Industrial Motor Control

ECET 4530

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Motor Control System Components

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Control System Components

Components commonly used in industrial motor control systems:

- Push-Buttons
- Contactors
- Relays
- Timers
- Overload Relays
- Optical (Beam) Detectors
- Proximity Detectors
- Limit Switches
- Programmable Logic Controllers (PLCs)
- Variable Frequency Drives (VFDs)
- Human-Machine Interface Panels (HMIs)

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Introductory Note

In terms of their **ratings** and design, motor control devices often fall into one of two primary classifications:

- **NEMA Rated Devices**
- **IEC Rated Devices**

National Electrical Manufacturers Association

International Electrotechnical Commission

where: **NEMA** is the **N**ational **E**lectrical **M**anufacturers **A**ssociation, which is the largest trade association of electrical equipment manufacturers in the United States, and

IEC is the **I**nternational **E**lectrotechnical **C**ommission, which is a non-profit, non-governmental international standards organization that prepares and publishes international standards for all electrical, electronic, and related technologies.

For detailed information: NEMA → www.NEMA.org
IEC → www.IEC.ch

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Introductory Note

NEMA vs. IEC

Although NEMA and the IEC both provide **standards and ratings** for different types of devices:

- **NEMA standards** are often based on designs that include safety factors over and above their design ratings and on standard "frame" sizes (making them directly compatible between different manufacturers), whereas
- **IEC standards** are often based on utilization categories that rate devices based on their intended use, with a focus on space and cost savings, by testing components to their exact design rating.

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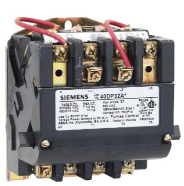
Introductory Note

NEMA vs. IEC

The are **advantages** and **disadvantages** to both standards:

- **NEMA rated devices** tend to be more robust, often having up to a 25% service factor, and thus are often suited for a wider range of applications.
- **NEMA rated devices** tend to be larger and more expensive than their IEC counterparts.



Note that NEMA devices tend to require enclosures (safety covers) due to exposed terminals, while IEC devices tend to have recessed terminals and thus are "finger safe".

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Introductory Note

NEMA vs. IEC

The are **advantages** and **disadvantages** to both standards:

- **IEC rated devices** are often application specific, which makes proper selection much more critical than with NEMA rated components.
- **IEC rated devices** tend to be less expensive and more compact than their NEMA counterparts.

Note that IEC rated devices often have many more options in terms of current or power ratings, which further increases the importance of proper selection.

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Introductory Note

NEMA vs. IEC

Neither system is better or worse; **they are just different**.

Yet, the **UL** (Underwriters Laboratory) testing is the same for all NEMA and IEC rated devices, ensuring that any of the devices are well-suited for the applications for which they are rated.

The key to proper selection is being able to properly define the operating characteristics required for the device, while also understanding the rating system of the chosen standard.

Note that, due to time constraints, only NEMA standard ratings will be discussed during this presentation.

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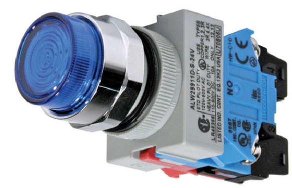
Push-Buttons

A **push-button** is a momentary contact device that contains one or more sets of **contacts** that actuate (change state) when the button is pressed and then return to their normal position when the button is released.



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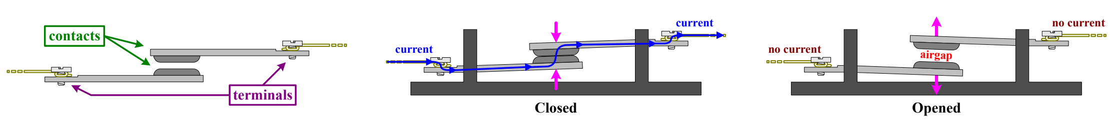
Contacts

Contacts are electrically conductive pieces of metal that, if placed in-series within the conductive path of a circuit, can either be:

- **Closed** – pressed together in order to complete the circuit by **allowing current to flow** from one to the other, or
- **Open** – pulled apart or separated in order to break the circuit, such that the air-gap introduced between the contacts will **prevent the flow of current** from one contact to the other, in-turn breaking any closed-loop current path in the circuit.



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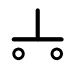
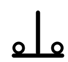
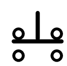
Types of Push-Buttons

A **push-button** is a momentary contact device that contains one or more sets of **contacts** that actuate when the button is pressed and then return to their normal position when the button is released.

Types of Push-Buttons	Symbol
Normally Open (NO)	
Normally Closed (NC)	
Combination	

The "type" of the push-button is specified by the "normal" position of its contacts, which is the position of the contacts (open or closed) when the button is not being pressed.

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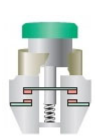
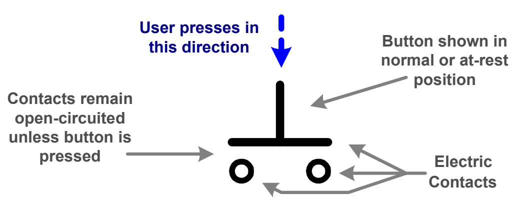
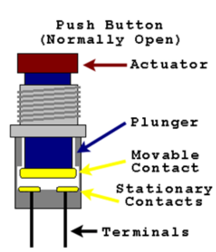
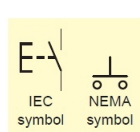
Normally-Open (NO) Push-Button

A **normally-open** (**NO**) **push-button** is a push-button that contains one or more sets of contacts that are (**normally**) in an **open** position when the button is not being pressed, but then actuate **closed** when the **button is pressed**.









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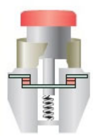
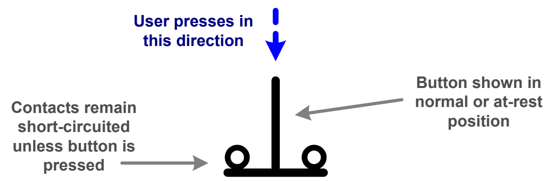
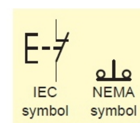
Normally-Closed (NC) Push-Button

A **normally-closed** (NC) **push-button** is a push-button that contains one or more sets of contacts that are (**normally**) in a **closed** position when the button is not being pressed, but then **actuate open** when the **button is pressed**.







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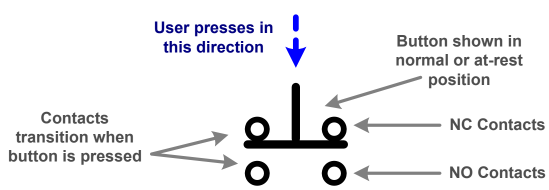
Combination Push-Button

A **combination push-button** is a push-button that **contains both** one or more sets of contacts that are **normally-open** and one or more sets of contacts that are **normally-closed**.



This push-button contains one set of NO contacts and one set of NC contacts.

Note that the combination push-button is typically designed such that one type of contacts will transition slightly faster than the other type when the button actuated.

(I.e. – either the NO contacts close before the NC contacts open, or vice-versa.)

[Whichever transitions first when actuated, the reverse will hold true when the button is released.]

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Contactors

A **contactor** is an electrically controlled switch that is specifically designed to be able to withstand the stresses that occur when either connecting or disconnecting a high-current device from its source of electric power.



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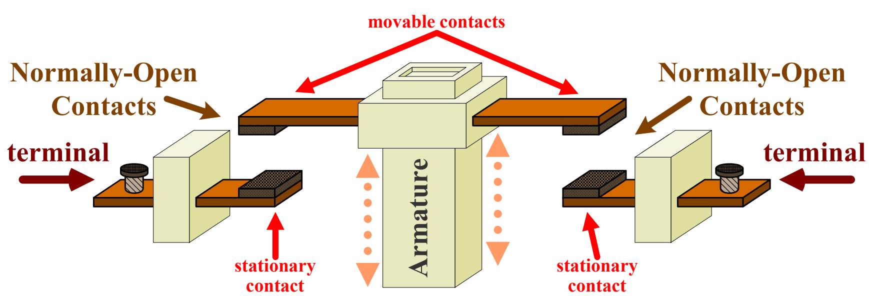
Main Contacts

The contactor's switching function is provided by one or more sets of **normally-open** (NO) **main contacts** that are attached to the movable armature of an electromagnet.



(The contacts are **actuated closed** by energizing the electromagnet's field coil.)

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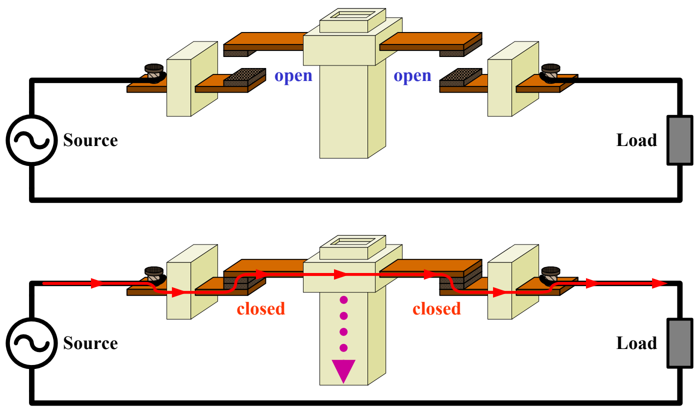
Main Contacts

Thus, when placed in-series between a load and its supply source, the contactor's normally-open **main contacts** can be used to energize and de-energize the load.



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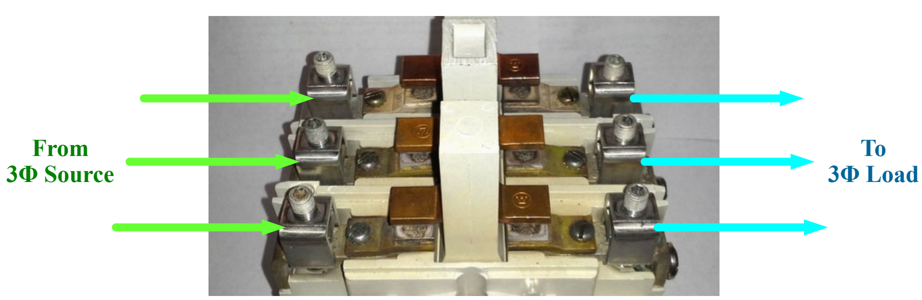
Main Contacts

Note that the contactor should contain a set of (**NO**) **main contacts** for each of the non-grounded supply lines that provide power to its load in order to be able to fully connect and disconnect the load from its source of electric power.

A three-phase load requires a contactor with three sets of main contacts.



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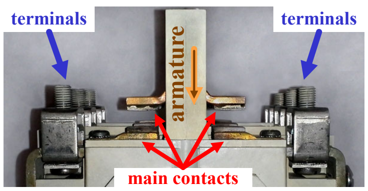
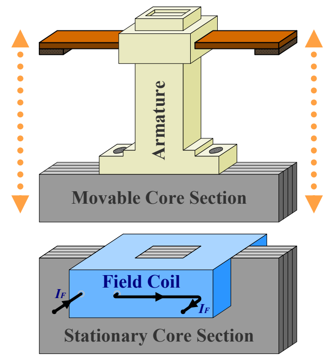
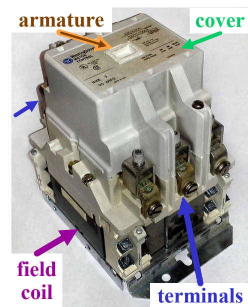
Electromagnet and Armature

The contactor's **electromagnet** consists of a **field coil** that's wound around a stationary section of magnetic core, and an **armature** that consists of a movable section of core along with one-half of the contact pairs.







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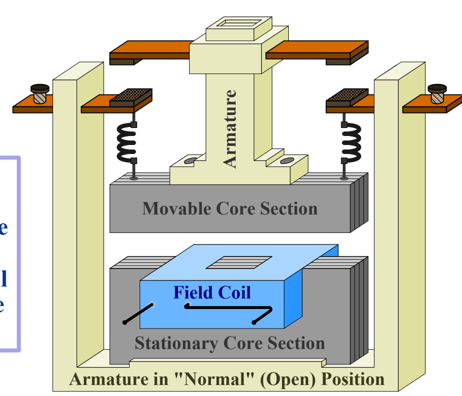
Electromagnet and Armature

In its **normal state** (de-energized), the armature is pulled away from the stationary section of core by a set of springs, such that the **main contacts** are held in their (normally) **open** position.

Note that the complete set of NO contacts actually consists of two pair of contacts that are connected in-series with each other, such that both pairs will simultaneously close when the armature is actuated.



This figure only depicts one set of the NO main contacts that would be placed in-series with one of the lines that supply power to the load.

A three-phase contactor would have two more sets of contacts attached to the armature.

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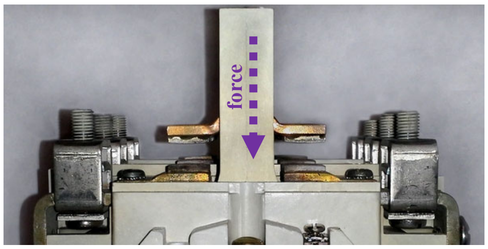
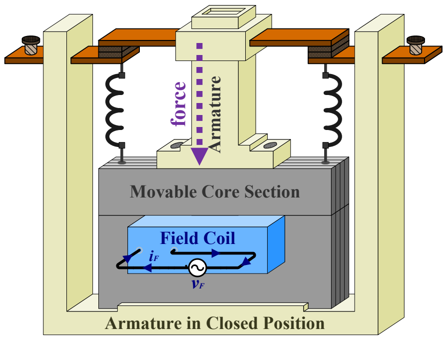
Contactor Operation

But, when the **field coil** is **energized**, the electromagnet develops a force that attracts the movable core section, in-turn overcoming the spring-force that holds the armature in place and **actuating the contacts closed**.





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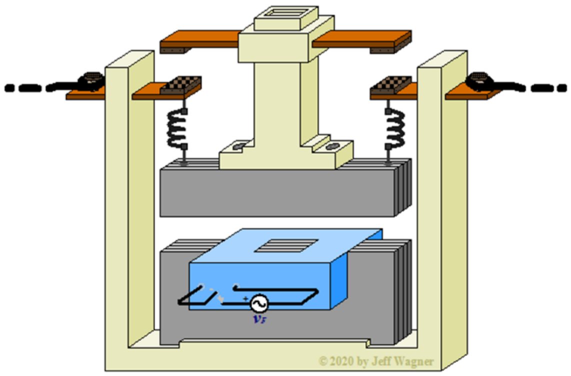
Contactor Operation

But, when the **field coil** is **energized**, the electromagnet develops a force that attracts the movable core section, in-turn overcoming the spring-force that holds the armature in place and **actuating the contacts closed**.

Animation showing the following sequence of events:
- **The field coil is energized**
- **A flux is developed by electromagnet**
- **The armature is attracted to the electromagnet, simultaneously actuating the contacts closed**
- **Current flows through contactor.**



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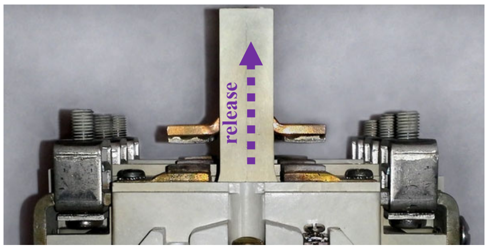
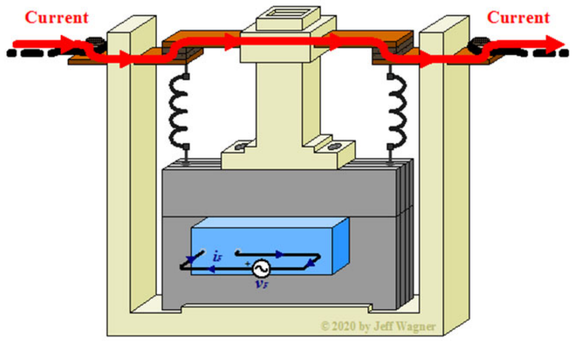
Contactor Operation

And then, when the **field coil** is **de-energized**, the electromagnet releases the movable core section, allowing the springs to pull the armature back to its normal position, in-turn **opening the contacts**.





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Contactor Selection

When **selecting a contactor** for use with a given load, there are three primary considerations:

- **Application –** The type of load to which the contactor will supply power, the operational characteristics of that load, along with other possible factors.
- **Coil Ratings –** The ratings of the contactor's field coil; must be matched to the ratings of the control-circuit.
- **Contact Ratings –** The main "power" ratings of the contactor; must be greater than or equal to the ratings of the load to which the contactor will supply power.

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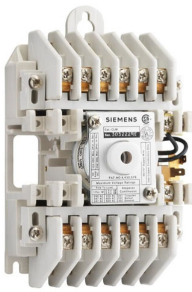
Contactor Ratings – Application

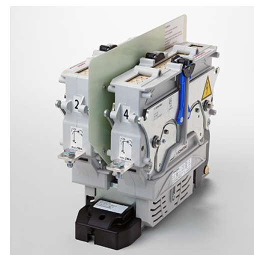
The **application** for which a contactor will be used can have a great affect on both the design and the ratings of the contactor.

Examples:

– Unlike the previously described contactors that are utilized for motor starting, **latching** contactors that contain two field coils, one to energize the load and the other to de-energize the load, are often used in **lighting control systems**.

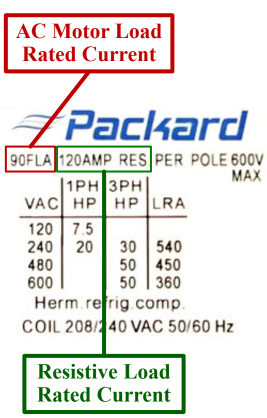


– When used to interrupt current in an active circuit, it is more **difficult to extinguish the arc** that's created when disrupting **DC current** than it is to extinguish the arc that's created when disrupting an AC circuit. Thus, DC contactor construction can vary greatly compared to AC contactors.



Contactor Ratings – Application

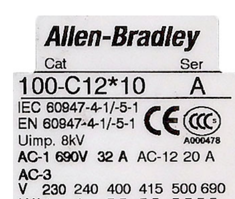
When a contactor is suitable for use in multiple applications, there may be **different ratings** that apply depending on its actual use.



On the other hand, contactors may be designated or rated for specific applications, such as IEC standard contactors that are rated based on utilization categories:

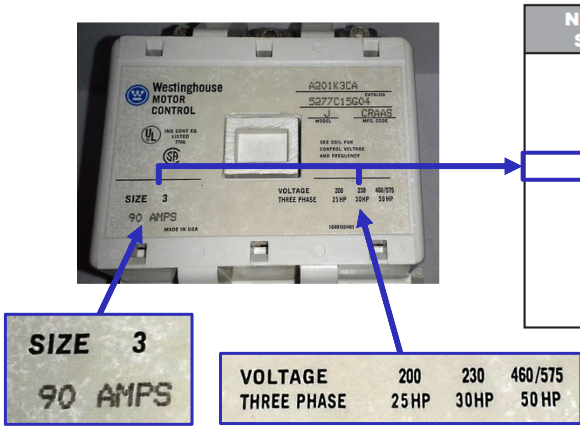
NATURE OF CURRENT	CATEGORY	TYPICAL APPLICATIONS
AC	AC-1	Non-inductive or slightly inductive loads, resistance furnaces.
	AC-2	Slip-ring motors: starting, switching off.
	AC-3	Squirrel-cage motors: starting, switching off motors during running.
	AC-4	Squirrel-cage motors: starting, plugging[1], inching[2].
	AC-5a	Switching of electric discharge lamp control.
	AC-5b	Switching of incandescent lamps.
	AC-6a	Switching of transformers.
	AC-6b	Switching of capacitor banks.
	AC-7b	Motor-loads for household applications.
DC	DC-1	Non-inductive or slightly inductive loads, resistance furnaces.
	DC-3	Shunt-motors, starting, plugging[1], inching[2], dynamic breaking of motors.
	DC-6	Switching of incandescent lamps.

Partial Listing of IEC Utilization Categories



Contactor Ratings – Application

Not that, as previously mentioned, this presentation will only focus on NEMA-rated contactors used for **motor-control** purposes.



NEMA Size	Continuous Amp Rating	HP 230 VAC	HP 460 VAC
00	9	1	2
0	18	3	5
1	27	5	10
2	45	15	25
3	90	30	50
4	135	50	100
5	270	100	200
6	540	200	400
7	810	300	600
8	1215	450	900
9	2250	800	1600

The above table shows the NEMA standard sizes for contactors and the maximum ratings of the motors that they are able to control.

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Contactor Ratings – Coil

The **coil ratings** for the contactor specify the nominal operating parameters for its **field coil**:

Rated Voltage

- The nominal operating voltage for the field coil to ensure that the contacts actuate when the coil is energized.
  - If AC, both voltage and frequency will be provided.
  - Must match the control circuit's operational voltage.

Rated Current (may not be shown on ratings label)

- The current drawn when supplied rated voltage.
  - Important if supplied by limited-current source.

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Contactor Ratings – Coil

In addition to the coil's rated voltage and current, there are two other ratings that, although rarely displayed, may be important if the contactor's branch circuit experiences large voltage drops during startup of the motor:

Pickup Voltage

- The **minimum voltage** required to **actuate the contacts** when energizing the coil.

Dropout Voltage

- The **minimum voltage** required to **hold-in the contacts** once the coil is energized and the contacts have already actuated.

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Contactor Ratings – Contacts

The two primary **contact ratings** are:

Maximum Switching Voltage

- The maximum (nominal) system voltage at which the contactor is designed to operate.
  - Contactors may be rated for AC operation, DC operation, or both.
  - If rated for both AC and DC operation, the rated voltages may differ.

Maximum Switching Current (Interrupting Rating)

- The maximum continuous current (per pole) that the contactor is intended to interrupt under standard test conditions.
  - Notable damage to the contacts may occur of the contactor is utilized to disrupt larger-than-rated currents.

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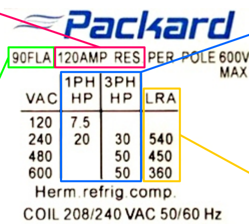
Contactor Ratings – Contacts

Note that the **current rating** for a contactor may instead be defined in terms of the **maximum load (current)** that can be connected to the contactor based on the **type of load**, or in terms of horsepower if the intended load is a motor.

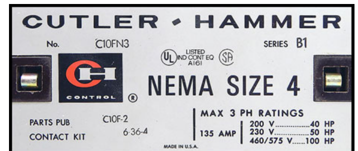
Maximum Load Current for a resistive load.

Maximum Full Load Amps for a motor or other type of inductive load.



Maximum Horsepower for a motor load as a function of operating voltage.

Maximum Locked Rotor Amps for a motor load as a function of operating voltage.



NEMA, standard-sized contactors are rated in terms of the connected motor's maximum allowable ratings in order to simplify the selection process for a contactor based on the motor that it will control.

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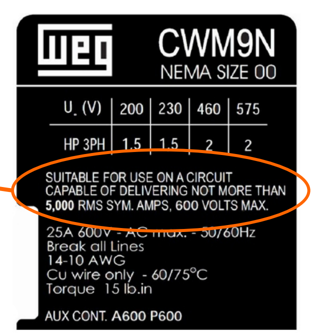
Contactor Ratings – Contacts

Note that the **current rating** for a contactor may instead be defined in terms of the **maximum load (current)** that can be connected to the contactor based on the **type of load**, or in terms of horsepower if the intended load is a motor.

In addition to the **contact ratings** for its power circuit, a contactor is also assigned a **S**hort-**C**ircuit-**C**urrent-**R**ating (**SCCR**) that defines the maximum symmetrical fault current that the contactor is able to withstand without sustaining damage. This value must be greater than the short circuit current available on the branch circuit to which the contactor is connected.



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Current Interrupting Capability

In addition to being able to energize and de-energize a load of a specific rating, **contactors designed for use with motors** must also be able to **safely interrupt** the motor's operational current, up to its locked-rotor current, without causing excessive surface damage to the contact tips.

But the **main contacts** of a contactor are NOT **designed to disrupt fault** (**short-circuit**) **currents***.

*** – A fault current is any current that flows outside of the normally conductive path provided by a circuit and, when resulting from a "short-circuit", can be exceptionally large and critically damage the contacts if disrupted by a contactor.**

Instead, fault protection is provided by the protective devices (fuses & circuit breakers) that are used to protect the branch circuit that supplies the motor.

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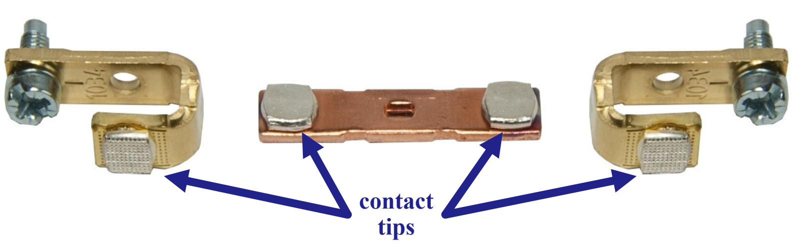
Main Contact Design

The **main contacts** are specifically designed to withstand the stresses that occur when either connecting or disconnecting a high-current device from its source of electric power.

Thus, the **tips** of the contacts are constructed from durable alloys, and usually have large surface areas to provide a small contact resistance in order to minimize the losses during operation.



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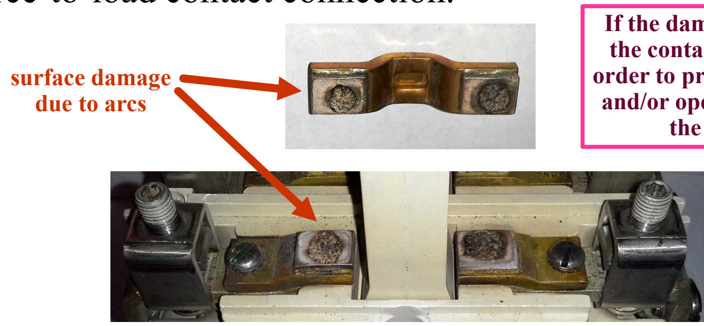
Main Contact Design

Yet, some **arcing** will always occur whenever the main contacts make or break the circuit between the source and the load.

And, despite their design, the arcing will eventually begin to damage the contact surfaces, in-turn degrading the overall source-to-load contact connection.



If the damage becomes excessive, the contacts must be replaced in order to prevent a contactor failure and/or operational problems with the contactor's load.

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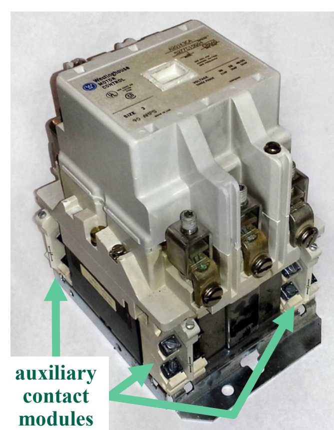
Auxiliary Contacts

Along with the main contacts, at least one set of (NO) **auxiliary contacts** is typically included with the contactor to provide the additional logic (function) that is required whenever the contactor is utilized as part of a motor starter.

Additional sets of **NO** and/or **NC** auxiliary contacts may also be included as needed.

Note that the auxiliary contacts are actuated whenever the main contacts are actuated.



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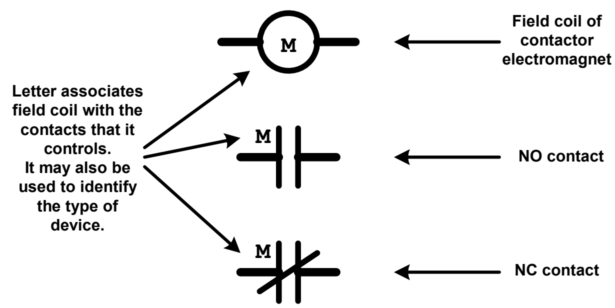
Contactors Symbols

When displayed within a schematic diagram, the **symbols** often utilized to depict a **contactor's internal components** are:



Although the same symbol is utilized for both the main contacts and the auxiliary contact, the auxiliary contact (along with any other control-circuit component) is typically drawn in a lighter type-face compared to that utilized for the main contacts (and any other power-circuit components).

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Basic Motor Controller Example

Motor Controller – Design a basic, two-pushbutton, start/stop motor controller for use with a three-phase 208V, induction motor.

Required Components:

1 – **NO Pushbutton** (**START** button)

1 – **NC Pushbutton** (**STOP** button)

1 – Three phase **Contactor** that is rated for a least 208V, and include at least one NO auxiliary contact.
(Note that the field-coil will be rated at 120V in this example.)

Note that this is not considered a "motor starter" because it will not provide overload protection for the motor. We will discuss overload protection later in this presentation.

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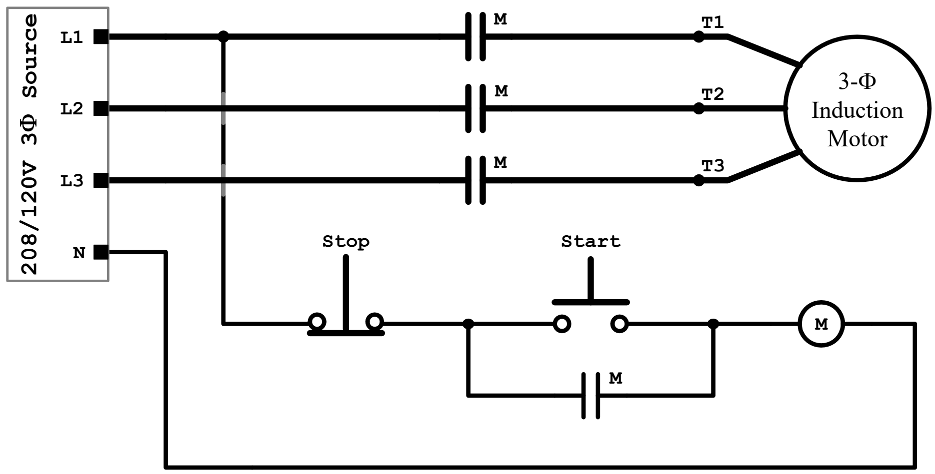
Basic Motor Controller Example



Schematic Diagram of the Basic Start/Stop 3Φ Motor Controller

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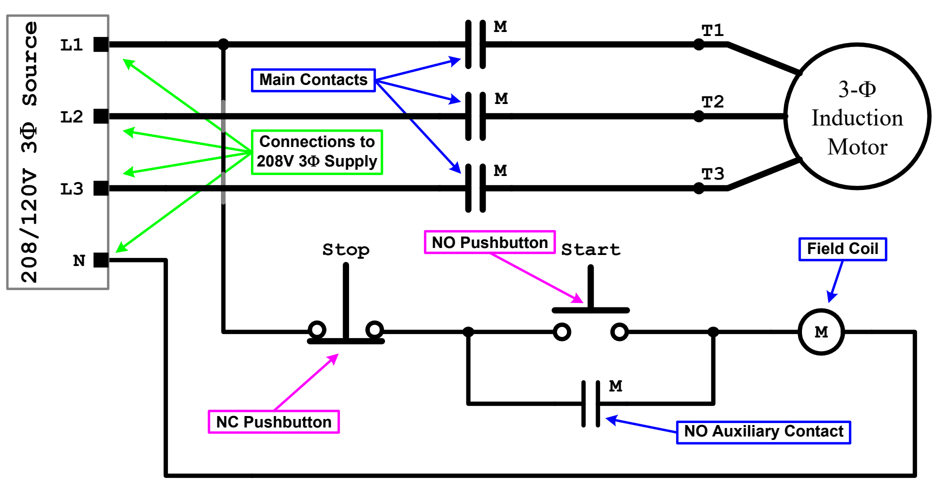
Basic Motor Controller Example



Schematic Diagram of the Basic Start/Stop 3Φ Motor Controller

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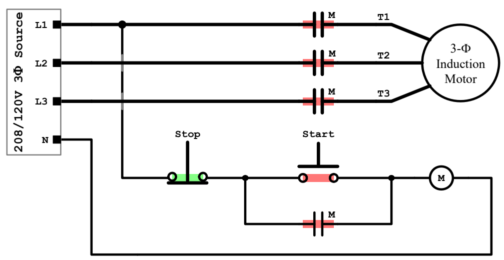
Basic Motor Controller Operation

Initial Conditions:

When the 3Φ supply is first switched on, the initially unenergized **field coil** will remain **unenergized** since current cannot flow through either the NO **START** button or the NO auxiliary contact.

The ▬ and ▬ colored bars behind the devices are being used to denote the conductive status of the devices in the circuit.

A ▬ behind a device denotes that it's conductive at the present time, while a ▬ denotes that the device will prevent the flow of current.



Note that, even though a ▬ may appear behind a contact or pushbutton, the actual flow of current also depends on whether or not the other devices in the circuit allow for a closed-loop path for current flow.

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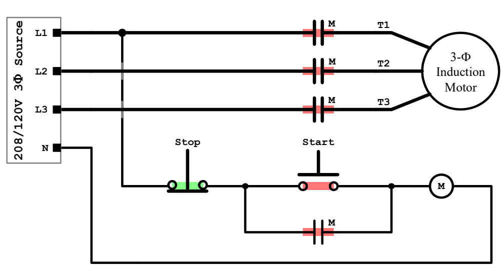
Basic Motor Controller Operation

Initial Conditions:

And, since the field coil is not energized, the **main contacts** will remain in their **normally-open positions**, isolating the motor from the 3Φ source.



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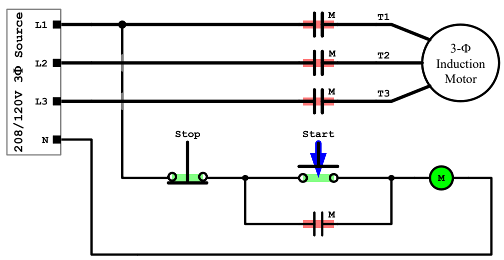
Basic Motor Controller Operation

Starting the Motor:

If the **START** button is **pressed**:

1) The button's **NO contacts close** and complete the circuit containing the field coil, thus **energizing the field coil**…



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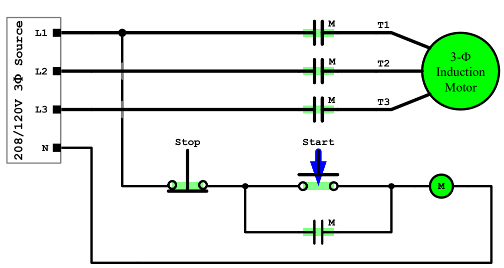
Basic Motor Controller Operation

Starting the Motor:

If the **START** button is **pressed**:

2) The energized coil (electromagnet) attracts the contactor's armature, in-turn, **actuating closed** all of the contactor's **NO contacts (**after a small time-delay due to distance traveled)…



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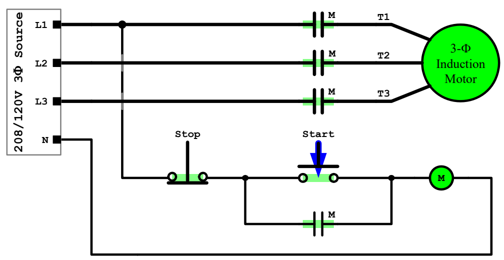
Basic Motor Controller Operation

Starting the Motor:

If the **START** button is **pressed**:

3) When the main contacts close, the **motor's terminals are connected to the line terminals** of the 3Φ supply, thus **energizing the motor** with full-rated voltage.



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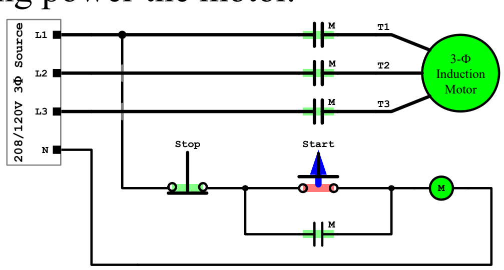
Basic Motor Controller Operation

Starting the Motor:

If the **START** button is **released**:

The **START button's contacts open**, but the **auxiliary contact** maintains a current path to the coil, keeping the electromagnet energized and "**holding-in**" the **armature** (contacts), in-turn maintaining power the motor.



When used for this purpose, the auxiliary contact is often referred to as a "hold-in contact".

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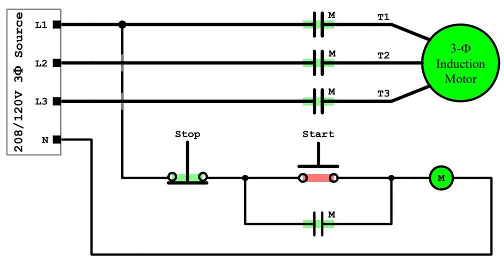
Basic Motor Controller Operation

Steady-state operation after startup:

Thus, once the **START** button has been pressed and released, the motor will continue operating as long as no other changes occur in the system.

Note that, once operational, pressing and releasing the START button again causes no change in the operation of the system.



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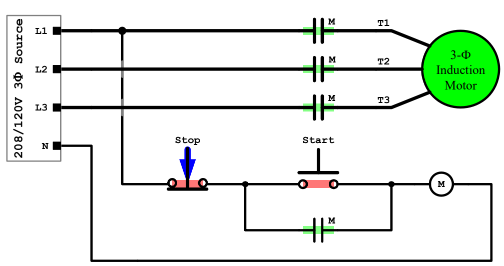
Basic Motor Controller Operation

Stopping the Motor:

If the **STOP** button is **pressed**:

1) The button's **NC contact opens** and breaks the circuit supplying the field coil, thus **de-energizing the field coil** (electromagnet)…



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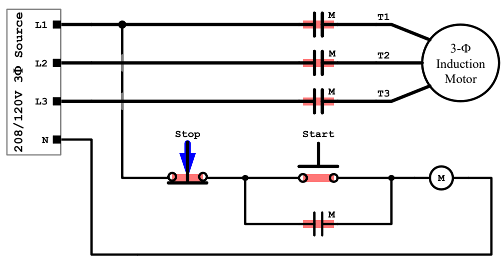
Basic Motor Controller Operation

Stopping the Motor:

If the **STOP** button is **pressed**:

2) When the coil is de-energized, the electromagnet **releases** the **armature,** causing it to "**drop-out**" and **return the contacts to their NO positions** (after a small travel delay)…



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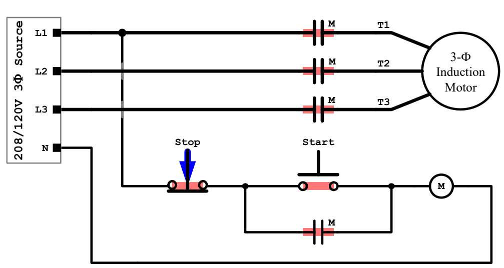
Basic Motor Controller Operation

Stopping the Motor:

If the **STOP** button is **pressed**:

3) When the main contacts open, the **motor is disconnected from the 3Φ supply** (de-energized), thus causing the **motor** to decelerate until it comes **to** a complete **stop**.



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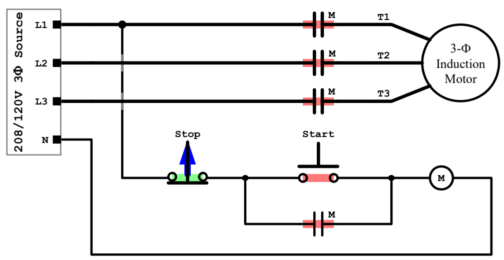
Basic Motor Controller Operation

Stopping the Motor:

If the **STOP** button is **released**:

The **STOP button's contact closes**, but the NO **START** button and NO auxiliary contact **prevent the field coil from being re-energized**, and thus **the motor remains stopped**.



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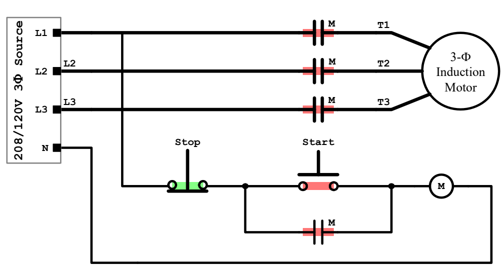
Basic Motor Controller Operation

Steady-state operation after shutdown:

Once the motor is stopped, the system has returned to the same operational state that existed before **START** was pressed, and thus it will remain stopped unless **START** is pressed again.

Note that, once stopped, pressing and releasing the STOP button again causes no change in the operational state of the system.



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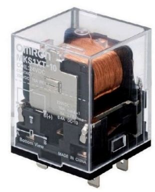
Relays

A **relay** is an electrically controlled switch, similar to a contactor, but more generic in use:

- **Energizes and de-energizes** smaller devices (low current) that are incorporated into a control system;
- **Performs switching functions** that can be utilized as part of the operational logic (relay logic) required by a control system.



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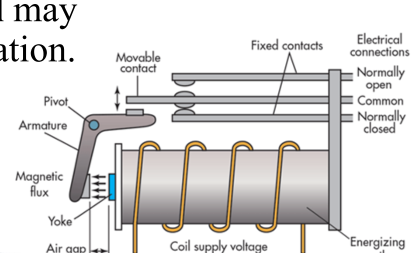
Relays

A **relay** may either be electromechanical or solid-state.

If **electromechanical**:

- Contains an electromagnet, the **field coil** may be rated for either an AC or a DC operation.
- May contain multiple **NO** and/or **NC** contacts that actuate simultaneously when the field coil is energized.



If **solid-state**, the relay performs the same tasks, but all of the internal components are electronic.

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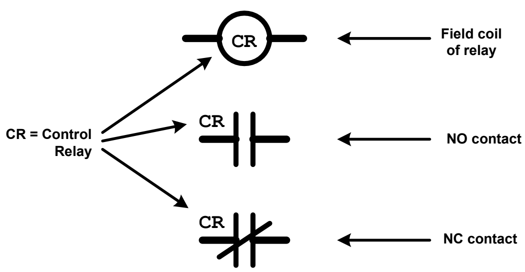
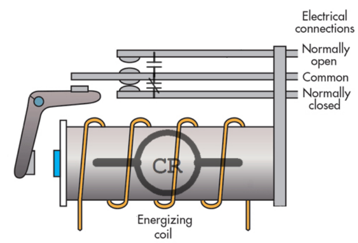
Relay Symbols

When displayed within a schematic diagram, the **same symbols** are used to depict a **relay's internal components**:





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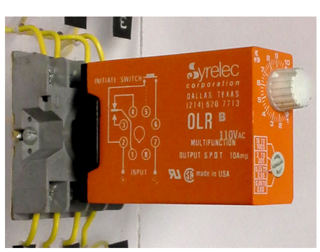
Timers

A **timer** is a device that is often utilized within a control system when there is a timed sequence of events that must occur:

- Delays actuating one or more sets of **NO** and/or **NC** contacts for a preset amount of time.



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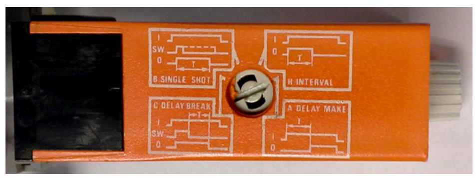
Timers

A **timer** is a device that is often utilized within a control system when there is a timed sequence of events that must occur:

- **Delays** actuating one or more sets of **NO** and/or **NC** contacts for a preset amount of time.
- Timers may be **electromechanical** or **solid-state**.
- Solid-state timers can often be configured to provide a variety of timing functions.



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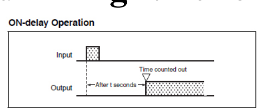
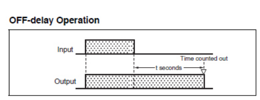
Timers

The four most commonly used **timing functions** are:

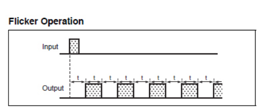
- **On-Delay Operation**



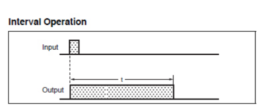
- **Off-Delay Operation**

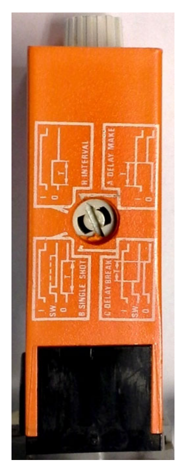


- **Flicker Operation**



- **Interval Operation**





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Overload Relays

Overload Relay is a type of relay that, in conjunction with a contactor, is designed to protect a motor from an overload.

An overload is defined as any current above the rated current (FLA) of the motor but limited to the motor's locked rotor current (LRA).

Note that currents in excess of the locked rotor current may also occur due to short circuits or ground faults, but they are not considered "overloads" and thus are covered by other protective devices (fuses & breakers).

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Overload Relays – Overload Concerns

Overload Concerns:

- A motor will draw overload currents if the torque required to drive the mechanical load coupled to its shaft is greater than the motor's rated torque.
- Overload currents also occur normally in a motor at startup.
- A low supply voltage can also result in a motor overload.
- When overloaded, the larger-than-rated currents cause excessive heating in the motor's windings that can damage or decrease the lifespan of the motor.
- Even a small overload can be damaging if sustained over time.

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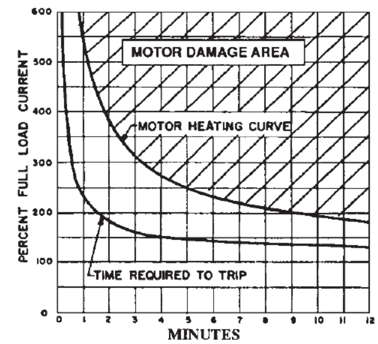
Overload Relays – Time Curve

Time Curve

- The **time curve** for an overload relay is theoretically set based upon the heating curve for the motor that it is protecting.
- Thus, overload relays typically operate on an **inverse time curve** such that they will "trip" (activate) faster for large overloads, but will temporarily delay tripping for smaller overloads.



Graph shows motor heating curve and overload relay trip curve. Overload relay will always trip at a safe value

Figure 3-7 Overload Relay Trip Curve

Taken from: "Fundamentals of Motor Control" – Square D Corp. 1991

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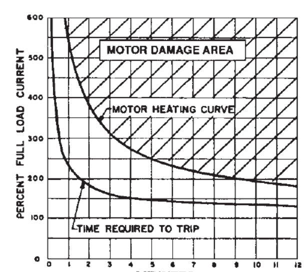
Overload Relays – Time Curve

Overload Relay – Time Curve

- In reality, an overload relay is adjusted to **allow the motor to draw** its large, **starting currents** for the short amount of time that the motor requires to accelerate to normal operating speeds, **while still tripping quickly** during a **failed start** (locked-rotor condition).



Graph shows motor heating curve and overload relay trip curve. Overload relay will always trip at a safe value

Figure 3-7 Overload Relay Trip Curve

- But, since the rate of heating is based on the magnitude of the overload, the motor is allowed to operate for a longer amount of time during a small overload in order to avoid stopping the motor for a temporary overload that it can safely outlast.

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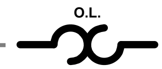
Overload Relay Components & Symbols

An "thermal" overload relay contains a set of **heaters** that heat-up at a rate that is based on the magnitude of the current that is flowing through the relay, and at least one **NC contact**.

- **Heaters**



  - A heater is placed **in-series** with **each line** that supplies power to the motor.
  - The excessive currents drawn by the motor during an overload will eventually cause the **heaters to overheat**, in-turn "tripping" the relay (opening its **NC contact**).

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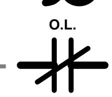
Overload Relay Components & Symbols

An "thermal" overload relay contains a set of **heaters** that heat-up at a rate that is based on the magnitude of the current that is flowing through the relay, and at least one **NC contact**.

- Heaters

- **NC Contact**



  - The NC contact is placed **in-series with** the contactor's **field coil**.
  - When the relay "trips" (NC contact opens), the coil will be de-energized, in-turn causing the main contacts to dropout (open) and de-energize the motor.

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Motor Starters

A **motor starter** is a combination device that utilizes a **contactor** to energize and de-energize the motor and an **overload relay** to provide overload protection, along with a pair of **pushbuttons**, one **NO** and one **NC**, that provide the means for controlling the motor's operation.

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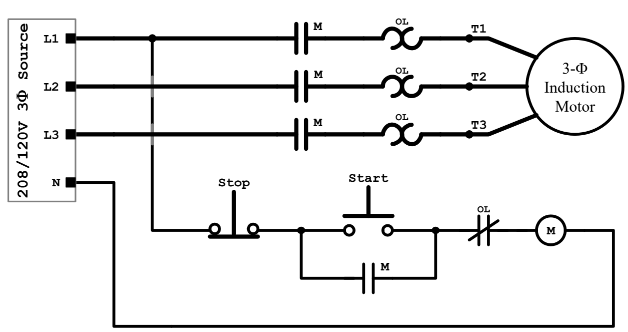
Motor Starter Wiring & Operation

The overload relay's heaters are connected in-series with each of the motor's supply lines, and its NC contact is connected in-series with the contactor's field coil, thus allowing **the overload relay to de-energize the field coil** during an overload, in-turn causing **the contactor to de-energize the motor**.



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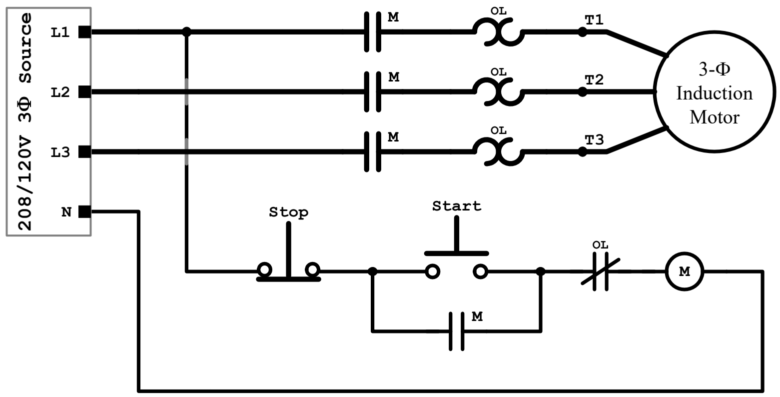
Motor Starters

The following figure shows the component connections for a basic **motor starter**:



Due to their location in the circuit, the OL heaters are often mistakenly assumed to de-energize the motor when an overload occurs.

Remember, it is the main contacts of the contactor that are used to energize and de-energize the motor.

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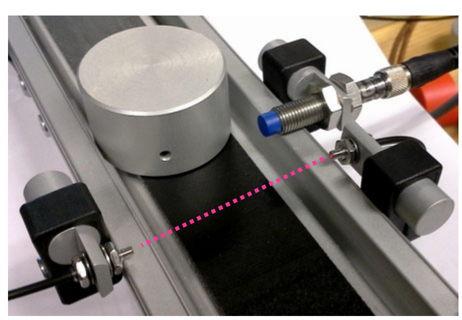
Optical Beam Detectors

Optical Beam Detector

- A device that produces a beam of light, and then actuates a set of contacts whenever an object disrupts the beam.



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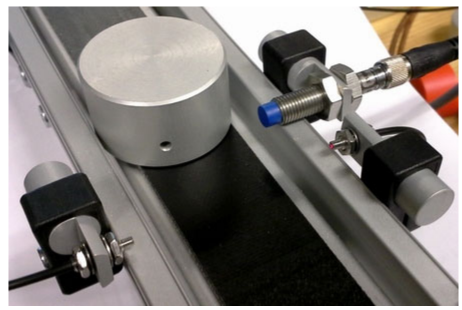
Proximity Detectors

Proximity Detector

- A device that utilizes an electromagnetic field to detect the presence or absence of an object, actuating a set of contacts whenever an object is detected in close-proximity to the sensor.
- An **inductive** detector is used to detect metallic objects.
- A **capacitive** detector can be used to detect both metallic and non-metallic objects.



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Limit Switches

Limit Switch

- **Mechanical position or safety switch** used to make or break an electrical connection as part of an automation system.
- Consists of an actuator that is linked to a set of contacts.
- When an object presses against the actuator, the state of the contacts will change (open → closed or closed → open).

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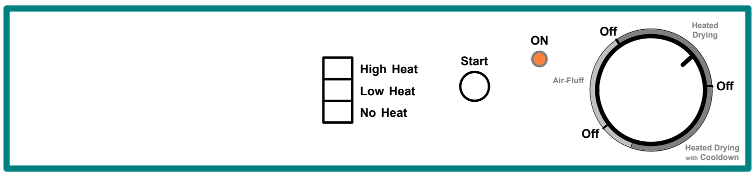
Motor Control System Example

Problem – Design a basic control system for a **clothes dryer** that has the following functionality:

- **Start Button** (with Orange Indicator Lamp)
- **Door Switch** (with Interior Light)
- **Timer** with multiple functions (heat, cool-down, stop)
- **High/Low/No Heat Selection**



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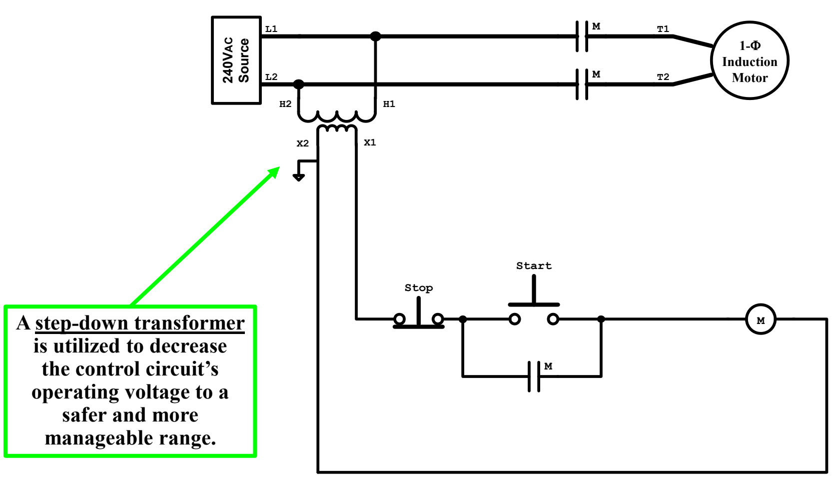
Control System for Clothes Dryer

Let's begin with a basic **stop/start controller**…



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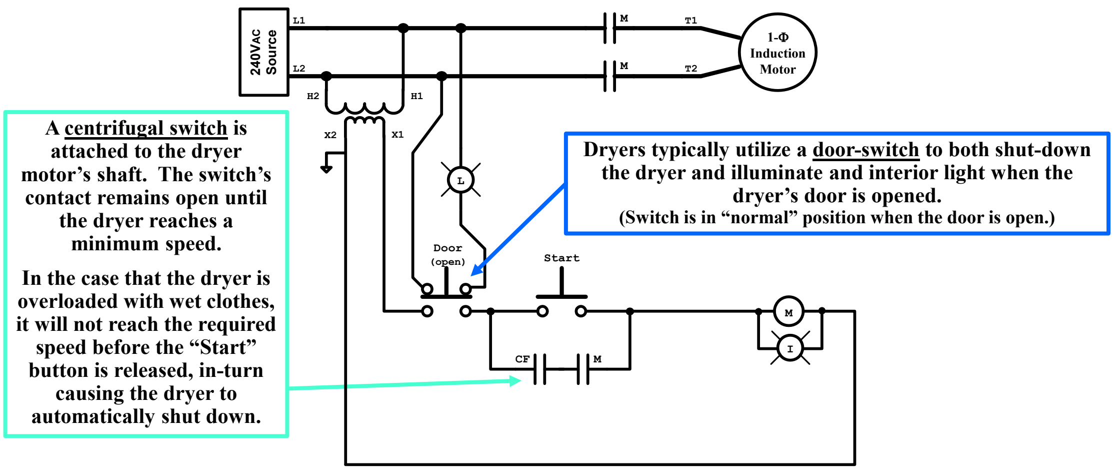
Control System for Clothes Dryer

And add an **indicator**, an **interior lamp**, and a **door switch**…



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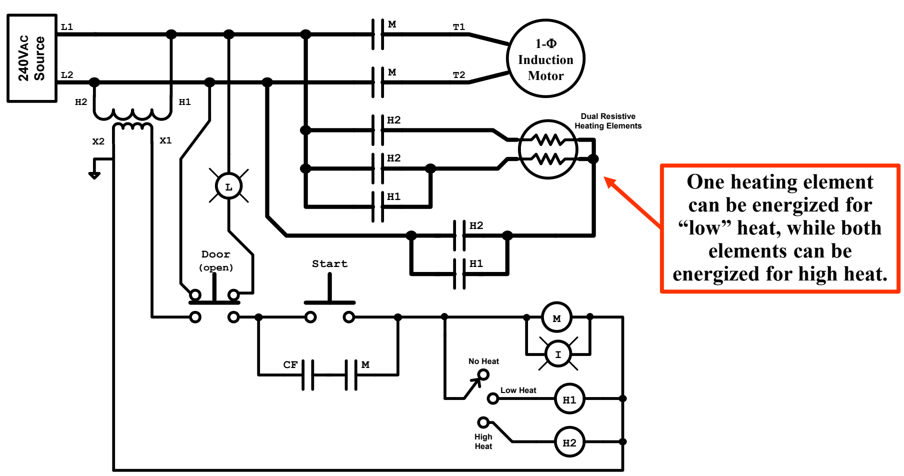
Control System for Clothes Dryer

And then the **heating elements** and a **selector switch**…



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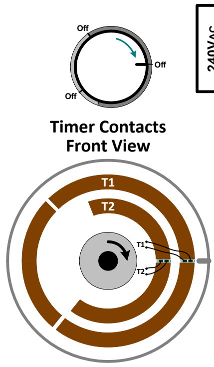
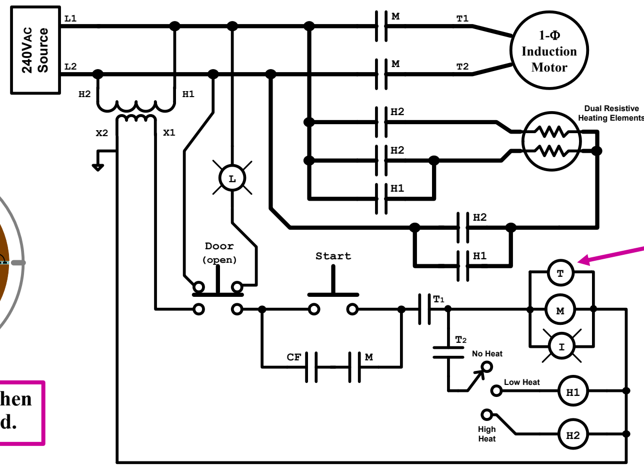
Control System for Clothes Dryer

And finally, a **timer** to complete the basic circuit.



Rotates clockwise when (T) is energized.



A motorized, rotating <u>timer</u> can be used to set the duration of the drying cycle and to limit during which portion of the cycle the heat is available.

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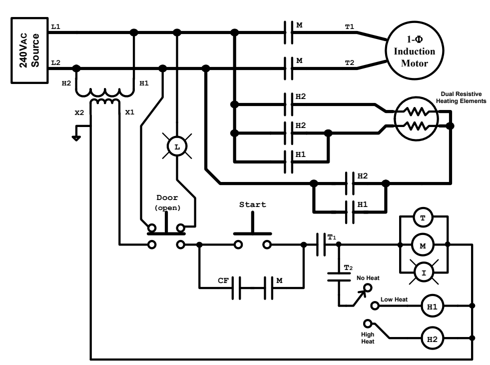
Control System for Clothes Dryer

Possible additions to the dryer control circuit:

- **Overload protection for the motor?**
- **Additional Indicator Lamps?**
- **Buzzer?**
- **Imbalance sensors?**
- **Moisture sensor?**
- **Safety Interlock Switches?**
- **…**



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