# Actuators
relays & motors

*Choose yourself and new technologies*

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## Outline

- relays
  - mechanical
  - electronic relay (SSR)
- Electric motors

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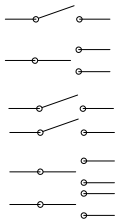
## Relays

SPST

SPDT

DPST

DPDT



**Single(Double)Pole**
**Single(Double;Triple)Throw**

CO – centre off/change over example
SPTT=SPCO

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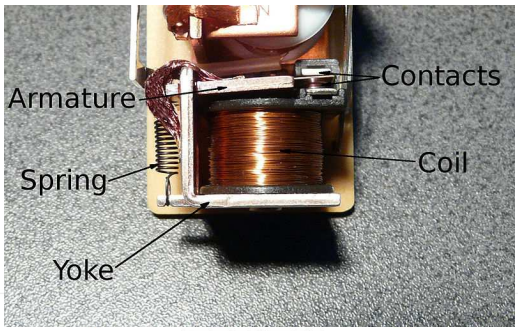
## Relay



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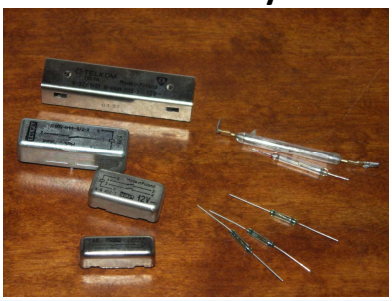
## reed relay





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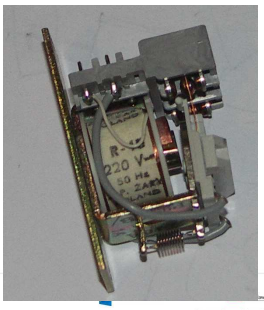
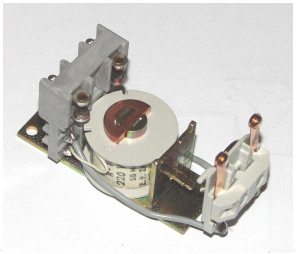
## Relays

## AC relay







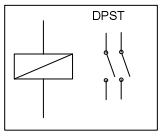
## Relays - types

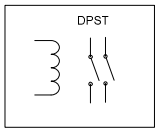
- Regular
- Latching (bistable)
- Polarized relay
- Reed relay
  - (mercury wetted)
- Contactor
- Solid state relay
  - transistor
  - triac
  - thyristor
- Other (safety switches, over current,……)





## Relay - diagram symbol



## References


- S. L Herman, Industrial motor control, Clifton Park, 2014
- T. R. Kuphaldt, Lessons In Electric Circuits, Volume II – AC, 6th Edition, 2007 (http://www.faqs.org/docs/electric/AC/index.html)
- J. Przepiorkowski, Silniki elektryczne w praktyce elektronika, BTC

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## Ohm's low for inductance

$$U_L = L\frac{dI}{dt}$$

$$U_L = X_L I_L = \frac{1}{i\omega C} I_L$$

TIPS:
- higher voltage applied – faster changes of current
- fast changes in current – higher voltage induced
- when current change „slope direction" – voltage change polarity:
  - positive voltage applied – current increased
  - current decreased – negative voltage induced

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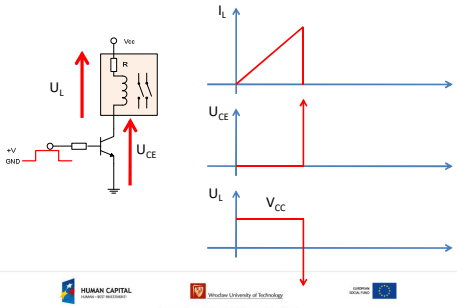
## Switching on and off an inductor

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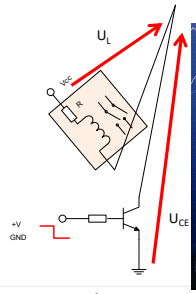
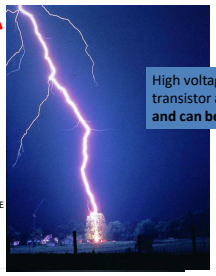
## Relay – spark discharge



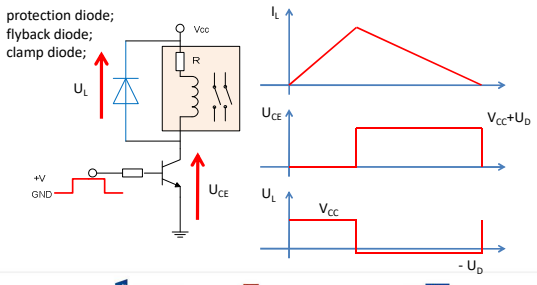
High voltage can destroy transistor and relay **and can be very dangerous !!!!**





## Switching on and off an inductor

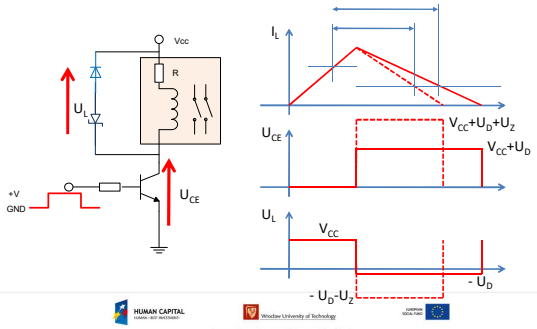
protection diode;
flyback diode;
clamp diode;





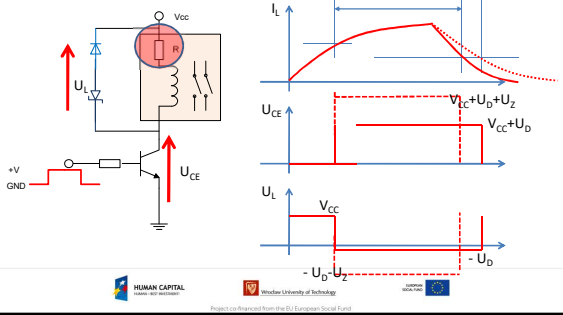



## Switching on and off an inductor



# Switching on and off an inductor

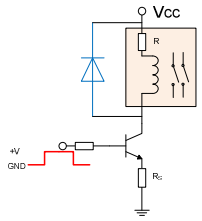
**- series resistor influance**








# Decreasing rise time (off to on time)

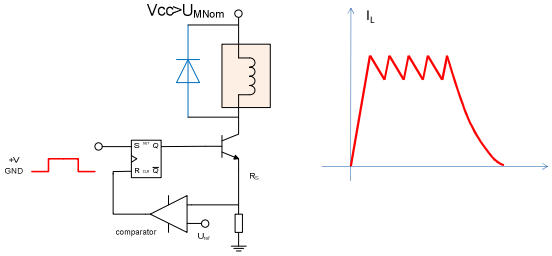



1. **Increase Vcc**
2. **add Rs to preserve Imax**
3. **result=> higher power dissipation**

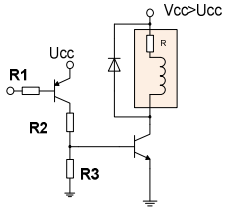




# Decreasing rise time with current limit



# Driving relays and motors




I<=1A



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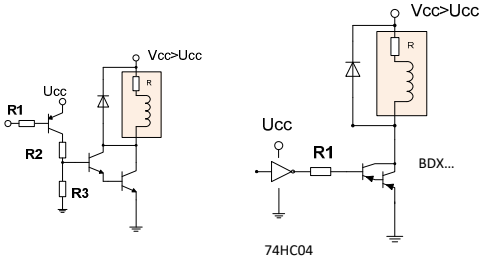
# Driving relays and motors



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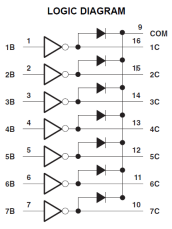
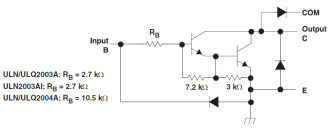
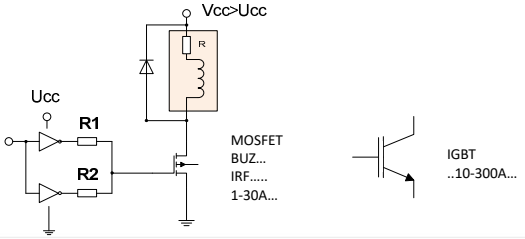
# Darlington array ULN2004




http://focus.ti.com/lit/ds/symlink/uln2004a.pdf

# Driving relay/motor with MOSFET and IGBT








# Solid State Relays (SSR) Solid State Contactor (SSC)

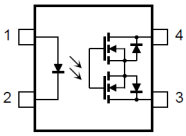




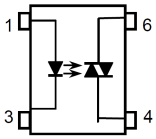


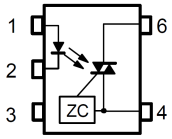

# SSR of different types

**can be used for AC driven mechanical relays**



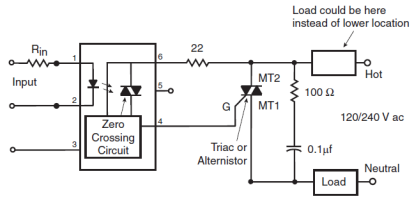

•Usually small power but can drive any type of load (including induction)
•AC and DC applications



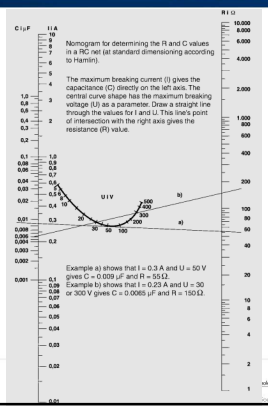

•Be carfull with inductive load – the load can be not switched off !!!
•AC applications only

# High power SSR







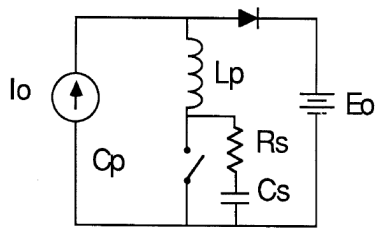

# RC snubber

<30V – other load
>30V – over contacts

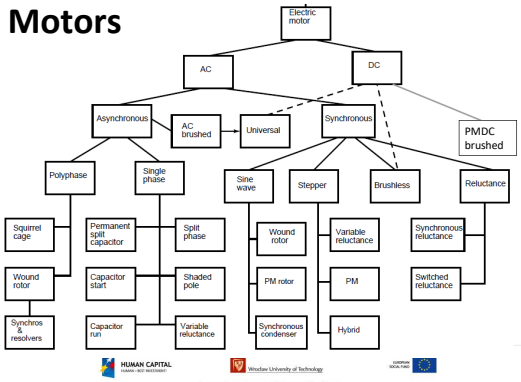
Protection elements:
- capacitive load
  - chock
  - NTC,
  - PTC( in series)
- induction load
  - surge arrester
  - varistor
  - transil



# RC snubber



# Motors








# Electric motors

- AC motors
  - squirrel cage (3 phase, 1 phase -shade pole, cpacitor, split phase)
  - synchronous
- DC motors
  - Permanent magnet DC
  - Universal motors
    - series
    - shunt
    - compound wound
- BrushLess DC (BLDC)
  - 2 phase
  - 3 phase
- Stepper motors
  - reluctance
  - permanent magnet
  - hybrid
- Linear (Voice Coil Motor – VCM)





| Type | Advantages | Disadvantages | Typical Application | Typical Drive |
|---|---|---|---|---|
| AC Induction (Shaded Pole) (31) | Least expensive<br>Long life<br>lowpower | Rotation slips from frequency<br>Low starting torque | Fans | difficult tocontrol |
| AC Induction (split-phase capacitor) (34) | Medium power<br>high starting torque | Rotation slips from frequency | Appliances<br>Stationary Power Tools | Uni/Poly-phase AC |
| AC<br>Squirrel cage<br>3ph (40) | High power | Rotation slips from frequency | Industry/ hp.mashines | Inverter frequency<br>Vector controll (fr/current) |
| Brushed DC (41) | Low initial cost<br>Simple speed control | Maintenance (brushes)<br>Medium lifespan | Treadmill exercisers<br>automotive motors (seats, blowers, windows) | Direct DC or PWM |
| BL DC (49) | Long lifespan<br>low maintenance<br>High efficiency | High initial cost<br>Requires a controller | Hard drives<br>CD/DVD players<br>electric vehicles | DC switching, Pwm |
| Universal motor (61) | High starting torque, compact, high speed | Maintenance (brushes)<br>Medium lifespan | Portable tools Grid powered | Uni-phase AC or Direct DC |
| Stepper DC 1ph/2ph (66) | Precision positioning<br>High holding torque | High initial cost<br>Requires a controller | Positioning in printers and floppy drives | DC switching |
| AC Synchronous (82) | Rotation in-sync with freq - hence no slip<br>long-life | More expensive | Industrial motors<br>Clocks<br>Audio turntables<br>tape drives | Uni/Poly-phase AC |

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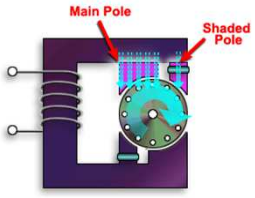
# Shaded pole induction motor



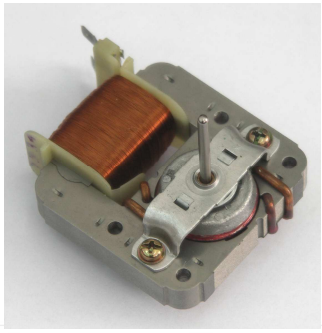

**advantages**
- Very cheap and reliable
- Extremely rugged in nature
- Easy to construct

**disadvantages**
- Low starting torque
- Low efficiency

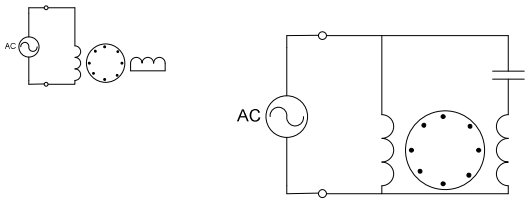




# Shaded pole induction motor



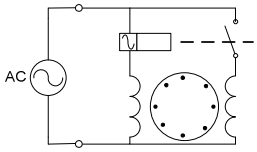
## Capacitor Run
## Permanent Split Capacitor(PSD Motor)







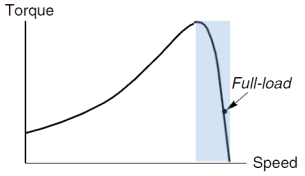

## Split Phase Induction Motor








## Induction Motor control
## by means of slip control



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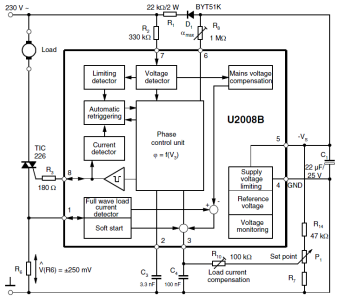
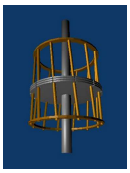
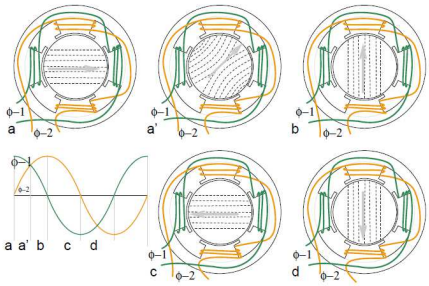







## Squirrel cage










## Squirrel cage – drivig inverter

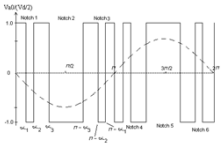



Fig.2 Programmed Harmonic Elimination of Fifth and Seventh Harmonics

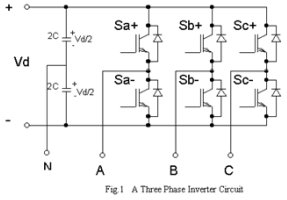
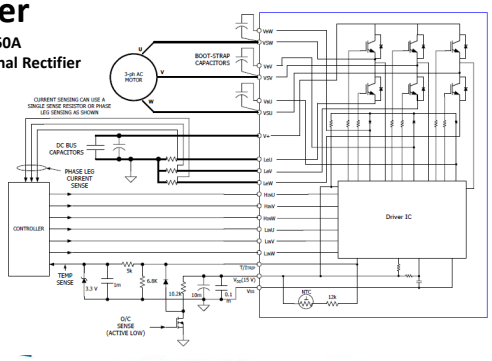



Fig.1 A Three Phase Inverter Circuit

# Inverter

**IRAMS10UP60A**
**by International Rectifier**





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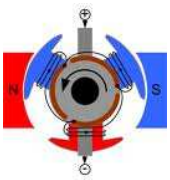
# DC motors

**PMDC – Permanent Magnet DC**

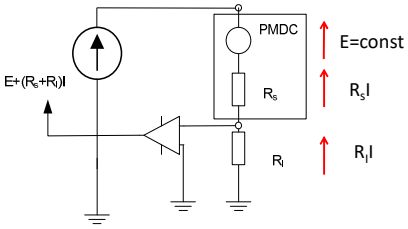



High starting torque,
compact,
high speed,
easy to controll,
cheap

Maintenance (brushes)
Medium lifetime,
Noisy
EMI emission

# DC motors

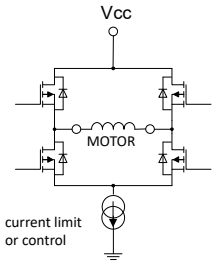
**PMDC – Permanent Magnet DC - control circuit**








# Direction controll - H bridge

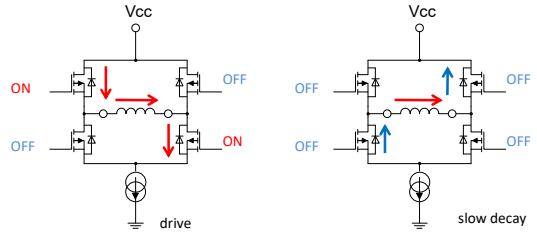



TIPS:
BJT, MOSFET, IGBT transistors can be used,
diodes conduct self inductance currents

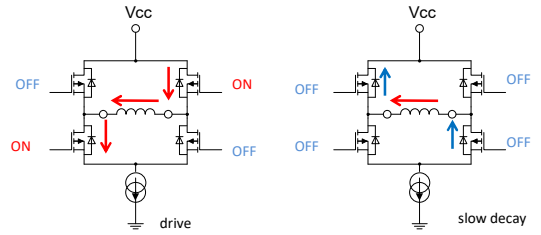




# H bridge operation 1



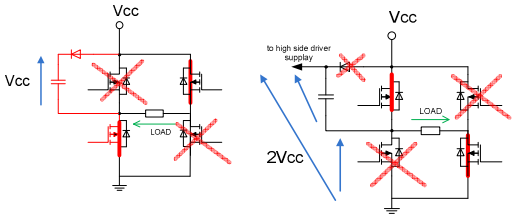
# H bridge operation 2








# Bootstrapping








# DC motors

**PMDC – Permanent Magnet DC -ironless (coil and disc) -pancake**

TIP:
very little momentum – fast start

http://www.designworldonline.com/ArticleDetails.aspx?id=1973

http://www.kurz-motor.de/eproduktetframetextgleichstromscheibenlaeufer.htm

| Type | Advantages | Disadvantages | Typical Application | Typical Drive |
|---|---|---|---|---|
| AC Induction (Shaded Pole) (31) | Least expensive<br>Long life<br>lowpower | Rotation slips from frequency<br>Low starting torque | Fans | difficult tocontrol |
| AC Induction (split-phase capacitor) (34) | Medium power<br>high starting torque | Rotation slips from frequency | Appliances<br>Stationary Power Tools | Uni/Poly-phase AC |
| AC<br>Squirrel cage<br>3ph (40) | High power | Rotation slips from frequency | Industry/ hp.mashines | Inverter frequency<br>Vector controll (fr/current) |
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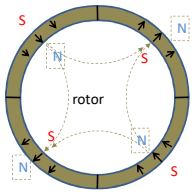
| Stepper DC 1ph/2ph (66) | Precision positioning<br>High holding torque | High initial cost<br>Requires a controller | Positioning in printers and floppy drives | DC switching |
| AC Synchronous (82) | Rotation in-sync with freq - hence no slip<br>long-life | More expensive | Industrial motors<br>Clocks<br>Audio turntables<br>tape drives | Uni/Poly-phase AC |





# BLDC (BrushLess DC) motors



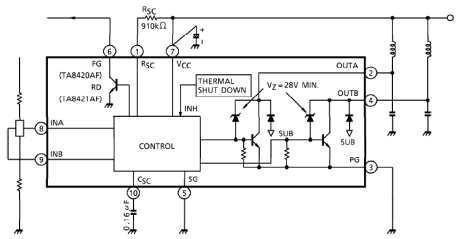





# BLDC
# 1 phase

Wrocław University of Technology Master programmes in English at Wrocław University of Technology

# TA8420/21 BLDC 2 phase driver

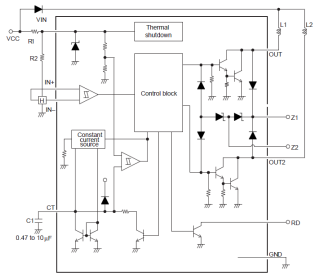




Project co-financed from the EU European Social Fund

Wrocław University of Technology Master programmes in English at Wrocław University of Technology

# LB1864 2 phase BLDC driver

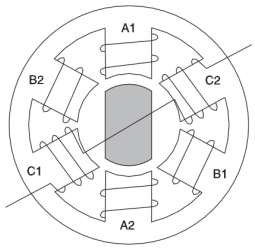




Project co-financed from the EU European Social Fund

Wrocław University of Technology Master programmes in English at Wrocław University of Technology

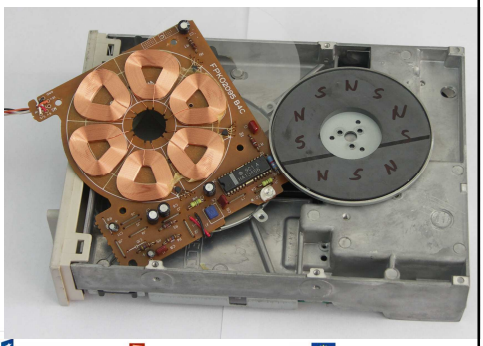
# 3 phase BLDC





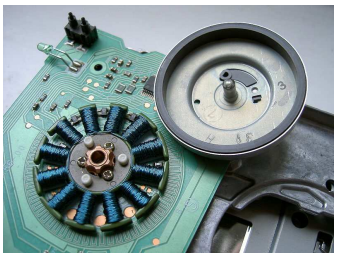
Project co-financed from the EU European Social Fund

## BLDC



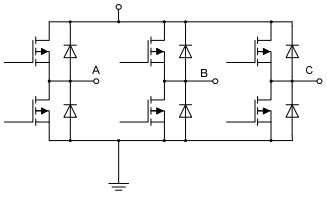


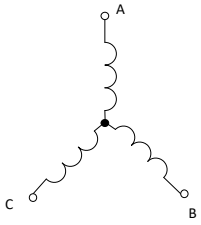
## BLDC



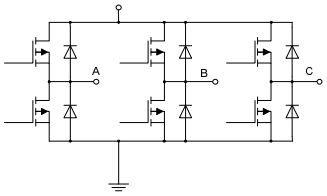


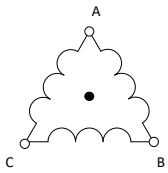
## BLDC – bipolar driving - star



## BLDC – bipolar driving - triangle

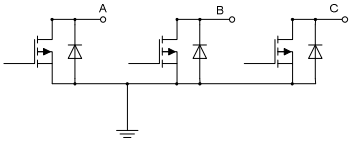


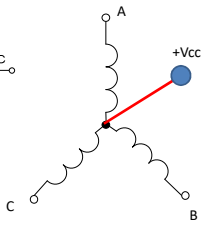








## BLDC – unipolar driving - star

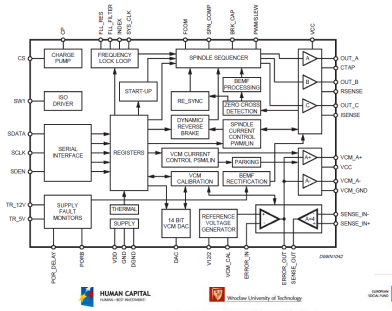







## L6268 driver BLCD + VCM(voice-coil-motor) (ST)



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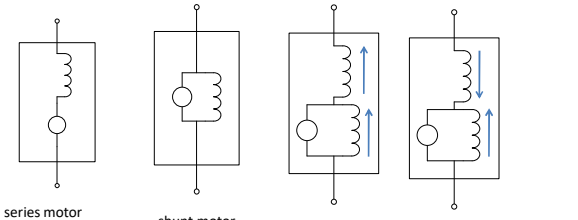
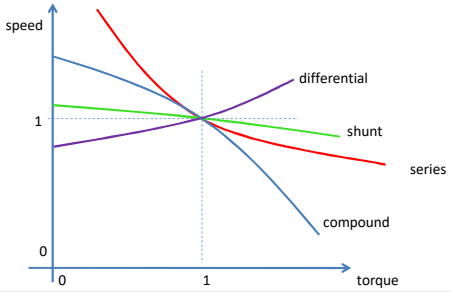
# Permanent magnet replaced by electromagnet – universal motor



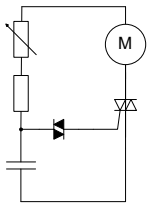





# Torque vs. speed



# Universal motor – driver / controller

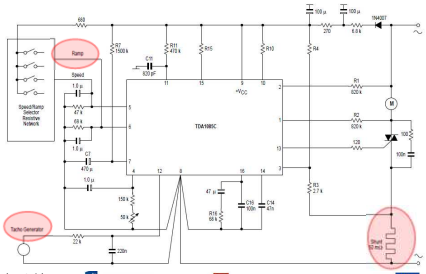



Tips:
1. voltage controlled
2. direction can be changed by switching stator or rotor winding
3. the example shown is the most simple





# Universal motor – driver/controller more sophisticated example




From Motorola materials (now ON Semiconductor)





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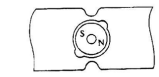
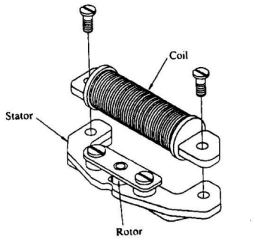
# Clock



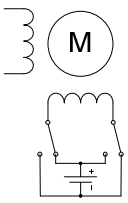

Silnik napędu zegarków (Quartz)



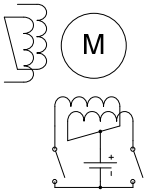





# stepper motors- bi/uni-polar




bipolar winding
H bridge needed

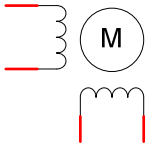



unipolar winding
single swich

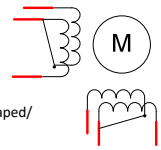




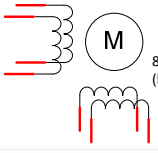
# (2 phase) steppper motor internal conections



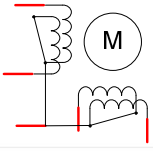

4 wires
(bipolar only)




6 wires
(bipolar handicaped/
/unipolar)

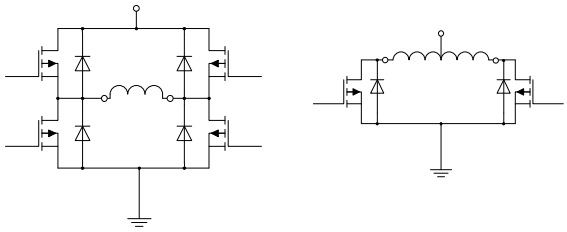



8 wires
(bipolar/unipolar)




5 wires
(unipolar only)

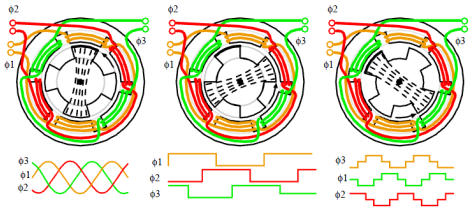
# Unipolar/Bipolar stepper motor driving







# Steppper motor – reluctance motor

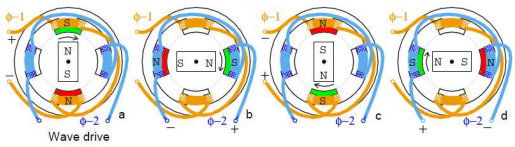



Lessons In Electric Circuits, Volume II – AC By Tony R. Kuphaldt, Sixth Edition, last update July 25, 2007





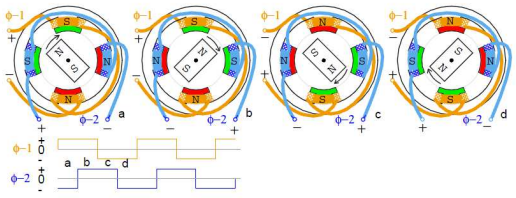
# Permanent magnet motor wave driving




Wave drive

Lessons In Electric Circuits, Volume II – AC By Tony R. Kuphaldt, Sixth Edition, last update July 25, 2007

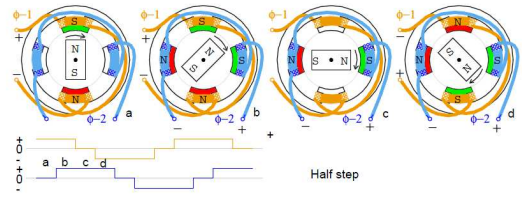
# Permanent magnet motor full step driving







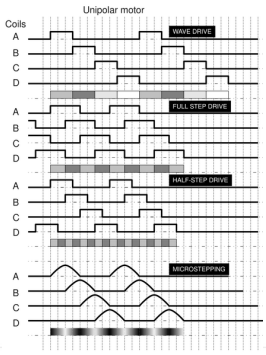

# Permanent magnet motor half step driving





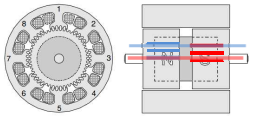



# Full/microstep driving

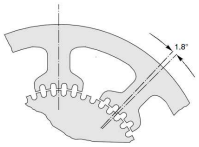


# Hybrid motor

1,3,5,7 – phase A
2,4,6,8 – phase B



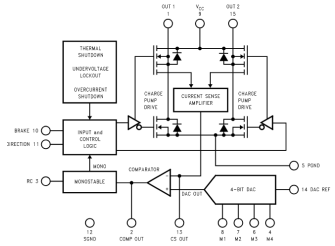
$$Step = \frac{360\,\mathrm{deg}}{N_{teeth} \cdot N_{phases}}$$







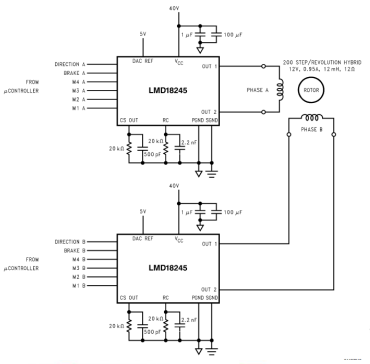

# LMD18245 3A, 55V DMOS Full-Bridge Motor Driver – National Instrument

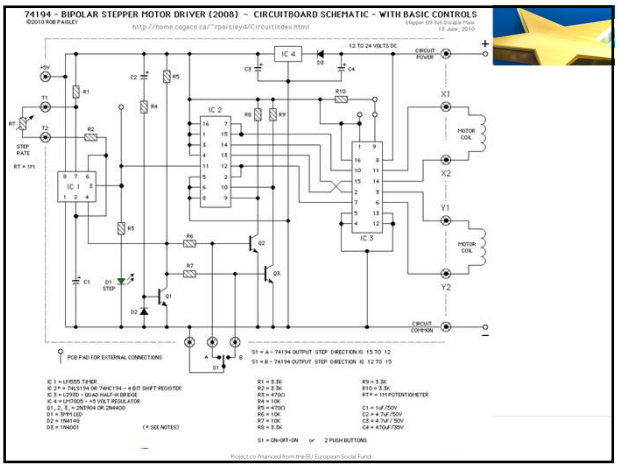


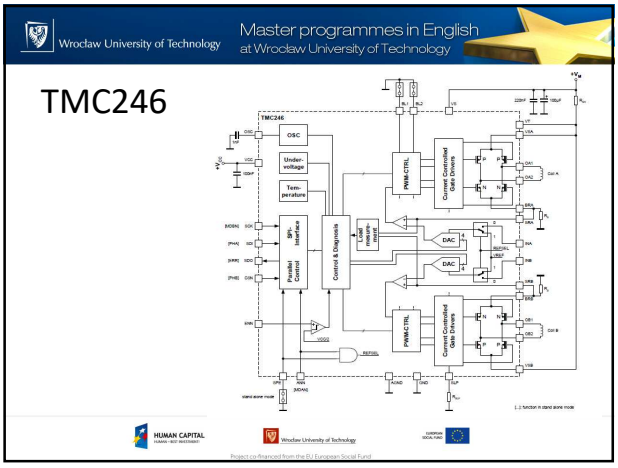


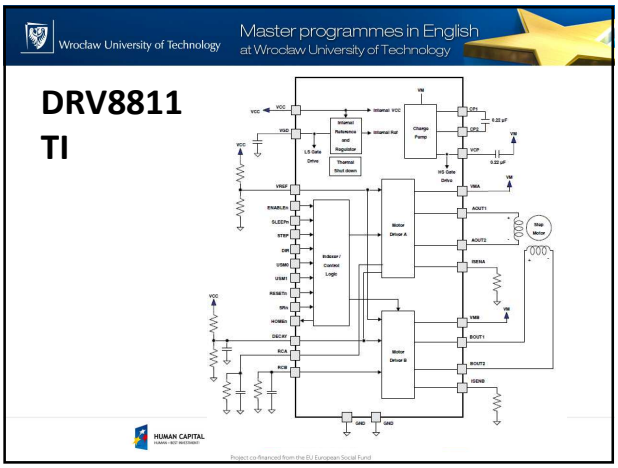



# LMD18245 application




74194 – BIPOLAR STEPPER MOTOR DRIVER (2008) – CIRCUITBOARD SCHEMATIC – WITH BASIC CONTROLS
12 TO 24 VOLTS DC
CIRCUIT POWER
MOTOR COIL
MOTOR COIL
CIRCUIT COMMON
PCB PAD FOR EXTERNAL CONNECTIONS
S1 = A – 74194 OUTPUT STEP DIRECTION IS 15 TO 12
S1 = B – 74194 OUTPUT STEP DIRECTION IS 12 TO 15
S1 = ON-OFF-ON or 2 PUSH BUTTONS


Wrocław University of Technology
Master programmes in English
at Wrocław University of Technology
TMC246
TMC246
OSC
Under-voltage
Tem-perature
SPI Interface
Parallel Control
Control & Diagnosis
PWM-CTRL
Current Controlled Gate Drivers
DAC
HUMAN CAPITAL
Wrocław University of Technology


Wrocław University of Technology
Master programmes in English
at Wrocław University of Technology
DRV8811
TI
Internal Reference and Regulator
Thermal Shut down
Charge Pump
Motor Driver A
Motor Driver B
Indexer / Control Logic
HUMAN CAPITAL

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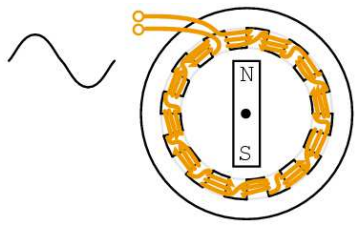
| AC Synchronous (82) | Rotation in-sync with freq - hence no slip<br>long-life | More expensive | Industrial motors<br>Clocks<br>Audio turntables<br>tape drives | Uni/Poly-phase AC |





# Synchronous motor

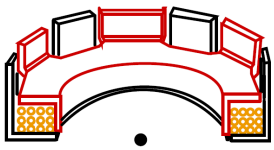



Lessons In Electric Circuits, Volume II – AC By Tony R. Kuphaldt, Sixth Edition, last update July 25, 2007

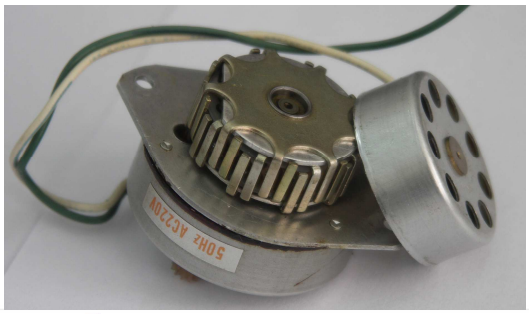




# Multipole synchronous motor



The inductionf or self starting and the bar magnet as synchronous motor

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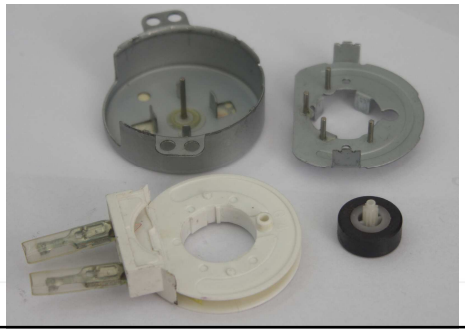
## Synchronous motor



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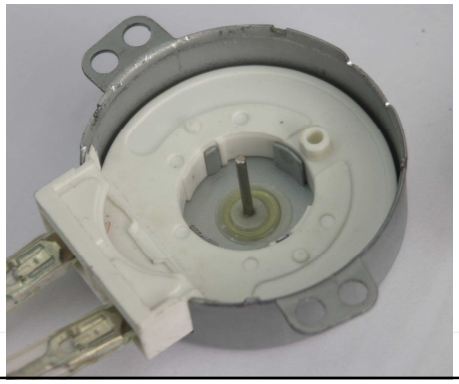

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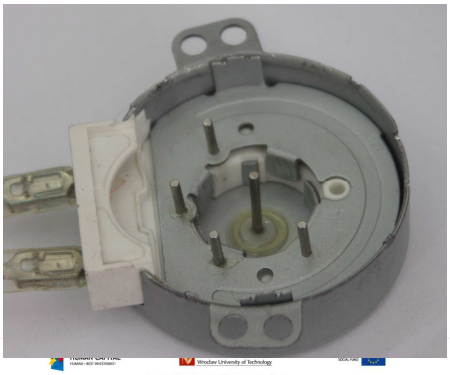

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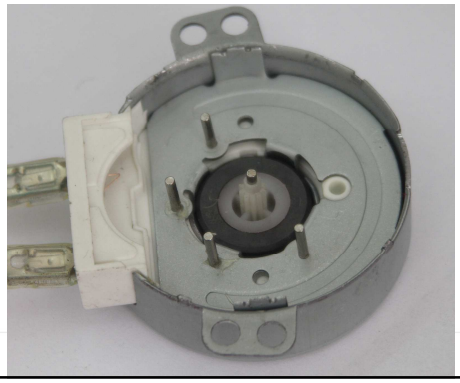
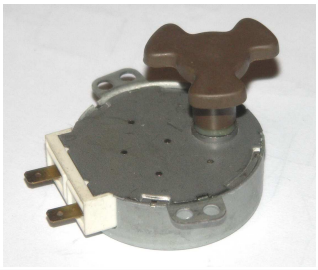


# Synchronous motor

**plat drive of microwave**







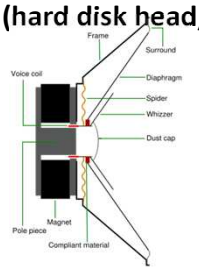
# VCM
# Voice Coil Motor



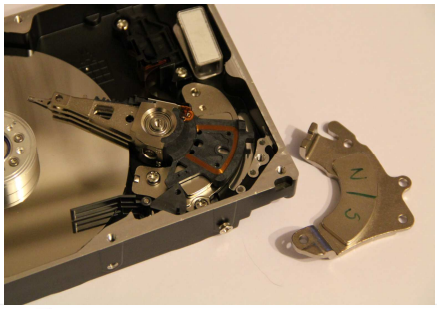


# VCM motors (actuators)

**(hard disk head, laser positioner in CD )**



## Linear motor



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## Summary

- Electromechanical relays
- SSR
- AC motors
  - squirrel cage (3 phase, shade pole, capacitor, split phase)
  - synchronous
- DC motors
  - Permanent magnet DC
  - Universal motors
- Brushless DC (BLDC)
- Step motors
- Linear (Voice Coil Motor – VCM)

HUMAN CAPITAL
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