CRAFT BREWERS CONFERENCE
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BREWERS ASSOCIATION

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Electronicals 101

Everything you never knew you didn't want to know about electricity, electronics, sensors, and logic.

John Blystone, PE

Manager of Engineering & Maintenance

Great Lakes Brewing Company

Cleveland, OH

Outline

1) Basics
   a) Ohm's law - Volts / Amps / Ohms – water analogy
   b) Energy, Power
   c) Series, Parallel
   d) Milli, kilo, mega, GIGA (pronounced JIGGA – Doc. Brown had it right!!!)
   e) Drawing/schematic basics
2) Direct Current and Alternating Current
   a) What/Why/where DC common today
   b) What/Why/where AC common today
   c) How we measure voltage in DC and AC
      i) Why Root Mean Square (RMS)
      ii) RMS vs Peak in AC waveforms
      iii) Define frequency
   d) AC phases, why more than one
3) Codes (written in someone else's blood, our adherence to them wise)
   a) NFPA 70 – National Electric Code
      i) How to install electrical devices to prevent fire and equipment damage
      ii) How to size electrical components like breakers and overloads to protect equipment
      iii) Requirement for access to electrical equipment
   b) NFPA 70B – Recommended Practice for Electrical Equipment Maintenance
   c) NFPA 70E – Standard for Electrical Safety in the Workplace
   d) NFPA 79 – Electrical Standard for Industrial Machinery
   e) NFPA 652 – Standard on the Fundamentals of Combustible Dust
   f) NFPA 61 – Standard for the Prevention of Fires and Dust Explosions in Agricultural and Food Processing Facilities
   g) Mention others, NFPA 68, 69, 77, and 499 related to 652/62 implementation
4) Basic Electromagnetics
   a) How voltage is created by magnets and motion
   b) How a magnet is formed by passing a current
5) Transformers
   a) How they work, what they do (related back to basic electromagnetics)
   b) Where you may see them in your facility, or in the parking lot
6) Motors
   a) What it takes to make one work
   b) DC Motors (quick review of types, basic wiring for simple PM style)
   c) Universal Motors (DC, but with stator field parallel to brushes)
   d) AC 3-phase Permanent Magnet (PM)
   e) AC 3-phase Induction Motor
   f) Servo motors
7) AC Motor On/Off Control
   a) Short Circuit Protection (Breaker/Fuse) sizing per NEC
   b) Overload sizing per NEC
   c) Variable Frequency Drives – NOT YET!!! Soon grasshopper…
8) Electronic Control Basics
   a) What's a switch
   b) What's a transistor
   c) What's a relay
   d) What is meant by digital vs. analog
   e) What is pulse width modulation (PWM)
9) Variable Speed AC Motor Control (Variable Frequency Drive)
   a) Power input
   b) DC Bus
   c) PWM output approximating sine wave (RMS) for all three phases
   d) How to change direction
   e) Paramaetergeddon – WRITE ALL NON-DEFAULT AND CHANGES DOWN!!!
10) Digital Logic
   a) Binary, Integer Numbers (base 2)
   b) IEEE Floating Point
   c) Relay pushbutton extender for high current
   d) Latching on/off circuit
   e) Typical Motor Control Circuit

Outline

11) Programmable Logic Controllers
    a) What is a PLC and how beer helped create them
    b) Typical PLC styles
    c) PLC components
    d) Parallels between relay logic and PLCs
12) Analog Signals
    a) 0-10 VDC vs 4-20mA
    b) Why shielded twisted pairs of wires
    c) How 4-20mA is really variable voltage
    d) Analog PLC input example, RAW data, scaling
13) Instruments
    a) Flow Meters
        i) Mag
        ii) Corriolis
        iii) TTB Calibration requirements for breweries
    b) Temperature Transmitters
        i) RTD
        ii) Thermocouple
        iii) Comparison of total accuracy and simplicity, pros/cons

14) Electrical Safety
    a) Why this is important
    b) How electricity can kill you
        i) Shock
            (1) Skin Resistance
            (2) Body Resistance
        ii) Arc Flash/Blast
    c) Grounding
        i) What is it, how does it work
    d) Equipment Inspections
        i) How and Why
        ii) How often
    e) Circuit Breaker Safety and operation
    f) Ground Fault Circuit Interrupters
        i) How they work
        ii) Where they're required
        iii) How they save your life
    g) Definition of a Qualified Electrical Worker
    h) Designing Safety into your Systems (HELLO EQUIPMENT PROVIDERS)

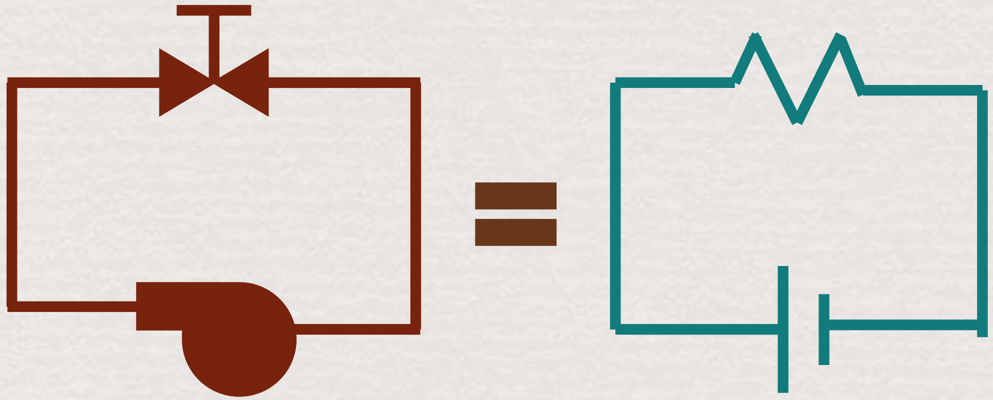
90 Minutes…

Buckle up!

Ohm’s Law

Fluid Analogy

- Voltage (V, Volts) = Pressure
- Current (I, Amperes or “Amps”) = Flow
- Conductance = % valve is open
  - Resistance (R, Ohms) = 1 / Conductance



Lines = Pipes

Pressure from Pump

Restriction from Valve

Lines = Wires

Voltage from Battery

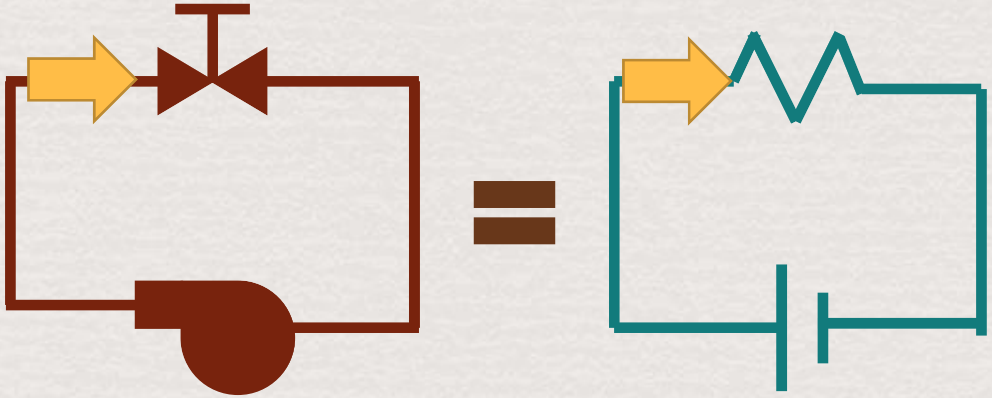
Restriction from Resistor

Ohm’s Law

Pump provides pressure, battery provides voltage

Valve provides resistance, as does the electrical resistor

Flow is determined by pressure and valve opening, current is determined by voltage and resistance



Ohm’s Law

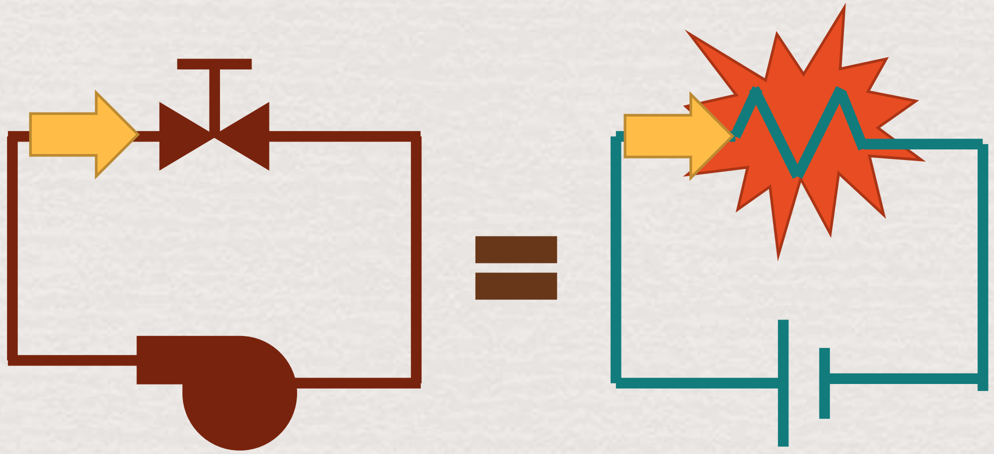
Voltage = Current * Resistance (V=iR)

Power = Pressure * Flow, Voltage * Current

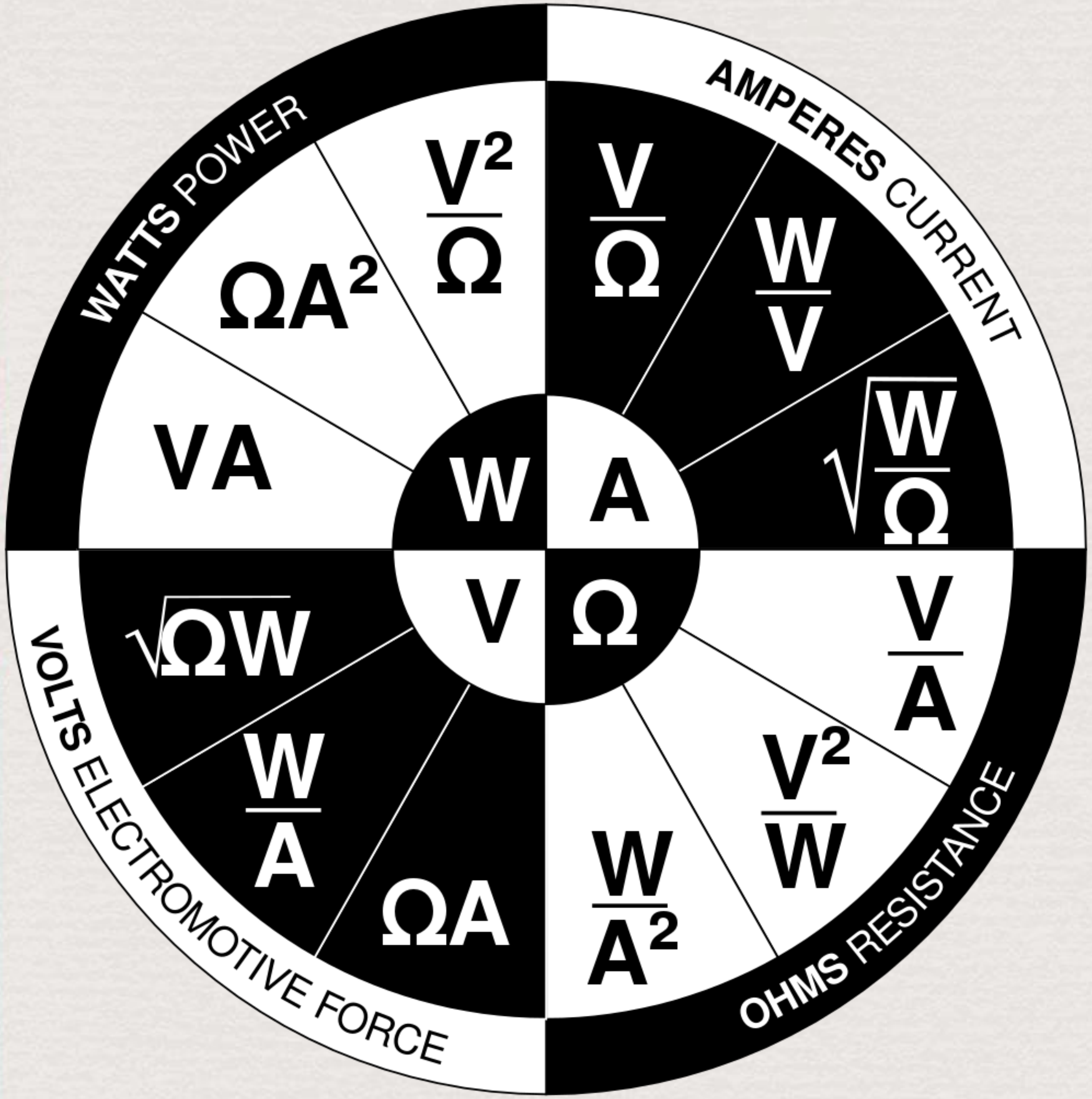
P (W, Watts) = iV

Combined with V=iR, $P = i^2R$

Power → heat, so devices heat from i^2R



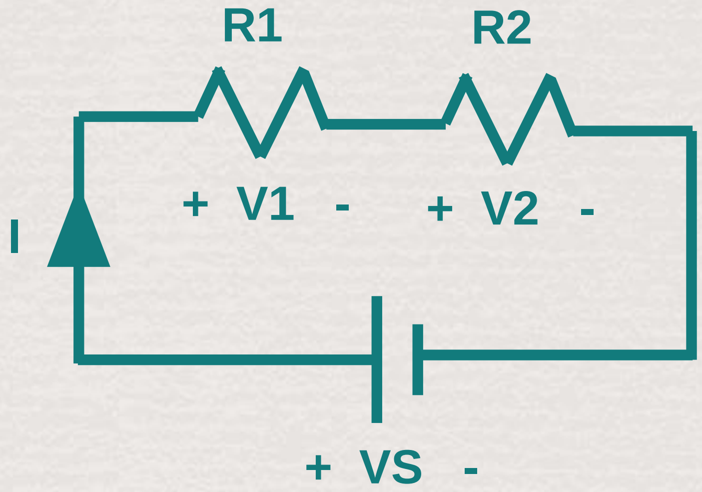
Ohm’s Law



By Per Mejdal Rasmussen - Own work, inspired by Teaching Ohm’Law to Techs by Daniel Sullivan, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=48171195

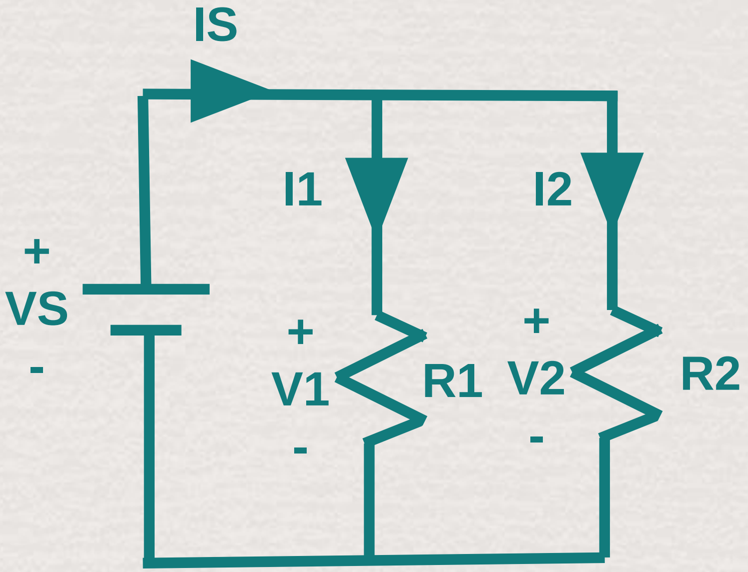
Series vs. Parallel

- Series – same current, but voltage drop across each resistor based on resistance

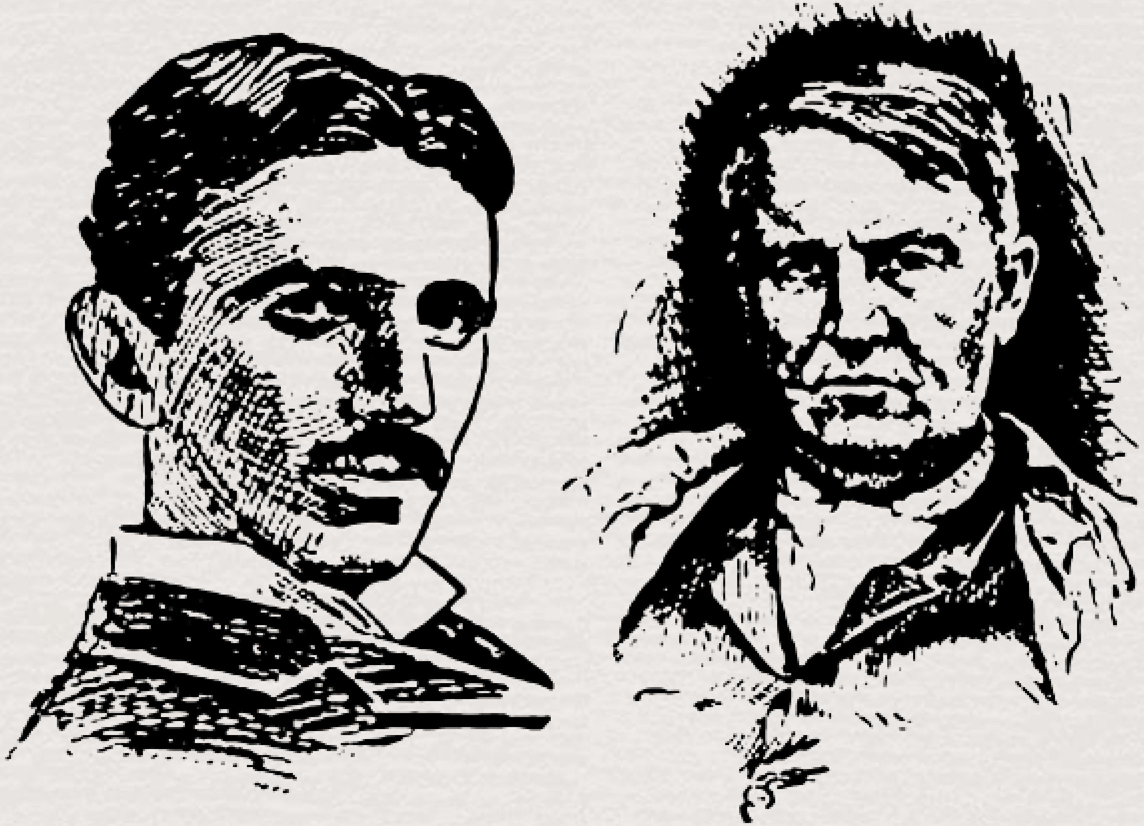


VS = V1 + V2
V1 = R1 * I
V2 = R2 * I

- Parallel – same voltage, but current through each resistor based on resistance



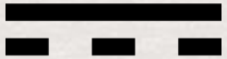
IS = I1 + I2
I1 = VS / R1
I2 = VS / R2

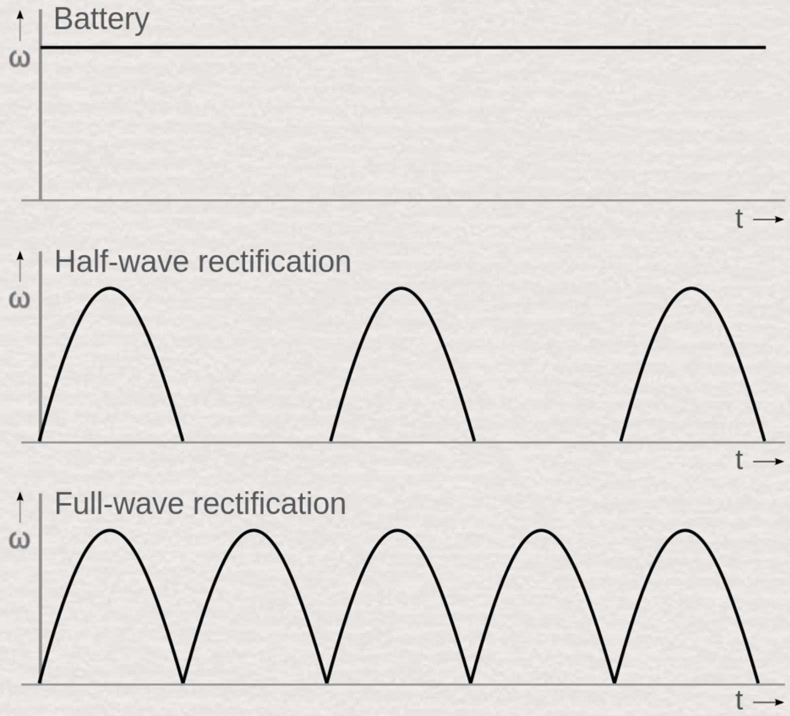


AC/DC

Direct Current

Direct Current indicates Single Direction Flow of Electrons





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Direct Current

PROS

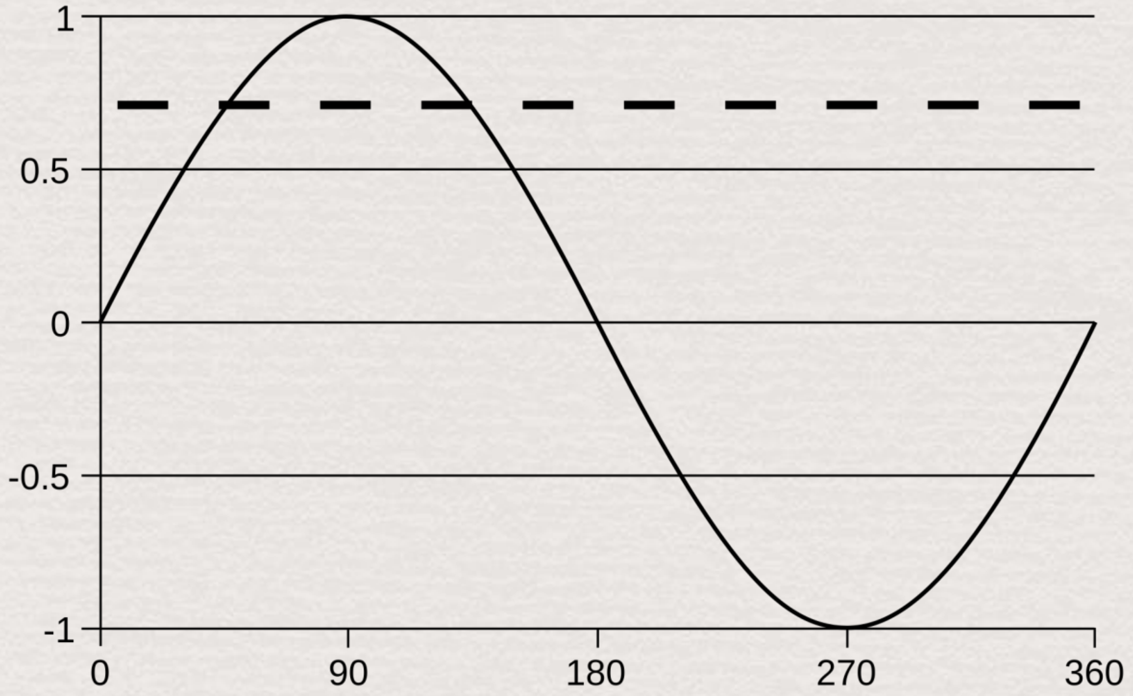
- Provides stable voltage for electronics
- Easy to store (batteries, capacitors, etc.)

CONS

- DC Motors require brushes and commutators, all wear parts that cause sparks
- Inability to increase voltage to lower i^2R losses for power distribution
- No “zero crossings” are arguably rougher on devices, and less safe

Alternating Current

Alternating Current
indicates
Regular Bi-directional Flow of Electrons



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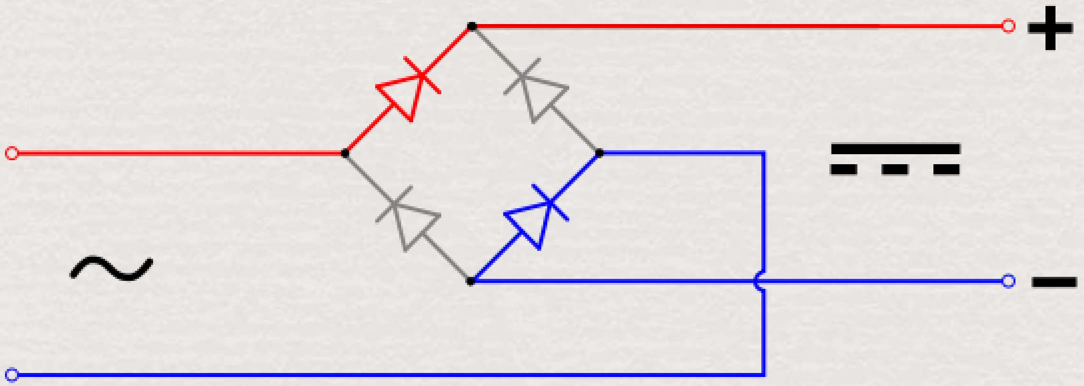
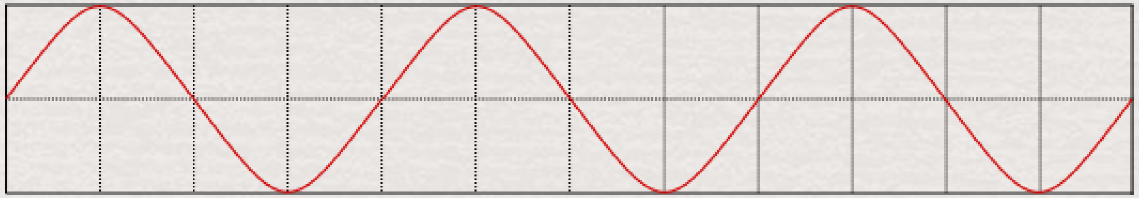
Direct Current Revisited

Diodes are Electronic Check Valves

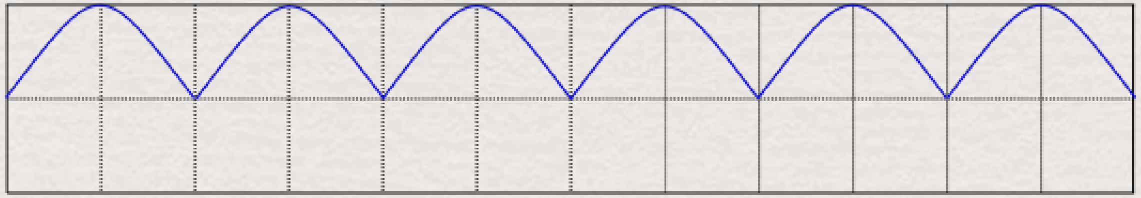
Allow AC to be “Rectified” into DC





Sinusoidal Signal

Half-wave Rectification

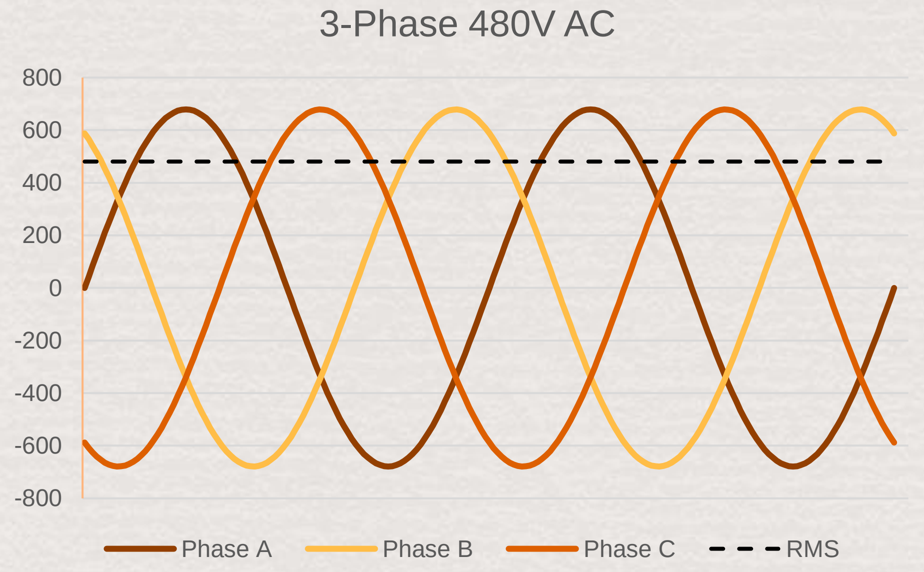


Full-wave Rectification

Alternating Current

PROS

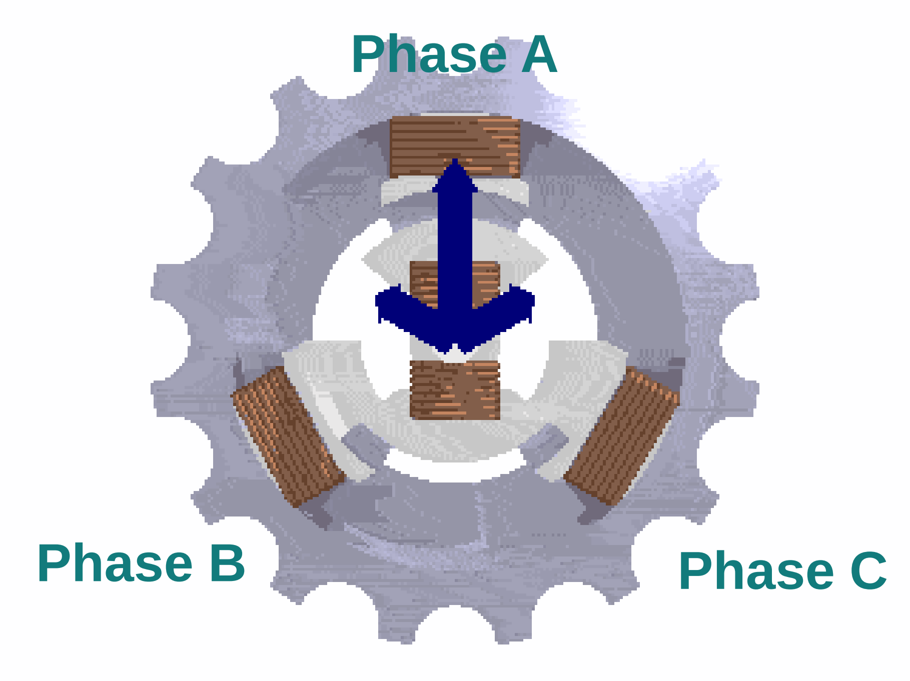
- Easy to generate in multiple "phases" that are out of synch with each other, allowing for simple motors
- Can use transformers to step voltage up/down to allow for efficient power distribution



CONS

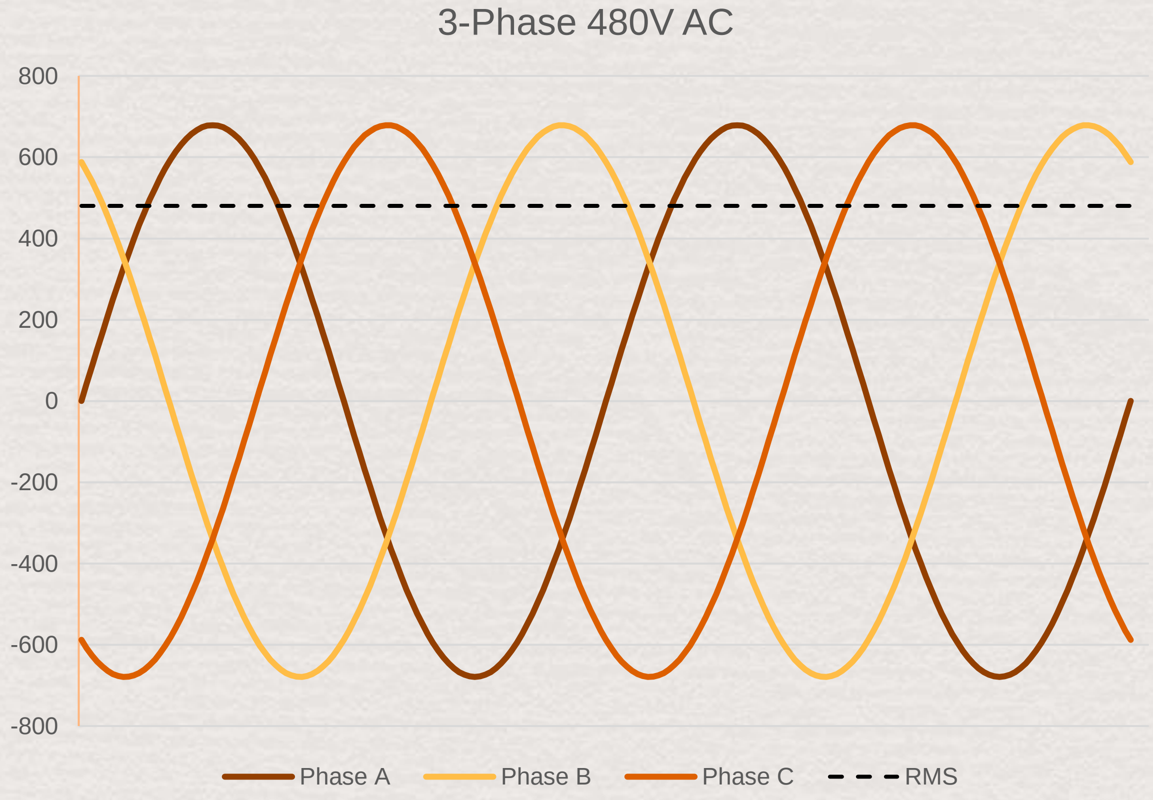
- Difficult to store
- Efficiency a complex conversation involving voltage and current waveforms and their relation to each other

Alternating Current



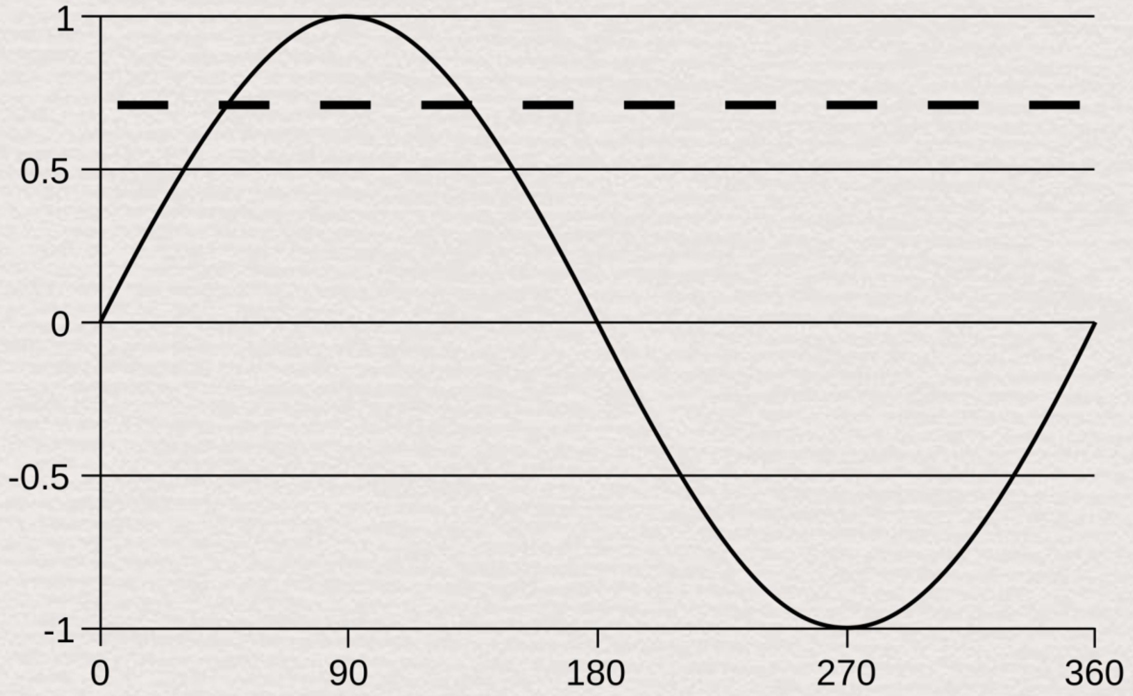
PROS

- Easy to generate in multiple "phases" that are out of synch with each other, allowing for simple motors.
- Phases called "A", "B", and "C", and each is a sine wave 120° from the others.



Alternating Current

AC Voltage is really Root-Mean-Square (RMS) value, Peak is higher!



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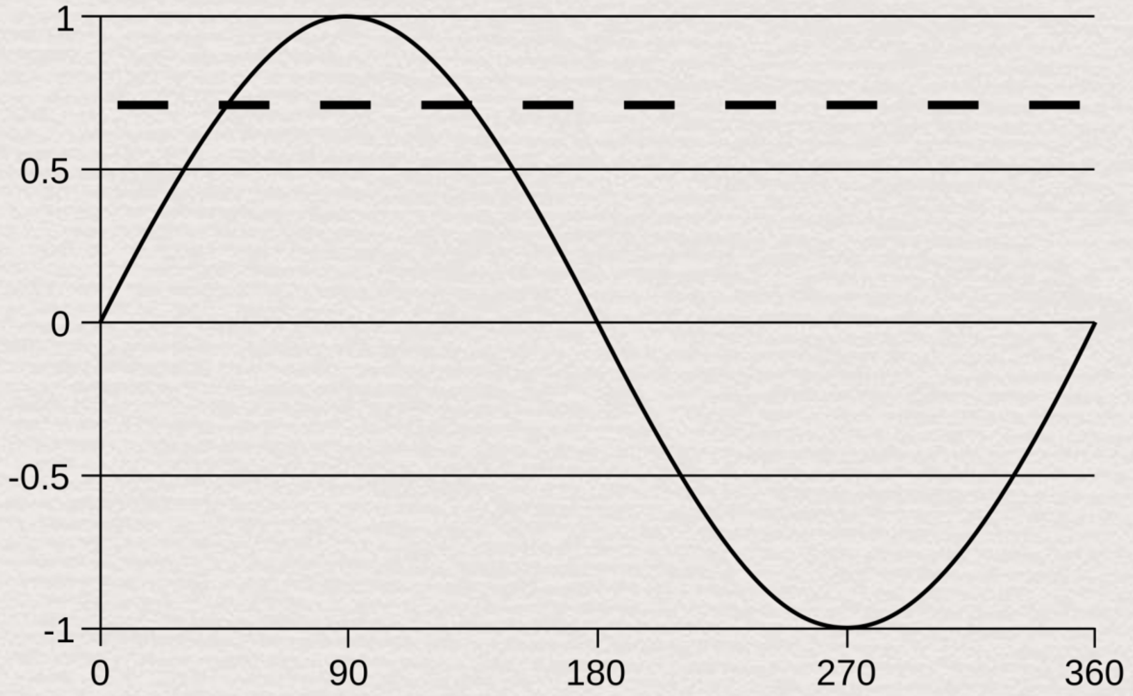
Alternating Current

Frequency is the number of times each phase goes through one cycle in a second.

North America is primarily 60 Hz (Hertz, AKA "Cycles Per Second" or "CPS"), while Europe is primarily 50 Hz. Chosen to be as low as possible without us being able to see bulbs flicker.



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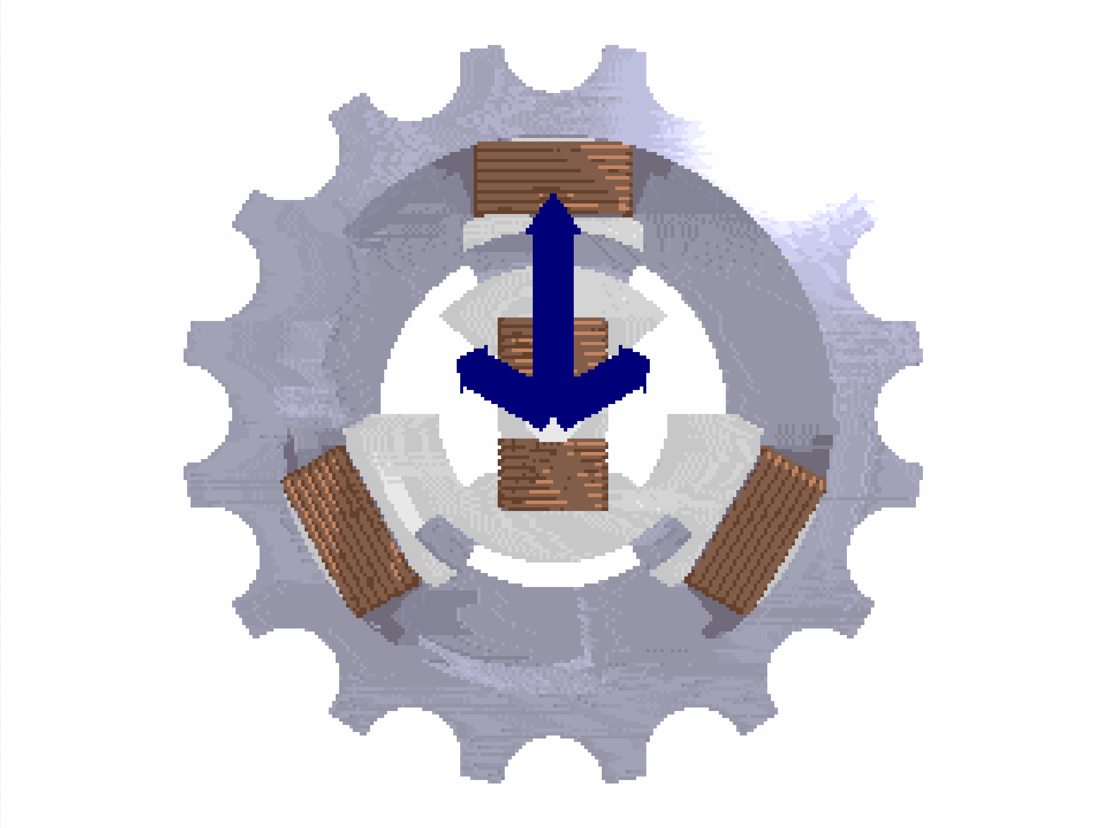
Basic Electro-magnetics

Voltage generated when coil of wire sees changing magnetic field.

Magnetic field generated when coil of wire has current passed through it.



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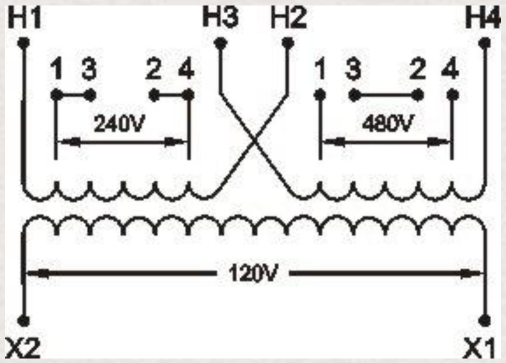
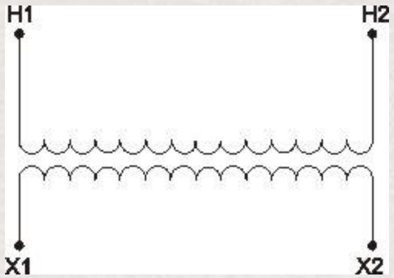
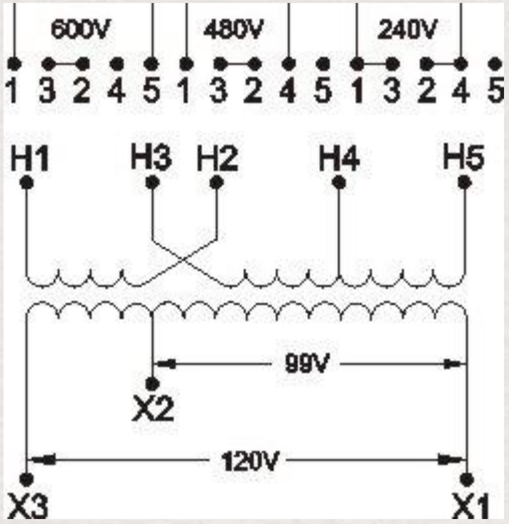
Transformers

- Two coils of wire wrapped around a common iron (ferrous) core (per phase) – one “input” and one “output”
- Ratio of coil wraps proportional to voltage change
- Input coil current induces 60 Hz magnetic field in coil
- 60 Hz magnetic field in coil induces voltage in Output coil







Transformers

- Typically “Dry” or “Oil Filled”
- Large, small, more than meets the eye!

Source: https://www.sgb-smit.com/

Source: https://commons.wikimedia.org/wiki/File:Polemount-singlephase-closeup.jpg

Source
https://en.wikipedia.org/wiki/Transformer#/media/File:Drehstromtransformater_im_Schnitt_Hochspannung.jpg

Transformers

- Typically “Dry” or “Oil Filled”
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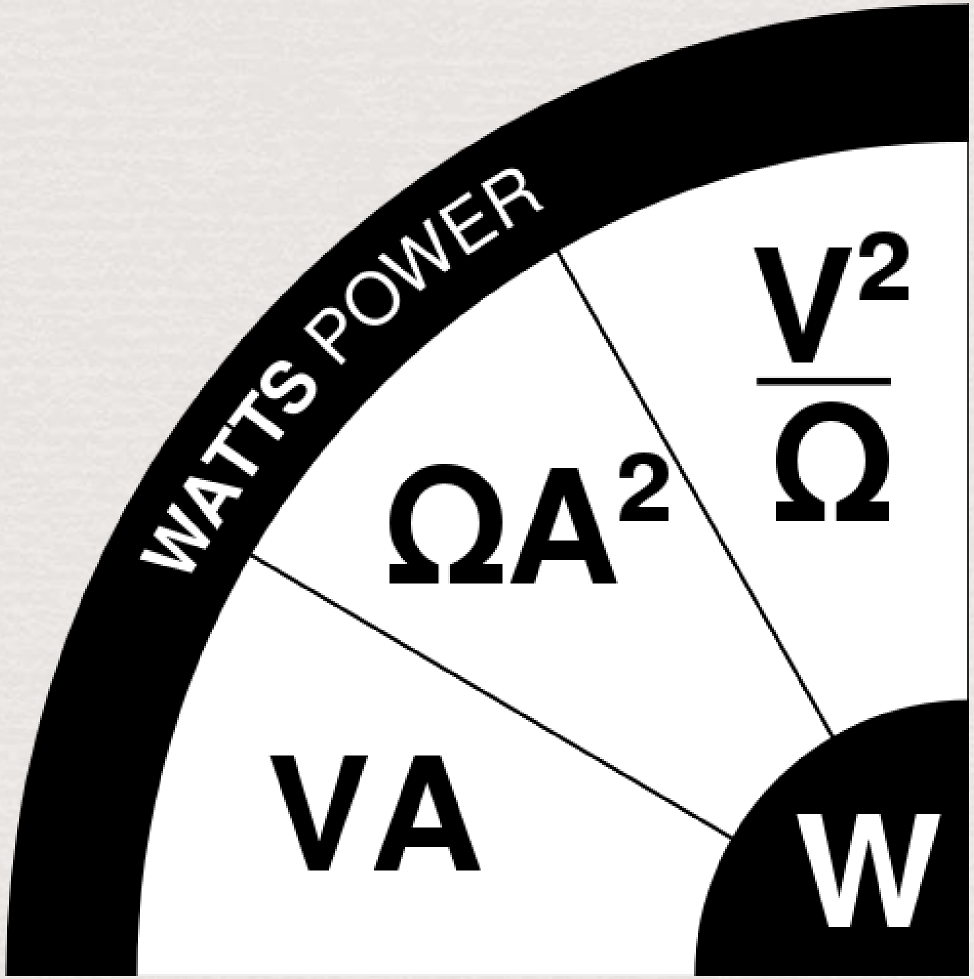
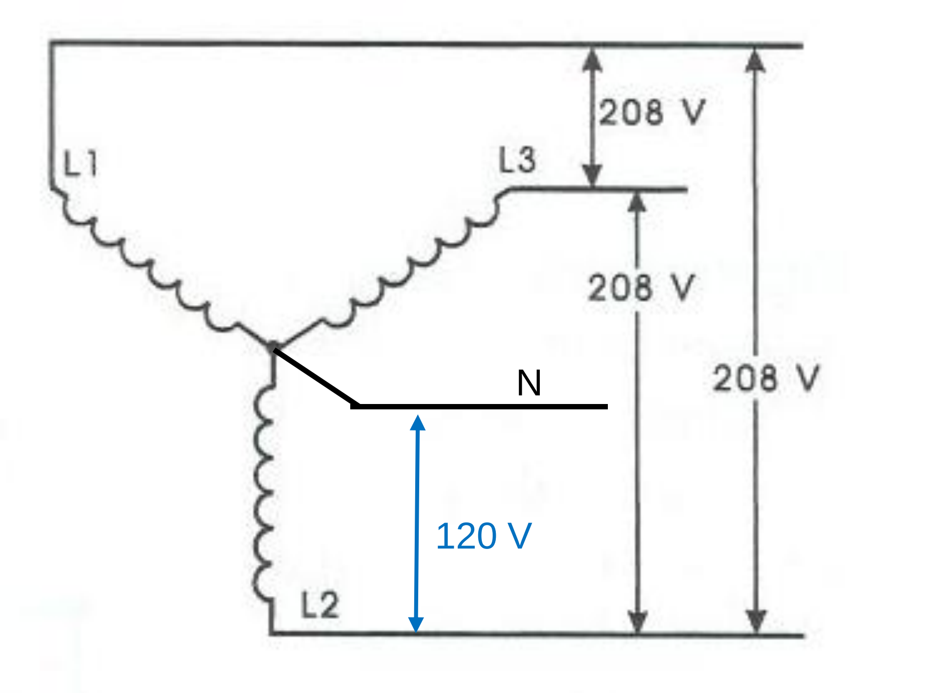
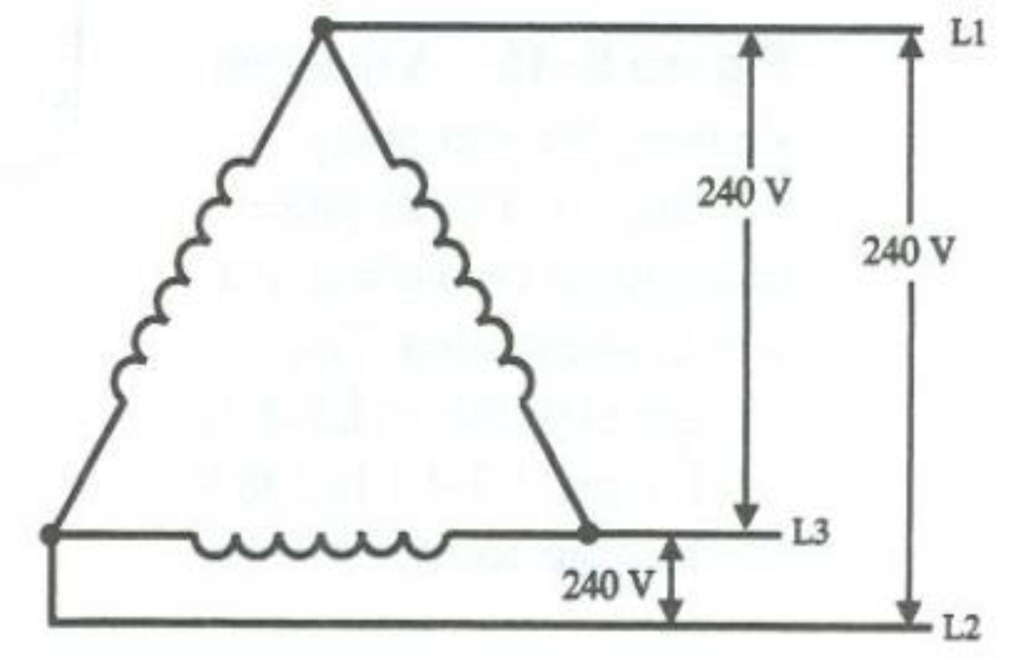


Transformers (& Motors)

Wye vs Delta

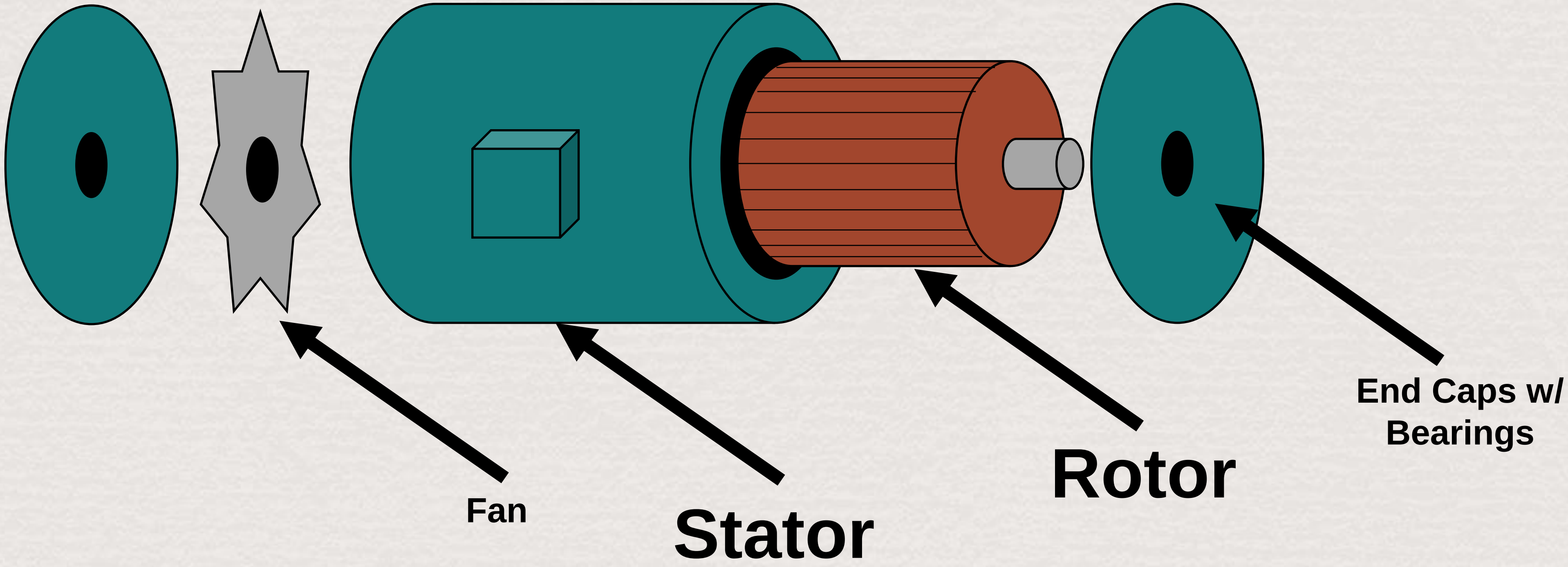




Motor Basics

Motors take electricity and turn it into rotational movement.

Generally comprised of similar parts…

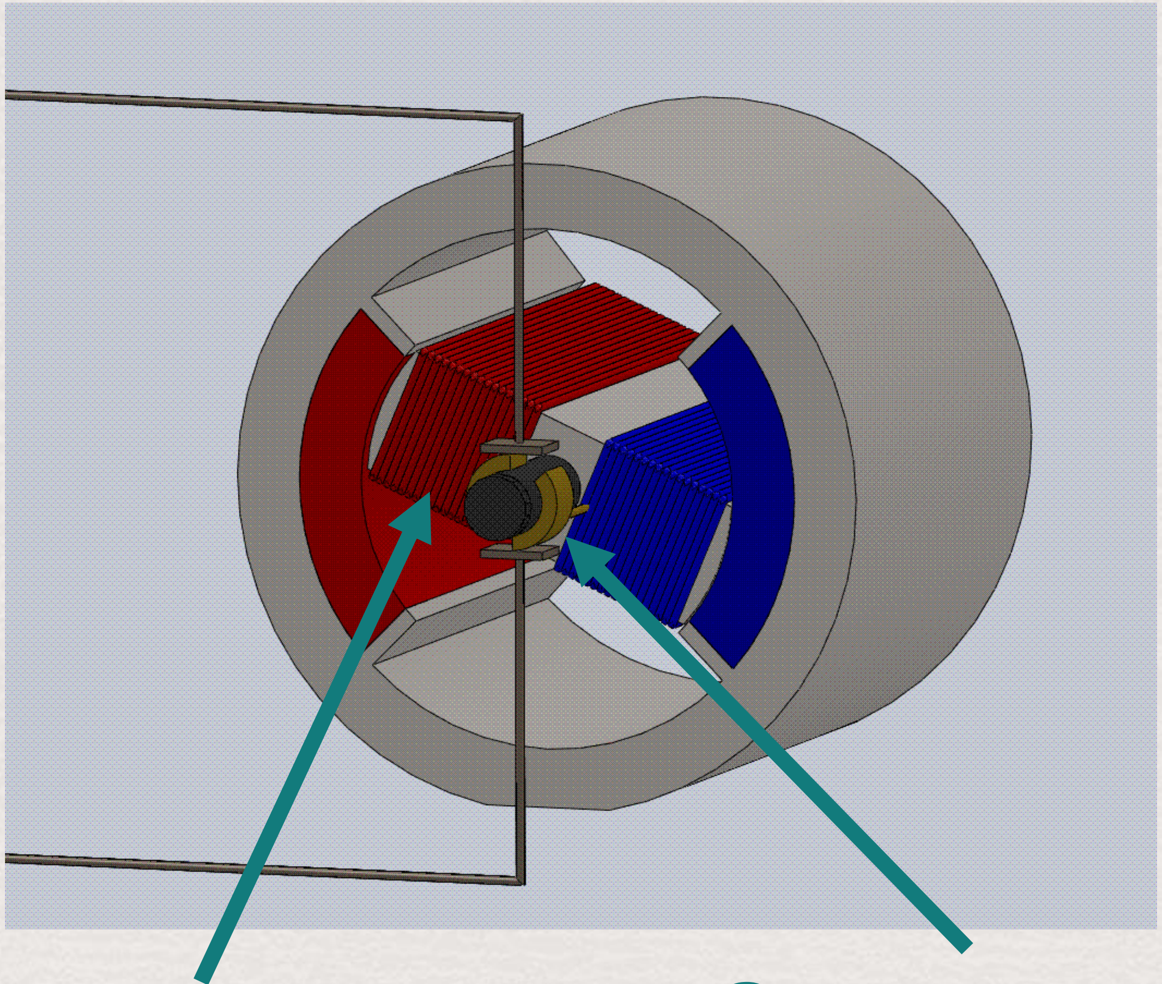


Brushed DC & Universal Motors

Use commutator and brushes to align rotor's magnetic field such that it produces torque in stator's field.

To reverse, just switch the two wires feeding commutator.

In breweries, towmotors and tools most likely, may have electromagnets for stator field.



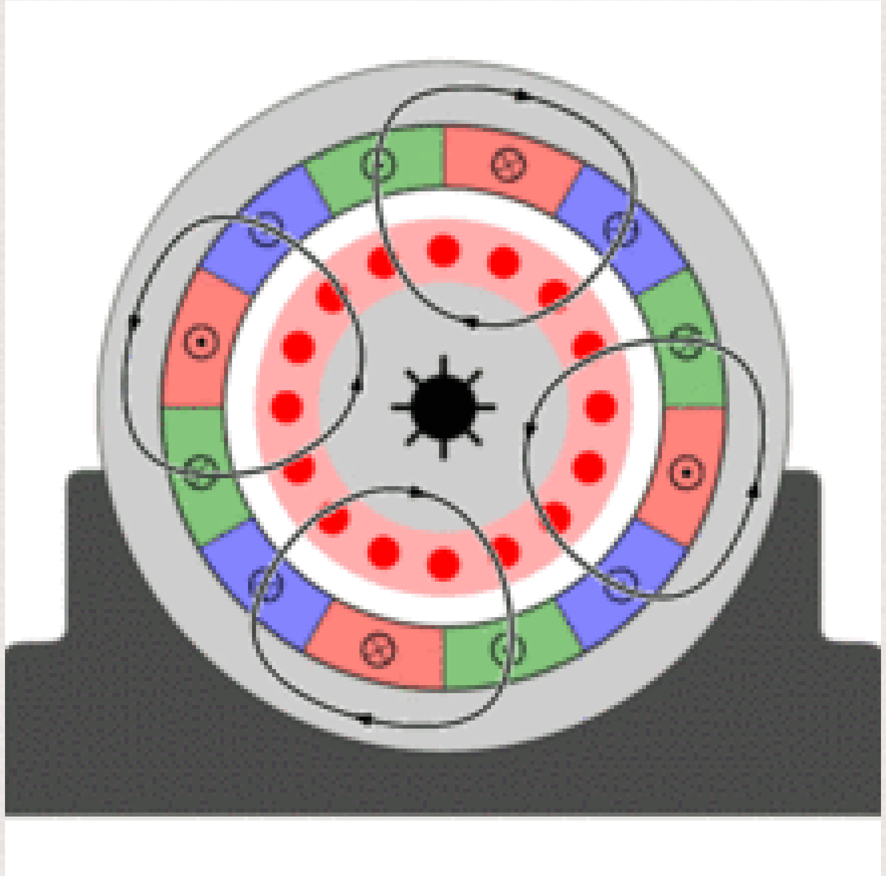
AC 3-phase Induction Motors

Loops in animation show magnetic fields.

Red dots on rotor are shorted bus bars.

Rotating magnetic field creates voltage and current in shorted bars, generating magnetic field.

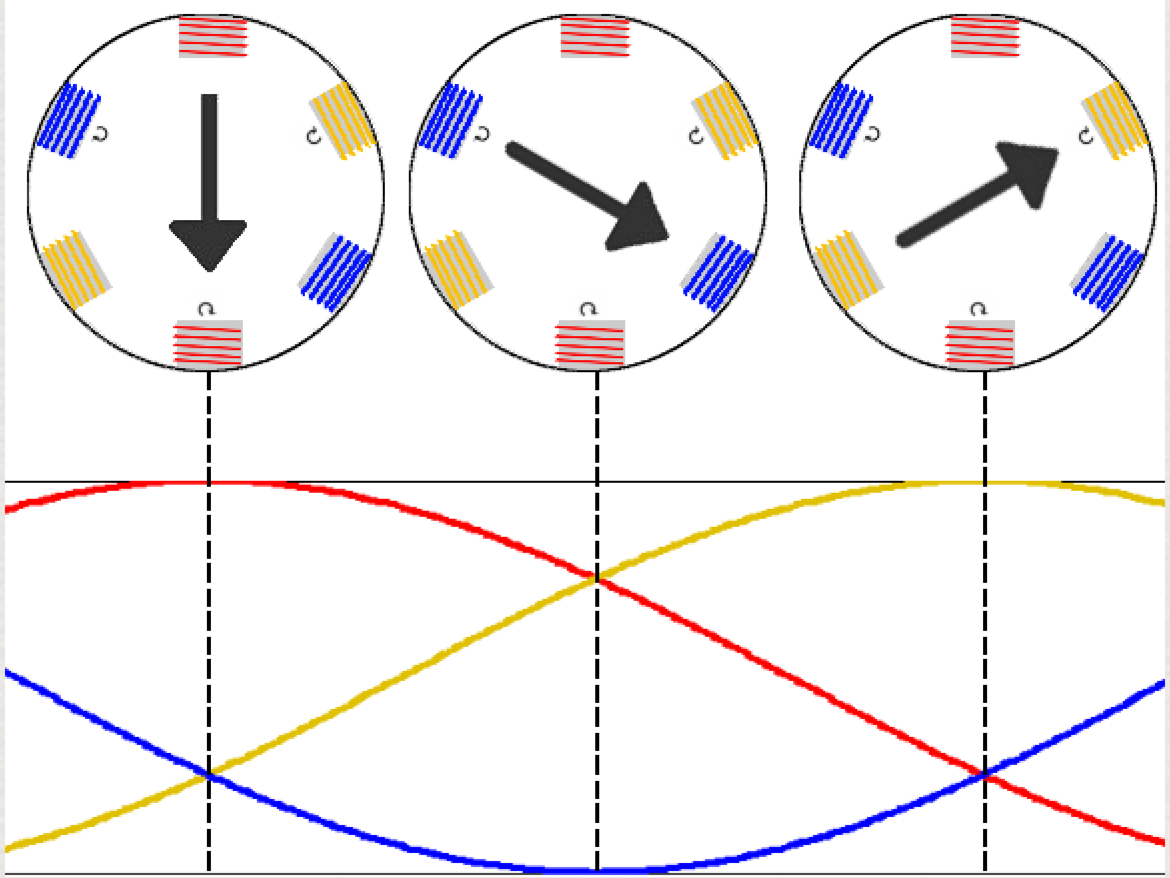
Rotor must “slip” through rotating magnetic field, so run slightly slower than field is turning.



How FAST does the motor turn?

Depends on number of "poles"…

$$n_s = \frac{120 \times f}{p}$$



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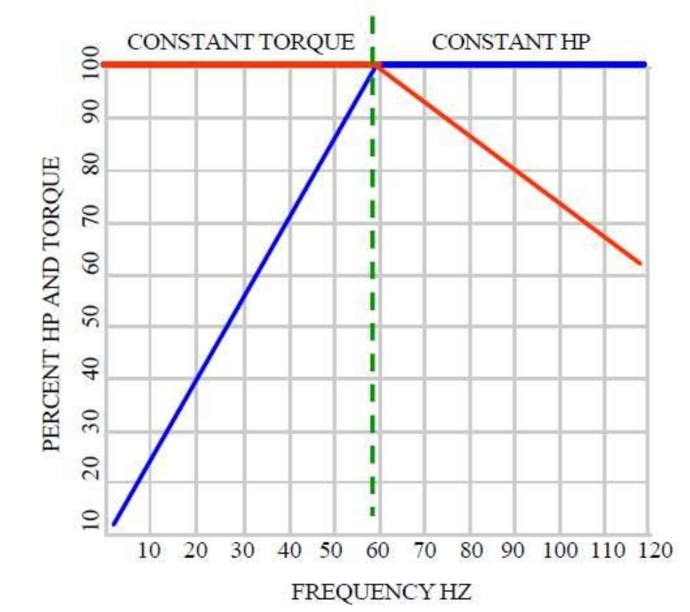
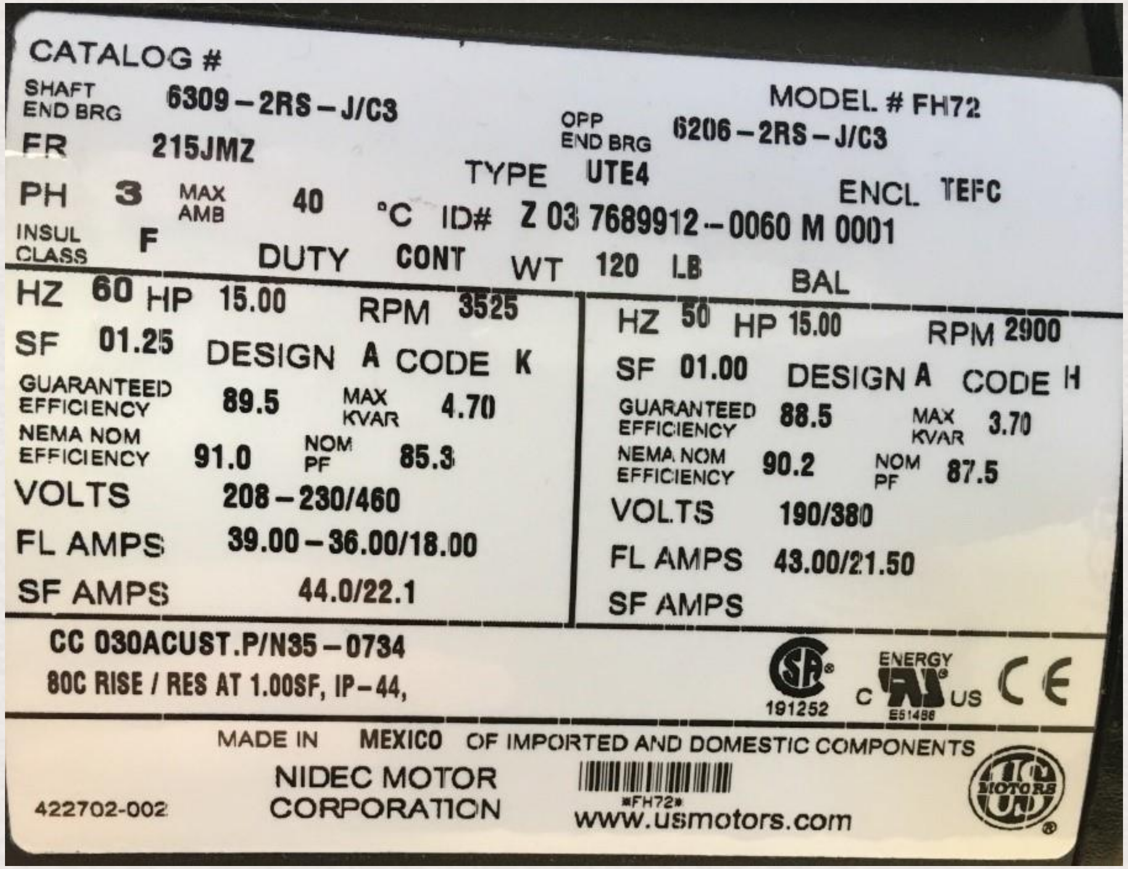
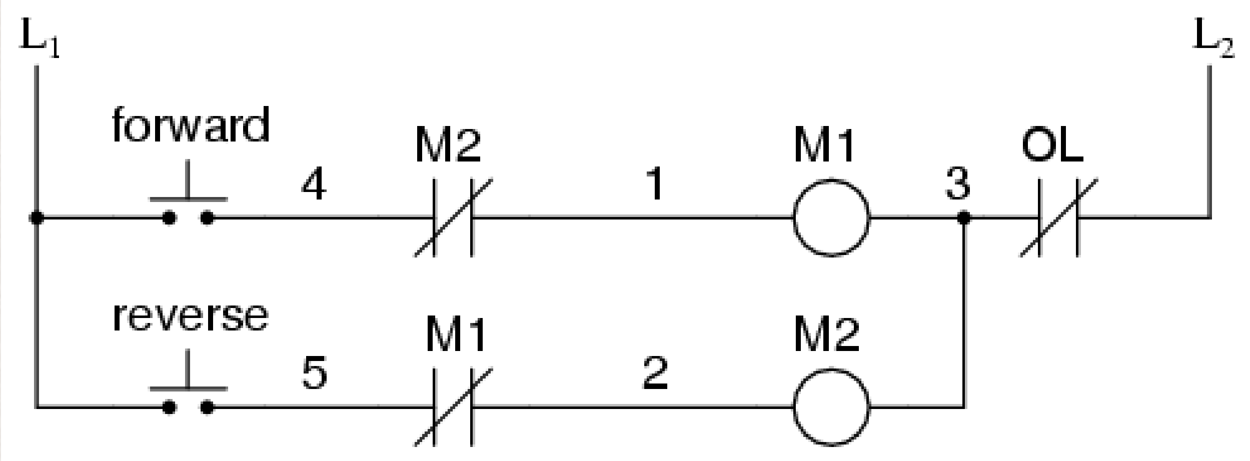


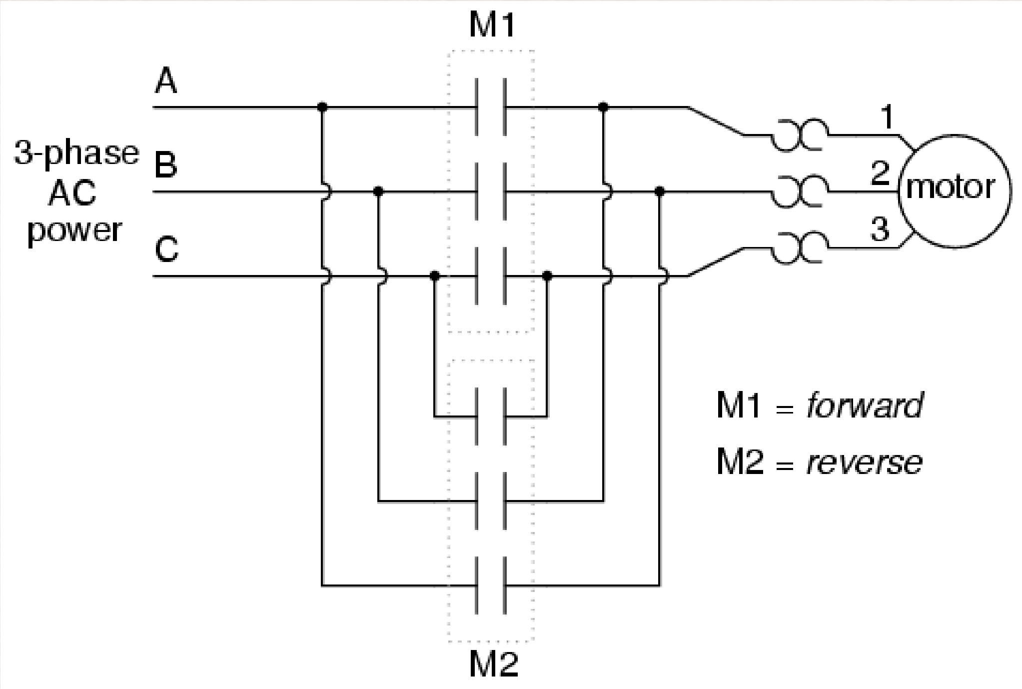
Basics of AC Motor Control

- Short Circuit Interrupting
- Overload Protection
- On/Off Control Device
- Control Circuit



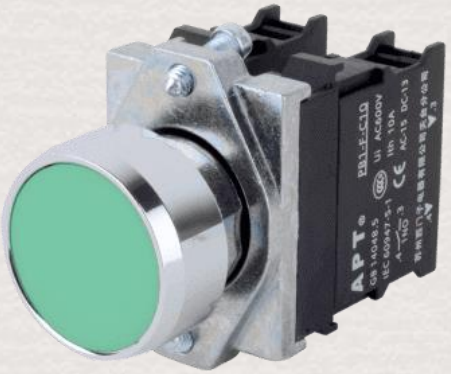
Basics of AC Motor Control





Electronics 101

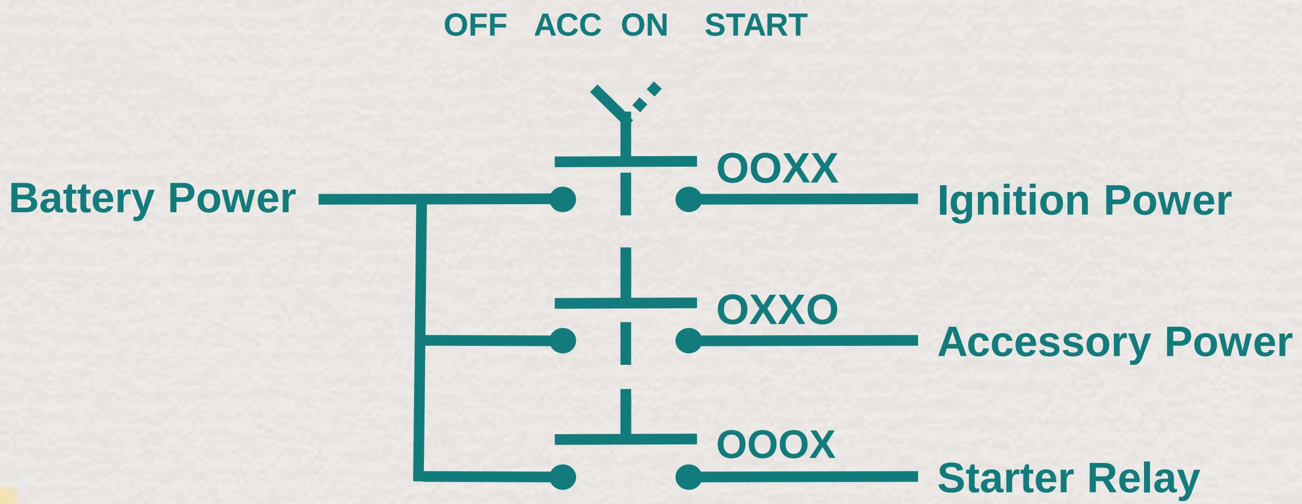
- Start with a switch – physical input toggles mechanism that either passes (on) or interrupts (off) current. "Switch" implies maintained. "Button" or "Push Button" implies momentary.



Source : https://en.wikipedia.org/wiki/Switch#/media/File:On-Off_Switch.jpg

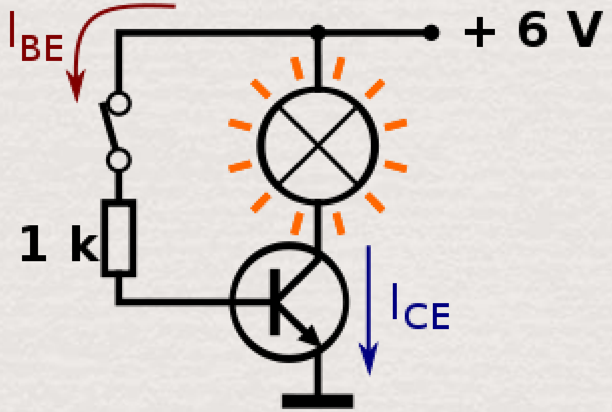
Electronics 101

- Switches can have multiple positions, different operations in different positions, and different types of contacts. For instance – car ignition!
  - Off – everything off
  - On – everything on
  - Start – accessories off, starter relay on, spring return to "On"



Electronics 101

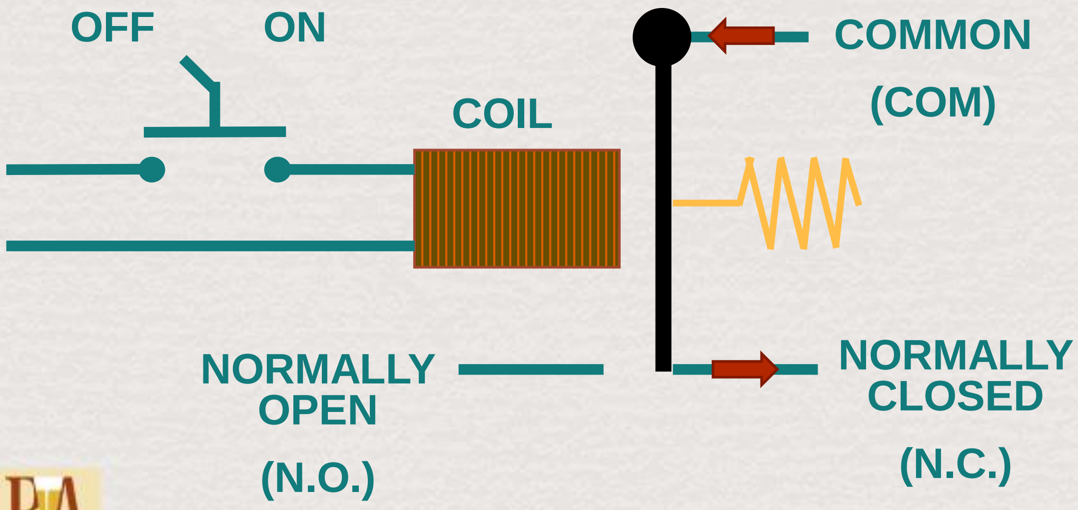
- A transistor is a switch – small current in one pin allows a large current to flow between the other two

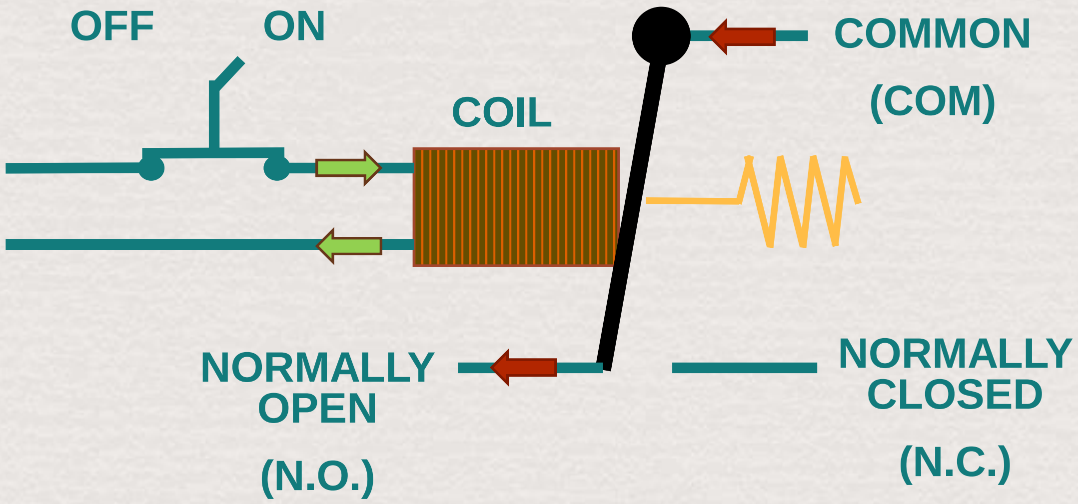


- Can be used to make Transistor-Transistor Logic "gates", such as "OR", "AND", "NAND", "NOR", "NOT", etc. that are the building blocks of all computers

Electronics 101

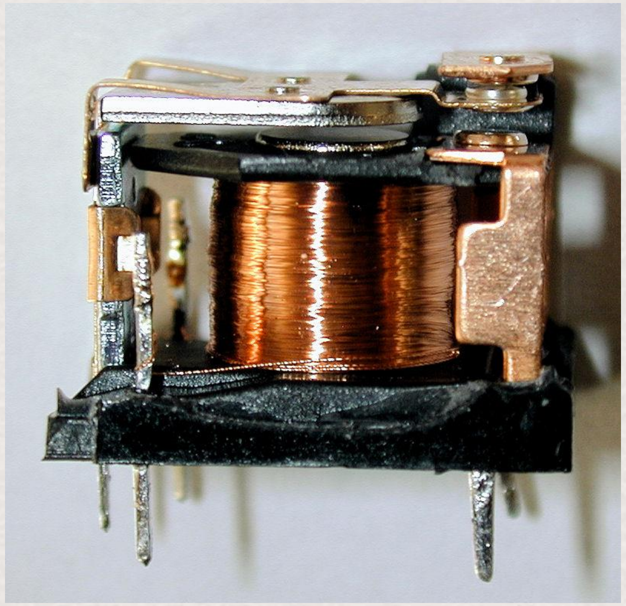
- A relay is an electro-mechanically operated set (or sets) of contacts
- Think of it as an electrically operated switch
- "Normal" condition means no power applied to coil
- Two types of contacts – Normally Open (N.O.), Normally Closed (N.C)





Electronics 101

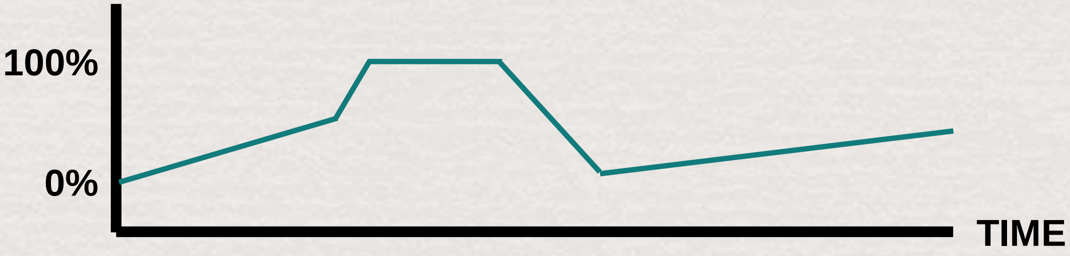
- Coils have a defined operating voltage – i.e. 24 VDC or 120 VAC
- DC Coils should have reverse diode in parallel – polarity matters!
- Contacts have ratings – pay close attention! Amps <> HP!



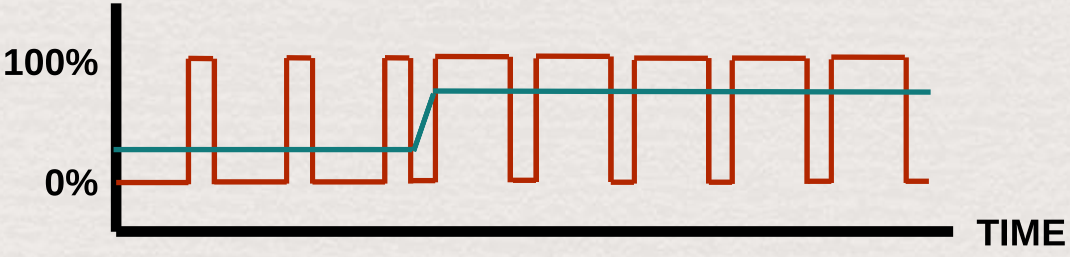
Electronics 101

- **Digital** = Two Values – zero and one, off and on, etc.
  - Light switch
  - Motor starter (relay)
  - Level Switch

- **Analog** = Many Values – 0-10V, 4-20mA, 3287-16383, etc.
  - Light dimmer
  - Variable Frequency Drive (VFD)
  - Tank Pressure



- **Pulse Width Modulation** = Digital used to time-approximate analog
  - Turn a light switch off/on fast enough, will look dim
  - Common with electric heaters

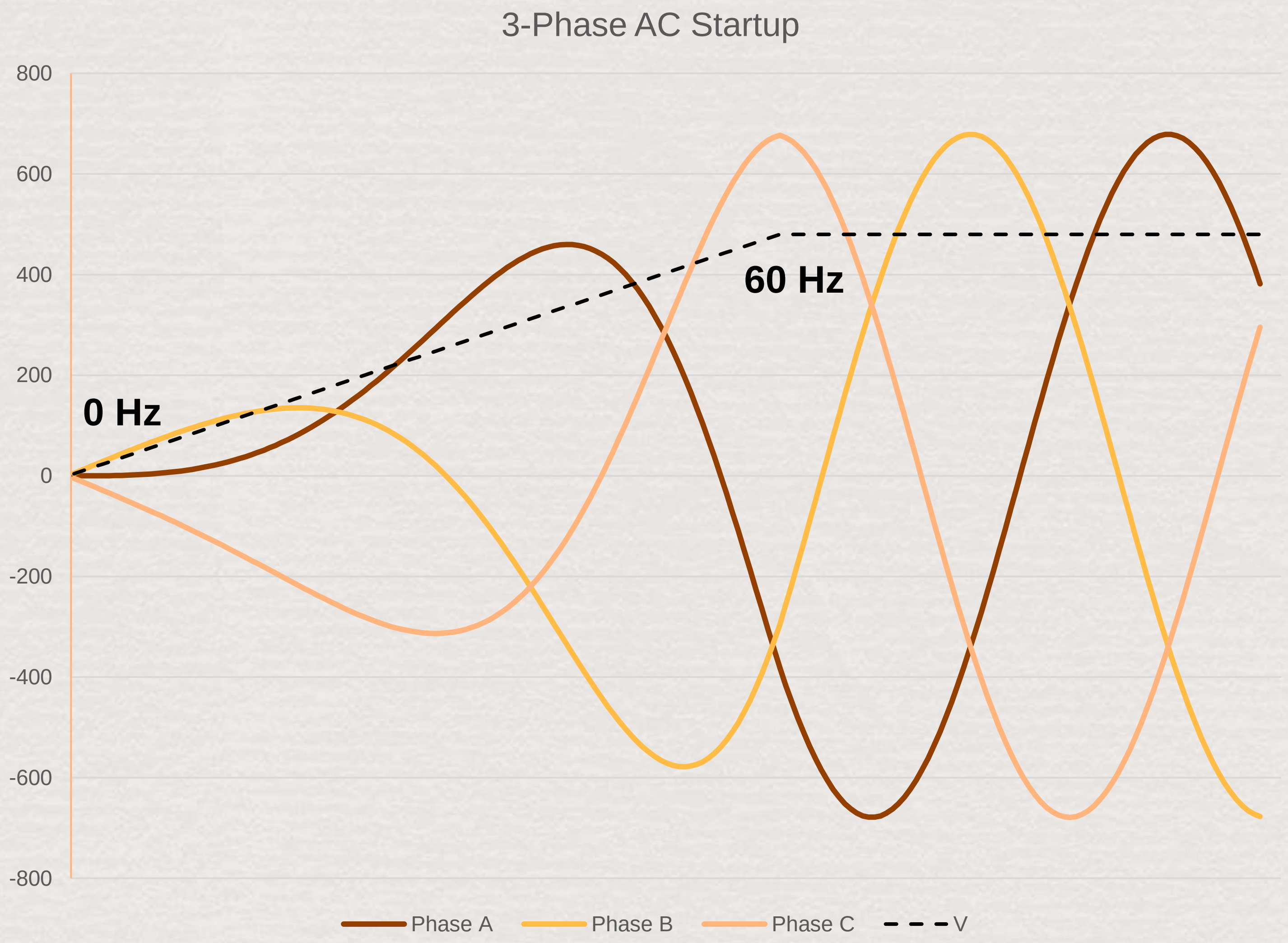


Variable Frequency Drive

Remember – an AC motor's speed is determined by FREQUENCY!

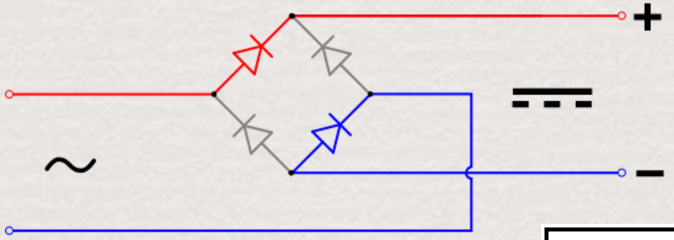
You want variable speed motor (pump, conveyor, etc.), then you have to vary the frequency.

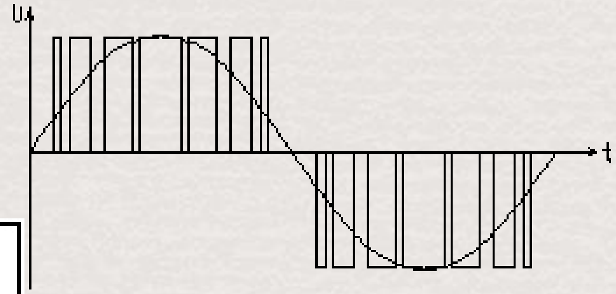
Not mentioned earlier – strength of magnetic field depends on frequency, so to keep constant we vary voltage and frequency (V/Hz)



Variable Frequency Drive

So – how do we vary voltage and frequency? A Variable Frequency Drive!





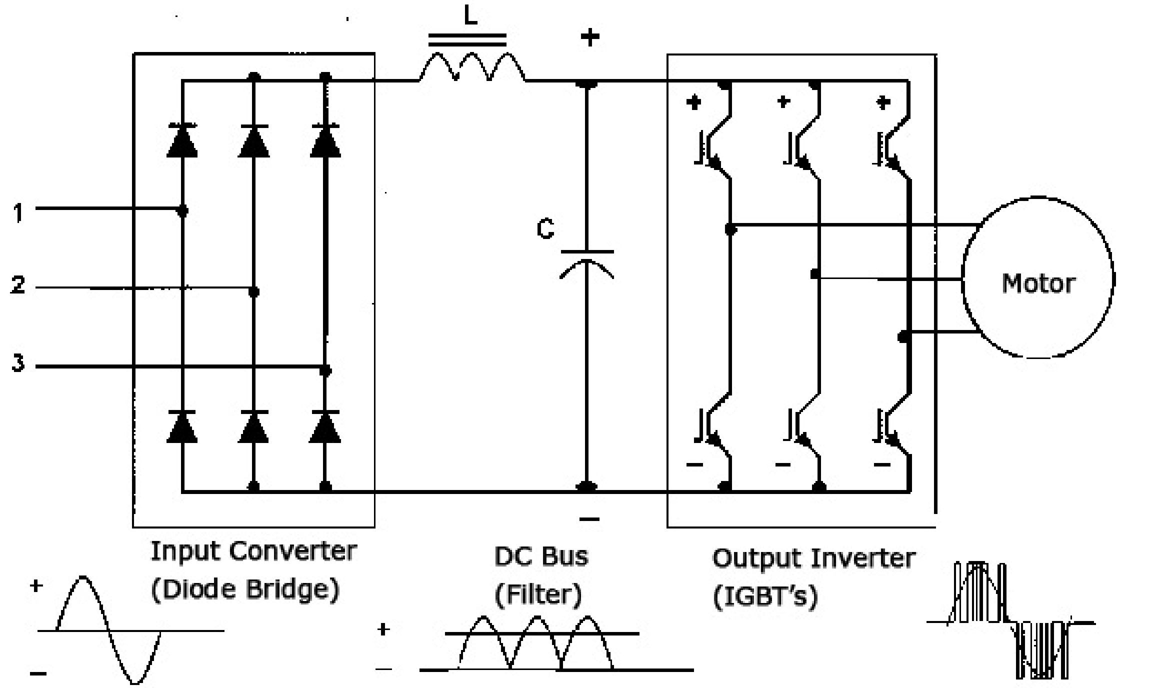
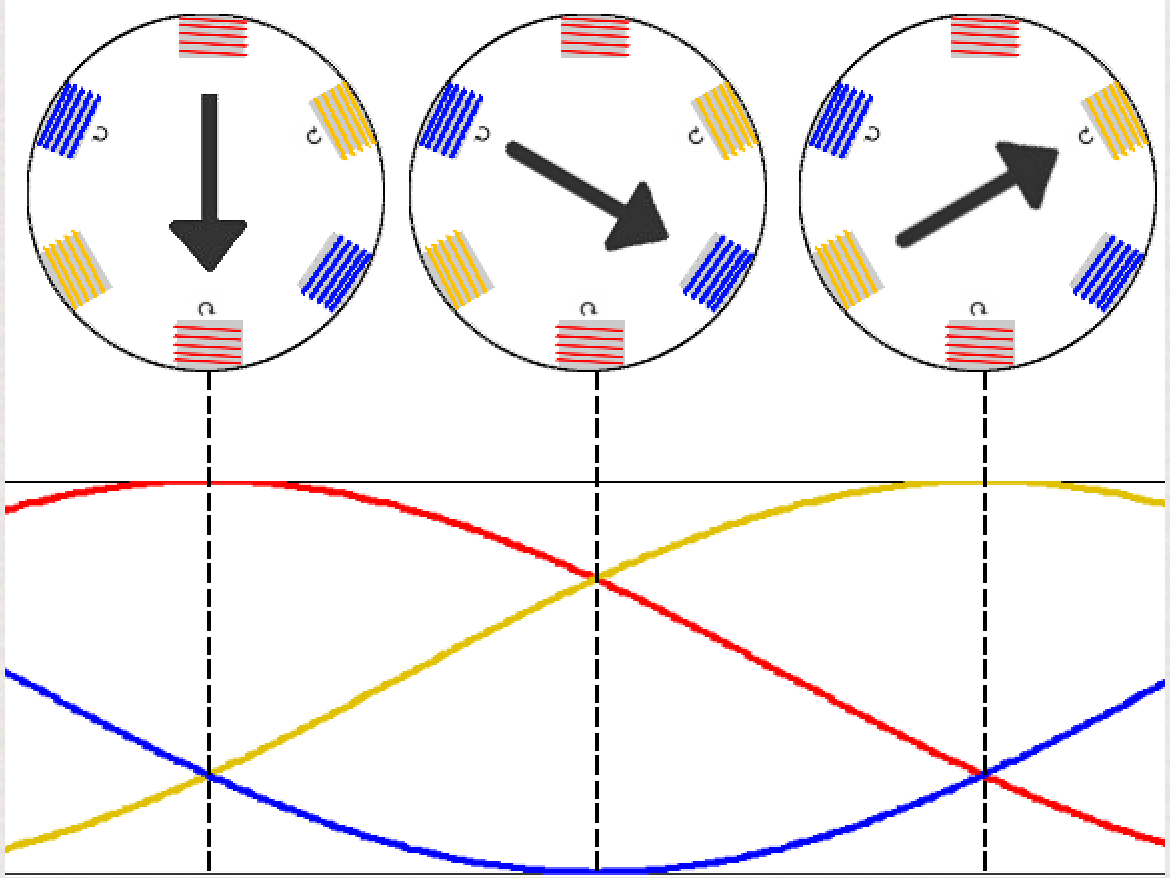


Figure 4-1: Typical Schematic of a PWM Variable Frequency Drive

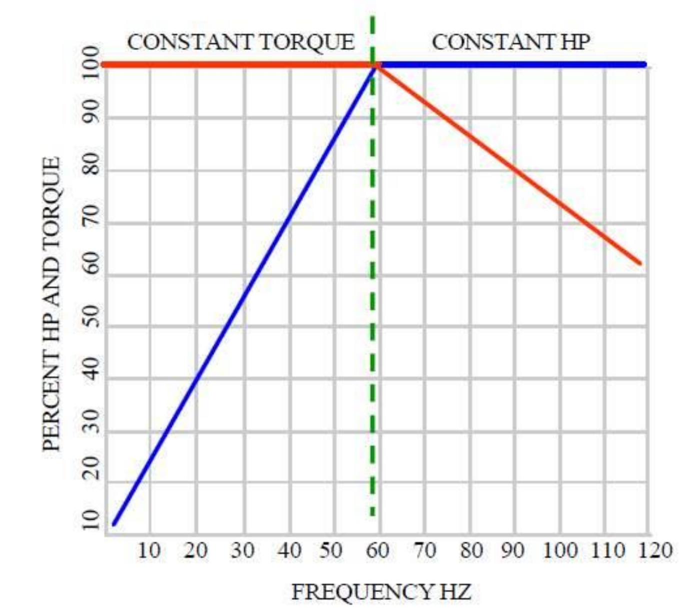
How FAST does the motor turn?

Depends on number of "poles"…

$$n_s = \frac{120 \times f}{p}$$



By Willplatts - Own work, Public Domain, https://commons.wikimedia.org/w/index.php?curid=3899711



Living with VFDs

PARAMETERS ARE EVERYTHING!!!

Record them all (ideally), or everything changed from factory defaults.

Keep manuals handy!

1 Main Drive PowerFlex 70

1.1 When you switch on for the first time:

- Select language -> Enter -> Enter -> The commissioning menu appears (manually with ESC -> Alt ->+/-)

1.2 Set parameter 196 to "All"

1.3 Parameter 197 is factory-set to 480 V. This parameter must be changed for 400 V.

1.4 Set parameter 46 (HP or KW)

1.5 Set the remaining parameters according to Table 1.1

	Parameter Name	Current Value	Value Number	
40	Motor Type	Induction / Synchro PM	0 / 2	Synchro parameter
41	Motor NP Volts	Data according to rating plate	-	Motor data
42	Motor NP FLA	Data according to rating plate	-	Motor data
43	Motor NP Hertz	Data according to rating plate	-	Motor data
44	Motor NP RPM	Data according to rating plate	-	Motor data
46	Mtr NP Pwr Units	Data according to rating plate	0 / 1	Motor data
53	Torque Perf Mode	Sensrls Vect (V/Hz value)	0	Synchro parameter
54	Maximum Voltage	400 V		For 460V motor→ 460V
55	Maximum Freq	100.0 (136) Hz	-	Masks, set-point value
69	Start/Acc Boost	2.5 (9.9) VAC	-	Synchro parameter
70	Run Boost	2.5 (9.9) VAC	-	Synchro parameter
71	Break Voltage	115.0 (85) VAC	-	Synchro parameter
72	Break Frequency	15.0 (22) Hz	-	Synchro parameter
82	Maximum Speed	100.0 (136) Hz	-	Masks, set-point value
83	Overspeed Limit	0.0 Hz	-	Masks, set-point value
90	Speed Ref A Sel	DPI Port 5	22	Bus parameter
140	Accel Time 1	10.0 sec	-	Ramps
141	Accel Time 2	10.0 sec	-	Ramps
142	Decel Time 1	2.5 sec	-	Ramps
143	Decel Time 2	5.0 sec	-	Ramps
146	S Curve	0 (20) %	-	Synchro parameter
155	Stop Mode A	Ramp	1	Ramps
156	Stop Mode B	Ramp	1	Ramps
161	Bus Reg Mode A	Dynamic Brak	2	Bus parameter
162	Bus Reg Mode B	Dynamic Brak	2	Bus parameter
163	DB Resistor Type	External Res	1	Bus parameter
190	Direction Mode	Reverse Dis	2	Masks, set-point value
196	Param Access Lvl	Advanced	1	Masks, set-point value
201	Language	German	-	Masks, set-point value
276	Logic Mask	XXXXXXXX XX101111	-	Masks, set-point value
277	Start Mask	XXXXXXXX XX000001	-	Masks, set-point value
278	Jog Mask	XXXXXXXX XX000001	-	Masks, set-point value
279	Direction Mask	XXXXXXXX XX000001	-	Masks, set-point value
280	Reference Mask	XXXXXXXX XX000001	-	Masks, set-point value
281	Accel Mask	XXXXXXXX XX000001	-	Masks, set-point value
282	Decel Mask	XXXXXXXX XX000001	-	Masks, set-point value
283	Fault Clr Mask	XXXXXXXX XX101111	-	Masks, set-point value
284	MOP Mask	XXXXXXXX XX000001	-	Masks, set-point value
285	Local Mask	XXXXXXXX XX000001	-	Masks, set-point value
361	Digital In1 Sel	Stop – CF	4	Digital input
362	Digital In2 Sel	Run	7	Digital input
363	Digital In3 Sel	Decel 2	22	Digital input

Tab. 1.1

File D	Group	No.	Parameter Name and Description See page 14 for symbol descriptions	Values	Related
DYNAMIC CONTROL (File D)	Stop/Brake Modes	161 162	**[Bus Reg Mode A]** **[Bus Reg Mode B]** Active bus regulation mode. Choices are dynamic brake, frequency adjust or both. Sequence is determined by programmed value or digital input programmed for "Bus Reg Md B." Dynamic Brake Setup If a dynamic brake resistor is connected to the drive, both these parameters must be set to either option 2, 3 or 4. Refer to the Attention statement on page 10 for important information on bus regulation.	Default: 1 "Adjust Freq" 4 "Both-Frq 1st" Options: 0 "Disabled" 1 "Adjust Freq" 2 "Dynamic Brak" 3 "Both-DB 1st" 4 "Both-Frq 1st"	155 156 160 163 361… 366
		163	**[DB Resistor Type]** Selects whether the internal or an external DB resistor used. If a dynamic brake resistor is connected to the drive, P161/162 [Bus Reg Mode x], A, B or Both (if used), must be set to either option 2, 3 or 4.	Default: 0 "Internal Res" 2 "None" EC Options: 0 "Internal Res" 1 "External Res" 2 "None"	161 162 166

ATTENTION: The drive does not offer protection for externally mounted brake resistors. A risk of fire exists if external braking resistors are not protected. External resistor packages must be self-protected. from over temperature or the protective circuit shown in Figure 1 on page 106 (or equivalent) must be supplied.

ATTENTION: The drive does not offer protection for externally mounted brake resistors. A risk of fire exists if external braking resistors are not protected. External resistor packages must be self-protected from over temperature or the protective circuit shown in Figure 1 on page 106, or equivalent, must be supplied.

ATTENTION: Equipment damage can result if a drive mounted (internal) resistor is installed and this parameter is set to "External Res." Thermal protection for the internal resistor is disabled, resulting in possible device damage.

Note about Binary

There are 10 types of people in the world; Those who understand binary and those who don't. (HINT – 0b10 in binary is decimal "2")

Computers are build on transistors, which have two states – so <u>everything</u> they do at some level is base 2, AKA binary. Memory just a bunch of transistors, each either on (1) or off (0), organized into "words" of a specific length.

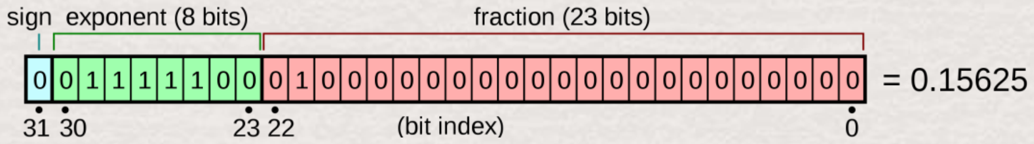
	8-Bit Word								
	MSB							LSB	
2^	7	6	5	4	3	2	1	0	Check
=	128	64	32	16	8	4	2	1	
0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	1	1
2	0	0	0	0	0	0	1	0	2
3	0	0	0	0	0	0	1	1	3
4	0	0	0	0	0	1	0	0	4
8	0	0	0	0	1	0	0	0	8
167	1	0	1	0	0	1	1	1	167
255	1	1	1	1	1	1	1	1	255

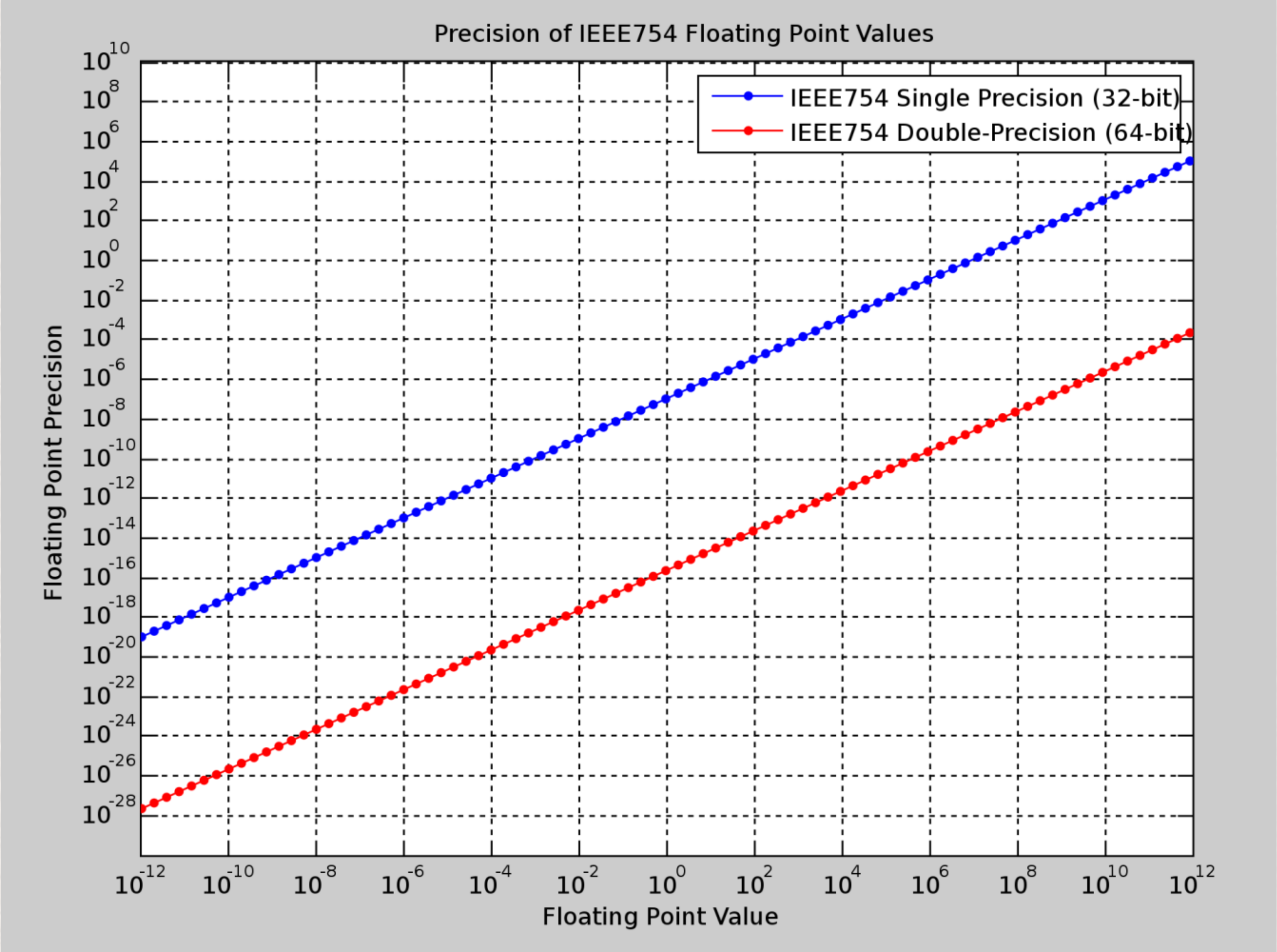
Floating Point Nonsense

That works for integers, but what about numbers that contain decimal points?

Enter IEEE Floating Point!

BUT…<u>not perfect</u>. Precision after the decimal point varies with magnitude of the number.

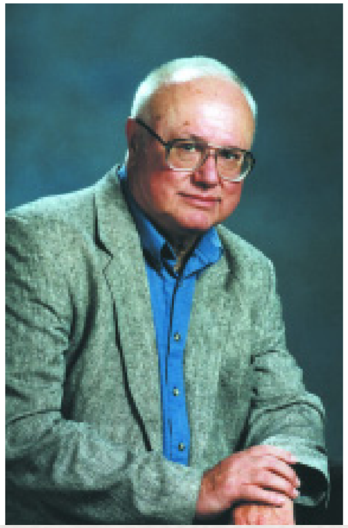




Why computers? PLCs!

This industry OWNS Programmable Logic Controllers!

The inventor, Dick Morley, invented them in 1978 DURING A HANGOVER!!!



Dick Morley is the founder of Modicon (now Schneider Automation, Inc.) and the inventor of the PLC.

Today, he continues his work as a nationally recognized expert in the field of computer design, artificial intelligence, automation, and authority on the factory of the future. Morley is an engineer, consultant and inventor, who holds more than 20 United States and foreign patents.

Memoir of an ubergeek: How we invented the PLC during a hangover, and other stories

Written by Dick Morley
Thursday, 22 September 2005 11:48

That's enough historical perspective. Now is the fun part: My innovation—the programmable logic controller (PLC) germinated on New Years' Day during a hangover—really! Our consulting company had been designing machine control systems using DEC mini-computers. Just like the philosophy of problem solving with shrink-wrap technology, our PLC was "one size fits all" and built like a brick greenhouse. There was no on/off switch, no fans and an object type of program that simulated relay logic. We didn't know about the General Motors effort or the Digital Equipment Company (DEC) effort. Like my Rottweilers, stupidity wins. We staggered into the marketplace with a clean sheet of paper and made a couple of bucks. Our initial seed money came from one of the founders of DEC.

Why computers? PLCs!

Before PLCs, we had panels and panels full of relays and analog control circuits.

What IS a PLC?

Industrially hardened computer that runs its “logic” continuously

Typically has expandable input/output (I/O) options

Typically can handle both digital and analog signals, both in/out

Most have some sort of communication capability for IO, drives, screens, etc.

Some even safety-rated, meaning e-stop system can be PROGRAMMED! ($$$)

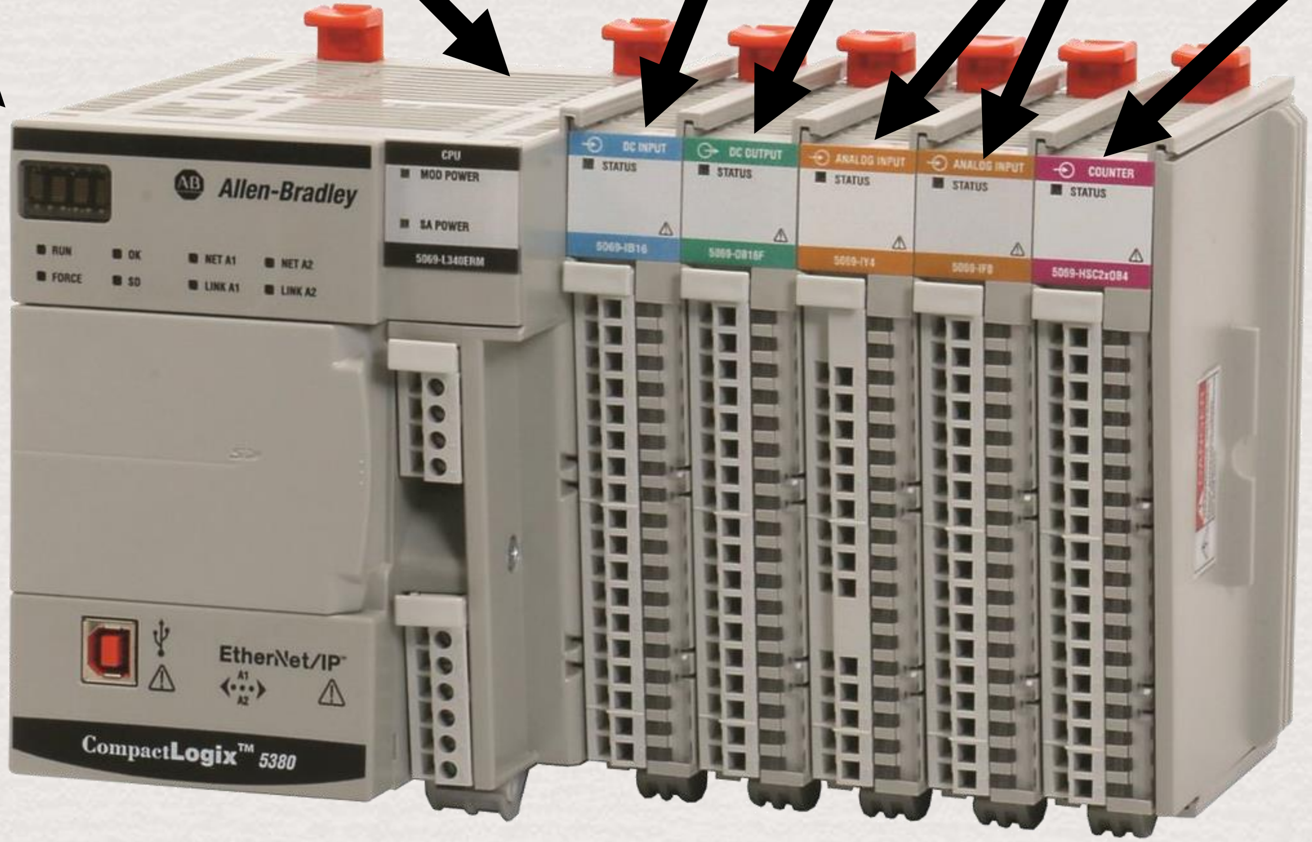
What are the parts of a PLC?

Power Supply
(integrated in this case)

Processor (PLC)

IO Cards

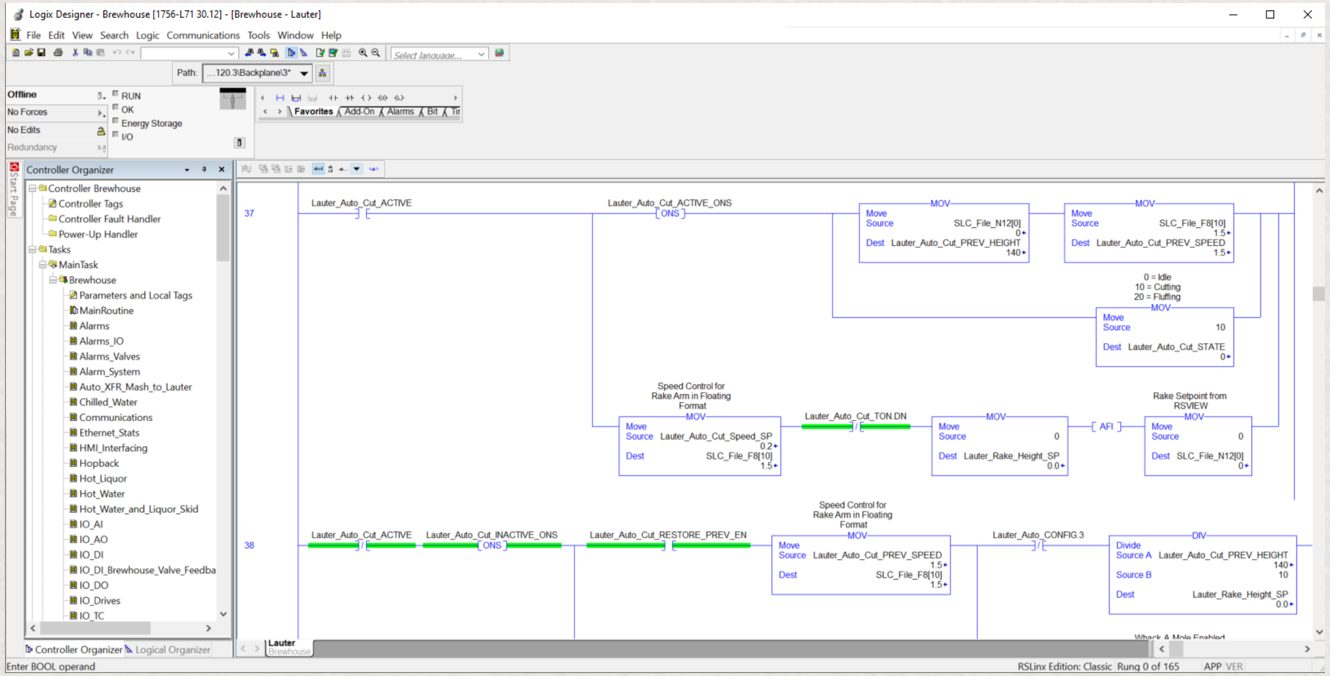
DC In — DC Out — Analog In (x2) — Counter (encoder)



How do you Program them?

Every manufacturer has their own software, typically unique to the type of PLC hardware, and/or firmware revision.

Most programmed in “Ladder Logic”, but “Function Block”, “Sequential Function Chart”, and “Structured Text” also options.



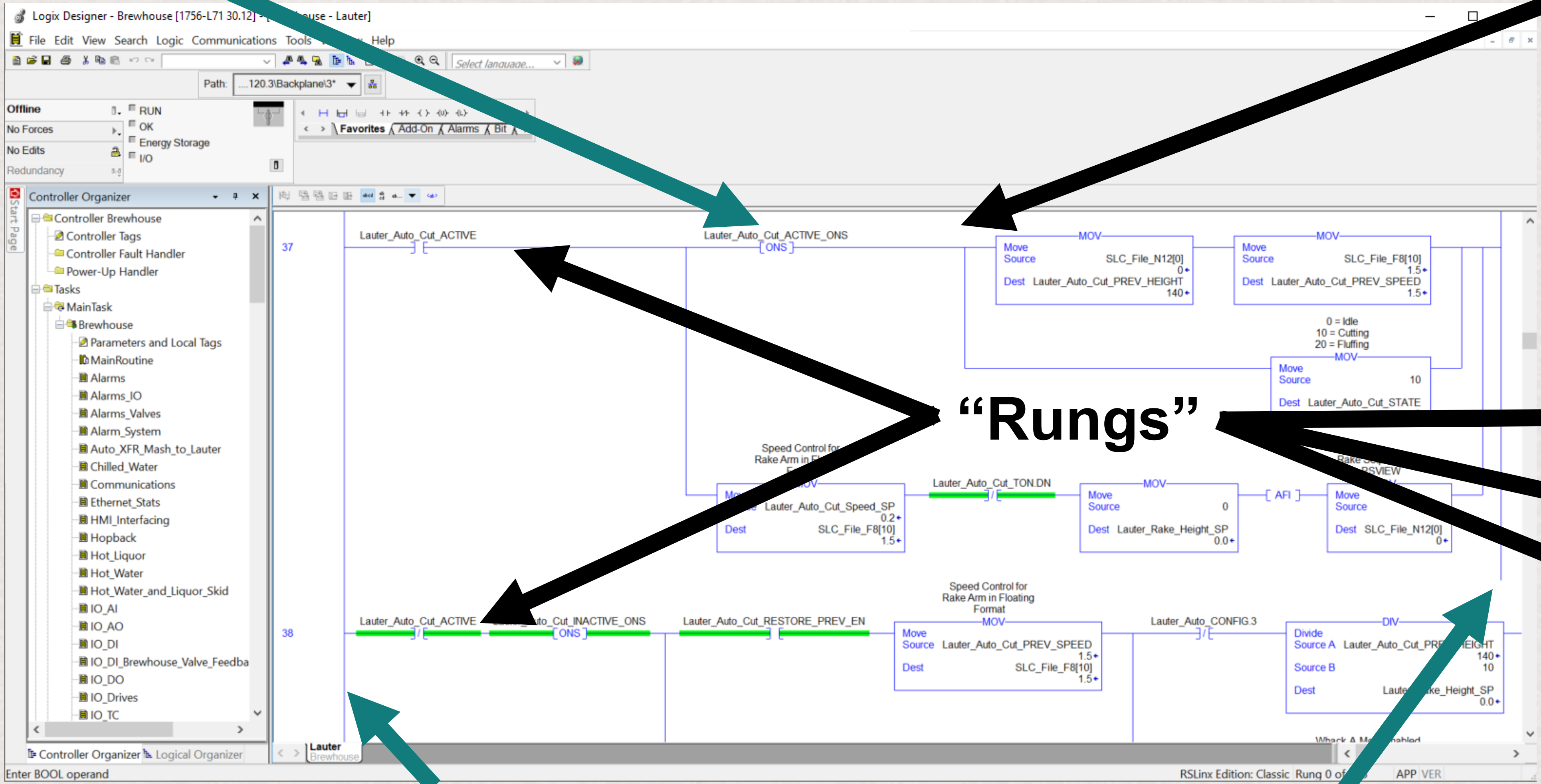
BREWERS ASSOCIATION

#CraftBrewersCon

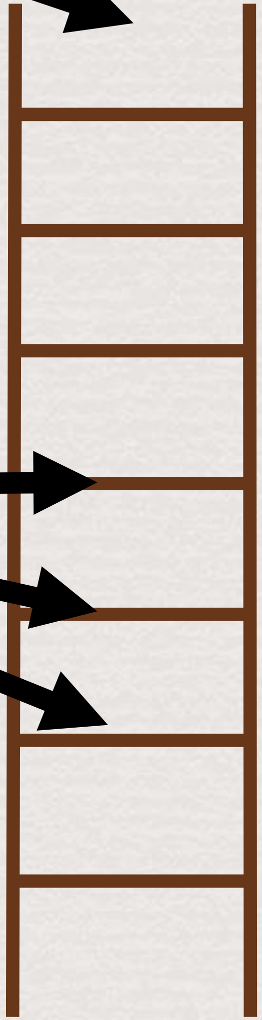
How do you Program them?

“Instructions”

“Ladder”



“Rungs”



“Hot Rail”

“Neutral” or “Common Rail”

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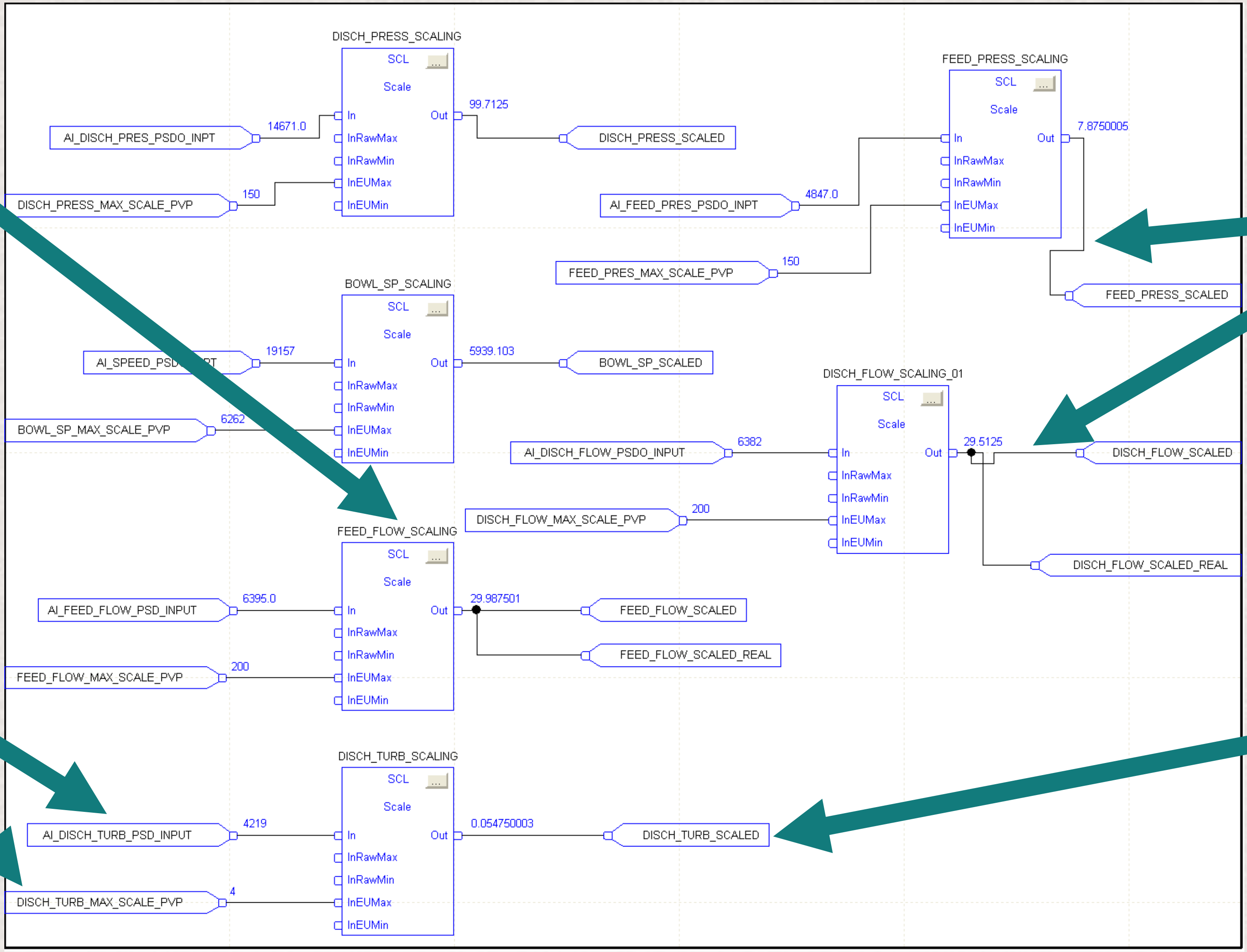
How do you Program them?

"Instructions"
AKA
"Function Block"

"Wire" or
"Connection"

Input Tags

Output Tag



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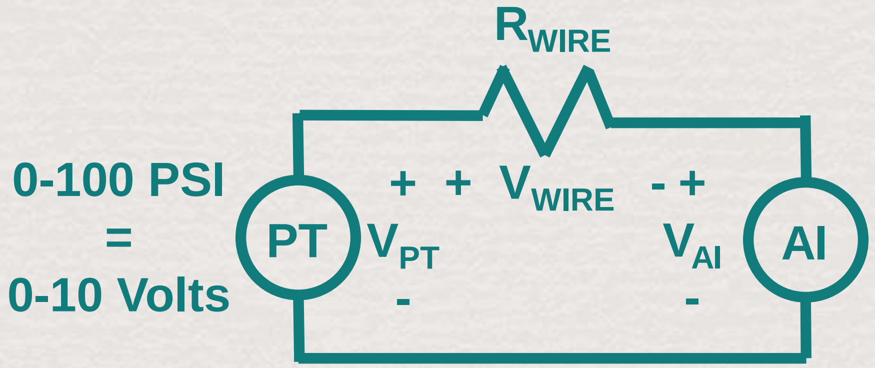
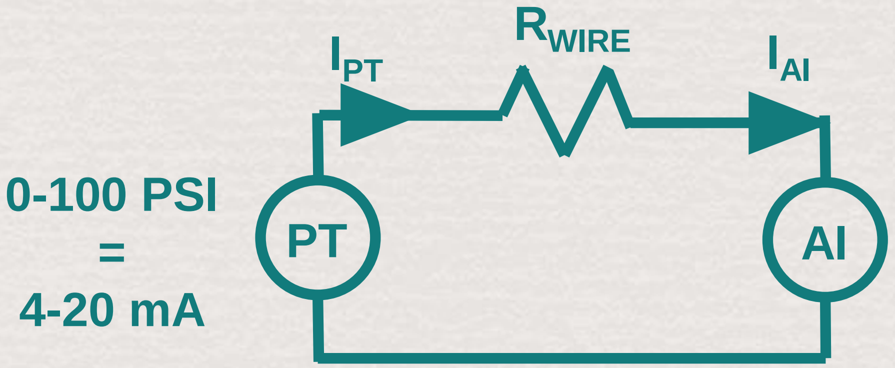
Analog Signals

Talked about Digital (on/off), what about Analog (variables)?





0-10 Volt

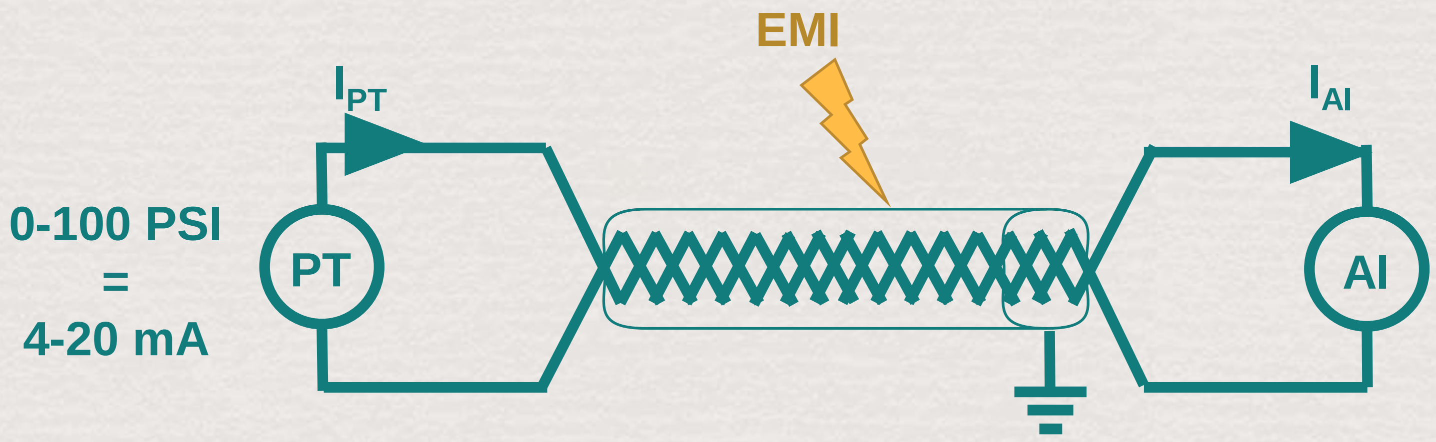
$V_{AI} <> V_{PT}$!

4-20 mA

$I_{AI} = I_{PT}$!

Analog Signals

Why "shielded twisted pair" cabling for analog signals?

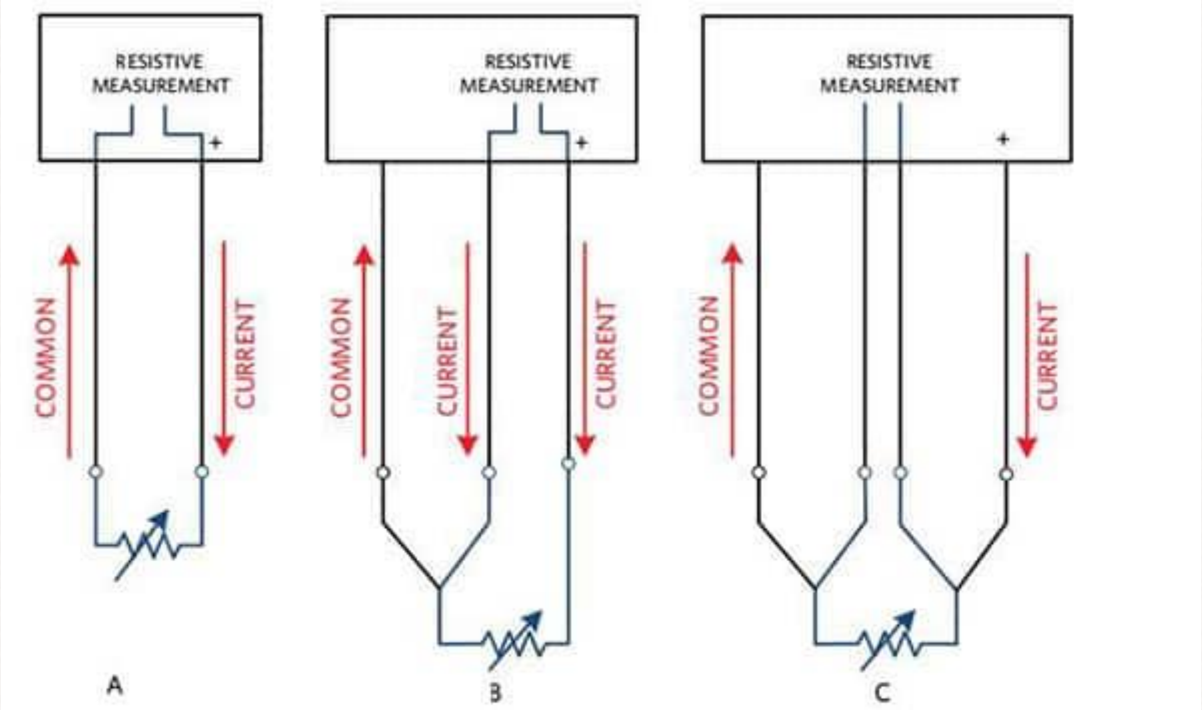


Regardless of type, shielded twisted pair important!

Temperature Signals

Two main types of temperature devices – Thermocouples and RTDs

T/C Type	Conductor +	Conductor –	T/C Junction Continuous Temperature range °C	INTERNATIONAL IEC 584-3:1989 BS 4937 Pt30:1993	(FORMER) UNITED KINGDOM BS 1843:1952	FRANCE NFE-18001	GERMANY DIN43714	JAPAN JIS C 1610-1981	USA ANSI MC 96.1	Cable Code
E	Ni-CR	Cu-Ni Constantan	0 to +800							EX
J	Fe	Cu-Ni Constantan	0 to +750							JX
K	Ni-Cr	Ni-Al	0 to +1100							KX
N	Ni-Cr-Si Nicrosil	Ni-Si-Mg Nisil	0 to +1100							NX NC
R	Pt-13Rh	Pt	0 to +1600							RCA
S	Pt-10Rh	Pt	0 to +1600							SCA
T	Cu	Cu-Ni Constantan	-185 to +300							TX
B	Pt-30Rh	Pt-6Rh	+200 to +1700							BX



Common Thermocouples **Common RTDs**

Either type can have 4-20 mA transmitter!

PLC Analog Inputs

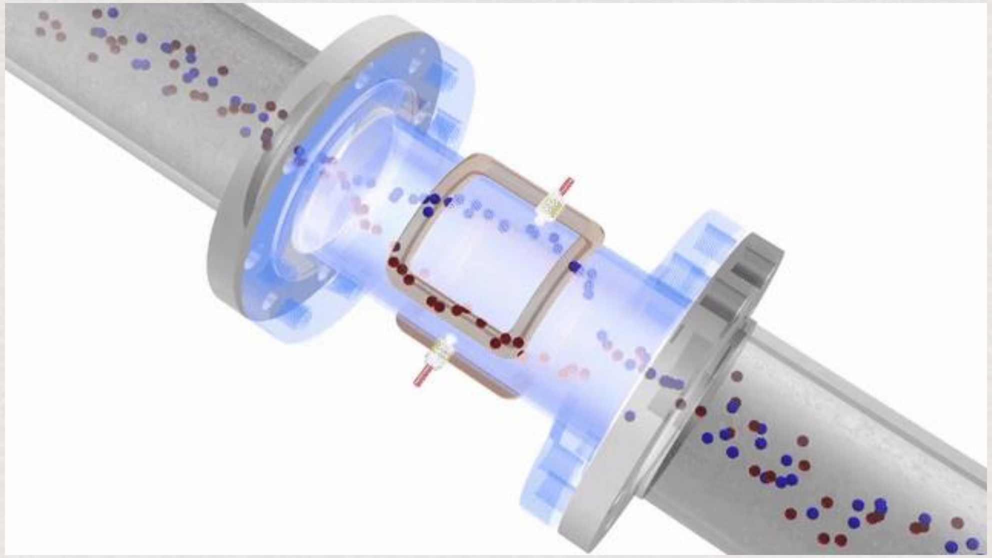
Regardless of type, precision and update speed matter!

	8-Bit Word								
	MSB							LSB	
2^	7	6	5	4	3	2	1	0	Check
=	128	64	32	16	8	4	2	1	
0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	1	1
2	0	0	0	0	0	0	1	0	2
3	0	0	0	0	0	0	1	1	3
4	0	0	0	0	0	1	0	0	4
8	0	0	0	0	1	0	0	0	8
167	1	0	1	0	0	1	1	1	167
255	1	1	1	1	1	1	1	1	255

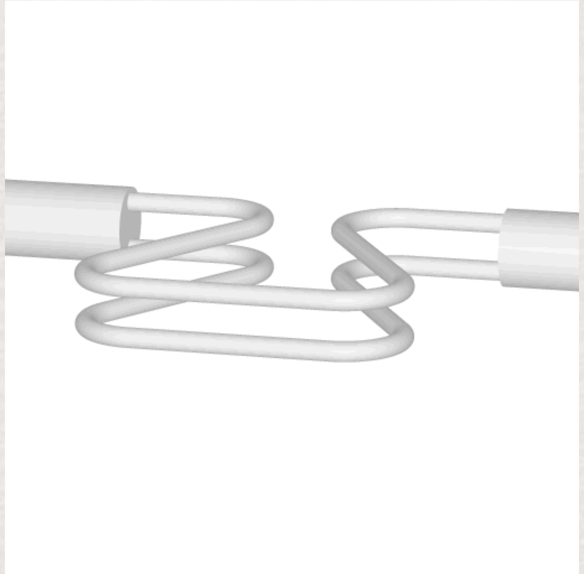
8-bit Example
From earlier

mA	8	10	12	14	16	bit
20	255	1023	4095	16383	65535	
4	51	205	819	3277	13107	
0	0	0	0	0	0	
1 bit =	0.078431	0.01956	0.004884	0.001221	0.000305	mA
Steps	204	818	3276	13106	52428	4-20mA
Bit %	0.4902%	0.1222%	0.0305%	0.0076%	0.0019%	

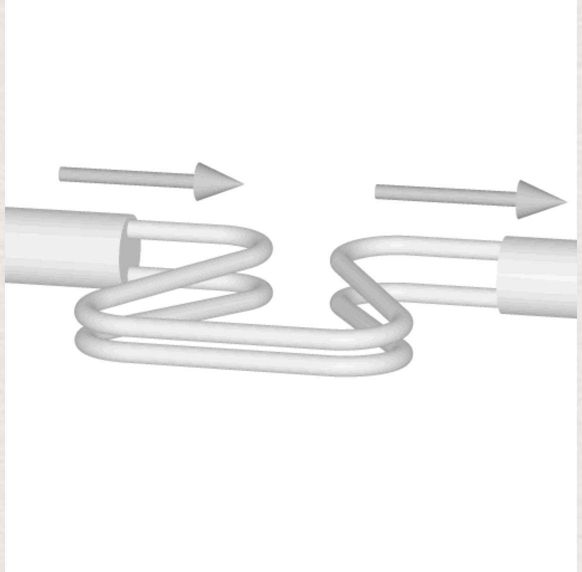
Fluid Flow Transmitters



No Flow



Flow



Magnetic (AKA "Mag") Meter

- Fluid MUST be conductive
- High-end models have tolerance for bubbles
- Care must be taken to bond to nearby pipes

Coriolis Mass-Flow Meter

- Fluid does not have to be conductive
- Less tolerant to entrained air and bubbles
- More sensitive to up/down-stream conditions

Flow Transmitters

Note 27 CFR 25.42 – "periodically test" means at least once a year! MUST calibrate to 0.5% or better!

§ 25.42 Testing of measuring devices.

(a) ***General requirements.*** If a measuring device such as a meter or gauge glass is used to measure beer, the brewer shall periodically test the measuring device and adjust or repair it, if necessary. The brewer shall keep records of tests available for inspection by appropriate TTB officers. Records of tests will include:

(1) Date of test;

(2) Identity of meter or measuring device;

(3) Result of test; and

(4) Corrective action taken, if necessary.

(b) ***Requirements for beer meters.*** The allowable variation for beer meters as established by testing may not exceed ±0.5 percent. If a meter test discloses an error in excess of the allowable variation, the brewer shall immediately adjust or repair the meter. Adjustments will reduce the error to as near zero as practicable.

(c) ***Authority to require tests.*** If the appropriate TTB officer has reason to believe that the accuracy or reliability of a measuring device is not being properly maintained, he or she may require the brewer to test the measuring device and, if necessary, adjust or repair the measuring device.

(Sec. 201, Pub. L. 85-859, 72 Stat. 1395, as amended (26 U.S.C. 5552))

Most likely, this means Magnetic or Coriolis!

Relevant Standards & Codes

- NFPA 70 – "National Electrical Code" or NEC
  - How to install electrical items safely so they don't catch on fire
- NFPA 79 – "Electrical Standard for Industrial Machinery"
  - How industrial equipment should be constructed so it doesn't kill someone
- NFPA 70E – "Standard for Electrical Safety in the Workplace"
  - OSHA's "consensus standard" for all things electrical safety (more to come)
- NFPA 70B – Recommended Practice for Electrical Equipment Maintenance
  - How you should maintain your equipment to prevent failures and worker injuries
- UL508A – UL Standard for Industrial Control Panels
  - Proves that your control panels were built per UL guidelines at a certified shop
- UL698A – UL Standard for ICP's in Hazardous Locations
  - Combustible Dusts are Class II, mostly Division II hazard, some Division I requiring additional safety considerations

Relevant Standards & Codes

- Contractors
  - Who is their Authority Having Jurisdiction, when were their workers last certified as Qualified Electrical Workers? Examples of them using safe work practices?
  - When was their last NEC knowledge assessment?
  - What type of PPE do they have, when was it cleaned and inspected?
  - What energized work are they going to perform, and why aren't they de-energizing?

- Equipment Builders
  - Verify panels are UL508A or UL698A certified
  - Discuss equipment location and hazards present as early as possible

- You
  - Realize as an employer you are on the hook for NFPA 70E safety compliance!

Electrical Safety

Why Electrical-focused Safety!?

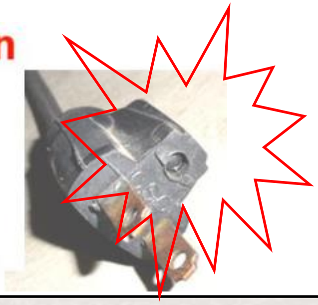
- OSHA's "Fatal Four" accounted for 63.7% of all work-place fatalities in 2016. Those are (#):
  1. Falls (384)
  2. Struck by Object (93)
  3. **<u>Electrocutions (82)</u>**
  4. Caught In/Between (72)

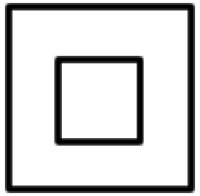
- Of those 4 types of incidents, electricity arguably makes for the scariest "near-misses". The following can happen, but not be fatal:
  - Exterior 2nd and 3rd degree burns from arc flash or shock
  - Explosion of tissue from shocks involving high current
  - Internal 4th degree (deep tissue) burns from shock
  - Fibrillation of the heart
  - Clamping of the heart and diaphragm
  - Permanent nerve damage resulting in severe chronic pain

General Electrical Safety

Grounding

All electrical equipment should be grounded (3-prong) or double insulated.





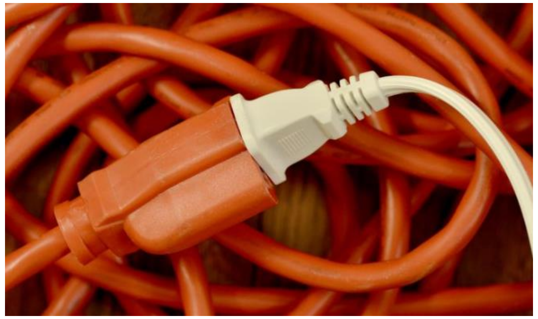
Symbol for double insulation

All Electrical Cords

Inspect before use and after suspected damage.

Extension Cords

Electrical extension cords should be rated for the load attached to them. In general, do not plug large device cord into smaller extension cord.



2-wire “lamp” extension cords only to be used with decorative lights or desk lamps.

Outlet strips must be plugged directly into a wall receptacle.

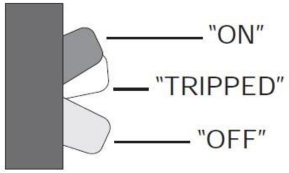
Not to be used for permanent installations.

General Electrical Safety

Circuit Breakers (CB)

CB's prevent circuit overloads that cause fires.
Rated in Amperes, AKA "Amps" or simply "A"

Handle Positions:



If TRIPPED, turn OFF.
If 50A or less breaker OFF and needed ON:

- **<u>Only turn on after suspected problem resolved</u>**
- **<u>Must</u>** have long-sleeve 100% cotton shirt and pants, safety glasses, and a leather glove on operating hand.
- Place operating hand on breaker handle, move body arm's length away
- Look in opposite direction and take a very deep breath
- Turn breaker on
- Notify electrical department of breaker location
- If it trips again – DO NOT TOUCH, CALL MAINTENANCE

Ground Fault Circuit Interrupters (GFCI)

GFCI devices prevent electrocution by making sure the current going out the "hot" wire is equal to the current coming back the "neutral" and disconnecting power if not.

Can be receptacle, breaker, or portable:

REQUIRED for all plug-in devices within 6 feet of sinks, tubs, showers, and exterior outlets.

To RESET, follow same procedure as CB's

Two Ways to Die from Electrons

Electrical Shock

An electrical shock occurs when current passes through your body. Most outlet circuit breakers are 20 Amps, yet it takes only 20 milli-amps (1/1000th the breaker's rating) to cause severe pain, and 100 milli-amps to clamp the heart and diaphragm which can result in electrocution (death by shock).

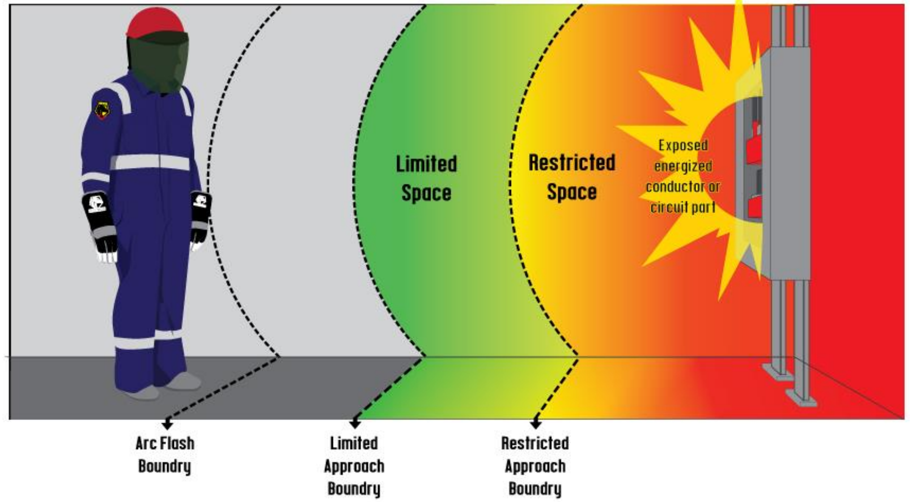
mA	Effect on Human Body
0.5 - 3	Tingling sensations
3 - 10	Muscle contractions and pain
10 - 40	"Let-go" threshold
30 - 75	Respiratory paralysis
100 - 200	Ventricular fibrillation
200 - 500	Heart clamps tight
1500 +	Tissue and Organs start to burn

Shown at (60 hz AC) – Effect will vary with frequency and duration of exposure

To prevent shock, never open electrical panels, always inspect cords and equipment before plugging in or turning on, use GFCI devices, and avoid damaged electrical equipment.

Arc Flash / Arc Blast

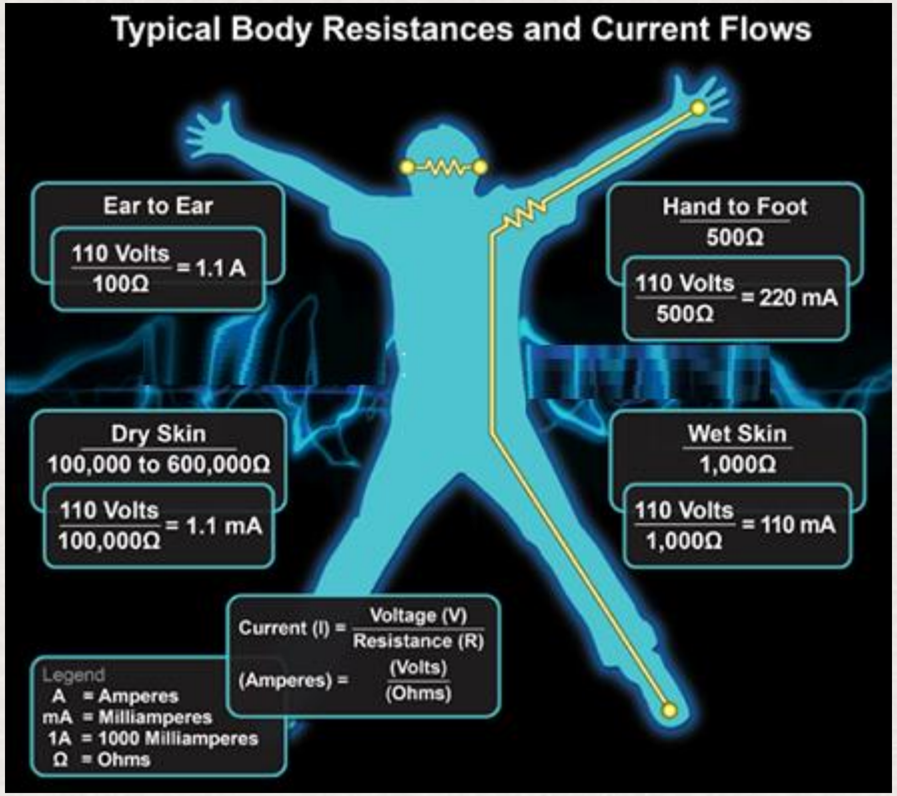
An Arc Flash is the sudden release of energy as a result of an electrical fault. Temperatures can reach 35,000 °F, or 10 times hotter than the surface of the sun. This vaporizes the metal conductors, causing an explosive force known as an Arc Blast. To avoid injuries, leave all work on electrical equipment to Qualified Electrical Workers and avoid electrical work areas defined by them using cones and caution tape. These are set up at or beyond the arc flash boundary, which is the distance 2nd degree burns are likely should a fault occur.



An LED's Current can Kill You!

So if a small current can kill me, why doesn't it!? Skin!

Dry skin, with a minimum resistance of 100kΩ, prevents low voltages from being perceived (3 mA).



	Dry Skin Resistance		
Voltage	5%	50%	95%
25	1750 Ω	3250 Ω	6100 Ω
100	1200 Ω	1875 Ω	3200 Ω
220	1000 Ω	1350 Ω	2125 Ω
1000	700 Ω	1050 Ω	1500 Ω

	Current		
Voltage	5%	50%	95%
25	**0.014**	**0.008**	**0.004**
100	**0.083**	**0.053**	**0.031**
220	**0.220**	**0.163**	**0.104**
1000	**1.429**	**0.952**	**0.667**

Key	
	= Muscle Contractions & Pain
(yellow)	= Can't let go
(orange)	= Resp. Paralysis, Fibrilation
(red)	= Clamped Heart & Diaphragm

mA	Effect on Human Body
0.5 - 3	Tingling sensations
3 - 10	Muscle contractions and pain
10 - 40	"Let-go" threshold
30 - 75	Respiratory paralysis
100 - 200	Ventricular fibrillation
200 - 500	Heart clamps tight
1500 +	Tissue and Organs start to burn

Shown at (60 hz AC) – Effect will vary with frequency and duration of exposure

But skin resistance isn’t much help

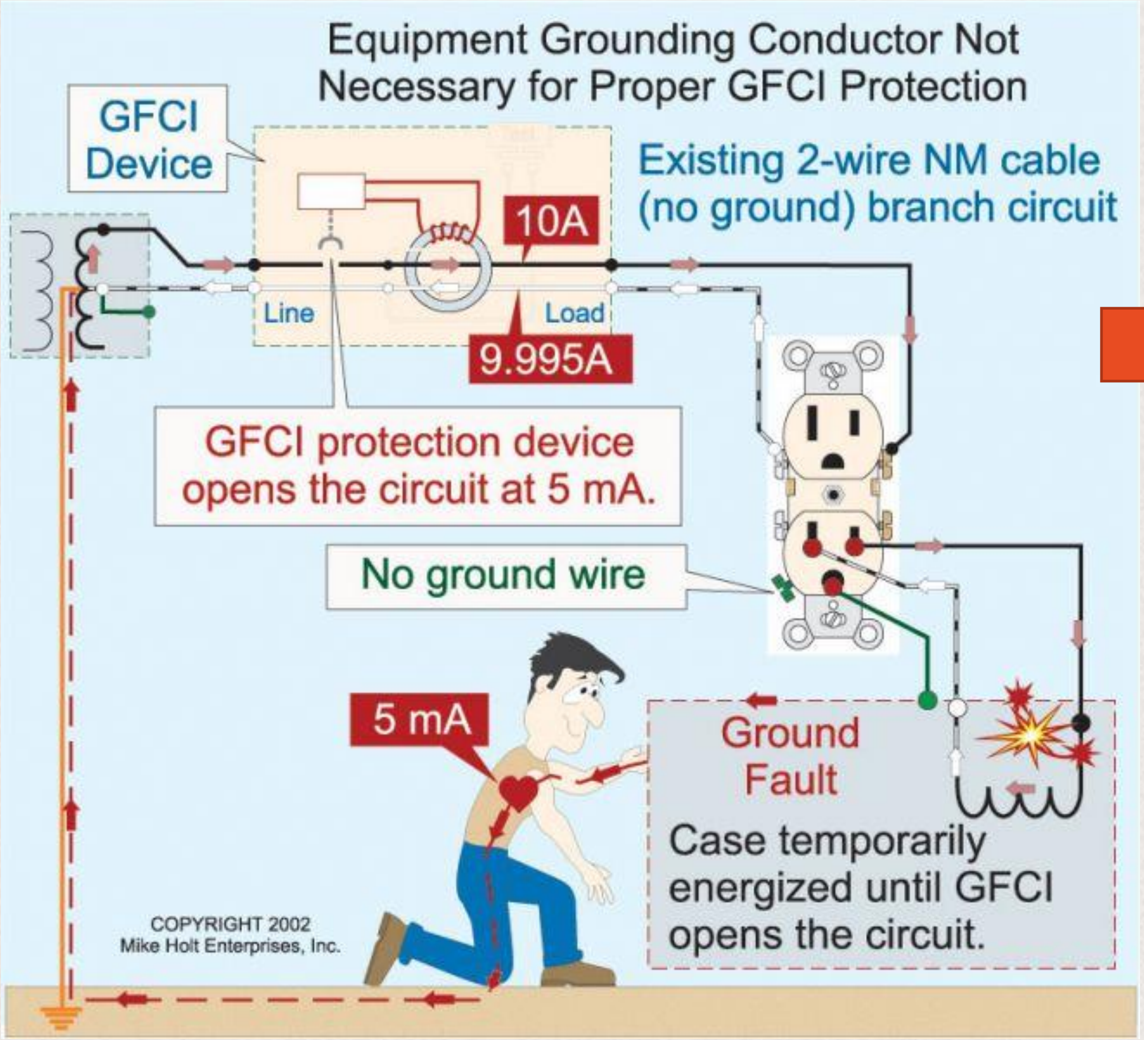
Nothing is a perfect insulator – as voltage goes up, skin breaks down!

Lightning happens when very high static electricity potential (voltage) turns air, which is normally an insulator, into a conductor.

Similarly, when the voltage gets high enough your skin will conduct. Without your skin, you’re essentially salt water – which is a very good conductor!

If you receive a perceivable shock, you should seek medical attention! EKG and blood test to detect internal damage are standard – EVERY SHOCK CAN BE DEADLY!!!

Ground Fault Circuit Interrupters



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Arc Flash & Arc Blast

Have a blast at work, don't experience a blast at work!

Arc Flash – explosive release of energy as a result of an electrical fault

Arc Blast – pressure wave resulting from the intense heat and expanding metal caused by an Arc Flash

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Arc Flash & Arc Blast

Have a blast at work, don’t experience a blast at work!

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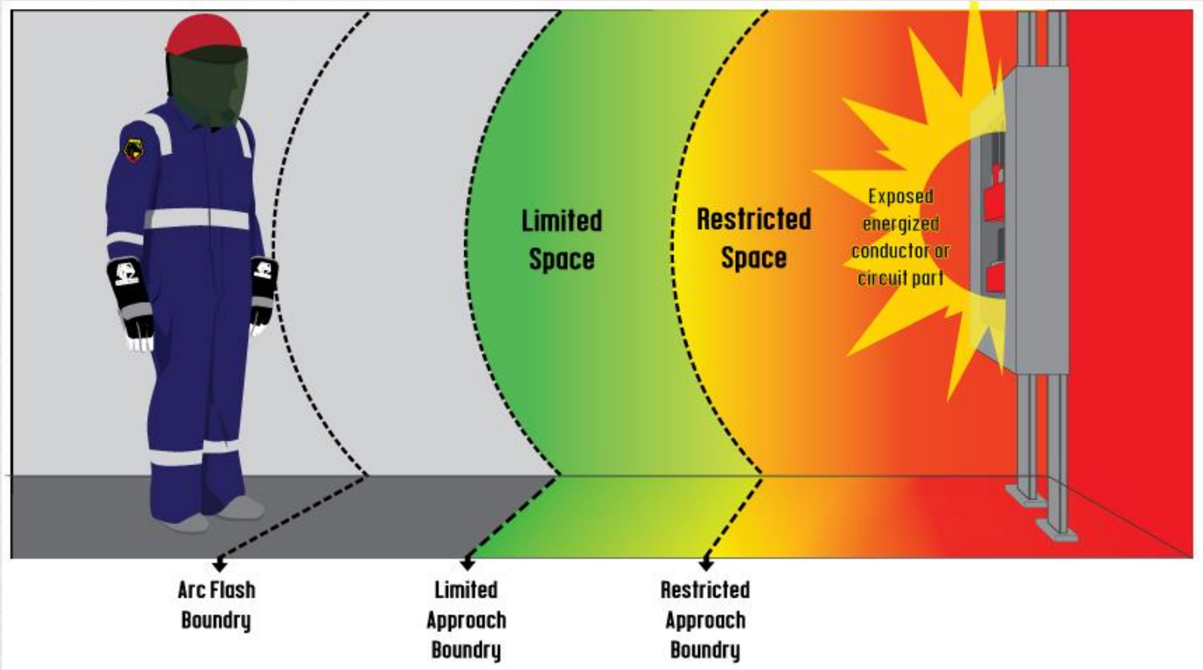
Arc Flash PPE

If you aren't sure, you're NOT a QEW (sorry)!



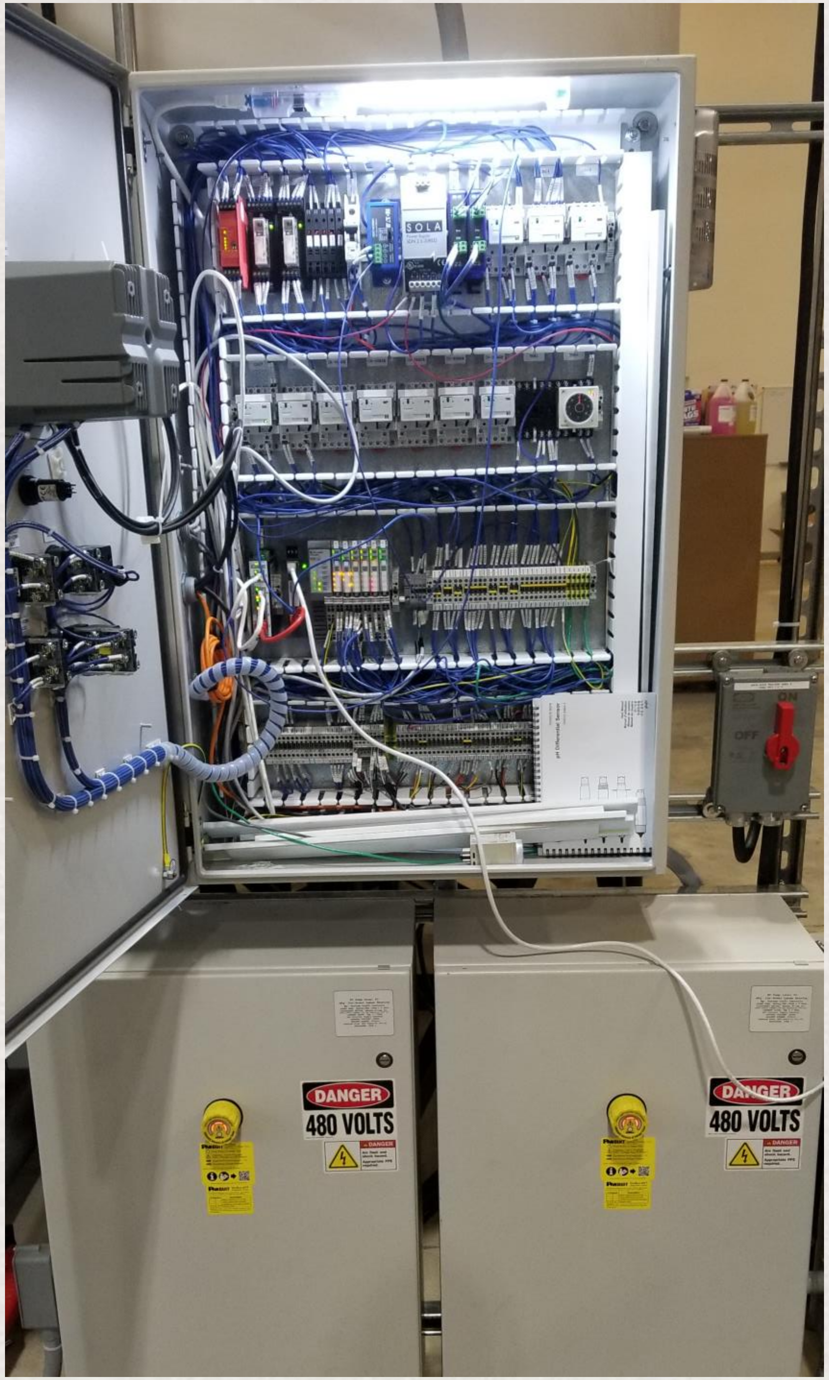
DESIGN FOR SAFETY

EQUIPMENT MANUFACTURERS – THIS IS FOR YOU!!!

Separate Hazardous (>50) and Non-Hazardous (<50) Voltage Panels!

Panduit ® Absence of Voltage Verification units on Hazardous Panels, or…

Plug-supplied equipment, allows for complete separation of conductors



THANK YOU!

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