current or the voltage we want to measure. This moving coil has obviously some sort of resistance which we call **inner resistance**,  $R_{ind}$ .

## Volt meter

We try to measure the voltage  $U_2$  across the resistance  $R_2$ :

The voltmeter we use is a “bad” instrument as its inner resistance is too low. When a resistance is low a heavy current is passing through it, and we can see that  $R_2$  and  $R_{ind}$  (volt-meter) are two parallel-connected resistors. The total resistance is naturally **lower** than  $R_2$ . You increase the resistance and thus the **voltage drop** across  $R_1$ . Result: The instrument indicates a lower  $U_2$  than expected.

Conclusion:  
The inner resistance of a **VOLTMETER** must preferably be infinitely high:  $R_{ind} = \infty$



## Passive and active components

### Ammeter

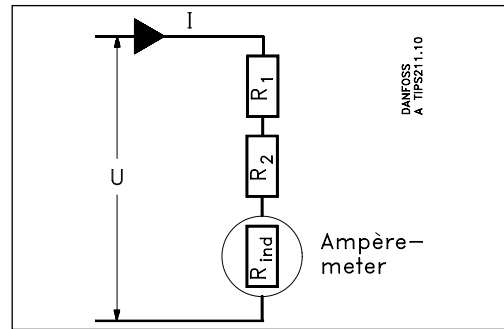
We are now going to measure the current through  $R_1$  and  $R_2$  with the same type of instrument as before.

The inner resistance of the instrument is placing itself in series with the total resistance of the circuit, i.e.  $R_1 + R_2 + R_{ind}$ .

Result: The instrument indicated lower current than expected.

Conclusion:

The inner resistance of an AMMETER should preferably be zero Ohm:  $R_{ind} = 0 \Omega$ !



### Ohmmeter

If you are in possession of a good instrument you will be able to measure with great accuracy the effective resistance across series and parallel connected resistors without having to make calculations.

However, where earlier on there should run a current in the circuit to enable us to perform measurements the circuit must now be dead when

measuring by means of a ohmmeter. The reason for this is that when changing to "OHM" we insert an incorporated battery which is used for reference voltage for measuring the resistance.

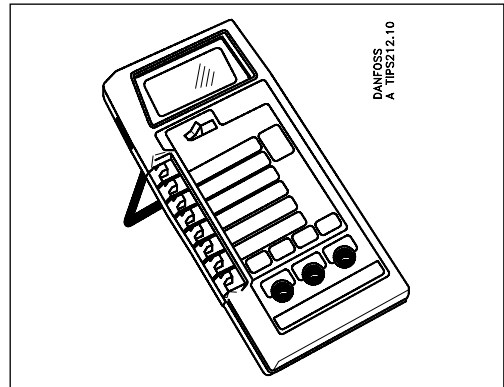
In connection with trouble shooting the ohmmeter is now mostly used to measure whether lead connections are correctly connected or

### Multimeter

For use in connection with the most common measurements of trouble shooting we almost always use a MULTIMETER, i.e. a UNIVERSAL INSTRUMENT.

Only very expensive needle instruments approximately fulfil the demands on inner resistance whereas this is nearly always the case with digital instruments. To this comes that digital instruments are also more sturdy and ensure the tough work to which they are exposed in the field.

The digital universal instrument shown below is of the make FLUKE and it is frequently used.

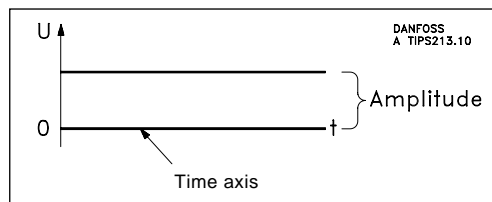


### Signals

Now, we must not forget that we are still in the chapter passive and active components and that so far we have only been talking about resistors.

Amongst passive components there are still **condensers** and **coils** to be dealt with.

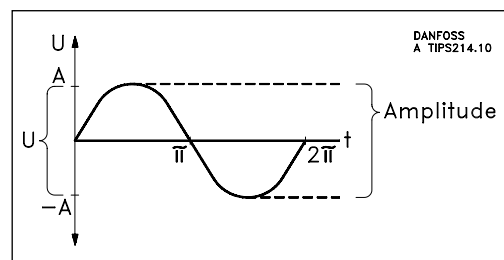
However, as they are very much used in the **alternating current world** we shall have to look at some other terms before dealing with the components themselves.



So far, we have mentioned voltages and currents which are constant with the time, i.e. direct current signals or DC (Direct Current).

You will see that **direct current has constant amplitude and polarity**.

To be able to understand the function of the two components - coils and condensers - we



shall also have to look at **Alternating Current signals** or AC (Alternating Current)-signals.

Mathematically it is described as follows:  $U = A \sin 2\pi f t$  where A is called amplitude and f is the frequency in periods per second, or usually called Hertz (Hz) or cycles.

It will appear from the figure that a **current periodically changing its polarity is an alternating current**.

The average value for a whole period of an alternating current is zero. The AC curve illustrated is **sinus-shaped**.

In most of Europe there is AC supply which everywhere has a frequency of 50 Hz whereas e.g. the USA and Canada is supplied with 60 Hz.

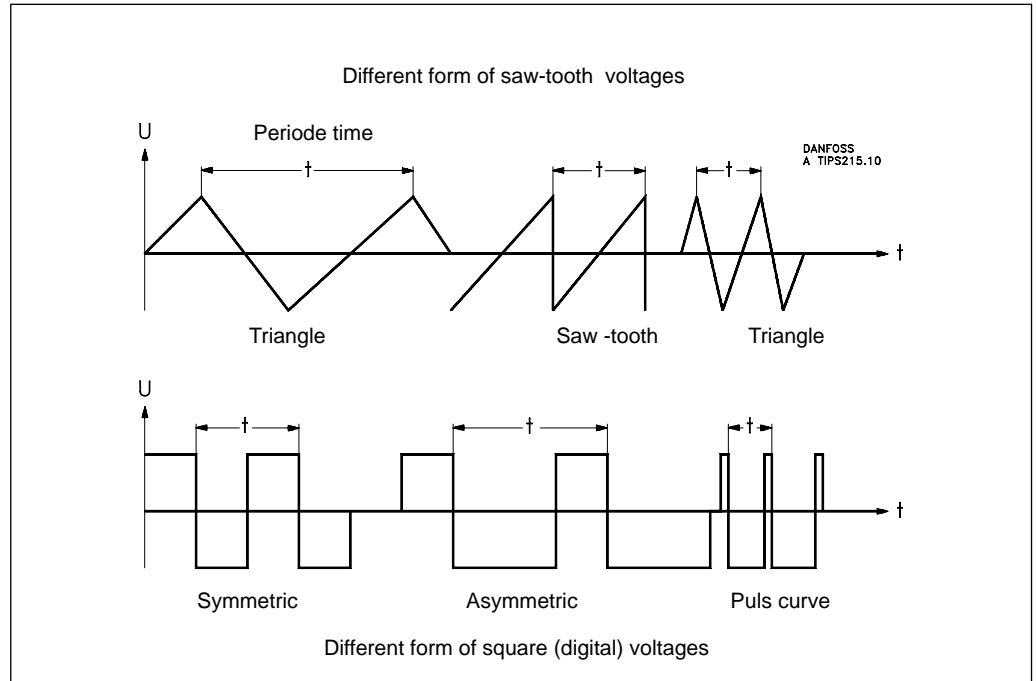


## Other curve shapes

Although the sinus signal is widely used in electronics there are other shapes of curves (signals) extensively used. All figures illustrated correspond to the picture you can see on the screen of an oscilloscope.

Different forms of saw-tooth voltages

Different form of square (digital) voltages



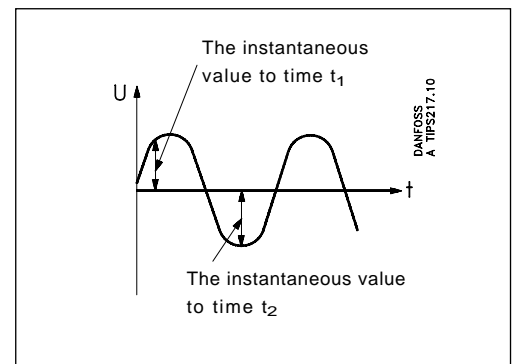
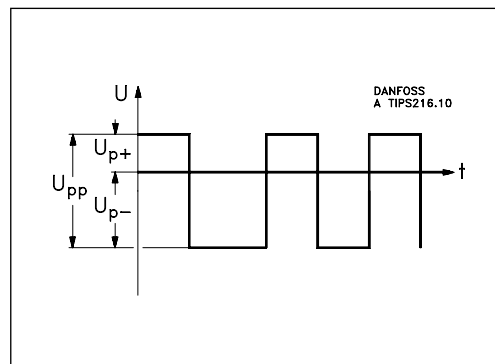
### Peak value

The peak to peak value is the sum of the maximum positive and negative deviation from zero.  
The peak value is the maximum deviation from zero.  
The peak to peak voltage is stated as  $U_{pp}$ .  
Peak value is also called maximum value.

There may be a positive peak value  $U_{p+}$  and a negative peak

value  $U_{p-}$  of different size.  
*Instantaneous value*

The instantaneous value is the value which the voltage has within the period you consider the voltage and it may assume all values from



## Mean value

If a resistance is connected to a alternating current there will be effect liberated in the resistance.  
The mean value of the alternating current is equal to the required size of direct current to be able to liberate the same effect.  
The size of the mean value depends on the

curve shape and will be a value between 0 and  $U_p$ .

When stating the size of an alternating current, e.g. 220 V, it is the mean value which is stated.  
When looking at our electronic components later on we shall be taking a closer look at the

## Capacitors and Coils

### The capacitor

With these two components we enter the world of alternating current and from now on we are going to look at circuits in two ways: a DC way and an AC way.

The capacitor

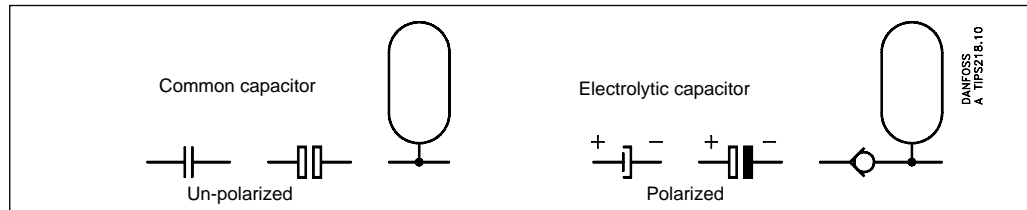
The characteristic feature of the capacitor is its ability to store and yield electric energy. It may to some extent be compared with a hydraulic pressure accumulator:

In diagrams the capacitor is called C (Capacitor) and its size is indicated in Farad, F. As one F is a very large size, we often use the sizes micro F ( $\mu\text{F}$ ), nano F (nF) or pico F (pF) corresponding to  $10^{-6}$ ,  $10^{-9}$  and  $10^{-12}$  F, respectively. In other words:

$$1 \text{ F} = 1000.000 \mu\text{F} = 1000.000.000 \text{ nF} = 1000.000.000.000 \text{ pF}$$

$$1 \mu\text{F} = 1.000 \text{ nF} = 1.000.000 \text{ pF}$$

$$1 \text{ nF} = 1.000 \text{ pF}$$

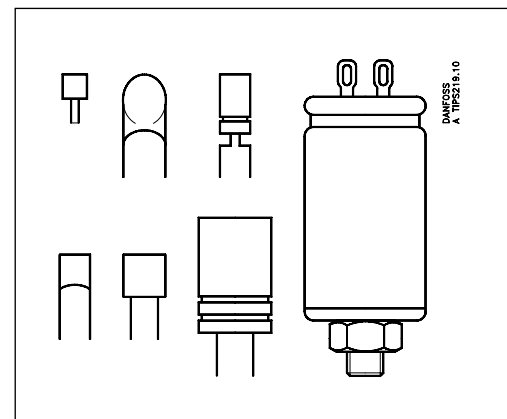


### Capacity

A **capacity** consists of 2 electrically conductive materials isolated from one another either by air or by a firm or liquid insulating material called dielectric. For example, there will always be a capacity between the conductors of a cable, between an electrically charged cloud and earth, between an antenna and earth and between supply mains and earth. The capacity between two conductors is sometimes desirable but often undesirable and caused problems, especially in circuits working at high frequencies.

A **capacitor** precisely consists of two conductors (metallic layer or plated) isolated from one another thus creating a capacity. Depending on the insulating material used, a capacitor is either called: Air capacitor, glass capacitor, glimmer capacitor, ceramic capacitor, plastic capacitor, electrolytic capacitor or tantalum capacitor.

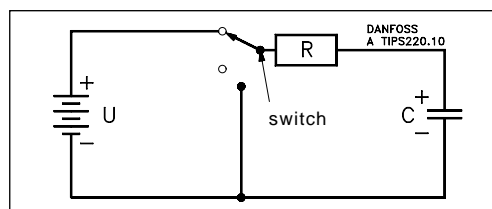
A capacitor acts differently depending on working at DC current or AC current. First of all, we'll look at the capacitor used at DC current as this is the easiest to understand.



As mentioned on the previous page a capacitor has the ability to be charged with energy, hold energy and yield it again when it is requested, almost like a dry cell.

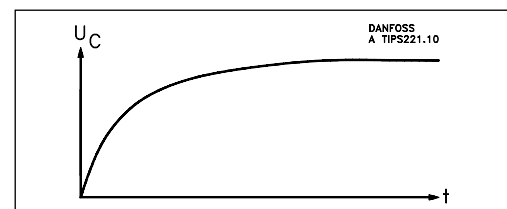
However, the dry cell or the dry battery can only yield 1.5 V per cell and an accumulator can yield 2 V per cell whereas a capacitor, depending on its type, can be charged with very high voltages.

### Charge and discharge



If the capacitor is connected to a DC voltage a current (electrons) will run from the voltage source through the resistor to the capacitor.

The voltage will gradually increase, first quickly and then slower and slower. When the capacitor has reached the same voltage as the voltage source there will no longer be electrons passing to the capacitor. Since, as already

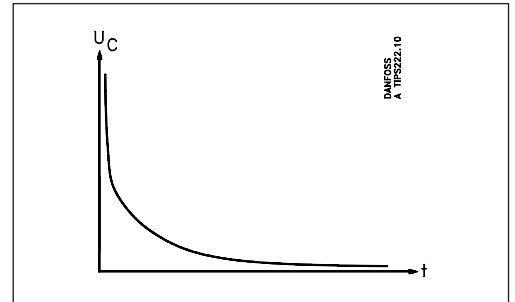


mentioned, its plates are isolated from one another there will be no current between the plates. **This means that the capacitor is blocking for direct current.**

If we turn the switch to middle position we cut off the battery and C will keep the charge (amount of current) it got during charging. If we turn the switch to bottom position C will be discharged through the resistor.

## Capacitors and Coils

The discharge current will at first be important and then as C's voltage is diminishing it will gradually decrease and finally reach zero.



### The capacitor used at alternating current

If a capacitor is connected to alternating current C will be charged and discharged at the same speed as the frequency of the alternating current. Consequently, there will be charging current with alternating direction in C's inlet lines which means that there is an alternating current in the circuit. C is thus acting as an **AC resistor**. It is also called **reactance**,  $X_C$ . **The resistor size** is calculated according to:

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

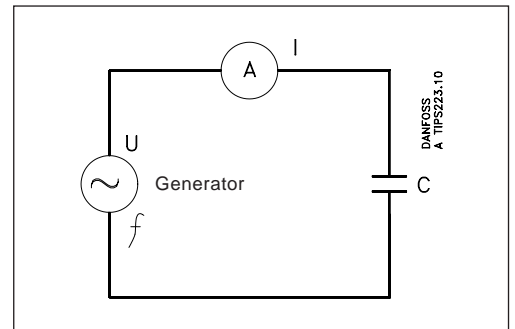
This formula looks familiar, doesn't? It looks like  $R = \frac{U}{I}$ , Ohm's law.

*Please note that we use CAPITAL letters in formulae on DC and **small** letters in formulae on AC.*

The reactance of a capacitor with **larger**

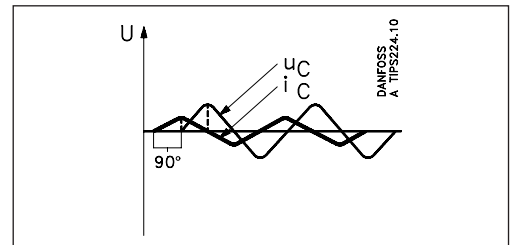
**capacity** it will naturally be capable of absorbing and yielding a larger amount of flow corresponding to the **reactance becoming smaller**.

If you increase the frequency  $f$  of the generator the capacitor must be charged and discharged quicker than at lower frequency, i.e. the current increases; the reactance gets correspondingly smaller at increasing frequency.



### Phase shift

As indicated, there is a heavy charging current at initial charge of a capacitor, but it gradually decreases as the voltage across C is increasing. At the beginning  $i_C$  is large, whereas  $u_C$  is zero. However, when C is charged,  $u_C$  is large, whereas  $i_C$  is zero. Popularly speaking, you can say that there must be a certain current to the capacitor before a tension can be created across it. This actually applies when C is supplied with an alternating current,  $i_C$ . See drawing. When  $i_C$  is at maximum,  $u_C = 0$  and vice versa.



There is a phase shift between current and voltage; the phase shift for a capacitor without loss is exactly 90° or 1/4 period where the current is in front of the voltage.

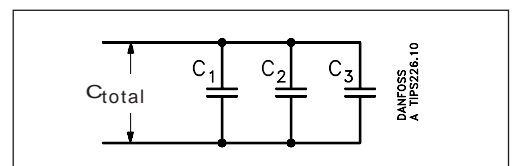
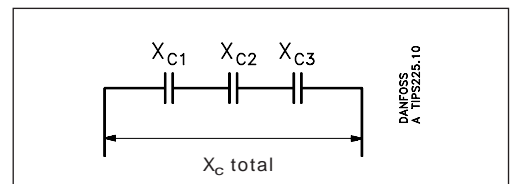
### Series and parallel connection

The total **reactance** is equal to the sum of the individual reactances, precisely as ruling for ordinary resistors viz:

$$X_{C_{\text{total}}} = X_{C_1} + X_{C_2} + X_{C_3}$$

When capacitors are connected in parallel, the plate area is actually increasing, and therefore the **capacity** will increase with this rise, viz:

$$C_{\text{total}} = C_1 + C_2 + C_3$$



## Capacitors and Coils

### Marking of capacitors

The vast majority of capacitors are marked with plain text although you will sometimes need a magnifying glass to read it. Besides the firm name it may say e.g.:  
10  $\mu$  100 V, and it is evident that this means 10  $\mu$ F and max. voltage of 100 V.

It may also say:

1  $\mu$  5 63, which means 1.5  $\mu$ F 63 V.

A third possibility:

0.22 40+.

In this case it is most likely 0.22 pF 40 V, and it is polarized as the pin closest to + must be connected to plus.

Others are colour marked with rings, bands or dots according to the same method as resistors; however, there are also makes that are marked with own codes; isn't that confusing?

**Electrolytic capacitors** are always marked with plain text; most of them are of sizes within the  $\mu$ F area, and the inlet lines are almost always marked + and - as they are only used in a certain direction in a DC circuit. If + or - is not indicated a red spot, if any, may indicate the + pin and a black dot or line the - pin.

Electrolytes are furthermore always in an aluminium case or holder.

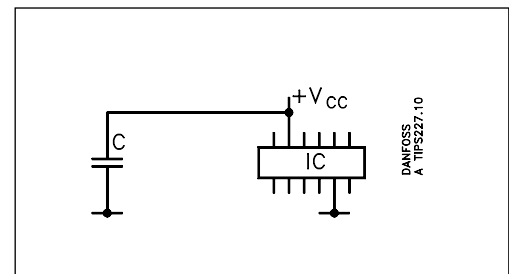
### Examples of application

Let's take a closer look at a few applications for capacitors:

#### Bypass

The reactance phenomenon is e.g. used to make AC short circuits, called bypasses.

This voltage must be stable and "clean" i.e. free from electrical noise - TRANSIENTS - and other quick changes that might disturb the function. This is done by BYPASSING +  $V_{CC}$  by means of a capacitor acting as an AC short-circuit across the IC.



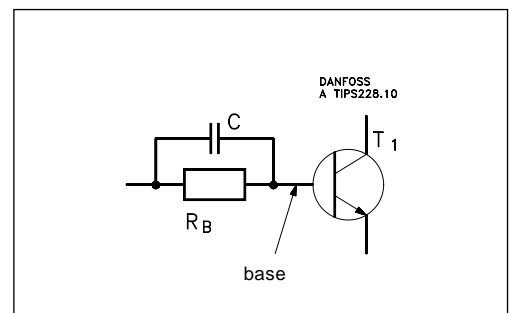
An Integrated Circuit (IC), needs a DC voltage to be able to work (+ $V_{CC}$ ).

### Speed-up

Through the resistor  $R_B$  we supply the transistor  $T_1$  with basic current. (What it is we don't know yet, but we shall later on).

In order to make sure that  $T_1$  is reacting as fast as possible upon the rapid signal changes which we lead into the base we are bypassing  $R_B$  with C which will work as a momentaneous short-circuit. In this way more current will be pressed into the base thus increasing the reaction speed.

Therefore, the capacitor is often called a SPEED-UP capacitor.



### Filters

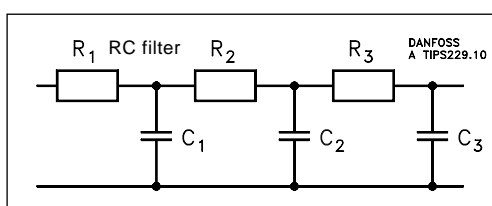
The frequency dependency is also used to create frequency dependent voltage dividers, called **filters**.

Just as we in hydraulics are filtrating dirt from the oil there are also "impurities" in the signals to be treated in e.g. transistors and ICs and DC supply voltage outlet. The noise may be

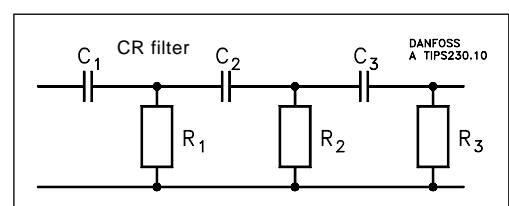
line noise from the net frequency, transients and electrical noise from close machinery. These are more or less filtered away by means of e.g. and **RC-link** (Resistor-Capacitor) or a **CR-link**.

Below you will be able to distinguish the immediate difference:

Low-pass filter



High-pass filter



## Capacitors and Coils

### Coils

In short, a coil is working as a reversed capacitor.

Seen with "AC" eyes a capacitor is an infinitely large resistor whereas a coil is a short circuit. This seems fair enough because a coil is wound by copper thread which is known to have a very low DC resistance. Its AC



Ordinary coil (air coil)

resistance is called **reactance**,  $X_L$ , and is expressed by the formula:

$$X_L = 2 \pi \times f \times L \text{ Ohm}$$

We can see that a high frequency (f) is equal to high reactance, and low frequency is equal to low reactance.

Inductance is measured in HENRY, H, dependent on turns, wire diameter, distance between windings and the magnetic properties for the material on which the coil is wound, called the **core**.

A core is increasing inductance - just think of a coil of a solenoid valve. The spool as a



Coil with iron core

component is a very large area which we are not going to elaborate on here. It may be everything from two small windings in a TV tuner passing across solenoid valve coils and relay coils, net transformers in voltage supplies to welding transformers of a weight which one man cannot lift.

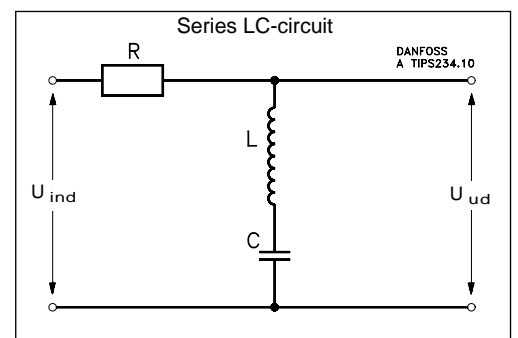
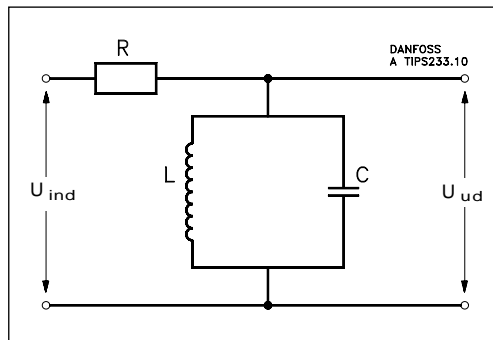
### Resonance circuits

Resonance circuits

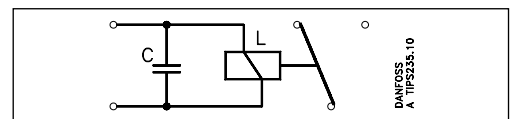
In an AC circuit capacitors and coils are making up a fine team:

They can make **resonance circuits**. You distinguish between two kinds as shown herebelow, both called **LC circuits** (coil/capacitor circuits) or an **impedance** and we shall revert to this subject when dealing with the transistor.

Parallel LC-circuit



Another frequently used connection between coil and capacitor is seen here where the capacitor is placed in parallel above a relay coil in order to prevent voltage peaks from being induced into the coil when interrupted.



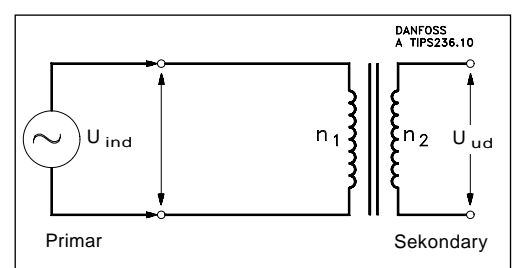
### Transformers

**Transformers** will be rather frequent in different forms of voltage supplies, either integrated in electronic accessories or as independent, net-connected voltage supplies. The latter might e.g. be a charger for accumulator batteries or a welding transformer. A transformer (often called a **trafo**) consists of 2 or several coils coupled together via the **magnetic circuit** in a common core.

The coils on the primary side (input side) and the secondary side (output side) are not connected to each other; they are **galvanically** separated.

However, there are exceptions. They are called **autotransformers** and an example is the ignition transformer of an automobile motor.

An **alternating voltage** which is connected to



the primary coil is creating a magnetic field in the core and this field **INDUCES** current into the secondary coil or the coils,  $n_2$ . If the number of windings on  $n_1$  and  $n_2$  are identical the output voltage will be equal to the input voltage. If the number of windings on  $n_2$  is increased the secondary voltage increases and vice versa.

## Transformers

**The power is equal on both sides.** Let's take the welding transformer as an example. Here we have many thin windings on the primary side to 220 V or 380 V mains connection and few but very thick windings on the secondary side yielding low voltage (usually 60 V - 70 V), but very high current, often several hundred Ampère. High enough to maintain a spark generating so much heat that it can melt the metal to be welded and the metal in the electrode stick.

*An example:*

A trafo has a welding voltage, loaded, of 60 V and a welding current of 150 Amp. Expressed in voltampère, VA, it is here the product of 60 V and 150 A = 9000 VA. The primary voltage is 380 V and the current consumption, loaded, 25 A. This is calculated to 9500 VA; the difference of 500 VA is loss liberated as heat in the trafo.

## Differential transformer

Say, what is a differential transformer?

In everyday language it is called an LVDT, which is short for Linear Variable Differential Transformer. An LVDT consists of a coil, an armature and some electronics. You find all of it embodied in what we call a PVEM, a PVEH or a PVES which is again used to remote control the directional spool of a proportional valve.

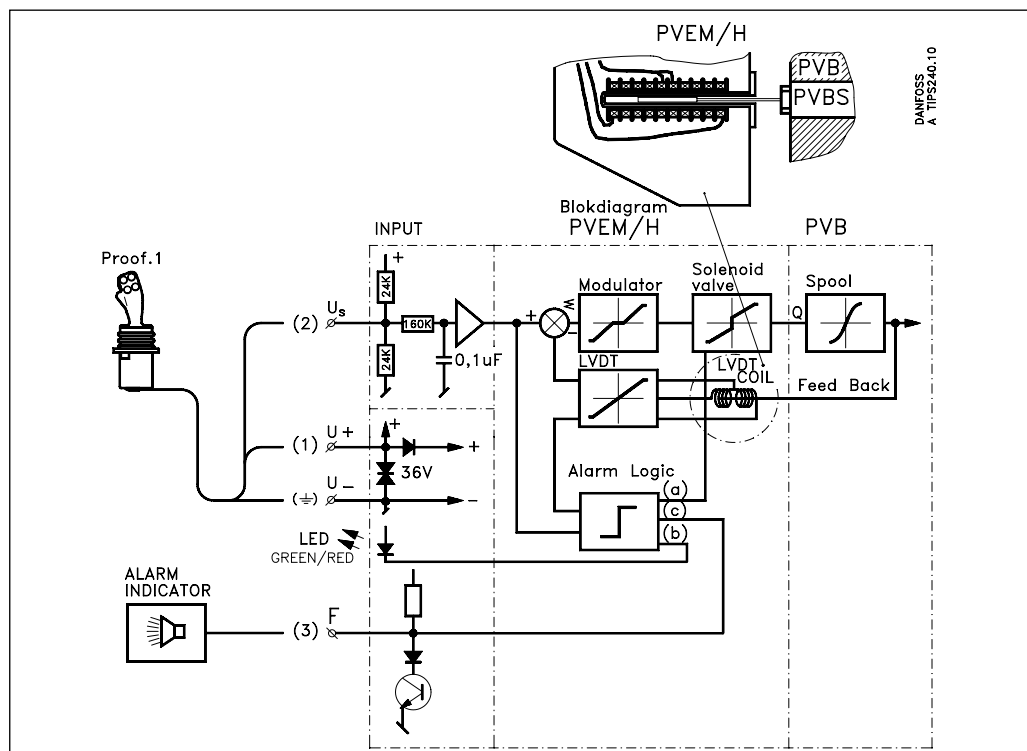
The coil has two windings end to end. A sinusoidal frequency of about 4 kHz is impressed on both ends of the two coil windings to establish a 180° phase shift of the frequency at one end. With the armature placed in the centre of the coil, the two frequencies at the centre of the coil will neutralize each other and thereby provide null voltage to the electronics.

The LVDT-circuit supplies a neutral DC voltage to a comparator which compares this voltage with the signal from, for example, a PROF1 joystick or the like. If the latter signal is neutral as well (corresponding to 50% of the supply voltage) nothing more will happen because the system balances.

If the armature is moved away from the centre and into one of the two coils, the coil holding the armature will induce a higher voltage than the other coil. Depending on which coil the armature actuates, the centre of the coils will pass either a positive or a negative voltage signal through the LVDT circuit to the cumulative point (*f*) immediately before the modulator. The modulator now determines which two of the four solenoid valves are to control the directional spool and in which direction.

Once the spool and thus also the armature in the LVDT coil have reached the position requested by the input signal from the PROF1 joystick, the spool will be retained in this position.

The armature is encapsulated in an oil-tight armature pipe to protect the coil and thus also the electronics from contact with the hydraulic oil. The armature is fitted with an extension pin which enables it just to reach down and touch the free end of the directional spool.



## Semi-conductors

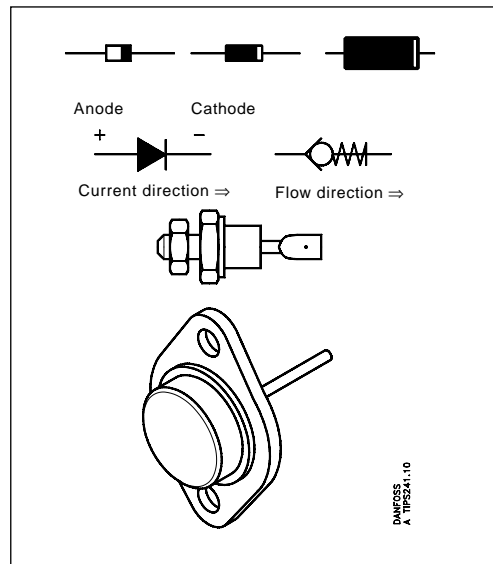
### Semi-conductors

Now we are leaving the passive components in order to take a closer look at the **active** components.

We have already dipped a little into them in the chapter on resistors, because now and then the borders may seem a bit vague!

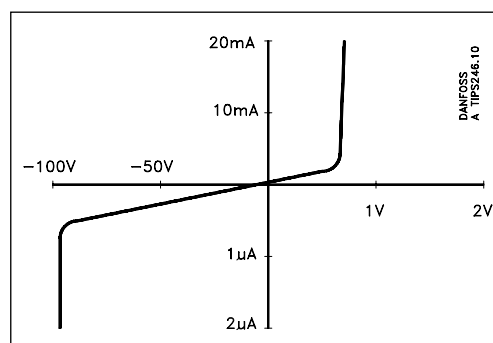
Welcome to the brave, silicon world!

The first semi-conductor we are going to look at is the **DIODE**, the check valve of electronics.



The diode is a one-way component permitting current to flow in one direction only, in the sense of the arrow, but only when the **ANODE** is more positive than the **CATHODE**.

There must usually be a voltage difference of 0.7 V before the diode "opens". It is precisely like a check valve where a soft spring force must be overcome by - let's say 0.7 bar - before the valve opens.



The opposite way is cut off, i.e. there is a small "leak" called **leakage current** and this is also the case with check valves but usually it is of no importance.

There are limits to how much voltage a diode can stand in the reverse direction before it collapses in the same way as there are limits for the pressure across a check valve before bursting.

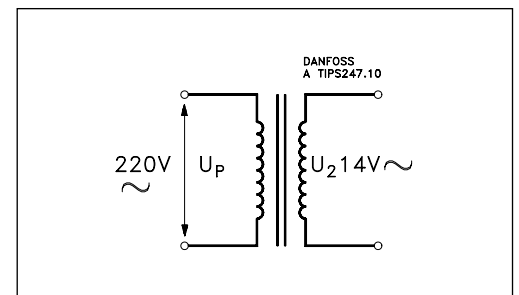
This voltage is called **PIV (Peak Inverse Voltage)**. If exceeded it'll cost a new diode!

The voltage drop in forward direction,  $U_f$  (forward) is as earlier mentioned typically 0.7 V

for **silicium diodes** and 0.2 V - 0.3 V for **germanium diodes**.

*What is their purpose*

One of the primary purposes is **RECTIFICATION** which is the first step for transforming an alternating current into a direct current which we are doing in many different connections. Depending on how "even" and smooth you want the direct current to be we are talking about **HALFWAVE RECTIFICATION** and **FULL WAVE RECTIFICATION**. We will study this in details seeing that we are going to build a charging device step by step.



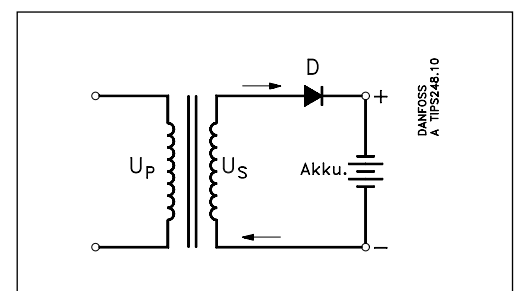
We'll take a trafo with a 220 V primary coil and a 14 V secondary coil wound in a way to yield (loaded with) - a charging current of 10 A from the secondary coil.

This is 140 VA (simple mental arithmetic). The primary coil shall also correspond to the 140 VA so we can easily calculate the current consumption at full load:

$$P = u \times I \quad \frac{P}{u} = I$$

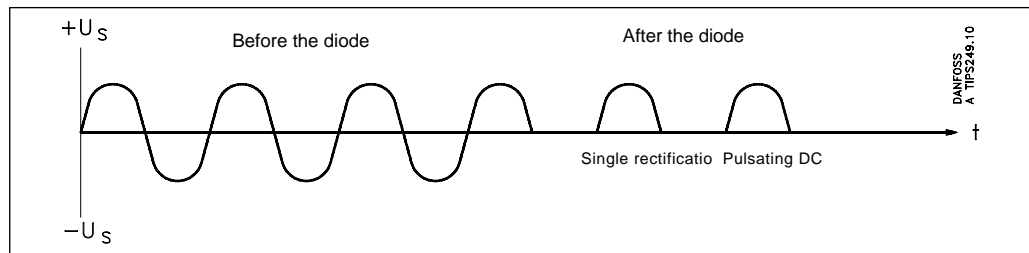
$$\frac{140}{220} = 0.64 \text{ A} + \text{a little more for heat loss}$$

Now, alternating current is certainly not capable of charging an accumulator as it is changing polarity 50 times a second. So, we shall have to rectify the alternating current, i.e. we shall have to cut off all negative half-waves. To do so we use a diode. This diode must physically be so powerful that it can stand a constant current of the 10 A yielded by the trafo. Such a diode must often be provided with cooling ribs or plates to remove the heat produced in it.



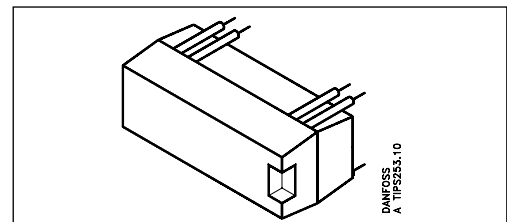
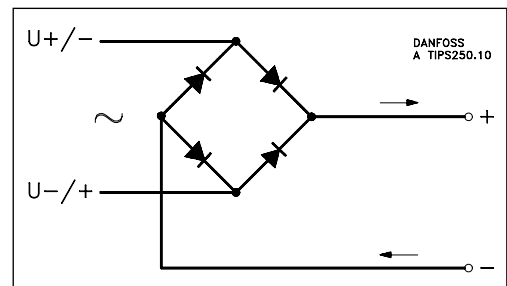
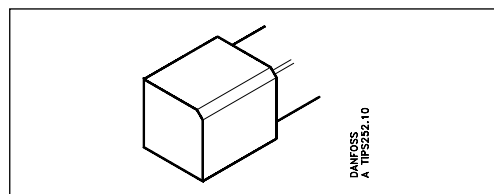
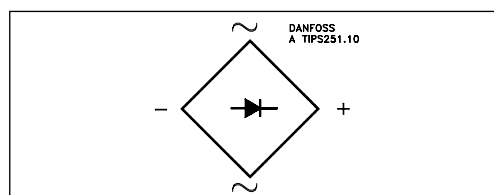
Before the diode we have a pure alternating current. After D we have excluded the negative half-waves. Now we have a **pulsating** direct current.

## Semi-conductors

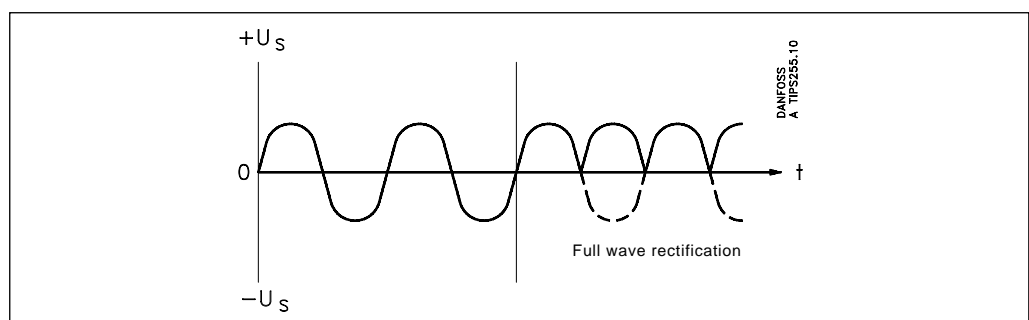
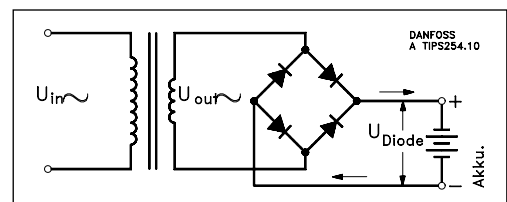


It is applicable, but inefficient, because we are only using half of the amount of current, so we must prefer a **full-wave rectification**.

This is obtained by means of a so-called DIODE BRIDGE i.e. 4 diodes put together in a **bridge coupling** also called **Graetz coupling**.

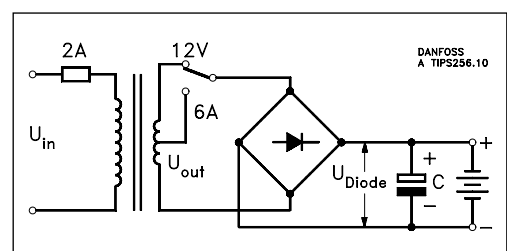


Let's take another look at our charging device, but now with a diode bridge in order to exploit both half-waves.



As it will appear from the curves we still have a pulsating direct voltage as the voltage is varying from 0 to max. 100 times a second. We want to **smooth out** this pulsation to do so we are going to use a capacitor or rather: a large electrolytic capacitor. It works in fact as an energy store between the positive peaks as within that time it yields the energy charged when the voltage increases.

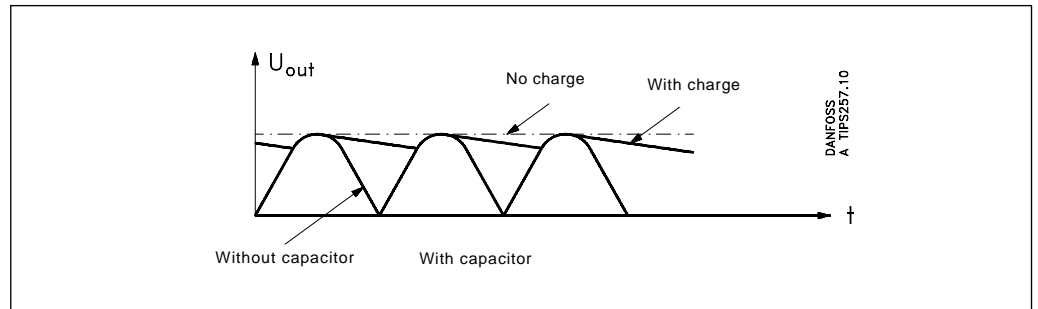
Max. voltage of the electrolyte is here chosen to be e.g. 40 V.



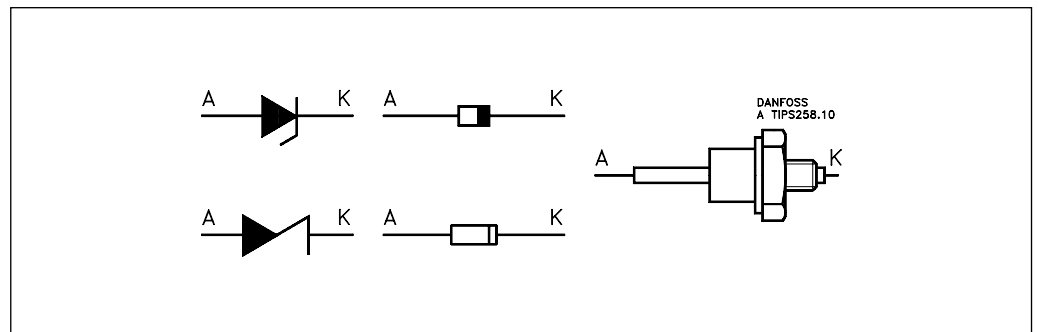
Our diagram and pertaining curves will look as follows:



## Semi-conductors



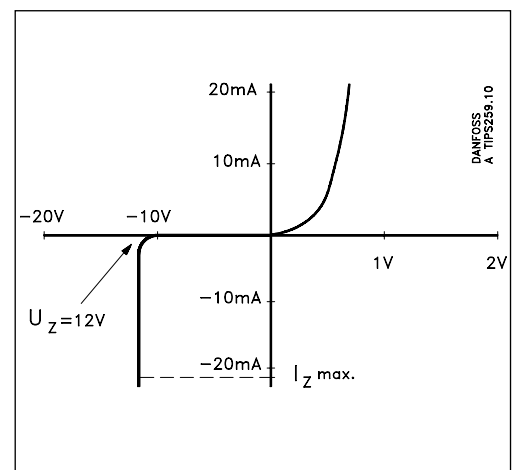
The weakly saw-toothed voltage under load is called **RIPPLE VOLTAGE** and it must be as small as possible. The closer we can get to the quite straight curve - the NO-LOAD voltage - the better. The interaction between load current and the capacity of the capacitor determines the size of the ripple voltage. However, it is hardly of any importance to a loading device, but most types of voltage supplies in electronic devices are built in the very same way, just much smaller. In these we are using more tricks to further dampen ripple frequencies and to keep the voltage **constant**, even during varying loads. For this purpose we use the **ZENER DIODE**.



The zener diode is a diode variant mainly for stabilizing purposes. A zener is made to stand the shock when PIV is exceeded.

Here we are now calling PIV for the **ZENER VOLTAGE**.

The zener diode is available for different voltages, in this case 12 V. They have normal diode characteristics in one direction, but also become conductive at the given voltage  $U_{Z1}$  zener voltage in reversed direction.



### Semi-conductors

There are many other diodes in the family, but here we'll only deal with another two as they are also being used in Danfoss' components. One of them is the LIGHT DIODE or as it is also called: LED, Light Emittend Diode.



It mainly consists of gallium arsenite ( $GaAs$ ) and this material emits light when a current is passing through it. It is indeed a very useful effect.

By changing the composition between  $GaAs$  and other materials the colours red, orange, yellow, green and even TWO different colours like e.g. red/green as in the PVEH will appear which is being used in the proportional valve PVG 32.

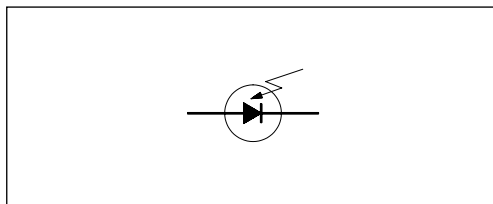
There are also LED's emitting **infrared** light. They are naturally called IR-LED.

Placed in the dark it is almost an isolator. Exposed to light it generates a voltage called the PHOTO VOLTAGE EFFECT.

In that condition you can take a current from it and it is then called a SOLAR BATTERY. If preset in reversed direction the reverse current ( $I_R$ ) will change linearly to the light intensity.

This effect is also used at Danfoss as a photo diode for oil or gas burners. This is all about diodes.

Then there is the PHOTO DIODE.



Indeed! an opposite LED

# Transistors

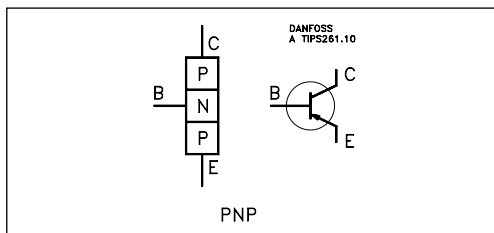
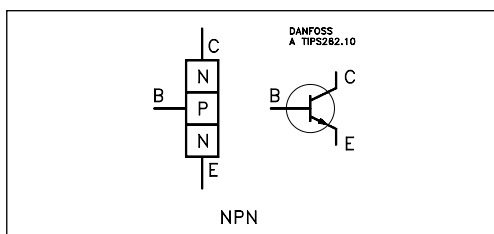
## Transistors

In almost all electronic components we come across - both at work and off duty - there are **transistors**.

Although we are not going to lose ourselves in the theory we should all the same have some sort of feeling of what is happening about the transistor technique.

The transistor is an amplifier element which at best may be compared to a pilot-controlled servo valve for also by means of transistors we can control a large current or effect with a small pilot current. Let's take a closer look.

The transistor has a laminated structure of silicon where the individual layers are differently treated, P or N doped. By doing so you'll get two different types of transistors, NPN and PNP. Their function is completely identical but with opposite polarity.



B is BASE, C is COLLECTOR, E is EMITTER.  
The base may be called:

**Bottom electrode**

The collector may be called:

**Current collector electrode**

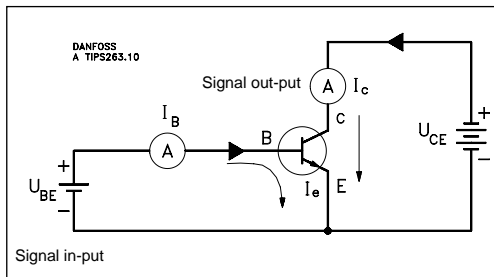
The emitter may be called:

**Input electrode**

The NPN transistor is most commonly used.

The basic features will be briefly outlined.

Let's take a look at this small diagram.

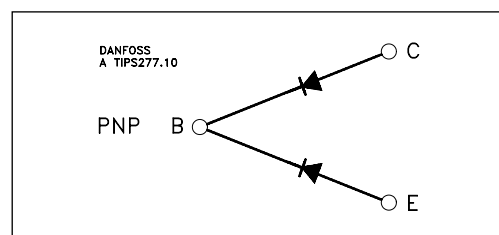
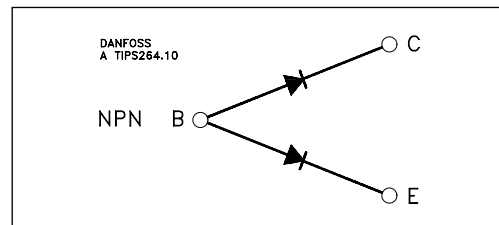


Rule 1:

The collector must always be more positive than the emitter (for a NPN).

Rule 2:

Base/emitter and base/collector behave like diodes:



Normally, the B/E diode is conductive and B/C back direction.

Rule 3:

Every transistor has maximum values for  $I_C$ ,  $I_B$ , and for  $U_{CE}$ .

You just don't exceed these values!

The number of times which  $I_{BE}$  is amplified across  $I_C$  is called the amplifier factor,  $\beta$ , (Beta factor).

The amplification is almost proportional to  $I_{BE}$  and for the different transistor types it may be everything between 8 and 800 times.

We know now that B/E is a diode and we also know that a voltage of 0.6 V is necessary to make it conductive.

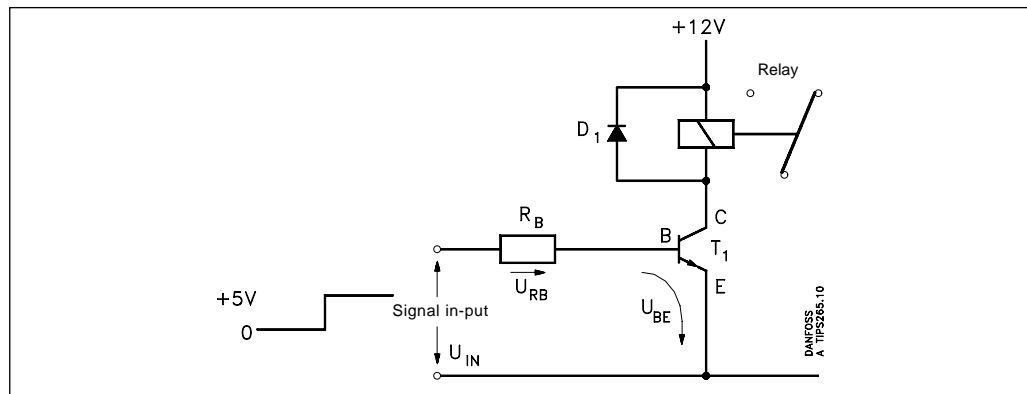
This means that the transistor is closed if the voltage e.g. is 0.5 V and consequently

$$I_B, I_C \text{ and } I_E = 0.$$

If  $U_B$  is increased to 0.6V the B/E-passage will open and the current  $I_B$  will be amplified by  $\beta$  to  $I_C$ .

$$\text{viz.: } I_C = \beta \times I_B$$

Circuit



And, what can we do with that?

Let's take a practical example - we'll use the transistor as a **switch without movable parts**. We want to activate a 12 volt relay which coil is drawing a voltage of 100 mA. We also want it to be activated with a signal of 5 V which is here a DC voltage peak quickly passing from 0 to +5 V and coming from some transducer. We also presume that we can draw 2 mA at most from this signal. From a transistor catalogue we choose one with  $I_C \text{ max.} = 100 \text{ mA}$  and according to the data sheet  $\beta$  is 80-150.

$R_B$  must have a size yielding sufficient  $I_B$  at minimum  $\beta = 80$

$$\text{So "worst-case" - } I_B = \frac{100 \text{ mA}}{80} = 1,25 \text{ mA}$$

$$U_{RB} = U_{in} - U_{BE} = 5 - 0,7 = 4,3 \text{ V}$$

$$R_B \text{ will be: } R_B = \frac{U_{RB}}{I_B} = \frac{4,3}{1,25} = 3,44 \text{ k}\Omega$$

Approximate standard value = 3,3 k $\Omega$

What is the diode  $D_1$  doing? well, it's doing the same thing as the condenser which we talked about in the chapter on coils.

As you may remember, a coil does not like to have the current passing through it interrupted. It reacts by generating a REVERSE (opposite polarity) voltage peak across its pins in a "desperate" attempt to maintain its magnetic field.

This voltage is high - several hundred volts - and may easily destroy the transistor (or burn the switches on an interrupter).

Therefore, a diode is placed transversely on the relay coil thus "cutting" the voltage peak when the relay is interrupted.

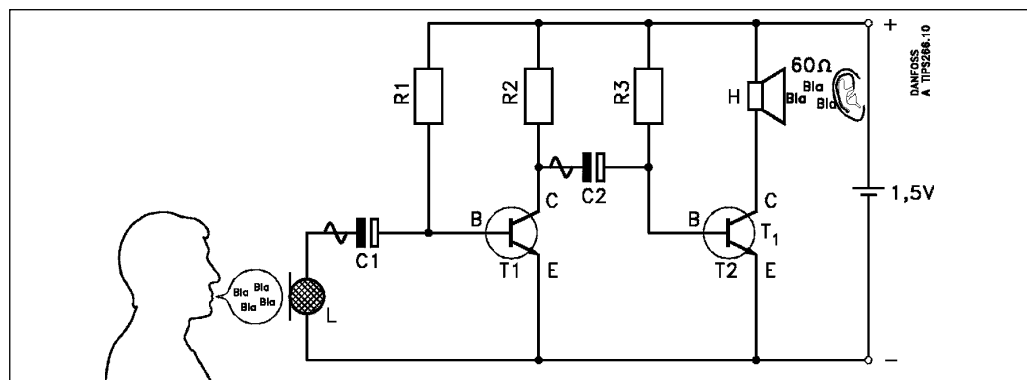
We are also going to look at the transistor as a **voltage amplifier** which is the most common application.

We'll make a monitoring amplifier for a telephone. Oh - but what is that? TWO transistors! This is getting complicated so let's explain further right from the beginning:

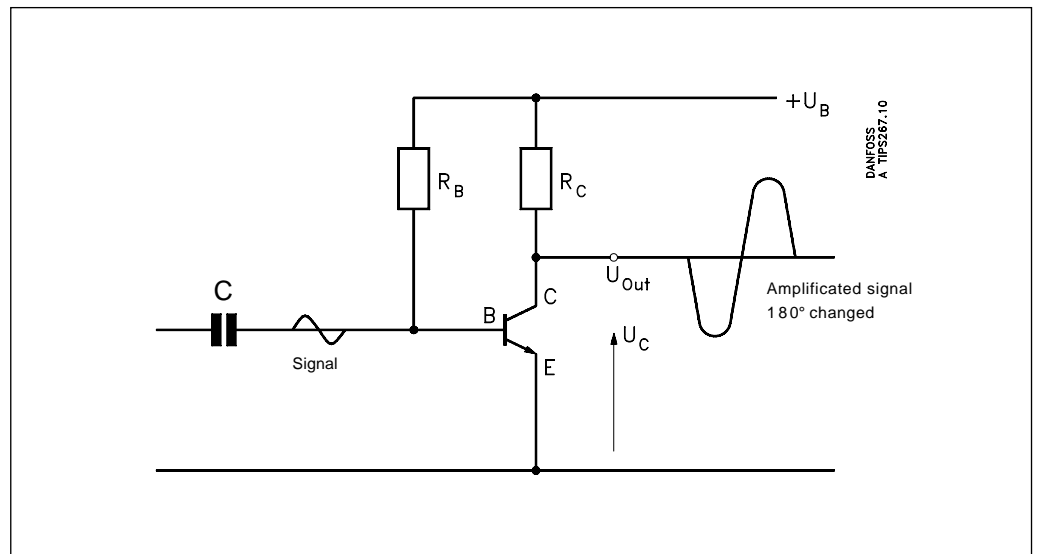
The input signal is yielded by a coil, L, of 180 mH - milli Henry - which is wound on a U-shaped iron core. This coil may be a parasite on the stray field inductively yielded by a telephone and induce a tiny voltage variation.

These small signals are sent across  $C_1$  to  $T_1$ 's base which has already opened for the passage EB-BC at the voltage we get across  $R_1$ . The signals we get from L are very different as they actually come from the variations in the voice from the person we are listening to.

This means that the signal amplified perhaps 100 times from  $T_1$  is led via  $C_2$  to the base of  $T_2$  where the signal is again amplified 100 times depending on the  $\beta$ -factor of the transistors. The amplified signal is now so large that a 60  $\Omega$  headphone can oscillate and via its membrane we hear the conversation. This signal amplification is indicated on the next page.



Circuit



Let's look at it first **without** signal.  
 $R_B$  and  $R_C$  are calculated to allow a current of e.g. 2 mA through the transistor: which means from  $+U_B$  through  $R_C$  to the collector and out of the emitter to frame (minus) in the transistor,  $I_C$  (collector current).

This current is calculated in a way that the voltage drop across  $R_C$  corresponds to

$$\frac{U_B}{2}$$

We are now sending a signal in from a microphone presuming that it is sinus-shaped, its frequency is 1 kHz and that it has an amplitude of 10 mV.

The positive half-wave will get more  $I_B$  (basic current) to run just as the negative half-wave will reduce  $I_B$ .

The collector current  $I_C$  will act like  $I_B$ , but  $\beta$  times more and any change of  $I_C$  will reflect itself as a voltage change across  $R_C$  and between the collector and frame (minus).

As a result we will see an amplified version on the collector of the input signal fluctuating symmetrically around a DC voltage =

$$\frac{U_B}{2}$$

And here you will find the reason for placing

$U_C$  between  $+U_B$  and 0 volt (frame): it must be able to fluctuate symmetrically both in positive and in negative direction.

The final amplification will be of the size 100 times. We can see that the **amplitude** is amplified, but the **length of wave** is the same. Otherwise, we'll get a **distorsion** of the signal (sound).

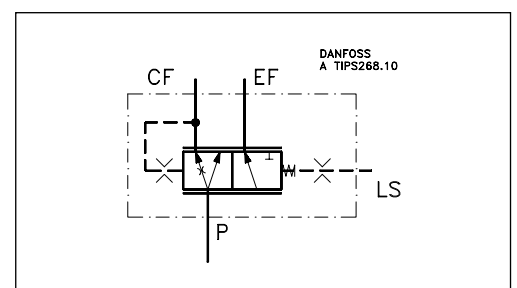
And the condenser C?  
 C has two purposes:

1. Prevent the basic voltage ( $U_B \approx 0.7\text{V}$ ) from being short circuited by the low DC resistor of the microphone.
2. Act an AC short-circuit for the signal, viz. a **COUPLING CAPACITOR**.

Let's take another look at hydraulics!  
 Take a look at this diagram of a priority valve, type OLSB.

Does it ring a bell?

P is the main supply ( $+U_B$ )  
 LS is signal input (base)  
 CF is signal output (collector)  
 EF is (with a little ingenuity) emitter and from P we get  $I_C$ , here the sum of the flow to CF and EF.



## Operational amplifier

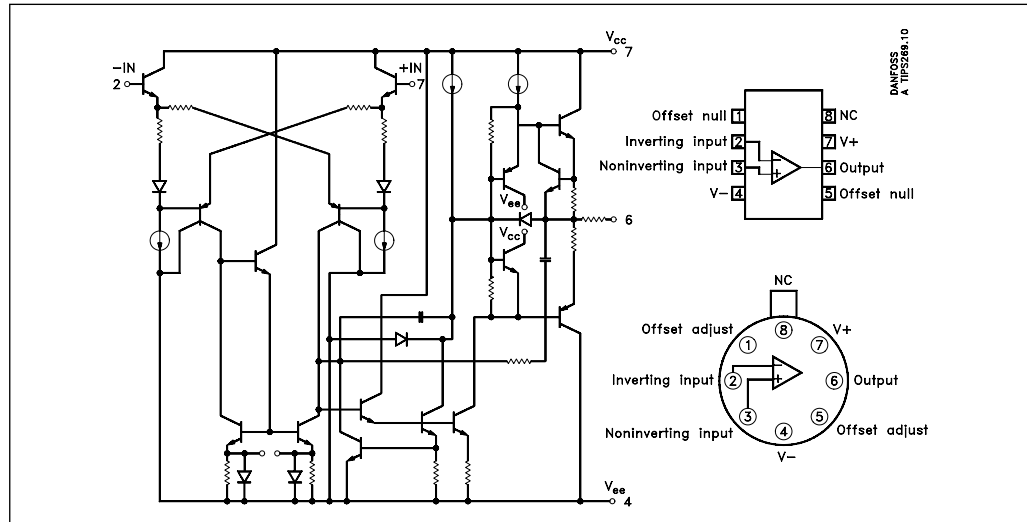
### Operational amplifier

Last of all, let's take a look at the **operational amplifier**, usually called Op-Amp (Operation Amplifier).

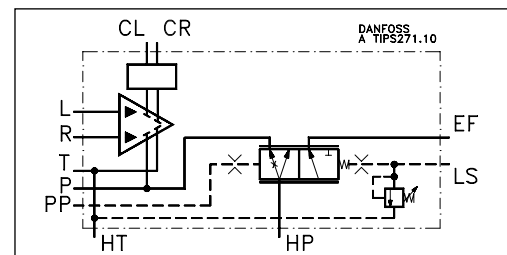
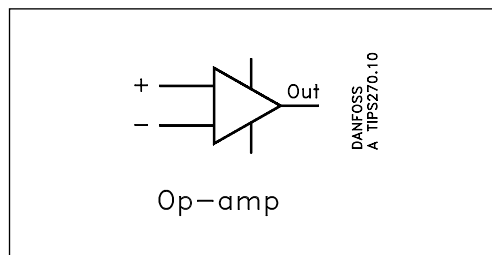
It belongs to the group IC (Integrated Circuits) which consists of very compact circuits cast in plastic or ceramics and provided with pins

which are connected to the integrated circuits.

The electronic circuit contained in an IC seldom takes up more space than a few mm<sup>2</sup>. The diagram below is a typical example of a circuit contained in an IC.



The Danfoss flow amplifier type OSQ is the hydraulic reply to the electronic operational amplifier. In the diagram sketch of OSQ we recognize the triangular amplifier symbol.



An amplifier built up on basis of one or several Op-Amps is "tailored" to the application requested by means of passive components connected on the outside to the pins of the IC.

The Op-Amp is used in a number of different connections, but we are only going to deal with the two most frequently used:

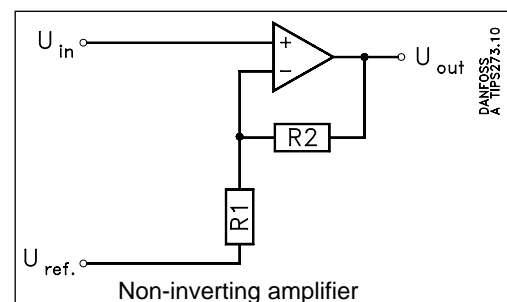
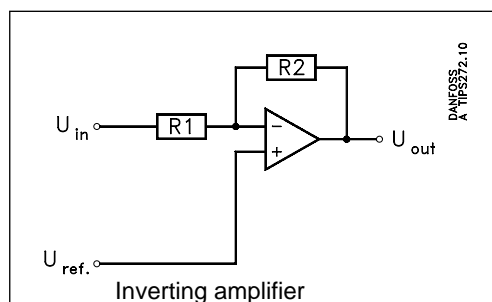
- 1: Inverting amplifier (negative amplification)
- 2: Non-inverting amplifier (positive amplification)

The two inputs of the Op-Amp is in the symbol

for an Op-Amp marked "+" and "-" and called non-inverting and inverting input, respectively.

The two amplifier principles are very easy to calculate seeing that:

- A: The input resistance in both + and - is calculated as  $\infty$ ; therefore, the current through  $R_1$  will be the same as through  $R_2$  in the above diagram.
- B: The voltage applied non-inverting input will always be copied to inverting input i.e. the voltage difference between + and - = 0



## Inverting amplifier

$$A_V = \frac{-U_{out}}{U_{in}} = -\frac{R_2}{R_1}$$

$U_{out}$  can be calculated direct from above:

$$U_{out} = -\frac{U_{in} \times R_2}{R_1}$$

## Non-inverting amplifier

$$A_V = \frac{U_{out}}{U_{in}} = \frac{R_1 + R_2}{R_1}$$

$U_{out}$  can also be calculated here:

$$U_{out} = U_{in} \times \frac{R_1 + R_2}{R_1}$$

## A practical example

As it will appear from the two examples you can calculate an amplifier arrangement merely by knowing  $U_{in}$  and the requested  $U_{out}$ , and selecting a resistance, - so now you will just have to calculate a resistance.

We are going to make a simple version of an electronic flow adjustment unit, EHF. Let's imagine a 24 volt installation.

Our largest input signal will be

$$U_{in_{max}} = 0,25 \times U_{cc} = 0,25 \times 24 = 6 \text{ volt}$$

We want a signal reduction of 25%, viz.

$$U_{out} = 0,75 \times U_{in} = 0,75 \times 6 = 4,5$$

As we now know  $U_{in}$  and  $U_{out}$  we can calculate the amplification

$$A_V = \frac{U_{out}}{U_{in}} = \frac{4,5}{6} = 0,75$$

As the amplification is less than 1 we have to choose an inverting amplifier.

We choose  $R_1$  to 10 kOhm and can then calculate  $R_2$  as

$$R_2 = -A_V \times -R_1 = -0,75 \times -10 \times 10^3 = 7,5 \text{ k}\Omega.$$

As PVE always looks at signals in relation to

$$\frac{U_{cc}}{2}$$

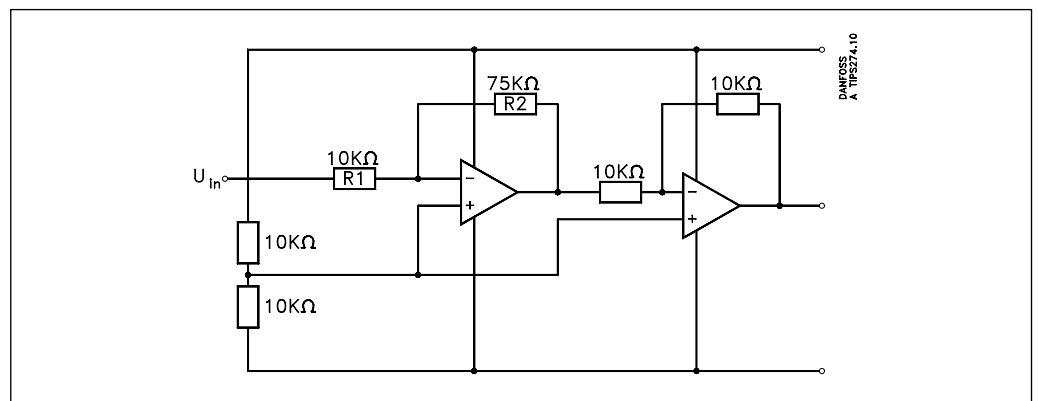
we have to let the Op-Amp have a reference to

$$\frac{U_{cc}}{2}$$

The inverting amplifier turns A signals into B and B into A which means that we have to invert the signal once again before sending it out.

This is done by means of an inverting amplifier with 1  $\times$  amplification.

## The finished circuit:



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## Trouble shooting

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### Trouble shooting

If reading this chapter would solve all problems of trouble shooting everything would indeed be extremely easy; we might even have done without all the previous pages!

However - it is far from that easy. Irrespective of our thoroughness and the number of failure situations imaginable we'll almost always come across new situations in practice.

However - a common denominator always applies whether dealing with hydraulics or electronics:

#### SYSTEMATIC TROUBLE SHOOTING

Don't learn from the butterfly fluttering aimlessly from flower to flower in a garden.

Think and work in logical order and literally follow the direction of the current whether talking about hydraulic or electrical currents.

1. Start with the beginning: Is there any oil in the tank? Are there pressure and flow at all on the hydraulic installation? If there are abnormal conditions here the error may be either hydraulic or electrical.

Therefore: Determine whether the error is electrical or hydraulic, but remember: Without specified pressure and flow it is not easy to find the cause of failure.

2. Next item: Power supply.  
Don't **ask** if there is current on the accumulator/battery - the answer will always be: "Yes, of course". This would also be the reply if we asked whether there is oil in the tank.

It is safer to **check** whether the battery voltage is correct. Also check whether there is water on the battery cells. If a lot of water is missing the terminal voltage of the battery may be o.k. in unloaded condition, but loaded it will drop many volts.

3. Are the fuses intact and emergency stop and/or key contacts, if any connected?

Has a lead perhaps been shaken loose in a terminal board in the mix box?

4. Are the leads from the power supply correctly polarized, plus to plus and minus to minus?

A PVE of the ON/OFF type will e.g. work correctly even if plus and minus has been switched whereas a PVE of the proportional type in that case will be completely dead.

Therefore, try to switch the Hirschmann plugs on an ON/OFF and a proportional PVE, respectively and check the functions again.

These totally fundamental conditions must naturally be all right before we start looking at the individual components and their inlines.

Is the user of the vehicle present he should be thoroughly questioned about

- The kind of failure and influence on the system
- For how long has he noticed that something was going wrong
- Has he been "fiddling" with leads and plugs himself, and
- Has he got hydraulic and electrical diagrams at his disposal?

Such diagrams are often enclosed with the directions for use following the installation or the vehicle. Unfortunately, they are often so schematic that they are not very useful anyway in a trouble shooting situation; still, they do show the order and the connections between the individual components.

Finally, a piece of good advice:

**LOOK  
LISTEN  
FEEL  
ASK  
THINK**

**before ACTING**

Take **NOTES** - they might turn out to be useful the next time.

In that way you gather **EXPERIENCE**.



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## Comments

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Comments

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**Comments**

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**Comments**

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**Comments**

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**Comments**

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## Danfoss Hydraulics

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Catalogues and leaflets are available for detailed information on the following hydraulic compo-

- Low-speed high-torque hydraulic motors
- Planetary gears
- Hydrostatic steering units
- Steering columns
- Valve blocks
- Flow-amplifiers
- Priority valves
- Torque amplifiers
- Variable displacement hydraulic pumps
- Proportional valves
- Remote control units
- Electronics for hydr. components
- Rotary actuators
- Gear wheel motors
- Gear wheel pumps
- Cartridge valves
- Directional control valves

Please contact the Danfoss Sales Organization for Hydraulics for further information.

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