

Part 1**PM1440GT Factory Original Electrical Control System:****A. Introduction:**

A Precision Matthews PM1440GT lathe has been converted from the standard 3-phase Factory Original Control Systems to run on single phase power using bi-polar solid state control electronics and a Variable Frequency Device (VFD). All previously built-in safety features are replicated or exceeded and new ones added. In addition new operational features have been incorporated. The purpose of this document is to provide sufficient detail to enable others to repeat and improve upon this design as well as allowing the author to recall what was done and why!

A major objective of this conversion was to fit the new conversion system into the original lathe cabinet. Hence, solid state circuits were used to eliminate most, if not all, of the original large mechanical relays, power transformer, and other parts.

The major objective of this document is to provide a record, but more importantly to provide an organized, detailed technical description for those who decide to try to duplicate or improve upon the conversion design. Simply viewing the Figures and Photos may be the best approach for those who want a short read.

This document is multipart.

The Part 1 is a technical description of the factory original PM1440GT electronics and its operation. Some readers may choose to skip Part 1. There it was observed that the 3-phase, 220V, machine electronics were built around the use of relays (contactors) for controlling the on-off, forward-reverse, jog, and "latching" safety features. The purpose of Part 1 is to enable understanding of the original design and should the need ever arise to allow one to reconstruct the original system. It might also be useful in repairing an original system which has failed. While only a few pages long the two Figures may be helpful even without reading the text.

The Part 2 describes the conversion to 220V 1-phase input power plus the addition of variable speed, additional functional features, while maintaining or improving safety features. All mechanical relays have been eliminated. This is accomplished via the use of the WJ200-022SF Hitachi Inverter, VFD, and custom designed solid state control electronics. The document is a detailed technical description of the new system, its features, design, construction, and its operation. Figure 3, which is described in depth, is an overall electronic schematic of the control electronics. Photo 7 & 8 are of the new conversion electronics, interconnections and control panel operational options.

The text is long and is primarily for those who wish to actually repeat this build. However, portions of the document can be skipped by those already familiar with VFD conversions. To facilitate searching the document the Table of Contents provides hyperlinks to the topic in the text. Every effort was made to ensure that it is technically correct, but errors usually creep in. Feedback, suggestions, and corrections on the design and this document are welcome.

B. General Description:

The Precision Matthews PM1440GT lathe is shown in Photos 1 and 2 and also at: <https://www.precisionmatthews.com/shop/pm-1440gt/>

Along with the front panel (Photo 3), where the control switches are located, the factory control electronics can be accessed via removal of the cover plate at the back of the steel lathe spindle stand (see Photo 2). Also, at the lathe stand end is a second cover plate that provides access to the back side of the electronics enclosure (see Photo 2). This second access, for the most part, contains mechanical parts and provides a pathway to allow wires from the back enclosure to be routed. The electronic switch for the mechanical foot break is also located here. Removing the back enclosure cover plate exposes the factory installed electronics. In Photo 4 and 5 the cover is removed to expose the hardware layout and wire routing. (Also shown are custom added casters and lathe leveling bolts.)

The parts in this cabinet, from top to bottom, consist of: 1) A row of wiring ports into this enclosure. Not obvious are additional ports on the sides which can be used for external power, coolant pump, lighting, accessory cables. 2) The control electronic components and wiring are attached to polymer based orange plate, which can be removed via the 4 visible bolts. 3) 22 pairs of screw terminals, connecting the outer components to the internal control electronics are located just below the row of ports. By disconnecting the incoming wires from the screw terminals the orange plate and all of the mounted electronics maybe lifted out. For this yet to be installed lathe, there are no 3 phase power lines to the lathe yet and so the three top right hand screw terminals remain open. There is a machine ground wire screw just below the ports on the right. 4) Just below the screw terminal is a wire routing channel which carries wires directly to components as well as to the vertically oriented wire routing channel located in the center of the mounting plate. There is also, a short horizontal wiring channel at the bottom right. 5) At the left is a heavy power transformer which converts one leg of the 220Vac 3 phase incoming power to create isolated 110Vac, 24Vac, and 12Vac outputs. As from, the factory, neither the 110Vac nor the 12Vac are used, but are available perhaps for a DRO, work light, etc. The 24Vac is used to control the relays, and is fused at 5 Amp. Hence, as wired this transformer is far larger and heavier than is actually needed. This 24Vac circuit fuse is located just to the right of the transformer and to the left of the vertical wiring channel. It is hard to see, but is just visible to the left of the vertical wiring channel or under the wires when the channel cover is removed. 6) Just below the transformer, at the bottom left is a multi-pole relay (contactor). This relay is wired to provide self-latching properties. Once, excited it stays turned on until something interrupts the current to its actuating coil. This relay action provides much of the safety features of the control system. 7) To the right of the vertical wire channel are 3 additional relays and just below the two left of these are programmable current limiting circuit breakers. The latching relay provides current to the excitation coils of these relays via various external control switches or by contacts on the other relays. Of these three relays, the center one next to the vertical wire channel is for controlling the current to the coolant pump motor. The current breaker just below it is set to approximately 0.3Amp or more, which is also the coolant pump motor rating. The center and right most relays provide power to the lathe's 3 phase (2.2KWatt) three horse power motor. The combination of these two relays is to allow the current path to be interchanged going to the motor and so allow the motor to have both a forward and reverse rotation as well as being turned on and off. Below the left of these two relays is the circuit breaker for the motor circuit which is set to approximately 11Amp/each phase line.

C. Factory Original Circuit Description:

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To enable one to understand the operation there Figures 1 and 2 are provided. Figure 1 is labeled “Electric Control Circuit Layout” and Figure 2 is labeled “Electric Control Schematic.” The Figure 1 is provided to allow one to do a direct comparison to the physical location of the components to Photo 1, while Figure 2, the schematic, provides a logical drawing of the circuits to allow one to understand the overall operation easier. In this the schematic the lathe’s front panel switches and other external connections are shown explicitly as they are connected to allow for minimal circuit tracing. The only difference between the actual Photo 3 and Figure 1 is to illustrate how to connect the 24Vac connection of the work light via screw terminals 10 and 11. However, it was not connected in the lathe when delivered.

At the left and top of Figure 2, one sees the 24Vac supply and its associated 5Amp fuse, which carries current to the series connected Cover-Interlock switch (the moving parts, spindle gears and motor belt are inside this cover), the Emergency-Stop (E-Stop) switch (front panel), and the Mechanical (Foot) Break switch (lathe stand end enclosure). These are all normally closed switches and if any of them are actuated then current ceases along this line and the motor power is removed. The front panel power indicator light goes out if the interlock or the E-Stop break the circuit, but does not if the foot break is actuated. (Caution: Just because this light is off, the power at the control electronics and many other parts of the lathe is still hot.) If all three of these switches remains closed power is supplied to the Coolant switch (front panel) and so if closed, current can flow through the Coolant pump relay coil to the breaker and on to the Coolant pump. This relay’s four contacts are normally open (NO), but close upon excitation and then provide 220Vac (one side of the three phase power) via wires R-S to the pump motor. The breaker for the pump motor must break both the R and S feeds and so this relay has three contacts. However, the left most of these contacts provides the same current as that flowing through the S wire. Hence, all three current sensors of this three line breaker are active (only two wires carry current to the pump motor). The sensors are set at ~0.3Amp to trip the breaker. Should more than 0.3Amps flow to the pump motor the sensors activate the breaker to shut the pump power off. If the motor were stalled, prevented from turning or had difficulty getting started, then the current could exceed the ~0.3Amp limit. (This might happen, especially during startup, if something, like lots of debris or coolant that was very viscous, were in the coolant reservoir to prevent the pump motor from turning or starting up quickly.) Also note that the left pair of contacts of the relay is unused as is one of the pair of contacts for the breaker.

Focusing on the center of Figure 2, one sees the “Self-Latching Relay” (Latching Relay) and above it in the drawing is shown the Reverse-Neutral-Forward switch (Photo 6), which is at the tail stock end of the lathe and is composed of two DPDT (Double-Pole-Double-Throw) switches, which are mechanically connected to the front lathe 3-position lever in such a manner to generate only three positions, one incoming and three outgoing connections. There is only one connection made for each of the three positions of the front lever. These components are supplied with the 24Vac power. When this switch is in the Neutral position it supplies current from the 24Vac supply to the Latching Relay’s excitation coil which then causes closer of its four normally open contacts. The left most connected contacts of this relay carries the 24Vac current back to the excitation coil input, which causes the relay to remain latched even if current is removed by the 3-position lever being moved from the Neutral position to the Reverse or Forward positions. However, should the lever be in either

the Reverse or Forward position and the 24Vac is interrupted (i.e. by E-Stop, Foot break, cover-interlock, Fuse, or Mains power loss) the relay becomes un-latched. When the interrupting issue is resolved, the self-latching relay is inactive, and will not provide power to the motor relays, until it is re-latch by moving the 3-position lever to the Neutral position again. This safety mechanism is to prevent the lathe from suddenly turning on when the interrupting issue is resolved.

150 Meanwhile the two right most contacts of this Latching Relay provide 24Vac current to the excitation coils of the motor power relays. As with the coolant relay the left most contacts are unused. If this relay is un-excited and so the contacts are open, then no power can flow to the motor relay excitation coils. One can also see that the front panel Jog switch can also supply power via the latching relay right most contact even when the direction switch is in the Neutral position. Current through the right most Latch Relay contacts causes the lathe to turn in the Forward direction (Counter-clockwise when viewing the spindle from the tail stock) while current through the middle-left contacts causes the lathe to run in the Reverse direction. So Jogging is allowed, but it only causes the lathe to turn in the Forward direction. One cannot cause a Jog in the reverse direction. This arrangement of the Jog switch essentially being in parallel with the F position of the Reverse-Neutral-Forward switch
160 brings up an interesting situation. Assuming the 3-position lever is in the Reverse position so that the lathe is running in the reverse direction. What happens if the Jog switch is closed? 24Vac is applied to both of the latching relay input contacts and passed on to the Motor relays! However, as will be seen this does not create a conflict.

The motor's current switching relays are at the right side of the diagrams. Note that these two relays are labeled Forward Motor Contactor (Relay) and Reverse Motor Contactor (Relay). To understand the connections, note that the 3 phase line power enters at the top right of the figure via lines labeled R, T, and S. At the figure bottom, the 3 phase power exits, to the motor connections W, V, and U. The purposes of these two relays are to turn
170 the power on and off, to start or stop the motor, and to reverse the direction between Forward and Reverse. Tracing the three lines R, T, and S through the contacts of the Forward direction relay (on the left) one sees that when the contacts are made the connections are S to U, R to V, and T to W. However, when the relay labeled Forward is turn off and the relay labeled Reverse is active, the connections for R to V do not change, but the connections for S and T are reversed with respect to W and V. The reversal of any pair of these 3 phase wires will cause the motor to run in the opposite direction. Note that these two four pole relays are different from the four pole latching and coolant relays as they have 3 NO (normally open) and 1 NC (normally closed, on the right hand side) sets of contact poles. When they are inactive the NC contacts will conduct current and so the
180 24Vac passes through the NC contacts and on to the excitation coil of the other relay. The power passes through the normally open contacts only when there is current passing through the relay's excitation coil. So, for example, when the Reverse-Neutral-Forward switch is in the F position current passes through the latching relay to the NC contacts of the Reverse motor relay on the far right and then on to the excitation coil of the Forward motor relay on the left. This current then excites the Forward relay coil to cause three NO contact pairs to be closed while causing the NC contact pair to be opened. Hence, this NC contact pair cannot provide current to the Reverse relay excitation coil. When the Reverse-Neutral-Forward switch is in the R the situation is totally reversed causing the 3 phase power to be

delivered through the Reverse motor relay. Furthermore, only one of the two motor relays can be excited at a time. Hence, one sees that should the Reverse-Neutral-Forward switch be in the Reverse position the motor will run in the reverse direction. Should the Jog switch be closed during this time, nothing happens since the NC contact of the Reverse Motor relay is open and so no excitation current can be provided to the Forward Motor relay. Should the Reverse-Neutral-Forward switch be in the F position, the lathe is running in the forward direction. Hence closing the Jog switch has no effect on the lathe's behavior. Jog only works when the 3 position lever is in the Neutral position and the only motion is a forward direction Jog. The Jog function would bring the lathe to full speed if it were left engaged, but the operator can momentarily close it and limit the lathe spindle motion better than he could if he just tried to momentarily moved the 3 position lever to a run condition. However, since the Jog function applies full 60Hz power to the motor, it tends to move the spindle more than one might hope for even if only momentarily turned on.

D. Summary of Factory Original Electronic Controls:

In summary, the lathe electronics can only generate power to run in one direction at a time and only if the safety "Self-Latching Relay" has been activated by first putting the three position lever to Neutral. This Self-Latching Relay provides safety to the user as it drops out of the latched state if 24Vac power is removed by one of the safety switches (Cover-Interlock, E-stop, and Foot Break) or if the mains power is shut off. It tends to prevent the lathe motor from starting accidentally after an operational fault. Likewise, the coolant motor pump is turned off if any of these conditions occurs. Otherwise the pump is on as long as it is switched on and so coolant is flowing even when the lathe spindle is not turning. However, should the coolant breaker trip, the coolant would cease to flow, but the lathe would not stop running. The front panel indicator light will turn off even though there can be power in the control enclosure. So it is not a good indicator that it is safe to remove the enclosure panel. One should always remove power to the lathe at a mains switch or breaker before entering the enclosure. There is no interlock switch on the control electronics enclosure panel. The lathe can only be jogged in the forward rotational direction. The large and heavy transformer in the control electronics enclosure is rather wasteful and could easily be replaced with a much smaller 24Vac transformer. The steel enclosure, that is part of the spindle stand and accessible only from the rear, is small and essentially cannot be enlarged. However, it is neatly placed so that it is totally out of the way, but totally inaccessible if the lathe is placed against a wall.

E. Other Factory Original PM1440GT Lathe Technical Details:

Lathe Label:

Brand: Precision Mathews Machinery

<https://www.precisionmathews.com/shop/pm-1440gt/>

Model: PM-1440GT

Serial No. 10811645

Motor: 3HP

Voltage: 220V 60Hz 3PH

Manufacture Date: 2019.11

The Factory Motor Details:

3-Phase Induction

Manufacturer: JIUH DAH Electric Co. LTD.

Type: JDF-H Frame: 90L

Poles: 4 Output: 3HP, 2.2KW

Volts: 220 HZ: 60

Amps: 9.6 INS. E

R.P.M.: 1720 DATE: 2019

Weight: SER. NO. 102218

Motor Belts:

Manufacturer: MITSUBOSHI Belting Ltd.

Model: RECMF-6300

Number: 2 (twin belts)

F. Figures & Photos List:

F1. Figures & Photos of Part 1:

- a. Photo 1 Original Lathe Full Front & Tail Stock End
- b. Photo 2 Original Lathe Full Rear & Spindle End
- c. Photo 3 Original Lathe Front Panel
- d. Photo 4 Original Rear Enclosure w/electronic components
- e. Photo 5 Original Rear Enclosure w/ wire covers removed
- f. Photo 6 Original Tail Stock w/Rev-Neu-FRW switches
- g. Figure 1 Original Control Electronics Physical Layout
- h. Figure 2 Original Control Electronics Schematic



Photo 1 (Part 1) Factory Original PM1440GT: Front side, tail stock end. Note the small electrical box containing the Reverse-Neutral-Forward switches. (Photo was taken at Precision Matthews) IMAG2235



Photo 2 (Part 1) Factory Original PM1440GT: Back Side, Head Stock End. Note back and End Enclosure covers. (Photo was taken at Precision Matthews. Installed Dolly casters do not come with the lathe and were installed prior to delivery.) IMAG2238

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280 Photo 3 (Part 1) Factory Original PM1440GT: Front Control Panels showing control switches and indicator light. Removal of the switch panel requires removal of two top speed gear levers. IMAG2288

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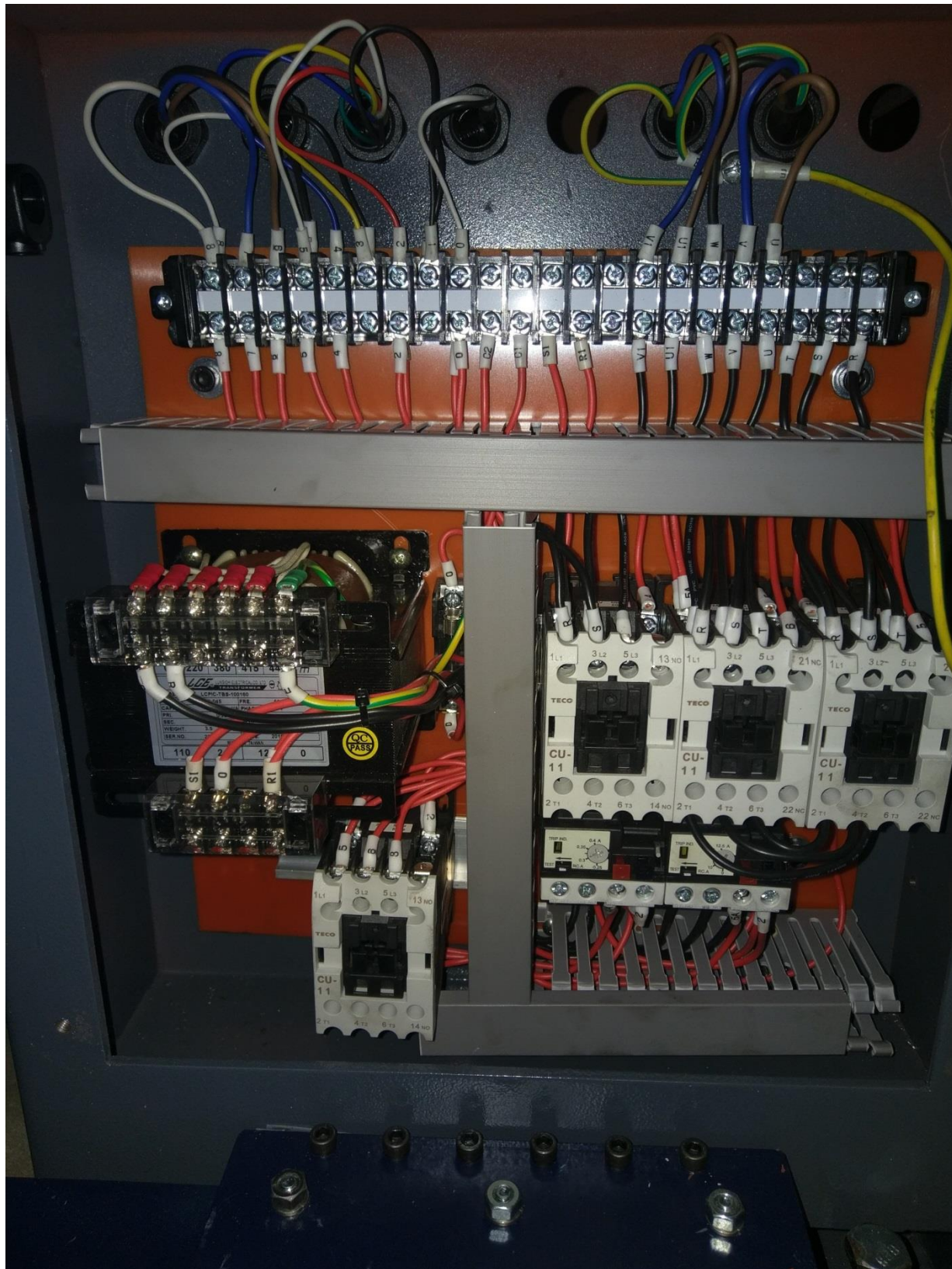


Photo 4 (Part 1) Factory Original PM1440GT: Control Electronics. IMAG2252

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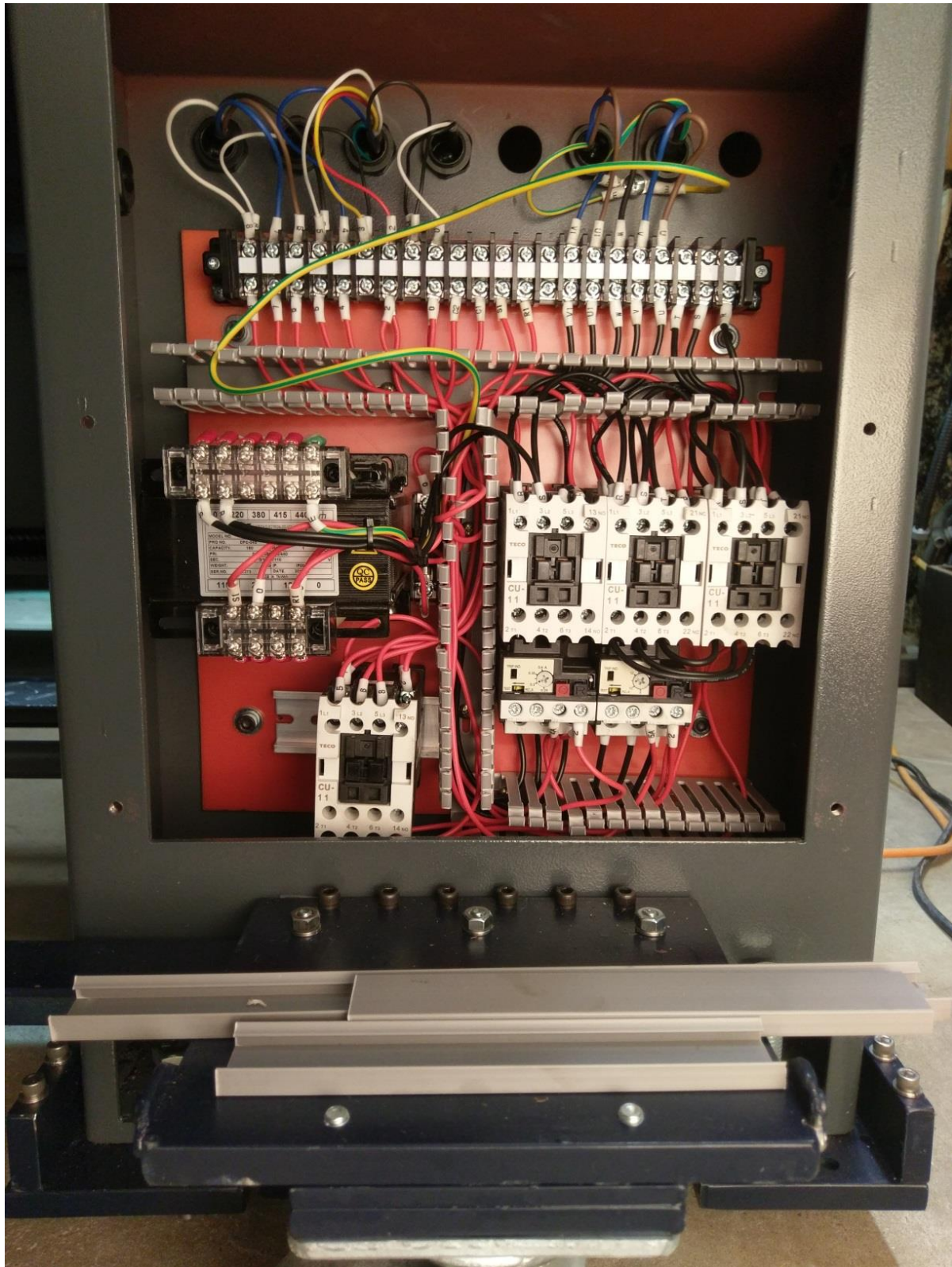


Photo 5 (Part 1) Factory Original PM1440GT: Control Electronics with wiring channel covers removed. IMAG2341

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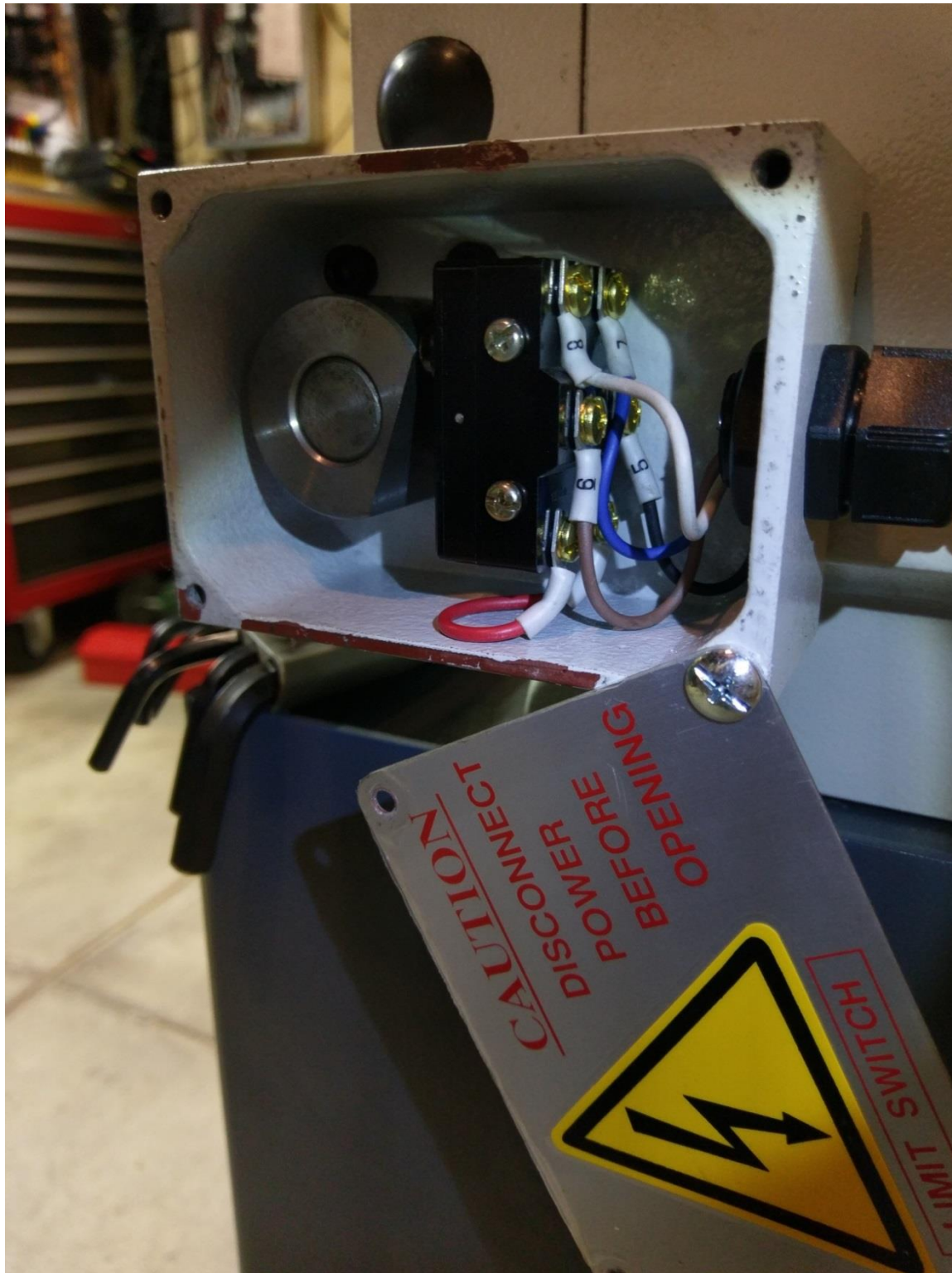


Photo 6 (Part 1) Factory Original PM1440GT: Reverse-Neutral-Forward DPST Switch pair near tail stock. IMAG2289

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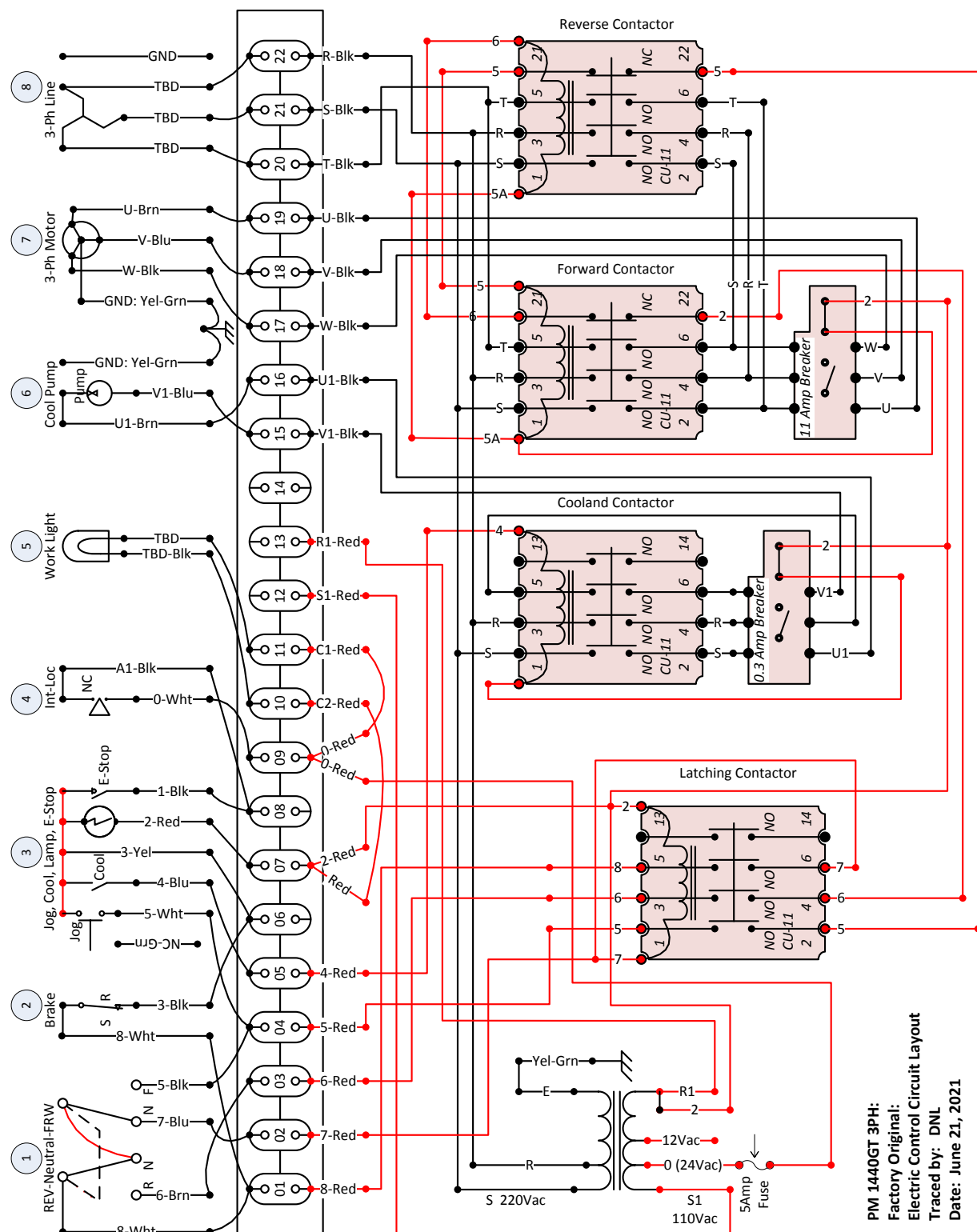


Figure 1 (Part 1) Factory Original PM1440GT: Control Electronics physical layout with wiring traced.

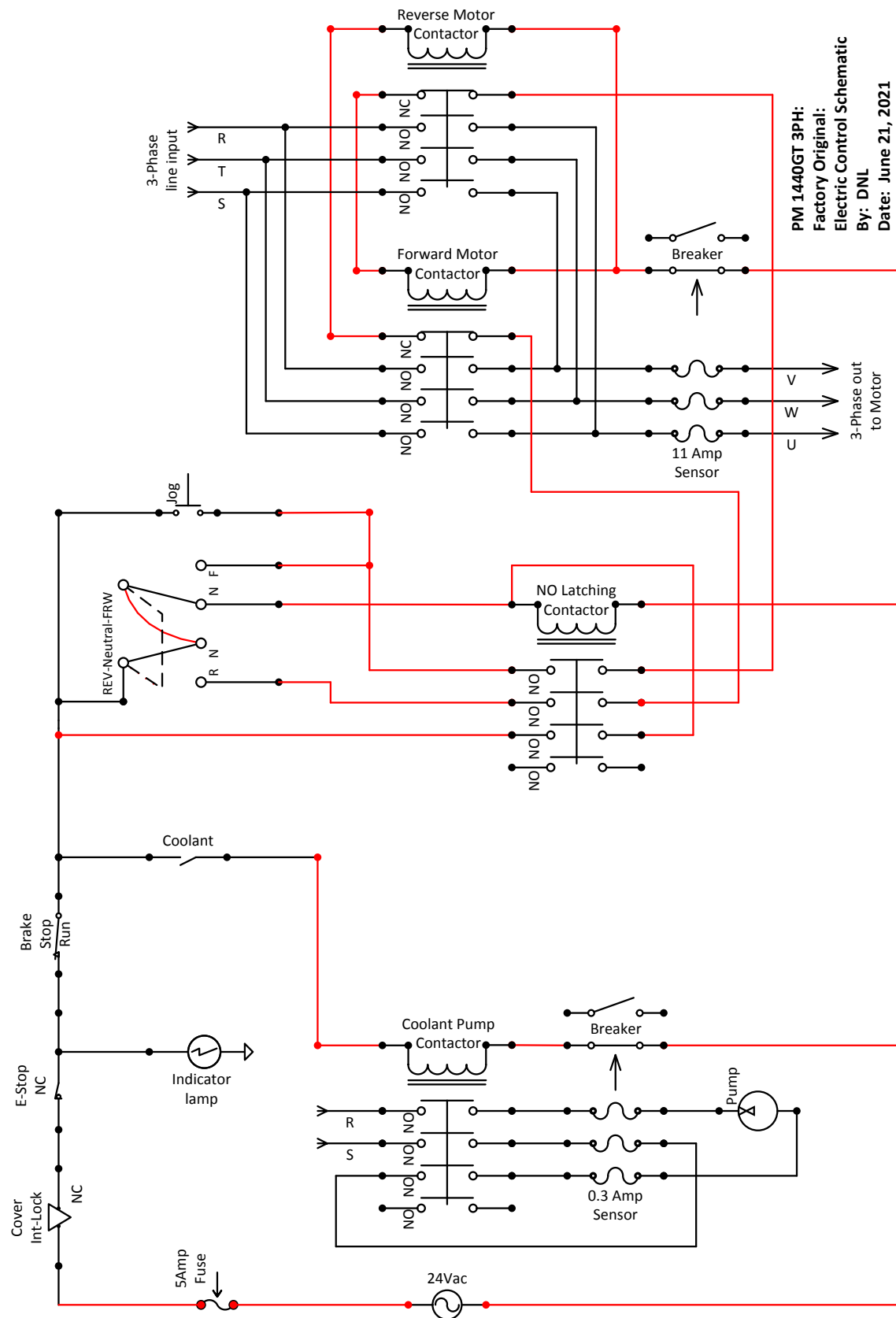


Figure 2 (Part 1) Factory Original PM1440GT: Control Electronics schematic.

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