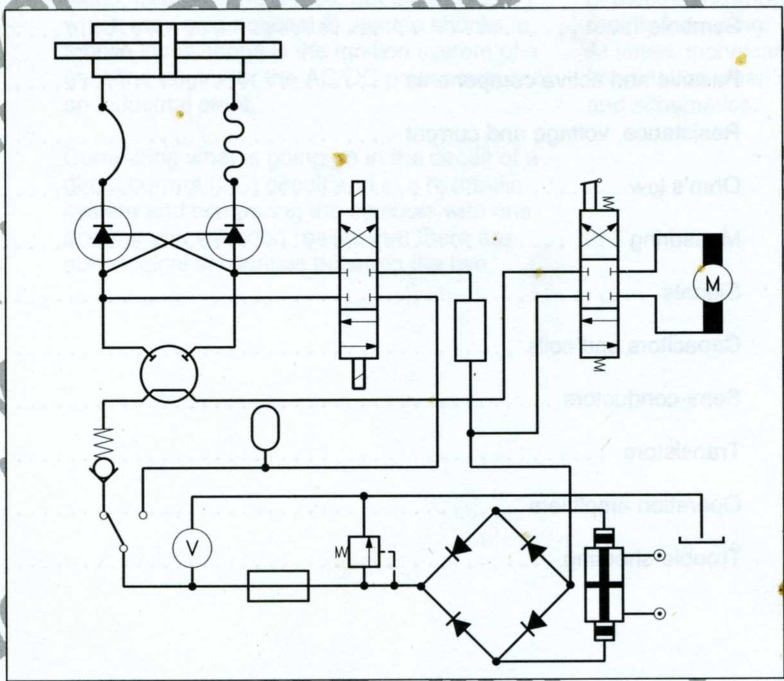
Danfoss
Fluid Power

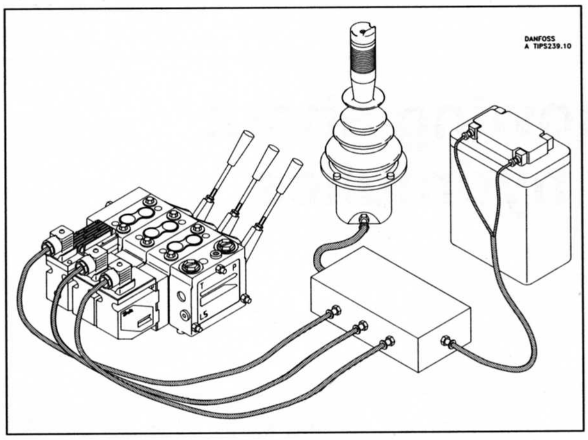
Training material

Facts worth knowing about electronics for hydraulics



DKMH.PF.000.A1.22 **520L0236** Book 10 Partition 2 www.danfoss.com/fluidpower

Contents



Danfoss Hydraulics

Facts worth knowing about electronics for hydraulics

Purpose

Purpose

The purpose of this training booklet is to give hydraulics technicians in service centers and sales departments enough basic knowlledge 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 idea that this booklet will enable you to go home and repair a television or stereo. They have a dangerously high volt level 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 levels described in the following text range from 0 to 42 volts, where it is highly unlikely for electrical shock to occur. 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 gasoline 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 comparing the symbols with one another you will soon realize that there are quite logical similarities between the two.

An understanding of common electrical signals will help the technican read and understand electric circuit diagrams. The electrical schematic is a guide for understanding the function of the electrical system and how the individual components are connected, just as the hydraulic diagram is for the hydraulic system.

Simple electronic circuits will also be described. Descriptions developing an understanding of electrical sketches and schematics in Danfoss catalogs, and the function of the components in the catalog.

In the following chapter, comparisons will be made between the electric and hydraulic symbols which have similar functions.

Besides international standards, there are also many national standards. You will frequently come across small differences in the symbol for the same thing. Some companies even apply their own "standards". The variety of electrical components and symbols is rapidly incriesing.
At times, technicans will need to use their imagination when reading electrical diagrams and schematics.

Basics

Just as Pascal, Bramah, Reynold and other physicists found and defined natural laws and principles for hydraulics, other discoverers have determined laws, principles and values for electronics..

Electrical pioneers include Volta, Ampère, Farady, Hertz, Ohm, Watt, Coulumb, and others such as the Dane Ørsted.

Each have lent their name to the units and laws they discovered and described. Remarkably, most of them lived from the middle of the 18th century to the middle of the 19th centrury!

A summary of the electrical units used throughout the text is included below.

Volt: unit for measured voltage.
Symbols in formulas: U
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: unit for measuring electric current,
Symbols in formulas: I
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, unit for measuring resistance.
Symbols in formulas: R (Resistance)
Defined by the German Georg Simon Ohm (1787-1854).

1 Ω is the resistance at 0°C in a 106,3 cm long mercurial column with 1 mm^2 section.

Watt: unit for measuring electric power.
Symbols in formulas: R
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: unit for measuring capacity.
Symbols in formulas: F
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 electromagnetism.

Shaft load and shaft versions

Designation	Symbol	Unit of measurement	Abbreviation
Voltage	U (E), u	volt	V
Current	I i	ampère	A
Resistance	R r	ohm	Ω
Power	P	watt	W (V · A)
Work (energy)	A	watt · hour	Wh (W · hour)

Designation	Unit of measurement	Abbreviation	Value
Voltage	mega volt	MV	$1,000,000 = 10^6$
	kilo volt	kV	$1,000 = 10^3$
	volt	V	$1 = 10^0$
	milli volt	mV	$\frac{1}{1,000} = 10^{-3}$
	micro volt	µV	$\frac{1}{1,000,000} = 10^{-6}$
Current	ampère	A	1
	milli ampère	mA	$\frac{1}{1,000} = 10^{-3}$
	micro ampère	µA	$\frac{1}{1,000,000}$
Resistance	mega ohm	MΩ	$1,000,000 = 10^6$
	kilo ohm	kΩ	$1,000 = 10^3$
	ohm	Ω	1
	milli ohm	mΩ	$\frac{1}{1,000} = 10^{-3}$
	micro ohm	µΩ	$\frac{1}{1,000,000} = 10^{-6}$
Capacitor	farad	F	1
	micro farad	µF	$\frac{1}{1,000,000} = 10^{-6}$
	nano farad	nF	$\frac{1}{1,000,000,000} = 10^{-9}$
	pico farad	pF	$\frac{1}{1,000,.000,000,000} = 10^{-12}$

Symbols

References

Electrical signatures:
IEC recommendations
117-1 to 7.

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

CETOP:
Comité Européen des
Transmissions
Oléohydrauliques et
Pneumatiques.

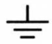
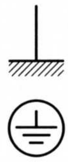
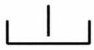
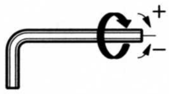
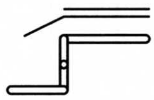
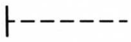
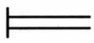
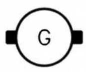
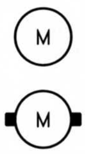
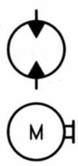
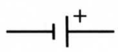
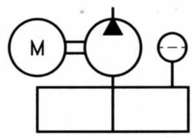
IEC 117 No.	Electrical symbols	Description	Hydraulic symbols if any	Comparitive description
3	∼	Alternating current. Changing polarity.		Pulsating flow, changing direction, few applications (hydraulic hammer)
1		Direct current. The current runs in one direction from plus to minus.	▶	The oil flow runs in one direction, usually from pump to tank
19	+	Positive polarity. Plus Identification color: red Red- DC circuits		Flow direction forward motion Identification color: red
20	—	Negative polarity. Minus Identification color: black Black- DC circuits		Tank line Identification color: 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	or	Crossing conductors without electric	or	Crossing tubes without connection connection

References

Electrical signatures:
IEC recommendations 117-1 to 7.

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

CETOP:
Comité Européen des Transmissions Oléohydrauliques et Pneumatiques.

IEC 117 No.	Electrical symbols	Description	Hydraulic symbols if any	Comparitive description
86		Earthing Identification color: Green/Yellow		
87		Frame connection often common minus Identification color: Green/Yellow		Tank connection Identification color: 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
		Battery, dry cell, or DC power supply (The long line is always + pole)		Power pack

References

Electrical symbols:
IEC recommendations
117-1 to 7.

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

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Comité Européen des
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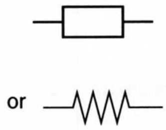
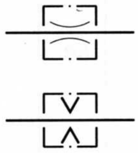
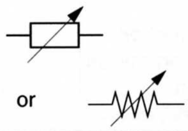
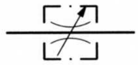
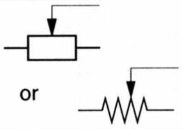
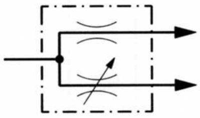
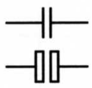
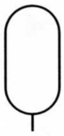
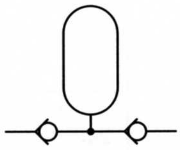
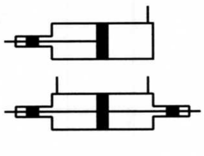
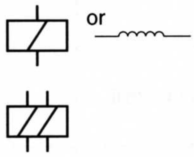
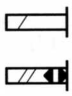
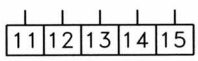
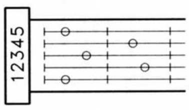
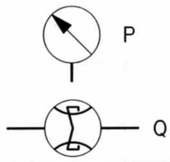
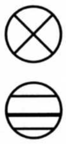
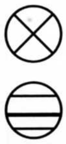
Oléohydrauliques et
Pneumatiques.

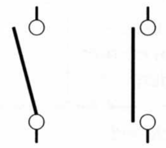
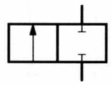
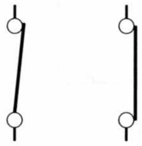
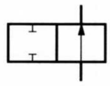
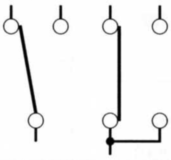
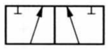
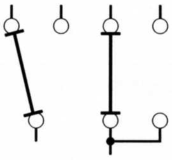
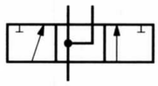
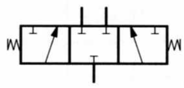
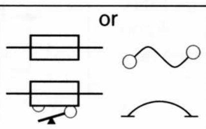
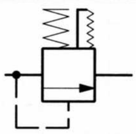
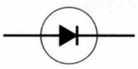
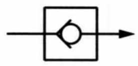
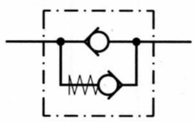
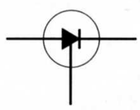
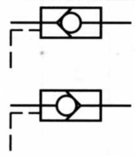
IEC 117 No.	Electrical symbols	Description	Hydraulic symbols if any	Comparitive description
74		Resistance, fixed, size indicated in Ohm		Orifice, throttling Viscosity depentent Viscosity independent
512		Variable resistance Largest resistance indicated in Ohm,		Orifice variable throttling
519		Potentiometer 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

References

Electrical symbols:
IEC recommendations 117-1 to 7.

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

CETOP:
Comité Européen des Transmissions 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		2/3 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.

References

Electrical symbols:
IEC recommendations
117-1 to 7.

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

CETOP:
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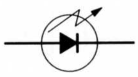
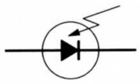
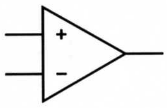
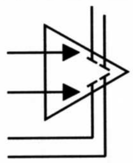
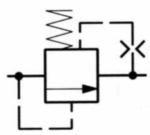
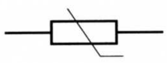
IEC 117 No.	Electrical symbols	Description	Hydraulic symbols if any	Comparitive description
		LED, Light Emitting Diode Lights up when current is passing through.		Pressure cut-out with control lamp
		Photo diode, closed in the dark, open in daylight. Controlled by light intensity.		Works as pilot-controlled check valve, the “pilot” is light
623		Transistor, PNP Amplifies an input signal by a factor to the output		Bears only just comparison with the pressure converter page 8 item 157.
624		Transistor. NPN Amplifies an input signal by a factor to the output.		Bears only just comparison with the pressure converter page 8, item 157.
522		Operational amplifier OP-AMP		OSQ. Flow amplifier This valve contains a hydraulic Op-Amp, a proportional amplifier.
		VDR-resistance. Voltage Dependable Resistor. Large resistance 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 at high temp.		
		PTC-termistor. Positive Temperature Coefficient. Large resistance at high temperature.		
617		LDR, photo-resistance Light Dependable Resistor. Large resistance in dark, small resistance 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 aperforming one or several functions if supplied with a voltage or a signal, like e.g. a voltage variation. These components are among others:

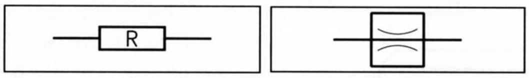
Diodes, transistors, op-amp's gates etc.
We are now going to start little by little with the easiest part - the **passive** components and the terms **voltage and current** and how we

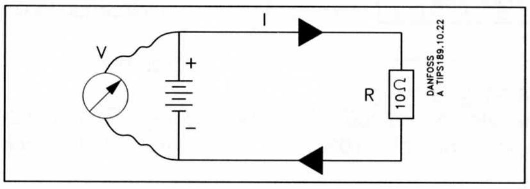
Resistance, voltage, current and Ohm's law

The voltage V is e.g. 12 V which forces a current I THROUGH the resistor R which is 10 Ω.

Symbols

Resistor — Throttle valve

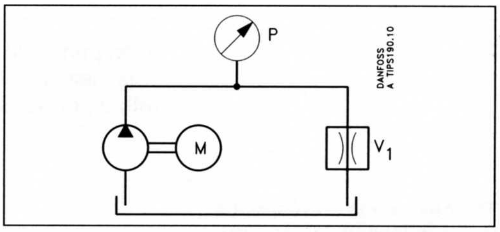




As earlier mentioned the size of resistance is indicated in **Ohm, Ω**

and depending on the size we normally use:
Ohm for resistance up to 999 Ω
kohm, kiloohm, from 1 kΩ (1,000 Ω) up to 999,999 Ω
Mohm, Megohm, from 1 mΩ (1,000 kΩ) 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 dont' you?).

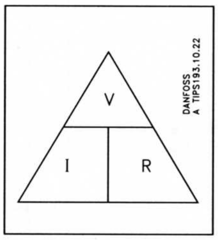


Here the differential pressure P across the relief valve is e.g. 12 bar and the flow through V_1 is the pump displacement multiplied by the number of revolutions.

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

$$V = I \times R$$

which means that voltage is equal to current multiplied by resistance. If two of the three values are know, the third can be easily calculated:



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

What is the current I through our resistance in the circuit on the previous section.

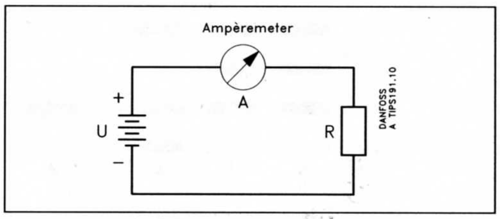
$$I = \frac{U}{R} = \frac{12\ V}{10\ \Omega} = 1.2\ A$$

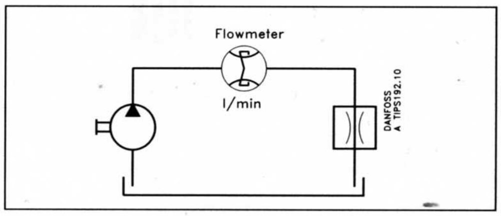
If U and I are known, but not R we find it this way:

$$R = \frac{U}{I} = \frac{12\ V}{1.2\ A} = 10\ \Omega$$

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 formula.
As you will see, a voltage **across** a resistor is reflecting the current passing **through** it.

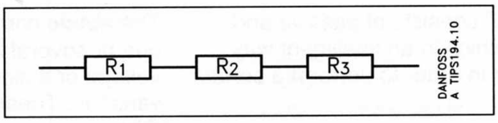
Current is often measured by measuring the voltage drop across a resistor. The measured voltage value is divided by the value of the resistor to determine the current flow. Measuring current with an ammeter can effect the current flow. The ammeter must be connected in series to allow the current to flow through it. The resistance of the ammeter can reduce the current flow. It can also be difficult to insert an ammeter in series with a resistor, e.g. a resistor on a printed circuit board.





Series and parallel connection

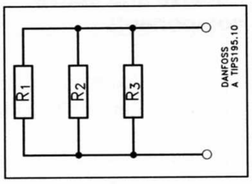
Total resistant $R = R_1 + R_2 + R_3$ etc.,



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

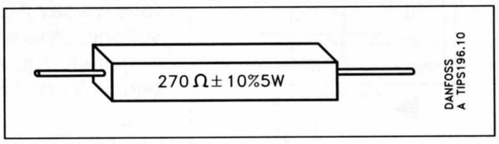
Total resistance in a parallel connection is found as follows:

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



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 ± 10% and

However, on physically small resistors there is no room for plain text. Here an international code marking consisting of normally 4 or 5 rings of different colors is used. When reading the colors you start with the ring close to the wire or opposite the thick ring. The first rings indicate the resistance in Ohm and a last (thick) ring, if any, indicates the tolerance in %. No tolerance indication means ± 20% tolerance.

Example:

Grey - Red - Black : 82Ω ± 20%
Grey - Red - Black - Red : 82Ω ± 2%

The color code corresponds to the following values (DIN IFC 62)

	1.Ring	2.Ring	3.Ring	4.Ring
Black		0	x1	
Brown	1	1	x10	
Red	2	2	x100	±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	±5% Gold
White	9	9	:100	Silver

DANFOSS A TIPS198.11

	1.Ring	2.Ring	3.Ring	4.Ring	5.Ring
Black		0	0	x1	
Brown	1	1	1	x10	±1%
Red	2	2	2	x100	±2%
Orange	3	3	3	x1 k	
Yellow	4	4	4	x10 k	
Green	5	5	5	x100 k	±0.5%
Blue	6	6	6	x1 M	±0.25%
Violet	7	7	7		±0.1%
Grey	8	8	9	:10	Gold
White	9	9	9	:100	Silver

DANFOSS A TIPS199.11.22

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 resitance against the current and power is the product of pressure multiplied by flow or (in electronics) **voltage multiplied by current**:

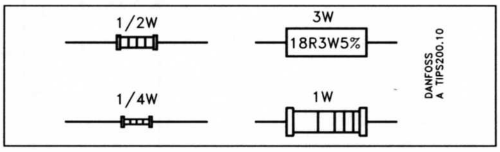
Power, P (in watt, W) = V (Volts) × I (amps)

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.

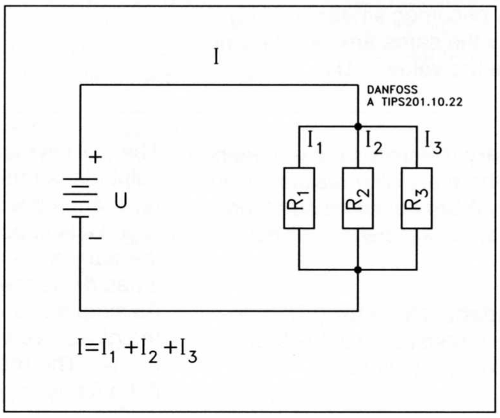
Therefore, all resistor sizes are available in several different power sizes of which the most frequently used are for 1/4 W, 1/2 W, 1 W and 3 W load corresponding to a throttle valve with e.g. 1/8", 1/4", 3/8" and 1/2" pipe thread connections. Resistor is usally sellected to have wattage rating of 2 x wattage generated by the circuit.

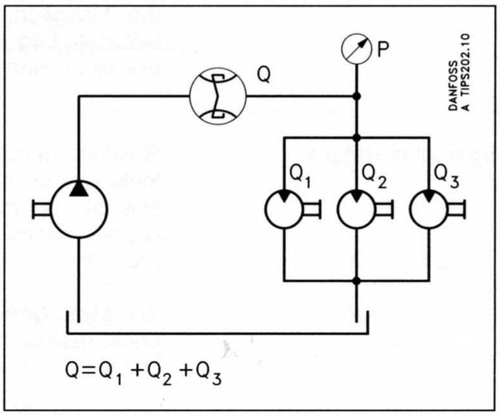


This is the approximate size of these resistors.

Current and voltage divider

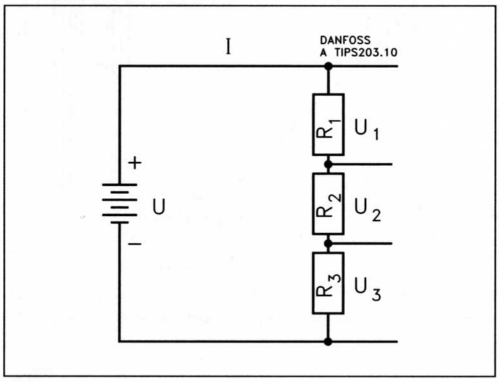
A **parallel circuit** is also a **current divider**.

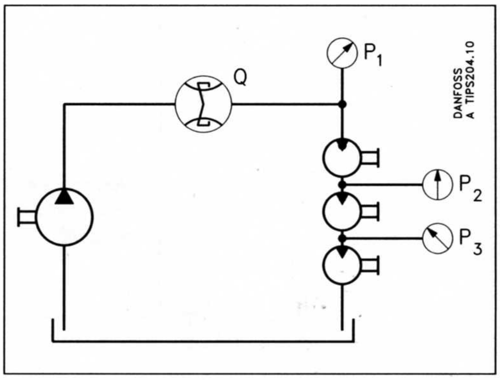




The voltage U (pressure P) is common to all resistors (throttles), but the current is divided in I_1, I_2 and I_3 (Q_1, Q_2 and Q_3) according to the resistance values.

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





Current I flows through each of the resistors. The voltage drop across each resistor is equal to the current (I) multiplied by the resistance (R). The total voltage (U) is equal to the sum of the three voltage drops across the individual resistors.. Flow Q flows through each of the motors. P_3 is the pressure drop from motor 3 inlet to tank. P_2 is the pressure drop from motor 2 inlet to tank. P_2 - P_3 = pressure drop across motor # 2.

Using Ohms law:

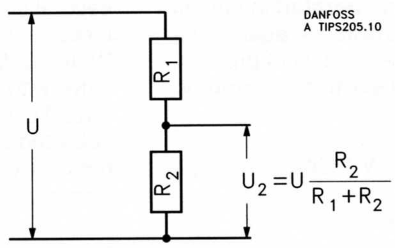
$$I = \frac{U}{R_1 + R_2}$$

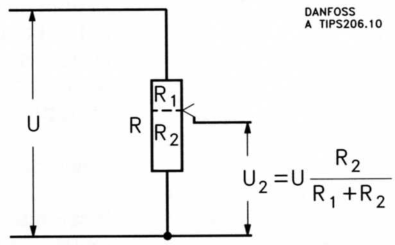
$$U_2 = R_2 \times I$$

$$U_2 = R_2 \left[\frac{U}{R_1 + R_2}\right]$$

$$U_2 = U \left[\frac{R2}{R_1 + R_2}\right]$$

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





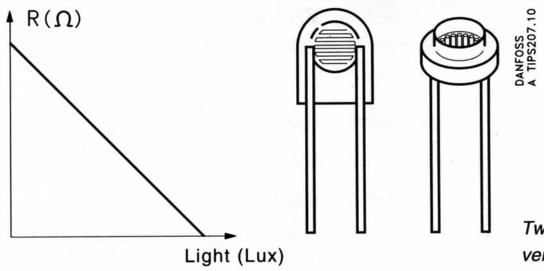
In the circuit with two resistors, U_2 is a fixed value. In the circuit with the potentiometer, the wiper of the potentiometer can be moved to change R_1 and R_2. As the wiper moves up in the illustration, R_1 becomes smaller and R_2 becomes larger by the same amount. Moving the wiper changes the value of U_2.

Special resistors

Besides the ordinary resistors we have been looking at so far, there are also resistors with special properties. A brief description of the characteristics of special resistors will be presented.

The **Light Dependable Resistor** (LDR) on photo resistor has a resistance value that changes as it is exposer to light.

The LDR 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. As simple example of an LDR application is the glass eye in the burner tube of an oil burner. The resistance of the LDR will indicate if the flame is on or off.



Resistance light characteristics for LDR resistors

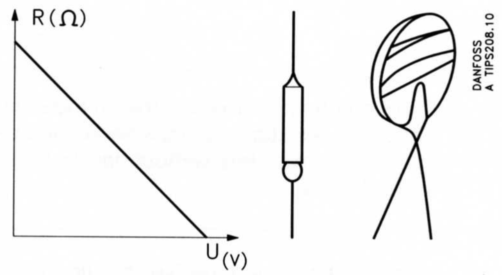
Two different LDR versions

The **Voltage Dependable Resistor**, VDR, is another type of special resistor.

The VDR is made of sintered silicium carbide, a material with the property that its resistance changes according to the voltage applied to it. The resistance decreases when the voltage is increased.

The VDR can be used to give a "soft start" to a circuit. Its resistance is large when a small voltage is applied. As the applied voltage increases, resistance dereases and allows more current to flow through the circuits. The function is similar to check valve with damper opening.

Resistance-voltage characteristics is VDR resistor



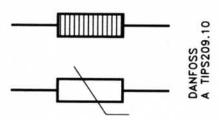
Common types of VDR resistors

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 = Negative Temperature Coefficient.
PTC = Positive Temperature Coefficient.

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 an accurate measurement, the voltage, current and resistance of the circuit should not change when the meter is connected to the circuit.

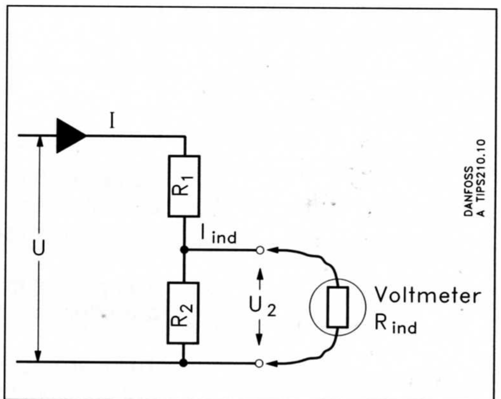
All measuring instruments will have an inner resistance, R_{ind}.

Volt meter

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

When the voltmeter is connected to the circuit, R_{ind} forms a parallel circuit with R_2. If R_{ind} is small, less current will flow through R_2. This will cause the meter to measure a voltage drop across R_2 that is smaller than the voltage drop with the meter disconnected.

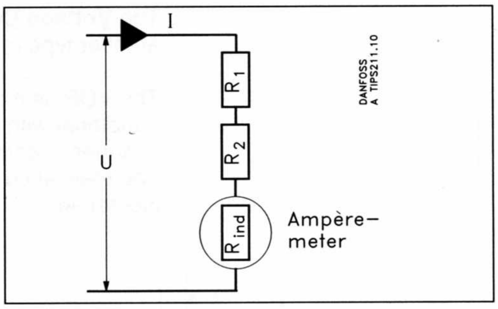
Conclusion:
The inner resistance of a VOLTMETER must preferably be infinitely high: $R_{ind} = \infty$



Ammeter

To measrure current, the ammeter is connected in series with the circuit. The Rind is large, the current will be reduced. The ammeter will read a lower value than the normal current flow in the circuit

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



Ohmmeter

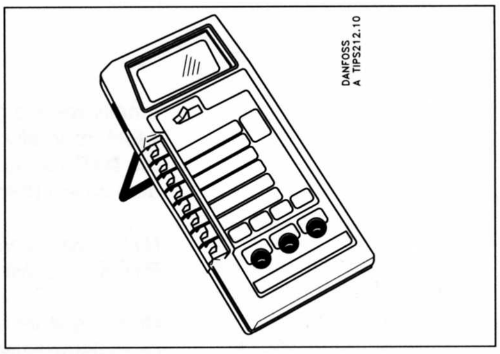
A good ohmmeter is capable of measuring effective resistance across series and parallel connected resistors without having to make calculations.

Since the ohmmeter connects a referance voltage across the resistor to measure its value, the resistor should be disconnected from

Multimeter

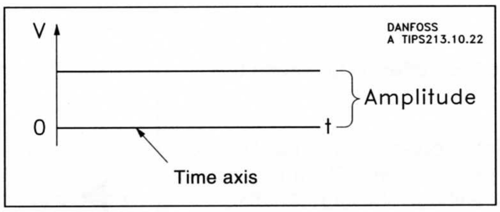
For most common trouble shooting we almost always use a DIGITAL MULTIMETER, i.e. a UNIVERSAL INSTRUMENT.

The digital multimeter shown here is FLUKE, one of many possible suppliers.



Signals

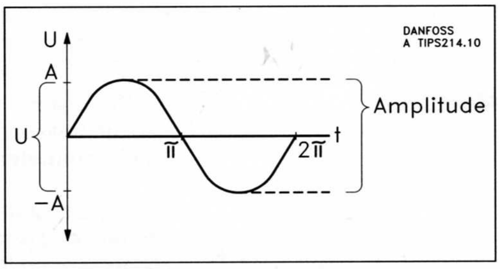
Now, we must not forget that we are still in the chapter passive and active components and that so far we have only been talking about resistors.
Amongst passive components there are still **condensers** and **coils** to be dealt with. However, as they are very much used in the **alternating current 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 signals.

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

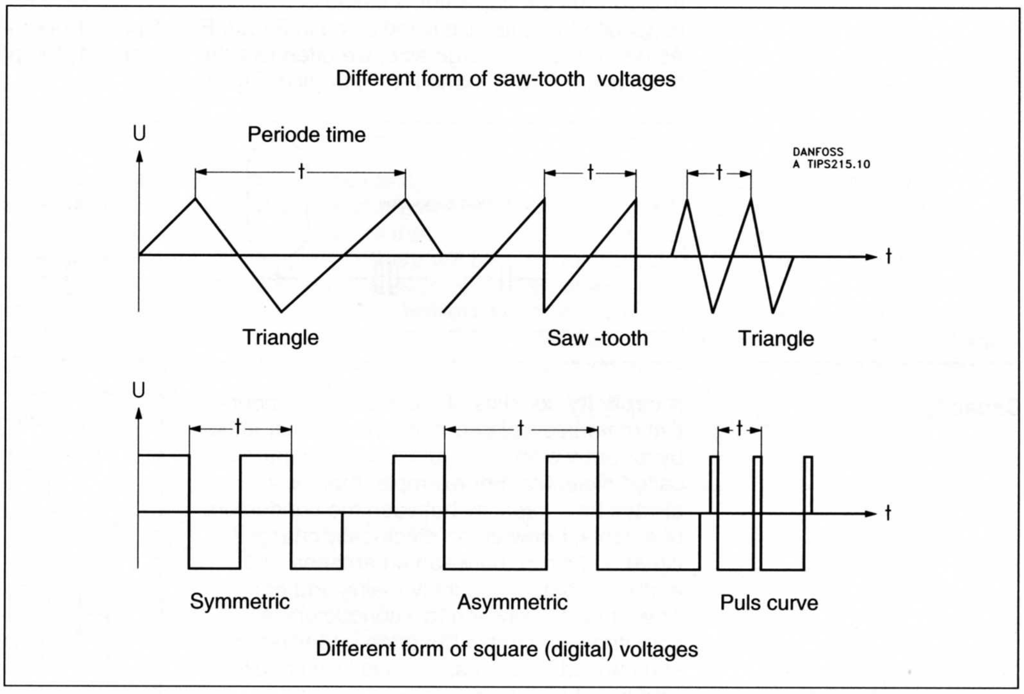
It will appear from the figure that a **current periodically changing its polarity is an alternating current**.
The average value for a whole period of a alternating current is zero. The AC curve illustrated is **sinus-shaped**.
In most of Europe there is AC supply which everywhere has a frequency of 50 Hz whereas e.g. the USA and Canada is supplied with 60 Hz.

Other curve shapes

Although the sinewave 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

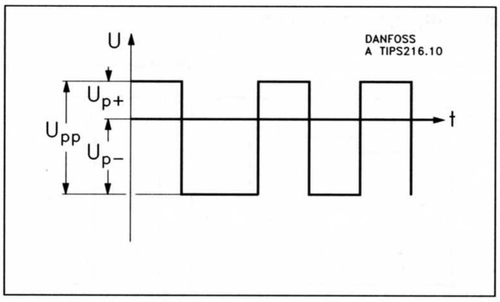


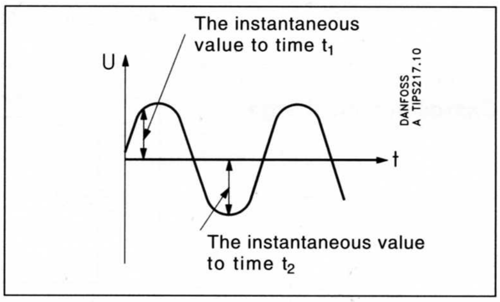
Peak value
The peak to peak value is the sum of the maximum positive and negative deviation from zero.
The peak value is the maximum deviation from zero.

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 Up- 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 U_p+ to U_p-.





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 type of signals used.

Danfoss

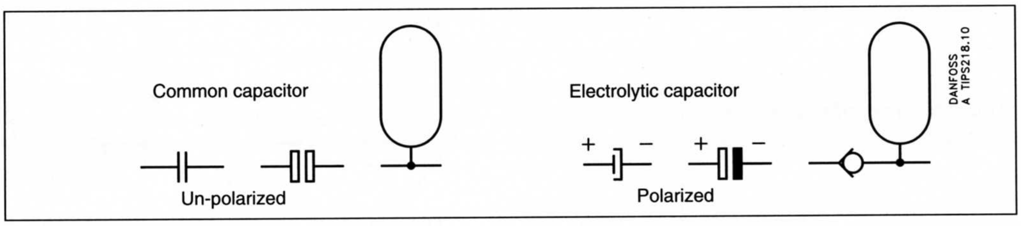
Capacitors and Coils

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 (µF), nano F (nF) or pico F (pF) corresponding to 10-6, 10-9 and 10-12 F, respectively. In other words:

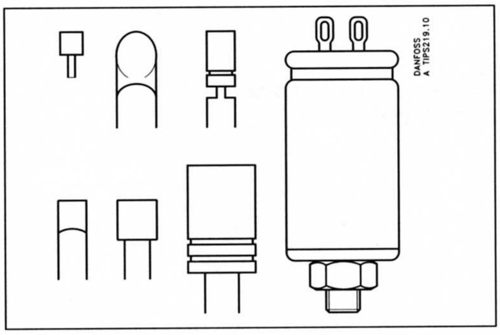
1 F = 1000,000 µF = 1,000,000,000 nF = 1,000,000.000.000 pF

1 µF = 1,000 nF = 1,000,000 pF
1 nF = 1,000 pF



Capacity

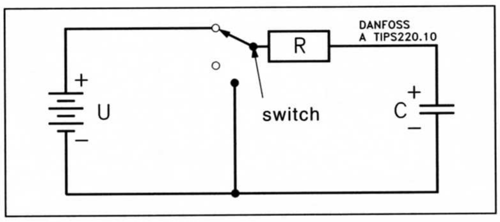
A **capacity** consists of 2 electrically conductive materials isolated from one another either by air or by a firm or liquid insulating material called dielectric. For example, there will always be a capacity between the conductors of a cable, between an electrically charged cloud and earth, between 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.

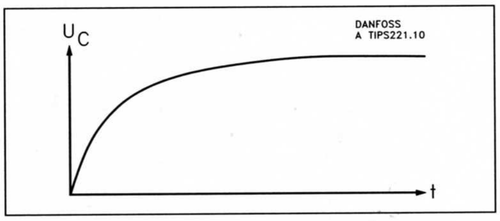


A **capacitor** precisely consists of two conductors (metallic layer or plated) isolated from one another thus creating a capacity. Depending on the insulating material used, a capacitor is either called: Air capacitor, glas capacitor, glim-mer capacitor, ceramic capacitor, plastic capacitor, electrolytic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

A capacitor acts differently depending on whether it is connected to DC current or AC current.
First of all, we'll look at the capacitor connected to DC current as this is the easiest to understand.
As mentioned priviously, 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.

Charge and discharge

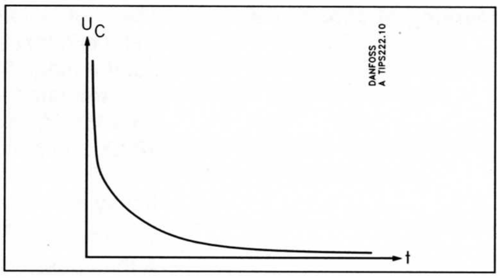




If the capacitor is connected to a DC voltage a current (electrons) will run from the voltage source through the resistor to the capacitor.

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 direct current**.
If we turn the switch to middle position we cut off the battery and C will keep the charge potential energy it got during charging. If we turn the switch to bottom position, C will be

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

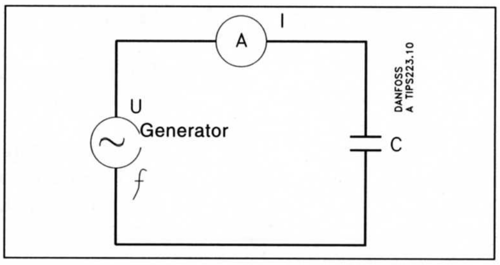
If a capacitor is connected to alternating current C will be charged and discharged at the same speed as the frequency of the alternating current. Consequently, there will be charging current with alternating direction in C's inlet lines which means that there is an alternating current in the circuit.
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? Its looks like $R = \frac{U}{I}$, Ohm's law.

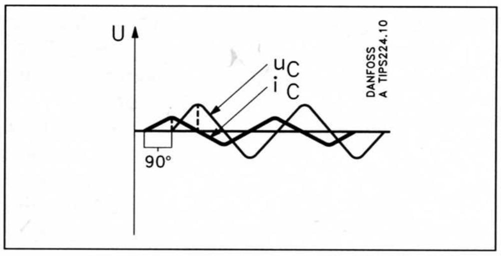
*Please note that we use CAPITAL letters in formula on DC and **small** letters in formula on AC.*

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 that at lower frequency, i.e. the current increases; the reactance gets corrrespondingly smaller at increasing



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, and u_C is zero.
However, when C is charged, u_C is large, and 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 = zero and vice versa.

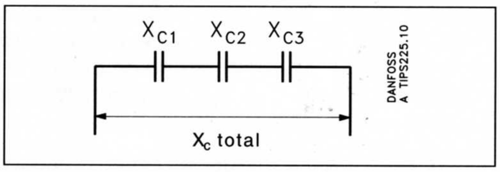


There is a phase shift between current and voltage; the phase shift for a capacitor without loss is exactly 90° or 1/4 period where the current is in front of the voltage.

Series and parallel connection

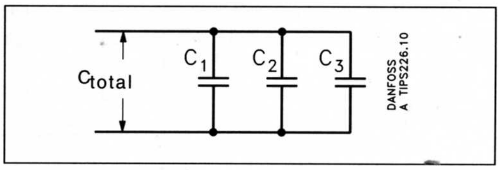
The total **reactance** is equal to the sum of the individual reactances, similar to ordinary resistors in series:

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



When capacitors are connected in parallel, the plate area is actually increasing, and therefore the **capacity** will increase.

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



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 µ 100 V, and it is evident that this means 10 µF and max. working voltage of 100 V.

It may also say:

1 µ 5 63, which means 1.5 µF 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 color marked with rings, bands or dots according to the same method as resistors; however, there are also makes that are marked with their own codes; isn't that confusing?

Electrolytic capacitors are always marked with plain text; most of them are of sizes within the uF 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 a cylindrical aluminium case or holder.

Warning:
Capacitor may fly apart if applied voltage exceeds rated working voltage. Rated working voltage should be 2x applied voltage.

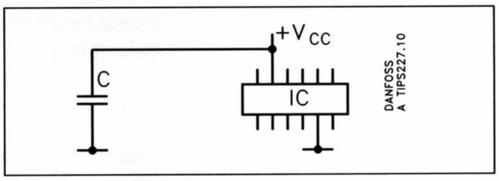
Examples of application

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.

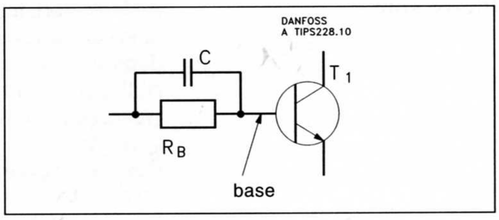
This DC voltage must be stable and "clean" i.e. free from electrical noise - TRANSIENTS - and other quick changes that might disturb the function.



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.

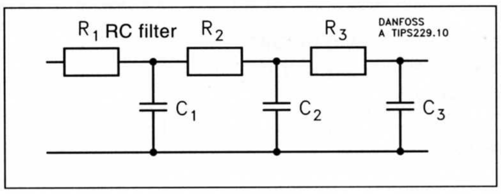


Therefore, the capacitor is often called a SPEED-UP capacitor.

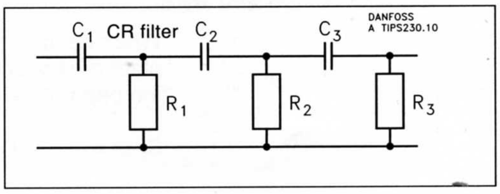
Filters

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

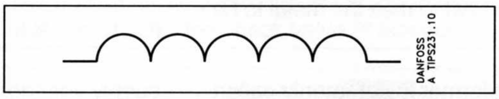


High-pass filter



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 resistance is called **reactance**, X_L, and is



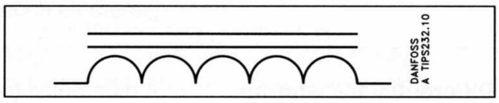
Ordinary coil (air coil)

expressed by the formula:

$$X_L = 2\,\pi \times f \times L$$

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

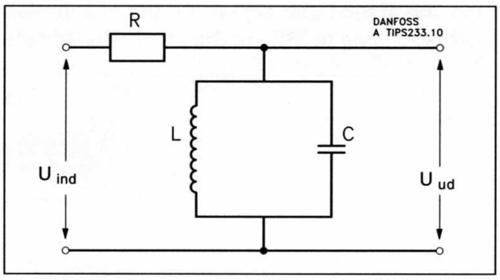
component is a very large area which we are not going to elaborate on here. It may be everything from two small windings in a TV tuner passing across solenoid valve coils and relay coils, net transformers in voltage supplies to welding transformers of a weight which one man cannot lift.

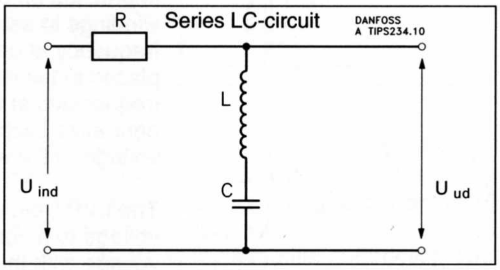
Resonance circuits

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

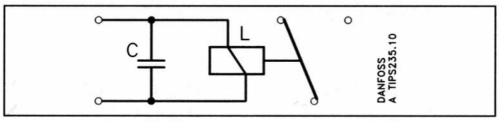
They can make **resonance circuits**.
Two kinds are shown below, both called **LC circuits** (coil/capacitor circuits) or an **impedance** and we shall revert to this subject when dealing with the transistor.

Parallel LC-circuit



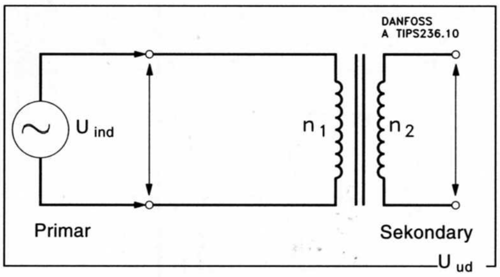


Another frequently used connection between coil and capacitor is seen here where the capacitor is placed in parallel above a relay coil in order to prevent voltage peaks from being induced into the coil when interrupted.



Transformers

Transformers are frequently used 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 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 <u>not</u> 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

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 connected 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. The high current is enough to maintain a spark that generates enough heat to melt the metal to be welded and the metal in the electrode stick.

An example:
A transformer has a welding voltage, loaded, of 60 V and a welding current of 150 Amp. Expressed in voltampére, 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

Differential transformer

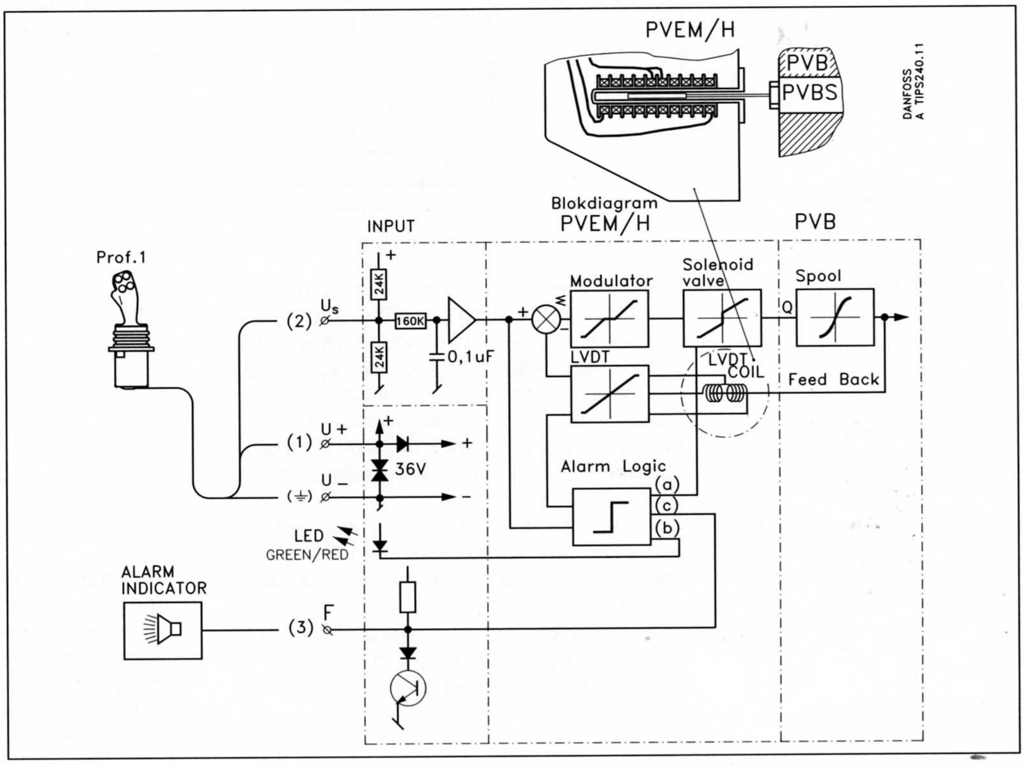
A differential transformer is commenly called an LVDT, which is short for Linear Variable Differential Transformer. An LVDT consists of a coil, an armature and some electronics. You find all of it embodied in what we call a PVEM, a PVEH or a PVES which is again used to remote control the directional 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 center of the coil, the two frequencies at the center 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 center 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 center 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.

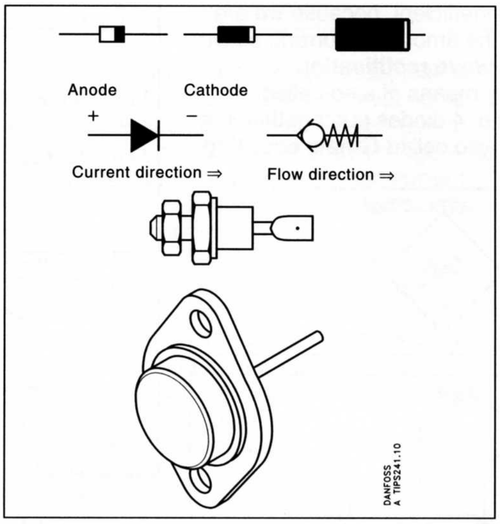
Once the spool and the armature in the LVDT coil have reached the position requested by the input signal from the PROF1 joystick, the spool will be retained in this position.

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

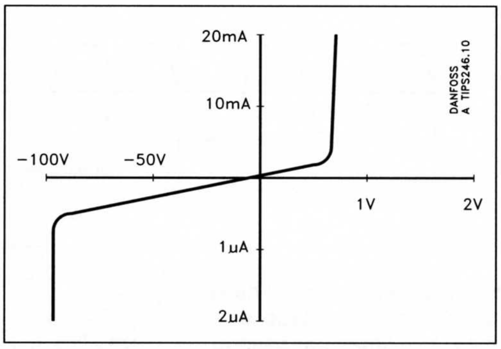


Semi-conductors

Now we are leaving the passive components in order to take a closer look at the **active** components.
We have already briefly discussed them in the chapter on resistors, becuase now and then the borders may seem a bit vague!
The first semi-conductor we are going to look at is the DIODE, the check valve of electronics.

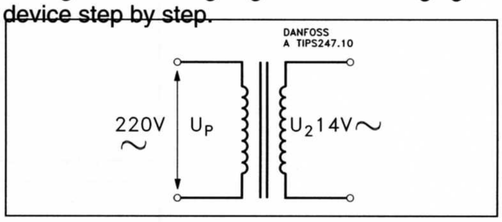


The diode is a one-way component permitting current to flow in one direction only, in the direction of the arrow, but only when the ANODE is more positive that the CATHODE. There must usually be a voltage difference of 0.7 V before the diode "opens". It is precisely like a check valve where a soft spring 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 for 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, Uf (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. 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.

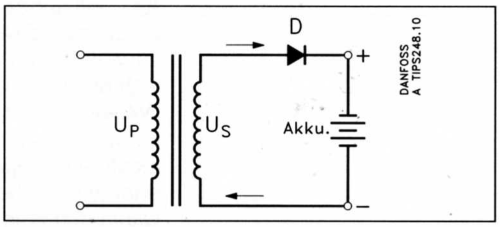


We'll take a transformer with a 220 V primary coil and a 14 V secondary coil wound in a way to yield (loaded with) - a charging current of 10 A from the secondary coil.
This is 140 VA (simple mental arithmetic). The primary coil shall also correspond to the 140 VA so we can easily calculate the current comsumption at full load:

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

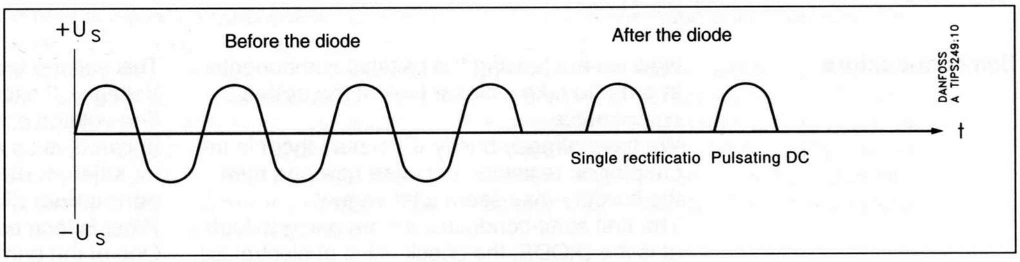
$\frac{140}{220} = 0.64$ A + a little more for heat loss

Now, alternating current is certainly not capable of charging an accumulator as it is changing polarity Hz. 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 that it can stand a constant current of the 10 A.
Such a diode must be sized so often be

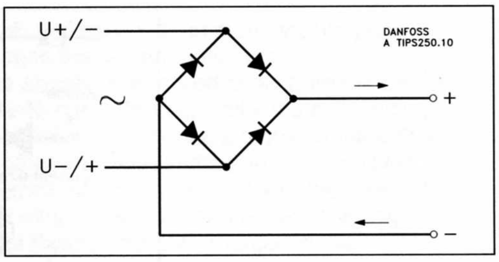


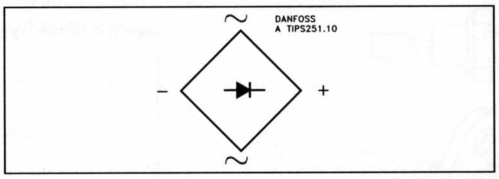
Before the diode we have a pure alternating current. After D we have excluded the negative half-waves. Now we have a **pulsating**

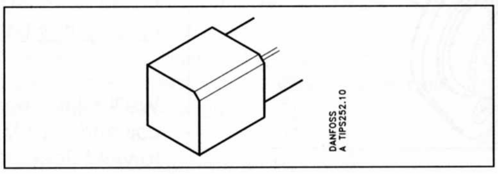
Semi-conductors

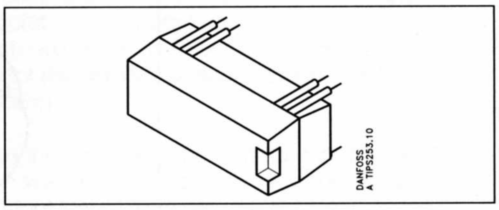


It is applicate, but inefficient, because we are only using half of the amount of current, so we must prefer a **full-wave rectification.** This is obtained by means of a so-called DIODE BRIDGE i.e. 4 diodes put together in a **bridge coupling** also called **Graetz coupling**.

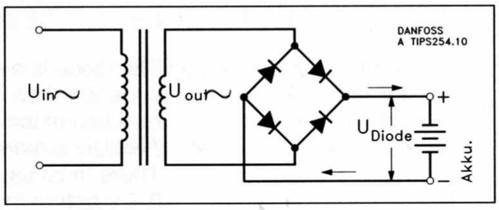


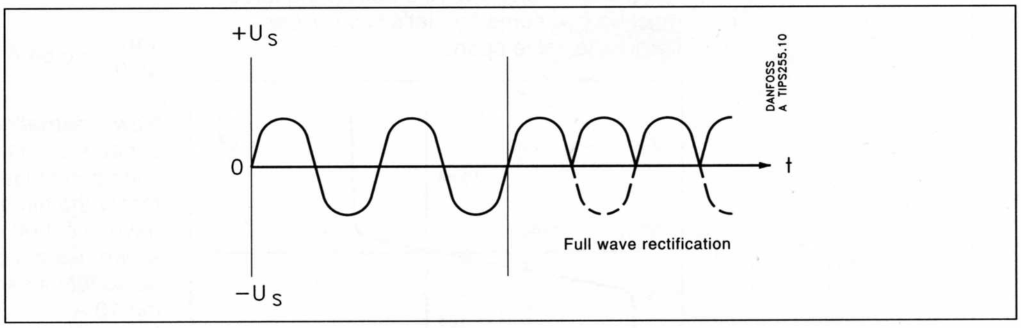






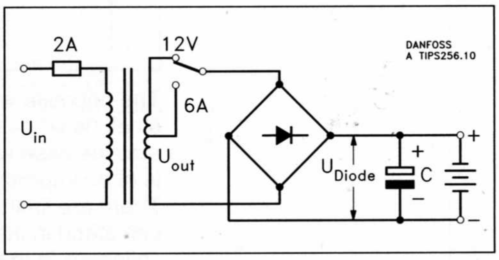
Let's take another look at our charging device, but now with a diode bridge in order to exploit both half-waves.





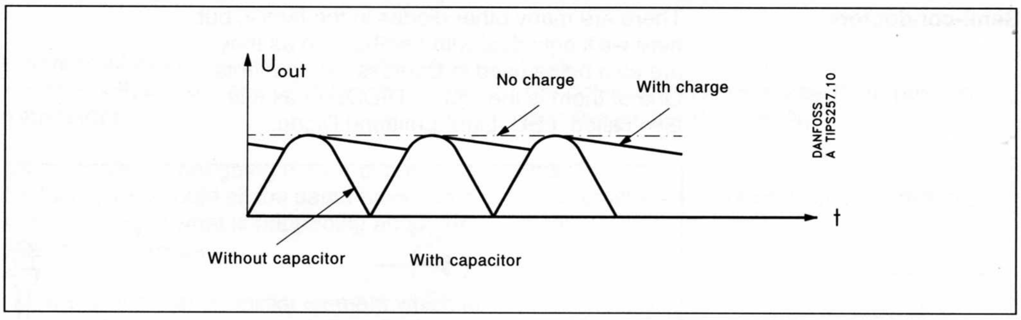
As it will appear from the curves we still have a pulsating direct voltage as the voltage is varying from 0 to max. 120 times per second with 60 Hz supply voltage
We want to **smooth out** this pulsation. We are going to use a capacitor or rather: a large electrolytic capacitor. It works in fact as an energy store between the positive peaks as within that time it yields the energy charged when the voltage increases.

The chosen max. voltage of the electrolyte is to be e.g. 40 V.

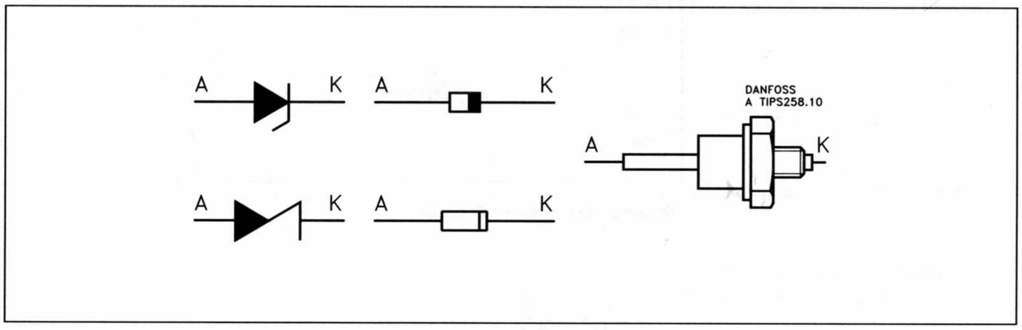


Our diagram and pertaining curves will look as follows:

Semi-conductors



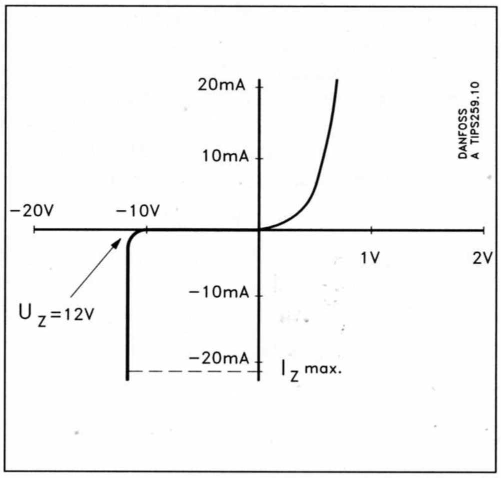
The small saw-toothed voltage under load is called RIPPLE VOLTAGE and it must be as small as possible. The closer we can get to the straight curve - the NO-LOAD voltage - the better. The interaction between load current and the capacity of the capacitor determines the size of the ripple voltage.
However, 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. Some power supplies take additional steps to further dampen ripple frequencies and to keep the voltage **constant**, even during varying loads.
For simple voltage regulation 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.

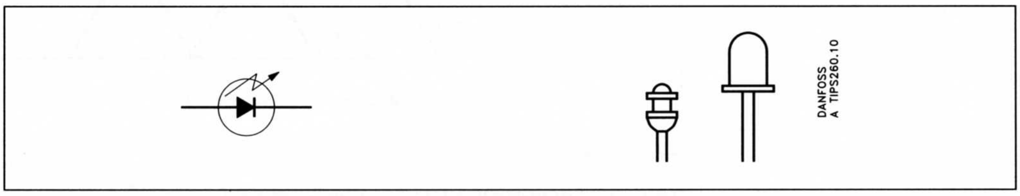
Here we are now calling PIV for the ZENER VOLTAGE.

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_{Zl} zener voltage in reversed direction.



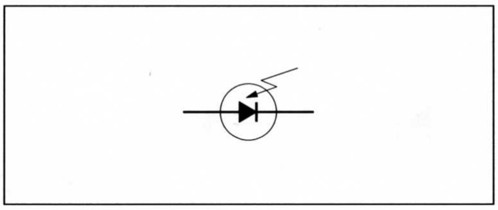
Semi-conductors

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 (G_aA_s) and this material emits light when a current is passing through it. It is indeed a very useful effect.
By changing the composition between G_aA_s and other materials the colors red, orange, yellow, green and even TWO different colors 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.

Then there is the PHOTO DIODE.



Indeed! an opposite LED

Placed in the dark it is almost an isolator. Exposed to light it generates a small 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.

Transistors

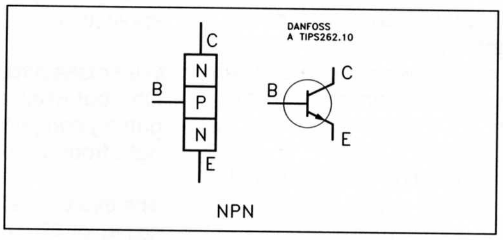
Transistors

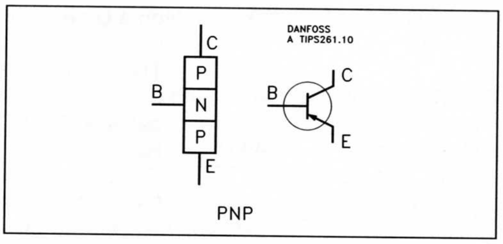
In almost all electronic components we come across - both at work and off duty - there are **transistors**.

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.

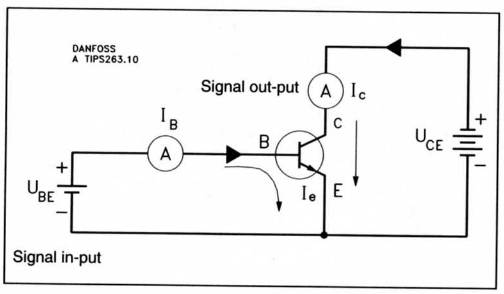
The transistor is an amplifier element which at best may be compared to a pilot-controlled servo valve for also by means of transistors we can contol a large current or effect with a small pilot current. Let's take a closer look.

The transistor has a laminated structure of silicium 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.



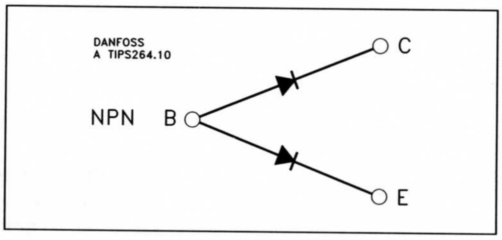


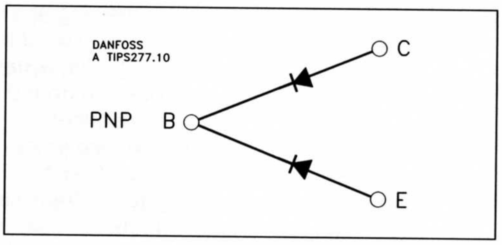
B is BASE, C is COLLECTOR, E is EMITTER.
The base may be called:
Bottom electrode
The collector may be called:
Current collector electrode
The emitter may be called:
Input electrode
The NPN transistor is most commonly used.
The basic features will be briefly outlined.
Let's take a look at this small 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}.

Exceed any of these values will damage the transistor.

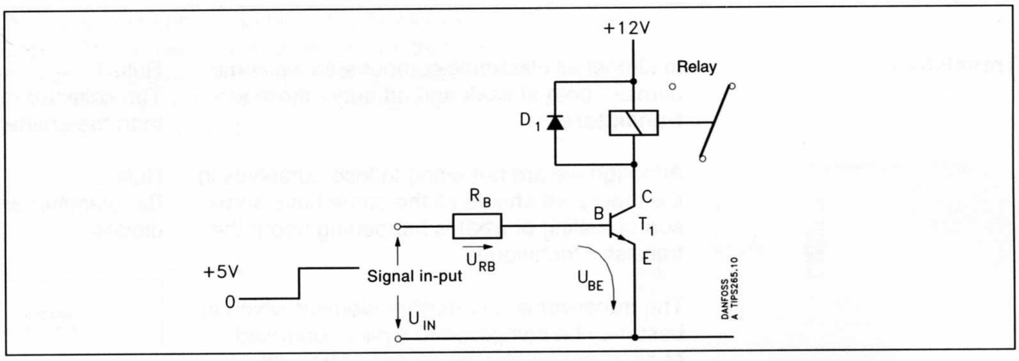
The number of times which I_{BE} is amplified across I_C is called the amplifier factor, ß, (Beta factor).
The amplification is almost proportional to I_{BE} and for the different transistor types it may be everything between 8 and 800 times.
We know now that B/E is a diode and we also know that a voltage 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 ß 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 at 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 catalog we choose one with I_C max. = 100 mA and according to the data sheet ß is 80-150.

R_B must have a size yielding sufficient I_B at minimum ß = 80

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

$U_{RB} = U_{in} - U_{BE} = 5 - 0{,}7 = 4.3$ V

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

Approximate standard value = 3,3 kΩ

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 "desparate" attempt to maintain its magnetic 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 in parallel with the relay coil thus "cutting" the voltage peak when the relay is interrupted.

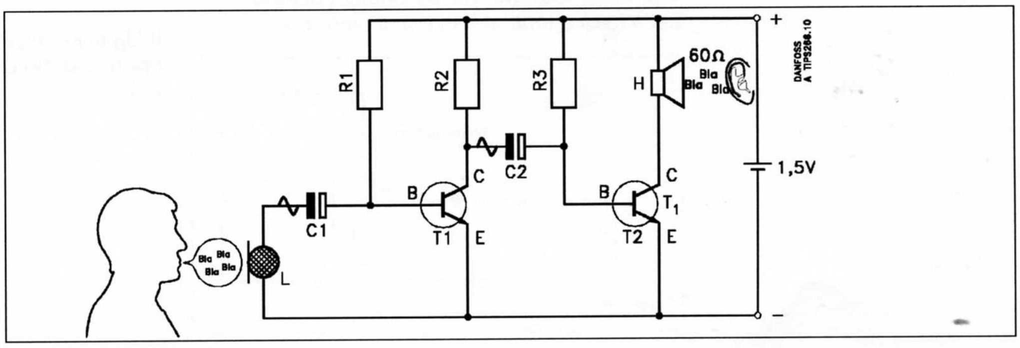
We are also going to look at the transistor as a **voltage amplifier** which is the most common application.

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:

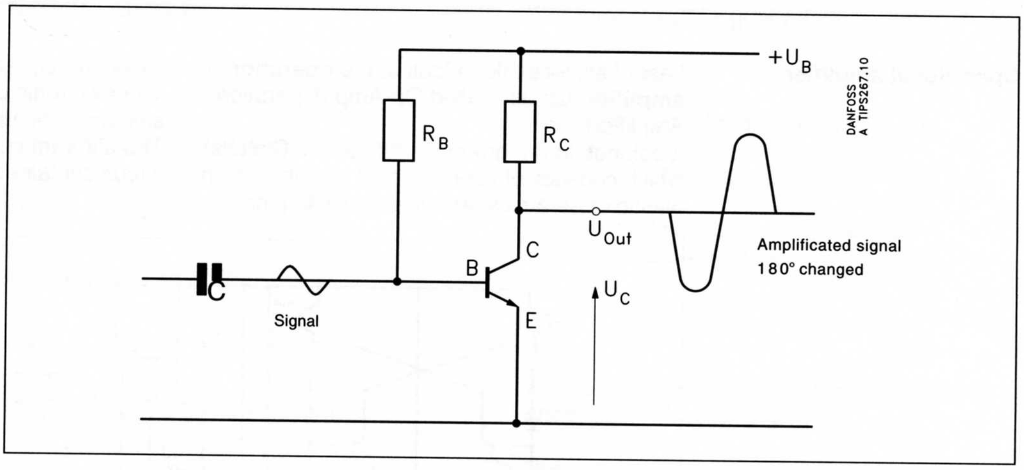
The input signal is generated by microphone coil, L, of 180 mH - milli Henry - which is wound on a U-shaped iron core.

These small signals are sent across C1 to T1'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 T1 is led via C1 to the base of T2 where the signal is again amplified 100 times depending on the ß-factor of the transistors. The amplified signal is now so large that a 60 Ω headphone can oscillate and via its membrane we hear the conversation.
This signal amplification is indicated on the



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: wich 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

$$\frac{U_S}{2}$$

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 <u>more</u> I_B (basic current) to run just as the negative half-wave will <u>reduce</u> I_B.

The collector current I_C will act like I_B, but ß 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:

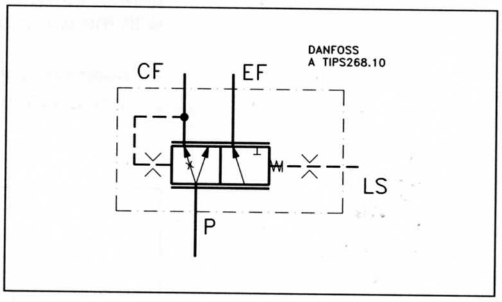
1. Prevent the basic voltage ($U_B \approx 0.7$ volt) from being short circuited by the low DC resistor of the microphone.

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?

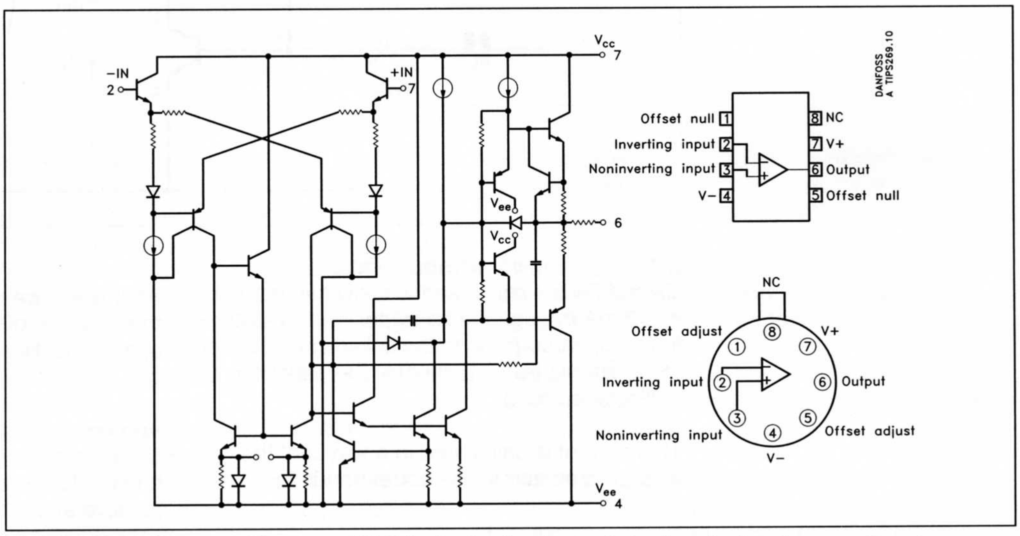
P is the main supply ($+U_B$)
LS is signal input (base)
CF is signal output (collector)
EF is (with a little ingenuity) emitter and from P we get I_C, here the sum of the flow to CF and EF.



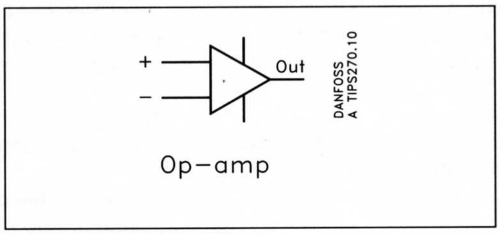
Operational amplifier

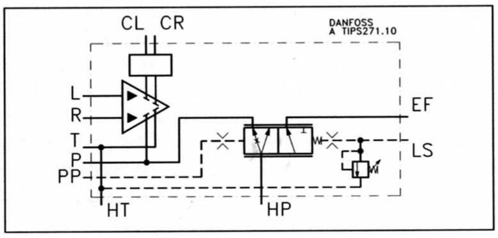
Operational amplifier

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 that a few mm². 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.



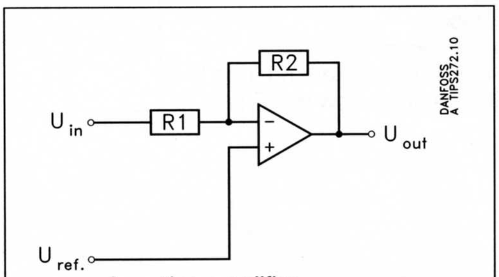


An amplifier built up on basis of one or several Op-Amps is "tailored" to the application requested by means of passive components connected on the outside to the pins of the IC. The Op-Amp is used in a number of different connections, but we are only going to deal with the two most frequently used:

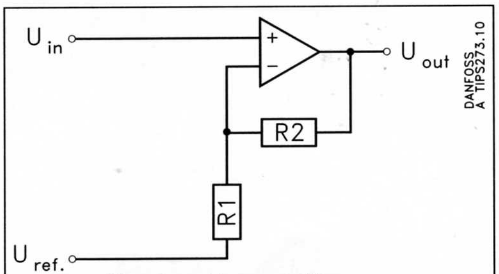
1: Inverting amplifier (negative amplification)
2: Non-inverting amplifier (positive amplification)

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 ∞; 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 volt.



Inverting amplifier



Non-inverting amplifier

Inverting aimplifier

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

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 that 1 we have to choose an inverting amplifier.

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

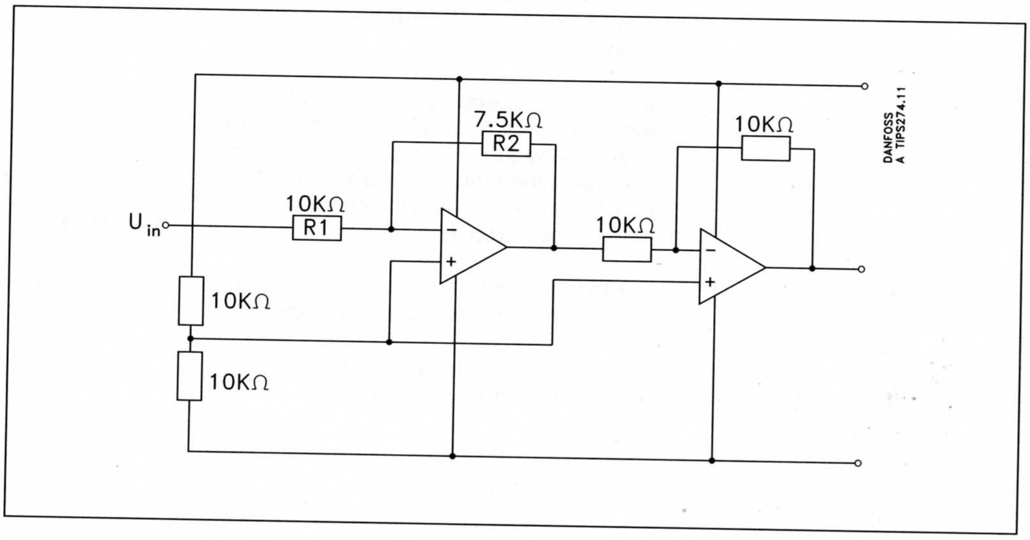
$$R_2 = -A_V \times -R_1 = -0.75 \times -10 \times 10^3 = 7.5\ k\Omega.$$

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 × amplification.

The finished circuit:



Trouble shooting

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 accu mulator/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**.

Comments

Comments

Comments

Service Shops

Authorized Service Shops

Australia	:	Danfoss (Australia) Pty. Ltd., Melbourne
Austria	:	HAINZL Industriesysteme, Gesellschaft m.b.H, Linz
Belgium	:	N.V. Danfoss S.A., Bruxelles
Brazil	:	Danfoss do Brasil Ind.e Com. Ltda., São Paulo
Canada	:	Danfoss Mfg. Co. Ltd., Mississauga
Denmark	:	Danfoss Hydraulik A/S, Stenløse
Finland	:	OY Danfoss AB, Espoo
France	:	Danfoss S.a.r.l., Trappes (Paris)
Germany	:	Danfoss GmbH, Offenbach/Main
Great Britain	:	Danfoss Limited, Greenford (London)
Iceland	:	HEDINN VERSLUN H/F, Reykjavik
India	:	DANTAL HYDRAULICS PVT Ltd., New Delhi
Italy	:	Danfoss s.r.l. Division Sordella, Torino
Japan	:	Danfoss K.K., Gotemba
Korea	:	UNITEK Corporation, Seoul
Netherlands	:	ITHO B.V., Schiedam
New Zealand	:	Danfoss (New Zealand) Limited, Auckland
Norway	:	Danfoss A/S, Skui
Republic of South Africa	:	Danfoss (Pty) Ltd., Johannesburg
Singapore	:	Danfoss Industries Pte. Ltd., Singapore
Spain	:	Danfoss S.A., San Sebastian de los Reyes, (Madrid)
Sweden	:	Danfoss AB, Mjölby
Switzerland	:	Danfoss Werner Kuster AG, Frenkendorf
Turkey	:	MERT Teknik A.S., Istanbul
U.S.A.	:	Danfoss Fluid Power Div. Racine, Wisconsin

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Czech Rep.	:	TECHNO TRADE, Olomouc
Greece	:	A. SKOURA & Co. E.E., Athens
New Zealand	:	Danfoss (New Zealand) Limited, Christchurch
Portugal	:	Danfoss (Portugal), da., Carnaxide
Taiwan	:	SYMBRIDGE Machinery Co. Ltd., Taipei

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