Electro-mechanics

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Introduction

- Energy transformation between electrical and mechanical forms.
- Electrical $\rightarrow$ Mechanical: Motor or actuator
- Mechanical $\rightarrow$ Electrical: Generator

Water pump
http://www.grainger.com

Electric propulsion system
http://www.ship-technology.com

Electric car
http://www.teslamotors.com
Introduction

What about these?

- Flywheel Energy Storage. Source: archithings.com
- Generator in a power plant. Source: hensel-industry.com
- Wind turbine cross section. Source: visual.merriam-webster.com
Energy Conversion

- It is common to have an intermediate coupling stage between electrical and mechanical energy transformations: Electromagnetics!

- Among the electromechanical energy conversion devices that can be used in senior design projects:
  - Electromechanical Relays
  - Transformers
  - Single-phase motors
  - Three-phase motors/generators
  - Stepper motors
Relays

- Low power signal controls a higher power contact:

- Solid-state relays use semiconductors as switches.

Image Source: http://2.bp.blogspot.com/-t6tbGLB7hN8/ULOb7z1R1jl/AAAAAAAAAYY/ZS86wSo6mLw/s400/relay.gif
Ideal transformers have $N_1$ turns of wire magnetically coupled through ferromagnetic material with $N_2$ turns of wire.

[http://image.made-in-china.com/2f0j00eByTQM1drkqW/Single-Phase-Transformer.jpg](http://image.made-in-china.com/2f0j00eByTQM1drkqW/Single-Phase-Transformer.jpg)
Transformers

\[ v_1(t) = N_1 \frac{d\phi(t)}{dt} \]
\[ v_2(t) = N_2 \frac{d\phi(t)}{dt} \]

\[ \frac{v_1(t)}{v_2(t)} = \frac{N_1}{N_2} = a \]

\[ \frac{i_1}{i_2} = \frac{N_2}{N_1} = \frac{1}{a} \]

(CURRENT \( i_2 \) FLOWING TO THE LOAD \( R \))
Three-Phase Rotating Magnetic Field

- Three-phase balanced (magnitude, frequency, and 120 degrees of phase shift) currents flowing through sinusoidally spaced three-phase windings produce a rotating magnetic field.

Image Sources:
http://www.basilnetworks.com/article/motors/images/motor2pole.gif
http://electriciantraining.tpub.com/14177/img/14177_91_1.jpg
Three-Phase Rotating Machines

- Induction Machines: Metal rotor bars
  - Aluminum bars in steel enclosure
- Synchronous Machines: fixed magnetic field
  - Permanent magnet (interior or surface mount)
- Wound rotor

Image Sources:
Stepper Motors

- Motion control applications with fixed steps.
- Several phases can be excited in several modes

Image Sources:
Electric Drives

- Speed, torque, and motion control require power electronics to modify voltage and current signals.

- Typical drives are shown in the next slides.

- Control of power electronic switches is provided by:
  - Microcontrollers (PIC, MSP430, Altec, etc.)
  - FPGAs (Xilinx, NI, etc.)
  - Digital Signal Processors (TMS from TI, etc.)
  - Analog control circuitry
Hex-Bridge

Stepper Motor Drive

Motor Leads:
- White (common)
- Red
- Orange
- Blue
- Green

Parallel Port Pins:
- 2
- 3
- 4
- 5
- 11
- 12
- 13
- 25

IC1

Motor Drive Circuit

VCC 4V

R1
R2
R3
R4
R5
R6
R7
R8
D1
D2
D3
D4
T1
T2
T3
T4
Control Signal Isolation (Opto-Couplers)

Gate Drive

- Required to limit the current into a switching device (MOSFET or IGBT)
- Provides voltage offset to turn-on a high-side switch (what is a high side switch?)
- Check dead-time circuits
Gate Drive

- Typical gate drive circuits:

![Gate Drive Circuit Diagram](image-url)
Gate Drive

- Typical gate drive circuits:

![Diagram of a gate drive circuit with IC1, IRF2453DPbf, IRF830, and various capacitors and resistors linked to VCC, COM, RT, SD, LO1, and LO2. Connectors A and B are linked to AC Load.]