Fundamentals
M4
ELECTRONIC FUNDAMENTALS

Rev.-ID: 1OCT2014
Author: KrA
For Training Purposes Only
©LTT Release: Oct. 09, 2014

EASA Part-66
CAT B1

Training Manual

Lufthansa Technical Training

For training purposes and internal use only.

© Copyright by Lufthansa Technical Training (LTT).

LTT is the owner of all rights to training documents and training software.

Any use outside the training measures, especially reproduction and/or copying of training documents and software – also extracts there of – in any format at all (photocopying, using electronic systems or with the aid of other methods) is prohibited.

Passing on training material and training software to third parties for the purpose of reproduction and/or copying is prohibited without the express written consent of LTT.

Copyright endorsements, trademarks or brands may not be removed.

A tape or video recording of training courses or similar services is only permissible with the written consent of LTT.

In other respects, legal requirements, especially under copyright and criminal law, apply.

Lufthansa Technical Training

Dept HAM US
Lufthansa Base Hamburg
Weg beim Jäger 193
22335 Hamburg
Germany

Tel: +49 (0)40 5070 2520
Fax: +49 (0)40 5070 4746
E-Mail: Customer-Service@LTT.DLH.DE

www.Lufthansa-Technical-Training.com

Revision Identification:

- The date given in the column "Revision" on the face of this cover is binding for the complete Training Manual.
- Dates and author's ID, which may be given at the base of the individual pages, are for information about the latest revision of that page(s) only.
- The LTT production process ensures that the Training Manual contains a complete set of all necessary pages in the latest finalized revision.

M4 ELECTRONIC FUNDAMENTALS

© Lufthansa Technical Training

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

M4.1 SEMICONDUCTORS

M4.1.1 DIODES

INTRODUCTION

General

Semiconductors are elements or compounds which, under normal conditions, contain relatively few free (moving) electrons. On a scale of electrical conductivity, they are between the conductors and the insulators.

The most important elements that are used for semiconductors are silicon and germanium. In addition, attempts are being made to manufacture pure inter−metallic compounds such as gallium arsenide which can be used in the same way as germanium or silicon.

Intrinsic Conductivity (i−conductivity)

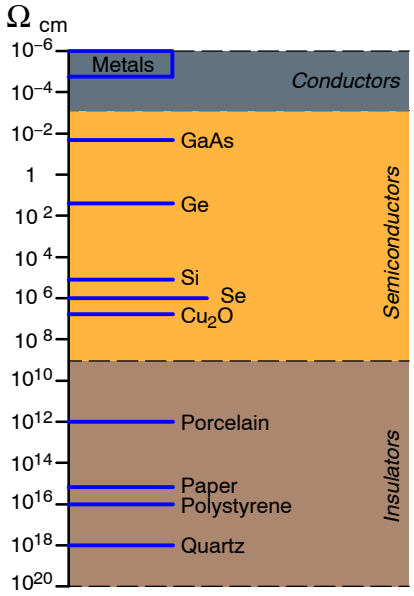
At 0 degrees Kelvin, a semiconductor is a non−conductor. When the temperature increases, an electron can be thrown off its atom and a positive charge remains which is called a defect electron or an electron hole.

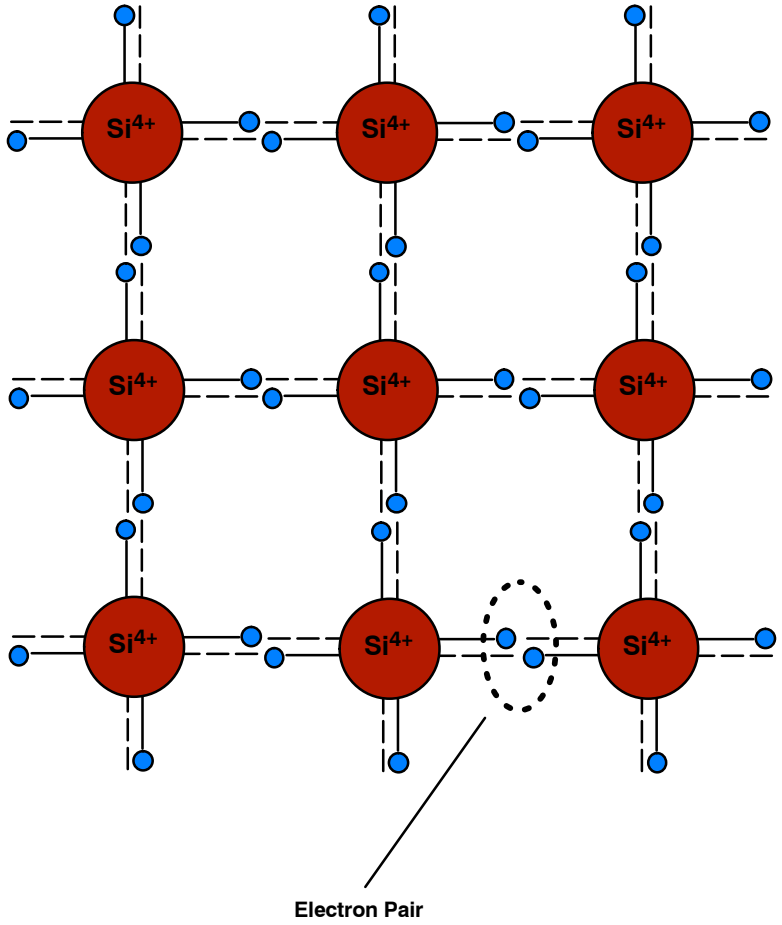
These free electrons move in random patterns until they find a hole and are then integrated into that atom.

When you apply voltage, the free electrons move toward the positive pole. Because the electrons jump from hole to hole, it seems that the holes are moving towards the negative pole. Thus electrons and electron holes permit the transport of charge. The conductive mechanism in a crystal is called bipolar. As the temperature increases, the number of free charge−carriers also increases.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training





Crystal lattice Composition

Figure 1 Semiconductor

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

SINGLE CRYSTAL SEMICONDUCTOR DIODES

Purpose

A semiconductor diode is a kind of valve for electrical current. It allows only one flow direction.

Doping

Single crystal semiconductor diodes consist of a semiconductive single crystal with a p−area and an n− area. The material which is used is usually silicon but sometimes germanium. Impurities are deliberately added to create conductivity. This process is called doping. Here the special properties of a P−N junction are exploited.

Flow Direction

If the positive pole of a voltage source is at the n−area and the negative pole is at the p−area, a depletion zone forms at the junction (because there are no free electrons or empty spaces for electrons) and the semiconductor blocks the charge.

With the negative pole at the n−area and the positive pole at the p−area, the depletion area breaks down and the semiconductor diode will let the current pass across the junction.

Threshold Voltage

If no voltage is applied, a small depletion area forms which must be removed before current can flow in the forward−biased direction. Semiconductor diodes only allow current to pass completely through them if the voltage is above the threshold voltage. In case of silicon diodes, 0.7 volts are required to break down the depletion zone. A silicon diode will only allow a current to flow completely through the junction at voltages above this level. This voltage level is called threshold voltage. For germanium diodes the threshold voltage is approximately 0.3 volts.

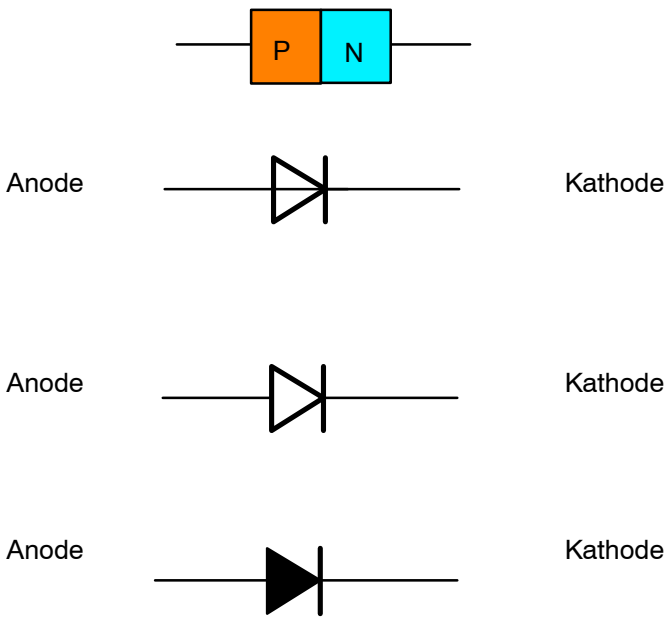
Wiring Symbol

The figure shows the composition of a semiconductor diode as well as its wiring diagram symbol. A semiconductor diode can block the current or let it through. You can see the direction of the triangle as the direction of the current flow in forward direction. This is the technical current flow.

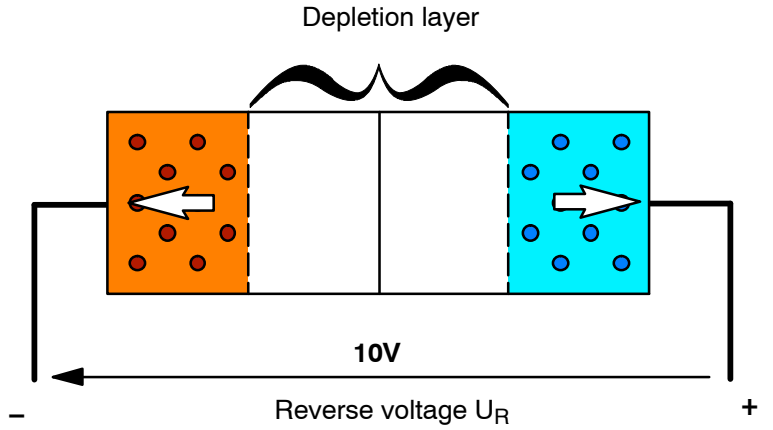
There are three variations of symbols, but they all mean the same type of diode.

FOR TRAINING PURPOSES ONLY!

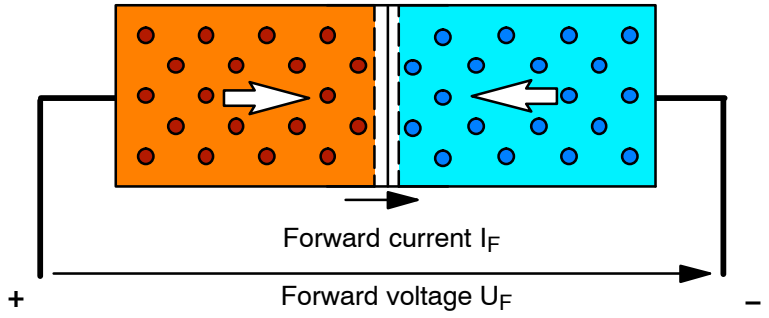
© Lufthansa Technical Training



Wiring Symbol



Diode in Reverse Direction



Diode in Forward Direction

Figure 2 Construction and Characteristic Curve of Diodes

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

PROPERTIES

Forward Biased Condition

The curve shows what happens in the forward area.

Above the threshold voltage, the curve for the silicon diode is very steep. In this area, the silicon diode has an very low resistance.

A germanium diode does not have such a low resistance.

Reverse Current

During operation, the junction area of the semiconductor diode does not block completely. A residual reverse–biased current still flows.

This reverse–biased current is caused by residual impurities in the crystal and is due to the fact that heat waves cause crystal bonds to break down.

Semiconductor diodes do not block an electrical current one hundred percent.

The amount of residual reverse–biased current varies according to the semiconductor diode type between a few nanoamperes and a few microamperes. It is slightly higher in germanium diodes than in silicon diodes.

Peak Inverse Voltage

If the voltage in the direction of the depletion zone is too high, a depletion zone breakthrough occurs and, in most cases, the semiconductor diode will be destroyed. The manufacturer always specifies the maximum permissible reverse voltage. In silicon diodes this can up to 5kV. In germanium diodes it must be less than 200 volts.

DO NOT exceed the maximum permissible reverse voltage level. This will destroy the semiconductor diodes.

Maximum Forward Current

During operation, the current flowing in the forward–biased direction heats the semiconductor crystal.

Silicon monocrystals can handle temperatures of approximately 200°C.

However, germanium monocrystals are destroyed at a temperature of 100°C.

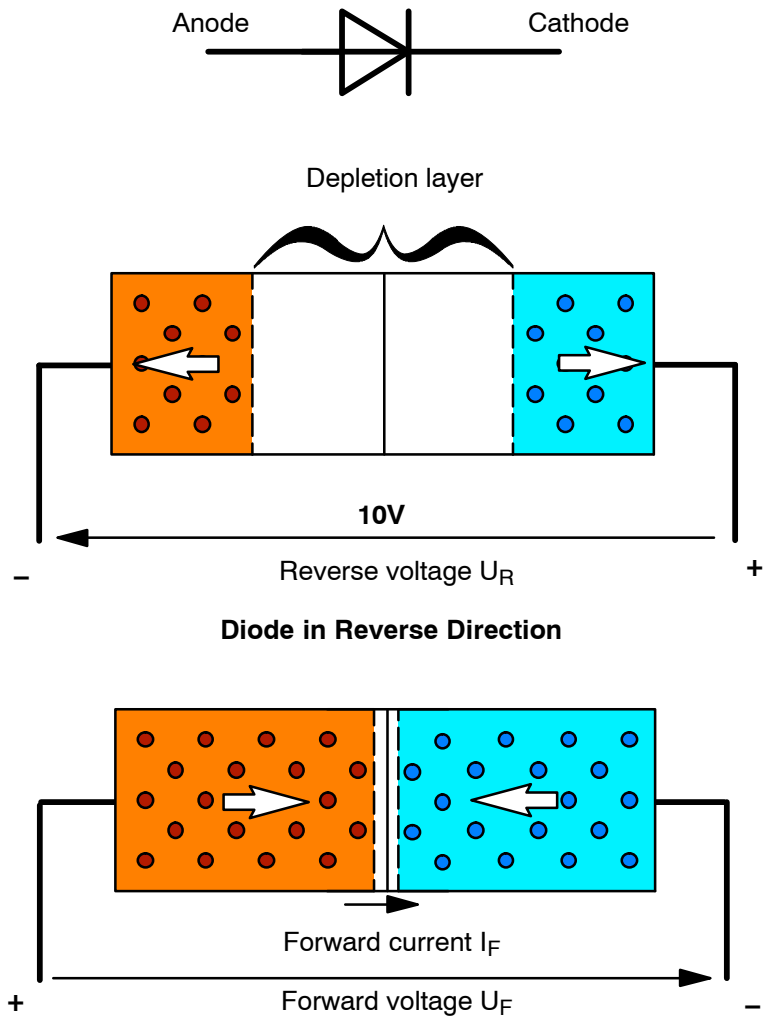
As a result, the current in the forward–biased direction must not exceed the limits given by the manufacturer. Every manufacturer specifies the maximum forward–biased current for each diode type. This value depends on the cooling system used with the diode.

DO NOT exceed the maximum forward current level. This will destroy semiconductor diodes.

Forward–biased currents of up to 1000 amperes are permissible for silicon diodes but germanium diodes are built for much smaller currents.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training



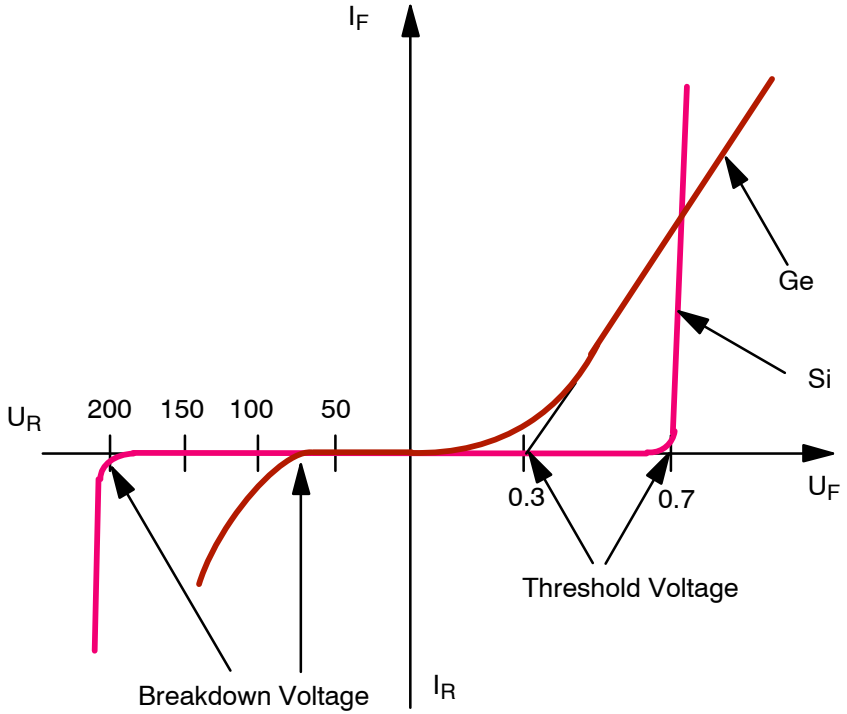


Figure 3 Construction and Characteristic Curve of Diodes

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

TYPES OF DIODES

General

There are three different types of single crystal semiconductor diodes:

- microdiodes
- rectifier diodes
- high power diodes.

Microdiodes

Microdiodes are mainly used in communication technology.

Their maximum forward–biased current lies mostly far below one ampere.

They have different names according to how they are constructed: junction diodes, point–contact diodes or planar diodes.

Rectifier Diodes

Rectifier diodes are primarily used for electrical power supply devices. They are used to construct rectifier circuits for small power outputs.

Their maximum forward–biased currents can be as much as 10 amperes.

High Power Diodes

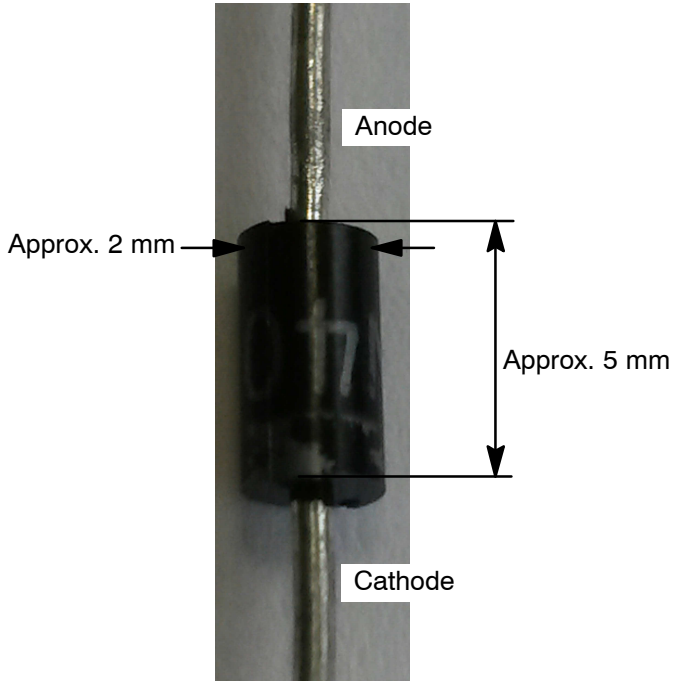
High power diodes have maximum forward–biased currents of approximately 10 to 1000 amperes. They are used in rectifier circuits for large power outputs.

Shapes

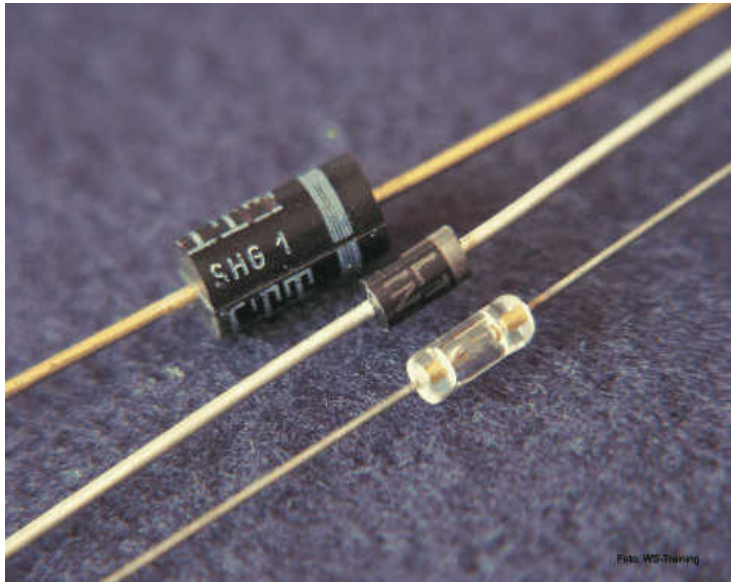
Single crystal semiconductor diodes come in a wide variety of different shapes. The figures below shows some typical housing shapes.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training



Microdiode



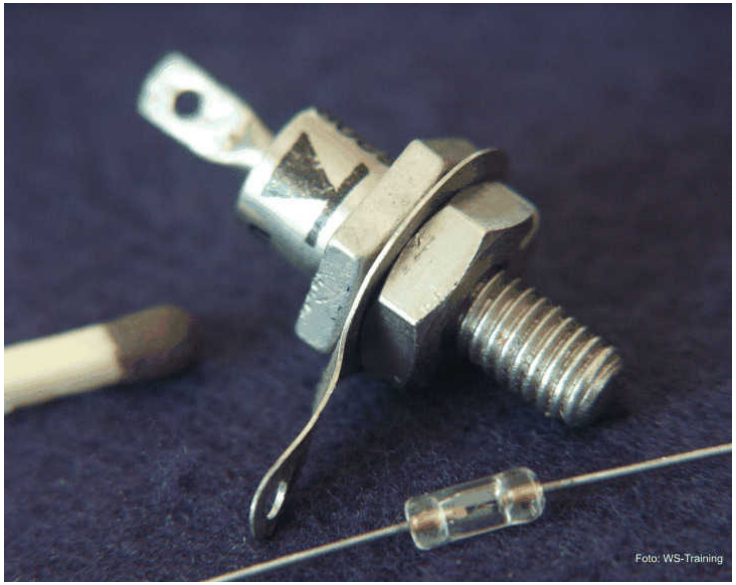


Figure 4 Shapes of Diodes

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

TESTING OF DIODES

General

As already stated, a diode will show a very high resistance (or open circuit) if wired in the reverse bias direction, and a very low resistance when wired in the forward bias direction.

These two situations can be measured using a multimeter.

Use of Multimeter

If the diode is faulty in the open circuit condition then the reading will be high resistance (or open circuit) in both directions.

If it has failed in the short circuit condition (less likely) then it will show low resistance in both directions.

Diode Test Position

When a multimeter is set to the diode test position it will supply a voltage sufficient to forward and reverse bias the diode. This voltage will be approximately 2.5–3.5 volts.

A serviceable diode will show around 0.7 volts on the multimeter when tested in the forward bias direction and will show the internal voltage of the meter when tested in reverse bias.

If a diode has failed open circuit, it will show the internal voltage of the meter in both forward and reverse bias.

If it has failed in the short circuit condition it will show zero (or nearly zero) in both directions.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training





Figure 5 Diode Testing

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

DIODES IN SERIES AND IN PARALLEL

Diodes in Series

If the voltages to be blocked by the diodes exceeds the maximum permissible reverse voltage of a diode several diodes may be connected in series.

Usually identical diodes are connected in series as the voltages across the diodes are identical.

In this case the total voltage that can be applied is the sum of the individual voltages of the diodes.

Example

Two diodes with a maximum reverse voltage of 60 V are connected in series.

The voltage applied in reverse direction is 100 V.

The individual voltages across the diodes are 50 V each.

The maximum permissible reverse voltage is 120 V.

Diodes in Parallel

Connecting diodes in parallel is possible in general but has several limitations.

Such a parallel connection is used when the forward current exceeds the maximum forward current of an individual diode.

The total current in forward direction is the sum of the individual currents of the diodes. As the current heats up the diodes their threshold voltage will decrease.

As the current distribution across the diodes should be symmetric all the diodes should be from the same production batch and must have the same temperature which could mean they have to be mounted on the same heat sink.

If this can not be granted a resistor has to be connected in series with every individual diode. As such a resistor will create losses it should have a very low resistance.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

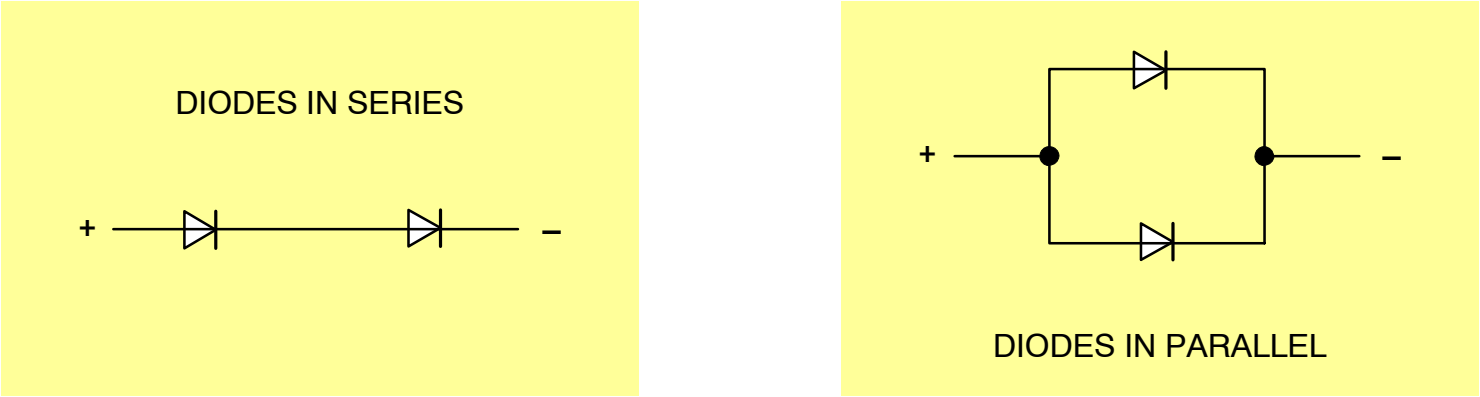


Figure 6 Diodes in Series and Parallel

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

USAGE OF DIODES

Decoupling

Diodes can be used as a decoupling network or to decouple electrical components. The goal is to control both lamps with switch S1, but only lamp L2 with switch S2.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

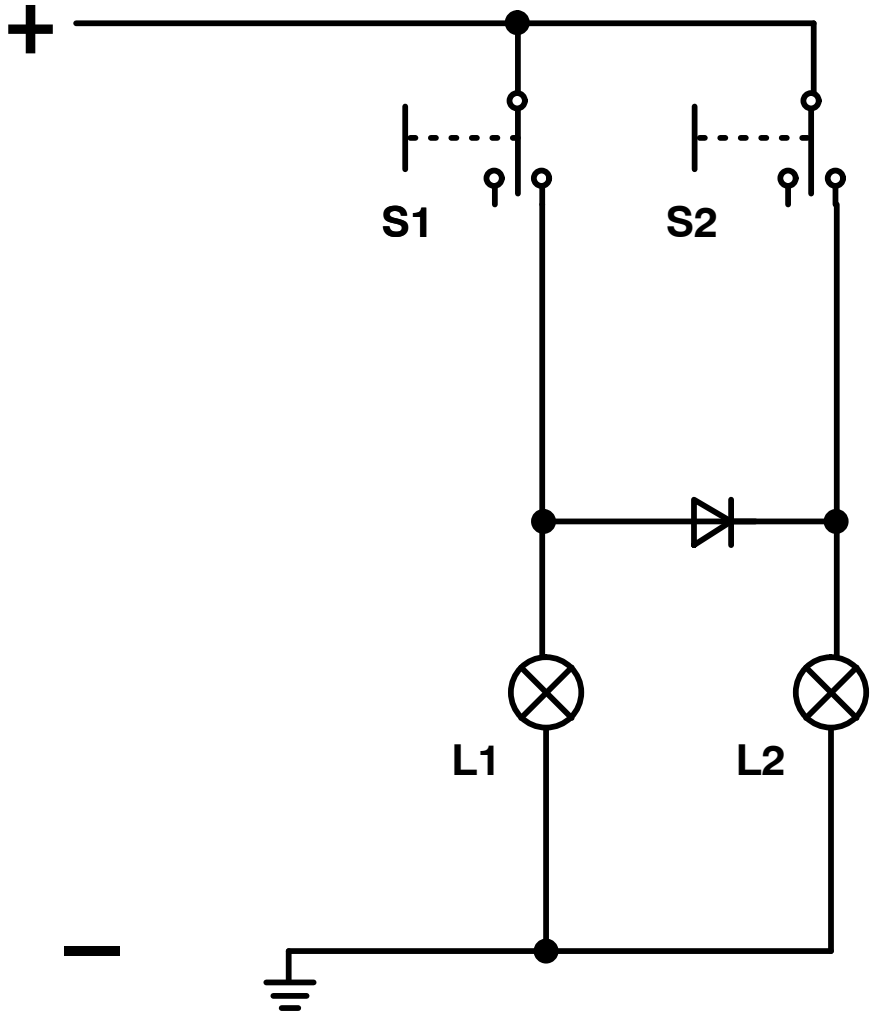


Figure 7 Light Decoupling

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

Free-wheeling diodes

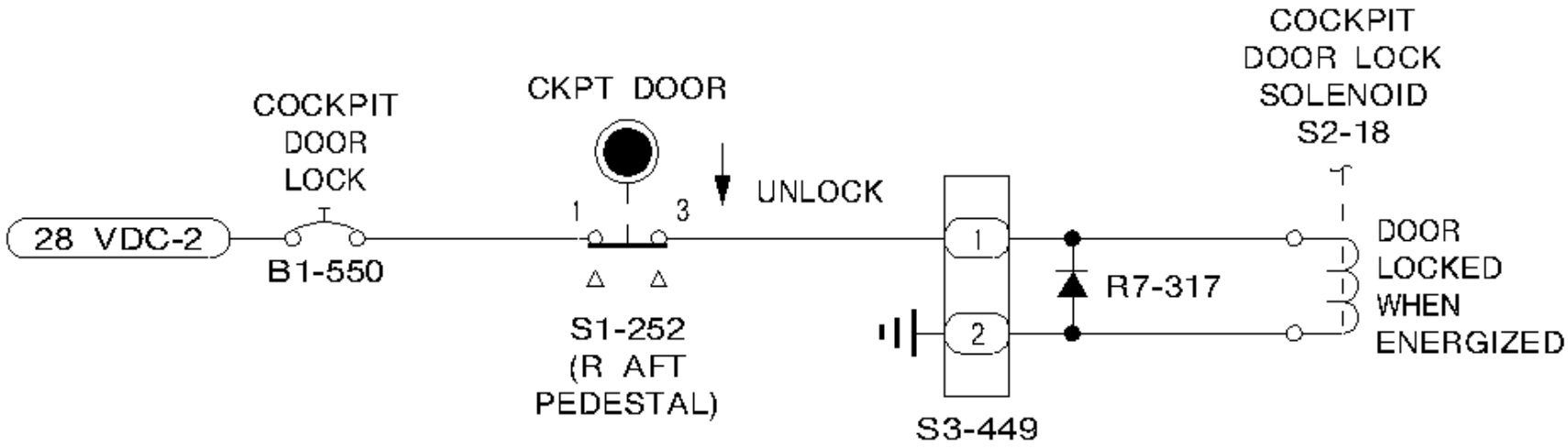
Diodes can also be used to short-circuit the back-emf that occurs when switching off relays. emf means electromotive force.

If the relay is supplied with DC the diode will operate in reverse direction.

If the power supply is switched off, the inductivity will generate the back-emf. This voltage will operate the diode in forward direction. Thus, other components will not be affected by the back-emf.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training



MD11 SSM

Figure 8 Back-emf-Diode

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

RECTIFIERS

General

The main application of diodes is the usage as a rectifier.

Rectifiers transform alternating current (AC) in direct current (DC).

Single-Wave Rectifier

The single–wave rectifier is also called a half–wave rectifier. It is the most simple rectifier. It only requires one diode.

Electrical current can only flow during the positive half–wave of the incoming alternating current but during the negative half–wave, the semiconductor diode blocks the current.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

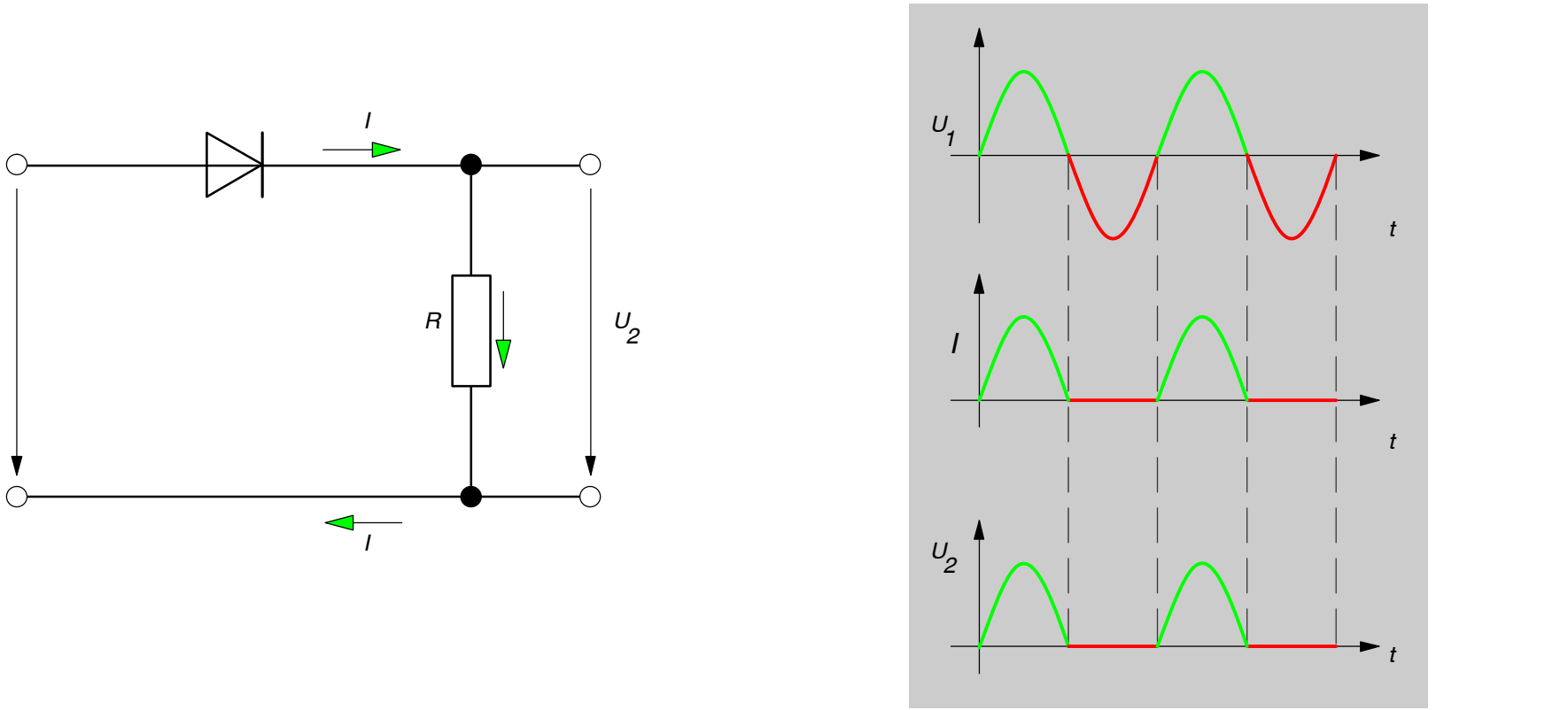


Figure 9 Single Wave Rectifier

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

Full-Wave Rectifier

A much better rectifier is the full wave rectifier as it supplies both half-waves to the load but it needs a transformer with a double coil or a tapped coil and two diodes.

Both, positive and negative part of the waveform are rectified and used.

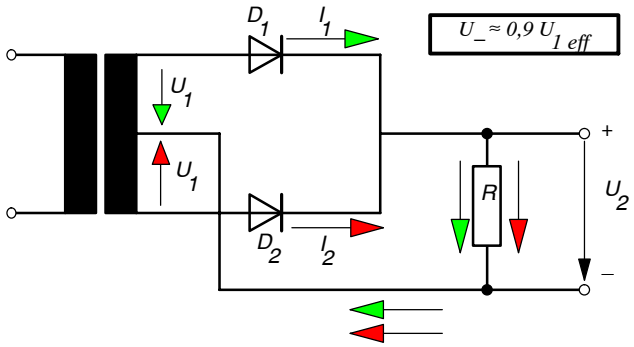
Bridge Circuits

The bridge circuit also supplies both half-waves. It requires four diodes for AC but six for three phase systems. The diodes function as a „directional signpost“.

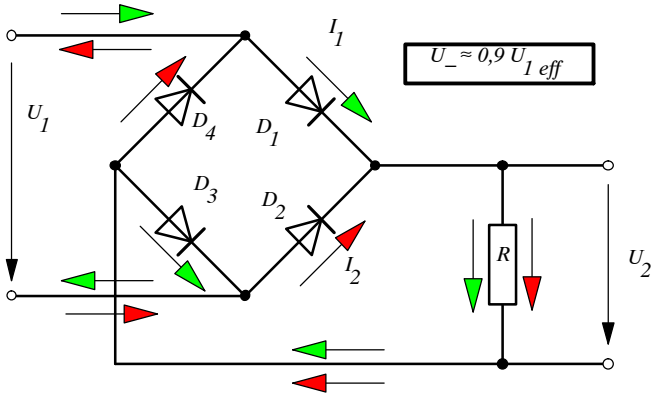
This is also known as a WYE Rectifier.

FOR TRAINING PURPOSES ONLY!

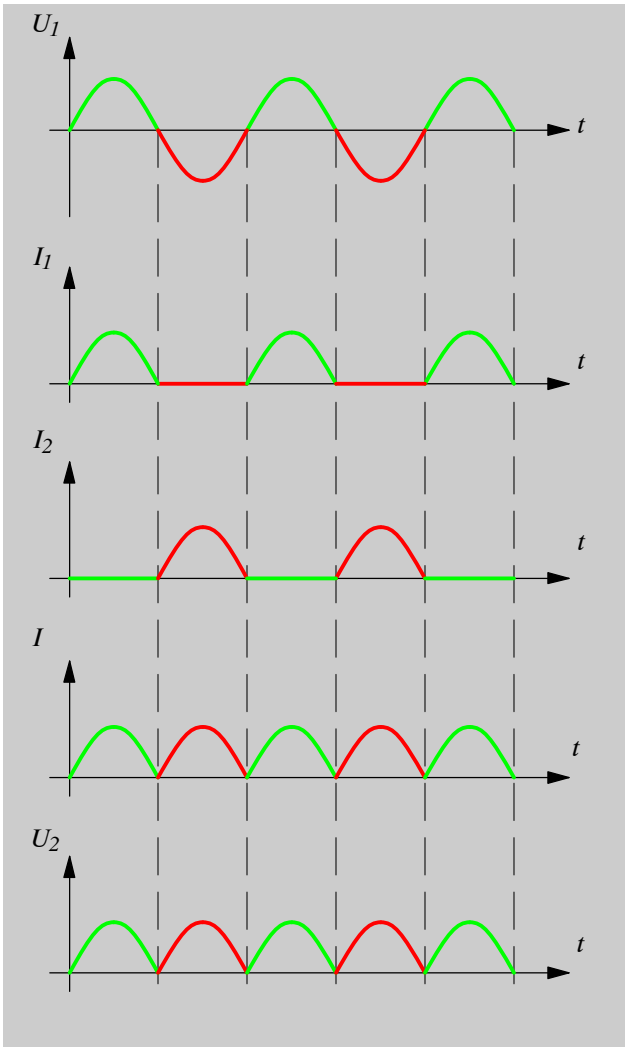
© Lufthansa Technical Training



Full Wave Rectifier



Bridge Rectifier



Voltage and Current on Full-wave and Bridge Rectifier

Figure 10 Full Wave / Bridge Rectifier

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

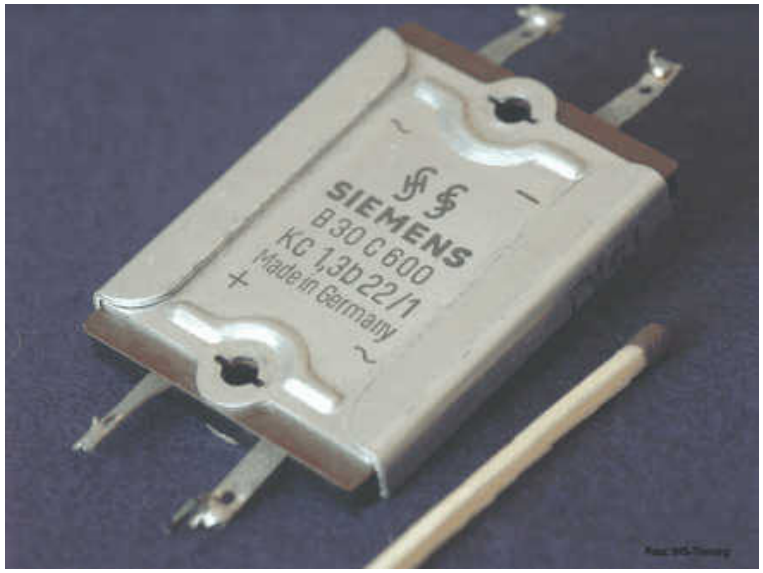
SHAPES OF RECTIFIERS

General

The figure shows the shapes of typical rectifiers.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training



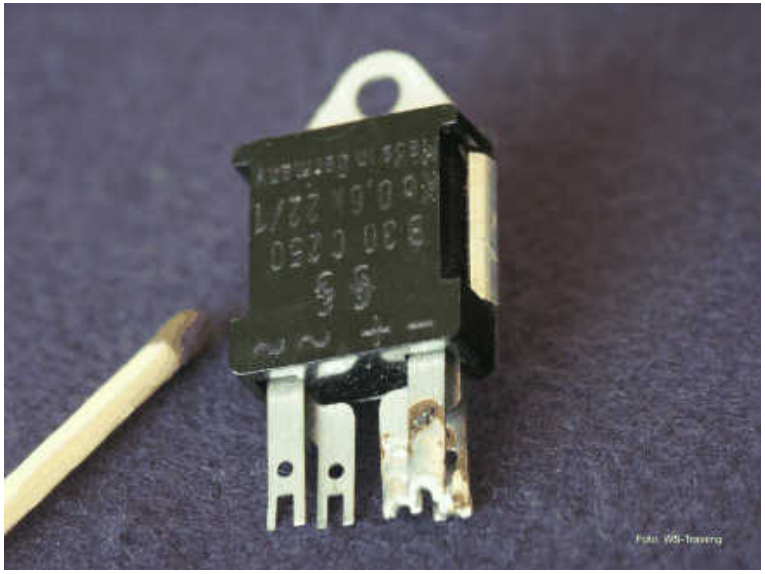








Figure 11 Shapes of Bridge Rectifiers (Examples)

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

APPLICATION OF RECTIFIERS

Generators

Rectifiers are used in brushless generators.

In the figure below we see a permanent magnet generator which produces AC power.

The power for the rotating field is induced by the exciter generator. The resulting current is rectified by rotating diodes.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

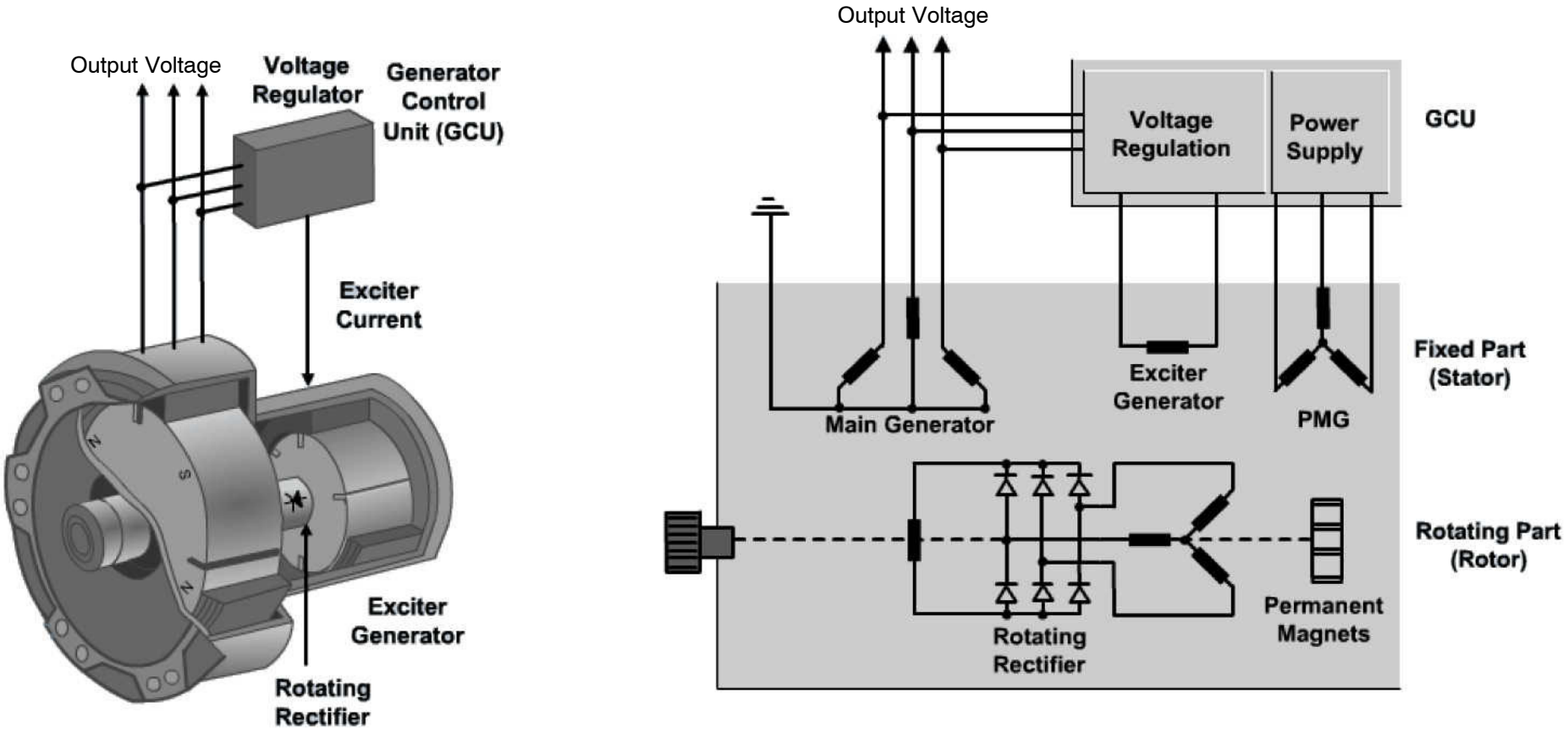


Figure 12 Brushless Generator

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

Transformer Rectifier Unit

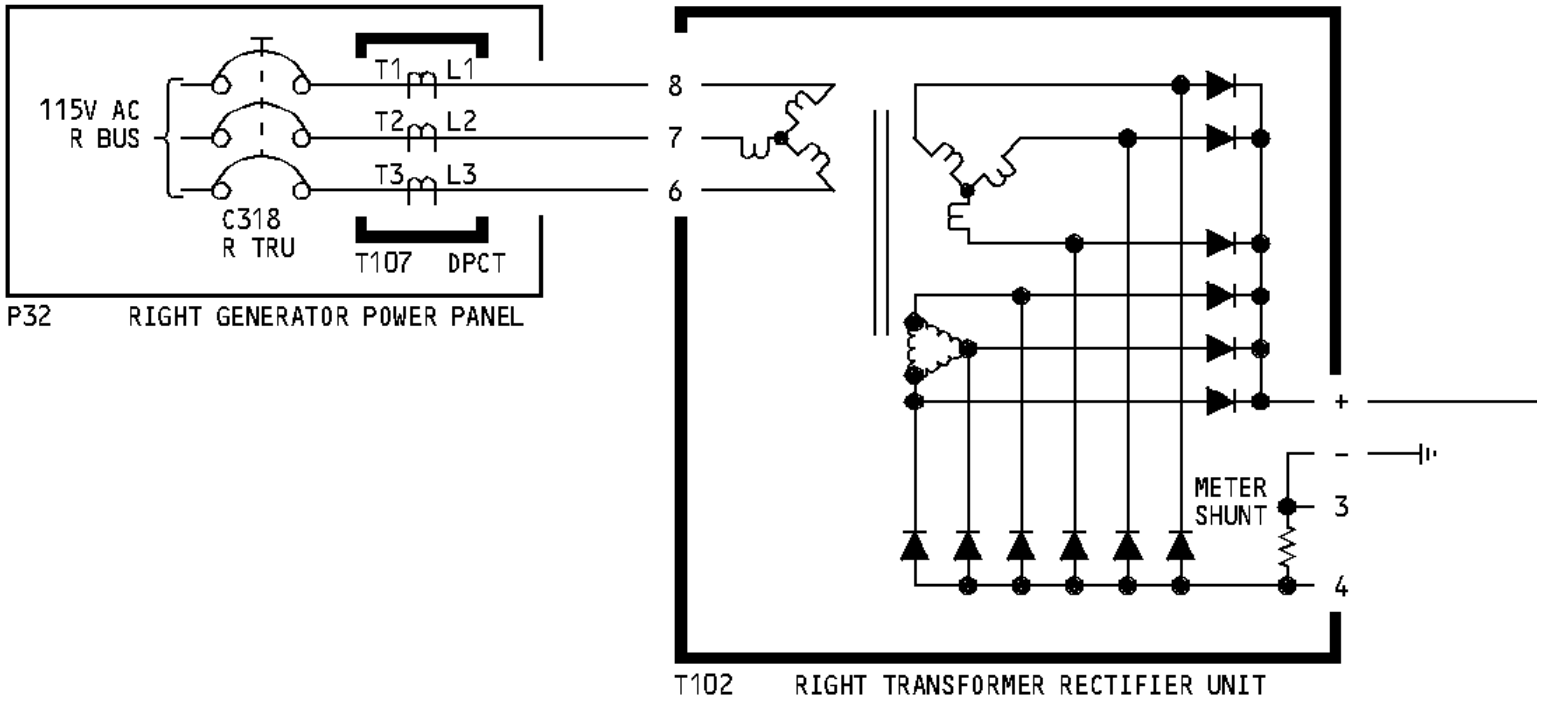
The figure shows a transformer rectifier unit.

These units transform AC power to DC power with a lower voltage.

The voltage transformation is done with transformers. Diodes in a bridge circuit perform the rectification.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training



B757 AMM 24-32-01

Figure 13 TR-Unit

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

Z-DIODE

General

Z-Diodes are silicon diodes with a specifically defined steep breakdown in the reverse biased direction. When the voltage is changed minimally, the current changes radically and the diode remains intact. Of course the maximum power dissipation level must not be exceeded.

The Zener effect states that after reaching critical field strength, valence electrons are torn out of their lattice structure. This raises the number of free charge−carriers so quickly that the conductivity of the material abruptly increases. This effect can only occur with highly doped material, from 10^{19} foreign atoms per cm^3.

The Zener effect is further supported by an avalanche effect. When a material is subjected to high field strengths, the free charge−carriers move at such a speed that valence electrons are torn out of their bonds. This, in turn, raises the number of free charge−carriers which again release further valence electrons, and so on.

The amount of the breakdown voltage U_{ZO} can be influenced by the amount of dopant introduced to the material during manufacture. There are Z−diodes with breakdown voltages of 2.7 volts up to breakdown voltages of hundreds of volts.

Z−diodes with a breakdown voltage of between 5 and 7 volts possess especially good properties.

Curve

Z-diodes show a very steep curve. This means that the dynamic resistance is especially small in the breakdown area.

Application

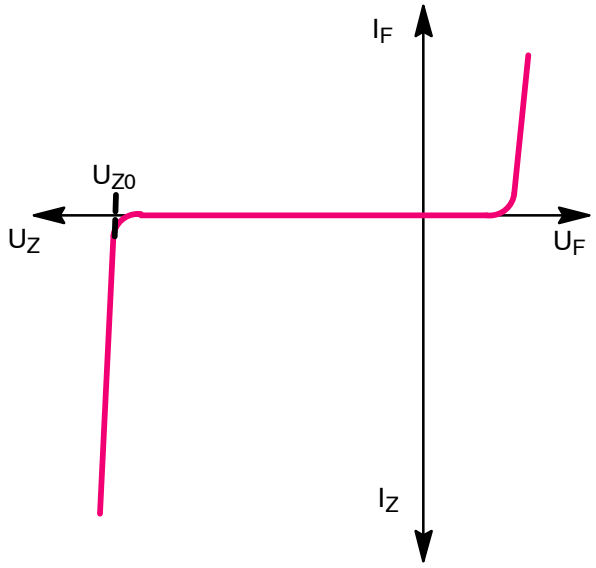
Z−diodes are mainly used to regulate electrical voltage.

In the entry area is the input voltage U_E; at the load resistance R_2 which is connected in parallel to the Z−diode is the regulated output voltage $U_A = U_Z$.

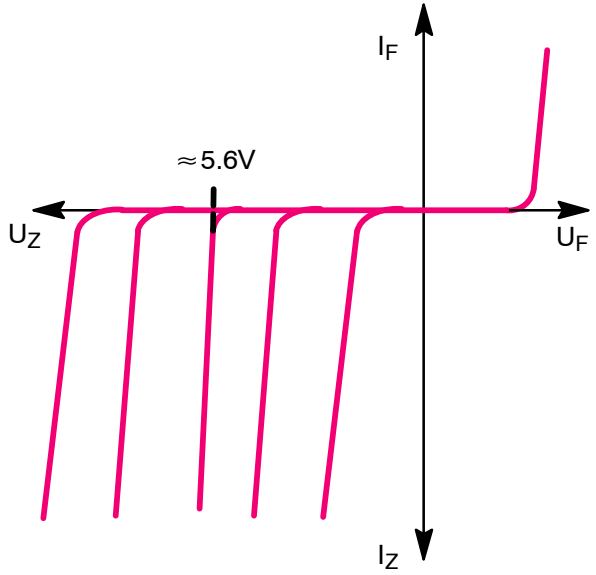
The difference between the input voltage U_E and the output voltage U_Z is purged at series resistor R_1.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training



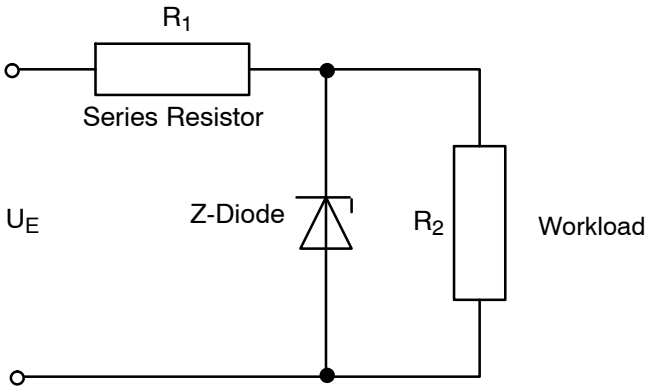
Characteristic Curve



Curves for different Z-Diodes



Wiring Symbol



Voltage Regulation with Z-Diode

Figure 14 Z-Diodes

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

LIGHT EMITTING DIODES (LED)

Optoelectronic Components

Optoelectronic components are important in all areas of electronics as sensors as well as visual signalling devices.

LED

LED stands for light emitting diodes. As the name states, they are semiconductor diodes that emit light. The colour of the light depends on the semiconductor material that is used.

Red LEDs only allow light to reach the surface because the underlying gallium–arsenic substrate is opaque. LEDs on a gallium–phosphorus substrate, on the other hand, make use of a reflective backing in order to exploit the light which is emitted downwards.

LEDs in the visible range are manufactured from GaAsP and GaP (possibly with the addition of other dopants). For diodes that emit infrared light, GaAs combinations with minimal amounts of zinc and silicon are used.

Usage

LEDs are used for a variety of signalling and indicating purposes. By adding reflectors or lenses and arranging them specially, they are useful for a wide range of alphanumeric displays with red as the usual colour.

A diode has a normal life span of 6 to 11 years.

Infrared LEDs

Infrared LEDs are used for controlling devices in industry, for photoelectric beams and for monitoring manufacturing facilities and are also used in communication technology (Language and music broadcasting as well as infrared remote controls using digital impulses are other areas with wide applications).

Polarity

LEDs are used in forward–biased direction.

Breakdown Voltage

The breakdown voltages in the reverse direction are between 20 and 50 volts and the switching times are between 50 nanoseconds for red light emitting diodes to 400 nanoseconds for green light emitting diodes.

Current

In normal operation, the forward biased current of an LED is somewhere between 5 mA and 40 mA at forward bias voltages between 1.4 and 4.5 volts (depending on the respective colour).

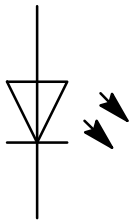
Because the I_F /U_F curve is very steep, it is preferable to supply these diodes with constant current (Series resistor).

LED materials

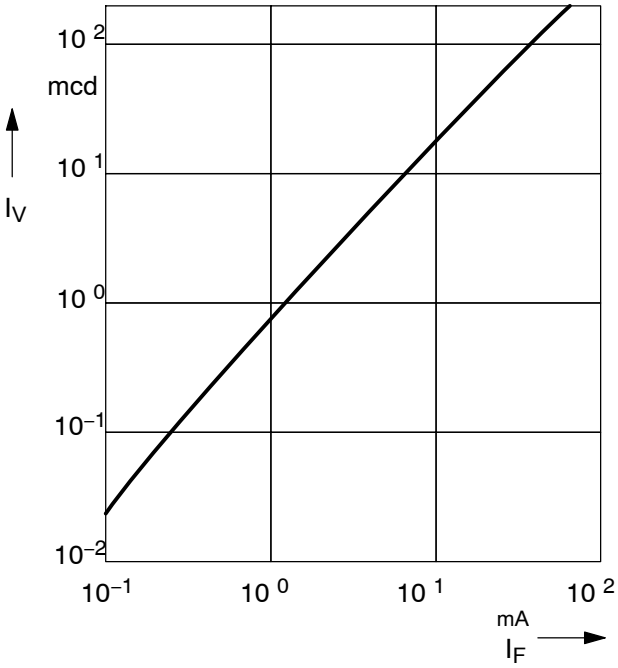
Material/Dopant	Wavelength
GaAs: Si	Infrared 930 nm
GaAs: Zn	Infrared 900 nm
GaAsP	Red 660 nm
GaAsP: N	Orange 630 nm
GaAsP: N	Yellow 590 nm
GaP: N	Green 560 nm
GaN SiC	Blue 450 nm

FOR TRAINING PURPOSES ONLY!

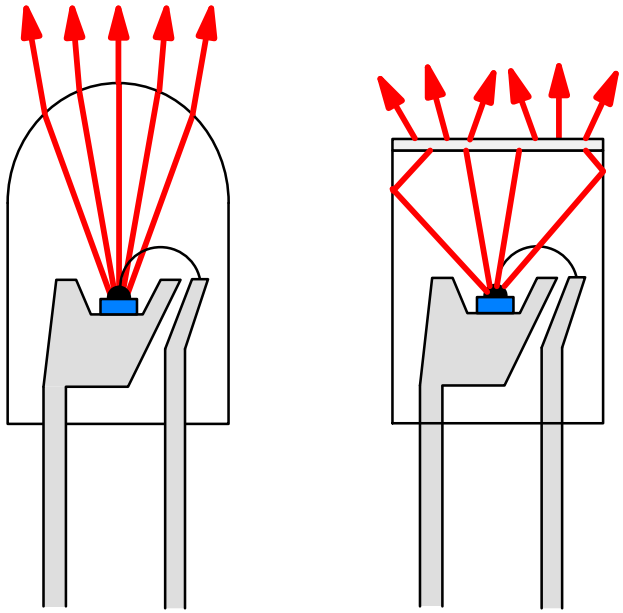
© Lufthansa Technical Training



Wiring Diagram Symbol



Dependence of luminous intensity on forward-biased current



Methods of LED construction

Figure 15 LED

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

PHOTODIODE

General

Photodiodes are semiconductors with a P-N-junction that is exposed to light.

Polarity

They are always connected in reverse direction.

Characteristics

If the junction is in the dark, they block the current like every other diode.

If the P-N-junction is illuminated, charges will be created within the depletion area. The diode becomes conductive.

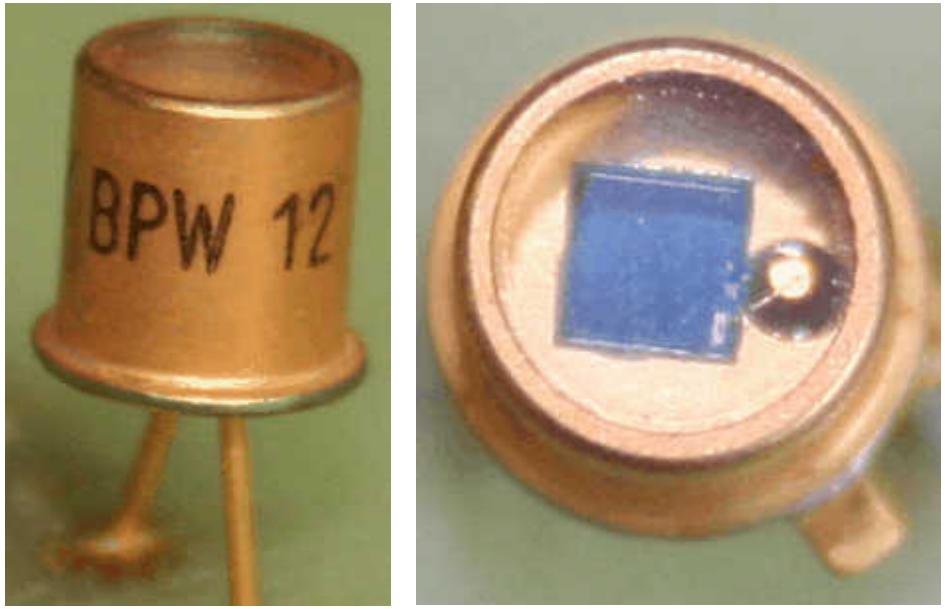
The amount of current in reverse direction is proportional to the amount of light. They may be sensible on light form UV to IR (Infra-Red).

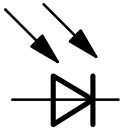
Material

Photodiodes can be made from silicon as well as from germanium.

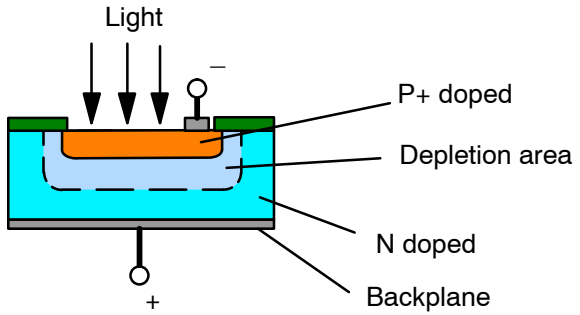
FOR TRAINING PURPOSES ONLY!

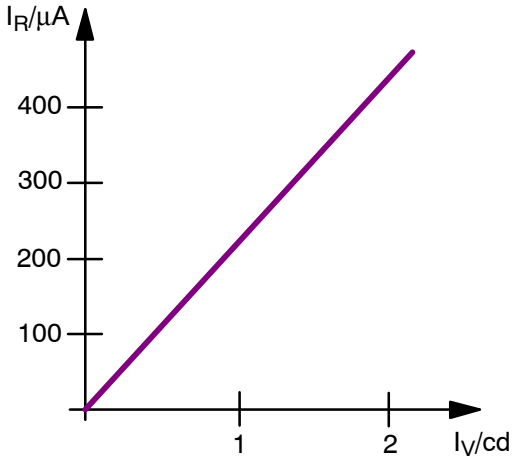
© Lufthansa Technical Training





Wiring Symbol





Relation between Reverse Current and Light

Figure 16 Photodiode

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

LIGHT DEPENDENT RESISTOR (LDR)

General

LDR stands for Light Dependant Resistor.

Light Dependent Resistors are no diodes, but they are made of semiconductor material.

LDR are semiconductor components without a depletion zone, which change their effective resistance in accordance with an internal photoelectric effect. When light is directed onto a surface made of semiconductor material, the resistance in the material diminishes because light energy releases electrons from their orbital bonds.

In an electric circuit they behave like ohmic resistors; their resistance value is independent of the direction of the current, so they can be used in circuits with direct current as well as in those with alternating current.

According to type they can handle voltages anywhere from 20 to 300 volts.

The intensity of the light in formulae is stated as I_V in cd (candela).

Polarity

The polarity doesn't matter.

Usage

Because of their sensitivity, LDR are especially useful (in appropriate circuit configurations) for measuring low levels of illumination.

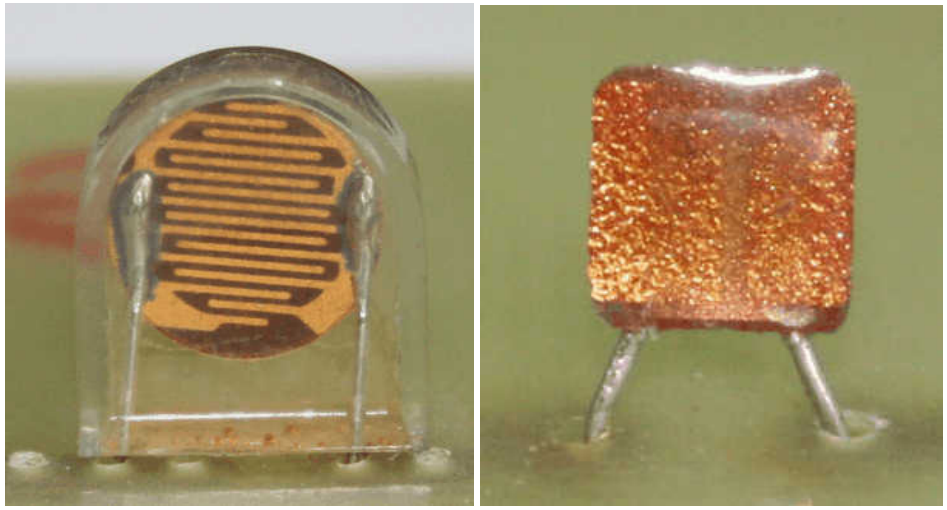
Material

The distribution of colour sensitivity depends on the main material used for the semiconductor and on the respective method of manufacturing.

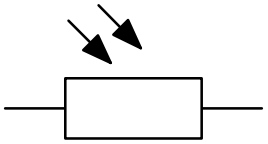
Cadmium, lead and indium compounds are mostly used in LDR production. Cadmium–Sulphur and Cadmium–Selenium LDR are light–sensitive in an optimal range between visible light and infrared light. (1µm); lead–sulphur and Indium–antimony types are used up to infrared wavelengths of 4–8 µm.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training



Construction of LDR



Wiring Symbol

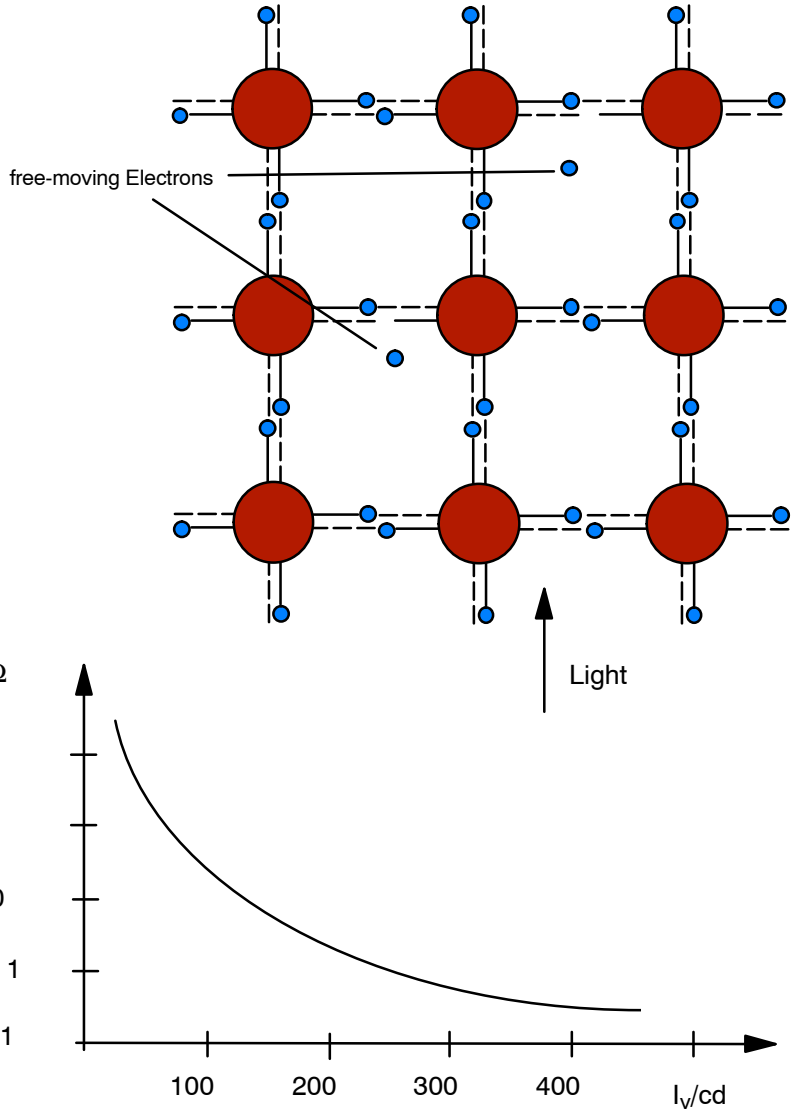


Figure 17 LDR

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

OPTICAL COUPLING DEVICES

General

Optical coupling devices are optoelectronic coupling elements used for transmitting signals while galvanic separating the input and output ports.

Usage

The most important task of an optical Coupling device is separating the electrical potential of the input port from that of the output port.

Construction

They contain at least one transmitter chip on the input side and a receiver chip on the output side. (Multiple configurations contain many coupling systems within one main housing.) Light−emitting diodes serve as transmitters whereby silicon−doped GaAs types are preferred due to their high effectivity at wavelengths in the region of 950 nm.

On the output side, there are many different possibilities as to the choice of receiver. In any case, the receiver must be as closely match the wavelength of the light being emitted as possible. Phototransistors are most often used; however, it must be noted that there are 2 different types: phototransistors with or without a base. If the base is accessible it is easier to adjust the operating point. One advantage is the high current amplification of phototransistors, which is between 200 and 1000. Much higher current amplification can be achieved using Darlington transistors as receivers. However optical coupling devices are also manufactured using photodiodes and photothyristors or LASCRs (light−activated silicon−controlled rectifiers).

Coupling

There are two methods of coupling:

- Direct coupling, where the light is reflected within the housing.
- Indirect coupling, where the light is reflected within a plastic coupling medium.

Test Voltage

The ability of the insulating material of the component to withstand large differences in direct current voltage is documented in the data sheets by specifying the insulation test voltage and the insulation resistance of the component. Normally the insulation test voltages are between 4 and 15 kilo volts (kV) and the insulation resistance is in the Terra−ohm region.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

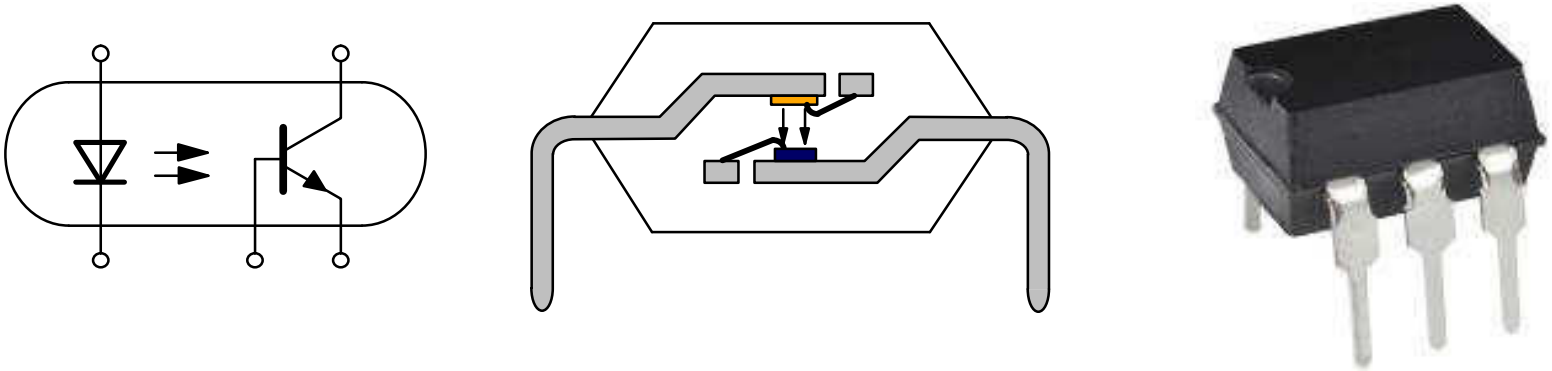


Figure 18 Optical Coupling Device

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

VARISTOR

General

A voltage dependant resistor is called Varistor.

Varistors are also called VDR resistors (voltage dependent resistors).

Varistors are no diodes, but they are made of semiconductor material.

Characteristics

The resistance level of varistors depends on the voltage that is applied.

The resistance of a VDR decreases with the voltage increasing.

At low voltages a varistor has a relatively high resistance level due to its barrier layer. However, higher voltages break through the barrier layers, thus reducing the resistance levels.

Polarity

The polarity of the voltage doesn't matter.

Usage

Varistors are chiefly used to protect systems against excess voltage.

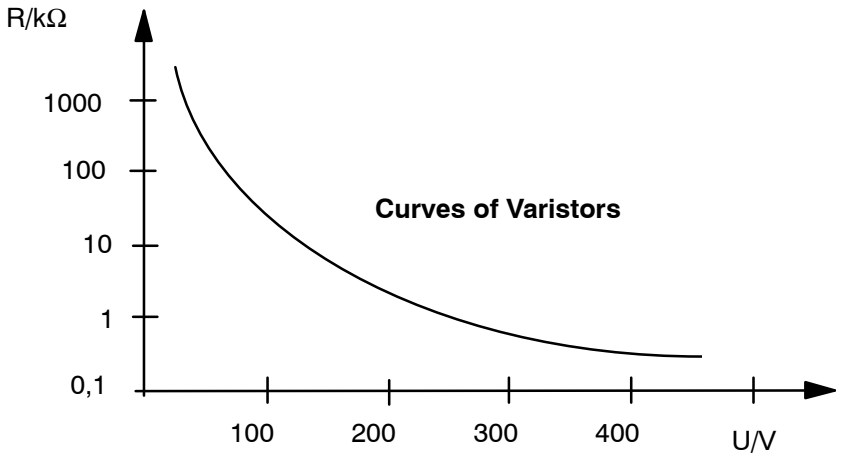
They can also be used to regulate voltages and suppress interference in small direct current motors as well as for lightning protection and for protecting contacts against cut–off currents in the case of inductors.

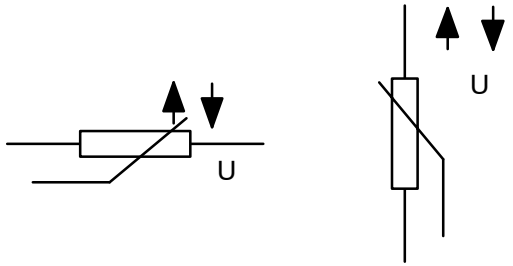
Material

The effective semiconductor layer of a VDR consists of many small highly conductive crystal particles, each of which is covered with an extremely thin barrier layer, which are sintered together.

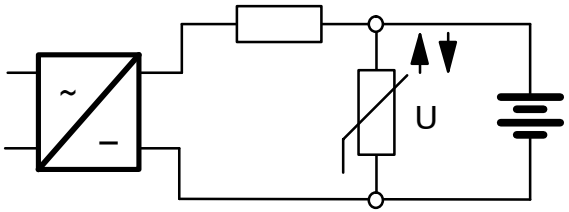
FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

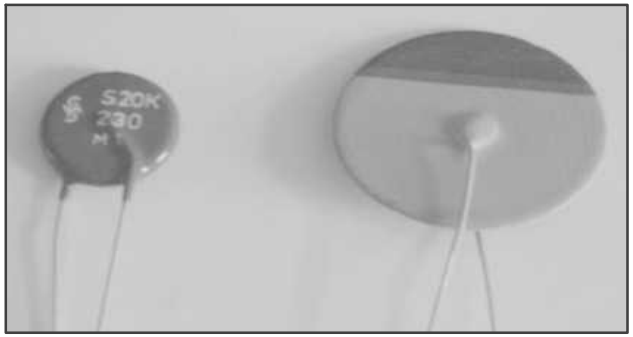


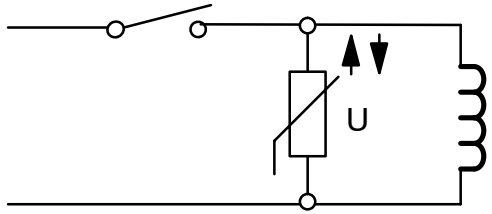


Wiring Symbol



Limiting charging currents





Suppressing cut-off currents/interference

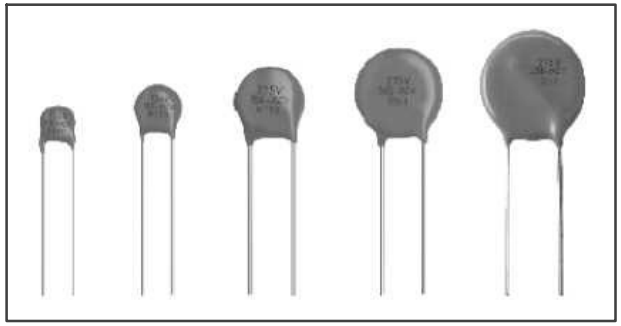


Figure 19 Varistor

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

THYRISTOR

General

Thyristors are fast electronic switches (up to 10 kHz).

They are diodes with a control terminals or gates. They operate at voltages below the zero sweep voltage and can be switched from high resistance to low resistance by a change of voltage at the gate.

Using thyristors, very large currents and high power levels can be switched. However the thyristors must be built in a special way for these currents. The figure shows the construction of a thyristor for such purposes.

Thyristor Construction

Thyristors are constructed in four alternating layers, P–N–P–N, so that three P–N junctions form between the layers.

Operation

Thyristors can be built in different ways. They are usually used with a gate on the cathode side (P–controlled thyristors) and are constructed as follows:

The n–controlled or anode–controlled thyristor is not used as often.

During operation in the circuit direction the voltage U_{AK} concentrates at the thyristor. The diodes D_1 and D_3 allow the current through, but the diode segment D_2 is wired in the reverse direction while the gate is not connected.

Zero Sweep Voltage

In the blocking state region the thyristor behaves as follows: If no current is applied to the gate, the transition from blocking mode to conducting mode takes place at a certain voltage U_{AK} which is called the zero sweep voltage.

Control Current

If the voltage is much less than the zero sweep voltage, the transition occurs as a result of the current at the gate.

The control current must be large enough and must occur for a specific minimum time period.

You can see from the curve in the figure how much controlling current is necessary to cause the thyristor to flip into the low–resistance state at a specific voltage, U_{AK}.

Low Resistance State

In its low resistance state, the barrier layers or junctions are inundated by charge–carriers and the control electrode becomes ineffective. A negative current applied to the the control electrode will **not** return a thyristor to its original high resistance state.

If a thyristor is in its low resistance state, it can no longer be controlled by means of a control electrode. It can only return to its high resistance state if the electrical current falls below a specific value, the so–called holding current I_H.

Current

Every thyristor can only be subjected to a specific maximum current. If this limit is exceeded, the thyristor will be destroyed.

Thyristors are currently being manufactured which, according to thyristor type, have maximum permissible amperes between 3A (microthyristors) and 4500 A (macrothyristors).

In order to keep the thyristor from overheating, it must be cooled.

Voltage

The highest permissible voltages are between 100 volts and 8000 volts.

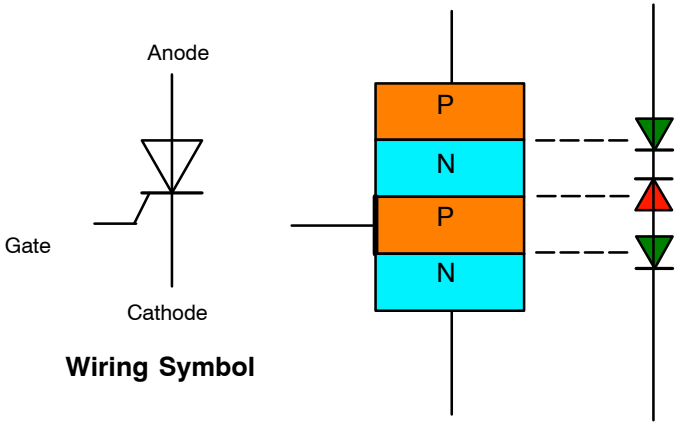
Certain maximum voltage levels must not be exceeded in the reverse direction.

Usage

Direct current power can be easily controlled using thyristors. Only a very small power level is necessary for control.

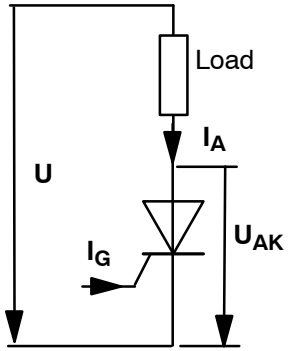
FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training



Wiring Symbol





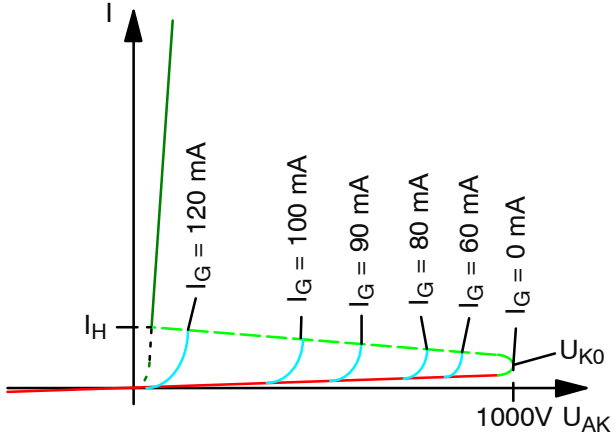


Figure 20 Thyristor

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

CONTROLLED PSU WITH THYRISTOR

Half-Wave Rectifier

Thyristors also function as rectifiers because when they are orientated with a negative voltage at the anode, one half−wave of the alternating current cannot pass through.

The half−wave rectifier circuit shown in the figure works with a thyristor as a rectifier element. During the negative half−wave of U, the thyristor blocks the current and during the positive half−wave it also initially blocks the current, working in the blocking range. At the point in time t, an electrical impulse is applied to the control electrode of the thyristor and it becomes a transmission gate. Now the current can flow through the thyristor and through the load resistor R.

Phase Angle Control

The control voltages are constantly released after a specific phase angle. This angle is called an ignition delay angle (symbol: φ_z). On the diagram is has been given as 60 degrees.

The thyristor only lets a part of the positive half−wave pass. Every half−wave is “cut into”.

This is called phase angle control or phase control.

By means of the phase control, the power output to a load resistor can be reduced from an extremely high level down to zero.

The larger the ignition delay angle is, the later the thyristor develops low resistance and the smaller the portions of current are which are transmitted to the load resistor.

The voltage U_2 can be regulated by the ignition delay angle (φ_z = 0 ... 180 degrees) between the maximum value and zero.

Smoothing

When this half−wave rectifier is followed by a set of filters, the output voltage is smoothed.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

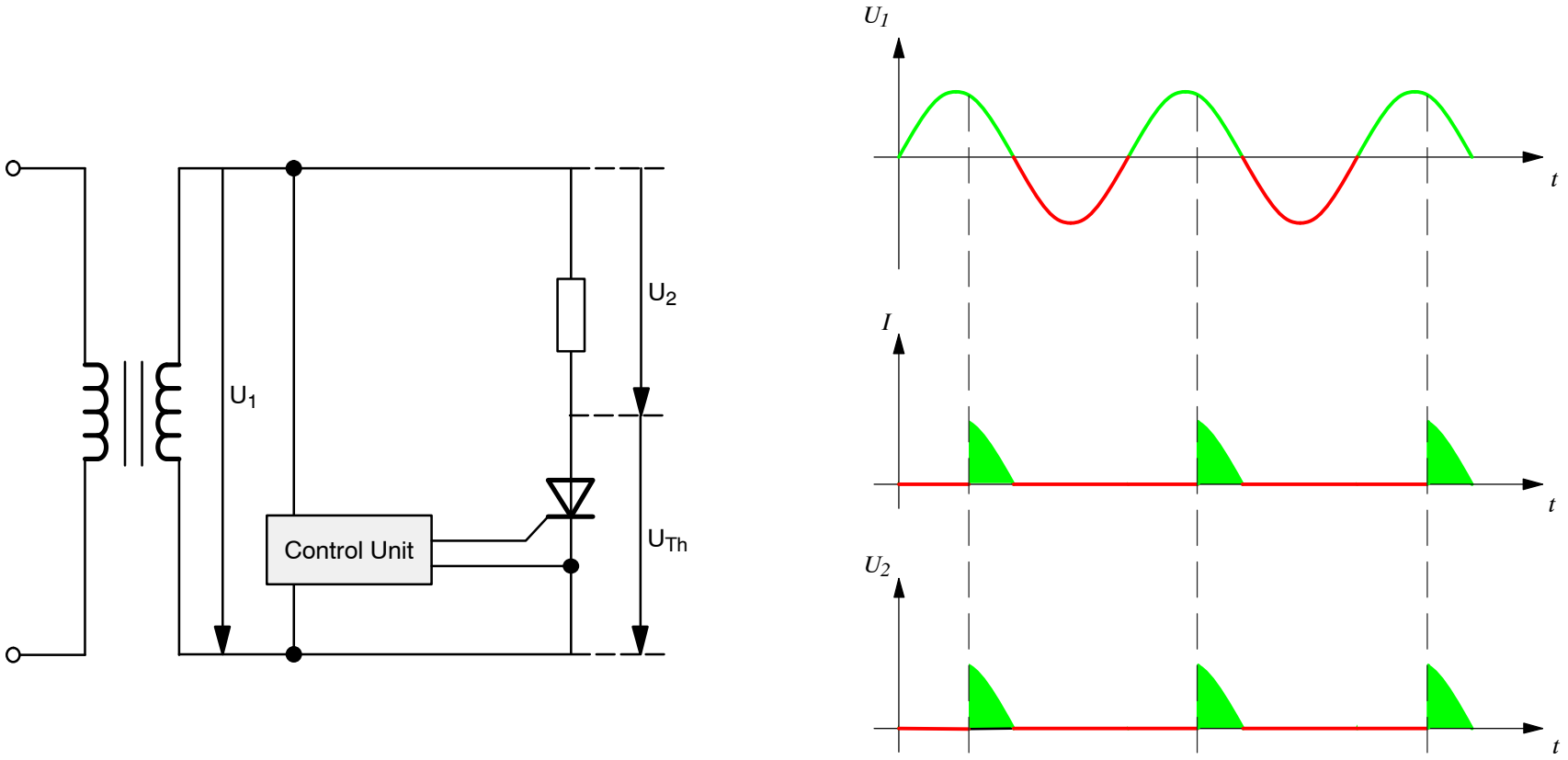


Figure 21 Controlled Power Supply

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

TRIAC

General

It is a constant challenge to provide the consumer with controllable power. So that it is possible to exploit the second half–wave as in the case of a regulated rectifier, thyristors are used in antiparallel circuits.

A triac, or bidirectional triode resistor is in principle the wiring of two thyristors in an antiparallel circuit. Both are united in one crystal and have a common junction.

As in the case of a thyristor, if the triac is in a low resistance state, the control electrode becomes ineffective. Only when the load current is smaller than the level of the holding current I_H will the the triac return to its high resistance state.

Polarity

A triac is switched into low resistance mode by applying an electrical current to the control electrode in either direction. It does not matter what the polarity between A_1 and A_2 is.

Curve

The curve of a triac has no cut–off region, but it does have a blocking region and a gateway region.

Usage

Because a triac can block current and let it pass in both directions of current flow, it is useful in regulating alternating current. The name “Triac” is an abbreviation for “triode alternating current switch”.

Today triacs are only being built to take load currents of about 20 A, so it is only possible to use them for medium–range power outputs.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

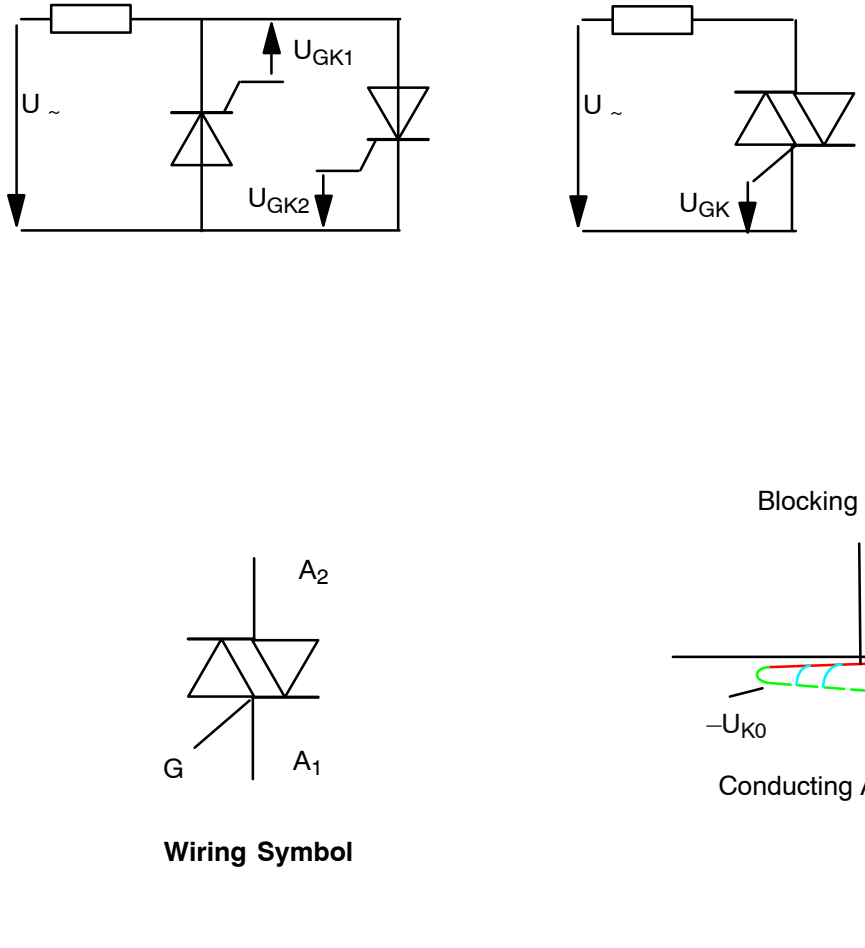


Figure 22 Basic Principle and Characteristic Curve of a Triac

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

DIMMER SWITCH CIRCUITS

General

In many cases, the effect that a rectifier has, as in the case of a thyristor, is not desired.

It is advantageous to regulate both half−waves of alternating current while adding AC power to the load resistance. This is always the case when regulating electric heating elements, lighting systems or electrical machines.

Here we will look at a dimmer circuit. The Figure shows a circuit with one triac. The lamp represents the load current. The triac must be switched to a low voltage state by applying the required electrical signals to the control electrode or gate, G.

These signals are produced by connecting R_1, R_2, C and one diac in series. The resistors charge the capacitor. When the switching voltage of the diac is reached, it switches to its low resistance state and the capacitor discharges. It then applies this current in the form of impulses to the control electrode of the triac and triggers the triac into its low resistance state. The triac remains in this mode until the level of the load current becomes lower than the level of the holding current. The same thing happens during the following half−wave, except that the voltage is switched in the opposite direction.

The charging time for C can be adjusted by means of the variable resistance R_2. At the same time, the ignition delay angle is set.

The phase control produces harmonic oscillations.

Interference Suppressors

The voltage and current diagrams given in the figure show that the output current and the output voltage are no longer described by a sine curve. They contain a large percentage of ripples that have frequencies which extend into the range of radio frequencies.

So it is necessary to take measures to suppress this interference. In the figure, choke L and capacitor C_2 function as interference suppressors.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

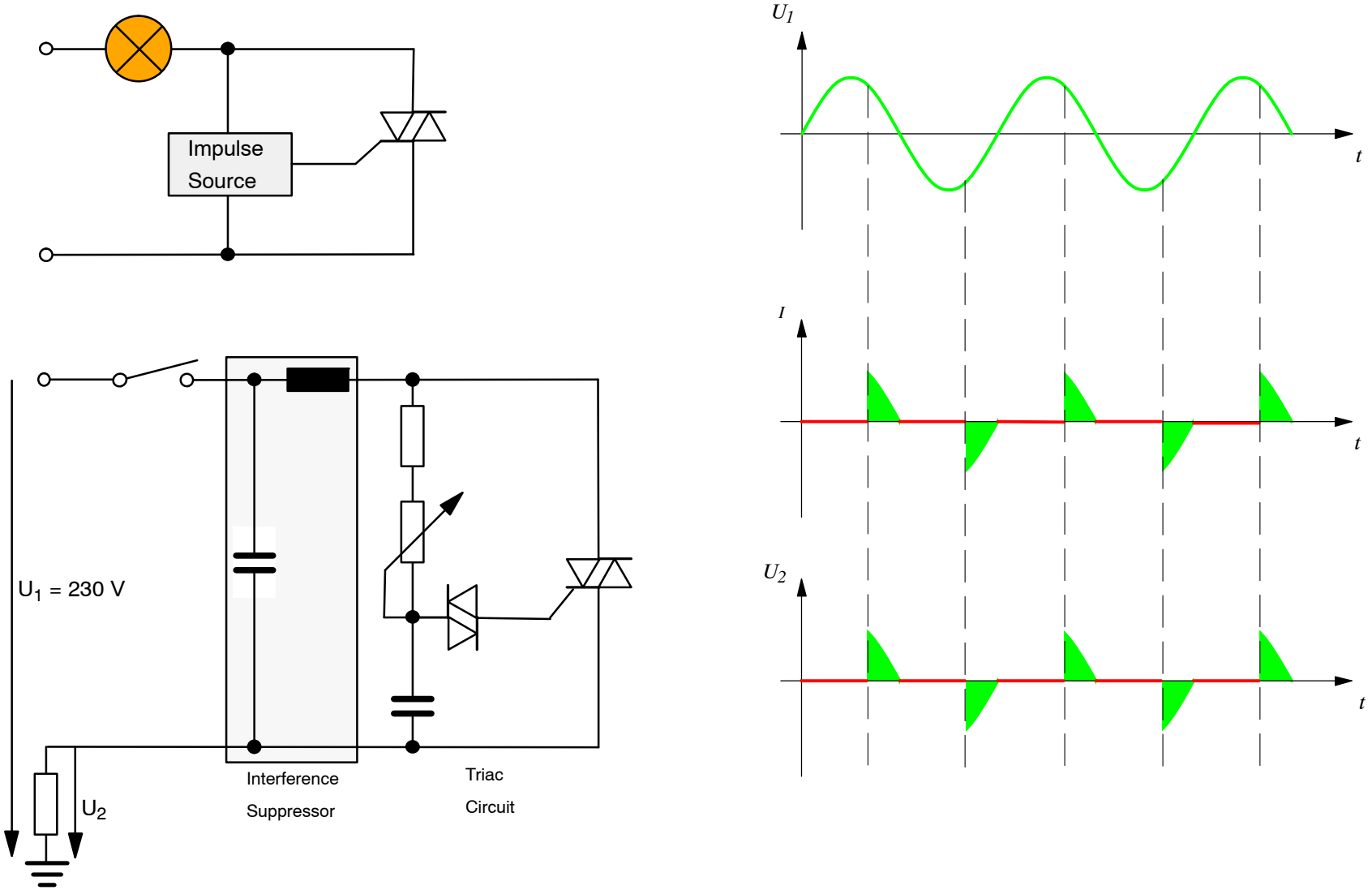


Figure 23 Dimmer Switch Circuit

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

M4.1.2 TRANSISTORS

INTRODUCTION

General

A transistor is used as a fast electronic switch or regulator for small and medium DC voltages and currents.

There are N–P–N transistors as well as P–N–P transistors.

Construction

A transistor consists of three sequential semiconductor layers.

The operating current flows through the N–layers as well as through the P–layers.

A transistor has three terminals:

- Emitter
- Base
- Collector.

Wiring Symbol

The wiring symbols for NPN-transistors and PNP-transistors are shown below. The circles are often omitted.

The terminal with an arrow is named emitter.

If the arrow points outside the transistor, it is a NPN transistor.

Terminal Markings

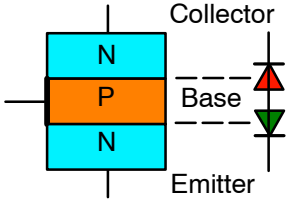
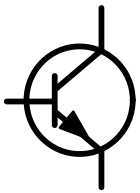
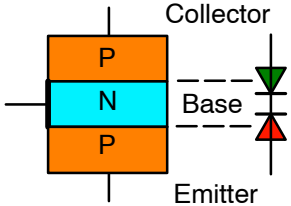
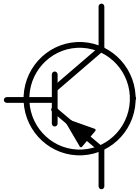
In the wiring symbol, the emitter is marked with the arrow.

Small transistors have a marking which shows the emitter.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

Table: Construction and Wiring Symbol

Type	Semiconductor Layers	Diode Equivalents	Wiring Symbol
NPN			
PNP			



Transistor on Heat Sink

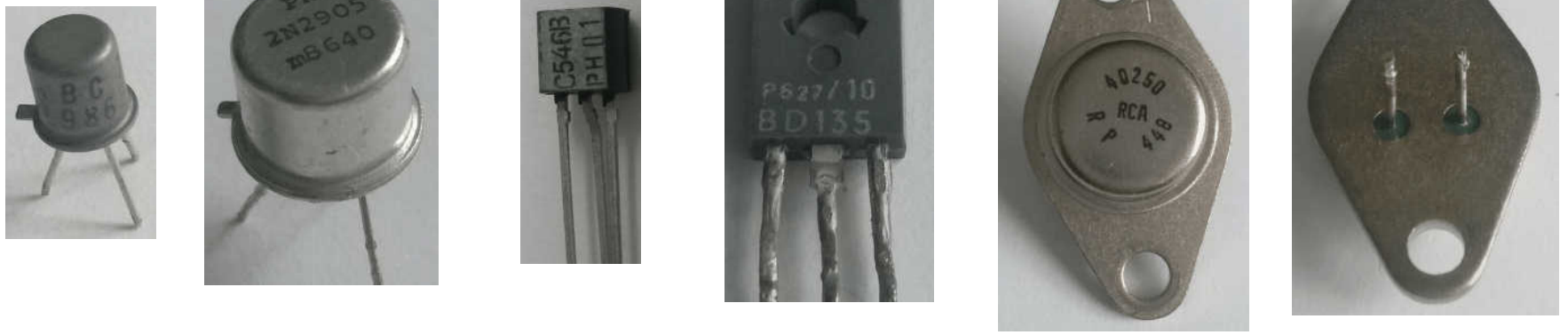


Figure 24 Transistors

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

DESCRIPTION

Layers

Each transistor has two P–N junctions where depletion layers form like in diodes.

- The first layer emits charge–carriers, which is why it is called the emitter.
- The middle layer is called the base or base region of the transistor. Its function is to regulate the emission of the charge–carriers.
- The last layer is called the collector. The collector collects the charges.

NPN and PNP

The difference between N-P-N and P-N-P transistors is the arrangement of the layers and therefore the direction of the two diodes inside the transistor.

- The NPN-transistor has a N-layer, a P-layer and a N-layer.
- The PNP-transistor has a P-layer, a N-layer and a P-layer.

The basic operation principle is the same to both N-P-N and P-N-P transistors.

Due to the direction of the two diodes inside the transistor the polarity of the voltages applied to the terminals is reversed.

Polarity

The arrow of the wiring symbol shows the direction of the current which flows between base and emitter.

N-P-N transistors require the Base voltage and the Collector voltage to be positive in respect to the Emitter.

P-N-P transistors require the Base voltage and the Collector voltage to be negative in respect to the Emitter.

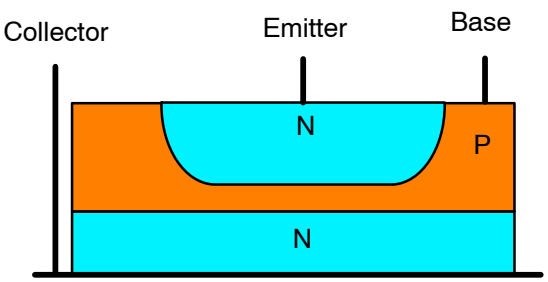
Terminals

The terminals are called collector (C), base (B) and emitter (E).

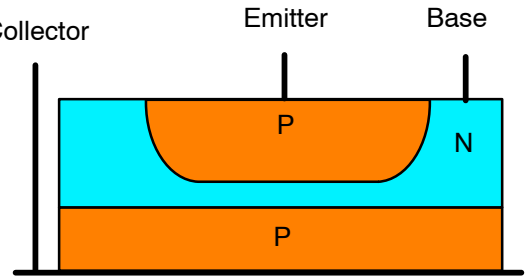
In many transistor contructions the collector is connected to the transistor housing.

FOR TRAINING PURPOSES ONLY!

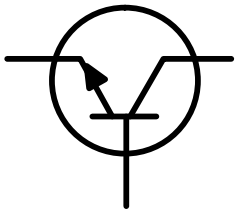
© Lufthansa Technical Training



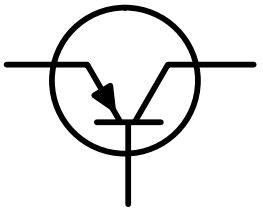
NPN-Transistor



PNP-Transistor



Wiring Symbol for NPN



Wiring Symbol for PNP

Figure 25 Construction of a Transistor

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

CHARACTERISTICS AND PROPERTIES

General

Here the example of an N–P–N transistor is used to demonstrate how transistors work.

Collector/Emitter Voltage

The collector has a positive voltage U_{CE} as opposed to the emitter so that the collector–base diode is in the blocking direction.

Voltage of the Base

As long as the voltage of the base in comparison with the voltage of the emitter does not exceed the diffusion voltage for silicon (0.7 volts), the base–emitter diode will be blocked.

If the voltage U_{BE} is increased to a point where it reaches the threshold voltage, the base–emitter diode will become conductive and the current flowing between the emitter and the base will inundate the extremely thin base zone.

The base zone contains an extremely low amount of dopant material which means that only a very small number of the charge–carriers reach the base connection. The majority (ca. 99%) of the charge–carriers is swept up by the electric field emanating from the collector and is pulled in that direction.

Current Amplification

The ratio of the collector current to the base current is called current amplification.

$$B = \frac{I_C}{I_B}$$

A Transistor is controlled between base and emitter. The load current flows across the collector and the emitter. A transistor has a current amplification effect because it can regulate a high collector current with a relatively small base current.

Voltage Source

Normally only one voltage source is used to supply current to both the base–emitter circuit and the collector–emitter circuit. The voltage for the base is provided by a voltage divider.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

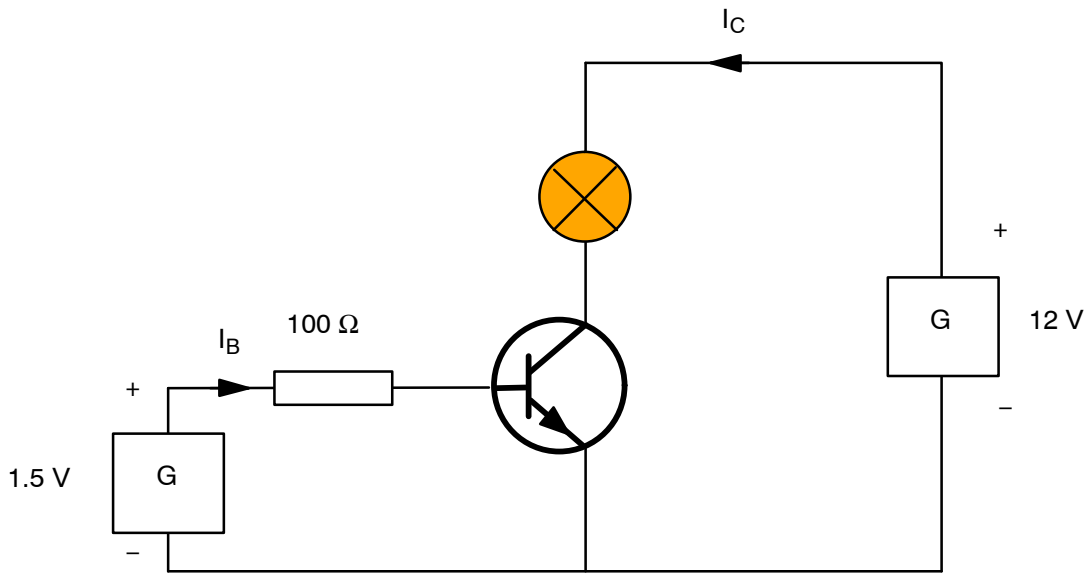


Figure 26 Transistors

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

THE TRANSISTOR AS A SWITCH

General

Transistor switching stages are used everywhere where small or medium amounts of power must be switched quickly with solid state technology.

The resistance levels of the transistors between the emitter and the collector are controlled between resistance as high as possible and resistance as low as possible.

In switching stages, transistors are only operated in the states “high resistance” = “switch open” and “low resistance” = “switch closed” as shown in figure 1.

Usage

Transistor switching stages are commonly used for computers, for electronic clocks, electronic counters and for control circuits of all kinds. They can be found, for example, in the ignition systems and directional lights of motor vehicles.

Circuit

The transistor in its switching function is often used in emitter circuits. Here the input and output terminals behave in the opposite manner: If there is no voltage at the base (input terminal), the transistor blocks and lets no current through. Then, because of the high resistance, no current is flowing so, in accordance with Ohm’s Law, there is no voltage across the resistor, therefore full voltage is at the output terminal. When the voltage at the input terminal increases to a level greater than 0.7 volts, the transistor switches to conducting, therefore at the output terminal almost no voltage can be measured.

Examples

The schematics shown in figure 2 is a typical emitter arrangement which in digital techniques is frequently used as inverter.

The switching of a light barrier with a switching transistor is shown in figure 3. When light strikes the photocell, the resistance value of R_x drops suddenly. The voltage at the base of the transistor rises. The transistor is put into a low resistance state. The collector current I_C flows through the relay and it is energized. When the beam of light is interrupted, R_x becomes highly resistive (about 1 Mega-Ohm). The transistor blocks: The relay becomes de-energized.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

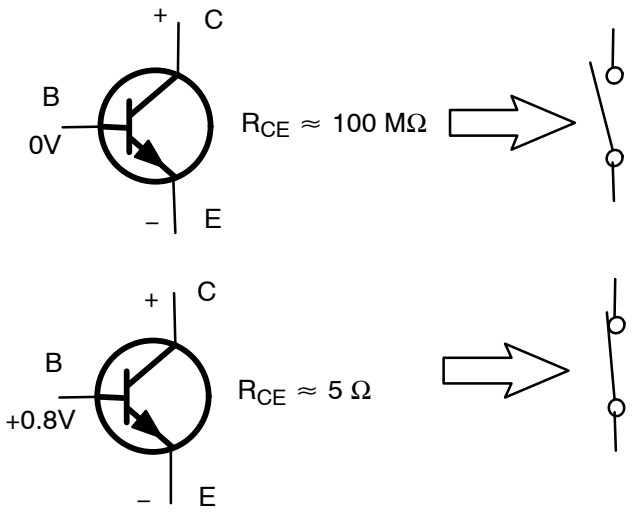


Fig 1: Transistor as Switch

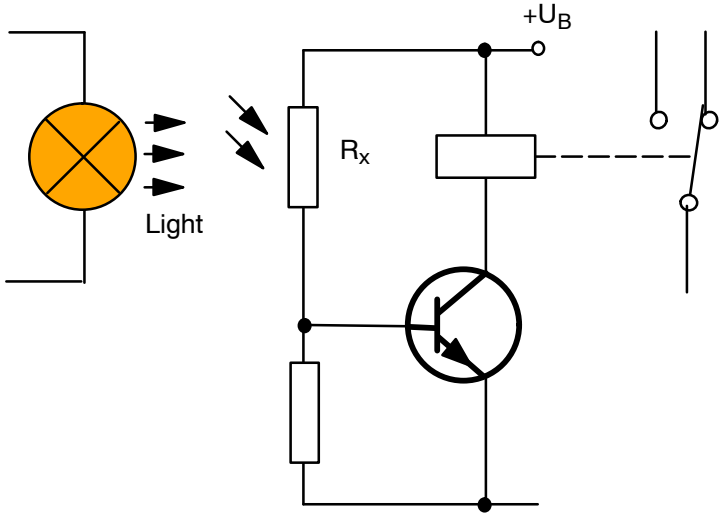


Fig 3: Light barrier with transistor

Fig 2: Transistor used as Switch

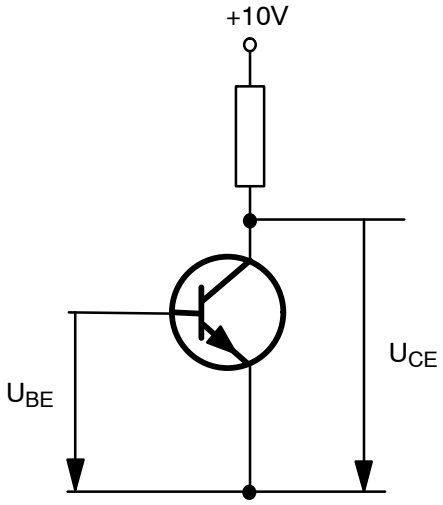


Figure 27 Example: Transistor used as a Switch

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

Example

This figure shows a schematic of an hydraulic system.

In the upper right area, you can see two indicator lights. They are controlled by transistors.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

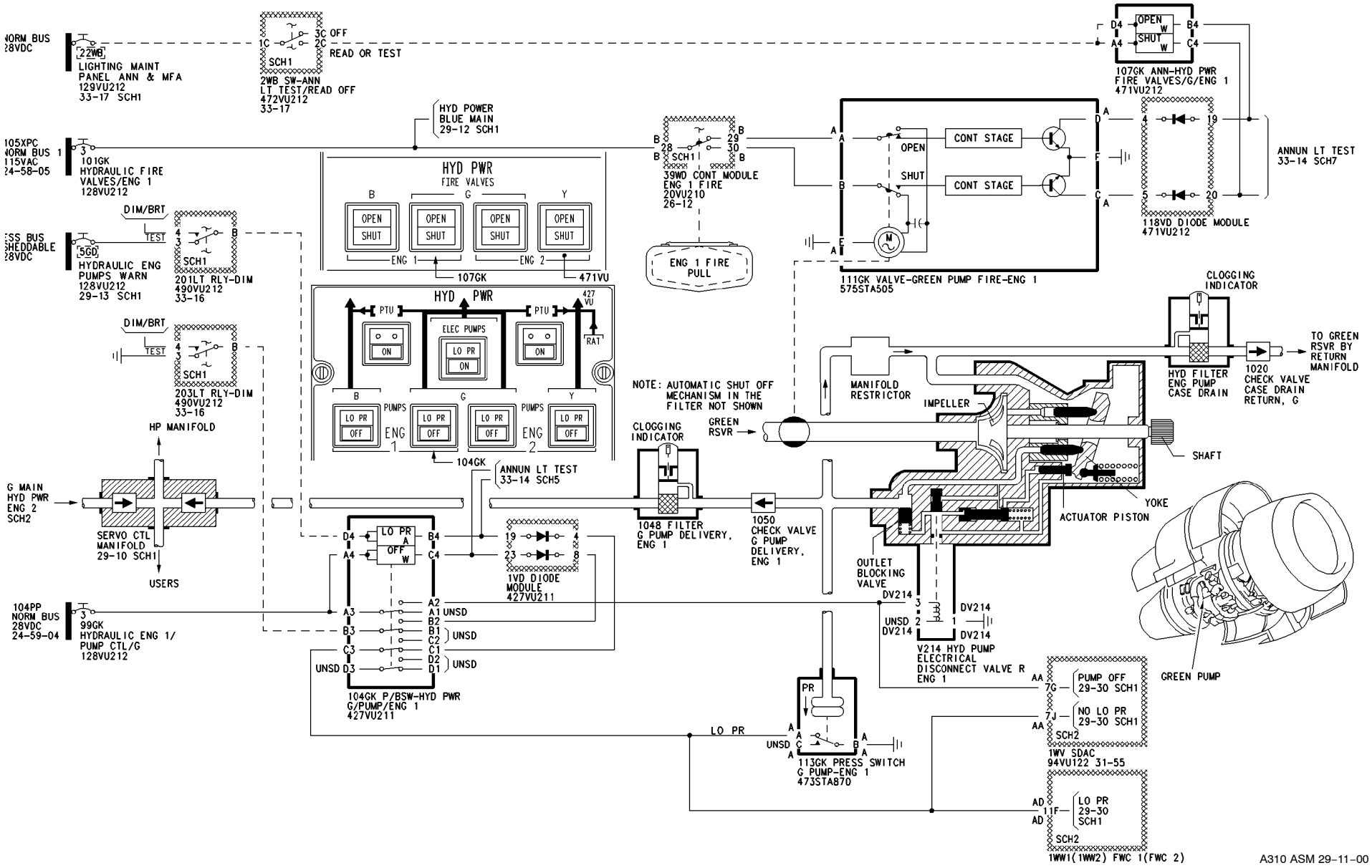


Figure 28 Example: Transistor used as a Switch

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

M4.1.3 INTEGRATED CIRCUITS

INTRODUCTION

General

Integrated Circuits are arrangements of several electronic components in a common housing.

Advantages

The major advantage is the very high density of the components, the total arrangement therefore will be very compact.

As well they are quite resistant to mechanical stress.

ICs are very cheap.

Disadvantages

The small housing and therefore the small surface is a disadvantage because some additional cooling might be required. A heat sink or fan must be attached then.

Another disadvantage is that ICs can not be repaired, a defective IC must always be replaced.

Elements

Usually the following components are integrated in ICs:

- Semiconductors (Transistors, Diodes)
- Resistors
- Capacitors

Inductors usually can not be integrated due to their large space requirements.

Usage

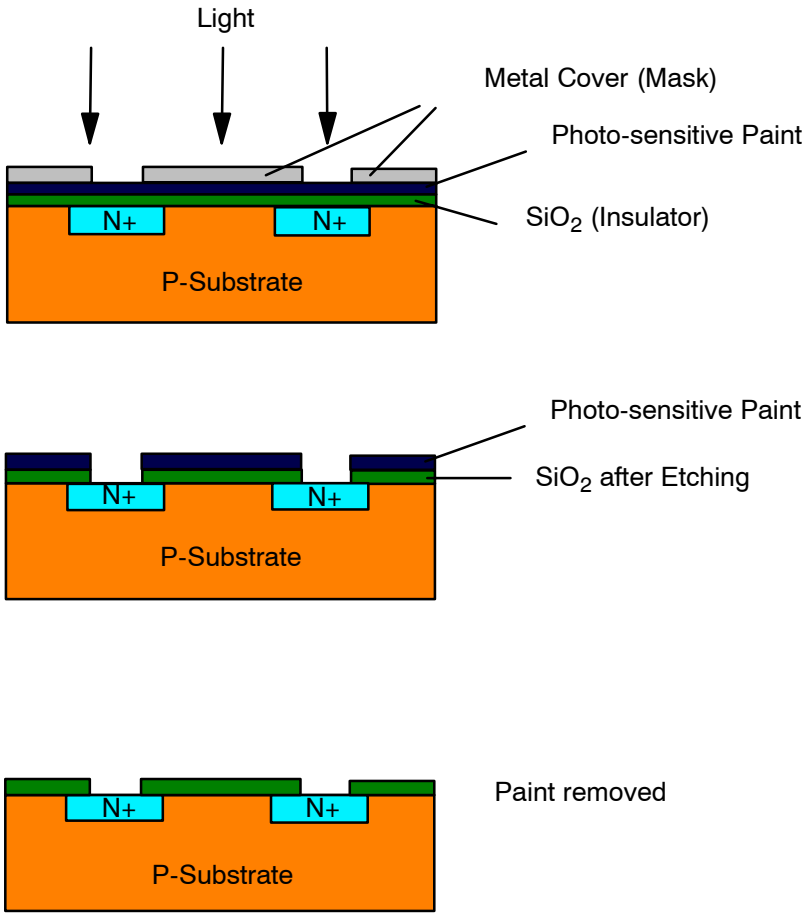
ICs can be found in each and every modern appliance, in analogues as well as in digital ones. Functional blocks can be found in a single IC, requiring only a very small amount of space, i.e. Processors (Computer), Amplifier (Entertainment) or Operational Amplifier (Voltage Regulators or Entertainment).

Production of ICs

Usually ICs are made from very pure Silicon. The structures are formed by vaporing processes (left), photographic processes (centre) and others.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training





Shape of IC

System Carrier for IC

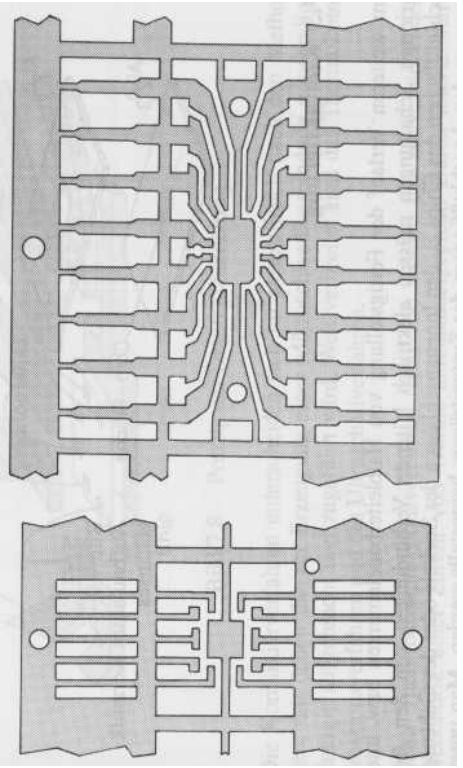


Figure 29 IC Production Process

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

OPERATIONAL AMPLIFIERS

General

Operational amplifiers consist of several amplifier stages. The operational amplifier is always a differential amplifier with two inputs and one output. The output stage is usually a push−pull power amplifier.

Because operational amplifiers are manufactured using integrated technology, they usually have very small dimensions.

Operational amplifiers can amplify both alternating and direct current.

Inputs

They have two input terminals.

The inverting input is usually designated with a minus sign and the non−inverting input with a plus sign.

Output

The output voltage is measured between the output terminal and the common terminal for both operating voltages.

When the difference input voltage U_1 is positive, a negative output voltage U_2 is the result; when there is a negative input voltage U_1, then there is a positive output voltage U_2.

Operating Voltage

Operational amplifiers are usually supplied with both a positive and a negative operating voltage.

The positive operating voltage of an operational amplifier lies between +5 volts and +18 volts, the negative voltage between −5 volts and −18 volts.

Both operating currents, as is the case for the trimming resistance, are usually not shown in the wiring diagrams. In the schematic symbols for an operational amplifier, just the two input terminals and the output terminal are usually shown.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

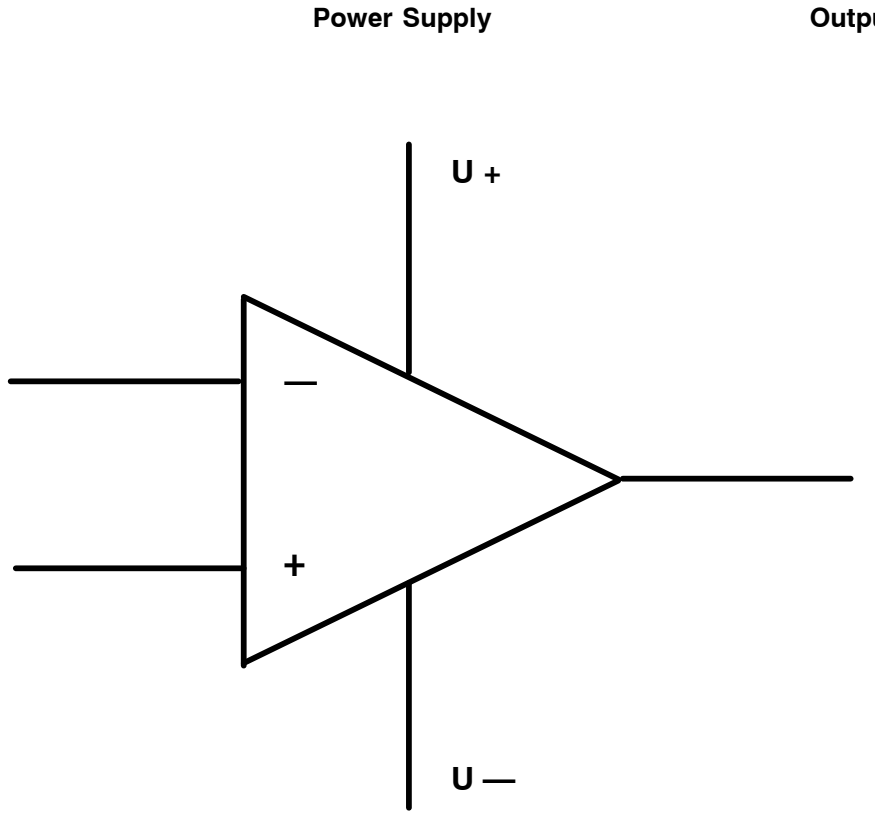


Figure 30 Operational Amplifier

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

Properties

The ideal operational amplifier has

- an amplification which is nearly infinite
- an input resistance which is almost infinite
- a very small output resistance
- an input voltage of approximately zero volts.

External Wiring

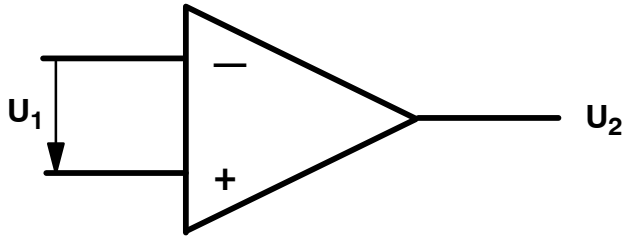
The external wiring, which is done in the form of negative feedback, determines how the circuit will function.

Usage

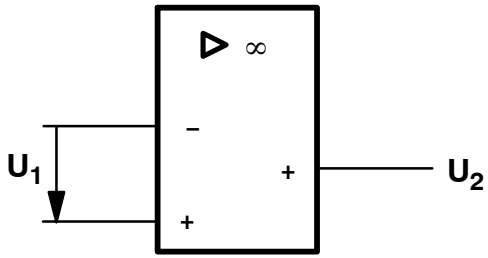
Operational amplifiers have been used primarily in analogue computers, which is where they get their name from. Today they are used for almost every kind of amplifying task in the analogue area but also in digital technology, for example as digital analogue transducers.

FOR TRAINING PURPOSES ONLY!

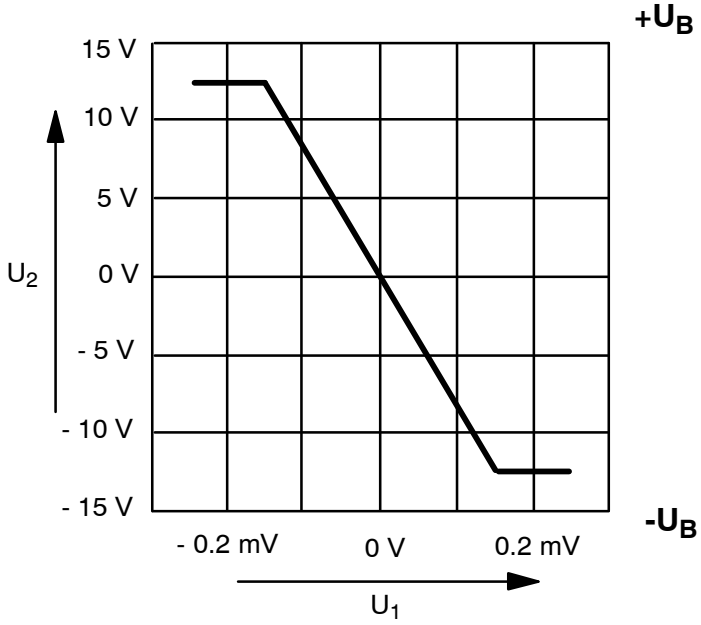
© Lufthansa Technical Training



Commonly used symbol



Symbol according to international standards



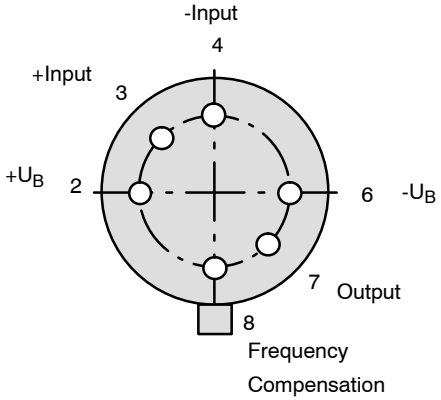
Excitation Curve

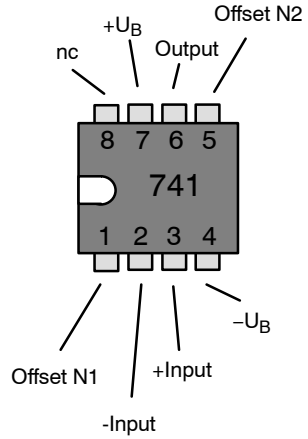
Figure 31 Schematics Symbol and Excitation Curve of OpAmp

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

HOUSING DESIGNS





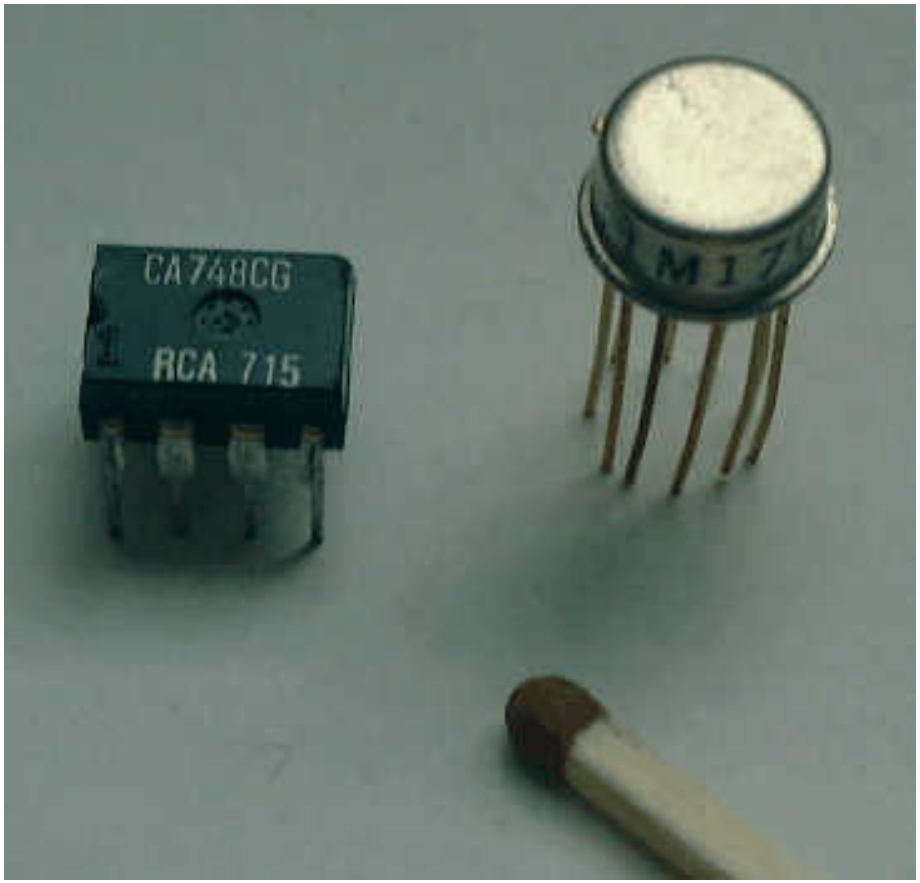
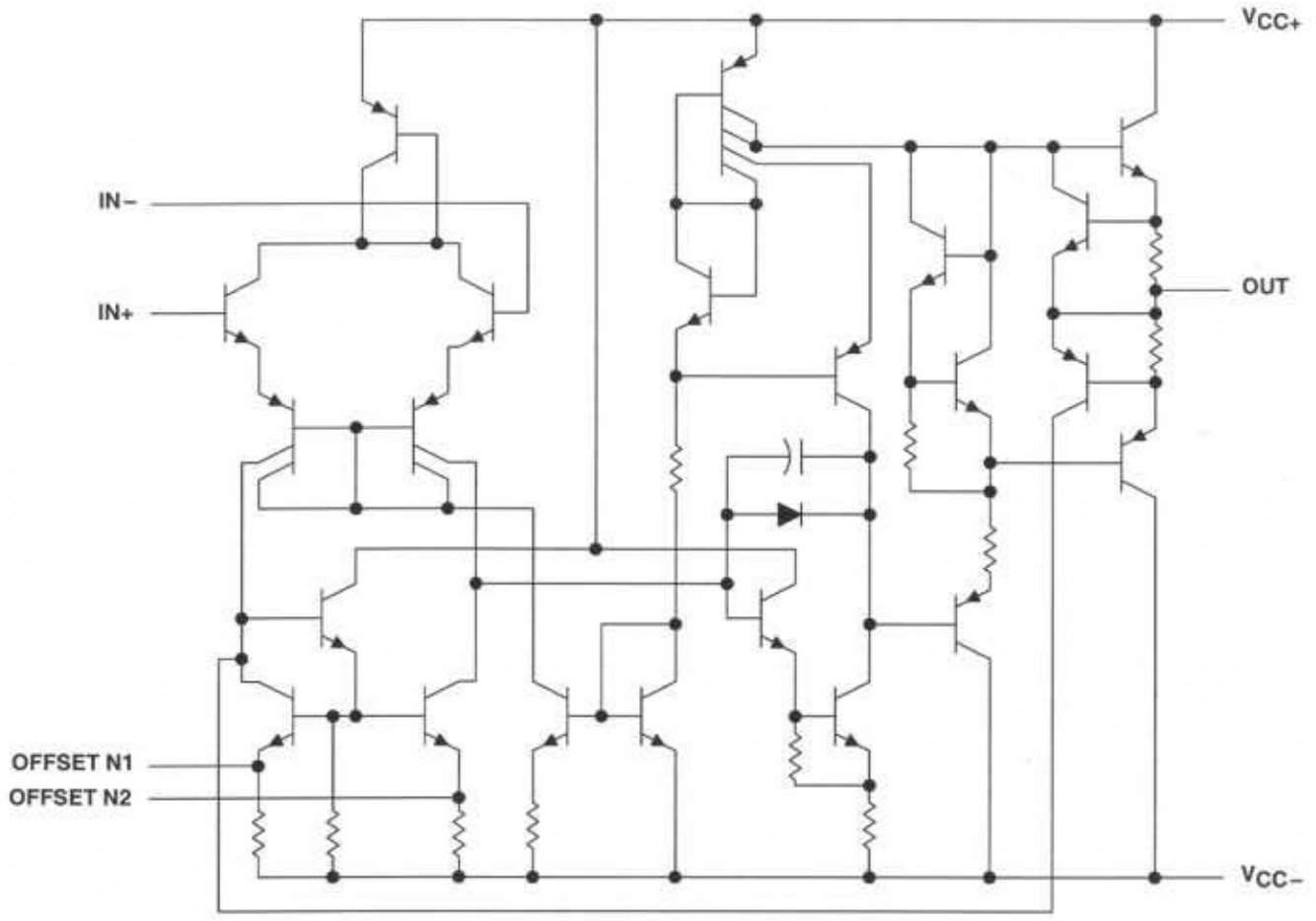


Figure 32 Housing Design of OpAmp

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training



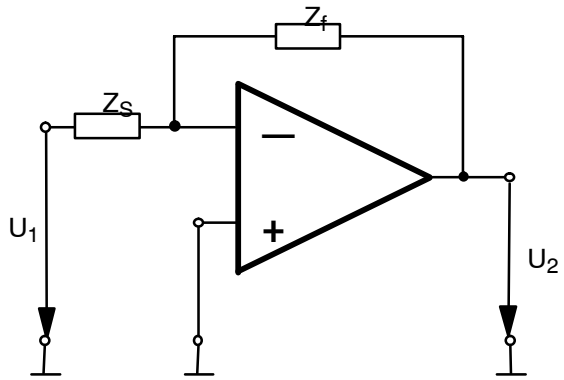
Component Count	
Transistors	22
Resistors	11
Diode	1
Capacitor	1

Figure 33 Interior of an OpAmp (741)

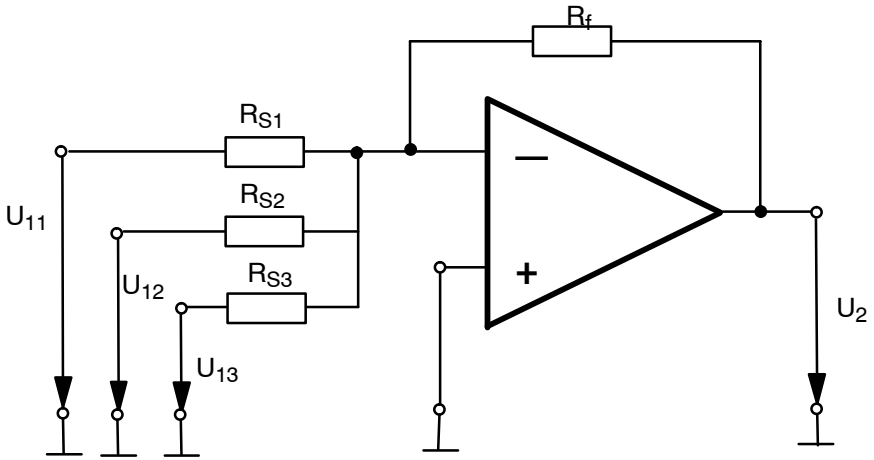
FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

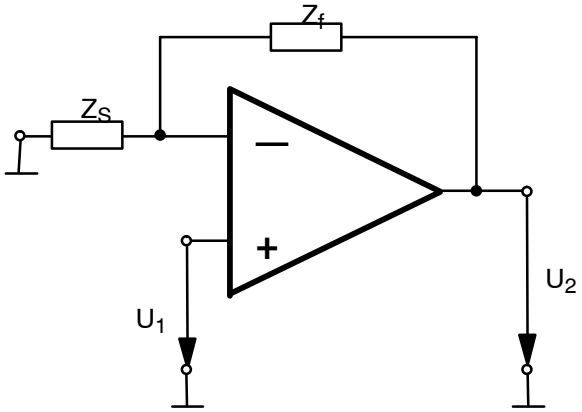
OVERVIEW OF STANDARD CIRCUITS



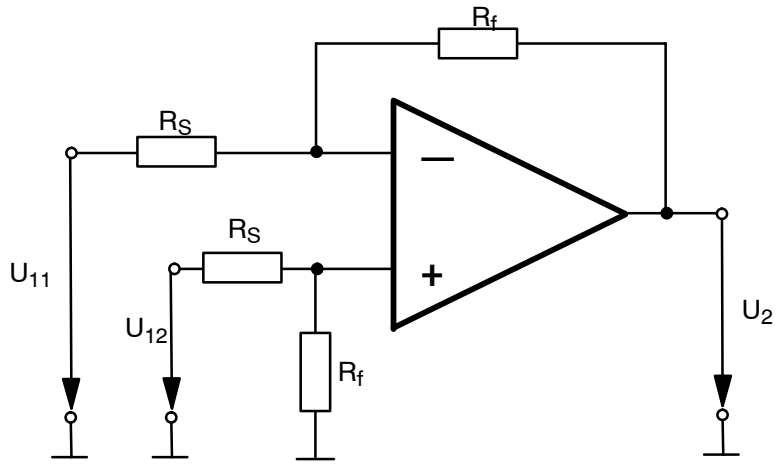
Inverting Amplifier



Adding Amplifier



Non-Inverting Amplifier



Subtracting amplifier

Figure 34 Overview of Standard OpAmp Circuits

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

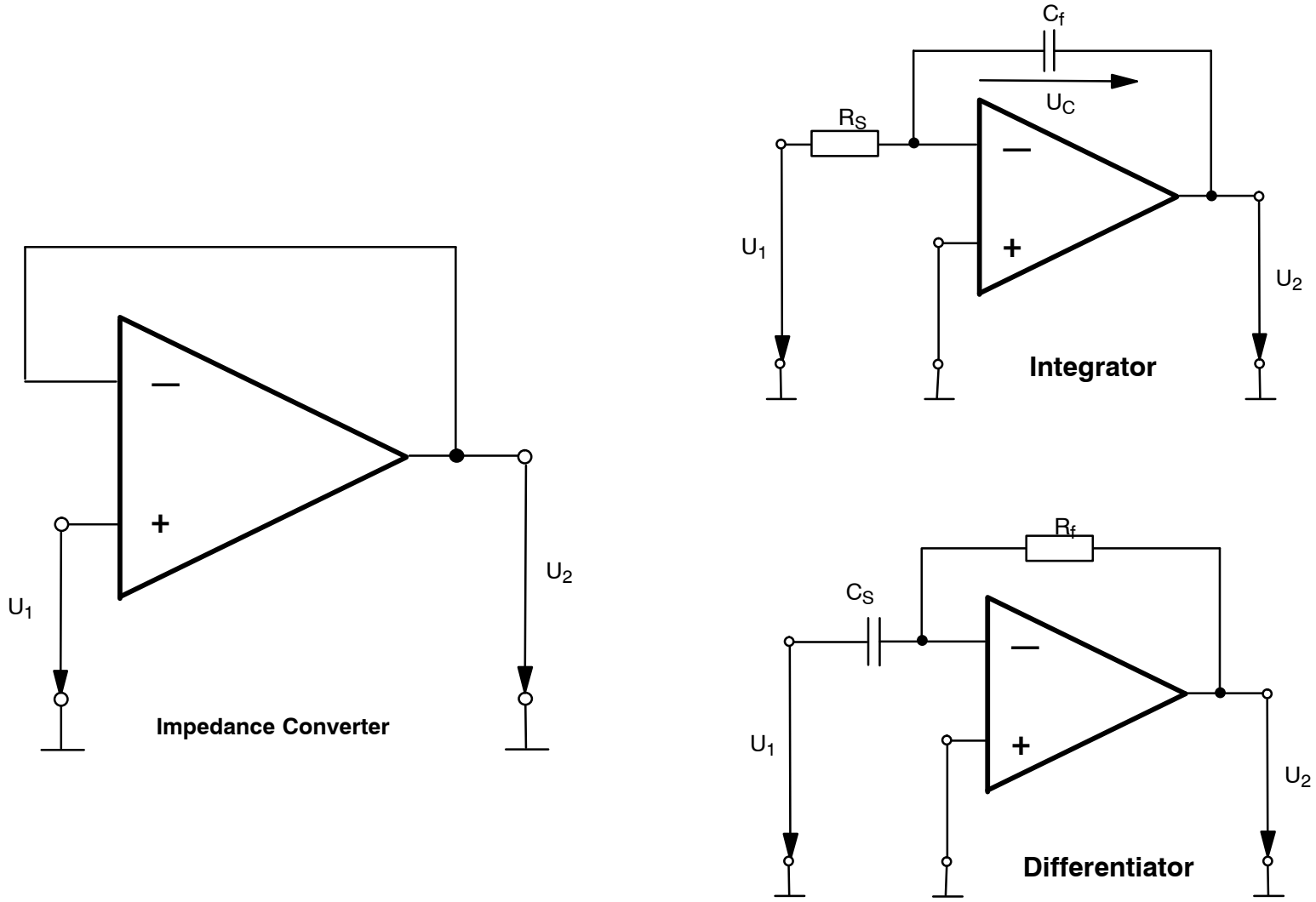


Figure 35 Overview of Standard OpAmp Circuits

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

ELECTRONIC REGULATORS WITH OP AMPLIFIERS

General

Electronic voltage regulators can be created with OP amplifiers by using corresponding input and feedback networks.

A few examples are given below.

From these basic types various combinations are possible.

P-regulator

There is a fixed ratio between input- and output voltage (proportional).

I-regulator

The duration a voltage is applied to the input will determine the output voltage (integrator).

D-regulator

The change in input voltage will determine the output voltage (differentiator).

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

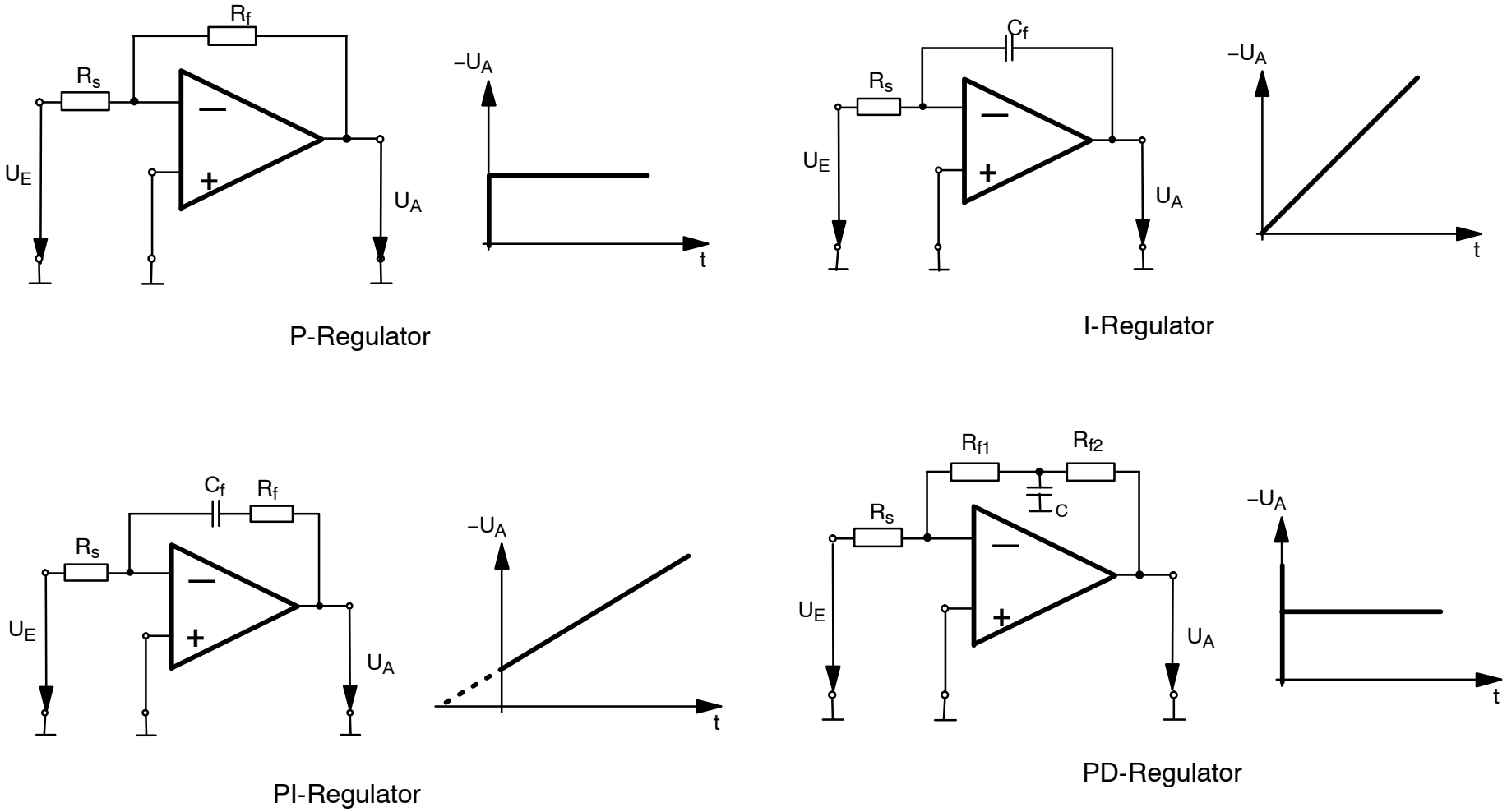


Figure 36 Overview of Electronic Voltage Regulators with OpAmp

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

M4.2 PRINTED CIRCUIT BOARDS

GENERAL

History

Since the 1970's printed circuit boards have been a popular medium for the installation of electronic components. They consist of a board, nowadays usually composites.

A thin layer of copper is laminated on it, in some cases both sides are laminated.

In addition to their robust physical strength and good electrical properties, they are also cheap and easy to manufacture. The previous method of wiring components together using separate wires to connect soldering eyelets has almost completely disappeared.

Multilayer

Also boards with several layers inside the board are available, up to 13 layers are used.

This is called multilayer techniques.

Basic Materials

Depending on the different requirements, various materials are used for printed circuit boards, most of which are different types of laminated paper.

The most common are the following:

- copper laminated paper treated with phenolic resin used mostly in radio & TV technology.
- copper laminated paper treated with epoxy resin used for its flame resistant properties.
- copper laminated glass silk weave. Laminated materials reinforced with fibreglass are stronger when subjected to mechanical stresses.
- laminated paper for additive processes, they come without copper plating.

Polyester, Teflon and ceramics are also used for specialized applications.

Layout

At the beginning we have a schematic which nowadays usually is created by using a simulation software. The schematic is inserted into the software and its function is simulated and tested.

Now the schematics is handed to a specific software that optimizes the layout concerning space requirements and interference creating the master layout for the board.

After the placing of the components is finished the conductive paths and drill holes are added.

The software itself tries to avoid crossings of the conducting paths as with one layer only crossings are not possible.

Also a plan is generated that indicates the position of the components on the upper, and sometimes, lower side. This comprises junctions between the layers on the upper and lower side of the board as well as layers on the inside.

This data now is handed to production where a film for light-sensitive paint based production or a printing machine master is created.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

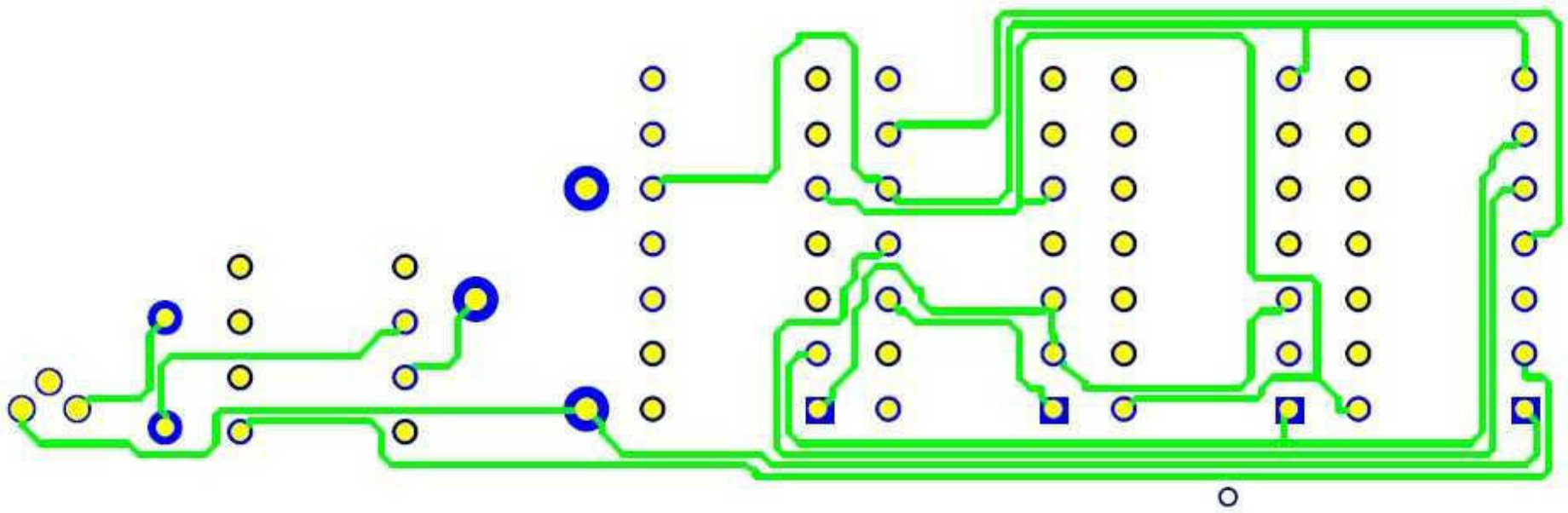


Figure 37 Computer-Generated Layout

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

MANUFACTURING PROCESS

Subtractive Process

In the subtractive process, boards laminated with copper on one or both sides are used.

The places on the board where the conducting paths and eyelets are to be located are protected by applying paint in a silk screen printing process or by light sensitive paint. Then the unprotected areas are etched away.

The layout of the PCB is generated by a special software using the schematics as a reference.

Disadvantage: Because only a small area of the board remains protected, much of the copper that covers the board is removed in the etching process. Copper is expensive and this process wastes valuable material.

Additive Process

In the additive process, boards are used that are not laminated with copper. Instead, the conducting paths are galvanized onto the board. In order to do this, the areas where conducting paths are to form must be made electrically conductive with a conductive paint that is printed on the board.

Placing the components

After the etching and drilling of the holes is done the components are placed on the board either by hand or by machines.

If machines are used the board is treated with a solder-inhibit paint which will not include the soldering points. This layout also comes from the layout software.

After the paint treatment the and placing the components the board is moved slowly across a bath of soldering tin. As the tin has been put into waveform movement this will automatically solder all the components.

In case SMD components are used a soldering paste is applied to the board where again the master comes from the layout software. Components are automatically placed and soldered by using infrared or a heat gun.

Protective Measures

Because copper can oxidize, precautions must be taken to prevent it from corroding.

- After manufacture, the boards are covered with soldering paint. In this way corrosion due to exposure to the air is prevented and the solder can be more easily applied.
- Do not touch the conducting paths. Oils from human skin can accelerate the corrosion process and solder cannot then be applied.
- Do not subject the board to mechanical stresses. Bending produces hairline cracks that cannot be seen by the naked eye. These cracks interrupt the flow of electricity.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

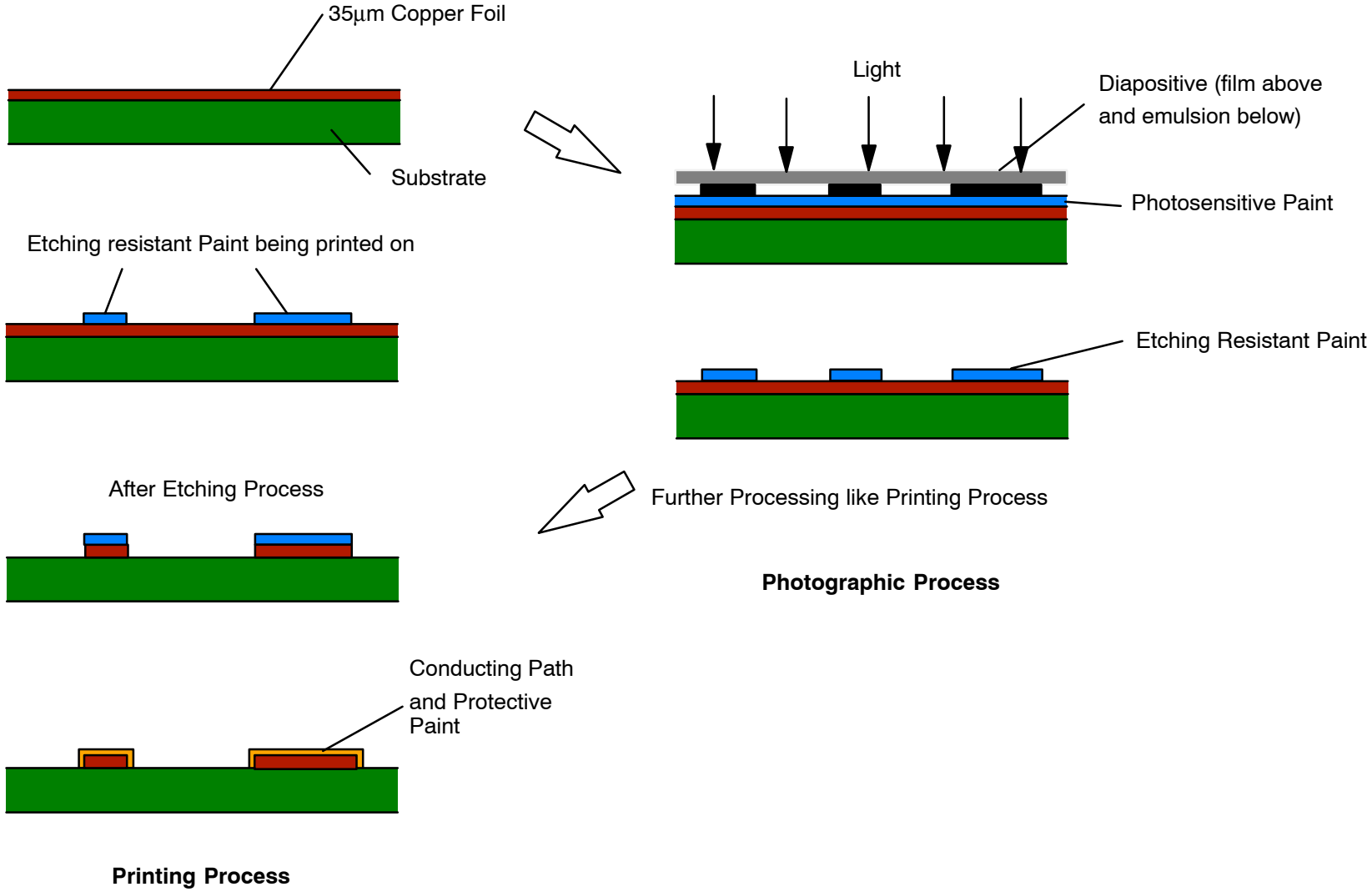


Figure 38 Processing of PCB

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

M4.3 SERVOMECHANISMS

INTRODUCTION

General

Synchros have been in use in various forms in the Forties of the last century. They are mainly used as components in electromechanical servo systems and for positioning waves on specific functional angles (remote angle transmission).

Recently, synchros in connection with suitable electronic interfaces have been used to build components that have become one of the cheapest and most reliable ways of performing digital measurements of functional angles.

The following table shows the English abbreviations for some of the synchros and resolvers.

Example

As an example, the wind turns a servo transmitter.

The transmitter sends electrical signals to a synchro receiver which will turn an indicator pointer. By this, this pointer is synchronized with the wind direction.

Abbreviations for Synchros

• TORQUE TRANSMITTER	TX
• TORQUE DIFFERENTIAL TRANSMITTER	TDX
• TORQUE DIFFERENTIAL RECEIVER	TDR
• TORQUE RECEIVER	TR
• CONTROL TRANSMITTER	CX
• CONTROL DIFFERENTIAL TRANSMITTER	CDX
• CONTROL TRANSFORMER	CT

Abbreviations for Resolvers

• RESOLVER TRANSMITTER	RX
• RESOLVER DIFFERENTIAL TRANSMITTER	RDX
• RESOLVER TRANSFORMER	RC

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

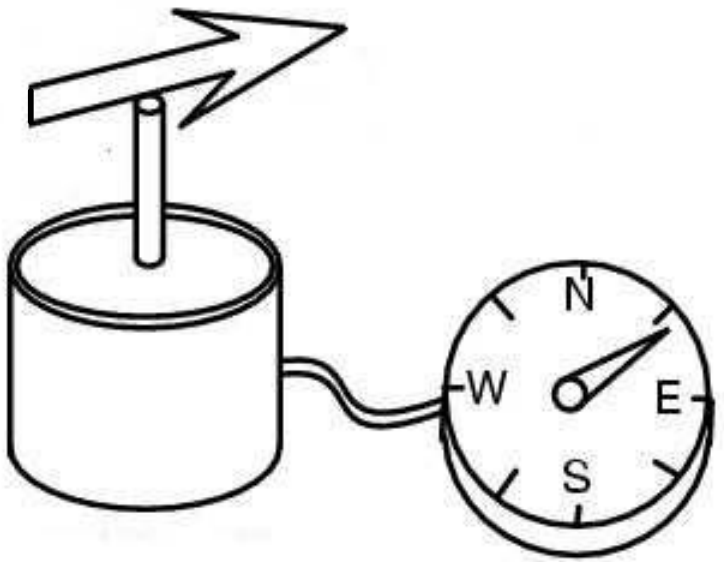


Figure 39 Synchro System

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

OPEN AND CLOSED LOOP SYSTEMS

General

Servo systems can be loosely divided into two different types:

- open loop systems
- closed loop systems.

Open Loop Systems

In an open loop system, the input position is converted to an electrical signal and this demand signal is amplified and sent to the motor to position the load.

The final position of the load is dependant on various factors over which the system has no control, for example; friction in the system, variations in the power supply, variations in the amplifier gain etc. Thus the final position of the system is not accurately controlled. This inaccuracy makes an open loop system unsuitable for close tolerance use.

Closed Loop Systems

In a closed loop system the signal is sent from the input, through the amplifier to the output motor and the load just as in the open loop system. However in the closed loop system the load position is then sensed and sent back to a summing amplifier or comparator which works out the difference between the demanded position and the actual position.

The difference is called the error signal and is amplified and sent to the output.

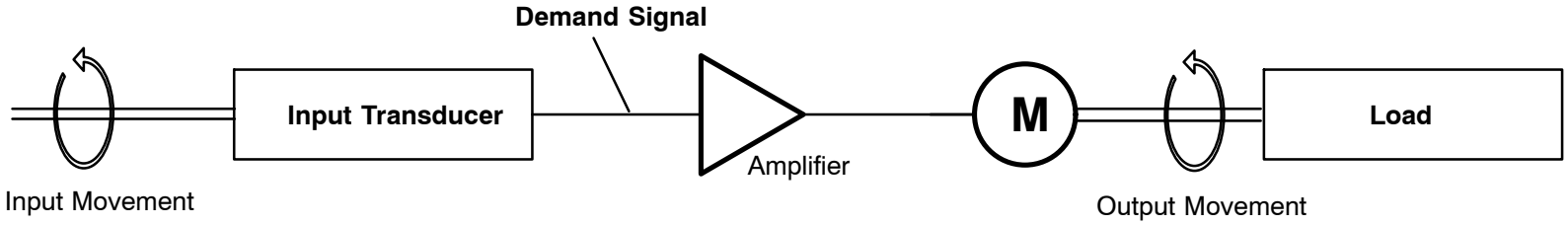
When the output has moved to the demanded position then the error signal is zero and the load stops moving. This makes the system far more accurate as any variations in power supply or in amplifier gain can be overcome.

Feedback Signal

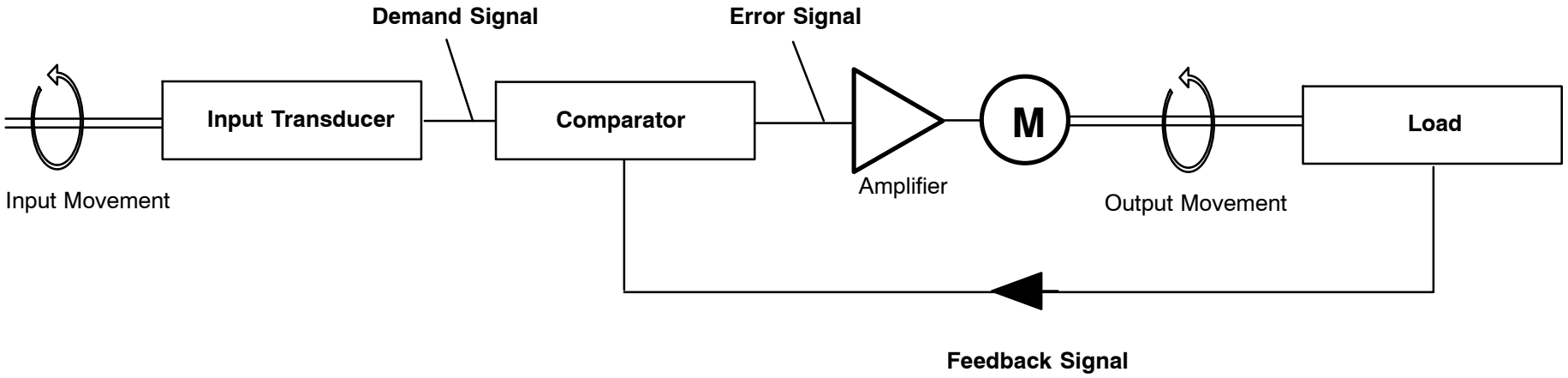
The signal of output position which is sent back to the comparator is referred to as feedback signal.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training



Open Loop System



Closed Loop System

Figure 40 Open Loop / Closed Loop System

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

CONSTRUCTION OF SYNCHROS

General

Synchros are similar in construction to alternating current generators. They have a laminated stator core which carries three coils which are staggered by angles of 120 degrees and wired in a star shaped configuration. The rotor is also laminated and carries a winding where the leads pass over slip rings on their way to the external connections. In the case of a torque synchro, the rotor has two specific poles, whereas control synchros have a circular rotor cross−section.

Size

Synchros are manufactured with a diameter between 0.5 and 3.7 inches. Synchro size is given according to the diameter of the synchro as measured in tenths of an inch. For example a synchro with a diameter of 1.06 inches is a size 11 synchro.

Excitation Voltage

Synchros are built for excitation voltages of 26 volts or 115 volts, 400 Hz.

The maximum voltage that occurs between two coil terminals, the secondary voltage, is normally 11.8 volts or 90 volts.

Signal Transfer

The transmitter synchro uses three wires to transmit the signal to the receiver synchro. Very often one of the wires is grounded.

Terminals

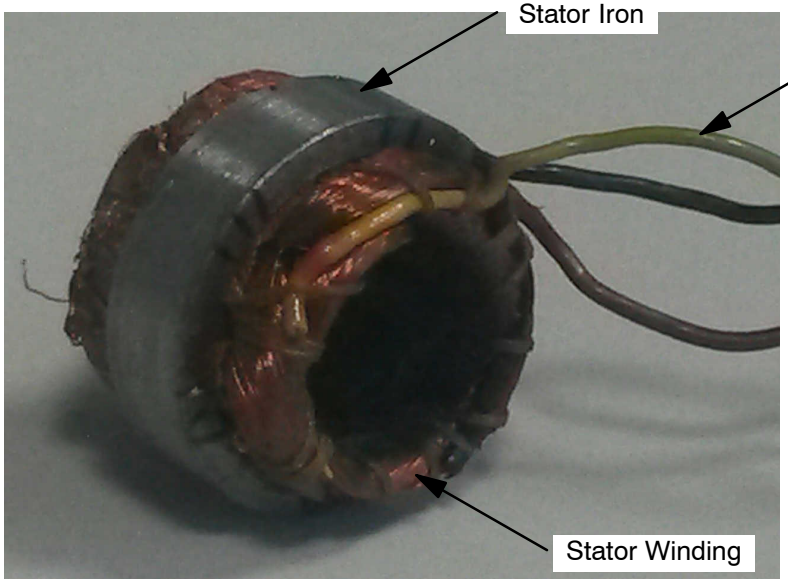
The connections for the stator coil are designated as S1, S2 and S3 and the rotors as R1 and R2.

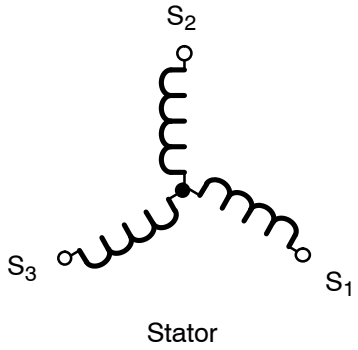
Instead of using the MIL designations S and R for the terminals, in the schematics for aircraft the ARINC (Aeronautical Radio Incorporated) terms are used.

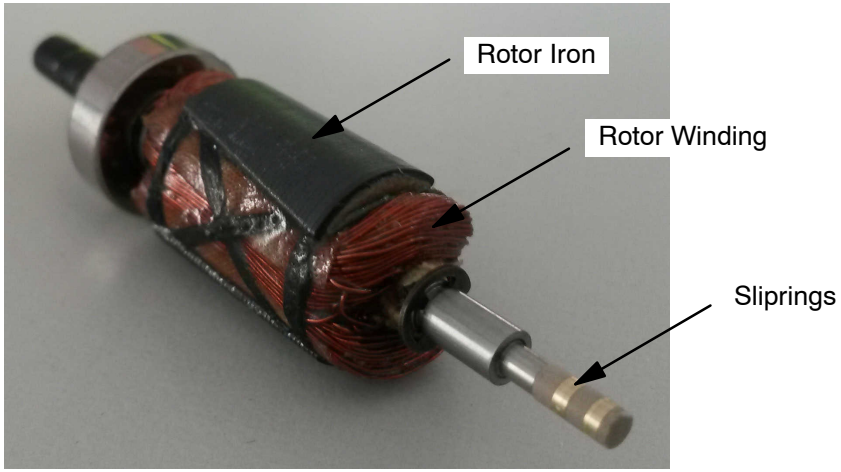
S1 : X	blue
S2 : Z	black
S3 : Y	yellow
R1 : H	red & white line
R2 : C	black & white line

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training







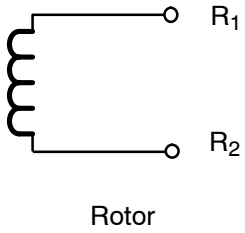


Figure 41 Construction of Synchros

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

OPERATION

General

Synchros work like three-phase transformers.

As Synchros operate with analogue voltages and currents they are analogue transducers.

The primary coils are usually represented by the rotor and the secondary coil by the stator windings.

Excitation Voltage

The excitation voltage U_R has the form of a sine wave.

Rotor Angle

The rotor angle θ is always 0, when the rotor axis is in alignment with the axis of the stator coil S_2.

Induced Voltage

The induced voltage US in the stator coil depends on the coupling factor K between the rotor coil and the stator coil and the angle θ between the two coil axes.

The maximum voltage for a stator coil is generated when $\theta = 0$, that is when the axes of both coils line up. This voltage is designated US0.

Diagram

The diagram shows the cosine shaped waveform of the amplitude of U_{S2} as a function of the angle of rotation.

If the rotor angle exceeds a value of 90 degrees, the voltage increases again after crossing the zero point, but now in the opposite phase position. There are principally only two phase positions possible in each of the stator coils, namely, the position of rotor excitation and that of the 180 degree opposite position.

Voltages in the stator coils as a factor of the rotor angle θ.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

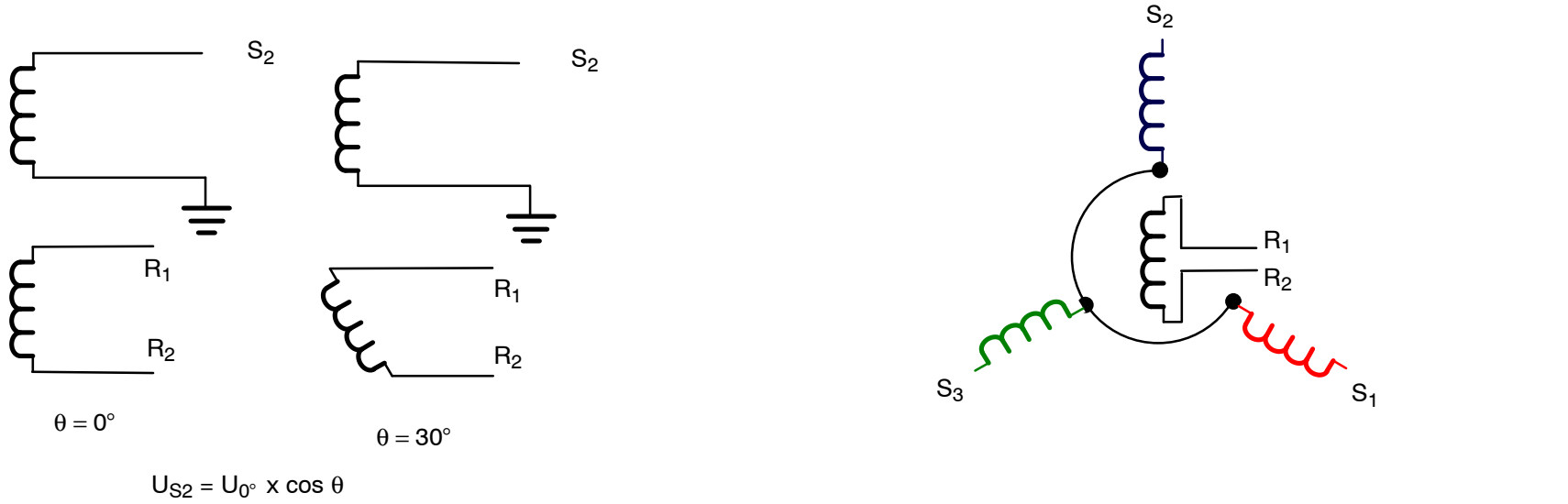


Figure 42 Operation of Synchros

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

Magnitude and Direction of the Magnetic Fields

The rotation moment necessary to put the rotor in the receiver position is created by the interaction between the magnetic fields of the stator and the rotor. The magnetic fields of the stator arise as a result of their electrical currents which in turn are proportional to the stator voltages. The course of the amplitude of the stator voltages is proportional to the cosine of the angle between the rotor coil and the stator. Thus the amplitude of the magnetic fields is also proportional to the cosine of the angle between the rotor coil and the stator.

In each case where voltages are induced, Lenz's Law applies, so that the conditions presented here result in the transmitter synchro.

In the stator of the receiver synchro the three stator fields do not exist independently of each other, but rather form an accumulated field. Because these are alternating fields, the diagram can only show one specific moment in time. When the direction of the field of excitation changes, all of the arrows on the diagram also change.

When the rotor in the receiver is activated and excited with the same voltage, it adjusts itself so that the magnetic field lines of both rotor and stator are aligned parallel to each other and in the same direction.

The following figure illustrates this.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

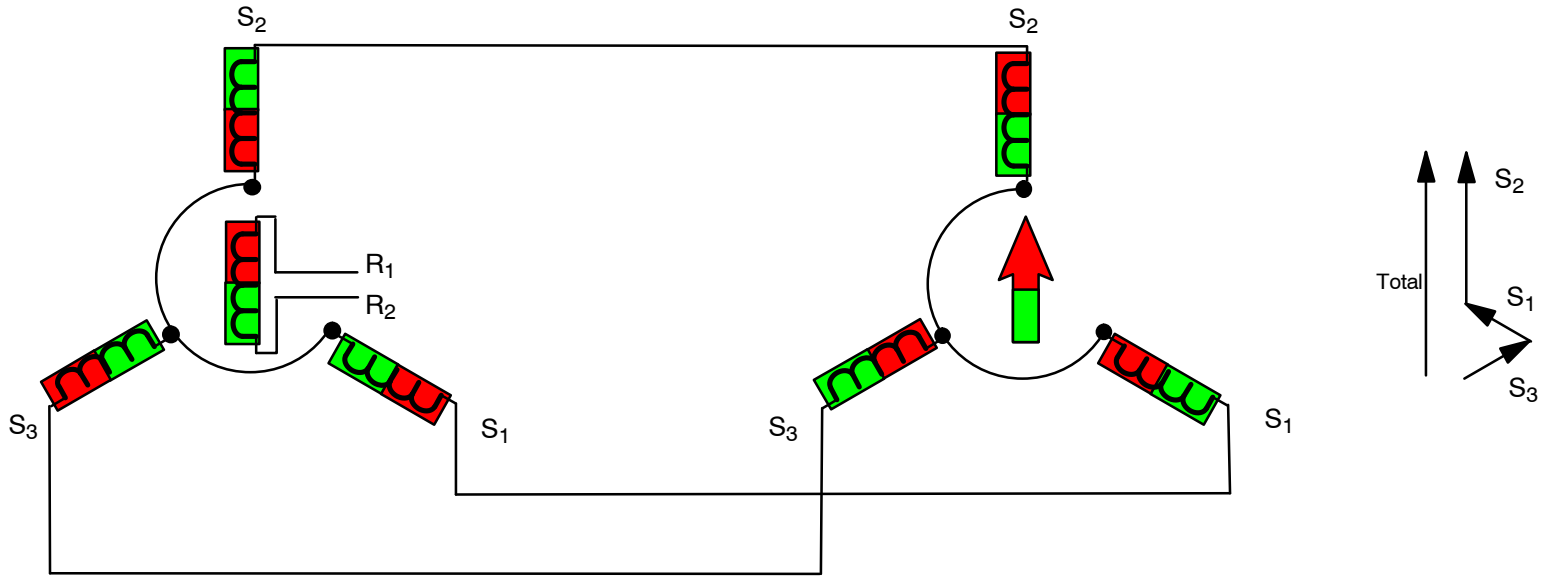


Figure 43 Magnetic Fields

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

Currents in a Synchro

Because the transmitter and the receiver are electrically and mechanically identical, the excited transmitter rotor also induces voltages in the receiver stator. The magnetic fields and electrical currents that result from this are of the same magnitude but in opposition to those of the transmitter. So they cancel each other out.

In an aligned synchro chain no currents flow except the magnetizing currents, which can be regarded as negligible.

Torque Moment Process

A torque moment is only present when magnetic fields are present, allowing current to flow. For this to happen, there must be a differential angle between the transmitter rotor and the receiver rotor.

The figure shows the course of the torque moment and the resulting currents.

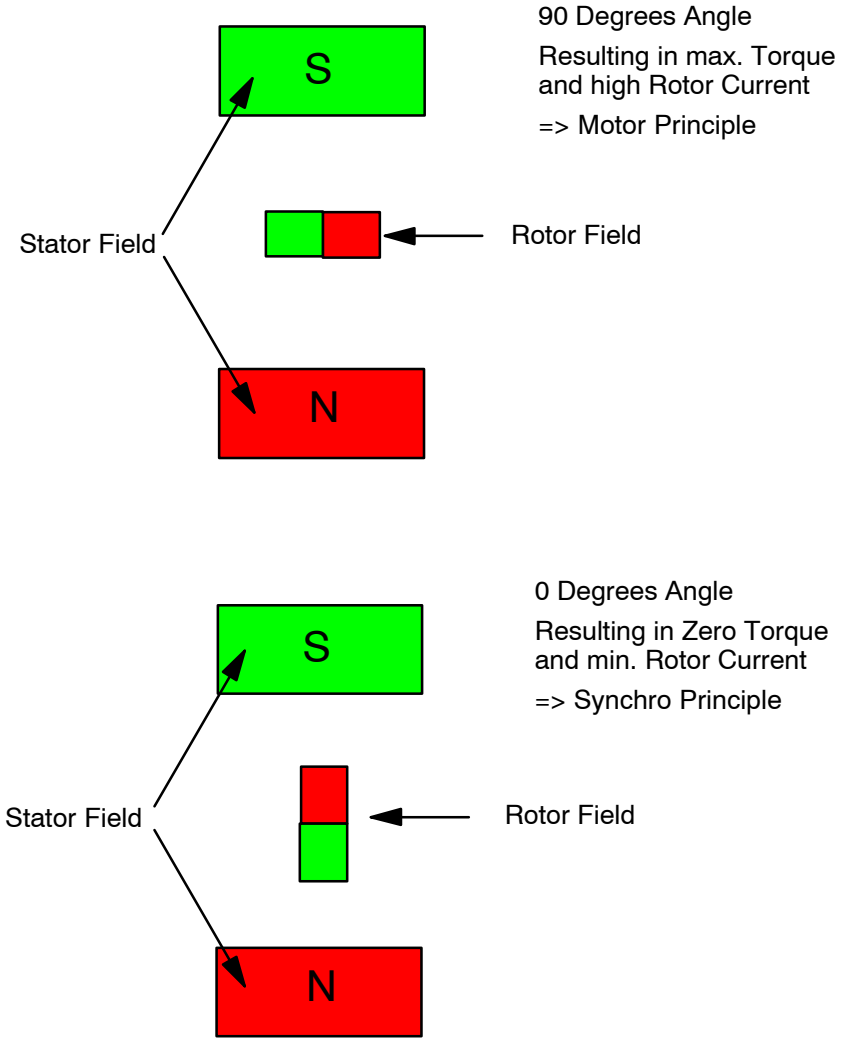
The currents increase up to an angle difference of 180 degrees, while the rotation moment reaches its maximum value at an angle of 90 degrees. This is because the torque moment for the forces working on the rotor begins to get smaller after it reaches an angle of 90 degrees.

Because the moment tends to get closer and closer to zero, the smaller the difference between the transmitter and the receiver becomes, friction from bearing and brushes have a negative effect on accuracy. The design of the synchro must take this into consideration and keep friction to an absolute minimum.

Because the torque momentum’s are proportional to the currents that are flowing, the system must be constructed so that resistance levels are low in order to allow sufficiently large currents to flow.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training



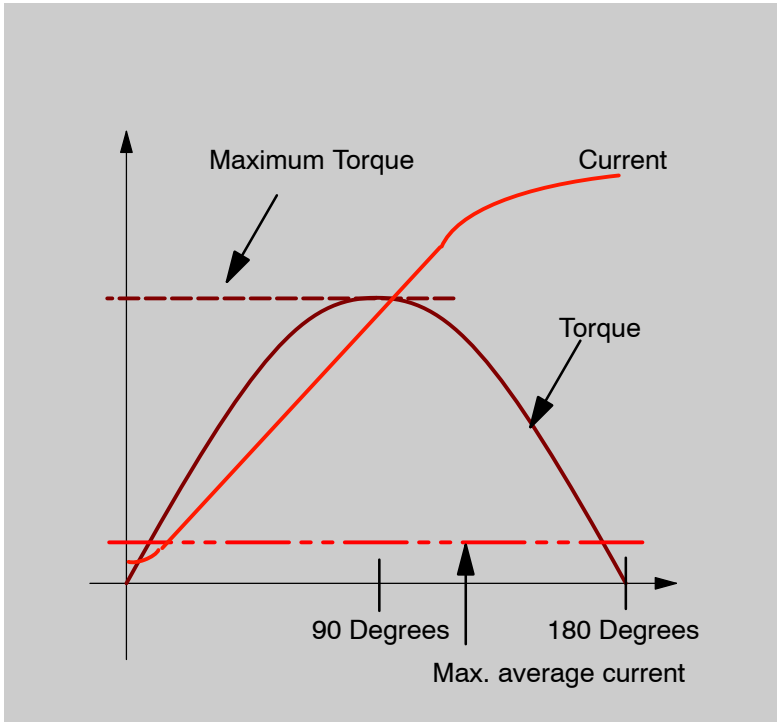


Figure 44 Current and Torque of Synchros

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

TORQUE SYNCHRO

General

The figure shows the construction of a synchro chain.

When the rotor of the transmitter synchro is turned by a force, there will be a torque which turns the rotor of the receiver synchro.

Operation

The electrical connections are made in such a way that the terminal of each transmitter is connected to the corresponding receiver terminal.

The moment transmitter and the receiver are electrically and mechanically identical.

If both rotors are excited simultaneously, the receiver rotor moves into the position of the transmitter rotor.

Wiring

In practice, one stator connection and one excitation terminal are at ground potential.

Follow Up

A servo system where the rotor of the receiver follows the rotor of the transmitter is also referred to as follow up.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

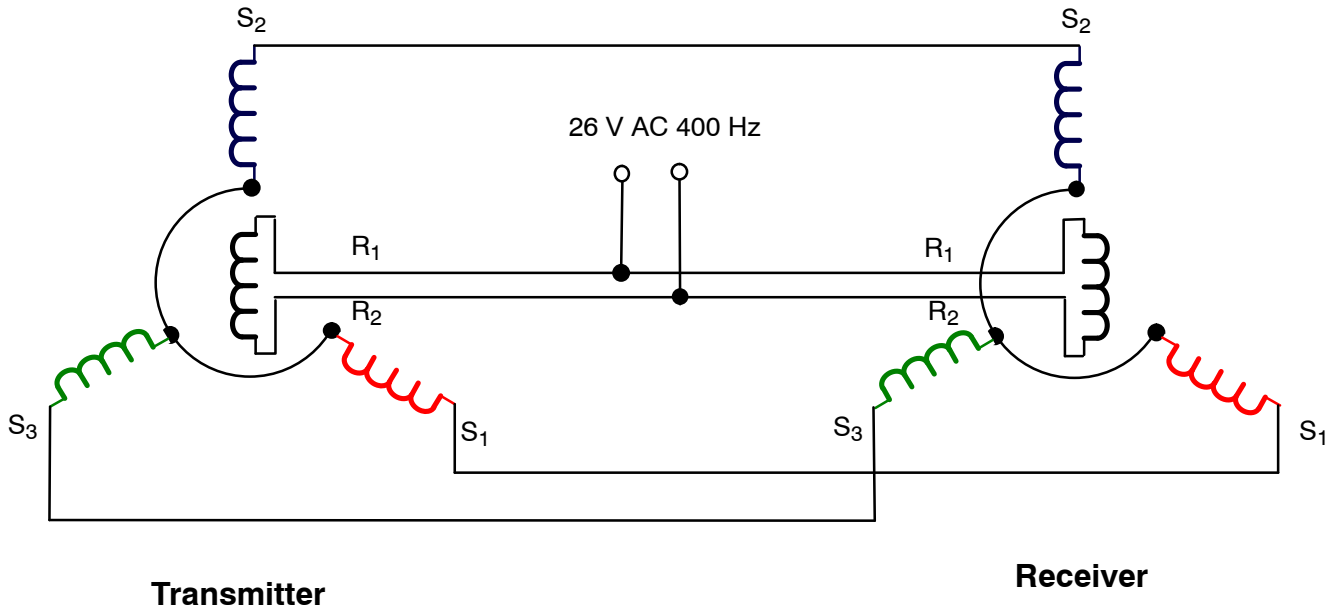


Figure 45 Torque Synchro Chain

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

Example

This is an example for a torque synchro chain.

The rotors of the transmitter synchros are connected to the lower or upper rudder of an airplane.

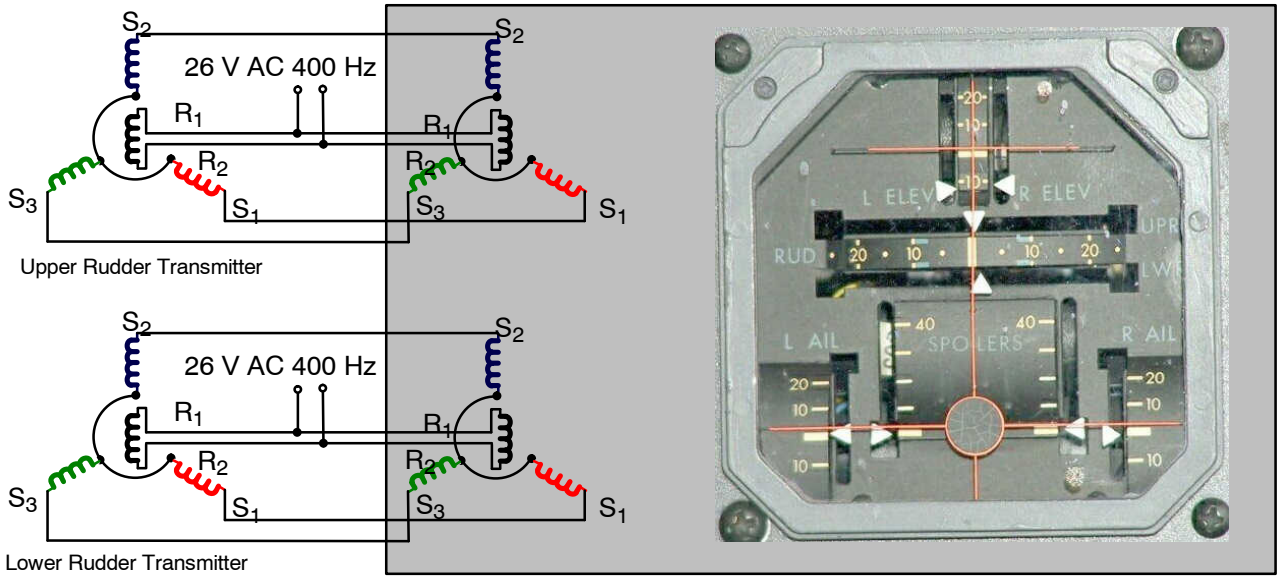
If a rudder moves, the related pointer in the indicator will move, too.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training







Position Indicator (Cockpit)

Figure 46 Torque System (Example)

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

DIFFERENTIAL TRANSMITTER

General

The application of a differential transmitter is to add or subtract angles.

Construction

In opposition to a torque transmitter, it has 3 coils wired in a star connection on the rotor, which has a circular cross section so that it does not influence the magnetic field of the stator.

In a differential transmitter, the coupling and the translations are chosen in such a way that the maximum voltages between two stator terminals are of the same magnitude as the maximum voltages between two rotor terminals.

Synchro Chain

The illustrations show the synchro chain in order to indicate the difference or the sum of the angles of rotation of the shafts of the TX and of the TDX.

- If both shafts are turned in the same direction, a subtraction is the result.
- If the shafts are rotated in opposite directions, an addition results.

Control System

The TR indicates the addition or the subtraction by the position of its rotor. The synchro chain can also be constructed as a steering system instead of as a torque system.

Instead of TX, TDX and TR, CX, CDX and CT can be used respectively.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

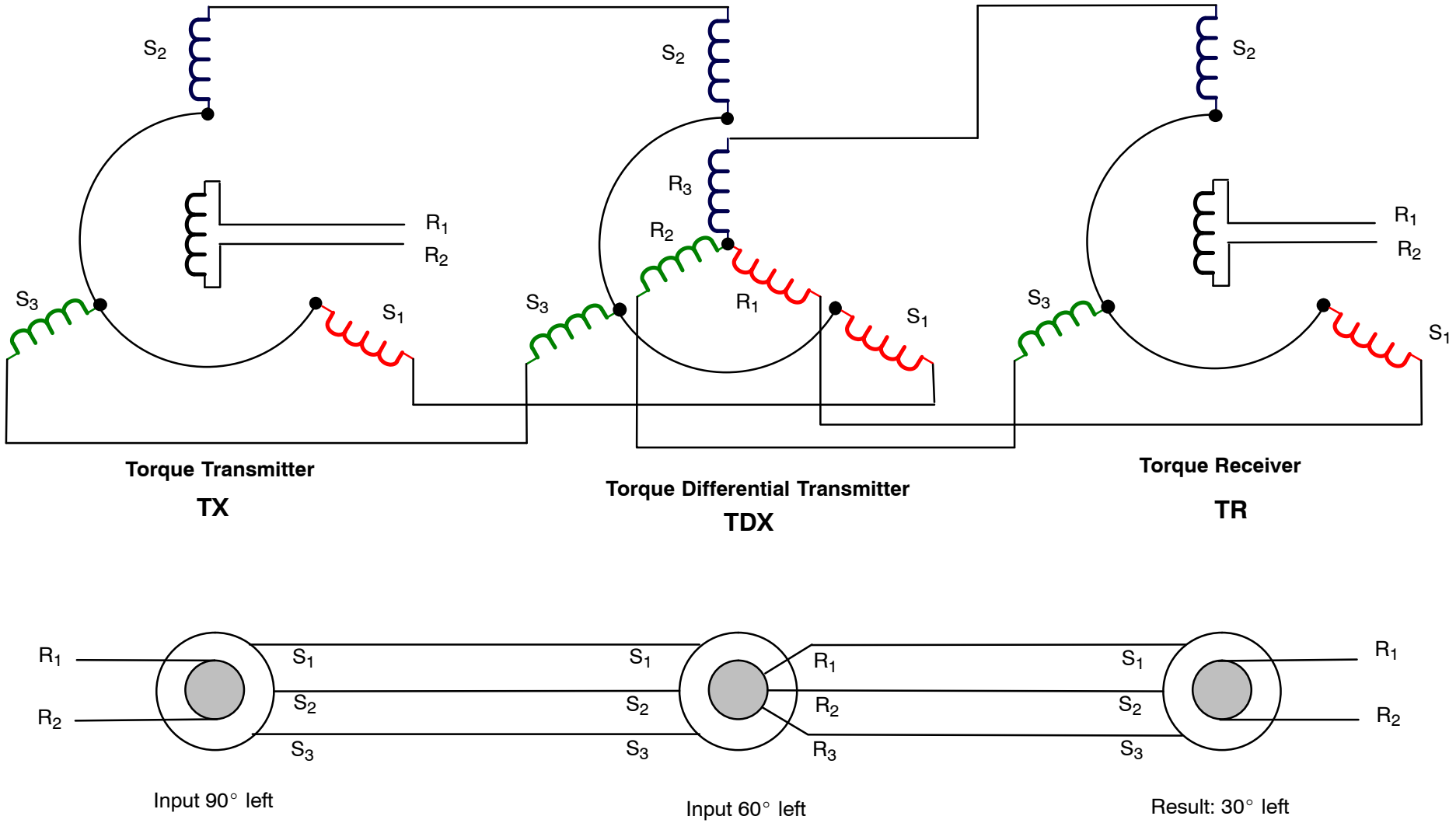


Figure 47 Differential Transmitter

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

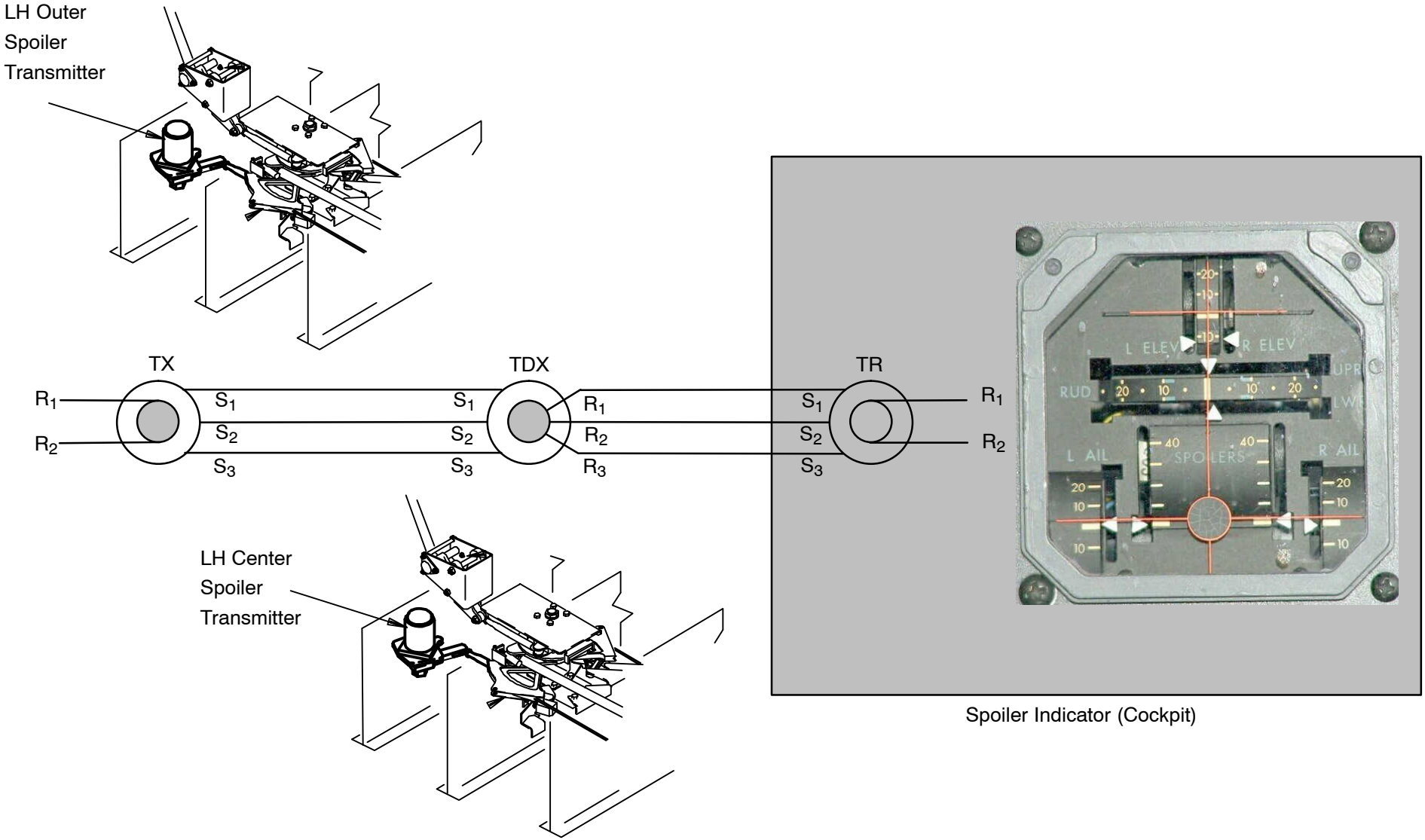
Example

The figure shows the position indication for the spoilers of an aeroplane.

The average position of the left hand outer spoiler and the left hand center spoiler is shown by the left pointer in the spoiler indicator.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training



Spoiler Indicator (Cockpit)

Figure 48 Differential-Transmitter (Example)

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

CONTROL SYNCHRO

General

Unlike torque synchros, the receiver of a control synchro chain does not generate torque but instead delivers a voltage which depends on the differential angle between the transmitter rotor and the receiver rotor.

The signal which is generated in the receiver (CT) can be used by computers.

Operation

CX and CT have high resistance in comparison with TX and TR. This means that there are many windings in the available space for the coil. Because the magnitude of the induction voltages is proportional to the number of windings, a very small angle between the stator field and the rotor coil axis in the CT is enough to produce sufficient voltage.

Starting with a value of zero, the voltage runs in a sine-shaped curve at an angle of rotation θ.

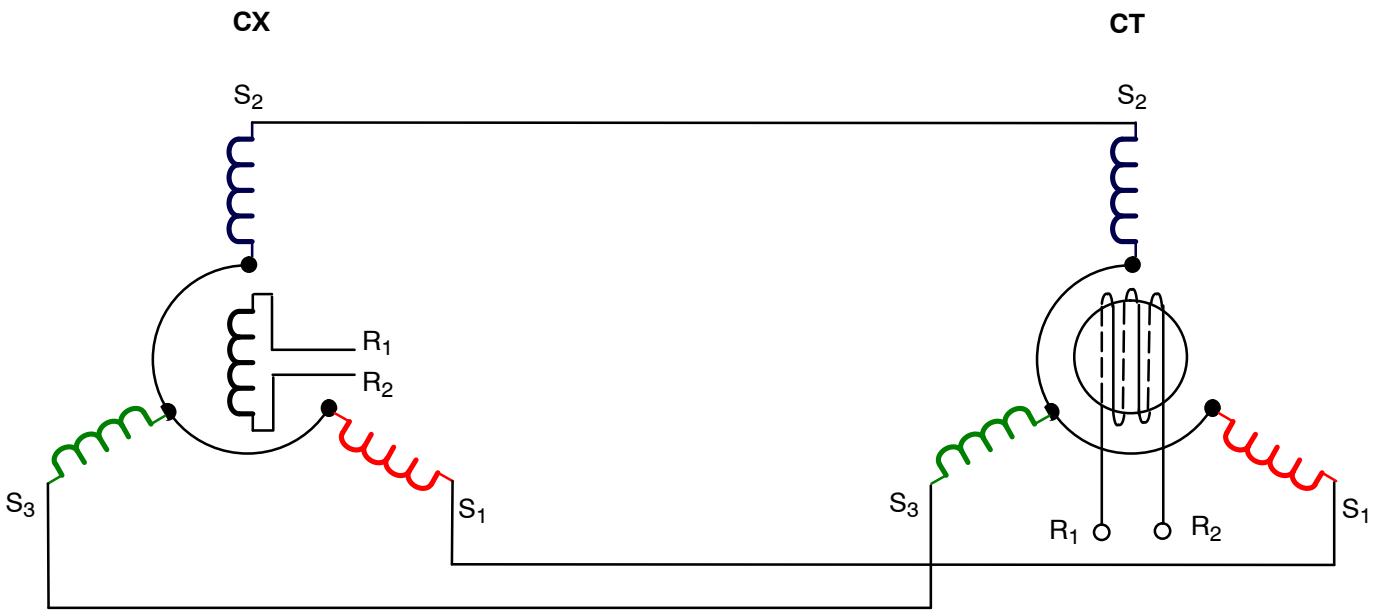
Because the sine curve is nearly flat at the zero crossover point, for small values of θ, the voltage and the angle of rotation are directly proportional to each other. At 15 degrees the sine curve deviates 1.2% from linearity, and at 30 degrees there is a deviation of only 4%.

Whether a left or right rotation is necessary in order to align the voltage of the CT to Zero is determined by the phase angle of the voltage in relation to the excitation voltage of the transmitter. These may either be in the same phase or in phase opposition to each other.

The rotor of the CT has a circular cross section to ensure that the magnetic field of the stator is not influenced.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training



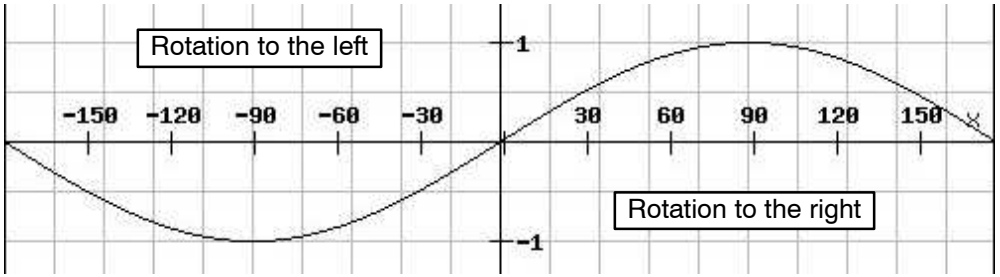


Figure 49 Control Synchro Chain

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

Example 1

In this example a value can be selected by turning a control wheel. This may be the position of a regulator valve.

The transmitter CX generates a current which flows through the receiver CT. The output signal has the voltage U_{R1R2}.

If the valve has the desired position, the voltage is zero.

If the valve does not have the desired position, there is a voltage. This can be used by a control unit for calculations to drive the valve to the desired position.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

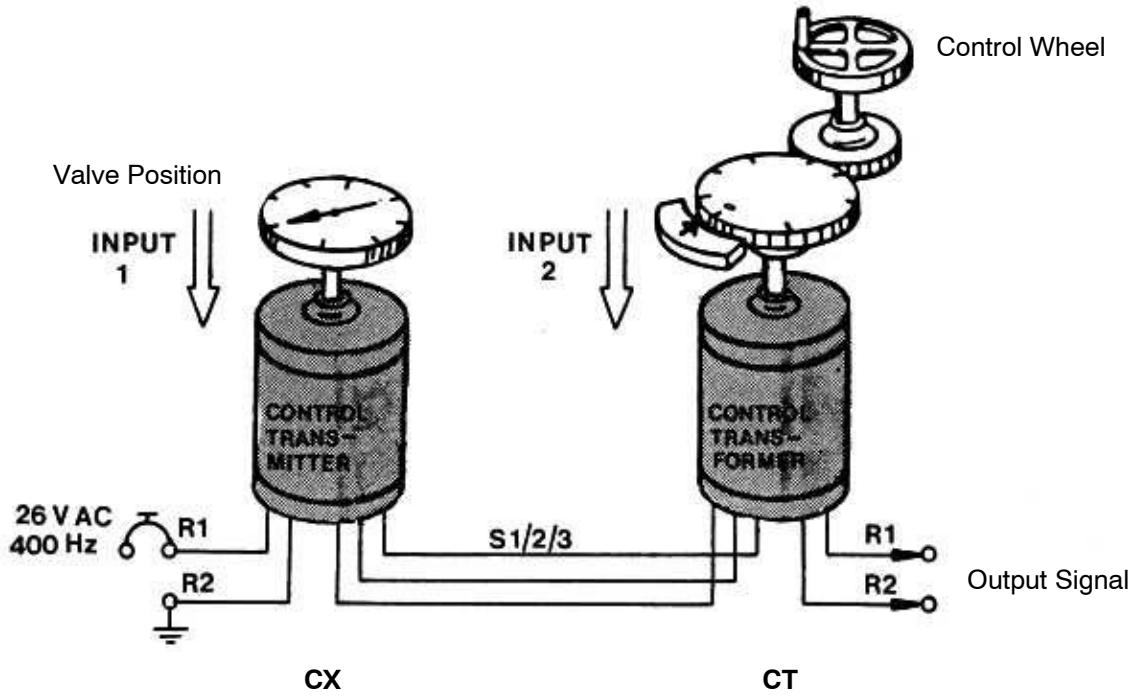


Figure 50 Control Synchro Chain (Example 1)

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

Example 2

Many aeroplanes have a stabilizer which can be moved within a limited range. On the Airbus 310, this is called “Trimmable Horizontal Stabilizer“. The short form is THS.

The THS is linked to a CX. The current from the CX is used within a computer named SDAC and two computers named FWC 1 and FWC 2.

SDAC stands for “System Data Analog Converter“. FWC stands for “Flight Warning Computer“.

The SDAC contains one CT which is not shown in the schematic. It sends digital signals to a display system. On the right display, the position of the THS is shown.

The FWCs contain one CT each. Before takeoff, the THS must have a certain position. If it is out of this limit, a message will be generated on the left display.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

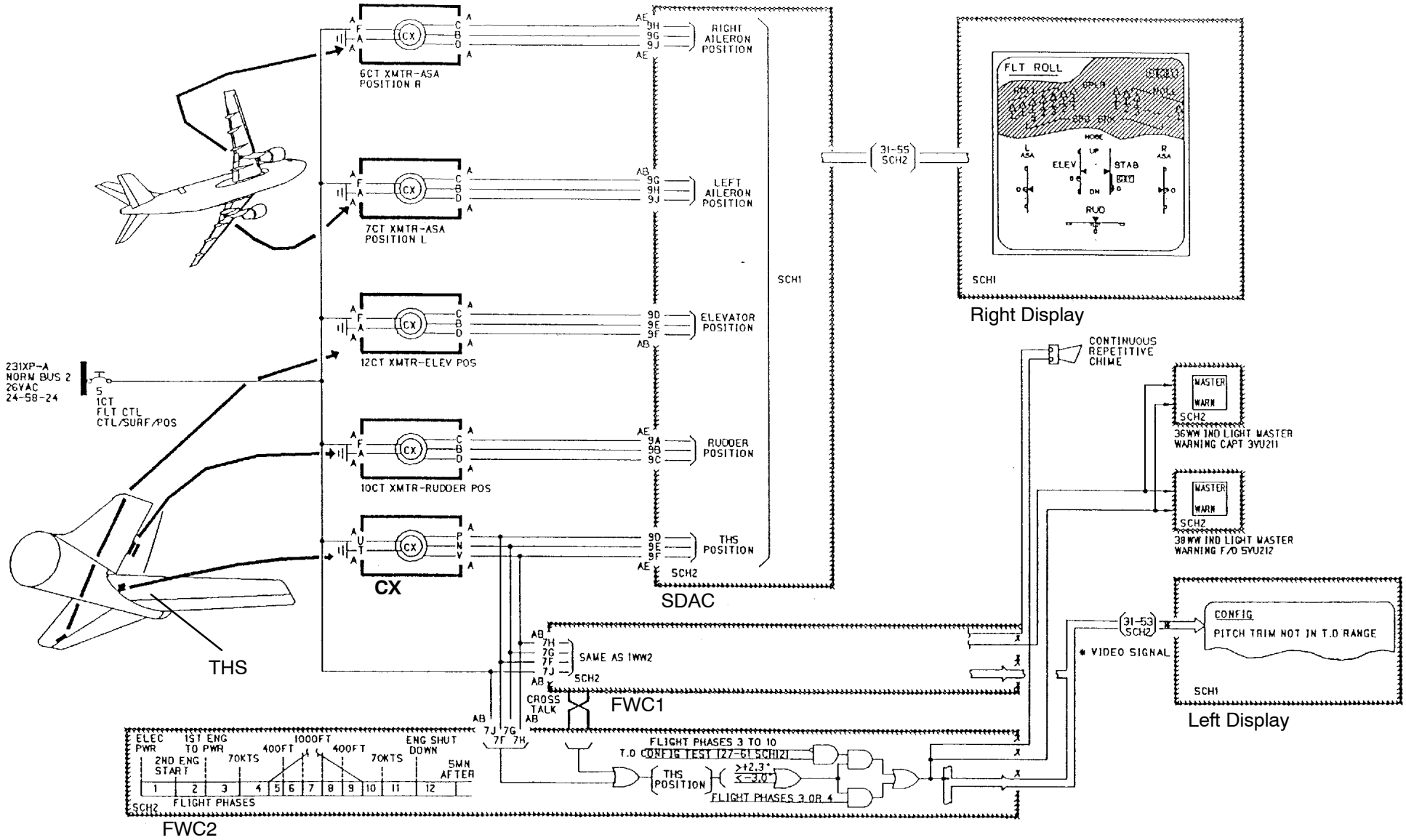


Figure 51 Control Synchro Chain (Example 2)

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

RESOLVER

General

Resolvers have coils in the stator and the rotor which are displaced by 90 degrees from each other.

The simplest resolver has a rotor with only one coil and the stator has two that are displaced by 90 degrees to each other. When the rotor coil is excited with an alternating current of the type A x sin (ωt), the following voltages will be found at the stator terminals:

$U_{S1\ S3} = V \times \sin(\omega t) \times \sin\theta$

$U_{S2\ S4} = V \times \sin(\omega t) \times \cos\theta$

V differs from A by the coupling factor K between the rotor and the stator.

V = K x A

These voltages are designated as resolver format voltages.

Usage

A resolver can be used just like a control synchro for transmitting angles. Resolvers exist only as control transmitters and receivers and not as torque transmitters and receivers.

Resolvers are often used to split an input angle into its sine and cosine components.

Construction

Probably the most commonly used form of resolver is the type with two stator coils, each displaced by 90 degrees and two rotor coils that have also each been displaced by 90 degrees.

Terminals

In addition to the MIL designations S and R, the ARINC designations are also used in the schematics.

R1 : A	red & white line
R3 : C	black & white line
R2 : B	yellow & white line
R4 : C	blue & white line
S1 : D	red
S3 : E	black
S2 : F	yellow
S4 : G	blue

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

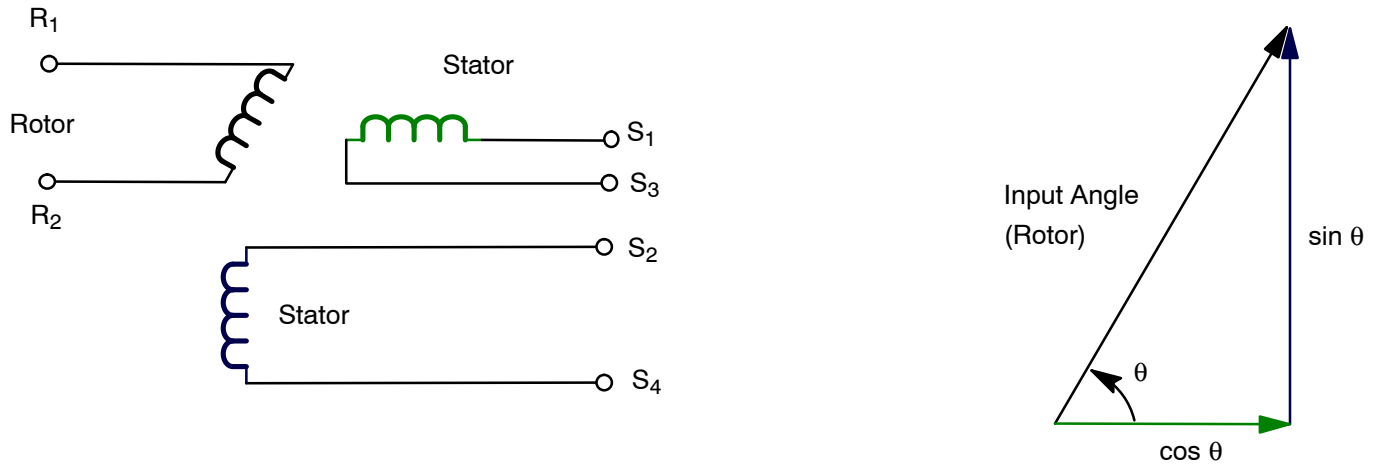


Figure 52 Basic Construction of Resolvers

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

LVDT

General

LVDT is the short form for Linear Variable Differential Transformer.

An LVDT is used to transfer linear movements but also angular movements such as rudder deflections.

Construction

It is comprised of a primary coil, N_1, two secondary coils wound in opposite directions and wired in series, N_2/N_3, and an iron core, which is mechanically hinged to the part whose movement is to be detected. The coupling between the primary and secondary coils changes according to the relative position of the iron core so that the amplitude and phase position of the output voltage depends on the relative position of the iron core.

Figure 1

The movable iron core is centred between N_2 and N_3

N_1 induces in N_2 and N_3 two voltages of equal magnitude with their phase positions in opposition to each other.

Figure 2

The coupling between N_1 and N_2 is stronger than between N_1 and N_3. The output voltage has the phase position of N_1 and an amplitude that is dependent on the magnitude of the deflection.

Figure 3

The coupling between N_1 and N_3 is stronger than between N_1 and N_2. The output voltage has a phase position that is in opposition to that of N_1 and an amplitude that is dependent on the magnitude of the deflection.

RVDT

Configurations which vary the coupling of the primary coils with the secondary coils by rotating the iron core are known as RVDTs (Rotating Variable Differential Transducers).

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

Figure 1

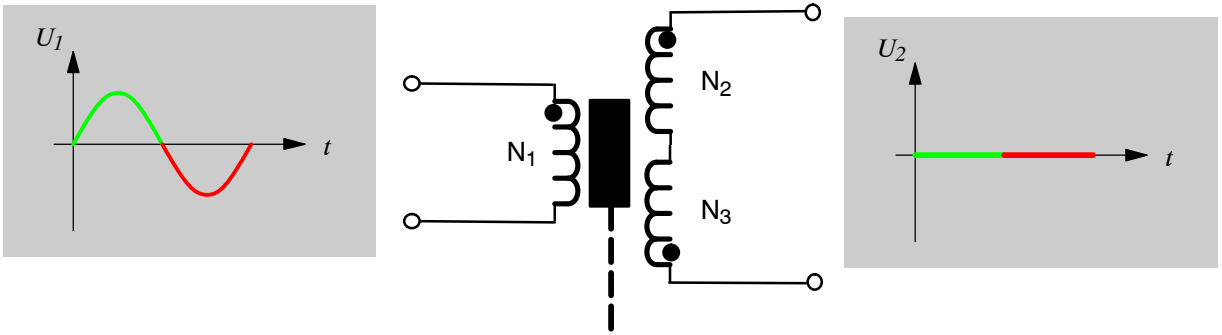


Figure 2

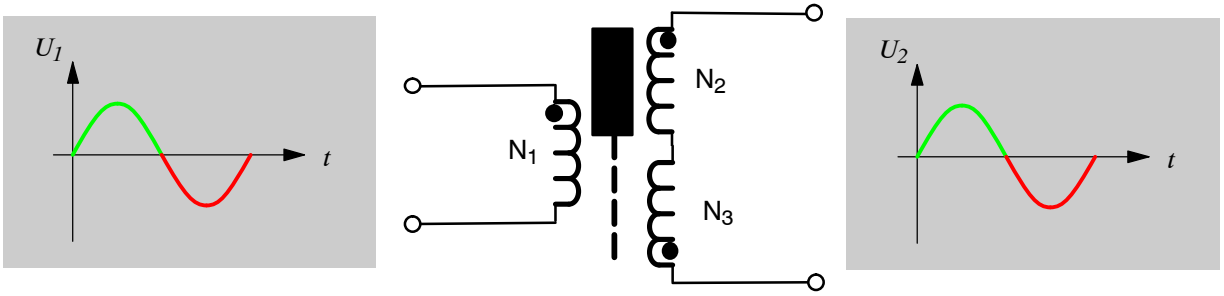


Figure 3

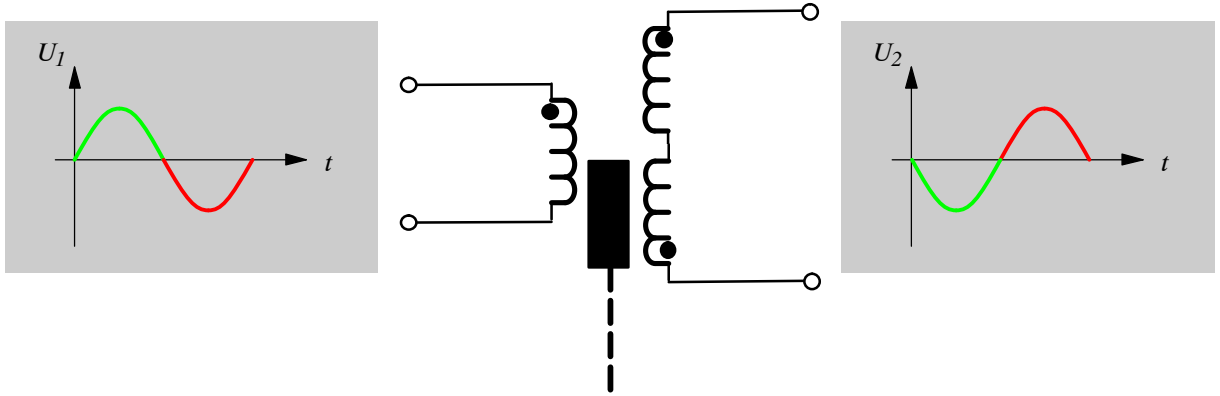


Figure 53 LVDT

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

Example

In this example, LVDT's transmit the position of ailerons to the Elevator Aileron Computer (ELAC).

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

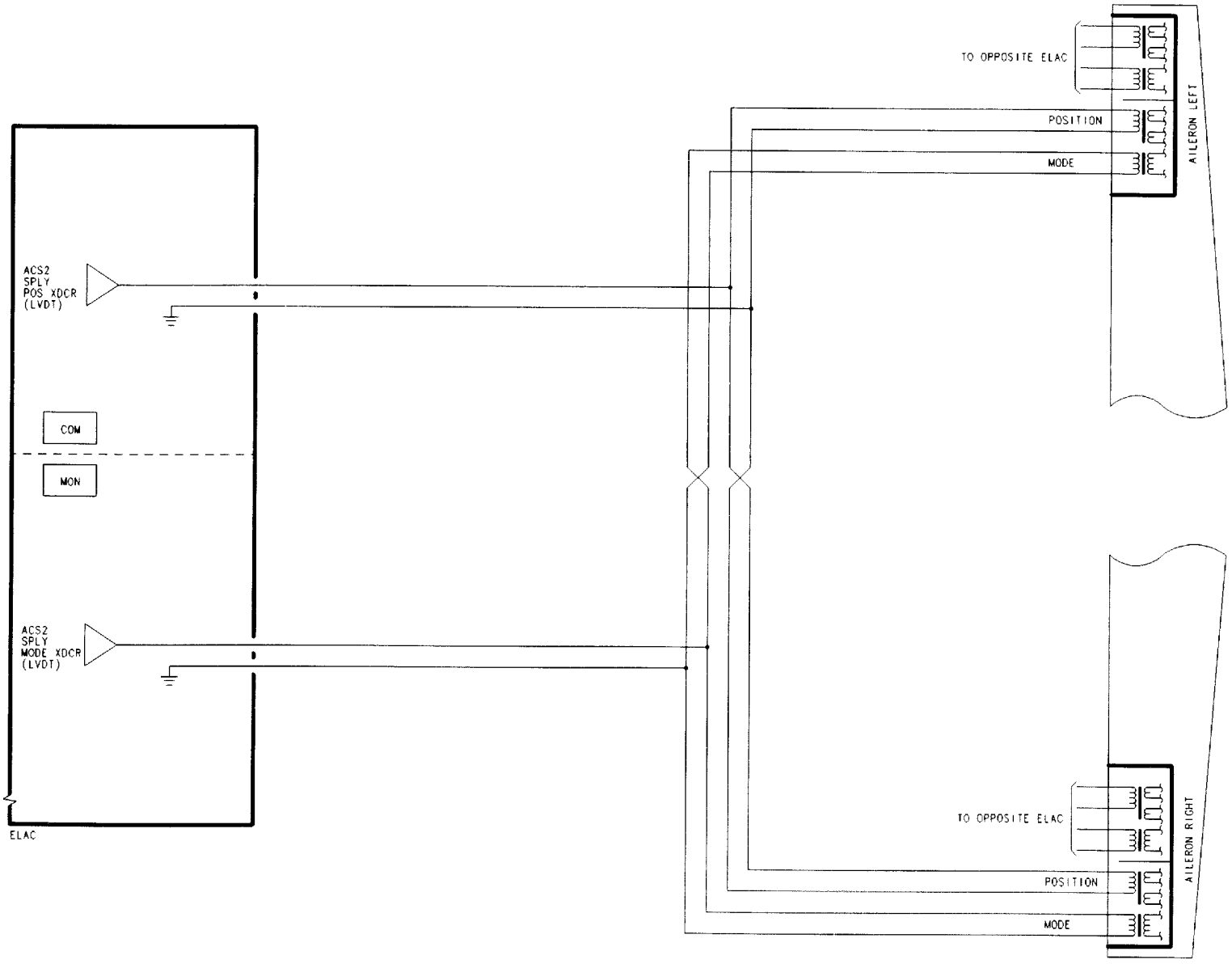


Figure 54 LVDT (Example)

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

INDUCTANCE TRANSMITTERS

General

The principle of inductance can be used to measure position or speed of a component.

Proximity Switch

One possibility to measure positions with inductance transmitters is the AC current method.

An inductor in an AC circuit resists the AC current because a back EMF builds up in the inductor.

The strength of the back EMF can be varied by the proximity of a ferrous metal plate or target to the inductor. This target raises the inductive reactance in the circuit and causes an increased resistance to current flow. If the target is moved away from the inductor then the inductive reactance is reduced and the current flow can increase. This method is used for position sensing in systems such as doors and landing gear.

This arrangement is often referred to as a Proximity Switch.

Induced Voltage Method

If a magnet is placed close to a coil there will be no induced voltage in the coil because there is no relative movement between the two.

If a conductive target is brought into proximity with the magnet then the magnetic field will increase in flux density and there will be a voltage induced into the coil. As the target is moved away again then the flux density drops and again a voltage is induced into the coil.

The frequency of the induced voltage is the same as the movement of the target.

This method is commonly used to measure engine shaft rpm with the target being mounted on, or part of, the engine shaft and the coil being close to it. As the shaft rotates the target is brought close to and removed from the coil, thus inducing an alternating current into the coil with the same frequency as the shaft rotation.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

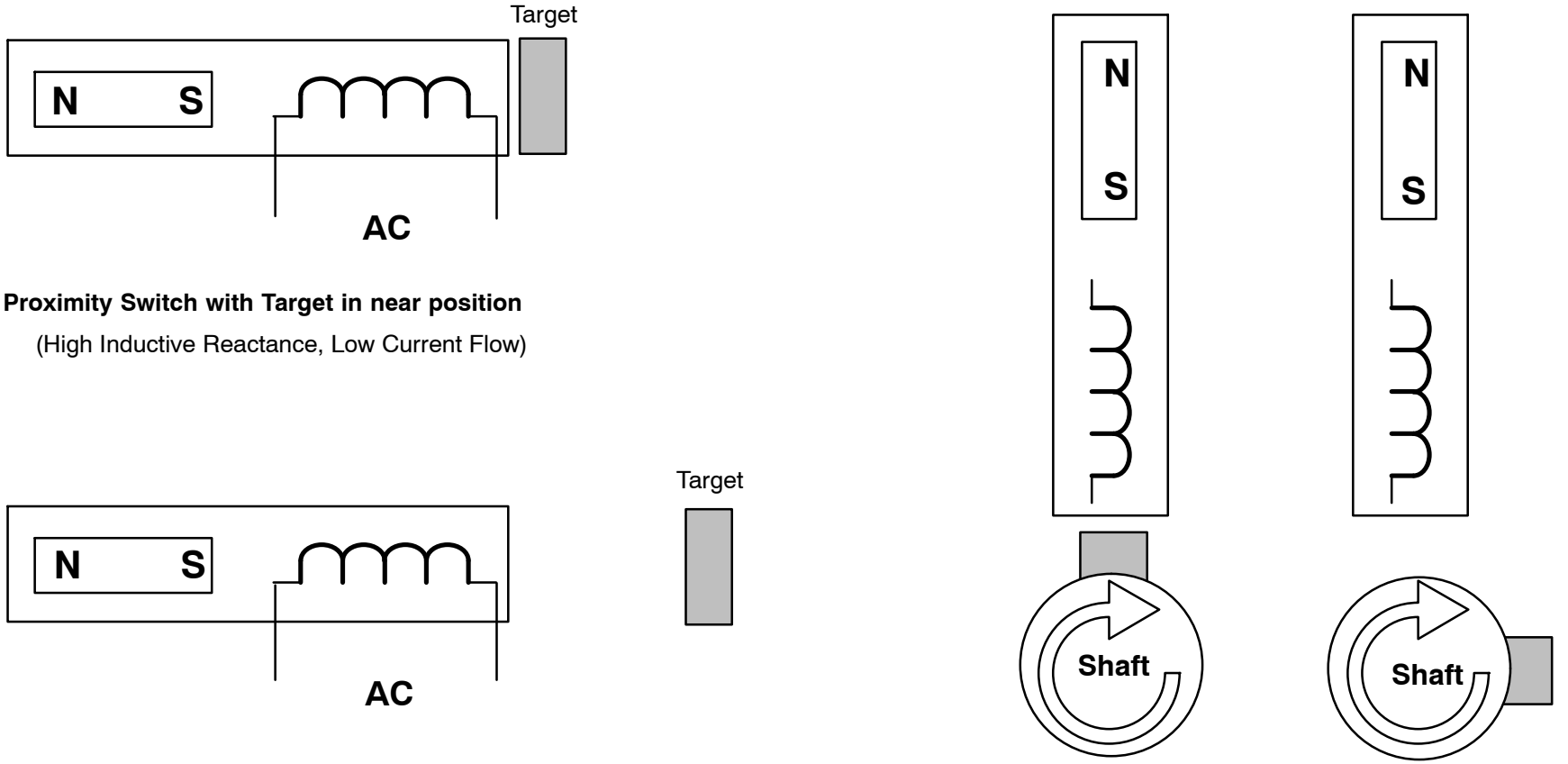


Figure 55 Inductance Transmitters

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

CAPACITANCE TRANSMITTERS

General

The principle of capacitance can be used as a method of measuring fuel level.

Operation Principle

A capacitor is a component which can hold a charge on two plates separated by a material known as a dielectric.

If the material of the dielectric is changed then the dielectric constant will change and the amount of charge which can be held by the capacitor will also change.

In the case of a fuel tank gauging unit we use a tubular capacitor which the fuel is free to flow in and out of so the space between the plates will be filled with air or fuel. As the dielectric constant of air is different to that of fuel then it can be calculated how much of the gap between the plates is filled with fuel and how much is filled with air, thus the fuel level is known.

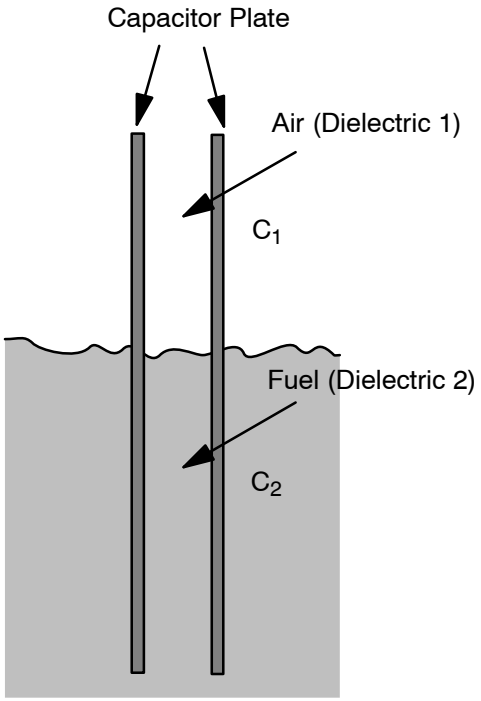
Each fuel tank will have a number of capacitance gauging units to take into account different flight attitudes.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training







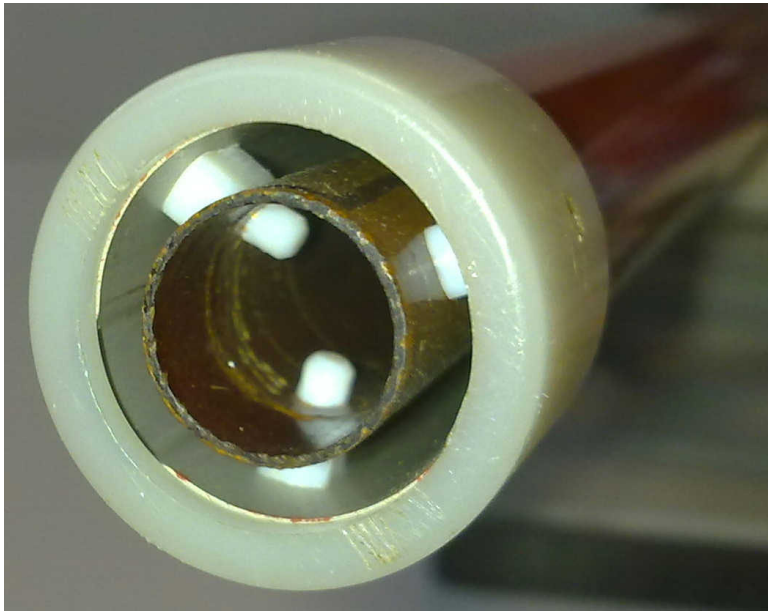


Figure 56 Capacitance Transmitter (Example)

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

SERVO SYSTEM

General

When larger rotation moments are required than a torque synchro chain can provide, servo systems are used.

Operation

In this case, control transmitter CX and control transformer CT are used to transmit angles.

The rotor of the CT delivers a voltage which is a measure of the differential angle between CX and CT. This voltage is passed on to the amplifier which drives the servo motor. The servo motor is in most cases a two–phase asynchronous motor. Using a capacitor, the one phase of this motor is displaced by an angle of 90° in relation to the excitation of the system. The amplifier then provides the second phase with a voltage which lies either in phase or in phase opposition to the excitation voltage, depending on the relation of the rotor coil of the CT to the zero position. In this way, the motor rotates to the left or to the right until the transmission has turned the rotor of the CT to the point where it no longer generates a voltage. The same transmission simultaneously carries out any mechanical adjustment to be provided by the servo system. Any rotation moment that is desired can be produced, depending on which amplifiers, motors and transmissions are used.

Even at the smallest differential angles between CX and CT, the motor has the full power of the amplifier at its disposal. This ensures that the system can start up accurately when it is on load.

However, it also means that, due to the moments of inertia of the rotating parts, the system rotates past the zero position. The CT then starts to produce a voltage which is in opposition to the previous one and this voltage is passed to the amplifier, rotating the motor in the opposite direction. As a result, the amplifier is always adding energy to the servo loop. This means that the system cannot come to rest but instead keeps oscillating around its zero position.

Damping

In order to prevent this from happening, damping must be achieved by means of a reverse coupling.

For this purpose a rate generator is used, which transmits a signal that is set in opposition to the signal from the CT.

FOR TRAINING PURPOSES ONLY!

© Lufthansa Technical Training

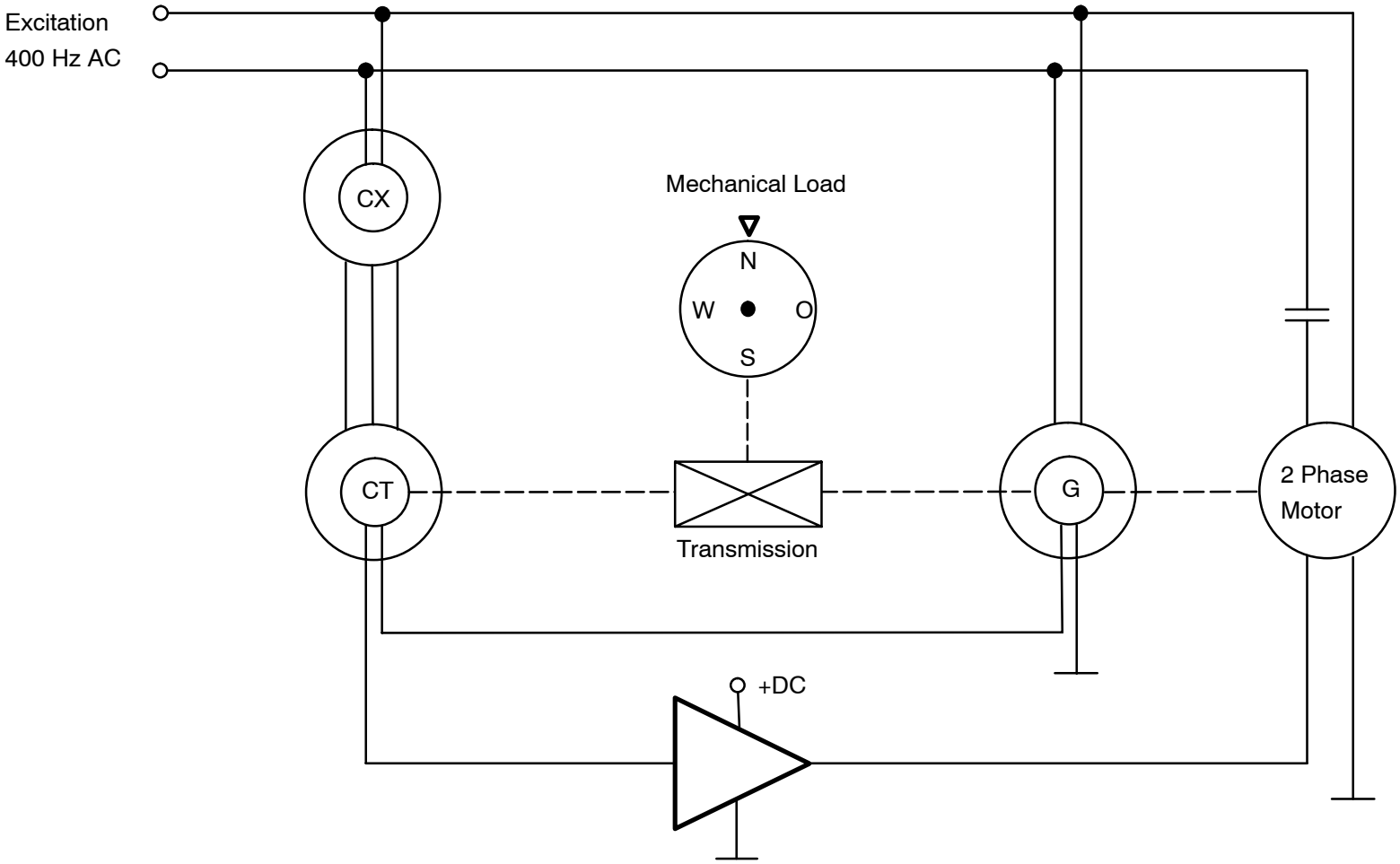


Figure 57 Servo System

FOR TRAINING PURPOSES ONLY!

TABLE OF CONTENTS

M4 ELECTRONIC FUNDAMENTALS 1

M4.1 SEMICONDUCTORS 2

M4.1.1 DIODES 2
INTRODUCTION 2
SINGLE CRYSTAL SEMICONDUCTOR DIODES 4
PROPERTIES 6
TYPES OF DIODES 8
TESTING OF DIODES 10
DIODES IN SERIES AND IN PARALLEL 12
USAGE OF DIODES 14
RECTIFIERS 18
SHAPES OF RECTIFIERS 22
APPLICATION OF RECTIFIERS 24
Z-DIODE 28
LIGHT EMITTING DIODES (LED) 30
PHOTODIODE 32
LIGHT DEPENDENT RESISTOR (LDR) 34
OPTICAL COUPLING DEVICES 36
VARISTOR 38
THYRISTOR 40
CONTROLLED PSU WITH THYRISTOR 42
TRIAC 44
DIMMER SWITCH CIRCUITS 46

M4.1.2 TRANSISTORS 48
INTRODUCTION 48
DESCRIPTION 50
CHARACTERISTICS AND PROPERTIES 52
THE TRANSISTOR AS A SWITCH 54

M4.1.3 INTEGRATED CIRCUITS 58
INTRODUCTION 58
OPERATIONAL AMPLIFIERS 60
HOUSING DESIGNS 64
OVERVIEW OF STANDARD CIRCUITS 66

M4.2 PRINTED CIRCUIT BOARDS 70
GENERAL 70
MANUFACTURING PROCESS 72

M4.3 SERVOMECHANISMS 74
INTRODUCTION 74
OPEN AND CLOSED LOOP SYSTEMS 76
CONSTRUCTION OF SYNCHROS 78
OPERATION 80
TORQUE SYNCHRO 86
DIFFERENTIAL TRANSMITTER 90
CONTROL SYNCHRO 94
RESOLVER 100
LVDT 102
INDUCTANCE TRANSMITTERS 106
CAPACITANCE TRANSMITTERS 108
SERVO SYSTEM 110

TABLE OF FIGURES

Figure 1 Semiconductor 3
Figure 2 Construction and Characteristic Curve of Diodes 5
Figure 3 Construction and Characteristic Curve of Diodes 7
Figure 4 Shapes of Diodes 9
Figure 5 Diode Testing 11
Figure 6 Diodes in Series and Parallel 13
Figure 7 Light Decoupling 15
Figure 8 Back-emf-Diode 17
Figure 9 Single Wave Rectifier 19
Figure 10 Full Wave / Bridge Rectifier 21
Figure 11 Shapes of Bridge Rectifiers (Examples) 23
Figure 12 Aircraft AC Generator 25
Figure 13 TR-Unit 27
Figure 14 Z-Diodes 29
Figure 15 LED 31
Figure 16 Photodiode 33
Figure 17 LDR 35
Figure 18 Optical Coupling Device 37
Figure 19 Varistor 39
Figure 20 Thyristor 41
Figure 21 Controlled Power Supply 43
Figure 22 Basic Principle and Characteristic Curve of a Triac 45
Figure 23 Dimmer Switch Circuit 47
Figure 24 Transistors 49
Figure 25 Construction of a Transistor 51
Figure 26 Transistors 53
Figure 27 Example: Transistor used as a Switch 55
Figure 28 Example: Transistor used as a Switch 57
Figure 29 IC Production Process 59
Figure 30 Operational Amplifier 61
Figure 31 Schematics Symbol and Excitation Curve of OpAmp 63
Figure 32 Housing Design of OpAmp 64
Figure 33 Interior of an OpAmp (741) 65
Figure 34 Overview of Standard OpAmp Circuits 66
Figure 35 Overview of Standard OpAmp Circuits 67
Figure 36 Overview of Electronic Voltage Regulators with OpAmp 69
Figure 37 Computer-Generated Layout 71
Figure 38 Processing of PCB 73
Figure 39 Synchro System 75
Figure 40 Open Loop / Closed Loop System 77
Figure 41 Construction of Synchros 79
Figure 42 Operation of Synchros 81
Figure 43 Magnetic Fields 83
Figure 44 Current and Torque of Synchros 85
Figure 45 Torque Synchro Chain 87
Figure 46 Torque System (Example) 89
Figure 47 Differential Transmitter 91
Figure 48 Differential-Transmitter (Example) 93
Figure 49 Control Synchro Chain 95
Figure 50 Control Synchro Chain (Example 1) 97
Figure 51 Control Synchro Chain (Example 2) 99
Figure 52 Basic Construction of Resolvers 101
Figure 53 LVDT 103
Figure 54 LVDT (Example) 105
Figure 55 Inductance Transmitters 107
Figure 56 Capacitance Transmitter (Example) 109
Figure 57 Servo System 111