Installing, Operating and Maintaining 1-2 HP Single-Phase Input 1-5 HP Three-Phase Input 1-5 HP Three-Phase Output General Purpose GP-1000 A-C V★S Drives

Instruction Manual D2-3064-7

July, 1988

V★S®

DRIVES

RELIANCE ELECTRIC

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Section 1
GENERAL INFORMATION

INTRODUCTION

The A-C V★S® Drive is for adjustable speed control of A-C induction and synchronous motors.

This manual contains installation, startup, and troubleshooting instructions and descriptions of operation and options for the Reliance Electric GP-1000 A-C V★S Drive Controller. It applies to 1 through 5 HP controllers operating from single-phase (1 and 2 HP) or three-phase (1 through 5 HP), 200/230 VAC, 50/60 Hz input and producing three-phase, 200, 208, 220, or 230 VAC output to A-C motors. Controller illustrations used in this manual are of the 5 horsepower controller.

RECEIVING AND HANDLING

Acceptance

Reliance Electric terms of sales, in all instances, are F.O.B. point of origin. Therefore, it is important that you thoroughly inspect this equipment before accepting shipment from the transportation company. If any of the items called for on the bill of lading or express receipt are damaged or the quantity is short, do not accept them until the freight or express agent makes an appropriate notation on your freight bill or express receipt. If any concealed loss or damage is discovered later, notify your freight or express agent within 15 days of receipt and request that he make an inspection. It is your responsibility to make claim against the transportation company for any shortage or damage in transit.

Claim for loss or damage in shipment must not be deducted from the Reliance Electric invoice, nor should payment of the Reliance Electric invoice be withheld awaiting adjustment of such claims inasmuch as the transportation company guarantees safe delivery.

If considerable damage has been incurred and the situation is urgent, contact the nearest Reliance Electric Sales Office for assistance.

Unpacking and Storing

After receipt inspection, repack and store the equipment in a clean, dry area until ready to use. Under no conditions should the equipment be stored where the ambient temperature will rise above 65°C (149°F) or fall below −40°C (−40°F), where corrosive conditions exist, or where high humidity is likely to cause condensation on the equipment. Reliance Electric publication D-8079 provides further information on storage procedures and precautions. Proper storage is a must to insure satisfactory drive operation and to maintain warranty coverage.

REFERENCE LITERATURE

The user is urged to refer to the publications listed in **Table 1-1** to become more familiar with the application and operation of this Reliance Electric A-C V★S Drive Controller and related Reliance Electric equipment and service. These manuals are available from your Reliance Electric Sales Office.

BASIC DRIVE COMPONENTS

Reliance Electric A-C V★S Drive packages consist of two basic drive components: an adjustable frequency A-C V★S Drive Controller and an induction motor. Each drive component can be purchased separately, or both components can be purchased as a complete drive package.

A-C V★S Drive Package

Reliance Electric offers a complete, integrated, performance-matched A-C V★S Drive package which includes an A-C V★S Drive Controller and the field-proven Reliance Electric Duty Master® XE energy efficient motor (**Figure 1-1**).

Controller

The A-C V★S Drive Controller (**Figure 1-1**) operates from 200/230 VAC, 50/60 Hz plant power with:

- Single-phase or three-phase input for 1 and 2 HP
- Three-phase input for 3 and 5 HP

The controllers provide variable voltage and variable frequency, three-phase, 0 to 200, 208, 220, or 230 VAC output to the A-C motor. The standard controller provides a normal operating output frequency range of 3 to 60 Hz.

Table 1-1. Reference literature.

Publication Number	Publication
B-7087	A-C Motor Efficiency
D-8079	Long Term Storage for Control Cabinets
B-3620	Installation, Operation and Care of Reliance Standard Integral Horsepower Induction Motors
B-2639	Duty Master Energy Efficient XE A-C Motors
D-9084	Selection and Application of A-C V★S Drives

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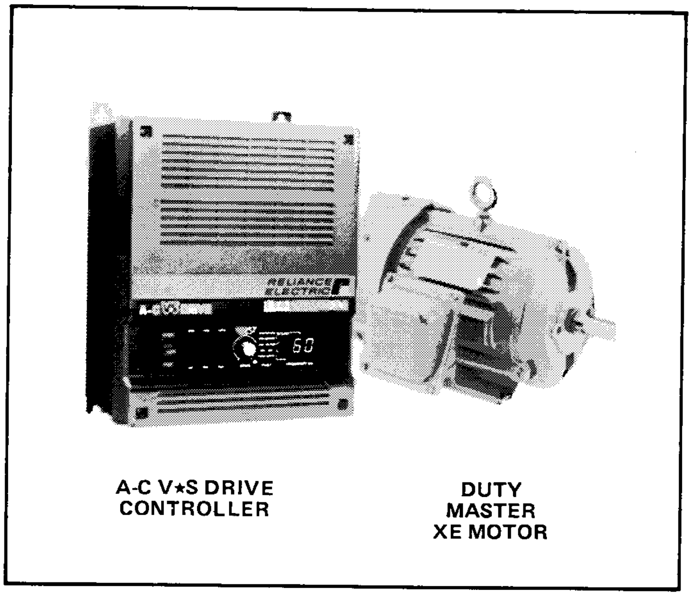


Figure 1-1. Typical A-C V★S Drive package.

Operator's Control Devices

Standard controllers include an All Function Operator's Control Station mounted on the front of the enclosure. The station has a Speed pot and switches for selecting Start/Stop, Run/Jog, Forward/Reverse and Automatic/Manual. In addition to these devices, the standard 3 and 5 HP controllers include a Digital Frequency Meter with First Fault indication (**Figure 1-2**). **Table 4-1** lists the possible faults. Other Local Operator's Stations can be supplied, if required. See **Table 5-1** for a list of available Operator's Control Stations.

Motor

A three-phase A-C motor (**Figure 1-1**) can be driven as an adjustable speed device by the A-C V★S Drive Controller. Furthermore, one or more motors can be used with a single controller **as long as the total motor full load current does not exceed the maximum motor sine wave current rating of the controller.**

CONTROLLER IDENTIFICATION

Reliance Electric A-C V★S Drive Controllers are manufactured as standard model number units to a set of Reliance Electric specifications or as modified units to customer specifications. The A-C V★S Drive Controller can be positively identified by the nameplate mounted on the outside of the bottom of the cabinet.

For Standard Model Controllers

When the A-C V★S Drive Controller is built to a Reliance Electric model number specification, its model number uniquely describes the hardware furnished. An alpha-numeric model number is printed on the controller's identification nameplate.

This model number will also appear on the shipping label on the outside of the controller shipping container. The model number provides identification as noted in the following typical A-C V★S Drive Controller model number 1AC2105U:

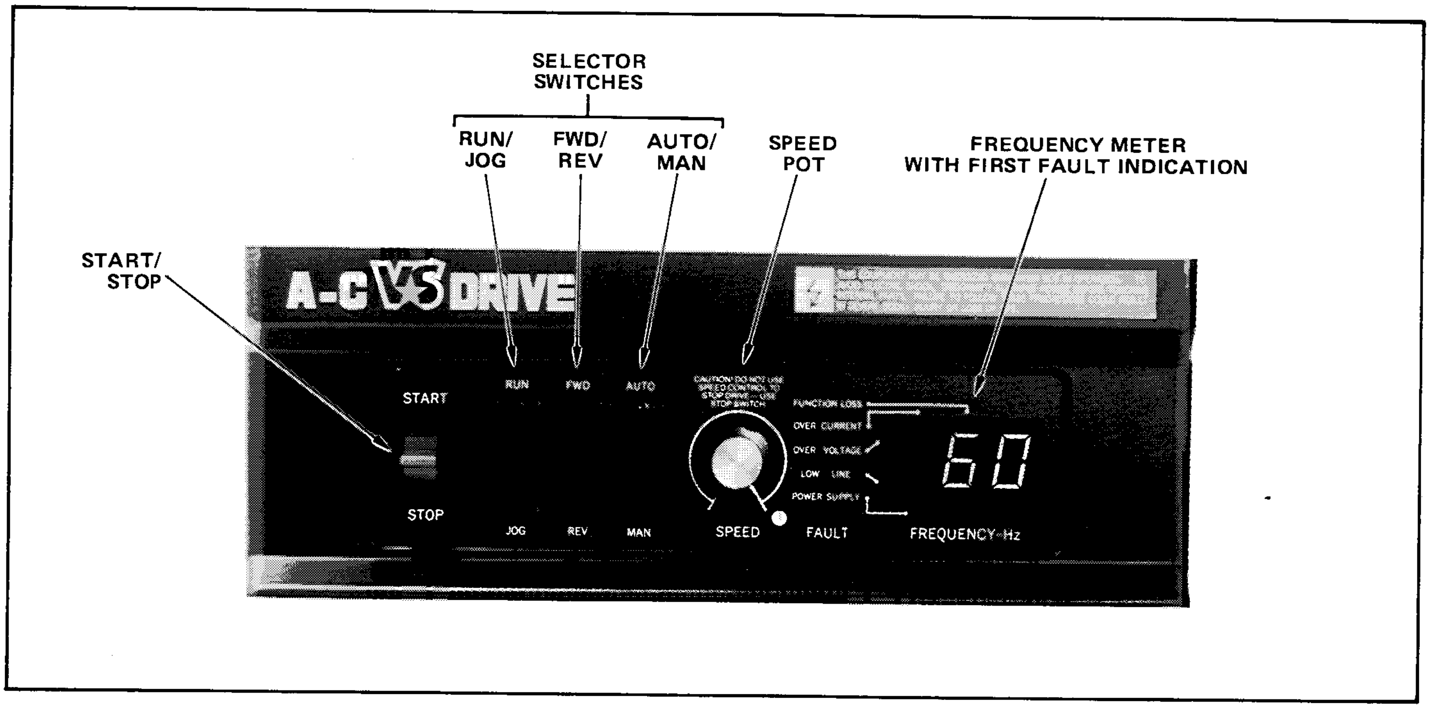


Figure 1-2. Standard All Function Operator's Control Station (3 and 5 HP controllers).

1 AC 2 1 05 U

- First Generation — 1
- A-C V★S Drive Controller — AC
- Voltage (200, 208, 220, 230 VAC) — 2
- Enclosure — 1
  - 0 or blank = chassis
  - 1 = NEMA 1
- Controller Horsepower — 05
  - 01 = 1 HP
  - 02 = 2 HP
  - 03 = 3 HP
  - 05 = 5 HP
- UL Listed/CSA Approved — U
  - C = CSA
  - U = UL

For Modified Controllers

When the A-C V★S Drive Controller is built to customer specifications, a Reliance Electric sales order number will be imprinted on the nameplate, appearing as a six digit number following a plant code prefix (such as 1GA-679042 or 10TT-896401). Use this identification number whenever discussing this drive equipment with Reliance Electric personnel. It uniquely describes a controller manufactured to customer specifications.

DRIVE CONTROLLER FEATURES

Standard Features:

- Operation on 200/230 VAC, 50/60 Hz input with:

  Single-phase or three-phase input for 1 and 2 HP
  Three-phase input for 3 and 5 HP
- Operation on 200, 208, 220 or 230 volts by jumper selection.
- Speed range of 3 to 60 Hertz.
- NEMA 1 enclosure.
- Standard fuses for easy replacement.
- Line-to-line or line-to-ground output short circuit protection.
- Instantaneous Electronic Trip (IET) on high D-C bus voltage, high motor current, high or low input A-C line, phase loss on input A-C line (3 – 5 HP), or low regulator power supply voltage.
- 4 to 20 mA input signal capability.
- RUN LED showing controller operating status (1 and 2 HP controllers).
- IET indication.
- Coast-to-rest on "stop" as standard, or ramp-to-rest as a modification.
- Auxiliary stop input signal capability.
- Automatic correction of output voltage for input voltage fluctuations.
- Torque boost for increased starting torque.
- Variable torque V/Hz curve selection.
- Motoring current limit and regenerative voltage limit.
- Operator's devices, supplied as standard, include control for:

Speed	Start/Stop
Forward/Reverse	Run/Jog
Auto/Manual	
- Digital Frequency Meter with First Fault indication on 3 and 5 HP controllers. Available on 1 and 2 HP controllers.
- Standard adjustments.

Acceleration	Current Limit
Deceleration	Volts/Hertz
Minimum Hertz	Torque Boost
Maximum Hertz	
- Single board, hybrid-based regulator for increased reliability.
- Operates with standard off-the-shelf NEMA B and synchronous motors.

Optional Features

- Remote Operator's Control Station with an Analog Frequency Meter.
- A selection of Local Operator's Control Stations available.
- Voltmeter with 0 – 250 volt scale for remote mounting.
- Ammeter with ampere scale corresponding to controller rating for remote mounting.
- Analog Frequency Meter with 0 – 120 hertz scale for remote mounting. For the other scales, contact your Reliance Electric Sales Office.
- Digital Frequency Meter with First Fault indication for local mounting on 1 and 2 HP controllers.
- Chassis controller with a Blank Local Operator's Control Station and a Customer Interface Module.
- NEMA 4/NEMA 12 enclosure.

- Dynamic braking.
- Isolated Customer Interface Module provides:

  Isolation for speed reference and operator's devices.
  Run and IET contacts.
  Terminal block for wiring remote operator's devices.
  0 – 10 VDC follower capability.
  Instantaneous Electronic Trip (IET) on function loss input.
- Coast-to-rest by opening the function loss input.
- Extended speed range to 240 hertz. Contact your Reliance Electric Sales Office for assistance.
- Other options are available. Contact your Reliance Electric Sales Office for information.

CONTROLLER SPECIFICATIONS

See **Table 1-2**. Application load and speed requirements must be considered to properly size the motor and controller. Refer to D-9084, "Selection and Application of A-C V★S Drives," or contact your Reliance Electric Sales Office for assistance.

Table 1-2. Controller specifications.

Description		NEMA B Induction Motor Nominal Horsepower Rating at 0.8 Motor Power Factor			
		1	2	3	5
Controller Input KVA		2.4	3.2	4.5	7.0
Max Input Amps (RMS)	Single-phase	12.0	15.5	–	–
	Three-phase	7.0	9.2	13.0	19.0
Max Motor Sine Wave Amps 230 Volt		4.1	6.8	9.6	15.2
Max Output Amps (RMS) 230 Volt		4.5	7.5	10.6	16.7

Service Conditions

Elevation . . . . 1000 m (3300 ft)
Ambient Temperature Range
Cabinet . . . . 0°C to 40°C (32°F to 104°F)
Chassis . . . . 0°C to 55°C (32°F to 131°F)
Atmosphere . . . . non-condensing relative humidity to 95%
A-C Line Voltage Variation . . . . –5% to +10%
A-C Line Frequency Variation (50/60 Hz) . . . . 48 – 62 Hz
Maximum A-C Line Distribution
System Capacity . . . . 500 KVA (1)
Storage Temperature . . . . –40°C to 65°C (–40°F to 149°F)

Application Data

PWM Modulation . . . . Sine wave
Standard Service Factor 1.0
Maximum Load . . . . 150% for one minute
Displacement Power Factor 0.96
Frequency Stability Long Term . . . . 0.5% of base speed
Continuous Speed Range (2) . . . . 3 to 60 Hz
Maximum RMS Output Voltage . . . . . . 200, 208, 220, 230 VAC
Linearity (Speed reference to output frequency) . . . . ±1%

Adjustments (Nominal Values)

Controller adjustments are preset for Reliance Duty Master XE motors (3600, 1800, 1200 rpm). Adjustments available if required:

Acceleration Time (4) . . . . Linear 1.5 to 20 seconds
Deceleration Time (4) . . . . Linear 1.5 to 20 seconds
Volts/Hertz (60 Hz Base) (5) . . . . 3.4 to 8.0 V/Hz
Voltage Offset . . . . 0 to 40 Volts
Minimum Hertz . . . . 0 to 35 Hz
Maximum Hertz (2) (3) . . . . 15 to 90 Hz
Current Limit . . . . 50 to 150%

Fuse Data

3 Input Fuses (FERRAZ SA20 or equivalent)
1 HP . . . . 20 amps
3 Input Fuses (FERRAZ URLO30 or equivalent)
2 to 5 HP . . . . 30 amps
1 Control Fuse (NAGASAWA GDL 3/10) . . . . 0.3 amp

Product Publications

Data Sheet D-2744
Application Manual D-9084

Controller Wiring Diagram
1 HP 63089
2 HP 63090
3 HP 63091
5 HP 63092

(1) A distribution system above 500 KVA requires using isolation transformers, line reactors or other means of adding similar impedance.
(2) Optional higher frequencies are available. Contact your Reliance Electric Sales Office for assistance when operation above 60 Hz is required.
(3) Min frequency adjustment is additive to Max frequency adjustment. See Figure 3-3.
(4) 4.5 – 60 seconds selectable by switch. See Section 2 "Extended Acceleration and Deceleration Times."
(5) Other V/Hz ratios are available.

Multimotor Applications

When it is necessary to run multiple motors from one controller, the following requirements must be followed to assure correct operation:

1. When all of the motors connected to the output of the controller are to start and stop at the same time, the sum of the sine wave currents of all the motors must be less than or equal to the maximum motor sine wave current rating of the controller.

2. When one or more of the motors connected to the output of the controller are to start and stop independently, two requirements must be followed:

   - Any motor that starts or stops while the controller is running must have a current rating less than 10% of the maximum motor sine wave current rating of the controller.
   - The sum of the sine wave currents of all the motors connected continuously on the output of the controller and the locked rotor sine wave current of any motor which is to start and stop independently must be less than or equal to the maximum motor sine wave current rating of the controller.

Efficiency Data

Energy-saving applications are a major use for the A-C V★S Drive Controller. Therefore, the efficiency of the A-C V★S Drive, in addition to the efficiency of external equipment, is important. The efficiencies of both the controller only and the controller with motor are listed in **Table 1-3** for general purpose applications.

Table 1-3. Typical controller efficiencies.

HP	Frequency (Hz)	Torque (%)	A-C V★S Drive Controller	A-C V★S Drive Controller with XE Motor
1	30	25	76.8	40.2
		50	82.5	56.3
		75	86.8	64.5
	45	50	85.2	62.8
		75	88.6	69.6
		100	89.5	70.9
	60	50	86.5	66.1
		75	90.0	72.5
		100	90.6	73.7
2	30	25	82.0	55.8
		50	87.7	67.8
		75	90.8	71.6
	45	50	90.1	73.6
		75	92.7	77.1
		100	93.4	76.8
	60	50	91.1	76.0
		75	94.0	80.0
		100	94.8	80.0
3	30	25	85.0	60.6
		50	89.6	71.4
		75	92.0	75.1
	45	50	92.0	76.3
		75	94.0	79.8
		100	94.7	79.7
	60	50	93.1	78.5
		75	94.9	82.0
		100	95.5	82.1
5	30	25	88.8	68.0
		50	92.0	76.3
		75	92.6	76.3
	45	50	93.8	80.5
		75	94.5	81.4
		100	94.9	80.2
	60	50	94.3	82.0
		75	95.2	83.6
		100	95.7	82.9

Section 2
INSTALLATION

DANGER
THIS EQUIPMENT SHOULD BE INSTALLED, ADJUSTED AND SERVICED BY QUALIFIED ELECTRICAL MAINTENANCE PERSONNEL FAMILIAR WITH THE CONSTRUCTION AND OPERATION OF THE EQUIPMENT AND THE HAZARDS INVOLVED. FAILURE TO OBSERVE THIS PRECAUTION COULD RESULT IN SEVERE BODILY INJURY OR LOSS OF LIFE.

DANGER
THE USER IS RESPONSIBLE FOR CONFORMING TO THE NEC, CEC, AND ALL OTHER APPLICABLE LOCAL CODES WITH RESPECT TO WIRING, GROUNDING, DISCONNECTS, AND OVERCURRENT PROTECTION. FAILURE TO OBSERVE THIS PRECAUTION COULD RESULT IN SEVERE BODILY INJURY OR LOSS OF LIFE.

These instructions should be read and clearly understood before beginning the actual installation.

GENERAL REQUIREMENTS

Location of the A-C V★S Drive Controller is important for proper performance and normal operating life. Therefore, unless designed for special environments, the A-C V★S Drive Controller should be installed in an area where the following conditions exist:

1. Ambient temperature does not exceed 40°C (104°F) for enclosed controllers or 55°C (131°F) for chassis mounted controllers.
2. Ambient temperature is not less than 0°C (32°F).
3. Line frequency needs to be between 48 and 62 Hz.
4. Line voltage variations are within +10%, –5%.
5. Altitude above sea level does not exceed 3300 feet (1000 meters) — For altitudes above 3300 feet, the derating factor is 5% for every additional 1000 feet up to 10,000 feet.
6. Ambient humidity is 0 to 95%, non-condensing.

For maintenance purposes make sure there is sufficient clearance in front of and around the equipment to allow for proper access and air flow.

SAFETY PRECAUTIONS

DANGER
EQUIPMENT IS AT LINE VOLTAGE WHEN A-C POWER IS CONNECTED TO THE A-C V★S DRIVE CONTROLLER. ALL UNGROUNDED CONDUCTORS OF THE A-C POWER LINE MUST BE DISCONNECTED FROM THE CONTROLLER BEFORE IT IS SAFE TO TOUCH ANY INTERNAL PARTS OF THIS EQUIPMENT. AFTER POWER IS REMOVED, USE A VOLTMETER AT TERMINALS 147(+) AND 45(–) TO VERIFY THAT THE D-C BUS FILTER CAPACITORS ARE DISCHARGED BEFORE TOUCHING ANY INTERNAL PARTS OF THE CONTROLLER. FAILURE TO OBSERVE THESE PRECAUTIONS COULD RESULT IN SEVERE BODILY INJURY OR LOSS OF LIFE.

1. Be sure to wear safety glasses at all times.
2. Have a backup technician, who is always in sight and ready to assist in the case of an emergency.

WIRING PRACTICES

Wire Sizing

Care should be taken to see that all interconnecting wiring is sized and installed in conformance with the National Electrical Code (NEC) published by the National Fire Protection Association, or the Canadian Electrical Code (CEC), and other applicable local codes.

Power Wiring

DANGER
THE NATIONAL ELECTRICAL CODE (NEC) REQUIRES THAT AN INPUT DISCONNECT BE PROVIDED IN THE INCOMING POWER LINE AND BE LOCATED WITHIN SIGHT OF THE CONTROLLER. DO NOT OPERATE THE CONTROLLER UNTIL THIS CODE REQUIREMENT HAS BEEN MET. FAILURE TO OBSERVE THIS PRECAUTION COULD RESULT IN SEVERE BODILY INJURY OR LOSS OF LIFE.

A power input disconnect within sight of the controller is required. Mounting it close to the controller is good practice to facilitate maintenance. Since this equipment does not include a line disconnect as standard, the user must provide either a circuit breaker or a fused knife switch in accordance with the NEC, or the CEC, and all local codes. Mounting of the input disconnect should follow codes as well.

Power wiring for both the input and output must be copper wire rated 60/75°C and should be sized to handle the maximum controller current as listed in **Table 1-2**. Wire size should be selected in accordance with the NEC, or the CEC, and all local codes.

The National Electrical Code and Canadian Electrical Code require that an overload protection device responsive to motor current be installed in each power line of the motor or that a thermal protection device responsive to motor heat be built into or attached to the windings of the motor to provide motor running overload protection for both the motor and the motor branch circuit. In the case of an A-C motor operating at speeds below one half the motor's rated speed, however, **the current responsive type of protection device (motor overload relay) will not give the intended protection for the fan-cooled motor because of the reduction in motor cooling action due to the reduced speed.** It is recommended, therefore, that the thermal responsive type of protection device be used, if at all possible, because it monitors the actual temperature of the motor windings.

The above devices are not furnished with the standard controller and are the responsibility of the user.

> **CAUTION:** Be sure to connect any motor thermal switch or overload device back to the A-C V★S Drive control circuit as shown in **Figure 2-5**. This assures that, if an overload results or the motor becomes overheated, the drive will shut down. Failure to observe this precaution could result in damage to, or destruction of, the equipment.

Control Signal Wiring

The control signal interconnecting wire must be twisted, three-conductor wire having two to three twists per inch. This signal wire must be run in separate steel conduit to eliminate the possibility of electrical noise pick-up. The conduit can be rigid steel or flexible armored steel. The signal wire should not be routed through junction or terminal boxes that contain non-signal wires. For signal wire distances of less than 150 feet, use a minimum of #22 AWG (Reliance part 417900-114X). For distances of more than 150 feet and less than 300 feet, use a minimum of #16 AWG (Reliance part 417900-79X). For distances of more than 300 feet, contact your Reliance Electric Sales Office.

If shielded wire is used for the twisted signal wire, the shields should not be attached to any ground point; they should "float."

The start/stop control wiring must be run in a separate conduit from the speed reference wiring.

→Nearby relays, solenoids, or brake coils can produce erratic drive behavior due to electrical noise transients. To eliminate this possibility, an R-C suppressor, such as Reliance part 600686-33A, should be added across the coils of these devices. Alternately, a 220-ohm, 0.5 watt resistor in series with a 0.5 microfarad, 600-volt capacitor can be used as a suppressor in 115 VAC and 230 VAC circuits.

INSTALLATION OF DRIVE MOTOR

1. Verify the motor is the appropriate size to use with the controller. Because the output of the A-C V★S Drive is not a pure sine wave, harmonics cause additional heating in the motor. Derating the A-C motor will compensate for this additional heating. Refer to D-9084, "Selection and Application of A-C V★S Drives," for application guidelines for constant torque loads. Refer to **Table 2-1** for motor derating values for centrifugal loads.
2. Install the A-C motor in accordance with its own installation instructions. Care should be taken to assure that the motor is properly aligned with the driven machine to minimize unnecessary motor loading due to shaft misalignment.
3. Be sure the motor frame is connected to earth ground.
4. If the motor is accessible while it is running, a protective guard should be installed around all otherwise exposed rotating parts.

Overspeed Protection

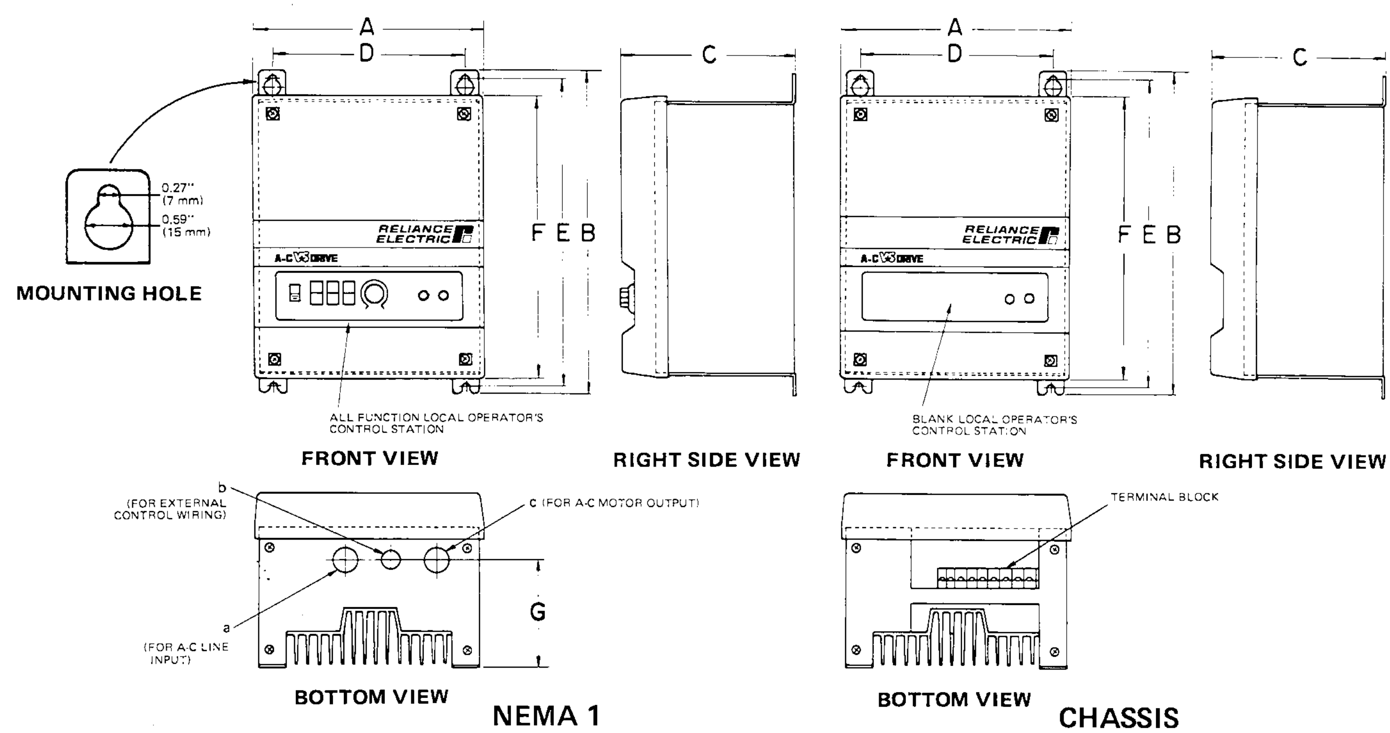
> **WARNING**
> **THE USER IS RESPONSIBLE FOR ENSURING THAT DRIVEN MACHINERY, ALL DRIVE-TRAIN MECHANISMS, AND PROCESS LINE MATERIAL ARE CAPABLE OF SAFE OPERATION AT AN APPLIED FREQUENCY OF 150% OF THE MAXIMUM SELECTED BASE FREQUENCY TO THE A-C MOTOR. FAILURE TO OBSERVE THIS PRECAUTION COULD RESULT IN BODILY INJURY.**

Table 2-1. Motor derating data for centrifugal loads.

Motor Insulation Class	Motor Service Factor	Motor Derating Percentage of Nameplate HP
B	1.0	15%
B	1.15	10%
F	1.0	5%
F	1.15	0%

INSTALLATION OF OPERATOR'S CONTROL DEVICES

The standard controller is supplied in a NEMA 1 enclosure with an All Function Local Operator's Control Station mounted on the front. The chassis controller is supplied with a Blank Local Operator's Control Station and a Customer Interface Module. For any application requiring the Remote Operator's Control Station or user-supplied operator's devices and/or a separately mounted Analog Frequency Meter, a Blank Operator's Control Station and the Customer Interface Module must be installed. Install and wire these options and devices according to the instruction sheet supplied with each option kit and **Figure 2-6**. Refer to **Table 5-1** for a list of these options.



HP		Diameter		
		a	b	c
1–2	mm	22.2	22.2	22.2
	inches	7/8"	7/8"	7/8"
3–5	mm	27.8	22.2	27.8
	inches	1-3/32"	7/8"	1-3/32"

HP	Model Number		Dimensions in mm							Weight in kg
	Chassis	NEMA 1	A	B	C	D	E	F	G	
1	1AC2001	1AC2101	218.4	310	166	182.5	296	270.9	102	7.0
2	1AC2002	1AC2102	218.4	310	166	182.5	296	270.9	102	7.0
3	1AC2003	1AC2103	248.4	350	179	212.5	336	311.0	112	10.0
5	1AC2005	1AC2105	248.4	350	179	212.5	336	311.0	112	10.0

HP	Model Number		Dimensions in Inches							Weight in lbs
	Chassis	NEMA 1	A	B	C	D	E	F	G	
1	1AC2001	1AC2101	8.60	12.20	6.54	7.19	11.65	10.67	4.02	15.4
2	1AC2002	1AC2102	8.60	12.20	6.54	7.19	11.65	10.67	4.02	15.4
3	1AC2003	1AC2103	9.78	13.78	7.05	8.37	13.23	12.24	4.41	22.1
5	1AC2005	1AC2105	9.78	13.78	7.05	8.37	13.23	12.24	4.41	22.1

Figure 2-1. Controller physical dimensions and weights for NEMA 1 enclosed and chassis controllers.

INSTALLATION OF DRIVE CONTROLLER

The A-C V★S Drive Controller is supplied standard in a NEMA 1 enclosure or optionally as a chassis. See **Figure 2-1** for the mounting dimensions and weights.

The controller should be mounted vertically with the input/output terminals at the bottom. Provide adequate clearance for air ventilation:

- At least 2 inches from the sides and 4 inches from the top and bottom of the controller to adjacent non-heat producing equipment, such as a cabinet wall.
- At least 2 inches from the sides and 10 inches from the top and bottom of adjacent controllers. For the best air movement with three or more controllers, do not mount the controllers in a vertical stack; offset the controllers.

When the controller is housed in a totally enclosed cabinet, size the enclosure using the following equation along with **Table 2-2**:

$$S = S_s + \frac{4S_t}{3} + \frac{2S_b}{3} \quad ^{(1)}$$

where:

S_s = Area of enclosure's four side surfaces
S_t = Area of enclosure's ceiling surface
S_b = Area of enclosure's bottom surface

(1) If a surface does not have at least a 1/2" layer of air beside it, it does not have any cooling effect. Use a zero area in the equation for any such surface.

For example, if you want to enclose a 1 HP chassis in an enclosure that is 30" high by 20" wide by 16" deep and the back side is 1/2" off the mounting wall, solve the equation and verify the answer with the **Table 2-2** specifications.

$$S = 2(30 \times 20) + 2(30 \times 16) + \frac{4(320)}{3} + \frac{2(320)}{3}$$
$$= 2800 \text{ sq. in.}$$

Referring to **Table 2-2**, note that a 1 HP controller requires 2.8 times 10^3 or 2800 sq. in. of surface area. The example enclosure meets the size requirements.

Table 2-2. Controller Power Loss and Recommended Cabinet Size.

HP	Power Loss (watts)	Effective Surface (S) Area	
		sq cm	sq in.
1 – 2	100	1.8×10^4	2.8×10^3
3	130	2.3×10^4	3.6×10^3
5	200	3.6×10^4	5.6×10^3

Wiring to the Controller

Remove the enclosure cover by loosening the screws at the four corners. Loosen the two slide screws at the lower left to release the Local Operator's Control Station hinge. Swing the station down to gain access to the fuses and terminals.

Before wiring the controller, make certain that the input power to the controller is of the correct voltage and frequency and that the plant supply is of sufficient ampacity to support input current requirements of the controller. Refer to the controller nameplate for correct input power information. If the correct voltage is not available, it will be necessary to use a transformer between the plant power supply and the controller. The controller is factory-set to operate on 230 VAC output. To operate on 200, 208, or 220 VAC, move the jumper from terminals 281—481 to 281—381.

> **CAUTION:** If the jumper position does not correspond to the input line voltage, the incorrect voltage is applied to the control transformer and an IET could result from a variation in line voltage within the +10% and –5% range. Failure to observe this precaution could result in damage to, or destruction of, the controller.

The 1 and 2 HP controllers can operate on either single-phase or three-phase input. If the power supply system provides both single-phase and three-phase input, use the three-phase input.

> DANGER
> THE NATIONAL ELECTRICAL CODE (NEC) REQUIRES THAT AN INPUT DISCONNECT BE PROVIDED IN THE INCOMING POWER LINE AND BE LOCATED WITHIN SIGHT OF THE CONTROLLER. DO NOT OPERATE THE CONTROLLER UNTIL THIS CODE REQUIREMENT HAS BEEN MET. FAILURE TO OBSERVE THIS PRECAUTION COULD RESULT IN SEVERE BODILY INJURY OR LOSS OF LIFE.

The controller is not equipped with an input disconnect.

Terminal Tightening Torques

When wiring to the input/output terminals of the controller, tighten the screws to the torques listed in **Table 2-3**.

Table 2-3. Terminal Tightening Torques (in-lbs).

HP	INPUT 181 182 183 (R) (S) (T)	OUTPUT 601 602 603 (U) (V) (W)	JUMPER 381 481 (R1) (R2)	D-C BUS 147 45 (+) (–)
1	8	8	8	8
2	20	8	8	8
3 – 5	20	8	8	8

Output Transformers

In all applications requiring the use of an output transformer, contact your Reliance Electric Sales Office for assistance.

Input Transformers

Autotransformers step the A-C power supply voltage up or down but do not provide isolation from the input power line. Isolation transformers also provide voltage step-up or step-down and, in addition, isolate the A-C V★S Drive Controller power circuitry from the line.

Isolation transformers help eliminate the possibility of:

- A-C line voltage transients reaching the controller, which might result in damage to the equipment.
- Damaging currents which could develop if a point inside the controller becomes grounded.

CAUTION: If an autotransformer or isolation transformer is used ahead of the controller, a power disconnecting device should be used between the power line and the primary of the transformer. If a circuit breaker is employed between the power line and the primary of the transformer, the circuit breaker trip rating should be coordinated with the inrush current (10 to 12 times full load current) of the autotransformer or isolation transformer. Do not connect the controller to an input transformer that is rated at more than 500 KVA. Distribution system capacity above the maximum recommended KVA requires using an isolation transformer, a line reactor, or other means of adding similar impedance. Failure to observe this precaution could result in damage to, or destruction of, the equipment.

Grounding

DANGER
THE USER IS RESPONSIBLE TO MEET ALL CODE REQUIREMENTS WITH RESPECT TO GROUNDING ALL EQUIPMENT. FAILURE TO OBSERVE THIS PRECAUTION COULD RESULT IN SEVERE BODILY INJURY OR LOSS OF LIFE.

Connect a suitable equipment grounding conductor or bonding jumper unbroken from the chassis ground terminal (**Figure 2-2, 2-3,** or **2-4**) to the grounding electrode conductor (earth ground).

Connect a suitable equipment grounding conductor or bonding jumper to the motor frame, the Remote Operator's Control Station (if used), the Dynamic Braking enclosure (if used), the power transformer (if used), and the controller enclosure. Run this conductor or jumper unbroken to the grounding electrode conductor (earth ground).

If it is necessary to have the secondary of the control transformer grounded, relocate the grounding jumper from J9 to J8. Refer to "Controller Regulator Modifications."

Basic Controller Interconnections

Figures 2-2, 2-3 and 2-4 show the location of power wiring in the 1 HP, 2 HP, and 3 – 5 HP controllers respectively. With the controller vertically mounted, the A-C input leads to terminals 181, 182, and 183 should enter through the bottom left hole. The A-C output to the motor from terminals 601, 602 and 603 should enter through the bottom right hole. The center hole is for external control wiring when used. **Figure 2-5** shows a typical interconnection diagram for a controller with the All Function Local Operator's Control Station. For a Remote Operator's Control Station, refer to **Figure 2-6** for a typical interconnection diagram.

***NOTE:** The Speed pot must be 5,000 ohms and 1/2 watt minimum.*

This controller is very versatile due to the many available modifications. For selections internal to the controller, refer to "Controller Regulator Modifications" that follows. For other modifications, refer to Section 5, **Appendix B**, "Description of Options."

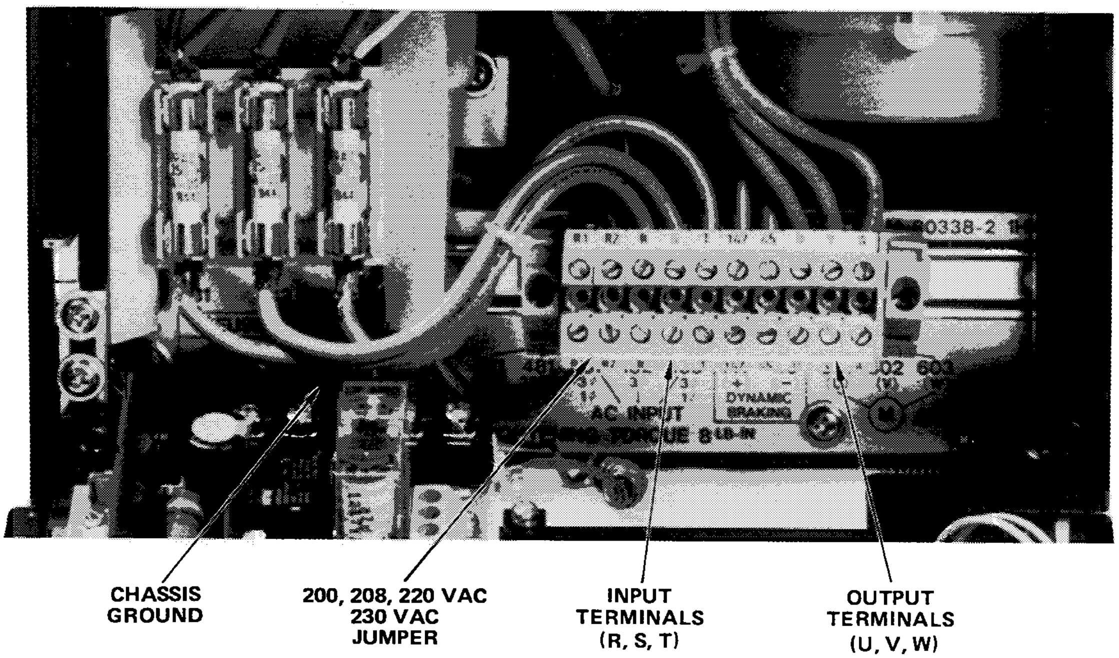


Figure 2-2. Basic wiring locations (1 HP).

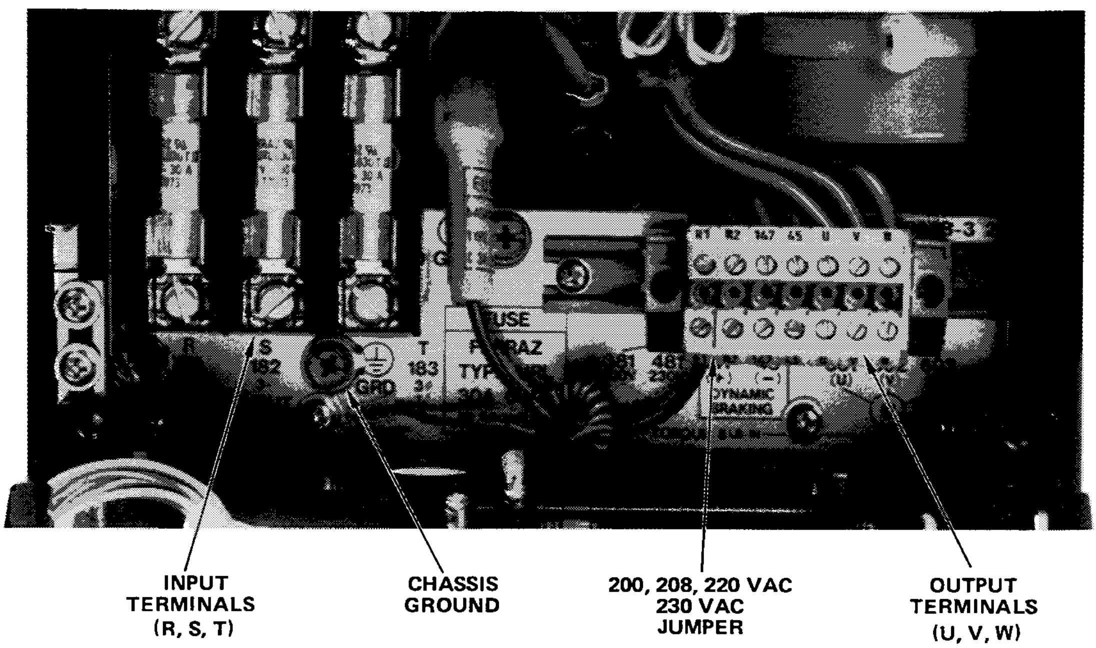


Figure 2-3. Basic wiring locations (2 HP).

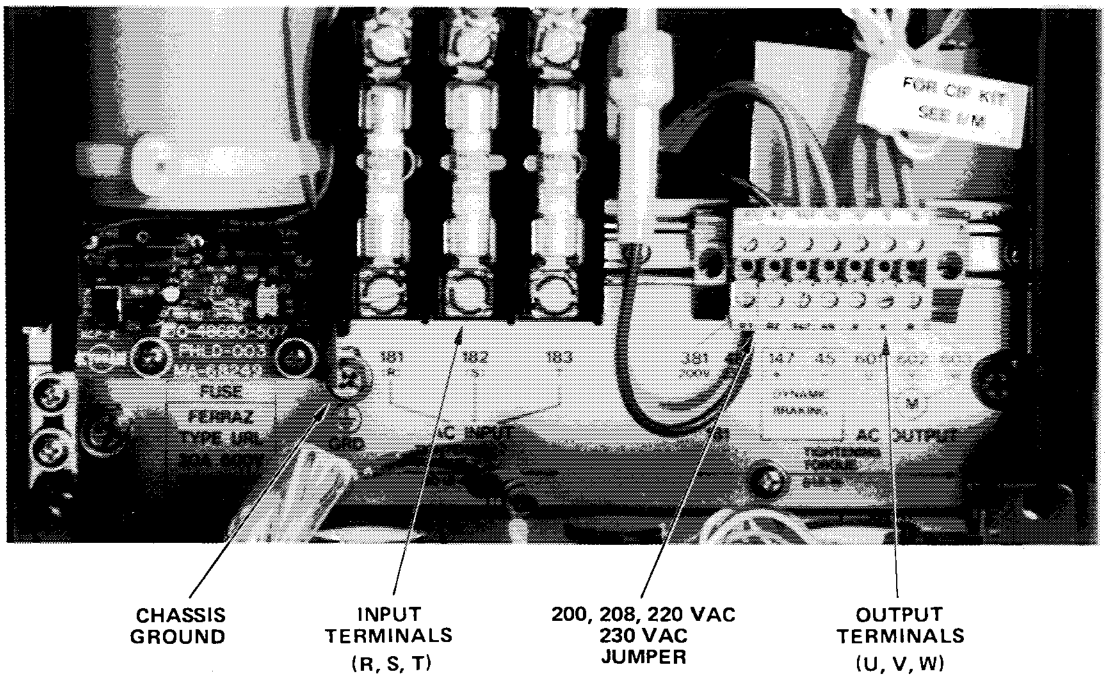
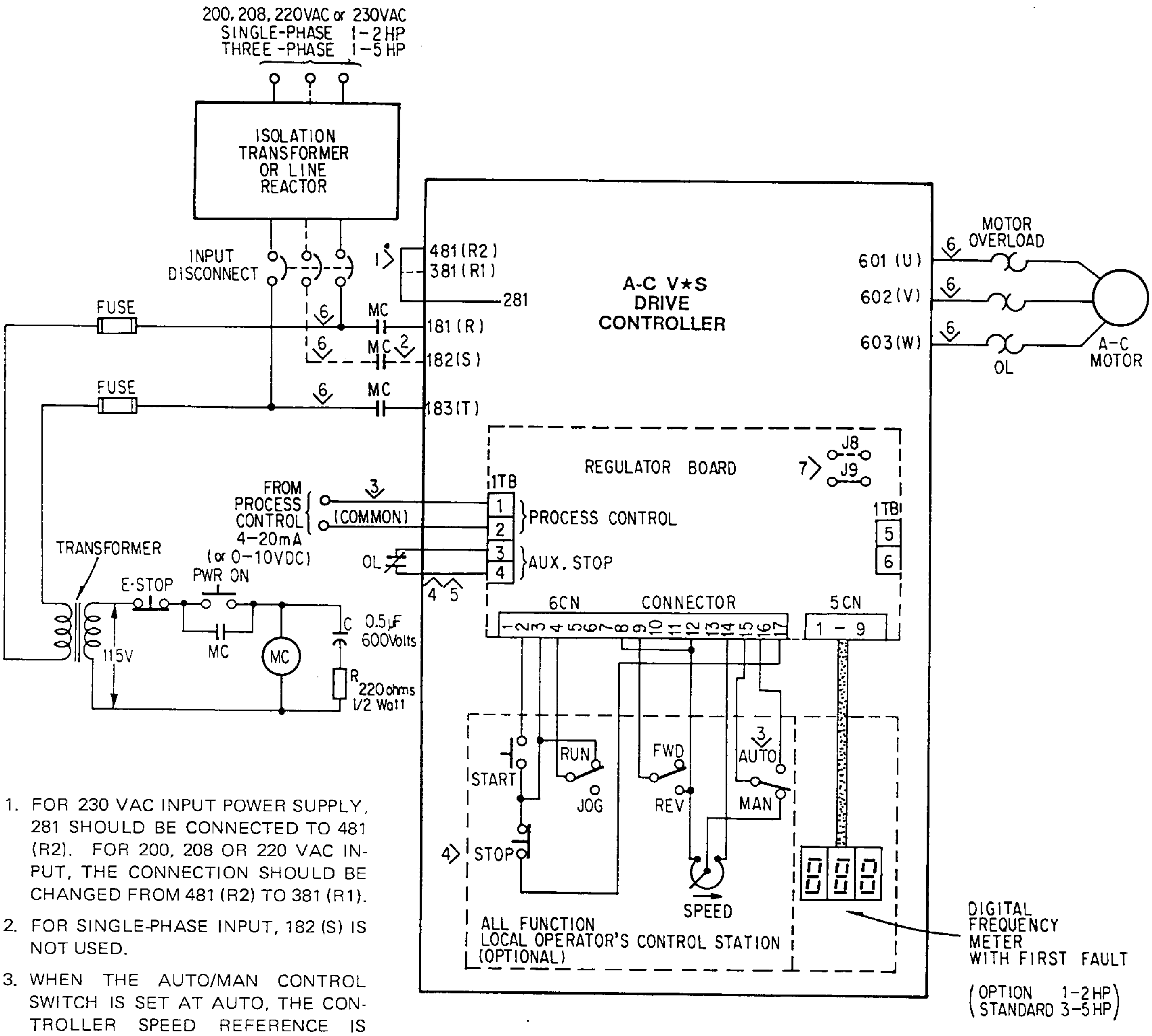


Figure 2-4. Basic wiring locations (3 HP, 5 HP).



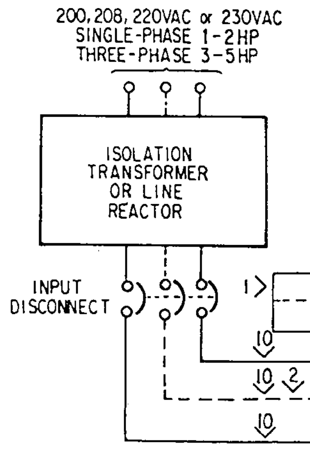
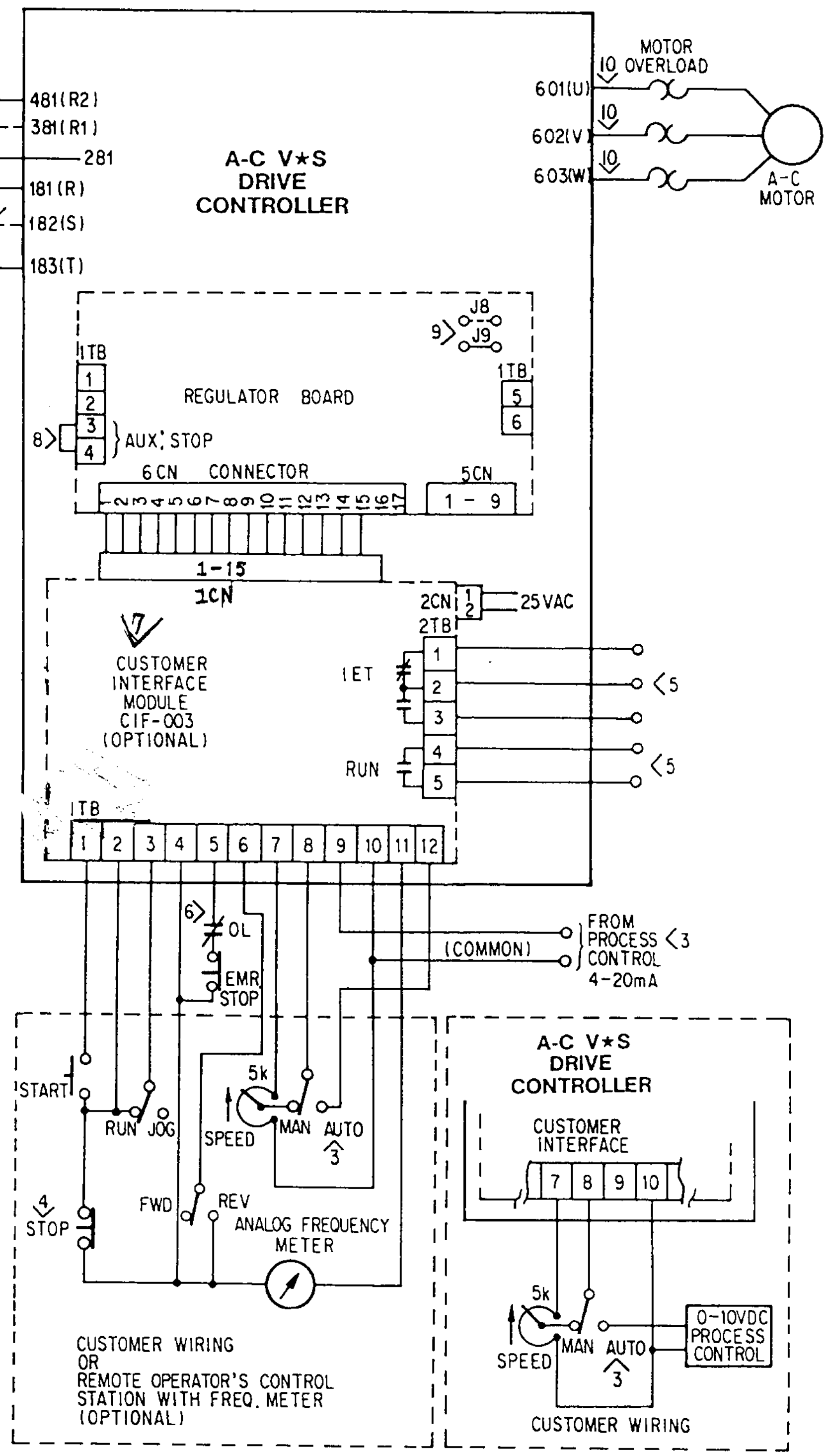
1. FOR 230 VAC INPUT POWER SUPPLY, 281 SHOULD BE CONNECTED TO 481 (R2). FOR 200, 208 OR 220 VAC INPUT, THE CONNECTION SHOULD BE CHANGED FROM 481 (R2) TO 381 (R1).
2. FOR SINGLE-PHASE INPUT, 182 (S) IS NOT USED.
3. WHEN THE AUTO/MAN CONTROL SWITCH IS SET AT AUTO, THE CONTROLLER SPEED REFERENCE IS CHANGED TO THE PROCESS CONTROL 4 – 20 mA SIGNAL OR 0 – 10 VDC SIGNAL.
4. THE STOP MODE WILL BE FUNCTIONAL EITHER IN THE COAST-TO-REST OR THE RAMP-TO-REST MODE USING THE SELECTOR SWITCH ON THE REGULATOR BOARD. **WHEN THE RAMP-TO-REST METHOD IS SELECTED, CONNECT AN EMERGENCY STOP SWITCH AS SHOWN.**
5. WHEN THE CUSTOMER INTERFACE MODULE (OPTIONAL) IS NOT USED, REMOVE THE FACTORY-INSTALLED JUMPER. THE AUX STOP CAN BE CONNECTED HERE.
6. USE ONLY COPPER WIRE RATED 60/75°C.

TERMINAL TIGHTENING TORQUES (IN-LBS)

HP	INPUT 181 182 183 (R) (S) (T)	OUTPUT 601 602 603 (U) (V) (W)	JUMPER 381 481 (R1) (R2)	D-C BUS 147 45 (+) (–)
1	8	8	8	8
2	20	8	8	8
3 – 5	20	8	8	8

7. THIS IS AN OPTIONAL GROUNDING CONNECTION. REFER TO "24 VDC GROUNDING."

Figure 2-5. Interconnection diagram (Local Operator's Control Station).

1. FOR 230 VAC INPUT POWER SUPPLY, 281 SHOULD BE CONNECTED TO 481 (R2). FOR 200, 208 OR 220 VAC INPUT, THE CONNECTION SHOULD BE CHANGED FROM 481 (R2) TO 381 (R1).
2. FOR SINGLE-PHASE INPUT, 182 (S) IS NOT USED.
3. WHEN THE AUTO/MAN CONTROL SWITCH IS SET AT AUTO, THE CONTROLLER SPEED REFERENCE IS CHANGED TO THE PROCESS CONTROL 4 – 20 mA SIGNAL OR 0 – 10 VDC.
4. THE STOP MODE WILL BE FUNCTIONAL EITHER IN THE COAST-TO-REST OR RAMP-TO-REST MODE USING THE SELECTOR SWITCH PROVIDED ON THE REGULATOR BOARD. WHEN THE RAMP-TO-REST METHOD IS SELECTED, CONNECT AN EMERGENCY STOP SWITCH.
5. THE CONTACT RATING IS 1 AMP AT 250 VAC (POWER FACTOR=0.4, L/R= 7 ms) OR 2 AMP AT 30 VDC.
6. THIS INPUT IS FOR FUNCTION LOSS. WHEN OPEN, THE MOTOR COASTS TO REST. THE CUSTOMER SAFETY CONTACT SHOULD BE CONNECTED HERE.
7. THIS MODULE IS AN ISOLATED INTERFACE.
8. WHEN THE CUSTOMER INTERFACE MODULE IS USED, THE AUX STOP IS NOT USED.
9. THIS IS AN OPTIONAL GROUNDING CONNECTION. REFER TO SECTION 2 "24 VDC GROUNDING."
10. USE ONLY COPPER WIRE RATED 60/75°C.

Figure 2-6. Interconnection diagram using Customer Interface Module.

Controller Regulator Modifications

The controller regulator has several built-in modifications which can be made by connecting a jumper or setting a DIP switch on the regulator PC board. The modifications are listed in **Table 2-4** and are located in **Figure 2-7**.

Table 2-4. Regulator modifications.

Modification	Jumper	Switch
Extended Speed Range	(1)	–
Variable Torque Curve	J4, J5	–
Variable Carrier Frequency	J6, J7	–
24 VDC Grounding	J8, J9	–
Regenerative Voltage Limit	–	1 SW (1)
D-C Offset at Zero Hertz	–	1 SW (2)
Ramp-To-Rest	–	1 SW (3)
Extended Acceleration and Deceleration Times	–	1 SW (4)

(1) Factory set at 60 Hz with wirewrap jumpered at J0—J1. Extended speed requires application assistance; contact Reliance Electric.

Extended Speed Range

The controller is factory set to provide a 60 Hz base frequency with a 90 Hz (150%) maximum. Two other ranges are available (**Table 2-5**). Contact Reliance Electric for application assistance with and instructions for this modification.

WARNING

THE USER IS RESPONSIBLE FOR ENSURING THAT DRIVEN MACHINERY, ALL DRIVE-TRAIN MECHANISMS, AND PROCESS LINE MATERIAL ARE CAPABLE OF SAFE OPERATION AT AN APPLIED FREQUENCY OF 150% OF THE MAXIMUM SELECTED BASE FREQUENCY TO THE A-C MOTOR. FAILURE TO OBSERVE THIS PRECAUTION COULD RESULT IN BODILY INJURY.

Extending the speed range does not change the maximum speed possible if the controller faults.

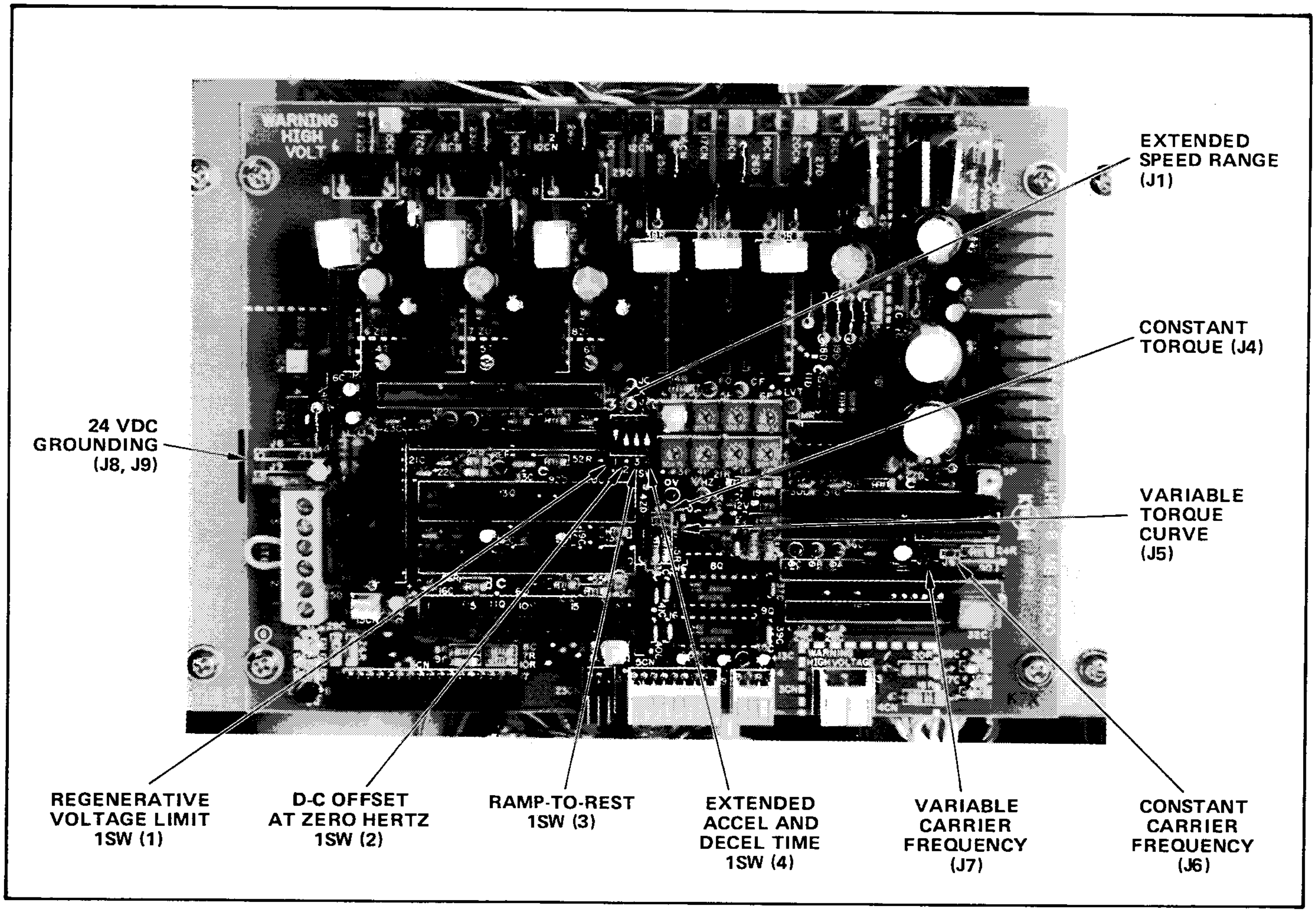


Figure 2-7. Location of modification jumpers and switches on the regulator.

Table 2-5. Possible speed ranges.

Base Frequency	Frequency Range
60 (standard)	0 – 90
120*	0 – 180*
240*	0 – 360*

* Requires application assistance; contact Reliance Electric.

Variable Torque Curve

The A-C V★S Drive Controller has been designed for general purpose applications. For variable torque applications that require energy savings at speeds below base speed, move jumper J4 to J5. A variable torque curve for 230-volt input is shown in **Figure 3-2**.

Variable Carrier Frequency

The controller is factory set to provide a constant carrier frequency of 3.5 kHz above a preset speed range. This high value lessens acoustic noise but produces a rather small fundamental output voltage in a low speed range. Adjusting the Torque Boost pot can provide more starting or breakaway torque. If the Torque Boost pot cannot provide enough voltage boost, move jumper J6 to J7 for the variable carrier frequency modification.

With this modification, the carrier frequency automatically decreases in proportion to the decrease in speed, providing enough starting torque in a low speed range (but with higher acoustic noise) to have smooth operation. See **Figure 5-5**.

24 VDC Grounding

The secondary winding for the 24 VDC start/stop circuit is isolated from other logic circuits. If code requires 24 VDC power supply for the start/stop circuit be grounded to earth, move jumper J9 to J8 to ground the positive to the chassis GND terminal.

> **CAUTION:** Do not provide this ground unless code requires it. If grounding is required, make sure the positive is grounded to the chassis GND terminal (jumper at J8). Failure to observe these precautions could result in damage to, or destruction of, this equipment.

Regenerative Voltage Limit

The controller is factory set to provide regenerative voltage limit by extending the deceleration time when the D-C bus voltage exceeds a nominal preset value. This feature prevents an IET during deceleration. If the Dynamic Braking Kit is installed, this circuit must be turned off. Switch the Dip Switch 1 SW(1) OFF.

D-C Offset at Zero Hertz

For the controller to operate a permanent magnet synchronous motor, move the Dip Switch 1 SW(2) to the ON position. This mode will provide D-C offset voltage at 0 Hz, which is required to synchronize the motor rotor at starting to avoid high current demand. Adjusting the Torque Boost pot provides 0 to 40 VAC at 0 Hz.

Controllers are shipped with Dip Switch 1 SW(2) in the OFF position for operation of standard induction motors. Adjusting the Torque Boost pot provides 0 to 40 VAC at 1 Hz.

> **CAUTION:** Operating induction motors with Dip Switch 1 SW(2) in the ON position could result in excessive motor heating at low speeds. Failure to observe this precaution could result in damage to, or destruction of, this equipment.

Ramp-to-Rest

The controller is factory set to provide a coast-to-rest stop. Move Dip Switch 1 SW(3) to the ON position to provide a ramp-to-rest stop.

> **WARNING**
> **THE RAMP-TO-REST FUNCTION REQUIRES PROPER OPERATION OF REGULATOR ELECTRONICS AND IS NOT FAIL-SAFE. WHEN THE RAMP-TO-REST STOP FUNCTION IS REQUIRED, THE COAST-STOP PUSHBUTTON IS REQUIRED. THE COAST-STOP PUSHBUTTON DISABLES THE REGULATOR AND ALLOWS THE MOTOR TO COAST-TO-REST. FAILURE TO OBSERVE THIS PRECAUTION COULD RESULT IN BODILY INJURY.**

When ramp-to-rest is selected, an Emergency Stop pushbutton and input contactor (MC) is one method that will disconnect power and allow a coast-to-rest stop. See **Figure 2-5**. An Auxiliary Stop contact stops the controller in the same way as the Local Operator's Control Station Stop switch.

Extended Acceleration and Deceleration Times

The controller is factory set to provide an acceleration and deceleration time from 1.5 to 20 seconds. To extend the minimum time from 1.5 to 4.5 seconds and the maximum time from 20 to 60 seconds, move Dip Switch 1 SW(4) to ON. See **Table 2-6**.

Table 2-6. Extended acceleration and deceleration time selection.

Switch 1 SW (4)	Min. Time (Seconds)	Max. Time (Seconds)
OFF	1.5	20
ON	4.5	60

Section 3
STARTUP ADJUSTMENTS

DANGER
EQUIPMENT IS AT LINE VOLTAGE WHEN A-C POWER IS CONNECTED TO THE A-C V*S DRIVE CONTROLLER. ALL UNGROUNDED CONDUCTORS OF THE A-C POWER LINE MUST BE DISCONNECTED FROM THE CONTROLLER BEFORE IT IS SAFE TO TOUCH ANY INTERNAL PARTS OF THIS EQUIPMENT. AFTER POWER IS REMOVED, USE A VOLTMETER AT TERMINALS 147(+) AND 45(−) TO VERIFY THAT THE D-C BUS FILTER CAPACITORS ARE DISCHARGED BEFORE TOUCHING ANY INTERNAL PARTS OF THE CONTROLLER. FAILURE TO OBSERVE THESE PRECAUTIONS COULD RESULT IN SEVERE BODILY INJURY OR LOSS OF LIFE.

SAFETY PRECAUTIONS

DANGER
THIS EQUIPMENT SHOULD BE INSTALLED, ADJUSTED AND SERVICED BY QUALIFIED ELECTRICAL MAINTENANCE PERSONNEL FAMILIAR WITH THE CONSTRUCTION AND OPERATION OF THE EQUIPMENT AND THE HAZARDS INVOLVED. FAILURE TO OBSERVE THIS PRECAUTION COULD RESULT IN SEVERE BODILY INJURY OR LOSS OF LIFE.

1. **Be sure to wear safety glasses at all times.**

DANGER
THE NATIONAL ELECTRICAL CODE (NEC) REQUIRES THAT AN INPUT DISCONNECT BE PROVIDED IN THE INCOMING POWER LINE AND BE LOCATED WITHIN SIGHT OF THE CONTROLLER. DO NOT OPERATE THE CONTROLLER UNTIL THIS CODE REQUIREMENT HAS BEEN MET. FAILURE TO OBSERVE THIS PRECAUTION COULD RESULT IN SEVERE BODILY INJURY OR LOSS OF LIFE.

2. **Be sure the input disconnect is in the correct position, either on or off depending on the work to be performed.**
3. **Have a backup technician, who is always in sight and ready to assist in the case of an emergency.**
4. Check the status of the drive shutdown interlocks. These interlocks can be safety switches installed around the driven machine and, when activated, will shut down the drive. If the interlocks are deactivated or by-passed, extreme caution must be used when performing the startup. **Return all interlocks to operation when startup is completed.**
5. Check to see that the controller cabinet is connected to earth ground. (Refer to **Figures 2-2, 2-3** and **2-4**).
6. Check to see that the motor frame is solidly connected to earth ground.
7. Disconnect any power factor correction capacitors connected to the motor.
8. Make sure electrical commons are not intermixed when monitoring voltage and current points in the controller. If electrical commons are intermixed, the controller may be damaged and/or personal injury may occur due to a short circuit fault.

DRIVE PACKAGE STARTUP PROCEDURE

This simplified drive package startup procedure can only be used when the controller and motor are purchased as a drive package; otherwise, proceed to "CONTROLLER ONLY STARTUP PROCEDURE."

The controller is shipped from the factory preadjusted to operate a NEMA B induction motor sized according to the controller's horsepower rating. The controller is adjusted to deliver constant torque over a 3 to 60 Hz speed range. Therefore, in most cases, this drive startup procedure is all that is required to start up the controller, locate any shipping damage, verify proper installation and field wiring, and provide a second check of adjustments.

DANGER
ALTHOUGH ZERO SET ADJUSTMENT ON THIS CONTROLLER ALLOWS FOR ADJUSTMENT DOWN TO ZERO SPEED, THIS ZERO SPEED SETTING MUST NOT BE USED WHERE THE OPERATOR MAY RELY ON A MAINTAINED ZERO SPEED. ELECTRICAL NOISE, IMPROPER WIRING, POWER LINE, OR MALFUNCTIONING COMPONENTS COULD CAUSE THE CONTROLLER TO TURN ON WHILE AT THE ZERO SPEED SETTING. FAILURE TO OBSERVE THIS PRECAUTION COULD RESULT IN SEVERE BODILY INJURY OR LOSS OF LIFE.

CAUTION: Do not use a megger to perform continuity checks in the drive equipment. This can cause damage to the controller circuitry.

1. Check the motor nameplate to verify that nameplate data properly corresponds to the controller output ratings:
   - Voltage: 200, 208, 220 VAC or 230 VAC, three-phase. If the motor has dual voltage capability, verify that it is connected for the voltage corresponding to the input voltage.
   - Current: Full load current must not exceed the controller's motor sine wave current rating. If the motor is overframed, the motor operating current must not exceed the controller's rated current; and, the motor horsepower rating must not be more than one size larger than the controller's horsepower rating.
   - Frequency: 60 or 50 Hz or other frequency consistent with the controller output frequency.
2. Check that the controller is wired according to the appropriate interconnection diagram (**Figure 2-5** or **2-6**). Be sure to use a 5K ohm Speed pot if supplied separately and adhere to all codes.
3. Make sure the input power voltage is selected as desired: terminals 281 to 481 (R2) for 230 VAC or terminals 281 to 381 (R1) for 200, 208, or 220 VAC.
4. Check for loose control and power electrical connections.
5. Check for, and eliminate, undesirable motor and controller grounds.

CAUTION: If the controller has been stored for over six months, the filter capacitors must be formed as described in Steps 1 thru 7 of "Final Startup Adjustments with Power On."

6. Connect a properly sized motor to the output of the controller.

DANGER
THE REMAINING STEPS ARE MADE WITH POWER ON. EXERCISE EXTREME CAUTION AS HAZARDOUS VOLTAGE EXISTS. FAILURE TO OBSERVE THIS PRECAUTION COULD RESULT IN SEVERE BODILY INJURY OR LOSS OF LIFE.

7. With the Speed pot at zero, turn the input power ON, push the Start switch and increase the Speed pot slowly until motor shaft rotation can be checked.
8. If shaft rotation is incorrect, push the Stop switch and wait until the motor has completely stopped. Turn the input power OFF.

   NOTE: *Do not push the start switch while the motor is rotating. An IET will occur. Always wait for the motor to completely stop. To reset the controller after an IET, push the Stop switch and wait for the motor to completely stop.*

   DANGER
   EQUIPMENT IS AT LINE VOLTAGE WHEN A-C POWER IS CONNECTED TO THE A-C V*S DRIVE CONTROLLER. ALL UNGROUNDED CONDUCTORS OF THE A-C POWER LINE MUST BE DISCONNECTED FROM THE CONTROLLER BEFORE IT IS SAFE TO TOUCH ANY INTERNAL PARTS OF THIS EQUIPMENT. AFTER POWER IS REMOVED, USE A VOLTMETER AT TERMINALS 147(+) AND 45(−) TO VERIFY THAT THE D-C BUS FILTER CAPACITORS ARE DISCHARGED BEFORE TOUCHING ANY INTERNAL PARTS OF THE CONTROLLER. FAILURE TO OBSERVE THESE PRECAUTIONS COULD RESULT IN SEVERE BODILY INJURY OR LOSS OF LIFE.

   After checking the D-C bus voltage, reverse any two of the three motor power leads.
9. Run the drive across the speed range under load. If the controller does not operate satisfactorily (the controller steady-state running operation is not proper, that is, the motor draws unnecessarily high current, operation is unstable, or the motor will not break away when starting), refer to the "CONTROLLER ONLY STARTUP PROCEDURE."

   NOTE: *Minor user adjustments may be necessary for satisfactory operation. Refer to Steps 25 thru 34 in "Final Startup Adjustments with Power On" and Table 3-1.*

CONTROLLER ONLY STARTUP PROCEDURE

This startup procedure is used when a controller is purchased to use with an existing motor or a separately ordered motor.

CAUTION: Do not use a megger to perform continuity checks in the drive equipment. This can cause damage to the controller circuitry.

Physical Controller Inspection

Remove the controller cover.

1. Check all control and power terminal connections for tightness.
2. Check to be sure that all fuses are in place and are properly seated in the fuseholders.
3. Check the chassis ground to earth ground for tightness of the connections.
4. Make sure the input power voltage is selected as desired: terminals 281 to 481 (R2) for 230 VAC or terminals 281 to 381 (R1) for 200, 208, or 220 VAC.

Test Equipment

This controller procedures a pulse width modurated (PWM) waveform to vary the speed of the motor. This waveform consists of a fundamental voltage component at the output frequency of the controller and harmonic components at multiples of the fundamental frequency. The fundamental voltage and the harmonic components are added to determine the total RMS output voltage.

The fundamental voltage component produces motor torque and the other harmonic components cause motor heating and do not produce motor torque. Consequently, all references to voltages in this manual are fundamental voltages — not total RMS voltage. If the fundamental voltage is set too low, the motor will draw higher currents which can cause controller trips. This is of concern because different voltmeters will read these voltages differently depending on their response to the PWM waveform.

Both analog and digital voltmeters will read the output voltages defferently depending on how the meter works and which scale it is on (readings can be off by as much as 40 VAC). If a digital meter is to be used, the Fluke 8022B is recommended. If an analog meter is to be used, a Triplett 630 is recommended.

Follow these guidelines when measuring the PWM output voltage (terminals.601, 602, 603):

- Keep the voltmeter lead lengths as short as possible (less than 5 feet long).
- When using the Fluke 8022B voltmeter, the reading will closely correspond to the fundamental voltage provided that the 200 VAC scale is used for voltages from 200 VAC to 230 VAC.
- When using the triplett 630 voltmeter, subtract 20 volts from the meter reading to obtain the fundamental voltage. This should be done for any voltage reading.

The only test equipment needed to perform this startup procedure are two volt-ohmmeters.

Preliminary Startup Adjustments with Power Off

DANGER
MAKE SURE INPUT POWER DISCONNECT IS OFF. FAILURE TO OBSERVE THIS PRECAUTION COULD RESULT IN SEVERE BODILY INJURY OR LOSS OF LIFE.

1. Use a voltmeter to check that the correct power is available on the incoming line side of the input disconnect.
2. Check the continuity of all fuses. If any fuse reads open, replace the defective fuse (**Table 1-2**).
3. Use an ohmmeter to check for grounds from the input power leads to the chassis ground and from the output power leads to the chassis ground. If a ground exists at either place, correct the ground condition before proceeding.
4. Verify that the controller pots (**Figure 3-1**) are set according to the initial factory setting column in **Table 3-1**.

CAUTION: Never re-adjust the 8P (V/Hz factor) and 9P (carrier frequency) pots. They are preadjusted and sealed at the factory. Any misadjustment could degrade performance. Failure to observe this precaution could result in damage to, or destruction of, the equipment.

Motor Checks

DANGER
BEFORE PROCEEDING WITH THE STARTUP PROCEDURE, DISCONNECT AND LOCK OUT ALL INCOMING POWER TO THE A-C V*S DRIVE CONTROLLER. FAILURE TO OBSERVE THIS PRECAUTION COULD RESULT IN SEVERE BODILY INJURY OR LOSS OF LIFE.

1. Disconnect the motor power leads from the controller.
2. Whenever possible, uncouple the motor from the driven machinery.

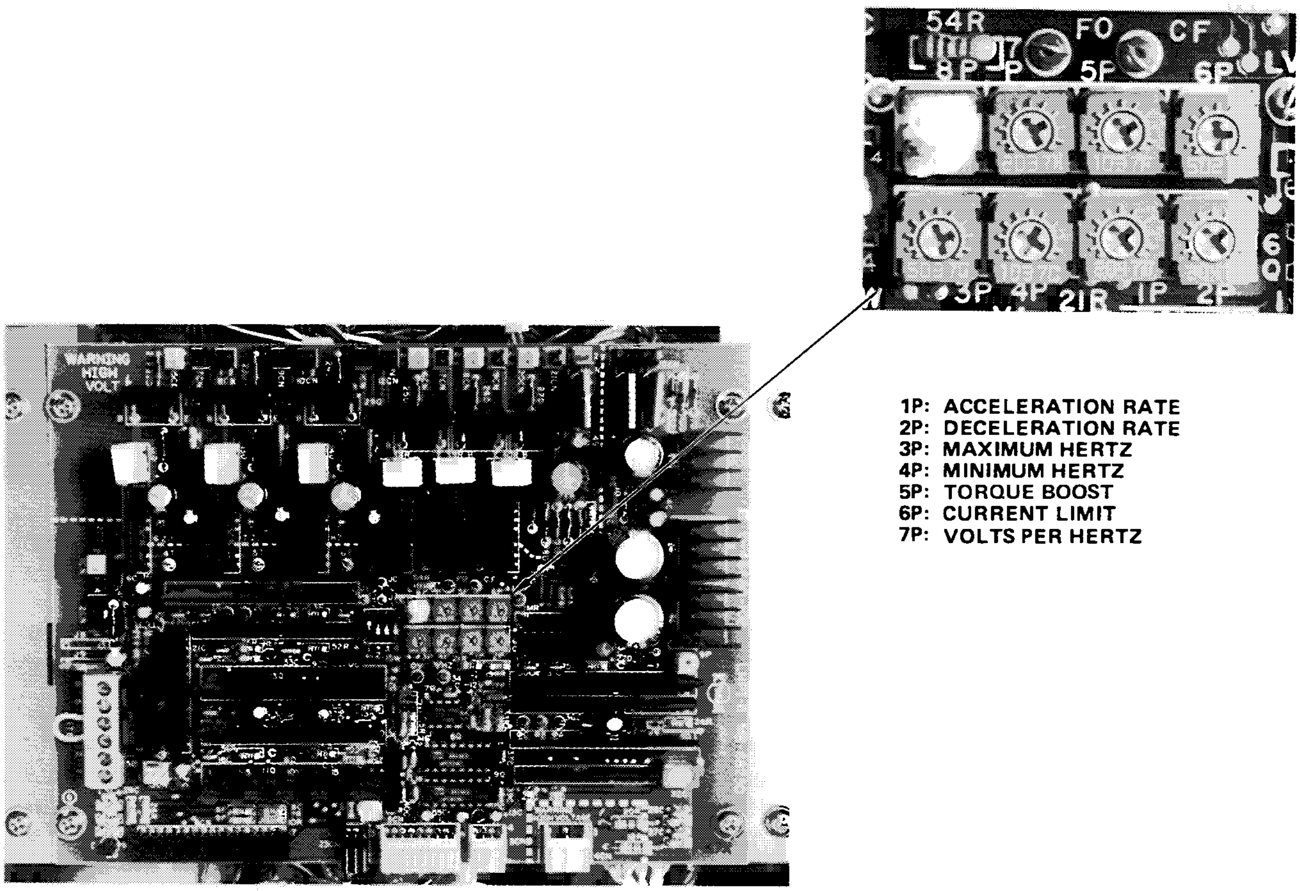


Figure 3-1. Regulator pots.

3. Rotate the motor shaft by hand to check that the motor is free from any binding or mechanical load problem.
4. Check the motor nameplate to verify that nameplate-data properly corresponds to the controller output ratings:

   - Voltage: 200, 208, 220 VAC or 230 VAC, three-phase. If the motor has dual voltage capability, verify that it is connected for the voltage corresponding to the input voltage.
   - Current: If an induction motor is being used, full load current must not exceed the controller's motor sine wave current rating. If the motor is overframed, the motor operating current must not exceed the controller's rated current; and the motor horsepower rating must not be more than one size larger than the controller's horsepower rating.
   - Frequency: 60 or 50 Hz or other frequency consistent with the controller output frequency.

   For synchronous motor applications, consult your Reliance Electric Sales Office.
5. Use an ohmmeter to check for any grounds between the motor frame and the motor power leads. If a ground exists, the ground condition must be corrected before proceeding.

Final Startup Adjustments with Power On

If any of the following steps cannot be made because of a controller problem, go to "Section 4, Troubleshooting," in this manual.

1. **Make sure the motor power leads are disconnected and power is OFF.**
2. Set a voltmeter on the 500 VDC (1000 VDC) or a similar high voltage scale. Connect the voltmeter to terminals 147(+) and 45(−) on the D-C bus capacitor. Read this voltmeter every time you turn power OFF to verify the D-C bus filter capacitors are fully discharged (zero).

Table 3-1. Controller pot settings.

Adjustment			Functional Description	Control Range	Initial Factory Setting
Name	Abbreviation	Pot			
Minimum Hertz	MIN HZ	4P	Sets motor frequency when Speed pot is fully counterclockwise.	J1: 0 to 35 hertz (1)	6 Hz
Maximum Hertz	MAX HZ	3P	Sets motor frequency when Speed pot is fully clockwise.	J1: 15 to 90 hertz (1)	60 Hz
Acceleration Rate	ACC	1P	Sets rate to accelerate from zero to maximum hertz. (Current limit overrides this function.)	1SW(4) OFF: 1.5 to 20 seconds from 0 to 60 hertz 1SW(4) ON: 4.5 to 60 seconds from 0 to 60 hertz	1SW(4) OFF 20 sec.
Deceleration Rate	DEC	2P	Sets rate to decelerate from maximum to zero hertz. (Voltage limit overrides this function.)	1SW(4) OFF: 1.5 to 20 seconds from 60 to 0 hertz 1SW(4) ON: 4.5 to 60 seconds from 60 to 0 hertz	1SW(4) OFF 20 sec.
Volts per Hertz	V/HZ	7P	Sets output frequency equal to D-C bus voltage divided by the V/Hz ratio.	3.4 to 8.0 V/Hz (1)	3.8 V/Hz
Current Limit	I. LMT	6P	Limits controller output frequency dependent upon D-C bus current.	50 to 150% of controller current rating	100% (2)
Torque Boost	T.BST	5P	Increases voltage in order to increase motor starting torque.	0 to 40 VAC	10 VAC

(1) This is the V/Hz with the base frequency set at 60 Hz (J1). If a base frequeny above 60 Hz is required, contact your Reliance Electric Sales Office for assistance. The V/Hz will change inversely as the base frequency increases.

(2) This is 100% of the controller's maximum output amps (RMS) and is equal to 110% of maximum motor sine wave current rating.

3. Put the Operator's Control Devices in the following positions:

   Run/Jog switch in RUN
   Forward/Reverse in FWD
   Automatic/Manual in MAN
   Start/Stop in STOP
   Speed pot in fully CCW

DANGER
EQUIPMENT IS AT LINE VOLTAGE WHEN A-C POWER IS CONNECTED TO THE A-C V*S DRIVE CONTROLLER. ALL UNGROUNDED CONDUCTORS OF THE A-C POWER LINE MUST BE DISCONNECTED FROM THE CONTROLLER BEFORE IT IS SAFE TO TOUCH ANY INTERNAL PARTS OF THIS EQUIPMENT. AFTER POWER IS REMOVED, USE A VOLTMETER AT TERMINALS 147(+) AND 45(–) TO VERIFY THAT THE D-C BUS FILTER CAPACITORS ARE DISCHARGED BEFORE TOUCHING ANY INTERNAL PARTS OF THE CONTROLLER. FAILURE TO OBSERVE THESE PRECAUTIONS COULD RESULT IN SEVERE BODILY INJURY OR LOSS OF LIFE.

4. Turn power ON.

5. Observe that the voltmeter reading gives the following D-C bus voltage with respect to the appropriate A-C input voltage:

A-C Input Voltage	D-C Bus Voltage
200 VAC	270 VDC
208 VAC	280 VDC
220 VAC	297 VDC
230 VAC	310 VDC

6. If the controller has been stored for over six months, let the controller sit with the Speed pot fully CCW and the power ON for fifteen minutes to charge the filter capacitors. **Put a tag on the controller that power is ON and hazardous voltage exists.**

7. Turn the power OFF. Verify the D-C bus voltage is zero (read the voltmeter).

8. With power OFF, set a second voltmeter on the 250 VAC or higher scale. Connect this voltmeter to any two of the three output power terminals [601(U), 602(V), and 603(W)].

9. With the Speed pot fully CCW, turn the power ON.

10. Push the Start switch. The controller output frequency should be 6 Hz (factory set). The second voltmeter should read about 60 VAC.

11. Gradually turn the Speed pot CW while reading the voltmeter. As the speed increases, the voltage increases. When the Speed pot reaches fully CW, the output voltage should about equal the input voltage. Output frequency should be 60 Hz.

12. Quickly turn the speed pot fully CCW. The voltage and frequency will decrease to 40 VAC and 6 Hz in about 20 seconds.

13. ***NOTE:*** *The output voltage of the PWM controller equals the fundamental voltage plus the harmonics. The V/Hz (volts/Hertz) pot is facory adjusted to produce 230 fundamental output voltage at 60 Hertz output frequency for 230 volts input using fundamental reading voltmeters. Do not adjust the V/Hz pot unless your application requires a different voltage at 60 Hertz. The factory adjustment will maintain the required 3.8 V/Hz characteristic over the speed range (the voltage will be slightly higher than this below 40 Hertz due to the torque boost adjustment which is set to provide up to 150 % torque capability for starting).*

If a different volts/hertz ratio is required (See **Figure 3-2**), adjust the V/Hz (7P) pot as follows (Note: this adjustment should be done with the motor disconnected):

- Turn the TBST (5P) pot fully CCW.
- Turn the Min Hz (4P) pot fully CW.
- With the Speed pot fully CCW, push the Start switch. The controller will ramp to approximately 35 Hz (Min Hz pot fully CW). Allow the controller to reach steady-state speed.
- While reading the second voltmeter, adjust the V/Hz pot until the voltage determined by the following equation is obtained:

$$\text{Voltage} = \frac{\text{Motor's Rated Voltage} \times 35\text{ Hz}}{\text{Motor's Rated Frequency}} + 20\text{ V}$$

For example, a motor rated at 230 VAC and 60 Hz would require a voltage reading of 154 VAC:

$$\frac{230 \times 35}{60} + 20 = 154\text{ VAC}$$

DANGER
ALTHOUGH ZERO SET ADJUSTMENT ON THIS CONTROLLER ALLOWS FOR ADJUSTMENT DOWN TO ZERO SPEED, THIS ZERO SPEED SETTING MUST NOT BE USED WHERE THE OPERATOR MAY RELY ON A MAINTAINED ZERO SPEED. ELECTRICAL NOISE, IMPROPER WIRING, POWER LINE, OR MALFUNCTIONING COMPONENTS COULD CAUSE THE CONTROLLER TO TURN ON WHILE AT THE ZERO SPEED SETTING. FAILURE TO OBSERVE THIS PRECAUTION COULD RESULT IN SEVERE BODILY INJURY OR LOSS OF LIFE.

14. If a minimum frequency other than 6 Hz is required, adjust the Min Hz (4P) pot as follows (See **Figure 3-3**):

- Turn the Min Hz pot fully CCW.

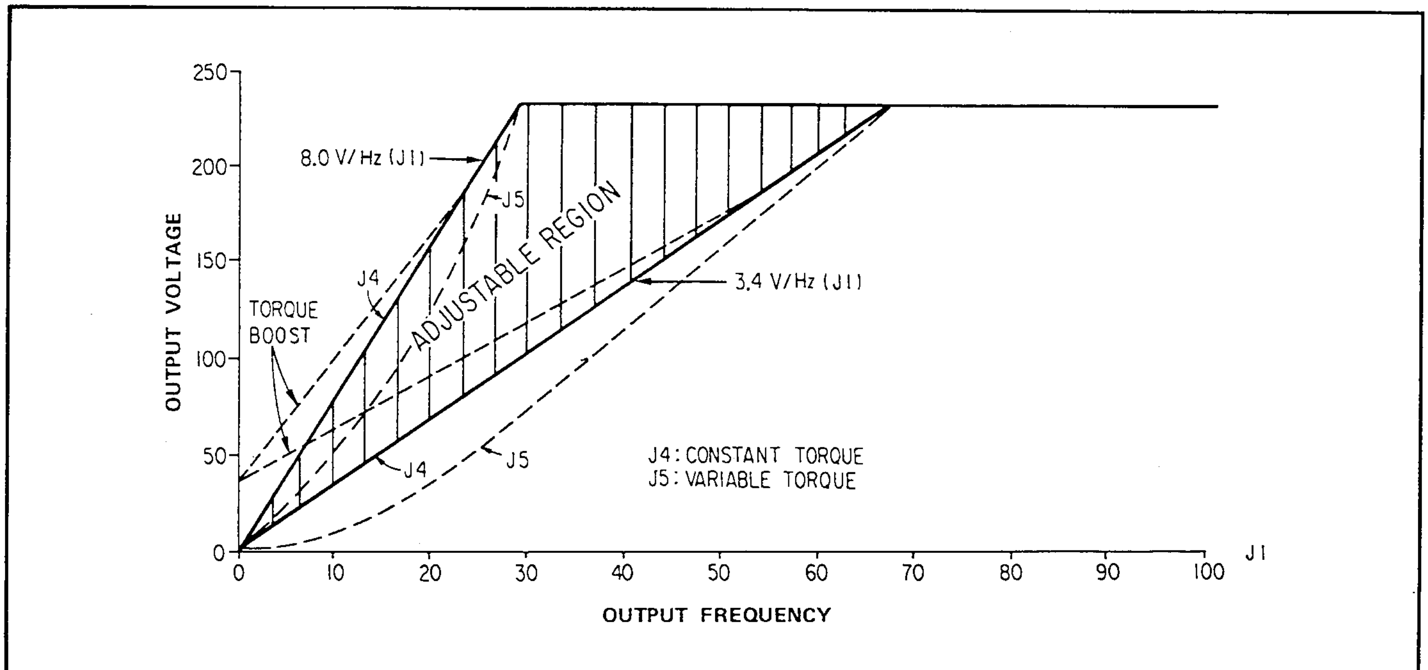


Figure 3-2. Volts/Hertz pot adjustable region for 230 V input.

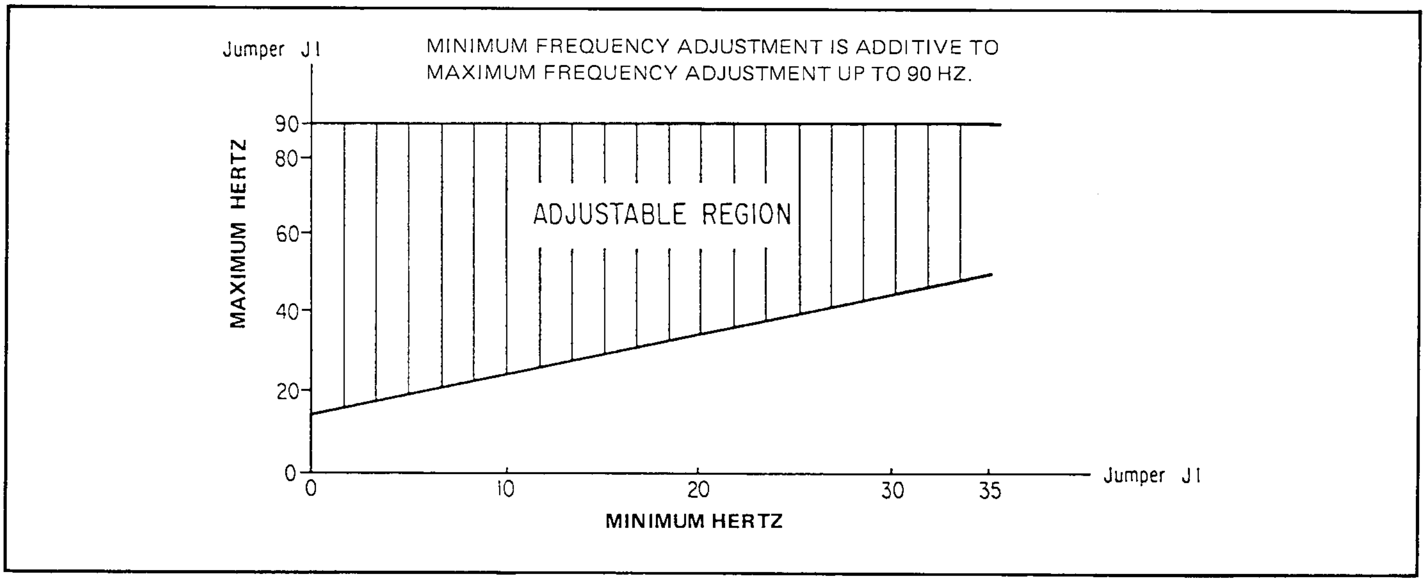


Figure 3-3. Relationship of Min Hz and Max Hz.

- Turn the Speed pot fully CCW.
- While observing the frequency meter, if supplied, adjust the Min Hz pot until the desired frequency is obtained. If the controller is not equipped with a frequency meter, determine the required pot position with the following equation and turn the Min Hz pot to that position:

$$\text{4P Position} = \frac{\text{Desired Min Hz}}{\text{35 Hz}} \times 8 + 1$$

Note that the pot has 10 divisions with 0 equal to 0 Hz and 10 equal to approximately 35 Hz. Therefore, each division equals 3.5 Hz.

15. If a maximum frequency other than 60 Hz is required or if minimum frequency was changed in Step 14, adjust the Max Hz (3P) pot as follows (See **Figure 3-3**): Note that the Min Hz pot must always be adjusted before adjusting the Max Hz pot.

- Turn the Max Hz pot fully CCW.
- Turn the Speed pot fully CW.
- While observing the frequency meter, if supplied, adjust the Max Hz pot until the desired frequency is obtained. If the controller is not equipped with a frequency meter, determine the required pot position with the following equation and turn the Max Hz pot to that position:

$$\text{3P Position} = \left(1.2 - \frac{18}{\text{Desired Max Hz} - \text{Desired Min Hz}}\right) \times 8 + 1$$

For example, if the desired minimum Hz is 30 Hz and the desired maximum Hz is 60 Hz, the required pot position is 5.8:

$$\left(1.2 - \frac{18}{60 - 30}\right) \times 8 + 1$$

Note that the application may require further adjustment.

16. Note the reading on the second voltmeter. Put the Forward/Reverse switch, if applicable, in the REV position. The reading should decrease to zero and then return to the original reading.
17. Put the Forward/Reverse switch in the FWD position.
18. Put the Auto/Man switch, if applicable, in the AUTO position. The Speed pot is now ineffective. Speed is controlled by a process controller reference signal of 4 to 20 mA or 0 to 10 VDC.
19. Put the Auto/Man switch in the MAN position.
20. Turn the Speed pot fully CCW and push the Stop switch.
21. Turn the power OFF. Verify the D-C bus voltage is zero (read the first voltmeter).
22. With power OFF, connect the motor power leads to the controller and couple the driven machinery to the motor, if not already coupled.

DANGER
THE REMAINING STEPS ARE MADE WITH POWER ON. HAZARDOUS VOLTAGE EXISTS. FAILURE TO OBSERVE THIS PRECAUTION COULD RESULT IN SEVERE BODILY INJURY OR LOSS OF LIFE.

23. With the Speed pot fully CCW, turn the power ON. Push the Start switch.

24. Turn the Speed pot slowly CW to check the motor shaft rotation. If shaft rotation is correct, go to Step 25. If shaft rotation is incorrect, change the motor shaft rotation direction as follows:

- Push the Stop switch and wait until the motor has completely stopped.
- Turn the power OFF.
- After verifying the D-C bus voltage is zero, reverse any two of the three motor power leads.

NOTE: *The torque boost pot is factory adjusted to produce the required voltage to produce up to 150 % starting torque for Reliance Electric standard and energy efficient motors. This setting would, in most cases, provide 150 % starting torque for other motors too. Do not adjust the torque boost pot unless starting torque is not adequate. Consult Reliance Electric if satisfactory performance can not be obtained.*

25. With the drive coupled to the machine, the torque boost may not be high enough to break away or accelerate the load within the current limit of the drive. The torque boost should be increased until either the motor performs properly or current limit is reached. If the motor does not run smoothly in a low speed range, turn power OFF and wait until the D-C bus capacitors are fully discharged. Relocate jumper J6 to J7. Set the torque boost pot at zero. Turn power ON and restart the drive. Using the Torque Boost pot, gradually increase the voltage until the motor runs smoothly.

NOTE: *Acoustic noise may become high as the carrier frequency becomes low in a low speed range. If satisfactory adjustment cannot be reached, contact your Reliance Electric Sales Office.*

26. Current limit is preadjusted for 110% of the motor sine wave current rating. To adjust current limit between the range of 50% (fully CCW) and 150% (fully CW), turn the Current Limit (6P) pot as necessary.

27. Turn the Speed pot to the maximum CW position and the motor will accelerate slowly to maximum speed (60 hertz). Maximum speed may not be reached due to current limit. The controller is not designed to supply 150% of the current rating for more than one minute. If satisfactory adjustment cannot be reached, contact your Reliance Electric Sales Office.

28. Turn the Speed pot fully CCW and the motor will decelerate to the minimum speed set with the Min Hz pot.

29. With the Speed pot fully CCW, quickly turn the Speed pot fully CW. If the acceleration time is too long, turn the Acceleration Rate (1P) pot a quarter turn CW and accelerate the motor again. Repeat the motor acceleration process until the desired acceleration time is achieved.

NOTE: *The shortest acceleration time is limited by the current limit circuit. When the Acceleration Rate pot no longer has any effect, the acceleration rate is at its maximum for the application. When the motor is in acceleration while the current is limited, the acceleration will not be smooth. To smooth the acceleration, turn the Acceleration Rate pot slightly CCW.*

30. Turn the Speed pot fully CW and wait until the motor reaches top speed. Quickly turn the Speed pot fully CCW. If the deceleration time is too long, turn the Deceleration Rate (2P) pot a quarter turn CW and decelerate the motor again. Repeat the motor deceleration process until the desired deceleration time is achieved.

NOTE: *The shortest deceleration time is limited by the voltage limit circuit. When the Deceleration Rate pot no longer has any effect, the deceleration rate is at its maximum for the application. When the motor is in deceleration while the D-C bus voltage is limited, the deceleration will not be smooth. To smooth the deceleration, turn the Deceleration Rate pot slightly CCW.*

31. Turn the Speed pot CCW and wait until the motor completely stops. Then put the Run/Jog switch in the JOG position.

32. Turn the Speed pot a quarter turn CW and push the Start switch. The motor will rotate while the Start switch is held in the START position. The speed depends on the Speed pot setting.

33. Turn the Speed pot CCW, and put the Run/Jog switch in the RUN position. Push the Stop switch.

34. Turn the power OFF. After verifying the D-C bus voltage is zero, remove the two voltmeters and any other instrumentation connected during startup. Close and secure the controller enclosure cover.

Section 4
TROUBLESHOOTING

DANGER
EQUIPMENT IS AT LINE VOLTAGE WHEN A-C POWER IS CONNECTED TO THE A-C V★S DRIVE CONTROLLER. ALL UNGROUNDED CONDUCTORS OF THE A-C POWER LINE MUST BE DISCONNECTED FROM THE CONTROLLER BEFORE IT IS SAFE TO TOUCH ANY INTERNAL PARTS OF THIS EQUIPMENT. AFTER POWER IS REMOVED, USE A VOLTMETER AT TERMINALS 147(+) AND 45(−) TO VERIFY THAT THE D-C BUS FILTER CAPACITORS ARE DISCHARGED BEFORE TOUCHING ANY INTERNAL PARTS OF THE CONTROLLER. FAILURE TO OBSERVE THESE PRECAUTIONS COULD RESULT IN SEVERE BODILY INJURY OR LOSS OF LIFE.

SAFETY PRECAUTIONS

DANGER
THIS EQUIPMENT SHOULD BE ADJUSTED AND SERVICED BY QUALIFIED ELECTRICAL MAINTENANCE PERSONNEL FAMILIAR WITH THE CONSTRUCTION AND OPERATION OF THE EQUIPMENT AND THE HAZARDS INVOLVED. FAILURE TO OBSERVE THIS PRECAUTION COULD RESULT IN SEVERE BODILY INJURY OR LOSS OF LIFE.

1. **Be sure to wear safety glasses at all times.**
2. **Be sure the input disconnect is in the correct position, either on or off depending on the work to be performed.**
3. Have a backup technician, who is always in sight and ready to assist in the case of an emergency.

TEST EQUIPMENT

Proper use of test equipment is essential to avoid damage to the controller. Listed below are several items which must be followed to prevent damage to the equipment or injury to the operator.

- Do not intermix commons. The inverter stage is isolated from the control logic section. The potentials are at different levels and intermixing can cause a short circuit.
- Use only one hand to connect test equipment leads to any point in the unit.
- Digital voltmeters (DVM) should be used with caution because some DVM's inject noise into the controller.
- **Never use a megger to check for drive control grounds or to test any internal parts on the controller.**

PRELIMINARY TROUBLESHOOTING REVIEW

1. Remove the enclosure cover and swing down the Local Operator's Control Station.
2. Excessive torque boost can cause high motor currents, both no load and full load, thus causing excessive heating in the motor and overloading of the controller. By the same token, no voltage boost can result in abnormally high currents under the conditions of hard starting, fast acceleration and transient load operations. If this symptom exists, turn to "Final Startup Adjustments with Power On" in Section 3.
3. Make a complete physical inspection of all control and motor wiring for correct and tight connections. Be sure that connectors on the regulator are correctly positioned and tight.
4. Check the input power voltage to be sure it is in the +10% −5% voltage tolerance range. Also check that the input power voltage corresponds with the voltage selected at controller terminals 281 to 481 (230 VAC) or 281 to 381 (220, 208, 220 VAC).
5. Check for poor wiring practices, such as:
   - Input and output leads running through the same conduit.
   - Input or output leads running parallel or in the same conduit with control signal wiring.
   - Control signal wire that is not twisted.
6. Make sure R-C suppressors are used across all relays, brakes and solenoid coils. Reliance Electric part 600686-33A suppressor or a 220-ohm, 0.5 watt resistor in series with a 0.5 microfarad, 600-volt capacitor can be used.
7. Check to see if an IET has occurred. A lit IET LED, if applicable, indicates that the IET has tripped. If the controller includes a Digital Frequency Meter with First Fault, the display will indicate the first fault causing the IET. If an IET has occurred, refer to **Table 4-1** for the possible cause. Clear the fault and reset the controller by pushing the Stop switch, waiting for the motor to completely stop, and pushing the Start switch.

8. Check that the frequency wirewrap jumper is positioned at J0 — J1 (60 hertz).

9. Check the ambient temperature to ensure it does not exceed 40°C (104°F) for enclosed controllers or 55°C (131°F) for chassis controllers.

Table 4-1. Possible causes of IET occurrence

Type of IET	Possible Cause
Overcurrent	Output line-to-ground or line-to-line short
	Motor current higher than 200% of the controller sine wave current rating
	Acceleration time too short
	Hall effect amplifier card is faulty
Overvoltage	Input voltage too high
	Deceleration time too short
	Input phase loss
Low Line	Input voltage too low
	Momentary power drop
Power Supply	±12 VDC on regulator board too low

Fault Symptoms

Identify the fault from the following symptoms and then turn to the figure indicated:

1. Motor will not run (**Figure 4-1**), which includes the following symptoms:
   - Controller will not start.
   - Input fuses are blown.
   - IET trips when the controller is started.
   - Controller starts, but with a loud humming noise, and then stops.
2. Motor will not reach maximum speed (**Figure 4-2**), which includes the following symptoms:
   - Controller starts but motor stays at low speed.
   - Controller has IET during acceleration.
3. Controller has IET during controlled deceleration (**Figure 4-3**).
4. Occasional IET while running but can be restarted (**Figure 4-4**).
5. Motor overheats above allowable temperature (**Figure 4-5**).

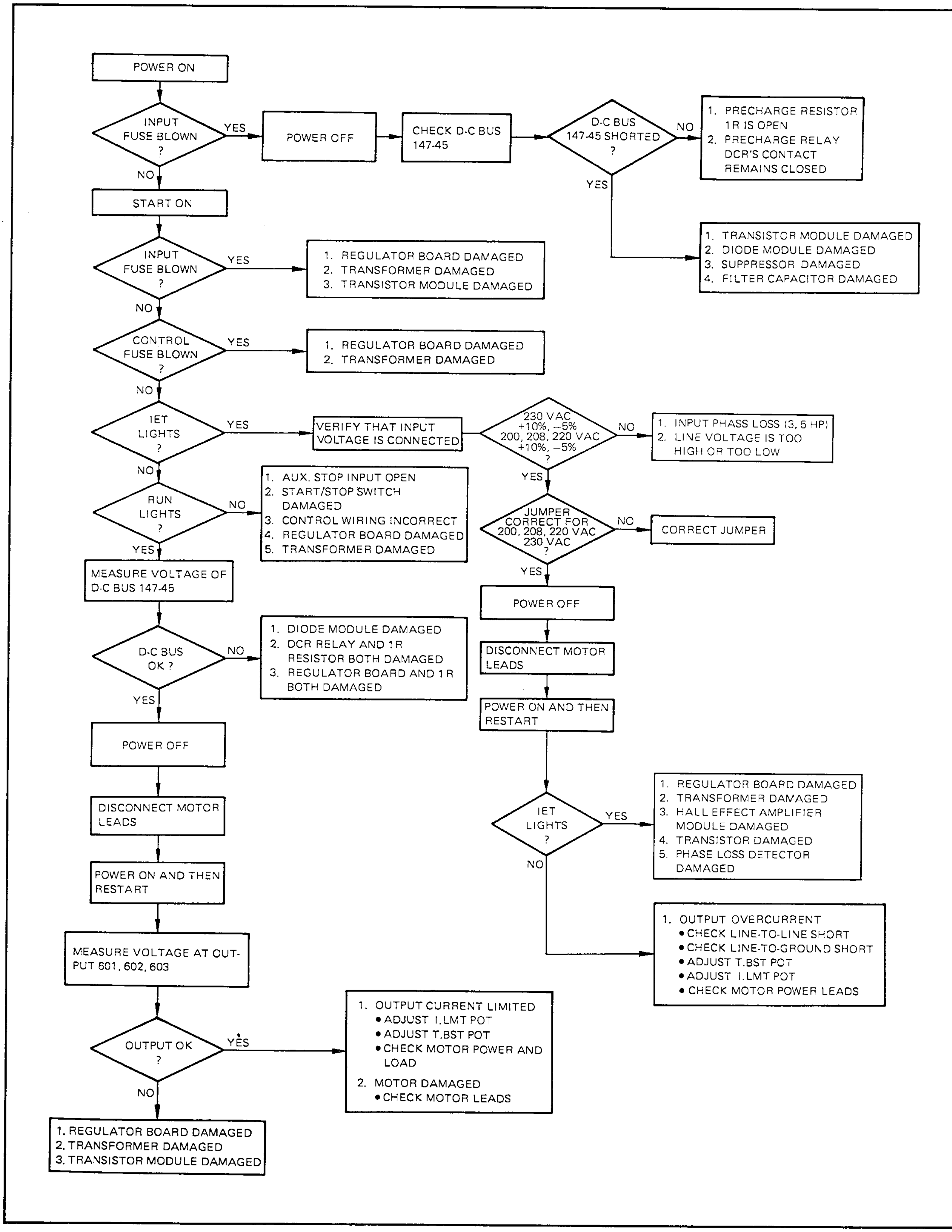


Figure 4-1. Motor will not run.

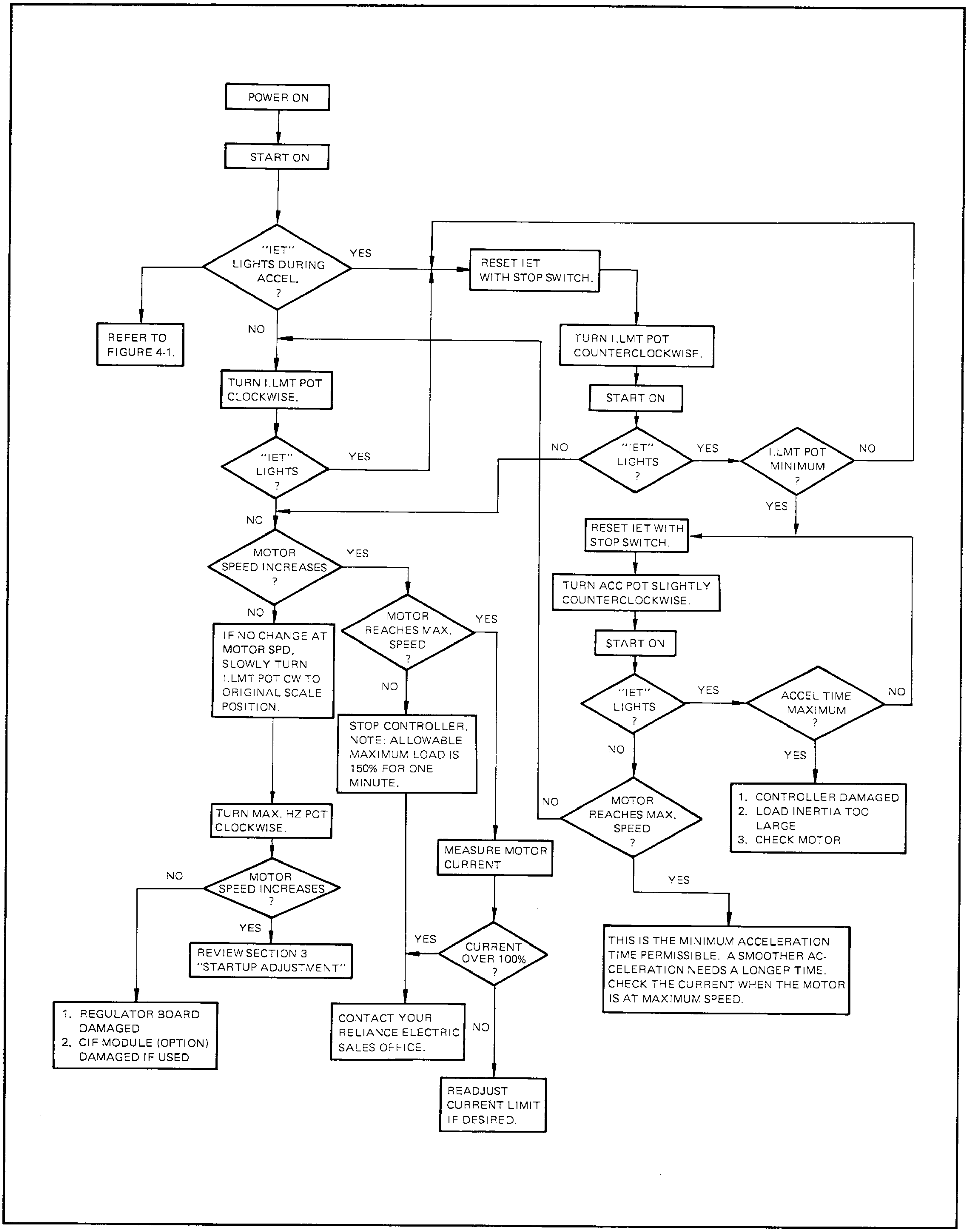


Figure 4-2. Motor will not reach maximum speed.

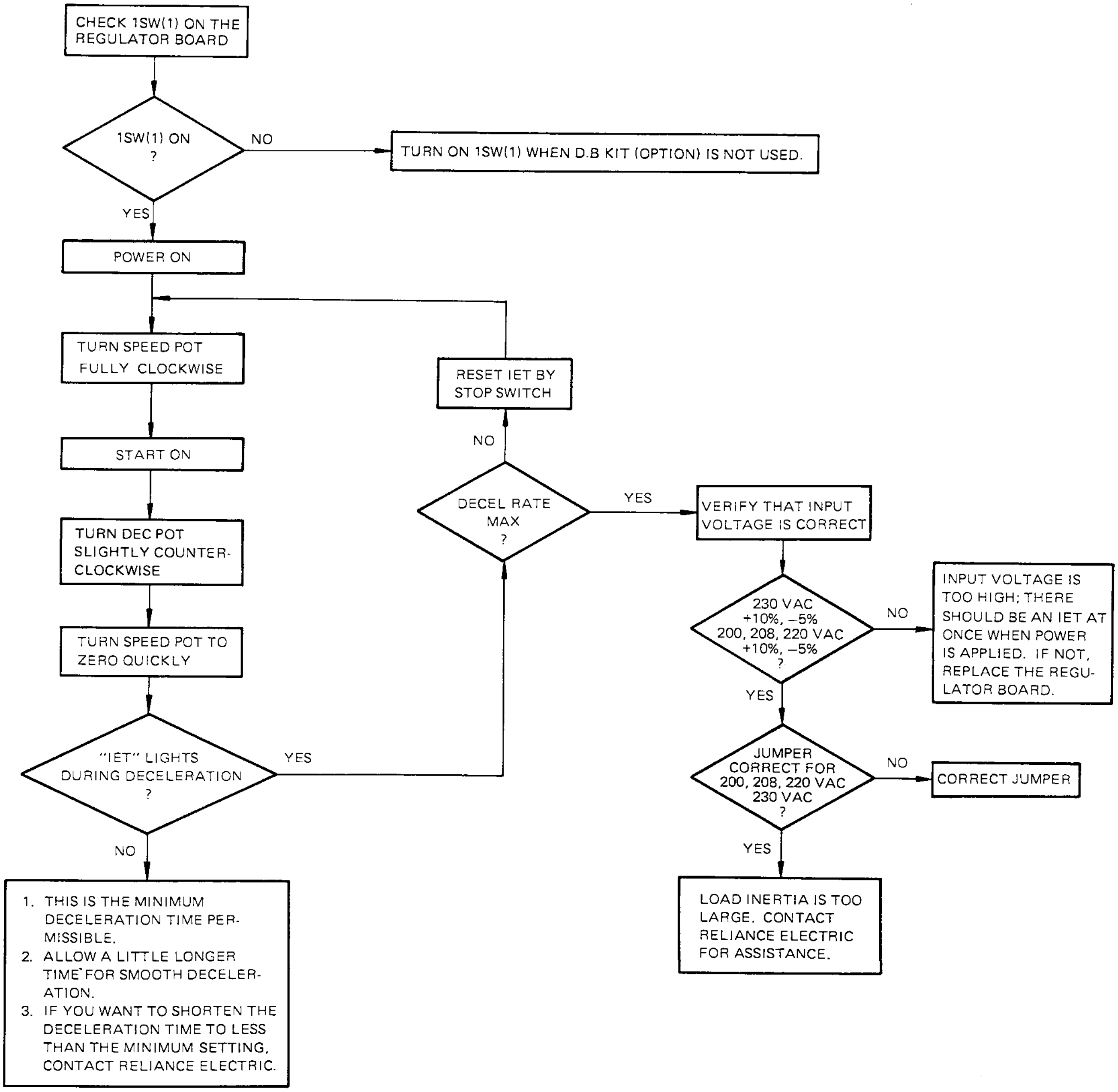


Figure 4-3. Controller IET during controlled deceleration.

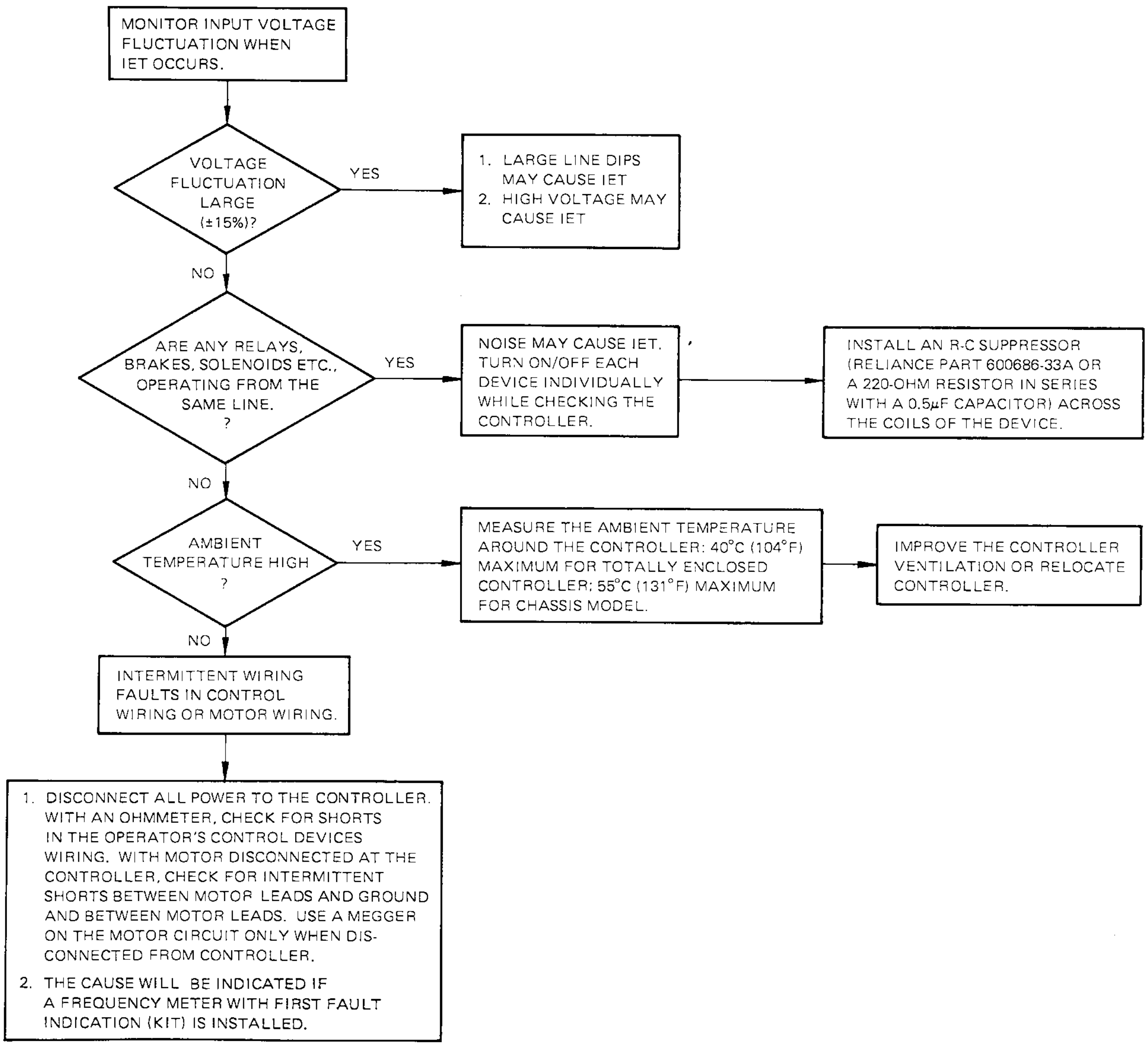


Figure 4-4. Occasional IET while running but can be restarted.

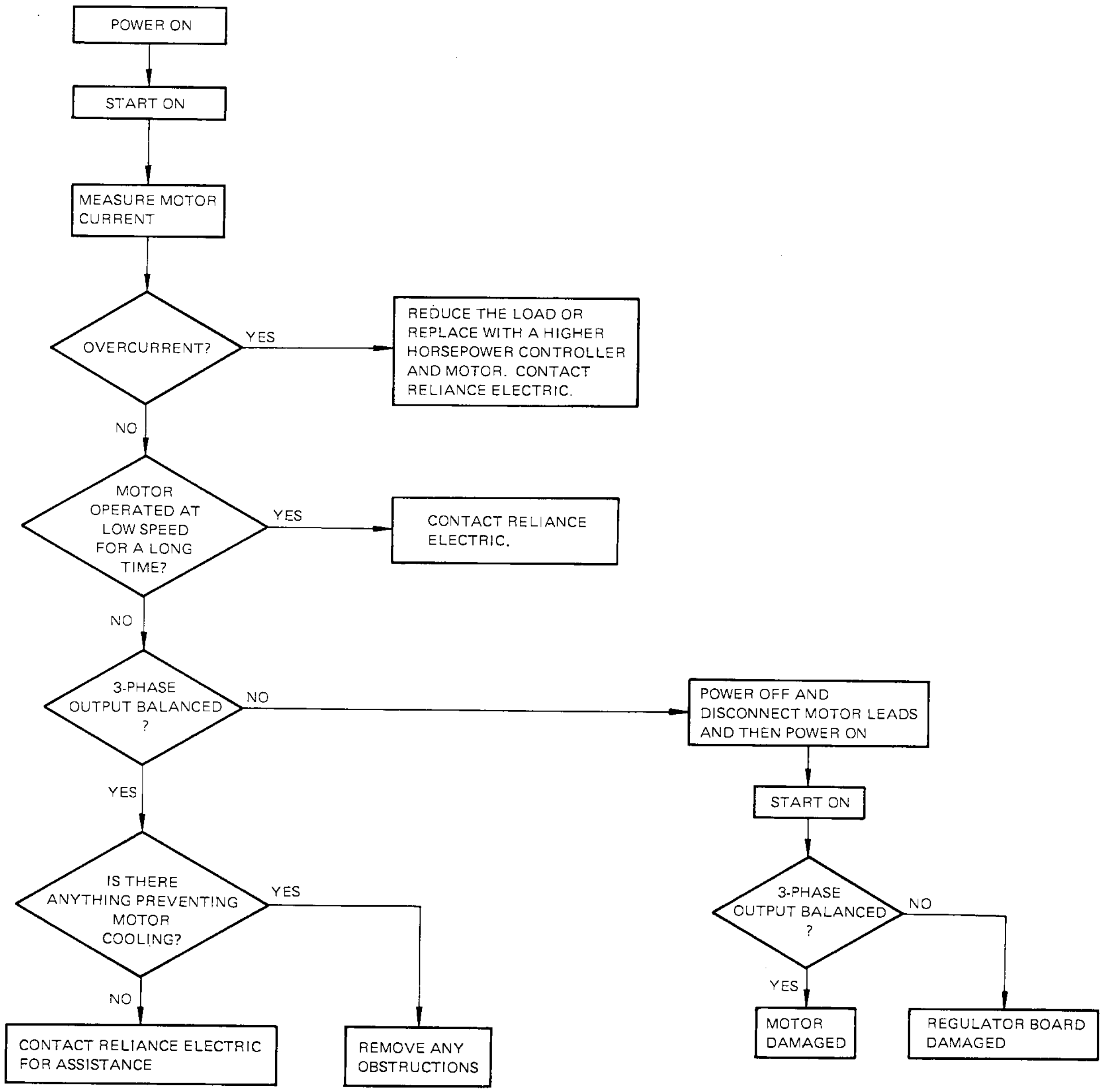


Figure 4-5. Motor overheats above allowable temperature.

Section 5

APPENDICES

A. DESCRIPTION OF OPERATION

CONTROLLER OPERATIONS

The standard A-C V★S Drive Controller has an All Function Local Operator's Control Station which is mounted on the front of the controller. There are five basic operating controls on the station: a Start/Stop switch, a Run/Jog switch, a Forward/Reverse switch, an Automatic/Manual switch and a Speed pot. (Refer to **Figure 1-2**.)

Start/Stop Switch

The controller is started by applying A-C power to the controller by means of the A-C input power line disconnect. Pushing the Start switch causes the motor to accelerate to the speed determined by the speed reference. The acceleration time depends on the time set on the Acceleration Rate pot.

The motor is stopped by pushing the Stop switch. The standard Stop mode is coast-to-rest, but ramp-to-rest can also be selected. Whenever the drive is stopped due to an instantaneous electronic trip (IET), the motor is restarted by first pushing the Stop switch, which resets the IET, and then pushing the Start switch.

Run/Jog Switch

When this switch is in the RUN position, the controller controls motor speed until the Stop switch is pushed. When this switch is in the JOG position, the motor runs only while the Start switch is pushed and held in. Releasing the Start switch stops the controller. The motor will stop in a coast-to-rest or ramp-to-rest mode depending on the mode selected.

Forward/Reverse Switch

This switch is provided for changing motor rotation direction. The rotation can be changed by interchanging any two output motor leads. The Forward/Reverse switch changes the phase rotation electronically. To operate the controller in the Reverse mode, put the Forward/Reverse switch in the REVERSE position. This can be done while the motor is at full speed in the forward direction. The motor will decelerate to zero speed in the ramp-to-rest mode and then accelerate in the opposite direction to the set speed.

Automatic/Manual Switch

The Automatic/Manual switch changes the speed reference from the Speed pot (MAN) to an external reference from a process controller (AUTO). The standard controller includes a process controller interface available to convert a 4 – 20 mA signal to 0 – 10 VDC.

Speed Pot

When in the manual (MAN) operating mode, the speed of the motor is controlled by the speed reference set with the Speed pot. While the motor is running, the speed can be increased or decreased by increasing (CW) or decreasing (CCW) the speed reference. When the controller is started, the motor will automatically accelerate to the speed determined by the Speed pot.

VARIABLE VOLTAGE/VARIABLE FREQUENCY CONTROLLER FUNDAMENTALS

Generally, we think of an A-C motor as a fixed-speed machine, operating from a constant voltage/constant frequency source, such as 230 VAC and 60 Hz. Speed under these circumstances is fixed. The Reliance Electric adjustable frequency A-C V★S Drive Controller is, on the other hand, a variable voltage/variable frequency three-phase output source designed specifically to vary the speed of conventional A-C motors. To adjust the speed of an A-C motor, the simultaneous control of both voltage and frequency is required.

The operating frequency of the controller, along with the basic design of the motor, determines the operating speed (rpm) of the motor. The output voltage of the controller establishes the proper magnetic flux level within the motor to meet the torque demands of the load over the entire speed range. The basic equation to determine motor synchronous speed is:

$$\text{Synchronous RPM} = \frac{\text{Controller Output Frequency} \times 120}{\text{Number of A-C Motor Poles}}$$

The relationship between output voltage and operating frequency is commonly referred to as the "Volts per Hertz" ratio (V/Hz). Except at low speed, this ratio is usually a constant established by the nameplate voltage of the motor divided by its frequency rating:

$$\text{V/HZ} = \frac{\text{Motor Nameplate Voltage}}{\text{Motor Nameplate Frequency}}$$

The Reliance Electric A-C V★S Drive Controller takes three-phase, constant A-C voltage, constant frequency input and transforms it into a three-phase, variable voltage, variable frequency output. This voltage and frequency output is completely compatible with the A-C adjustable speed requirement of the A-C motor.

The A-C V★S Drive Controller consists of two main parts (**Figures 5-1** and **5-2**):

1. Power circuit
2. Controller regulator

The power circuit consists of solid state switches which transform the constant voltage, constant frequency input power into variable voltage, variable frequency output power. The controller regulator controls when the solid state switches in the power circuit turn ON and OFF.

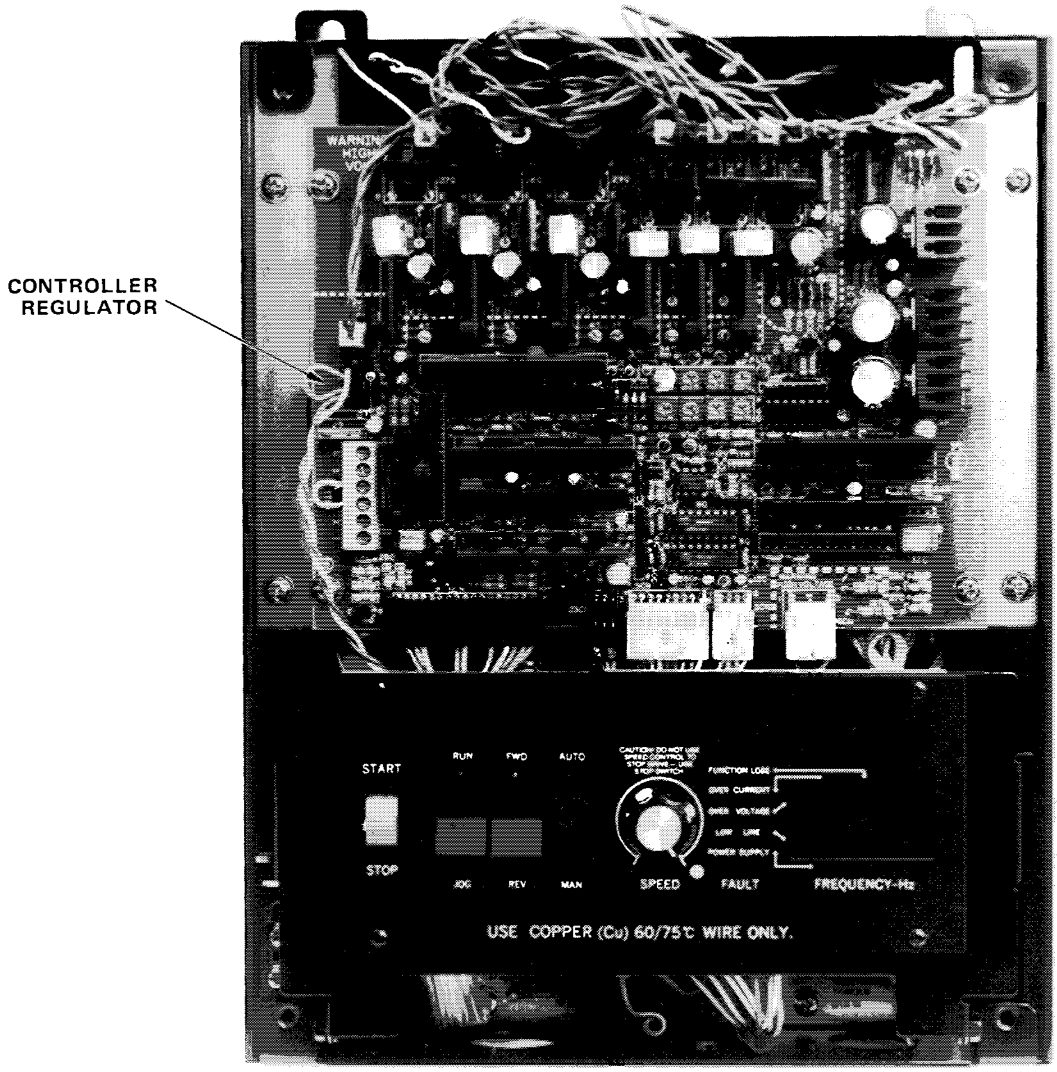


Figure 5-1. Location of regulator.

Power Circuit

Figure 5-3 shows the actual power circuit schematic divided into three sections. These sections will be discussed from left to right, which is the same direction in which the power flows.

The first section is the **input rectifier**. A-C power is applied to terminals 181, 182 and 183 and is full wave rectified by the diode module (1DM) to constant D-C voltage. This voltage is approximately 310 VDC (230 VAC input). Three input fuses (1FU, 2FU, 3FU) are provided to protect the power circuit from any ground faults. A suppressor (1ZNR) is provided to limit voltage transients within the maximum voltage rating of the diodes.

The rectified voltage is then filtered by the **D-C bus filter**. The filter capacitor is charged through resistor 1R to limit the charging current. Relay DCR is energized and shorts out the charging resistor when the bus filter capacitor 1C voltage reaches approximately 90% of the rated bus voltage. Resistors 2R and 4R discharge the bus voltage when the input power is removed.

The (+) and (–) D-C bus conductors pass through the Hall Effect Amplifer, which detects D-C bus current.

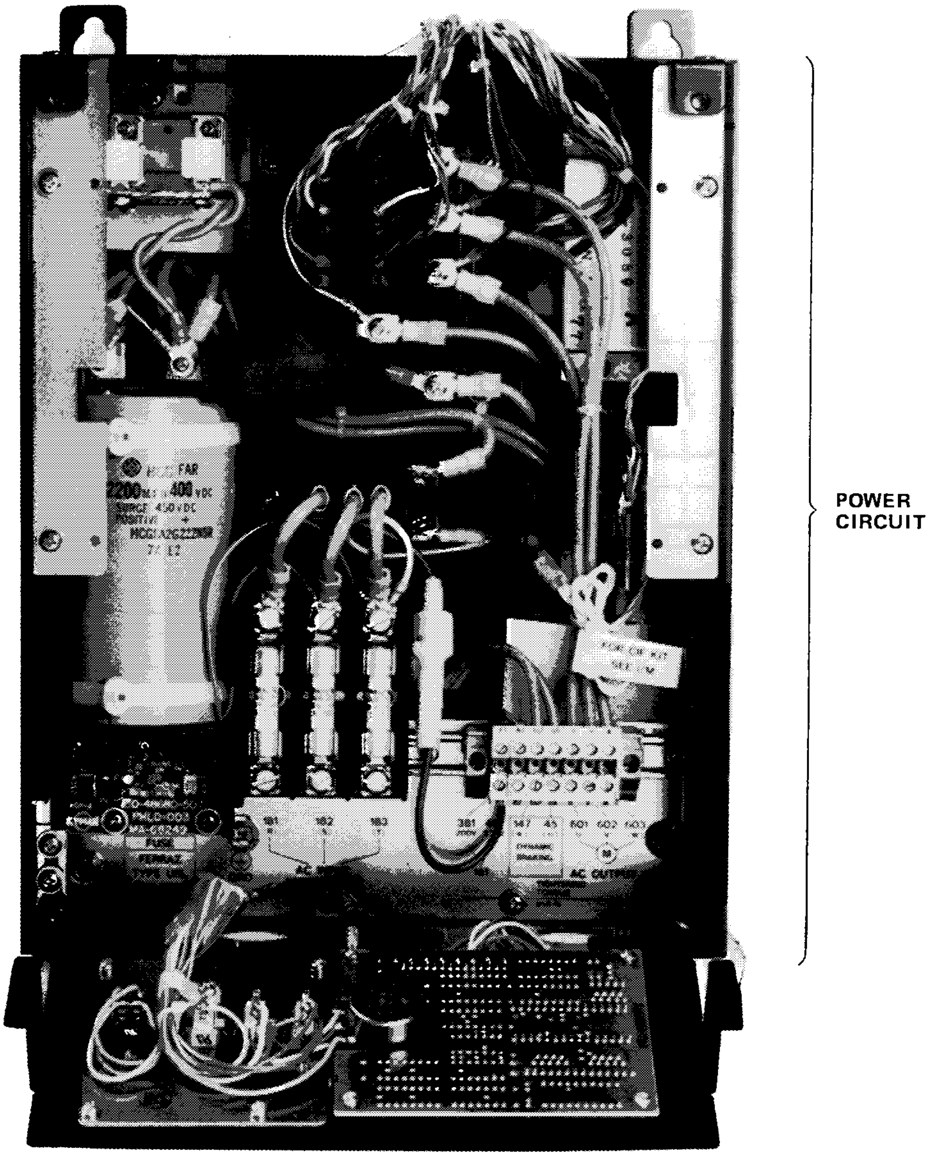


Figure 5-2. Location of power circuit.

This isolated current signal goes to the controller regulator as a feedback signal. The current feedback is used to protect against a short circuit in the output inverter section.

The filtered D-C bus voltage is fed into the **output inverter** section. This section transforms D-C bus voltage into three-phase A-C variable voltage and variable frequency by switching transistors in the transistor module (1TM). The transistor module has six transistors and anti-parallel diodes around them to provide a path for reactive motor current.

In summary, constant voltage is produced by rectifying and filtering the incoming A-C power line. Variable voltage/variable frequency is produced by six output transistors inverting constant D-C voltage to PWM voltage waveform.

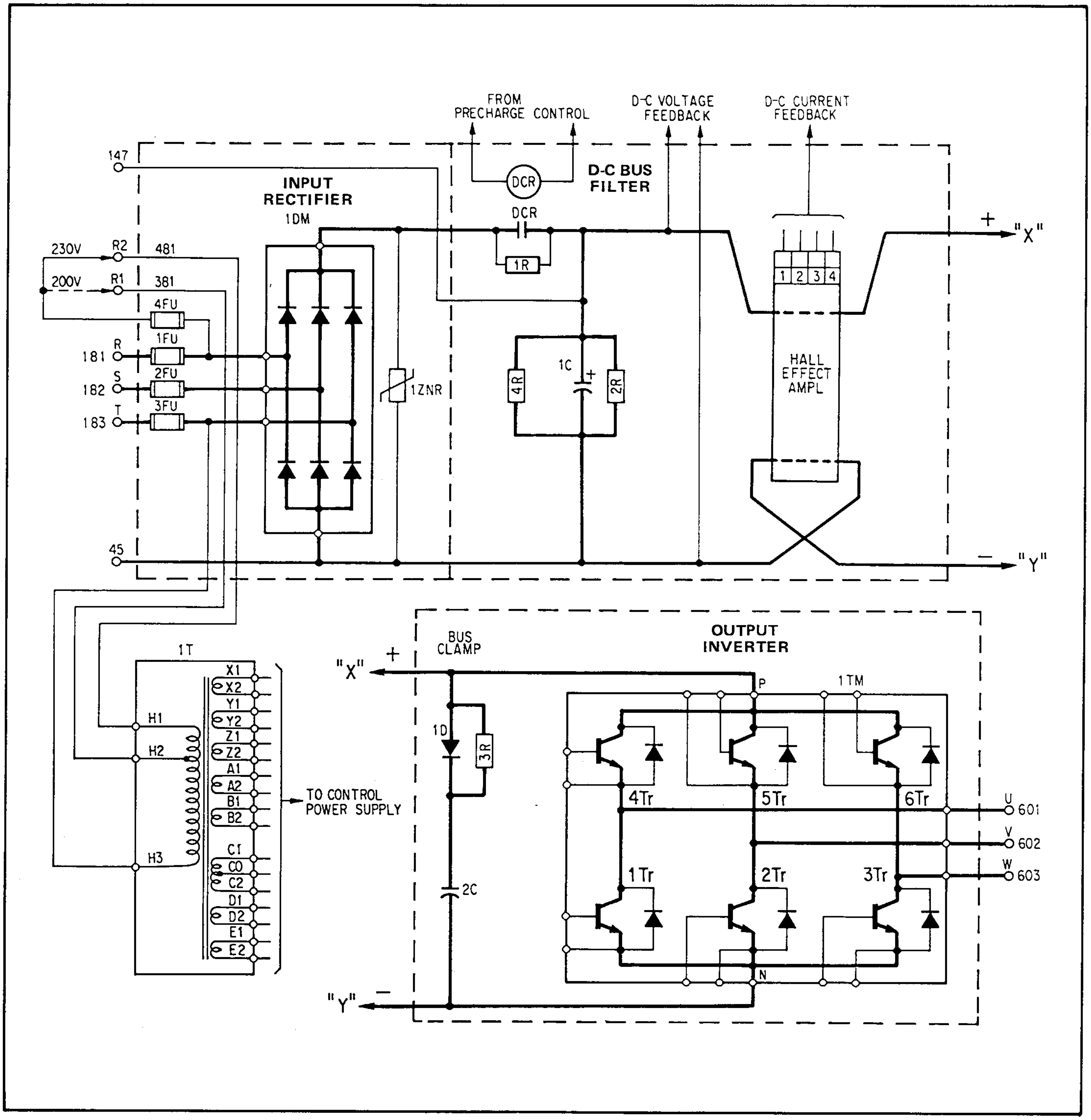


Figure 5-3. Power circuit functional schematic.

Controller Regulator

The controller regulator is a single printed circuit board. **Figure 5-4** shows the controller regulator block diagram. It is divided into nine sections as described below.

The first section is the **input signal conditioner**. The input to this section is the speed reference signal from either a Speed pot or process controller (Not isolated; use the Customer Interface Module when isolation is required.). The first conditioning that is done on the input is to set minimum and maximum hertz using the Min and Max Hz pots. These adjustments cause the reference never to go below minimum hertz or to go above maximum hertz. When the Min Hz pot is set to zero and the speed reference is zero, the motor would be energized by D-C offset in the Run mode.

Next, the reference signal goes into the ramp control. This block takes step changes in reference and transforms the changes into a controlled ramp on both increasing and decreasing inputs. The amount of time which it takes to go from zero to full reference and back to zero can be adjusted by the Acceleration and Deceleration Rate pots, respectively. These times range from 1.5 to 20 seconds. Typical voltage output of the ramp control is 6 volts equal to 60 hertz. Acceleration and deceleration rate can be extended up to three times the maximum time.

A Current Limit pot is provided in the **current limit** circuit, which sets the required limit value. The current limit circuit compares the current limit value with the D-C bus current feedback. If the D-C bus current exceeds the limit value, the current limit circuit modifies the ramp control to limit the D-C bus current and extend acceleration or deceleration time.

The **voltage limiter** has fixed limit reference. When in the regenerative mode, the D-C bus voltage will rise as the motor decelerates. If the bus D-C voltage exceeds the limit reference, the signal conditioner generates a limit signal. This signal goes to the ramp control to limit the D-C voltage and extend the deceleration

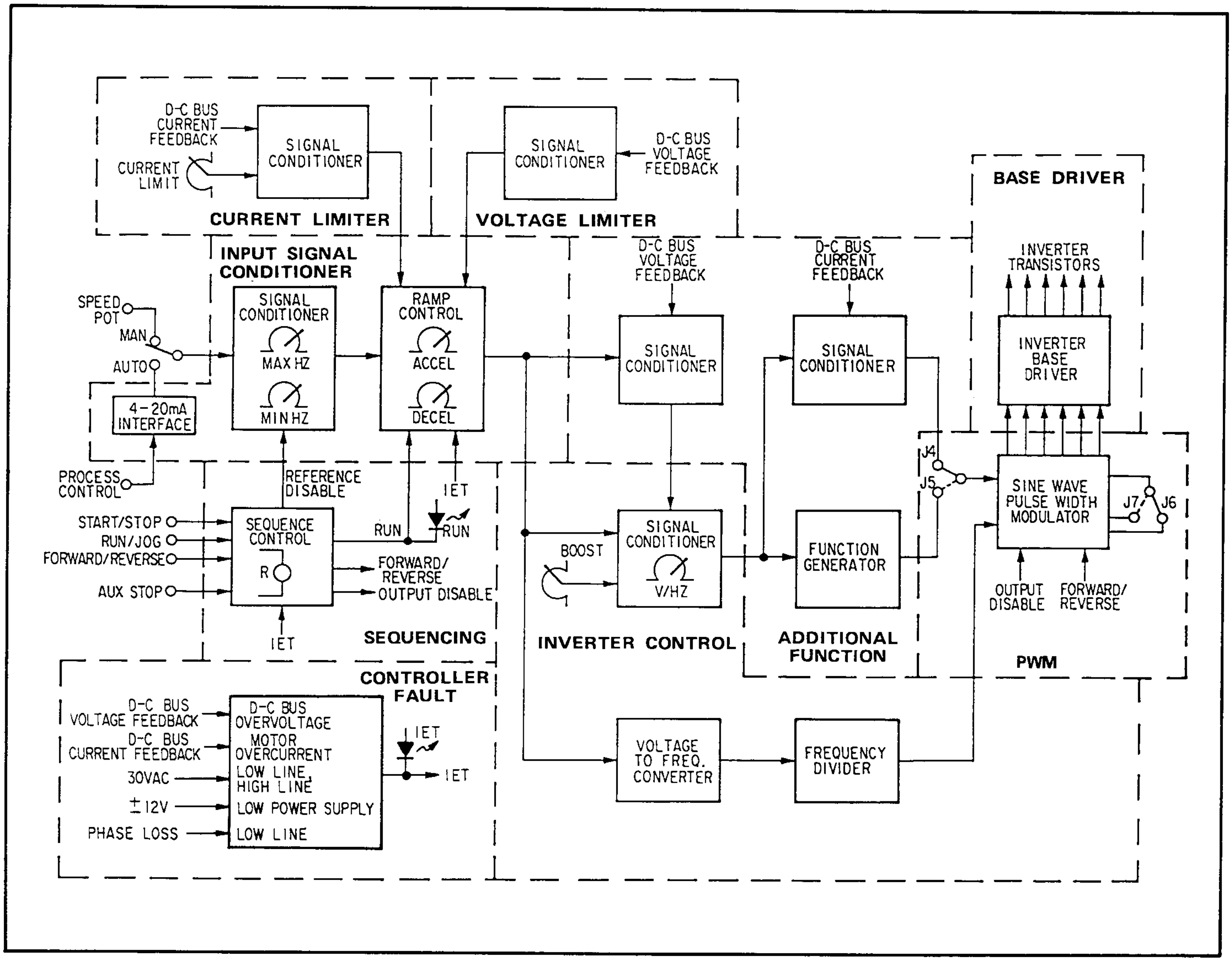


Figure 5-4. Controller regulator block diagram.

time. This limit function operates if the D-C bus voltage exceeds 380 VDC.

This function may be selected by switching Dip Switch 1SW(1) to the ON position. If the dynamic braking option is used, the Dip Switch should be in the OFF position to remove this function from the circuit.

The conditioned timed reference is the reference for the **inverter control section**. This goes to the signal conditioner block which defines the Volts/Hertz ratio, dependent upon the Volts/Hertz pot and the Torque Boost pot settings. It also goes to the voltage-to-frequency converter and the frequency divider. These blocks determine the output frequency of the controller. The torque boost is required to offset the IR drop of the A-C motor at a low speed to produce constant torque capability.

D-C torque boost at zero hertz or A-C torque boost at 3 hertz may be selected by Dip Switch 1SW(2). In the OFF position, A-C torque boost will be provided at 3 hertz for operation of standard induction motors. In the ON position, D-C torque boost at zero hertz is provided for operation of permanent magnet synchronous motors to provide synchronous operation from starting. This limits the current demand during acceleration.

The **additional function section** provides automatic output voltage correction for A-C line power voltage fluctuations and either automatic torque boost for constant torque loads or an energy saver function generator for centrifugal torque loads.

The automatic torque boost is selected with jumper J4. The automatic torque correction circuit compares the timed reference to the D-C bus voltage feedback and automatically corrects output voltage for A-C line voltage fluctuations up to 95% output voltage. The automatic torque boost circuit monitors D-C current feedback and adjusts the output voltage with the D-C bus current.

The function generator block is provided for saving energy and reducing acoustic noise on centrifugal pump and fan applications. This is done by means of a volts/Hz curve which is approximately reduced with the square of the speed reduction since torque is proportional to speed squared on a centrifugal load. See **Figure 3-2**. This function should not be used for constant torque applications because the drive would not be able to produce full load torque at low speeds. Jumper J5 should be used for centrifugal torque applications.

The next section is the **PWM section** which generates the sine wave pulse-width modulation signal corresponding to the volts/Hz and frequency signals. **Figure 5-5** illustrates the theory of generating the sine wave PWM. Jumper J6 selects "constant" carrier frequency of the PWM, while J7 selects "variable" carrier frequency of the PWM. With the "variable" selection, the carrier frequency is automatically decreased in proportion to a decrease in speed. It is possible to have torque increase in a low speed range though the acoustic noise may also increase.

The **base driver section** is an amplifier for switching the six inverter transistors to produce the required pulse widths. The signal from the regulator is isolated by an optical coupler. The output of the optical coupler is current amplified by a drive transistor which, in turn, supplies the required base driver to the power transistor. These base drivers require an isolated power supply which is supplied by additional secondaries of the regulator power supply transformer.

The **controller fault section** monitors selected signals within the controller and generates a fault signal whenever these signals exceed preset limits. The conditions for an IET are as follows:

1. D-C bus voltage (310 VDC nominal) exceeds 420 volts
2. D-C bus current exceeds 200% of full load current
3. Regulator A-C input voltage (30 VAC nominal) is not within +11%, −15%.
4. Regulator D-C power supply (±12 VDC nominal) is 9.6 volts or less
5. Input phase loss occurs.

The output of the IET circuit turns OFF the regulator in a controlled manner by turning off the sequencing control, the ramp control and the PWM modulator. This redundancy assures the controller turns OFF when a fault occurs. The controller can only be reset by pushing the Stop switch or turning power OFF and then ON again. If an external IET contact is required, an external IET contact (form C) is available by adding the Customer Interface Module Kit.

The final section is the **sequencing section**. This is the interface between the regulator and the Start/Stop inputs from the operator's control devices or the process controller. Input circuits for Start/Stop, Run/Jog and Aux Stop are isolated by a relay and an isolated secondary winding. The input circuit for FWD/REV is not isolated. If external controls are required, use the Customer Interface Module Kit.

The Start/Stop switch picks up the RR relay if the Aux Stop input is closed. Contacts from the RR relay are connected to the sequence logic as a start/stop input.

There are two Stop modes: coast-to-rest and ramp-to-rest. The normal Stop mode is coast-to-rest set with Dip Switch 1SW(3) in the OFF position. The Stop switch or the Aux Stop input will then cause a coast-to-rest. This stop mode instantly turns OFF the controller and the motor coasts to rest. If the controller is restarted while the motor is still in motion, an IET will occur due to high D-C bus voltage caused by regeneration.

The ramp-to-rest Stop mode is set with Dip Switch 1SW(3) in the ON position. With this setting the Stop switch or the Aux Stop input will cause a ramp-to-rest. With this method the controller can be restarted while the motor is still in motion without causing an IET because the motor voltage and frequency are kept under control until the motor stops rotating. A Coast-Stop pushbutton must be provided for emergency stop. See **Figure 2-5** for wiring. If the Customer Interface Module Kit is installed, the Coast-Stop pushbutton may be connected to the function loss input to generate the Stop command. The switches connected to the input are normally closed contacts connected in series. Refer to **Figure 2-6**.

Opening the function loss input causes an IET. An IET instantly turns OFF the controller and the motor coasts to rest. In order to restart, the Stop switch must be pushed to reset the IET, then the Start switch is pushed to start the controller.

Normally, the Run/Jog switch is in RUN. In the Jog mode, the run relay (RR) will not latch by pushing the Start switch. Therefore, the controller operates only while the Start switch is being pushed. The motor speed is determined by the Speed pot setting. The acceleration and deceleration time is determined by the acceleration and deceleration adjustments in the Jog mode.

The Forward/Reverse input selects the phase rotation of the inverter control section. This can be changed at any motor speed. When the direction is changed, the sequencing control automatically causes the ramp control to go to zero at the deceleration rate setting. Near zero, the frequency of the inverter control reverses, after which the sequencing releases the ramp control, and the motor ramps to the speed reference at the acceleration rate setting.

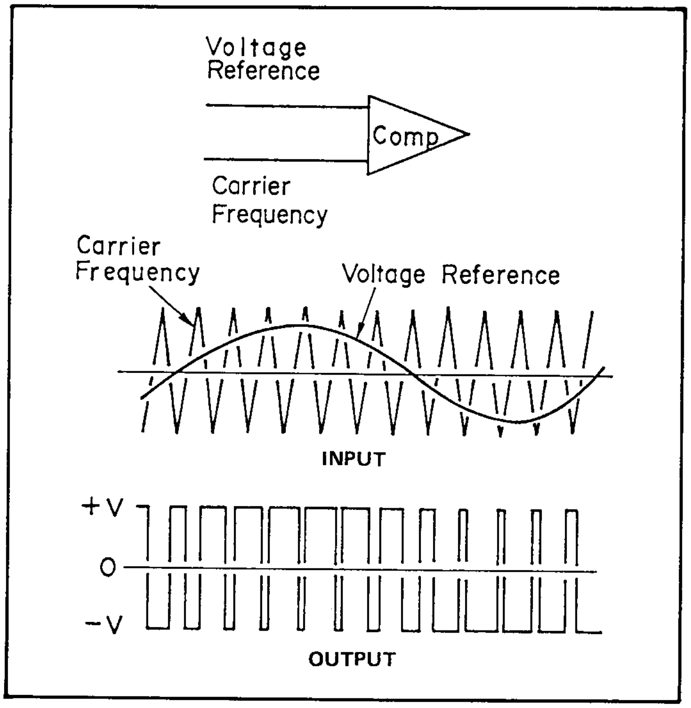


Figure 5-5. Theory of generating PWM signals by comparators.

B. DESCRIPTION OF OPTIONS

The Reliance Electric A-C V★S Drive Controller is designed to accept several pre-engineered options. General descriptions of these options are included in this appendix. Further information can be found in the specific instruction manual for each option.

STANDARD OPTIONS

All of the options listed in **Table 5-1** are designed to be added either by Reliance Electric or by the customer. Each option is packaged separately and has its own model number identification.

OPTIONS THAT MOUNT IN CONTROLLER

Local Operator's Control Station Kits

The controller has a Local Operator's Control Station on the front of the cabinet. Ten Local Operator's Control Stations are available. See **Table 5-2**.

Digital Meter

The Digital Meter displays not only the controller output frequency but also the first fault causing an IET. Local Operator's Control Station with cutout for the meter is required.

Customer Interface Module Kit

The customer interface module is required when using the Remote Operator's Control Station or user supplied operator's devices and/or for a separately mounted Analog Frequency Meter. It provides isolation for operator's devices and for a process control input signal of 4 – 20 mA or 0 – 10 VDC.

Normally open and normally closed IET contacts and a normally open RUN contact are provided for customer use. The contacts are rated 1 amp at 250 VAC and 2 amps at 30 VDC. The kit can be used with an operator's station: 1LS2000A or 1LS2004. The chassis controller is supplied with a Blank Local Operator's Control Station and a Customer Interface Module.

Cabinet Conversion

This option provides the necessary hardware to allow converting the NEMA 1 enclosure to the chassis configuration. It consists of a Blank Local Operator's Control Station, a Customer Interface Module, and the chassis enclosure's top and bottom plates.

OPTIONS THAT MOUNT OUTSIDE CONTROLLER

Remote Operator's Control Station

The Remote Operator's Control Station includes the Start/Stop, Run/Jog, Forward/Reverse, and Automatic/Manual function switches; a Speed pot; and Analog Frequency Meter. Use of the remote station requires the Customer Interface Module and a Blank Local Operator's Station. The frequncy meter on the Remote Operator's Control Station connects to the Customer Interface Module (option) in the A-C V★S Drive Controller.

Table 5-1. Standard Options.

Description	Model Number	Instruction Sheet
Local Operator's Control Station Kit	See Table 5-2	D2-3105
Remote Operator's Control Station NEMA 1 with Start/Stop Run/Jog, Forward/Reverse, Automatic/Manual, Speed pot, Analog Frequency Meter	1RS2000	D2-3065
Customer Interface Module Kit (1)	1CI2001	D2-3104
Dynamic Braking Kit (1)		
230 V, 1 – 2 HP (UL)	1DB2002U	D2-3066
230 V, 1 – 2 HP (CSA)	1DB2002C	D2-3066
230 V, 3 – 5 HP (UL)	1DB2005U	D2-3066
230 V, 3 – 5 HP (CSA)	1DB2005C	D2-3066
Voltmeter	1VM2000	D2-3071
Ammeter		
1 – 2 HP	1AM2002	D2-3073
3 – 5 HP	1AM2005	D2-3073
Frequency Meter	1FM2000	D2-3072
Digital Meter with First Fault Indication	1DM2000	D2-3113
Cabinet Conversion (NEMA 1 to Chassis) Kit		
1 – 2 HP	1CK2002	
3 – 5 HP	1CK2005	

(1) This kit can be used only with a controller having a model number with a "U" or "C" suffix.

Table 5-2. Local Operator's Control Station Kits.

Description	Function			Run/IET LEDs (2)	Digital Meter Cutout (1)	Model Number
	Start/Stop Run/Jog Speed Pot	FWD/REV	AUTO/MAN			
Blank	NO	NO	NO	YES	NO	1LS2000A
	NO	NO	NO	NO	YES	1LS2004
Basic	YES	NO	NO	YES	NO	1LS2010
	YES	NO	NO	NO	YES	1LS2011
Reversing	YES	YES	NO	YES	NO	1LS2012
	YES	YES	NO	NO	YES	1LS2013
Automatic	YES	NO	YES	YES	NO	1LS2014
	YES	NO	YES	NO	YES	1LS2015
All Function	YES	YES	YES	YES	NO	1LS2002A
	YES	YES	YES	NO	YES	1LS2016

(1) Operator's Control Stations with a cutout for the Digital Meter are not supplied with the meter. The Digital Meter with First Fault Indication (Model 1DM2000) must be ordered along with the station.

(2) Operator's Control Stations with Run/IET LEDs can be used only with a controller having a model number with a "U" or "C" suffix.

Dynamic Braking Kit

The Dynamic Braking Kit provides rapid deceleration of the drive motor by providing 150% intermittent braking of the motor. The kit dissipates the power regenerated by the motor during deceleration through a resistor.

The 1 and 2 HP models are rated for 0.7 lb ft^2 and the 3 and 5 HP models are rated for 2.0 lb ft^2 – each for six starts/stops per minute. The kits are provided in a separate enclosure for field wiring.

Voltmeter

The voltmeter reads 0 to 250 VAC and connects directly to the output of the A-C V★S Drive Controller.

Ammeter

The ammeter reads current in one of the output lines of the A-C V★S Drive Controller. It uses a current transformer as its input. The ampere scale depends on the controller rating.

Frequency Meter (Analog)

The frequency meter indicates actual output frequency of the A-C V★S Drive Controller by monitoring two of the controller output terminals.

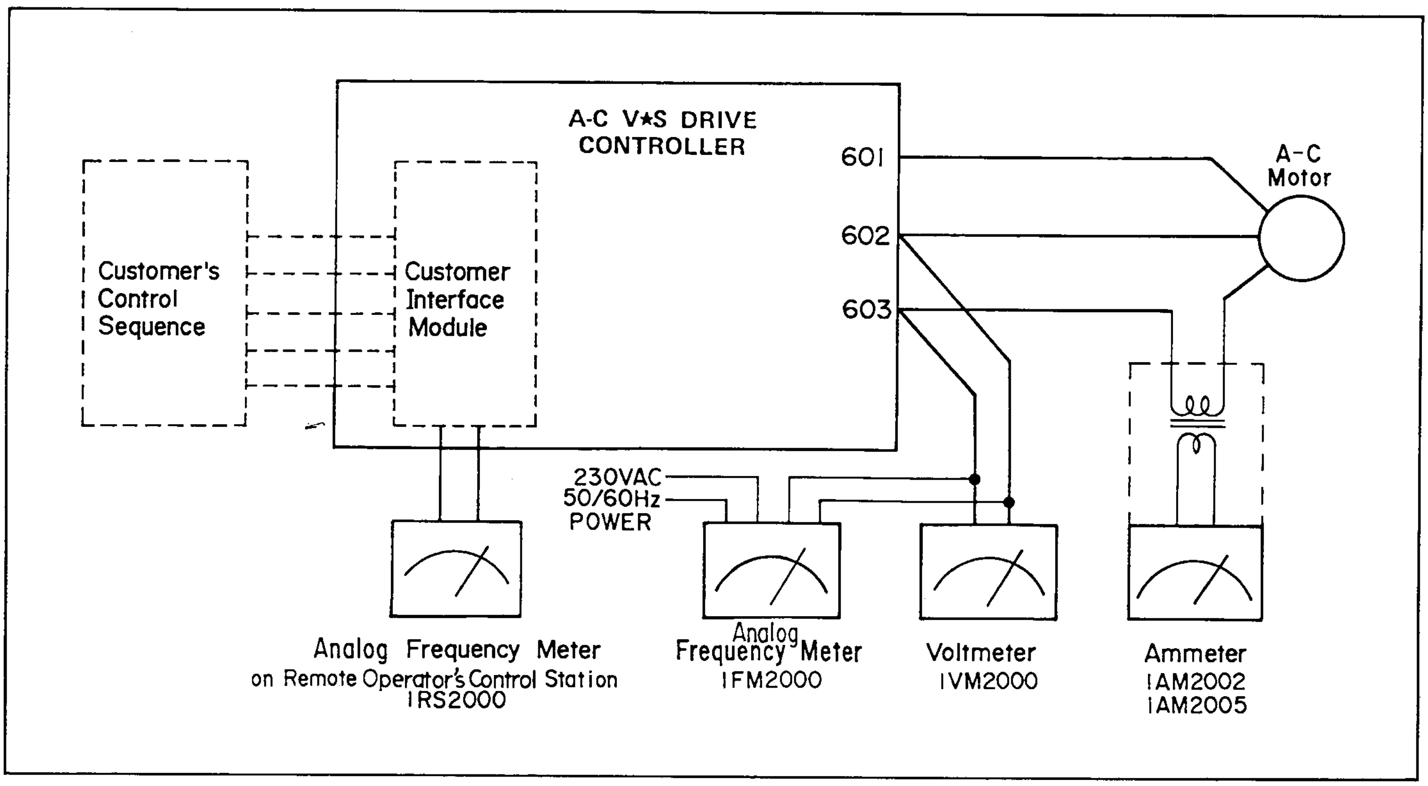


Figure 5-6. Interconnection diagram for meter options.

C. COMPONENT PARTS DATA

Table 5-3. Replacement parts list.

Description	Qty. Per Drive	Reliance Part Number
Diode Module		
1 – 3 HP	1	701819-40AG
5 HP	1	701819-41AG
Transistor Module		
1 HP	1	602909-236AA
2 HP	1	602909-237AA
3 HP	1	602909-238AA
5 HP	1	602909-239AA
Capacitor		
1 HP, 3 HP	1	600442-21C
2 HP, 5 HP	1	600442-21D
Precharge Relay Assembly		
1 HP	1	803431-R
2 HP	1	803431-S
3 HP	1	803431-T
5 HP	1	803431-Y
Input Suppressor		
1 – 5 HP	1	86023-1A
Bus Clamp		
1 – 2 HP	1	86022-0A
3 – 5 HP	1	86022-1A
Discharge Resistor Assembly		
1 HP	1	86030-1A
2 HP	1	86030-2A
3 – 5 HP	1	86030-3A
Regulator PC Board		
1 – 2 HP	1	0-48680-102 (or 802285-76)
3 – 5 HP	1	0-48680-102
Phase Loss Detector PC Board		
3 – 5 HP	1	0-48680-507
Control Transformer		
1 – 2 HP	1	411027-201B
3 – 5 HP	1	411027-201A
Hall Effect Amplifier		
1 HP	1	86032-1A
2 HP	1	86032-2A
3 HP	1	86032-3A
5 HP	1	86032-5A
Input Fuse①		
1 HP	3	402410-502U
2 – 5 HP	3	64676-58B
Control Fuse①		
1 – 5 HP	1	64676-22J

① Refer to Table 1-2 for fuse specifications.

Table 5-4. Recommended spare parts for six controllers.

Description	Qty.	Reliance Part Number
Diode Module		
1 – 3 HP	1	701819-40AG
5 HP	1	701819-41AG
Transistor Module		
1 HP	1	602909-236AA
2 HP	1	602909-237AA
3 HP	1	602909-238AA
5 HP	1	602909-239AA
Precharge Relay Assembly		
1 HP	1	803431-R
2 HP	1	803431-S
3 HP	1	803431-T
5 HP	1	803431-Y
Regulator PC Board		
1 – 2 HP	1	0-48680-102 (or 802285-76)
3 – 5 HP	1	0-48680-102
Control Transformer		
1 – 2 HP	1	411027-201B
3 – 5 HP	1	411027-201A
Input Fuse①		
1 HP	12	402410-502U
2 – 5 HP	12	64676-58B
Control Fuse①		
1 – 5 HP	6	64676-22J

① Refer to Table 1-2 for fuse specifications.

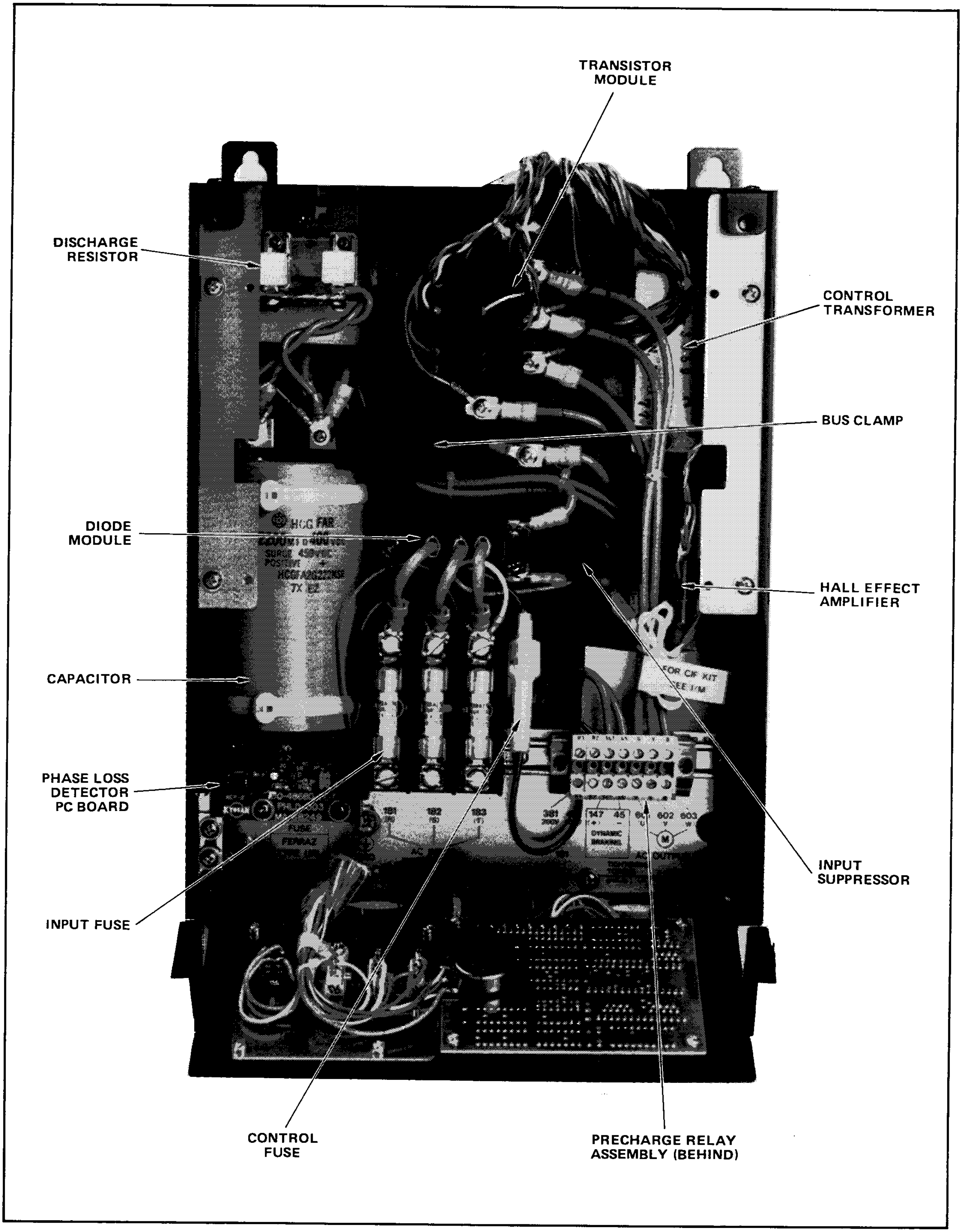
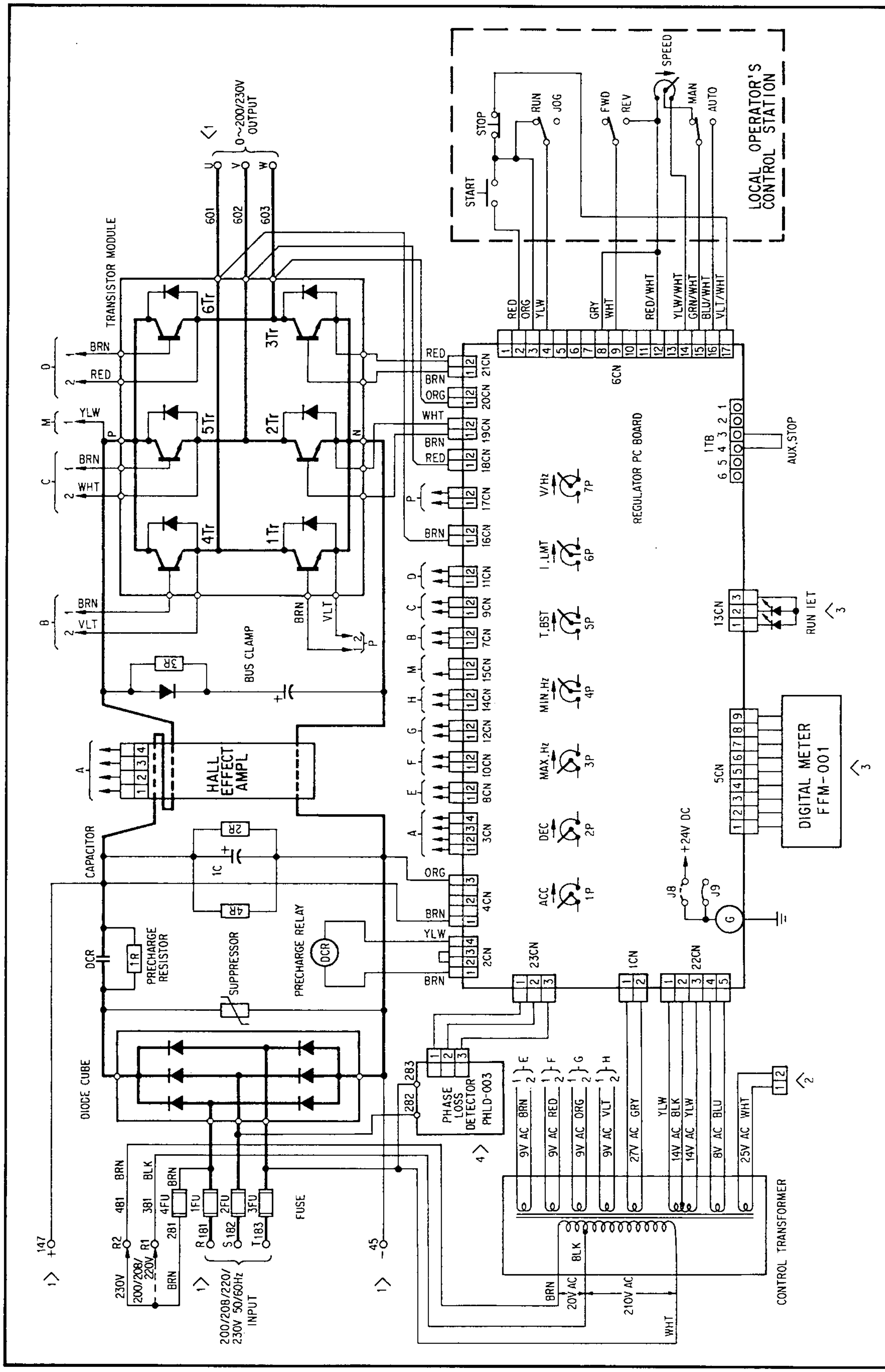


Figure 5-7. Component identification (5 HP).

D. WIRING DIAGRAMS



1. USE ONLY COPPER WIRE RATED 60/75°C.
2. THIS IS AN OPTIONAL CONNECTOR FOR CUSTOMER INTERFACE MODULE (MODEL 1CI2001).
3. IF DIGITAL METER IS SUPPLIED, RUN AND IET LEDs ARE NOT SUPPLIED.
4. THIS IS NOT AVAILABLE ON 1 – 2 HP CONTROLLER.

TERMINAL TIGHTENING TORQUES (IN-LBS)

HP	INPUT 181 182 183 (R) (S) (T)	OUTPUT 601 602 603 (U) (V) (W)	JUMPER 381 481 (R1) (R2)	D-C BUS 147 45 (+) (–)
1	8	8	8	8
2	20	8	8	8
3 – 5	20	8	8	8

Figure 5-8. Typical power circuit wiring diagram (Sheet 1).

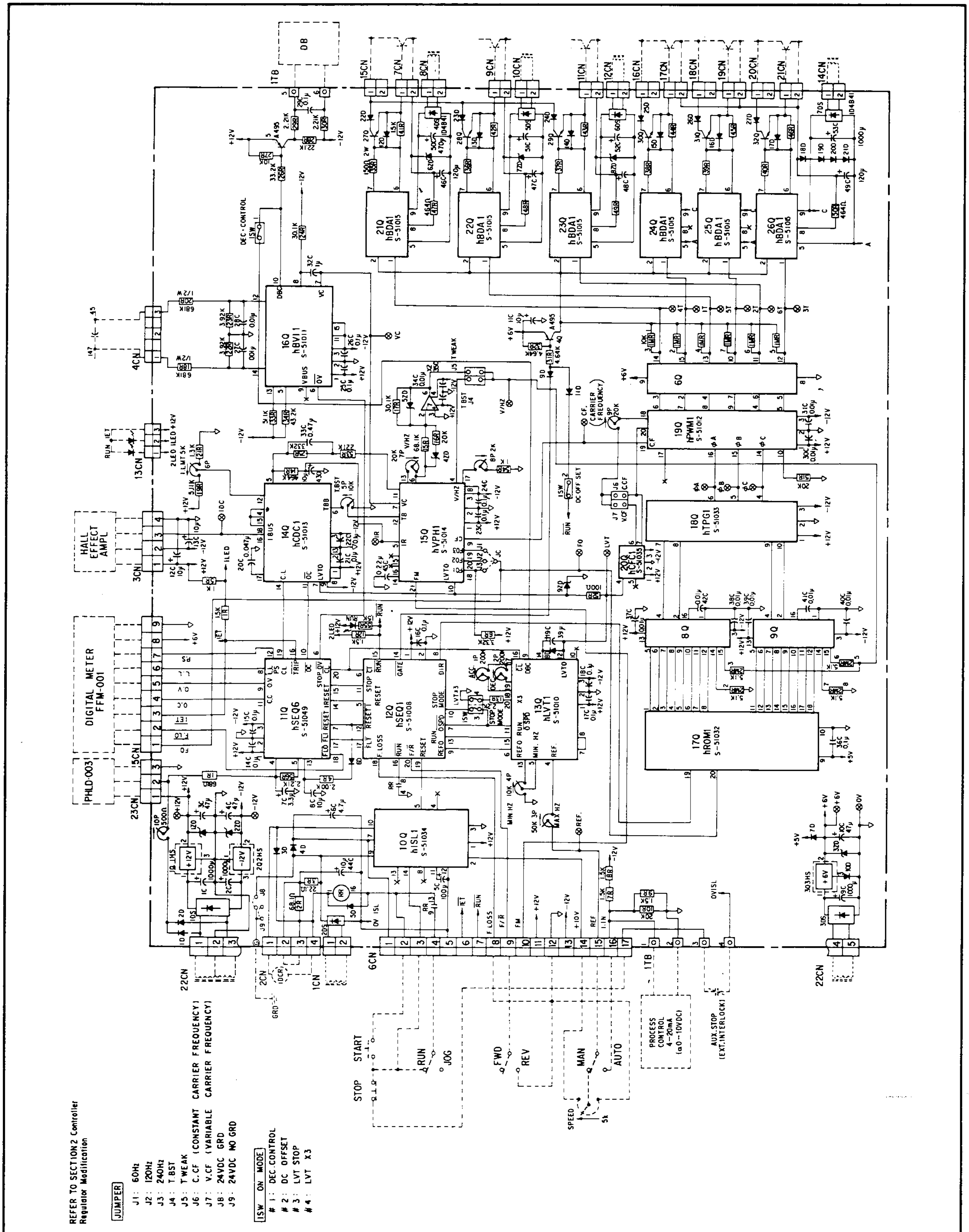


Figure 5-9. Typical regulator schematic (Sheet 2).

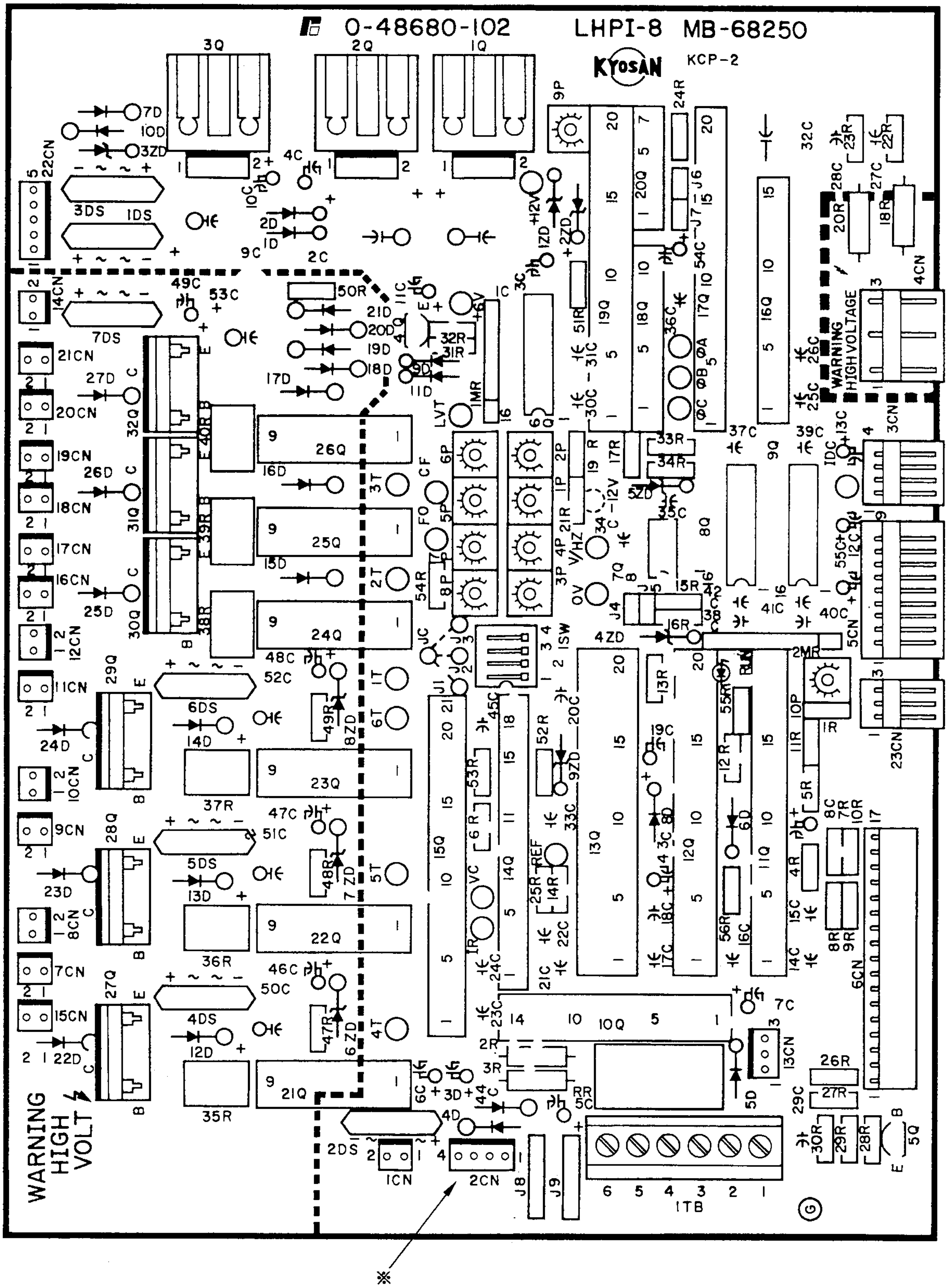


Figure 5-10. Typical layout of regulator board (Sheet 3).

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