ECET 4530 – Industrial Motor Control **Sample Exam II part A – Version I – Problems**

Instructions: *This exam is closed book, except for an 8½"x11" sheet of handwritten notes.*
Show all of your work and make sure that your work is legible and that your reasoning can be followed.
No credit will be given for illegible, illogical or unjustified work. Place all final answers in the spaces provided.

Problem #1) Specify whether each of the following statements are true or false by **printing** either "**TRUE**" or "**FALSE**" in the blank answer space preceding each statement.

_____ An **Overload Relay** primarily consists of a set of heater coils that are used to "detect" a motor overload and a normally-closed contact that is used to de-energize the field coil of the motor's main contactor when an overload is detected.

_____ Although the **Auxiliary Contacts** in a contactor typically actuate simultaneously with the Main Contacts, the auxiliary contacts can be actuated independently from the Main Contacts if needed in order to perform control functions for the motor controller.

_____ For safety reasons, **PLC-based motor controller**s should utilize normally-closed (NC) pushbuttons to initiate "Stopping" functions and normally-open (NO) pushbuttons to initiate "Starting" functions for the system.

_____ With respect to PLCs, **relay-type** output modules do not actually create their output voltages. Instead, they only "make or break" the conductive path for current flow between an external-connected source to an externally-connected "load".

_____ A Boolean-type **tag** is used to identify a bit stored in the PLC's memory and can be used to associate that bit with the state of specific instructions in the PLC's program.

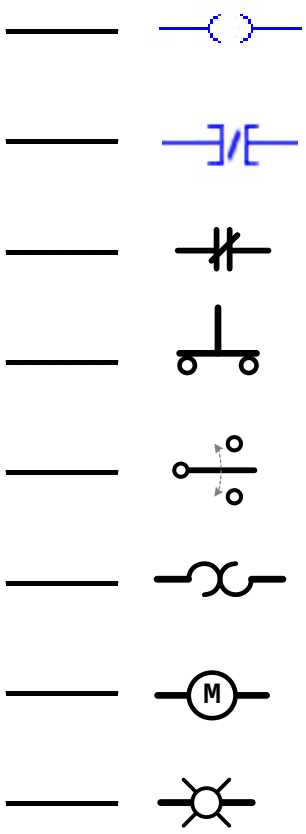
_____ Given an **XIC instruction** (shown to the right) that has been assigned a tag that is aliased to "Input 0", if a +24V_{DC} voltage is applied to input port zero (0), then the logic-state of the XIC instruction will be "**true**".

_____ A **Series-Resistance Motor Starter** attempts to start a motor by initially supplying the motor through a set of series-connected resistors and then bypassing the resistors after a sufficient amount of time has passed for the motor to reach normal operating speeds.

_____ The logical "**OR**" function can be duplicated within a relay-logic system by placing two normally-closed (NC) contacts in parallel with each other.

_____ In order for **BOOTP** to successfully perform its function, either the MAC (hardware) addresses of the control system devices (PLCs, VFDs, etc.) or the Tag Names of the control system devices must be entered into BOOTP's configuration windows.

Problem #2) Match each of the symbols shown in the left-hand column with the correct device listed in the right-hand column by writing the letter associated with the correct device next to the appropriate symbol. Note that both standard NEMA symbols and Compact Logix ladder diagram device symbols may be shown in the first column.



A) OTE – "Output Energize" Instruction

B) OTP – "Output Port" Instruction

C) XIC – "Examine if Closed" Instruction

D) XIO – "Examine if Open" Instruction

E) Indicator Lamp

F) Field Coil of Contactor

G) Normally Closed Pushbutton (shown in the open position)

H) Normally Closed Pushbutton (shown in the closed position)

I) Normally Open Pushbutton (shown in the open position)

J) Normally Open Pushbutton (shown in the closed position)

K) Normally-Open Contact

L) Normally-Closed Contact

M) Overload Relay's Heater (Thermal) Element

N) Fuse

O) None of the above

Problem #3) Given the following rung that contains a logic instruction and an On-Delay Timer (TON), describe in-detail the operation of the timer if the rung condition becomes "true" and remains true for 10 seconds (i.e. – when the "Start" bit is set to a 1 for 10 seconds), after which the rung condition returns to a "false" state. Be sure to include the timer's **ACC**umulator, **EN**able bit, and **D**o**N**e bit in your description.

Problem #1) Specify whether each of the following statements are true or false by **printing** either "**TRUE**" or "**FALSE**" in the blank answer space preceding each statement.

___TRUE___ An **Overload Relay** primarily consists of a set of heater coils that are used to "detect" a motor overload and a normally-closed contact that is used to de-energize the field coil of the motor's main contactor when an overload is detected.

___False___ Although the **Auxiliary Contacts** in a contactor typically actuate simultaneously with the Main Contacts, **the auxiliary contacts can be actuated independently from the Main Contacts if needed in order to perform control functions for the motor controller**.

___TRUE___ For safety reasons, **PLC-based motor controller**s should utilize normally-closed (NC) pushbuttons to initiate "Stopping" functions and normally-open (NO) pushbuttons to initiate "Starting" functions for the system.

___TRUE___ With respect to PLCs, **relay-type** output modules do not actually create their output voltages. Instead, they only "make or break" the conductive path for current flow between an external-connected source to an externally-connected "load".

___TRUE___ A Boolean-type **tag** is used to identify a bit stored in the PLC's memory and can be used to associate that bit with the state of specific instructions in the PLC's program.

___TRUE___ Given an **XIC instruction** (shown to the right) that has been assigned a tag that is aliased to "Input 0", if a +24V_{DC} voltage is applied to input port zero (0), then the logic-state of the XIC instruction will be "**true**".

___TRUE___ A **Series-Resistance Motor Starter** attempts to start a motor by initially supplying the motor through a set of series-connected resistors and then bypassing the resistors after a sufficient amount of time has passed for the motor to reach normal operating speeds.

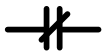
___False___ The logical "**OR**" function can be duplicated within a relay-logic system by placing two **normally-closed (NC)** contacts in parallel with each other.

___False___ In order for **BOOTP** to successfully perform its function, either the MAC (hardware) addresses of the control system devices (PLCs, VFDs, etc.) **or the Tag Names of the control system devices** must be entered into BOOTP's configuration windows.

Problem #2) Match each of the symbols shown in the left-hand column with the correct device listed in the right-hand column by writing the letter associated with the correct device next to the appropriate symbol. Note that both standard NEMA symbols and Compact Logix ladder diagram device symbols may be shown in the first column.

A 

D 

L 

J 

O 

M 

F 

E 

A) OTE – "Output Energize" Instruction

B) OTP – "Output Port" Instruction

C) XIC – "Examine if Closed" Instruction

D) XIO – "Examine if Open" Instruction

E) Indicator Lamp

F) Field Coil of Contactor

G) Normally Closed Pushbutton (shown in the open position)

H) Normally Closed Pushbutton (shown in the closed position)

I) Normally Open Pushbutton (shown in the open position)

J) Normally Open Pushbutton (shown in the closed position)

K) Normally-Open Contact

L) Normally-Closed Contact

M) Overload Relay's Heater (Thermal) Element

N) Fuse

O) None of the above

Problem #3) Given the following rung that contains a logic instruction and an On-Delay Timer (TON), describe in-detail the operation of the timer if the rung condition becomes "true" and remains true for 10 seconds (i.e. – when the "Start" bit is set to a 1 for 10 seconds), after which the rung condition returns to a "false" state. Be sure to include the timer's **ACC**umulator, **EN**able bit, and **D**o**N**e bit in your description.

When the Rung Condition becomes TRUE and remains TRUE for 10 seconds:

- **The TON is Enabled and the Timer_S.EN bit is set (Timer_S.EN = 1)**
- **The timer immediately begins counting from 0 → 5000 (5 seconds). (I.e. – Timer_S.ACC increments from 0 → 5000)**
- **When the Accumulator reaches the Preset (5000), the Timer_S.DN bit is set (Timer_S.DN = 1) and the Accumulator stops counting (remains at 5000).**
- **The timer remains in this condition until the Rung Condition returns to a FALSE state, at which time the timer is Disabled.**
- **When the timer is Disabled, both the Timer_S.EN and the Timer_S.DN bits are reset (Timer_S.EN = 0 and Timer_S.DN = 0) and the Accumulator is reset back to zero (Timer_S.ACC = 0)**

Problem #1) Specify whether each of the following statements are "**TRUE**" or "**FALSE**".

_____ An **Overload Relay** typically consists of a set of heaters that "detect" an overload and a normally-open contact that closes to indicate the occurrence of an overload.

_____ Normally-Closed (NC) pushbuttons are typically utilized with **PLC-based motor controller**s in order to provide "stopping" functions because they will automatically trigger a "stop" function in the case of a control-system ($+24V_{DC}$) supply-voltage failure.

_____ The logical "**AND**" function (i.e. – "A" and "B") can be represented within a relay-logic system by placing a normally-open (NO) "A" contact in-series with a normally-open (NO) "B" contact.

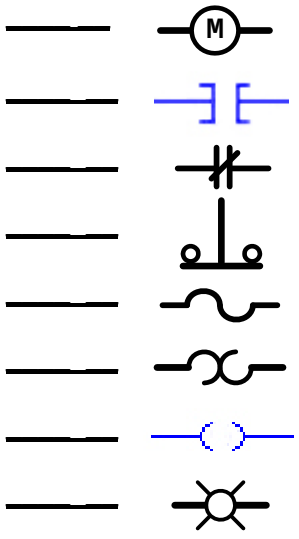
_____ Once the RSLogix 5000 software has been properly configured and a ladder-logic program has been entered into the software, the program must be compiled and **downloaded** onto the PLC before the PLC is able to "run" the program.

_____ **BOOTP** is a PC-based software process that can be used to assign a pre-determined IP address to any control system device (PLC, VFD, etc.) that requires an address, provided that the MAC (hardware) address of the device that requires an IP address is known.

_____ Provided that the drive has already been activated, using a MOV instruction to place a value of **60** into the **VFD:O.FreqCommand** memory location within the VFD will cause the VFD to vary its output frequency until it is producing a set of 60Hz AC waveforms.

_____ With respect to OW-16 relay-type output modules installed in the CompactLogix PLCs in the lab, the **magnitude of the voltage** provided by output port "XX" to its connected load is determined by the value stored in the tag <Local:1:I.Data.XX.Voltage>, when "XX" is the port number ranging from 00 to 15.

Problem #2) Match the symbols shown in the left-hand column with the devices listed in the right-hand column



A) OTE – "Output Energize" Instruction

B) OTP – "Output Port" Instruction

C) XIC – "Examine if Closed" Instruction

D) XIO – "Examine if Open" Instruction

E) Indicator Lamp

F) Main Contactor's Field Coil

G) Normally Closed Pushbutton

H) Normally Open Pushbutton

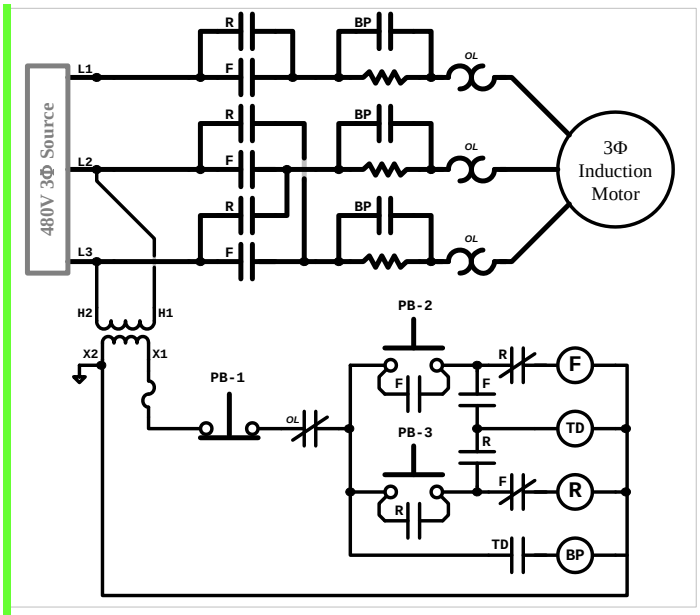
I) Normally-Open Contact

J) Normally-Closed Contact

K) Overload Relay's Heater (Thermal) Element

L) Fuse

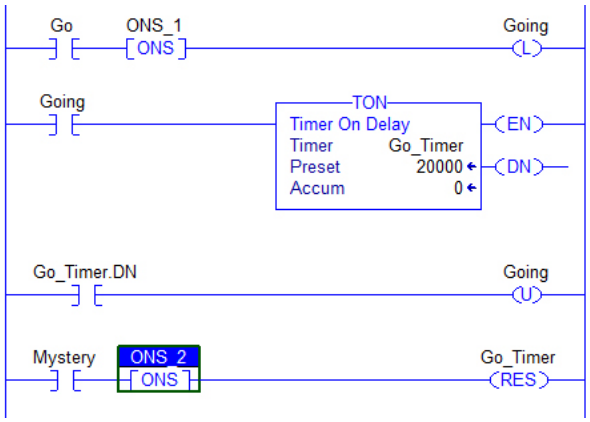
Problem #3) Given the following schematic diagram of a motor-control system: (TD ≡ On-Delay Timer)



a) Describe in detail the overall motor-control system. (For example: "The system is a partial-winding starter with overload-protection…")

b) Describe the motor-control system's operation from an operator's point of view.

Problem #4) Given the following rungs of ladder-logic:



Assuming that "Go", "Going" and "Mystery" are all initially **FALSE**,

If "**Go**" changes from **FALSE** ➡ **TRUE** at an arbitrary time of **t = 0** seconds, and then "**Mystery**" changes from **FALSE** ➡ **TRUE** exactly **5** seconds later,

Describe in detail the operation of the TON timer beginning at time **t = 0** seconds with respect to the timer's Accumulator, Enable bit, and Done bit.

ECET 4530 – Industrial Motor Control **Sample Exam II part A – Version II – Solutions**

Problem #1) Specify whether each of the following statements are "**TRUE**" or "**FALSE**".

False An **Overload Relay** typically consists of a set of heaters that "detect" an overload and a **normally-open contact** that closes to indicate the occurrence of an overload.

TRUE Normally-Closed (NC) pushbuttons are typically utilized with **PLC-based motor controller**s in order to provide "stopping" functions because they will automatically trigger a "stop" function in the case of a control-system ($+24V_{DC}$) supply-voltage failure.

TRUE The logical "**AND**" function (i.e. – "A" and "B") can be represented within a relay-logic system by placing a normally-open (NO) "A" contact in-series with a normally-open (NO) "B" contact.

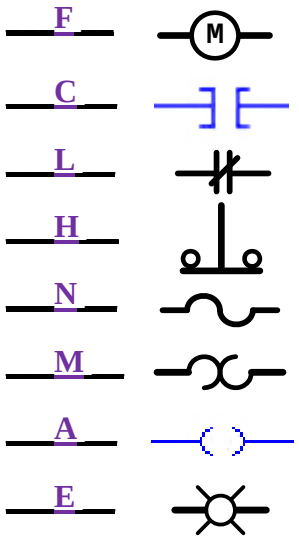
TRUE Once the RSLogix 5000 software has been properly configured and a ladder-logic program has been entered into the software, the program must be compiled and **downloaded** onto the PLC before the PLC is able to "run" the program.

TRUE **BOOTP** is a PC-based software process that can be used to assign a pre-determined IP address to any control system device (PLC, VFD, etc.) that requires an address, provided that the MAC (hardware) address of the device that requires an IP address is known.

False Provided that the drive has already been activated, using a MOV instruction to place a value of **60** into the **VFD:O.FreqCommand** memory location within the VFD will cause the VFD to vary its output frequency until it is producing a set of 60Hz AC waveforms.

False With respect to OW-16 relay-type output modules installed in the CompactLogix PLCs in the lab, the **magnitude of the voltage** provided by output port "XX" to its connected load is determined by **the value stored in the tag <Local:1:I.Data.XX.Voltage>,** where "XX" is the port number ranging from 00 to 15.

Problem #2) Match the symbols shown in the left-hand column with the devices listed in the right-hand column



A) OTE – "Output Energize" Instruction

B) OTP – "Output Port" Instruction

C) XIC – "Examine if Closed" Instruction

D) XIO – "Examine if Open" Instruction

E) Indicator Lamp

F) Main Contactor's Field Coil

G) Normally Closed Pushbutton

H) Normally Open Pushbutton

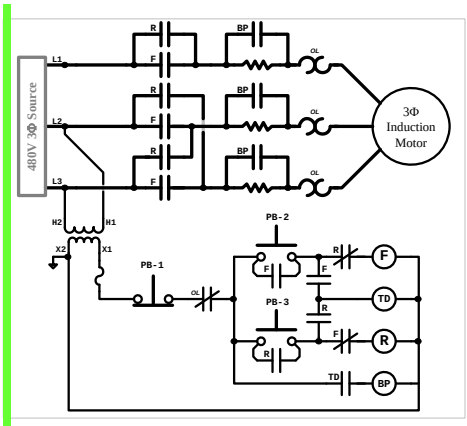
I) Normally-Open Contact

J) Normally-Closed Contact

K) Overload Relay's Heater (Thermal) Element

L) Fuse

Problem #3) Given the following schematic diagram of a motor-control system: (TD ≡ On-Delay Timer)



a) Describe in detail the overall motor-control system.

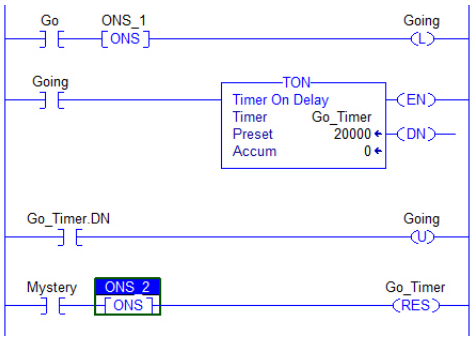
This is a Reduced-Voltage (Series-Resistance) motor-control system with Directional Control and Overload Protection.

b) Describe the motor-control system's operation from an operator's point of view.

To Start the motor in the Forward direction:
– Press-and-Release PB-2
To Start the motor in the Reverse direction:
– Press-and-Release PB-3
To Stop the motor:
– Press-and-Release PB-1

When starting the motor in either direction, the motor will initially be started with reduced voltage and then automatically switched to full-voltage after a preset time-delay.
To change directions, the motor must first be stopped and then restarted
When an Overload occurs, the motor will automatically stop and cannot be restarted until the overload relay resets.

Problem #4) Given the following rungs of ladder-logic:



Assuming that "Go", "Going" and "Mystery" are all initially **FALSE**,

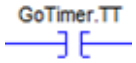
If "**Go**" changes from **FALSE** ➡ **TRUE** at an arbitrary time of **t = 0** seconds, and then "**Mystery**" changes from **FALSE** ➡ **TRUE** exactly **5** seconds later,

Describe in detail the operation of the TON timer beginning at time **t = 0** seconds with respect to the timer's Accumulator, Enable bit, and Done bit.

When "Go" changes from FALSE ➡ TRUE at time t = 0, Going is Latched (Going = 1), causing the XIC on the second rung to become TRUE, in-turn making the rung condition TRUE:
- **The TON is Enabled and the Go_Timer.EN bit is set (Go_Timer.EN = 1)**
- **The timer immediately begins counting (I.e. – Go_Timer.ACC begins incrementing)**

When the Accumulator reaches 5000 (5 seconds), "Mystery" changes from FALSE ➡ TRUE, causing Go_Timer to be RESET. Note that the ONS on the last rung only allows the RES instruction to become TRUE for one scan of the program.
When Go_Timer is RESET, the Accumulator is reset to zero (Go_Timer.ACC = 0), after which:
- **The timer begins counting again (I.e. – Go_Timer.ACC begins incrementing)**
- **When the Accumulator reaches the Preset value of 20000 (20 seconds later), the Go_Timer.DN bit is set (Go_Timer.DN = 1) the Accumulator stops incrementing (remains at 20000), and the timer remains in this state.**

Problem #1) Specify whether each of the following statements are "**TRUE**" or "**FALSE**".

_____ The instruction 

will return a "**TRUE**" logic state whenever GoTimer is enabled provided that the value stored in GoTimer's Accumulator has not reached GoTimer's Preset value.

_____ An **Overload Relay** operates on a time-curve to avoid shutting-down a motor during start-up due to the normally-large starting-currents that a motor will draw provided that the motor is able to achieve a normal operational speed within a short amount of time.

_____ The CompactLogix PLCs in the lab must be **switched from "Run" to "Program" mode** (either remotely or using the key-switch) before a new program can be compiled and downloaded onto the PLC by the RSLogix 5000 software.

_____ An **Overload Relay** typically consists of a set of heaters that "detect" an overload and a normally-closed contact that opens to indicate the occurrence of an overload.

_____ Although the **Auxiliary Contacts** in a contactor typically actuate simultaneously with the Main Contacts, the auxiliary contacts can be actuated independently from the Main Contacts if needed in order to perform control functions for the motor controller.

_____ **Normally-Closed** (**NC**) **pushbuttons** are typically utilized within a PLC-based motor control system in order to provide "stopping" functions because they will automatically trigger a "stop" function in the case of a control-system (+24V_{DC}) supply-voltage failure.

_____ Although **contactors** are designed to be able to disconnect an energized motor from its supply lines (i.e. – shut-down the motor), even during overload conditions, contactor's are not designed to interrupt short-circuit currents or other similarly-large fault currents.

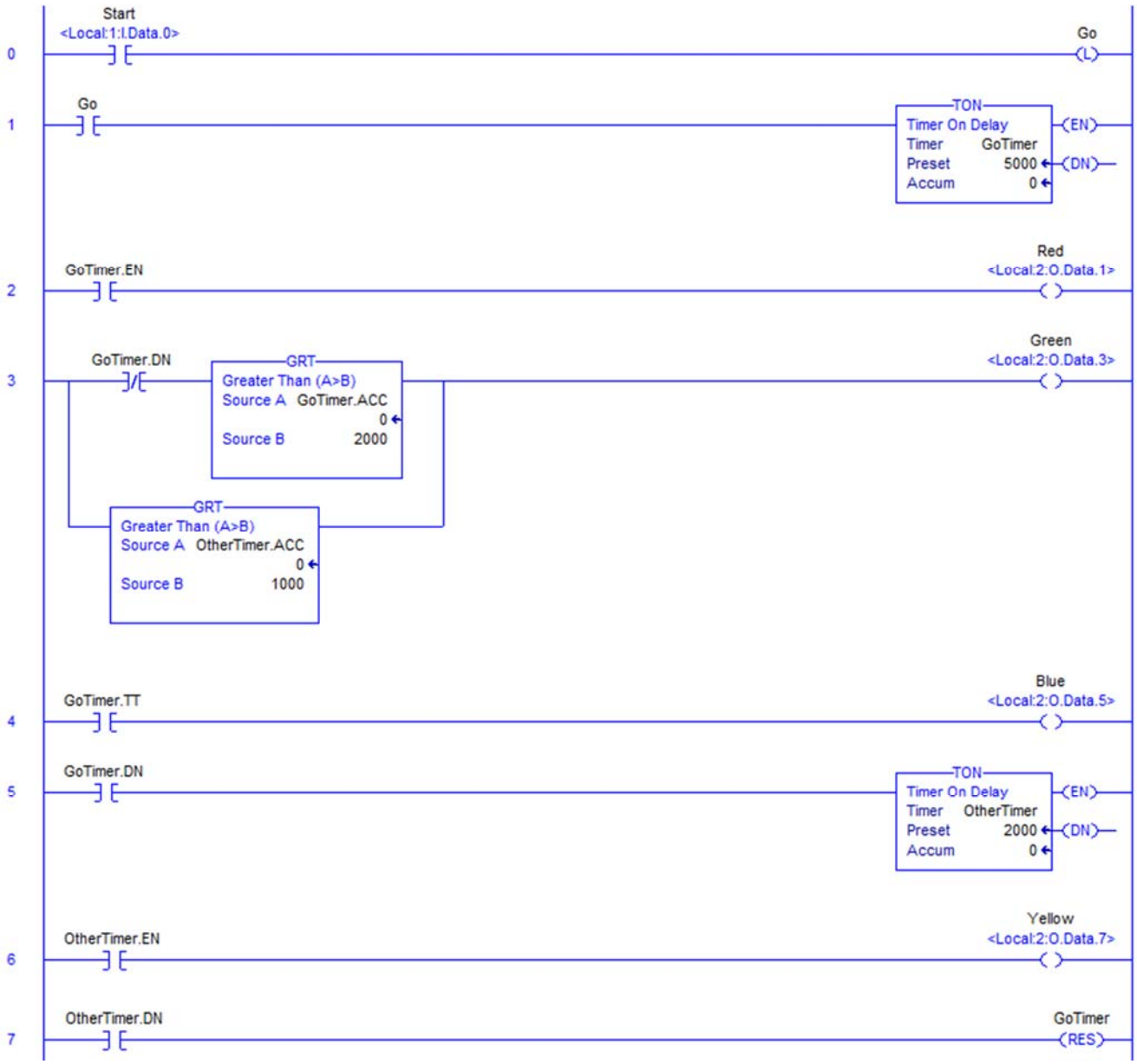
_____ A **Boolean-type Tag** is used to identify a bit stored in the memory of the PLC or some other connected control system device (such as a VFD) and can be used to associate that bit's value with the state of a specific instruction in the PLC's program.

_____ Given the logic **instruction** (shown to the right) that has been assigned a tag that is aliased to "Input 0", if a +24V_{DC} voltage is applied to input port 0, then the logic-state of the instruction will be "**TRUE**".

_____ **BOOTP** is a software process that can assign IP addresses to devices (PLCs, VFDs, etc.) that request an address provided that the MAC (hardware) address of the requesting device has already been linked to an IP address in BOOTP's Relation List.

_____ If a VFD has been activated and is driving a motor with a set of 60Hz waveforms, **the motor can be stopped** by either using a MOV instruction to place a zero (**0)** into the **VFD:O.FreqCommand** memory location within the VFD or by latching the **VFD:O.Stop** bit.

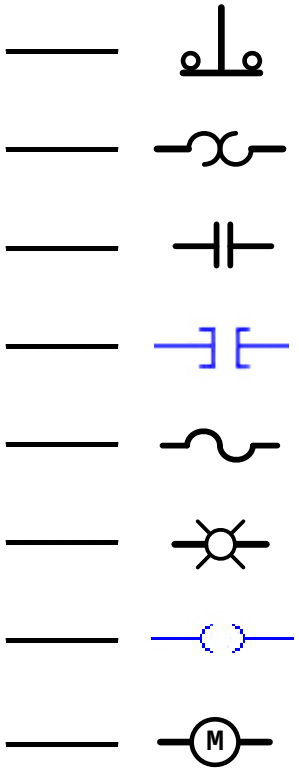
Problem #2) Given the following PLC-based system shown on the last page and the following Ladder-Logic program that the PLC is executing:



If the "**Start**" button is pressed at time **t = 0**, specify the timespans during which each light is "**ON**" for the first 14 seconds of operation (after the button is pressed) by writing "**ON**" in the appropriate timespan boxes in the following table:

time	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
timespan (seconds)	**0→1**	**1→2**	**2→3**	**3→4**	**4→5**	**5→6**	**6→7**	**7→8**	**8→9**	**9→10**	**10→11**	**11→12**	**12→13**	**13→14**	
Red															
Green															
Blue															
Yellow															

Problem #3) Match the symbols shown in the left-hand column with the items listed in the right-hand column.



P) OTE – "Output Energize" Instruction

Q) OTE – "Output Execute" Instruction

R) OTP – "Output Port" Instruction

S) XIC – "Examine if Closed" Instruction

T) XIO – "Examine if Open" Instruction

U) Indicator Lamp

V) Main Contactor's Field Coil

W) Normally Closed Pushbutton

X) Normally Open Pushbutton

Y) Normally-Open Contact

Z) Normally-Closed Contact

AA) Overload Relay's Heater (Thermal Element)

BB) Overload Relay's Trip Contact

CC) Fuse

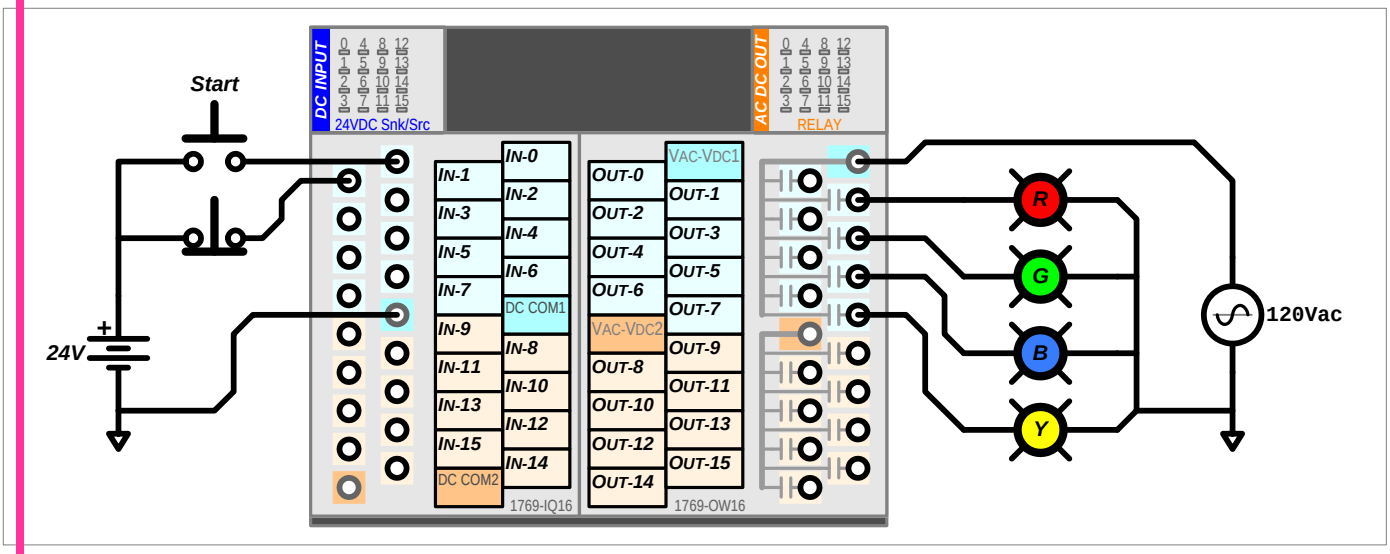
DD) None of the above

Problem #4) Given the motor-control system shown on the next page:

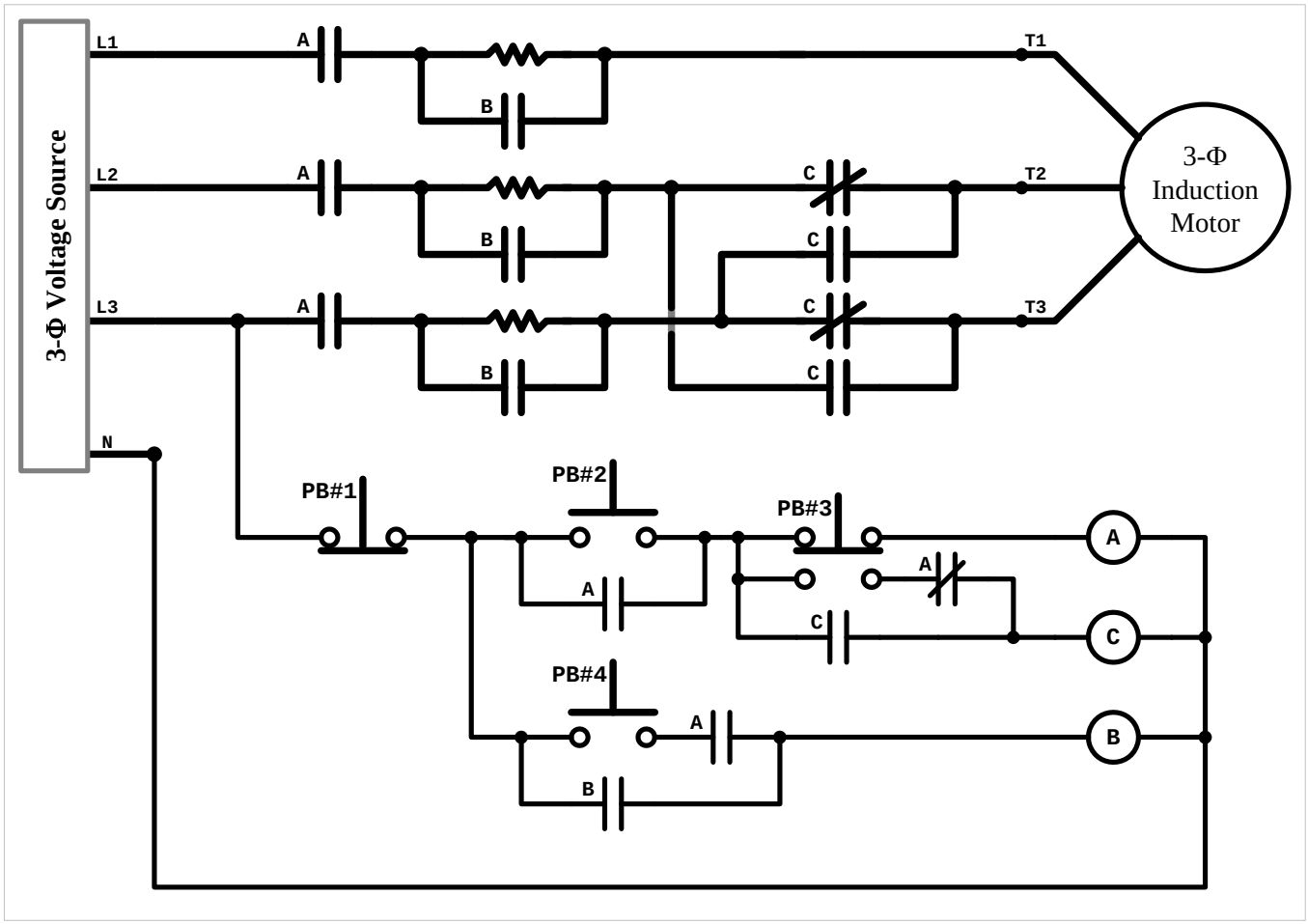
c) Describe in detail the **overall function** of the motor-control system.
(For example: "The system is a partial-winding starter with overload-protection.")

d) State the **exact set of steps** that are required to properly start the motor in the reverse direction.

e) Is it possible to **start** the motor with **full-voltage** initially applied across its terminals at startup? Justify your answer.



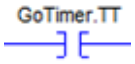
PLC-based System for Problem #2



Motor Control System for Problem #4

ECET 4530 – Industrial Motor Control **Sample Exam II part A – Version III – Solutions**

Problem #1) Specify whether each of the following statements are "**TRUE**" or "**FALSE**".

___**TRUE**___ The instruction 

will return a "**TRUE**" logic state whenever GoTimer is enabled provided that the value stored in GoTimer's Accumulator has not reached GoTimer's Preset value.

___**TRUE**___ An **Overload Relay** operates on a time-curve to avoid shutting-down a motor during start-up due to the normally-large starting-currents that a motor will draw provided that the motor is able to achieve a normal operational speed within a short amount of time.

___**TRUE**___ The CompactLogix PLCs in the lab must be **switched from "Run" to "Program" mode** (either remotely or using the key-switch) before a new program can be compiled and downloaded onto the PLC by the RSLogix 5000 software.

___**TRUE**___ An **Overload Relay** typically consists of a set of heaters that "detect" an overload and a normally-closed contact that opens to indicate the occurrence of an overload.

___**False**___ Although the **Auxiliary Contacts** in a contactor typically actuate simultaneously with the Main Contacts, **the auxiliary contacts can be actuated independently from the Main Contacts** if needed in order to perform control functions for the motor controller.

___**TRUE**___ **Normally-Closed** (**NC**) **pushbuttons** are typically utilized within a PLC-based motor control system in order to provide "stopping" functions because they will automatically trigger a "stop" function in the case of a control-system (+24V_{DC}) supply-voltage failure.

___**TRUE**___ Although **contactors** are designed to be able to disconnect an energized motor from its supply lines (i.e. – shut-down the motor), even during overload conditions, contactor's are not designed to interrupt short-circuit currents or other similarly-large fault currents.

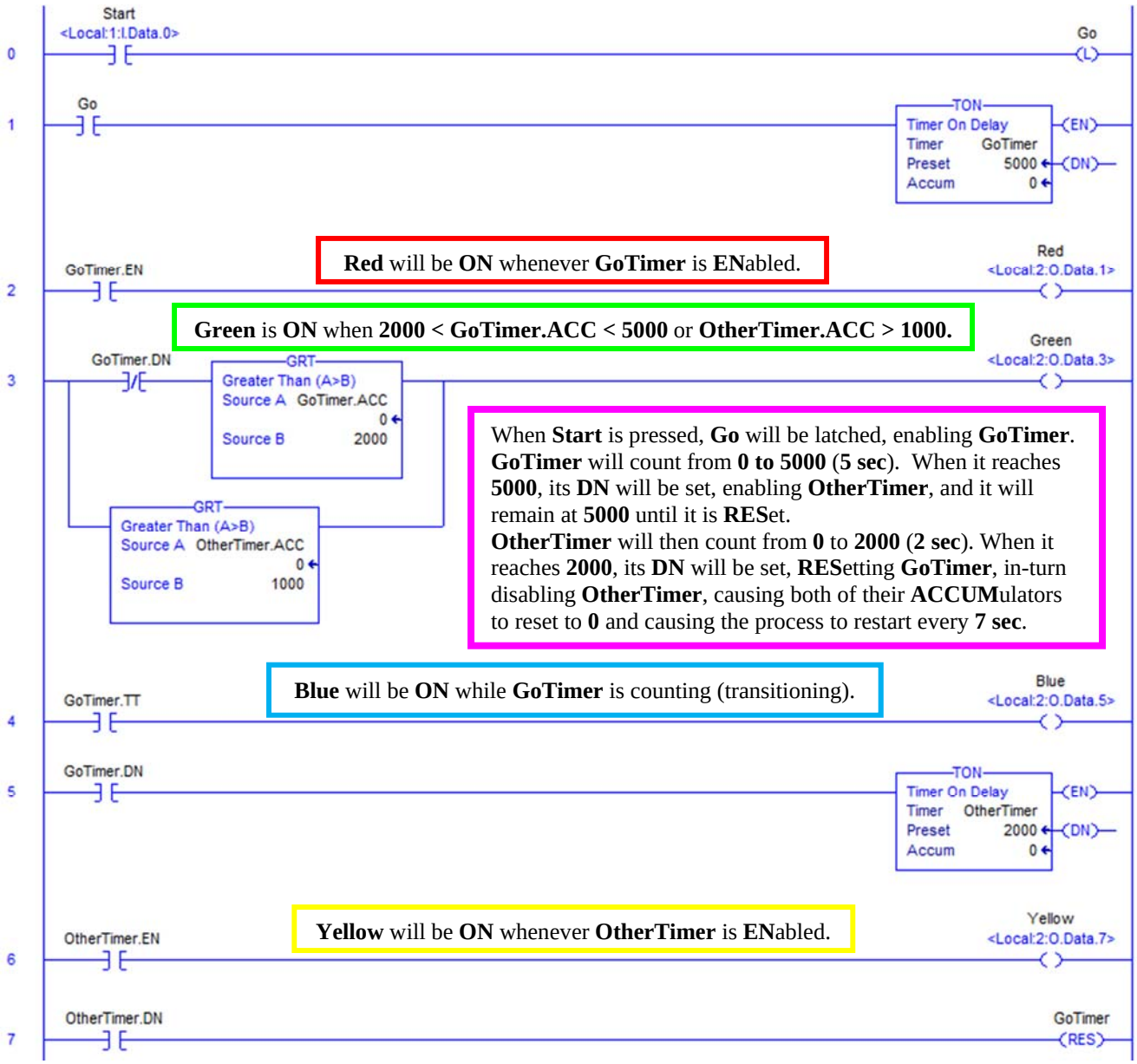
___**TRUE**___ A **Boolean-type Tag** is used to identify a bit stored in the memory of the PLC or some other connected control system device (such as a VFD) and can be used to associate that bit's value with the state of a specific instruction in the PLC's program.

___**False**___ Given the logic **instruction** (shown to the right) that has been assigned a tag that is aliased to "I.Data.0", if a +24V_{DC} voltage is applied to input port 0, then the logic-state of the instruction will be "**TRUE**".

___**TRUE**___ **BOOTP** is a software process that can assign IP addresses to devices (PLCs, VFDs, etc.) that request an address provided that the MAC (hardware) address of the requesting device has already been linked to an IP address in BOOTP's Relation List.

___**TRUE**___ If a VFD has been activated and is driving a motor with a set of 60Hz waveforms, **the motor can be stopped** by either using a MOV instruction to place a zero (**0**) into the **VFD:O.FreqCommand** memory location within the VFD or by latching the **VFD:O.Stop** bit.

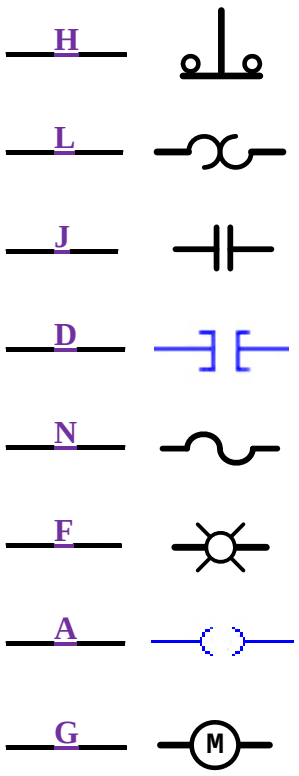
Problem #2) Given the following PLC-based system shown on the last page and the following Ladder-Logic program that the PLC is executing:



If the "**Start**" button is pressed at time **t = 0**, specify the timespans during which each light is "**ON**" for the first 14 seconds of operation (after the button is pressed) by writing "**ON**" in the appropriate timespan boxes in the following table:

time	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
timespan (seconds)	**0→1**	**1→2**	**2→3**	**3→4**	**4→5**	**5→6**	**6→7**	**7→8**	**8→9**	**9→10**	**10→11**	**11→12**	**12→13**	**13→14**	
Red	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	
Green			ON	ON	ON		ON			ON	ON	ON		ON	
Blue	ON	ON	ON	ON	ON			ON	ON	ON	ON	ON			
Yellow						ON	ON						ON	ON	

Problem #3) Match the symbols shown in the left-hand column with the items listed in the right-hand column.



EE) OTE – "Output Energize" Instruction

FF) OTE – "Output Execute" Instruction

GG) OTP – "Output Port" Instruction

HH) XIC – "Examine if Closed" Instruction

II) XIO – "Examine if Open" Instruction

JJ) Indicator Lamp

KK) Main Contactor's Field Coil

LL) Normally Closed Pushbutton

MM) Normally Open Pushbutton

NN) Normally-Open Contact

OO) Normally-Closed Contact

PP) Overload Relay's Heater (Thermal Element)

QQ) Overload Relay's Trip Contact

RR) Fuse

SS) None of the above

Problem #4) Given the motor-control system shown on the last page:

f) Describe in detail the **overall function** of the motor-control system.
(For example: "The system is a partial-winding starter with overload-protection.")

It is a series-resistance reduced-voltage starter with directional control.

g) State the **exact set of steps** that are required to properly start the motor in the reverse direction.

1 – **Press** and **Hold PB#3**
2 – **Press** and **Hold PB#2** [energizes contactor-C (set for reverse)]
3 – **Release PB#3** [energizes contactor-A (resistance start)]
4 – **Release PB#2**
5 – Wait 1-2 seconds to allow motor to accelerate to normal operating speeds.
6 – **Press** and **Release PB#4** [energizes contactor-B (normal operation)]
[bypasses resistors for full-voltage operation]

h) Is it possible to **start** the motor with **full-voltage** initially applied across its terminals at startup?
Justify your answer.

YES

Not the first time since **contactor-B** cannot be energized until **contactor-A's** contacts have actuated closed. Even if **PB#2** and **PB#4** are pressed at the same time, there will still be a small time delay during which the motor will be energized through the resistors (at a reduced voltage).
But, after it is already running, pressing **PB#3** will cause **contactor-A** to dropout while **contactor-B** remains energized (resistors bypassed). If **PB#1** is not pressed to "properly" stop the motor, the next time **PB#2** is pressed to start the motor, it will be started will **full-voltage** across its terminals.