

# CHOICE D.C.MOTOR CONTROL

SERVICE MANUAL  
Choice<sup>®</sup> Series Drives

**Use With  
Instruction Manual**

Models

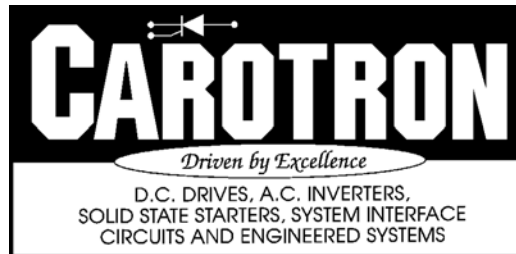
CDC320-000

CDC340-000

CDC360-000

CDC375-000

CDC3150-000



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# 1

## -----About This Guide-----

This guide is meant to supplement the CHOICE Instruction Manual and DCM100 Users Guide for CHOICE® Series DC Drives. Installation, wiring and start-up information is found in these other manuals. Here we will address problems in operation, drive failure, also how to correct these situations.

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## General Description

The CHOICE® CDC300 Series of non-regenerative DC motor controls (drives) provides a full range of speed or torque control for 5-150 HP DC motors rated for NEMA type "D" power supplies.

Five basic models are offered in a compact panel mount assembly. Each model is customer connectable for operation at 230 or 460 VAC input. Semiconductor fuses are provided for AC line protection with auxiliary line fuses for optional equipment. Fuse protection is also provided for the 115 VAC input and for the field supply circuits.

Standard relay logic interfaces with customer supplied operators for Emergency Stop, Ramp Stop, Run Forward, Jog Forward and also Run Reverse and Jog Reverse when the unit is operated with separately supplied forward and reverse armature contactors. Additional models include options such as armature contactor(s), brake resistors, disconnect switches, blower starters, enclosures and field economy or field regulator supplies.

An accessory drive circuit monitor, DCM100-000, is available to assist in set-up and troubleshooting by plugging in to the CONTROL board to access 20 separate signals.

## -----Features-----

- Programmable for 230 or 460 VDC three phase line input.
- Hall Effect sensor for isolated armature current feedback
- 10 megohm impedance isolation for armature voltage feedback
- Independently adjustable linear acceleration and deceleration from 1-60 seconds
- Electrically isolated power modules rated

- at 1400 volts PIV and 1000 volts/microsecond dv/dt
- Semiconductor fuses for power circuit protection
- R/C networks for AC line transient protection
- 10 ampere rated field supply
- Provisions for interfacing an optional field supply or field regulator with the Field Loss protection circuit

- Foldback current limit to allow 1 minute overload and then foldback to 112% of the current range selected
- Overcurrent Trip when motor current is sustained at 112% of range selected for 5 minutes
- Speed feedback is jumper selectable for armature voltage, DC tachometer voltage (7, 50 or 100V/1000 RPM), AC tachometer voltage (45 or 90V/1000 RPM), or digital encoder (300 PPR)
- Tachometer feedback is insensitive to input polarity
- 12 VDC @ 50 mA encoder power supply
- Summing input for auxiliary input signals with on board trim pot for scaling and jumper selection for polarity
- Terminal strip access to Accel/Decel

- output, Velocity Loop output and Current Loop input for versatile control functions
- Inner Current Loop for responsive and precise control of motor torque
- Insensitive to phase rotation of the line
- Status LED's for Run, Zero Speed, Jog and Foldback
- 115 VAC logic for pushbutton operator interface
- Zero Speed logic for ramp to stop and anti-plugging protection
- Jog Delay circuit to allow rapid jogging without de-energizing the armature contactor to give longer contactor life
- 5 selectable armature current range to match motor armature current
- High frequency multi-pulse trigger for reliable SCR triggering

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## Specifications

### A.C. INPUT

- 230 VAC  $\pm$  10%, 3 phase, 50/60 Hz  $\pm$  2 Hz
- 460 VAC  $\pm$  10%, 3 phase, 50/60 Hz  $\pm$  2 Hz

### A.C. INPUT

#### -SINGLE PHASE CONTROL VOLTAGE SUPPLY

- 115 VAC  $\pm$  10%, 1 phase, 50/60 Hz  $\pm$  2 Hz

### ARMATURE OUTPUT

- 0 to 240 VDC @ 230 VAC input
- 0 to 500 VDC @ 460 VAC input

### FIELD OUTPUT

- 150 VDC, 10 *amps* max, @ 230 VAC input
- 300 VDC, 10 *amps* max, @ 460 VAC input

### HORSEPOWER RANGE

- Model CDC320-00: 36 FLA, 10 HP @ 240 VDC, 20 HP @ 500 VDC

- Model CDC340-000: 71 FLA, 20 HP @ 240 VDC, 40 HP @ 500 VDC
- Model CDC360-000: 107 FLA, 30 HP @ 240 VDC, 60 HP @ 500 VDC
- Model CDC375-000: 140 FLA, 40 HP @ 240 VDC, 75 HP @ 500 VDC
- Model CDC3150-000: 256 FLA, 75 HP @ 240 VDC, 150 HP @ 500 VDC

### SPEED REGULATION

- Armature Feedback:  $\pm$  1.0% of base speed
- Tachometer Feedback:  $\pm$  0.5% of base speed
- Encoder Feedback:  $\pm$  0.5% of base speed

### TORQUE REGULATION

- $\pm$  2.0% of current range selected

### SPEED RANGE

- 20:1 motor dependent

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## Model Identification

The CHOICE® series controls are offered in basic chassis models and contactor models available with factory installed options. The basic model will have a model number label with applicable rating information. Contactor models will have an additional label showing the contactor horsepower rating and any additional option dash numbers. These model

and option numbers are shown in the following tables.

**NOTE: The contactor run-brake and reversing models listed below include the control voltage (115 VAC) transformer as well as the armature contactor(s).**

**TABLE 1: MODEL NUMBERS**

<b>MODEL NUMBER</b>	<b>HP RATING 230/460 INPUT</b>	<b>DESCRIPTION</b>
CDC320-000	5-10/5-20	BASIC CHASSIS MODEL
CDC340-000	15-20/25-40	BASIC CHASSIS MODEL
CDC360-000	25-30/50-60	BASIC CHASSIS MODEL
CDC375-000	40/75	BASIC CHASSIS MODEL
CDC3150-000	50-75/100-150	BASIC CHASSIS MODEL
CDC320-C15	5-7.5/10-15	CONTACTOR RUN-BRAKE CHASSIS
CDC320-C20	10/20	CONTACTOR RUN-BRAKE CHASSIS
CDC340-C30	15/25-30	CONTACTOR RUN-BRAKE CHASSIS
CDC340-C40	20/40	CONTACTOR RUN-BRAKE CHASSIS
CDC360-C60	25-30/50-60	CONTACTOR RUN-BRAKE CHASSIS
CDC375-C75	40/75	CONTACTOR RUN-BRAKE CHASSIS
CDC3150-C100	50/100	CONTACTOR RUN-BRAKE CHASSIS
CDC3150-C125	60/125	CONTACTOR RUN-BRAKE CHASSIS
CDC3150-C150	75/150	CONTACTOR RUN-BRAKE CHASSIS
CDC320-R15	5-7.5/10-15	CONTACTOR REVERSING CHASSIS
CDC320-R20	10/20	CONTACTOR REVERSING CHASSIS
CDC340-R30	15/25-30	CONTACTOR REVERSING CHASSIS
CDC340-R40	20/40	CONTACTOR REVERSING CHASSIS
CDC360-R60	25-30/50-60	CONTACTOR REVERSING CHASSIS
CDC375-R75	40/75	CONTACTOR REVERSING CHASSIS
CDC3150-R100	50/100	CONTACTOR REVERSING CHASSIS
CDC3150-R125	60/125	CONTACTOR REVERSING CHASSIS
CDC3150-R150	75/150	CONTACTOR REVERSING CHASSIS

**NOTE: The options listed in TABLES 2, 3 and 4 are used with and mount on the chassis of the contactor run-brake and reversing models listed above.**

<b>TABLE 2: BLOWER &amp; STARTER OPTIONS</b>		
<b>OPTION NUMBER</b>	<b>BLOWER MODELS USED WITH</b>	<b>DESCRIPTION</b>
CDC3BS-001	MTP-FVB2180, 230VAC, 1PH	0.6 TO 1.0 AMP OVERLOAD RANGE FOR 1 PHASE BLOWER
CDC3BS-002	MTP-FVB3210, 460VAC, 3PH MTP-FVB3250, 460VAC, 3PH	0.4 TO 0.6 AMP OVERLOAD RANGE FOR 3 PHASE BLOWER
CDC3BS-003	MTP-FVB3210, 230VAC, 3PH MTP-FVB3250, 230VAC, 3PH MTP-FVB4280, 460VAC, 3PH	0.6 TO 1.0 AMP OVERLOAD RANGE FOR 3 PHASE BLOWER
CDC3BS-004	MTP-FVB4280, 230VAC, 3PH MTP-FVB6320, 460VAC, 3PH MTP-FVB6400, 460VAC, 3PH	1.4 TO 1.8 AMP OVERLOAD RANGE FOR 3 PHASE BLOWER
CDC3BS-005	MTP-FVB6320, 230VAC, 3PH MTP-FVB6400, 230VAC, 3PH	2.8 TO 4.0 AMP OVERLOAD RANGE FOR 3 PHASE BLOWER

<b>TABLE 3: FIELD ECONOMY, SUPPLY &amp; REGULATOR OPTIONS</b>		
<b>OPTION NUMBER</b>	<b>MODELS USED WITH</b>	<b>DESCRIPTION</b>
CDC3FE-001	230/460 VAC INPUT CHOICE MODELS	FIELD ECONOMY UNIT 150VDC @ 230VAC 3 PHASE INPUT 300VDC @ 460 VAC 3 PHASE INPUT
CDC3FE-002	230 VAC INPUT CHOICE MODELS	FIELD ECONOMY UNIT 200VDC @ 230VAC 1 PHASE INPUT
CDC3FE-003	230 VAC INPUT CHOICE MODELS	FIELD ECONOMY UNIT 240VDC @ 230VAC 3 PHASE INPUT
CDC3FS-000	230 VAC INPUT CHOICE MODELS	FIELD SUPPLY UNIT 150/240VDC @ 230VAC 3 PHASE INPUT
FR1000-000	ALL CHOICE MODELS	FIELD REGULATOR UNIT 230/460VAC 1 PHASE INPUT

<b>TABLE 4: DISCONNECT SWITCH OPTIONS</b>		
<b>OPTION NUMBER</b>	<b>MODELS USED WITH</b>	<b>DESCRIPTION</b>
CDC3DS-150	CDC320-C15, C20, R15, R20 CDC340-C30, C40, R30, R40 CDC360-C60, R60, CDC375-C75, R75	150 AMP 600 VAC MOLDED CASE DISCONNECT SWITCH
CDC3DS-225	CDC3150-C100, C125 CDC3150-R100, R125	225 AMP 600 MOLDED CASE DISCONNECT SWITCH
CDCEDS-400	CDC3150-C150, R150	400 AMP 600 VAC MOLDED CASE DISCONNECT SWITCH

<b>TABLE 5: ENCLOSURE OPTIONS</b>		
<b>OPTION NUMBER</b>	<b>MODELS USED WITH</b>	<b>DESCRIPTION</b>
CDC3EN-001	CDC320-C15, C20, R15, R20; CDC340 C30, C40, R30, R40; CDC360-C60, R60	NEMA 12 ENCL.
CDC3EN-002	CDC375-C75 & R75	NEMA 12 ENCL.

**TABLE 5: ENCLOSURE OPTIONS (cont.)**

CDC3EN-003	CDC3150- C100, C125, C150, R125, R150	NEMA 12 ENCL.
CDC3EN-H01	CDC3DS-150 OPTION ON MODELS: CDC320-C15, C20, R15, R20; CDC340 C30, C40, R40; CDC360-C60, R60	NEMA 12 ENCL. W/ DISCONNECT HANDLE
CDC3EN-H01	CDC3DS-150, OPTION ON MODELS: CDC320-C15, C20, R15, R20; CDC340 C30, C40, R30, R40; CDC360-C60, R60	NEMA 12 ENCL. W/DISCONNECT HANDLE
CDC3EN-H02	CDC3DS-150 OPTION ON MODELS: CDC375-C75 & R75	NEMA 12 ENCL. W/DISCONNECT HANDLE
CDC3EN-H03	CDC3DS-225 OPTION ON MODELS: CDC3150-C100, C125, R100, R125	NEMA 12 ENCL. W/DISCONNECT HANDLE
CDC3EN-H04	CDC3DS-400 OPTION ON MODELS: CDC3150-C150 & R150	NEMA 12 ENCL. W/DISCONNECT HANDLE

**TABLE 6: DYNAMIC BRAKING OPTIONS**

<b>OPTION NUMBER</b>	<b>MOTOR USED WITH</b>	<b>DESCRIPTION</b>
CDC3BR-205	5 HP, 240 VDC ARM.	NEMA 12 ENCLOSED 10 Ohm 300 WATT BRAKE RESISTOR
CDC3BR-207	7.5 HP 240 VDC ARM.	NEMA 12 ENCLOSED 5Ohm 600 WATT BRAKE RESISTOR
CDC3BR-210	10 HP 240 VDC ARM.	NEMA 12 ENCLOSED 4.4 Ohm 750 WATT BRAKE RESISTOR
CDC3BR-215	15 HP 240 VDC ARM.	NEMA 12 ENCLOSED 3 Ohm 1000 WATT BRAKE RESISTOR
CDC3BR-220	20 HP 240 VDC ARM.	NEMA 12 ENCLOSED 2.2 Ohm 1500 WATT BRAKE RESISTOR
CDC3BR-225	25 HP 240 VDC ARM.	NEMA 12 ENCLOSED 1.7 Ohm 2000 WATT BRAKE RESISTOR
CDC3BR-230	30 HP 240 VDC ARM.	NEMA 12 ENCLOSED 1.7 Ohm 2000 WATT BRAKE RESISTOR
CDC3BR-240	40 HP 240 VDC ARM.	EXPANDED METAL ENCLOSED 1.3 Ohm 2080 WATT BRAKE RESISTOR
CDC3BR-275	75 HP 240 VDC ARM.	EXPANDED METAL ENCLOSED 0.62 Ohm 2232 WATT BRAKE RESISTOR
CDC3BR-405	5 HP 500 VDC ARM.	NEMA 12 ENCLOSED 40 Ohm 375 WATT BRAKE RESISTOR
CDC3BR-407	7.5 HP 500 VDC ARM.	NEMA 12 ENCLOSED 20 Ohm 750 WATT BRAKE RESISTOR
CDC3BR-410	10 HP 500 VDC ARM.	NEMA 12 ENCLOSED 20Ohm 750 WATT BRAKE RESISTOR
CDC3BR-415	15 HP 500 VDC ARM.	NEMA 12 ENCLOSED 14 Ohm 1000 WATT BRAKE RESISTOR
CDC3BR-420	20 HP 500 VDC ARM.	NEMA 12 ENCLOSED 10 Ohm 1500 WATT BRAKE RESISTOR
CDC3BR-425	25 HP 500 VDC ARM.	NEMA 12 ENCLOSED 7 Ohm 2000 WATT BRAKE RESISTOR
CDC3BR-430	30 HP 500 VDC ARM.	NEMA 12 ENCLOSED 6 Ohm 2000 WATT BRAKE RESISTOR

**TABLE 6: DYNAMIC BRAKING OPTIONS (cont.)**

CDC3BR-440	40 HP 500 VDC ARM.	NEMA 12 ENCLOSED 5 Ohm 3000 WATT BRAKE RESISTOR
CDC3BR-450	50 HP 500 VDC ARM.	NEMA 12 ENCLOSED 3.4 Ohm 4000 WATT BRAKE RESISTOR
CDC3BR-460	60 HP 500 VDC ARM.	NEMA 12 ENCLOSED 3.4 Ohm 4000 WATT BRAKE RESISTOR
CDC3BR-475	75 HP 500 VDC ARM.	EXPANDED METAL ENCLOSED 2.6 Ohm 4160 WATT BRAKE RESISTOR
CDC3BR-4150	150 HP 500 VDC ARM.	EXPANDED METAL ENCLOSED 1.24 Ohm 4464 WATT BRAKE RESISTOR




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## Conventions, Glossary & Abbreviations

### CONVENTIONS

The following conventions will be used throughout this manual:

All measurements are referenced to circuit common unless otherwise noted. Circuit common is not earth or chassis ground. Please refer to the symbols below:

Circuit Common	
Chassis Ground	
Earth Ground	

All signal level wiring, such as tachometer, encoder, and potentiometer, should use fully insulated shielded cable whether or not shown in this manual. The shield should be connected at one end only to circuit common. The other end of the shield should be clipped and insulated to prevent the possibility of accidental grounding.

All internal relays have suppression devices in parallel with coil whether or not shown in this manual.

The arrows on potentiometers signify the CW terminal. The opposite lead is the CCW terminal, and the middle lead is wiper.

OP-AMP IC packages have been given the prefix designation "A" instead of the "IC" found on all other IC packages. Furthermore, many ICs are double, quad, or hex packages. In these cases, each section is given a letter designation to distinguish it from the other OP-AMPs in the same IC package. For example, the first two OP-AMPs in A1 would be A1-A and A1-B.

The **bold** letters in the schematic diagrams refer to the DCM100-000 check points. Refer to SECTION 10.

### GLOSSARY

#### **Drive**

The electronic device used to control the speed, torque, horsepower, and direction of a DC motor. It is also referred to as the control.

#### **Electromotive Force (EMF)**

This is another name for the armature voltage generated by the drive. The voltage generated by the motor is called counter EMF.



**Full Load Amps (FLA)**

The amount of current necessary to produce rated horsepower at full speed.

**Horsepower (HP)**

The measure of the amount of work a motor can perform during a given time period.

**Regenerative Control**

A drive capable of controlling the flow of power to and from the motor. Regeneration occurs when the counter EMF produced by the motor is greater than the voltage applied to the motor by the drive.

**Silicon Controlled Rectifier (SCR)**

A solid-state switch, also called a thyristor, that can be used to provide controlled rectification of large current at high voltages.

**Abbreviations**

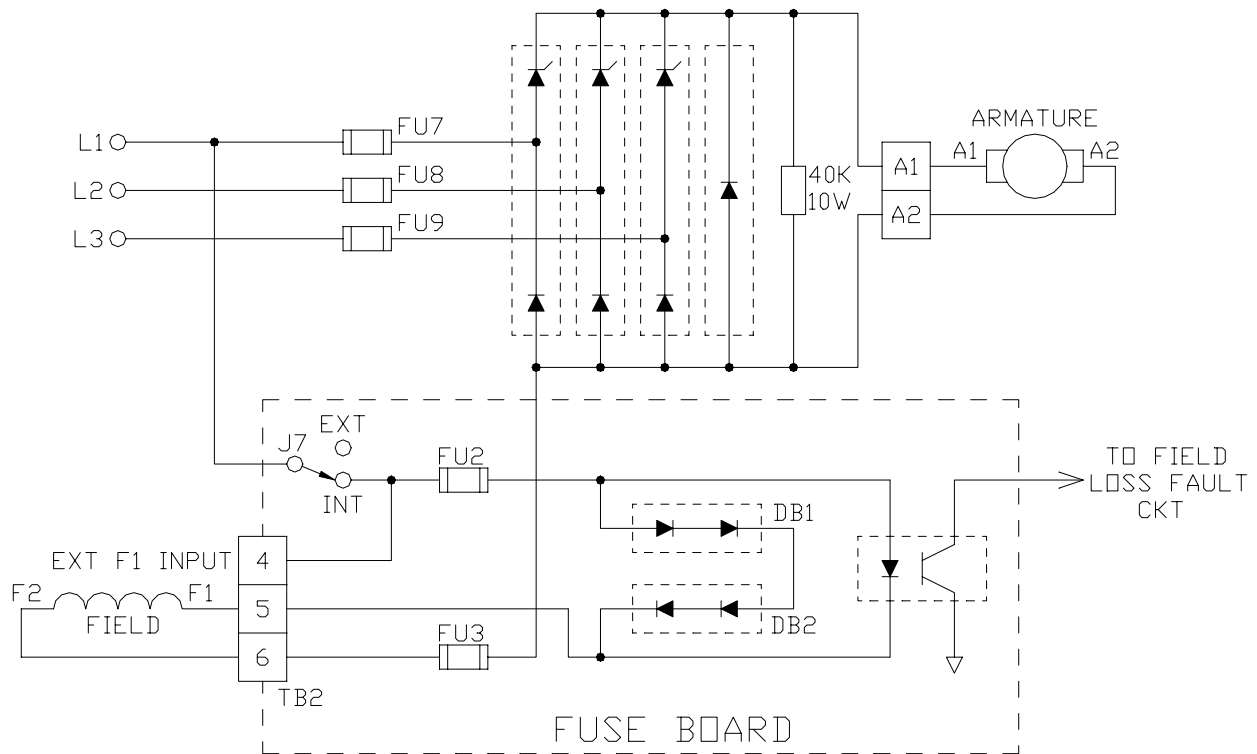
<b>CW</b>	Clockwise
<b>CCW</b>	Counter clockwise
<b>dv/dt</b>	Rate of change in voltage versus per rate of change in time
<b>FL</b>	Full load
<b>Hz</b>	Hertz
<b>IC</b>	Integrated Circuit
<b>IR</b>	Internal resistance
<b>NL</b>	No load
<b>PIV</b>	Peak Inverse Voltage
<b>pot</b>	Potentiometer
<b>PPR</b>	Pulses Per Revolution
<b>R/C</b>	Resistor/Capacitor
<b>RPM</b>	Revolutions Per Minute
<b>FET</b>	Field Effect Transistor
<b>DB</b>	Dynamic Braking
<b>CRDB</b>	Contacting Reversing/Dynamic Braking

# 6

## Description of Operation

### 6.1 ARMATURE POWER BRIDGE

The armature power bridge of the CHOICE<sup>®</sup> is a full wave semiconverter, type "D", configuration that consists of three SCR's and four diodes. Refer to FIGURE 1.

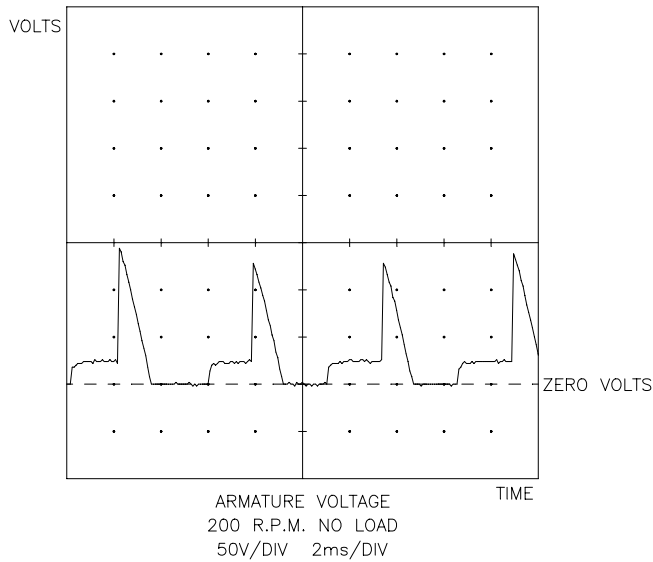


**FIGURE 1**

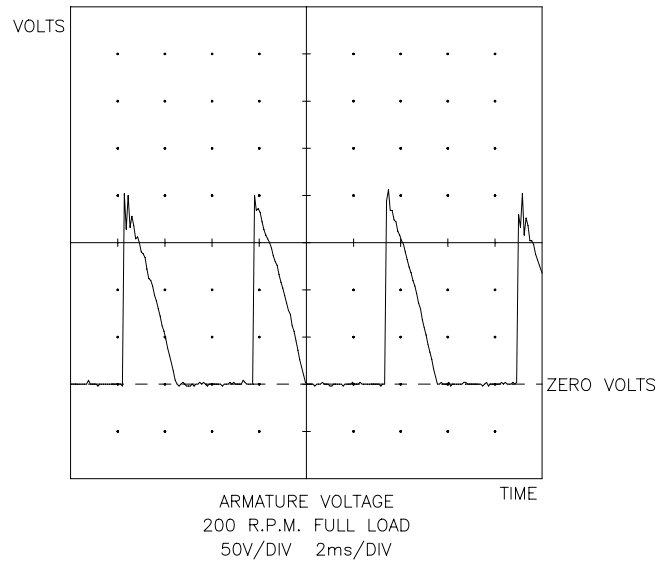
Each phase of the AC line connects to an SCR and a diode housed in an isolated power module. A fourth diode-only module is in parallel with the bridge output and acts as a freewheeling or flyback diode. As a semiconverter, only half (the three SCR's) of the rectifier components are controlled which gives an output ripple frequency equal to three times the AC line frequency – 180 Hz for 60

Hz lines and 150 Hz for 50 Hz lines. Because of this, the output is sometimes mistakenly called a half-wave output.

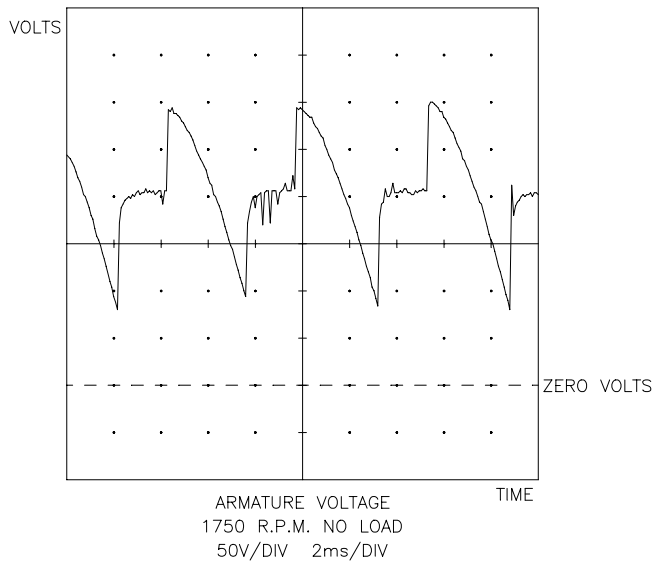
Refer to FIGURE 2 – 5 for typical bridge output waveforms at various unloaded and loaded speeds.



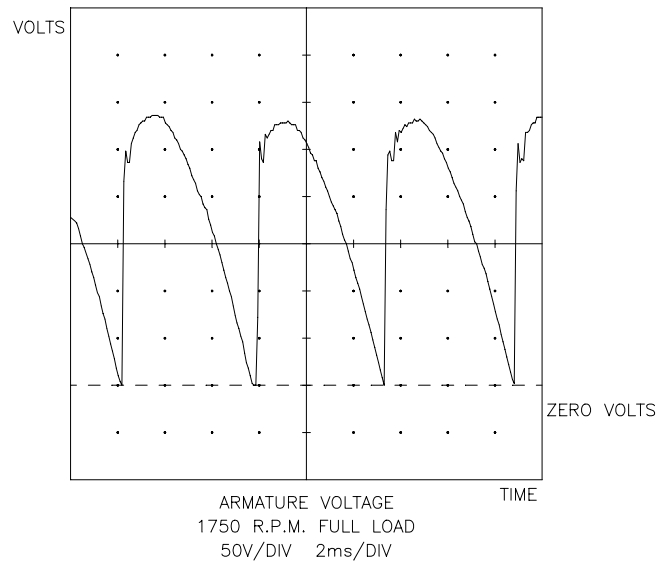
**FIGURE 2**



**FIGURE 3**



**FIGURE 4**



**FIGURE 5**

The power modules are some of the few components that must be sized according to the horsepower rating of the control. They are all rated at 1400 volts PIV with 1000 volts/microsecond  $dv/dt$  to permit reliable operation over a wide range of AC line voltage. They are directly controlled by gating signals from the POWER/TRIGGER board and are temperature protected by a thermostat on the same heatsink.

There are several vendors that can be used

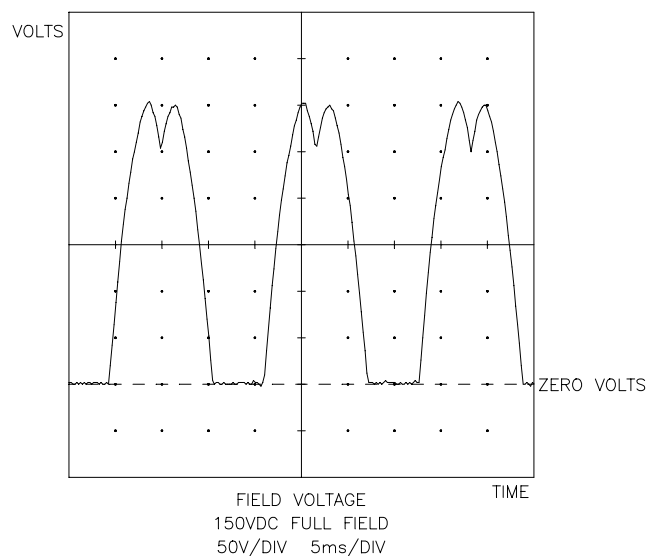
as replacements for these parts. Special attention should be paid to the terminal connections for the gate and cathode signal leads coming from CN6A on the POWER/TRIGGER board. CAROTRON routinely manufactures with EUPEC or SEMIKRON brand devices that do not have a separate "cathode signal" terminal. Although devices with these terminals can be used with little difficulty, some do place the terminals in different order and may cause problems if the

proper connections are not made. Refer to SECTION 8 for information on testing these components and SECTION 11 for making situations.

## 6.2 FIELD SUPPLY

The field supply voltage and current is actually taken from the diodes in the lower uncontrolled half of the armature power bridge described in SECTION 6.1. See FIGURE 1.

Circuitry on the FUSE board connects the positive, F1, motor lead through current sensing components and fuse FU2 to the L1 line input. The F2 motor lead is connected through fuse FU3 to the diode or A2 side of the power bridge. This gives a field voltage derived from two of the three phase lines being half wave rectified with respect to the third, L1, line. The diode connected to L1 acts as a freewheeling diode for the field winding. The field voltage level is approximately 0.65 times the AC line voltage and this waveform can be



**FIGURE 6**

seen in FIGURE 6.

The presence of field current is sensed by passing the current through four 25 ampere rated diodes to derive a voltage drop which is used to drive an optoisolator. The diodes are enclosed – two each in doubler modules, DB1 and DB2, mounted on the left side panel of the control next to the FUSE board. Jumper J7 on the FUSE board can break the connection of the F1 circuit from L1 to allow an external field supply to be connected through the current sensing circuitry via TB2-4.

## 6.3 CONTROL VOLTAGE SUPPLY AND RELAY LOGIC

The control voltage transformer is supplied by the customer when using basic CHOICE<sup>®</sup> models and is included with contactor models – refer to TABLE 1. When the three phase power is applied to the drive, the transformer primary voltage should be applied simultaneously to prevent a PHASE LOSS trip condition. CAROTRON recommends connecting the primary to one phase of the auxiliary, output at TB2-8 & 9 on the RELAY board. The 115 VAC secondary connects to

TB2-2 & 3 and is fused by FU1, a MDA 5A fuse. The fused secondary can be measured at TB3-20 & 21 on the RELAY board.

The basic CHOICE<sup>®</sup> drive includes ten relays for isolated interface of customer operators or logic such as pushbuttons, selectors, relay contacts, motor thermostats and the armature contactor. Refer to the RELAY board schematic in SECTION 12. Most of these relays are located on the RELAY board and all that are controlled directly by customer supplied logic are powered by the control voltage transformer. The relay circuitry is designed to provide safe sequencing of the armature contactor(s) for emergency stop, ramp to stop and reversing.

The 115 VAC voltage signals applied to the RUN FORWARD, RUN REVERSE, JOG FORWARD and JOG REVERSE relay coils are also current limited, rectified and filtered to drive optoisolators on the CONTROL board for RUN and JOG enabling of the control circuitry. Refer to OPERATING MODE CONTROL in SECTION 6.10 for detail on this control circuitry. The CONTROL board doesn't need to know which direction has been selected. Reversing is controlled by armature voltage polarity which is determined by the

armature contactors as selected by the relays listed above.

The CONTROL board the FAULT PILOT, PILOT ZERO SPEED and JOG DELAY relays on the RELAY board. The FAULT PILOT relay is normally energized to supply 115 VAC at TB3-1 for all of the operator, relay and condition causes the relay to de-energize and stop operation. See SECTION 6.11 for information on the fault circuits.

The ZERO SPEED relay provides interlocking of all RUN and JOG relay to prevent the energization of one relay when the other is in use. It also allows ramping to stop by holding the armature contactor energized until zero speed is reached. This function is defeated in the event of a fault or emergency stop by the E-STOP relay.

The JOG DELAY relay is timer controlled to keep the armature contactor energized for 3 – 4 seconds after jogging to prevent unnecessary cycling of the contactor during rapid and repeated jogging. See SECTION 6.10 for more information on the zero speed and jog delay circuits.

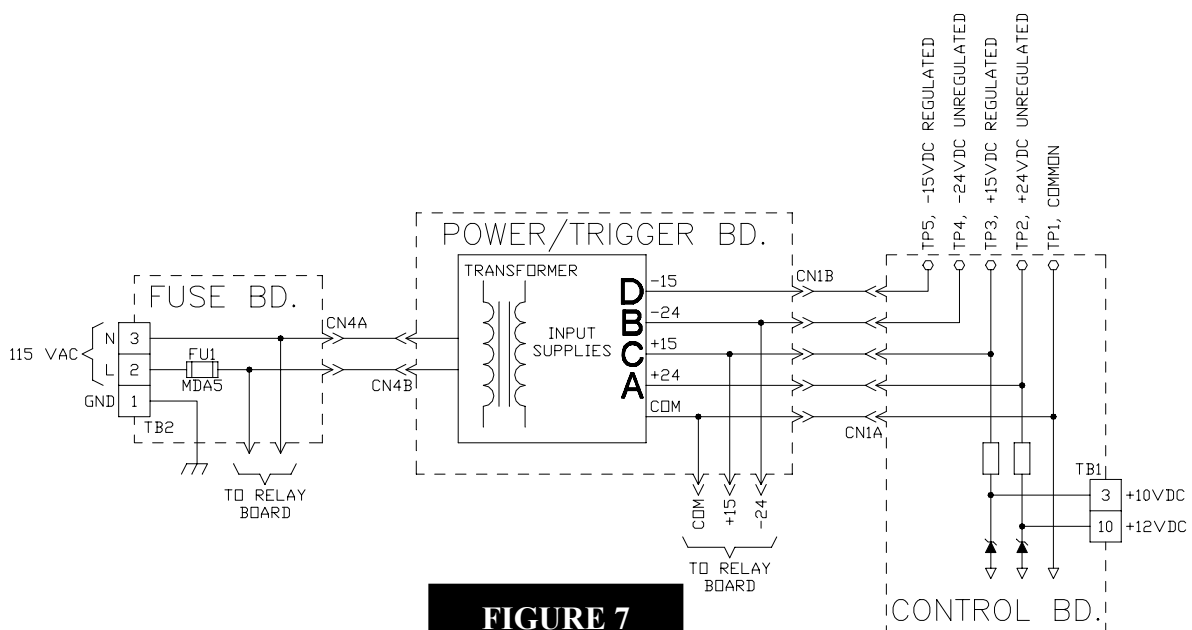


FIGURE 7

## 6.4 POWER SUPPLIES

The power supplies are located on the POWER/TRIGGER board. Refer to FIGURE 7. The supplies are isolated by a 24 VA transformer which is powered from the 115 VAC control voltage via FU1 on the FUSE board.

The transformer dual 17 VAC secondaries are rectified and filtered to give unregulated  $\pm 24$  VDC supplies which are used directly by

the pulse transformers, ZERO SPEED relay and clamping logic on the CONTROL board. Two IC regulators further reduce the supplies to  $\pm 15$  VDC which power most of the circuitry in the drive. Also, zener diodes are used on the CONTROL board to establish +10 VDC for the speed pot and +12 VDC for an encoder supply. The +24, -24, +15, & -15 VDC supplies can be measured at TB2-5, and DCM check points A – D.

## 6.5 REFERENCE CIRCUITRY

CHOICE<sup>®</sup> drive can make use of several voltage signals to control the speed of a motor. Refer to FIGURE 8.

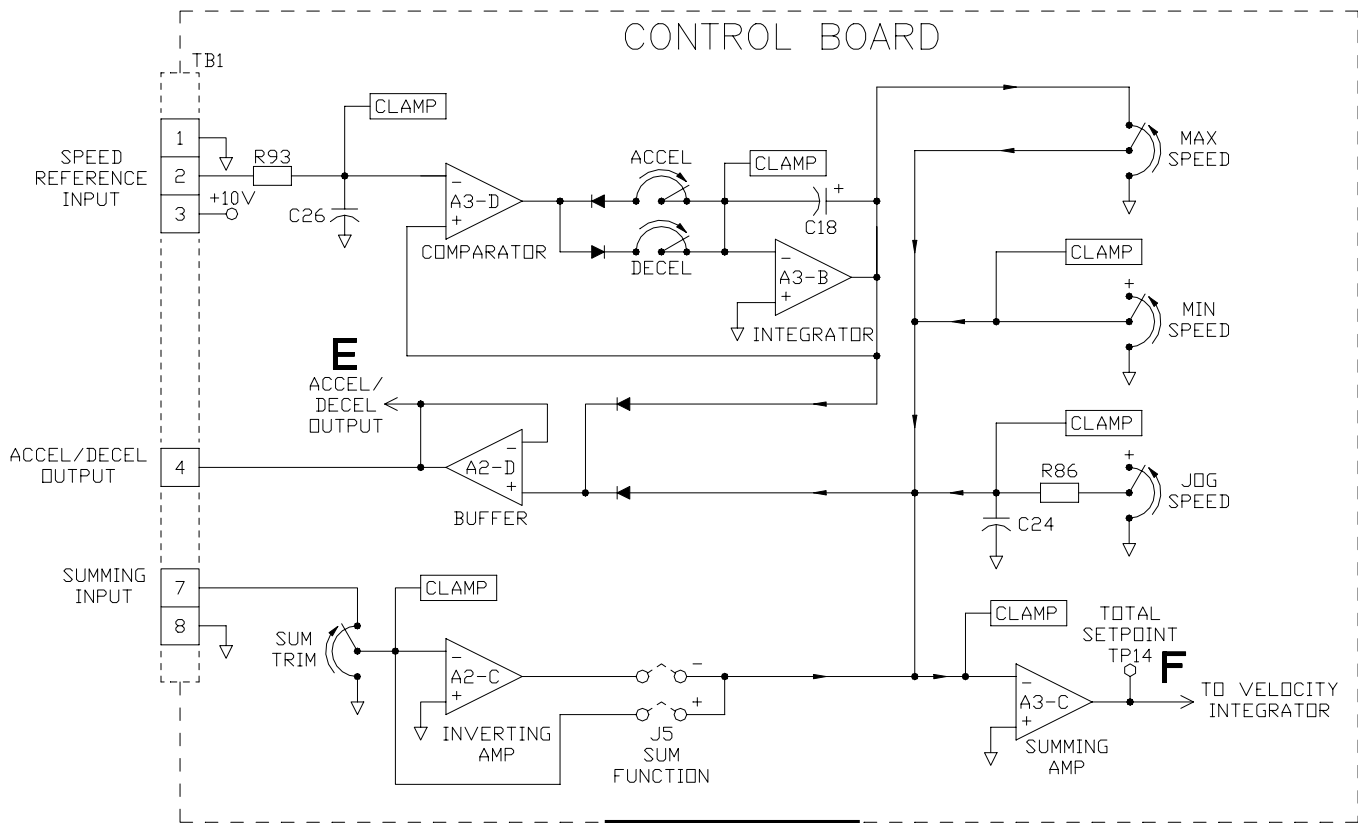


FIGURE 8

Signals from an external speed pot trimmed by the MAX SPEED, the MIN SPEED, SUM INPUT and JOG SPEED can all be part of the TOTAL SETPOINT for speed.

Normal operation with a speed pot connected to TB1-1, 2 & 3 uses a +10 VDC signal from TB1-3. This signal is trimmed by the speed pot to set the input to the accel/decel circuit at TB1-2. The terminal 2 signal is given noise immunity by the R93/C26 R/C network. OP AMPs A3-B and A3-D form a closed loop circuit that uses the reference level to control the charge and discharge time of capacitor C18. The charge and discharge follows a linear ramp and the time can be changed by varying the resistance of the ACCEL and DECEL pots. This ACCEL/DECEL output is connected to the MAX SPEED pot and through the A2-D buffer stage to TB1-4. This signal can also be measured at DCM check point E. A FET clamps the input to the ACCEL/DECEL circuit when the drive is at stop and in the JOG mode. See SECTION 6.10 for information on the FET clamps.

The MAX SPEED pot wiper connects to summing amplifier A3-C. Also summed are the MIN SPEED, SUM TRIM and JOG SPEED pot signals. The MIN and JOG pots

trim the +15 VDC signals to set their levels and each has FET's to clamp their signals at stop and when in the RUN mode for JOG pot. The JOG pot wiper also has the R86/C24 R/C network to soften start-up in the JOG mode. See SECTION 6.10 for information on FET clamps.

The SUM TRIM pot receives input from TB1-7. Its wiper is connected to the A2-C inverting amplifier and to the J5 programmed to add or subtract from the TOTAL SETPOINT. This signal can be monitored at TP14 (F). It also has a FET clamp.

## 6.6 FEEDBACK CIRCUITRY AND ISOLATION

CHOICE<sup>®</sup> drive continuously monitor feedback signals that are related to motor velocity and current. They also precisely sense the AC line voltage and frequency in order to properly synchronize gating of the SCRs. At the same time, the drive must be isolated from the sensed signals for ease of interface, noise immunity and safety.

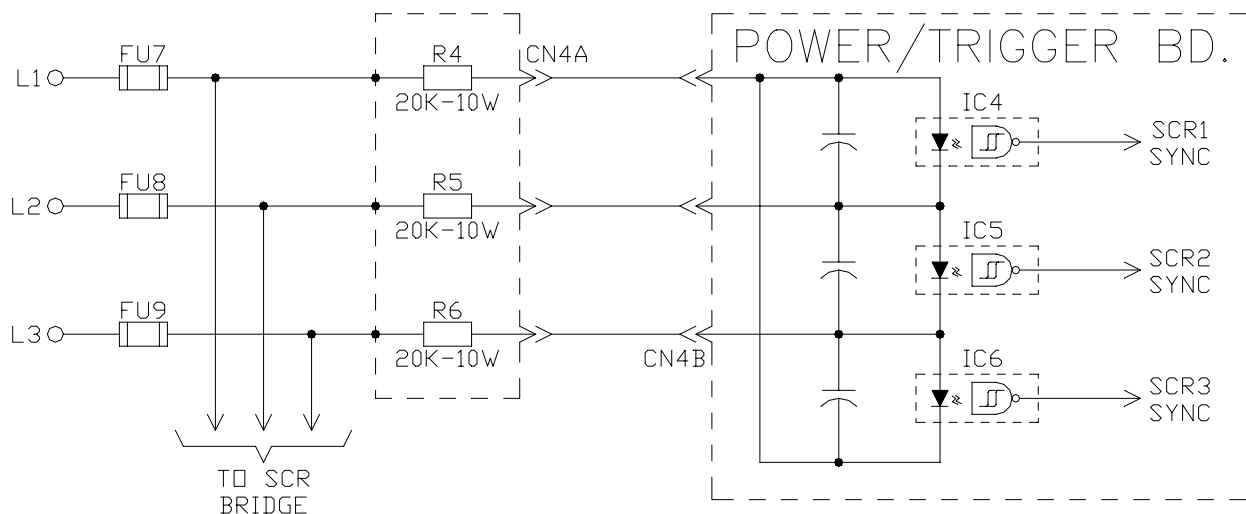


FIGURE 9

## LINE VOLTAGE SENSING

Sensing of the three phase line voltage is done by connecting impedance isolating resistors and optoisolators in a delta configuration across the line. Refer to FIGURE 9. The outputs are used to derive synchronized gating signals for the SCRs and for PHASE LOSS protection. Refer to SECTION 6.9 for a description of the trigger circuit and SECTION 6.11 concerning the PHASE LOSS fault circuit.

## ARMATURE CURRENT SENSING

Motor armature current is sensed by threading the positive bridge output conductor through a hall effect type sensor. It gives an isolated output voltage that is an accurate reproduction of the current signal. Refer to FIGURE 10. Three sensor rating and sensitivities are used to cover the range of currents for motors up to 150 HP – see TABLE 7 for a listing. The Model CDC3150-000 drive has an IFB board, P/N C10748-003, to power

and mount the sensor while all other models have the sensor mounted on the RELAY board.

The output at zero armature current is approximately 50% of the +15 VDC sensor supply voltage. An increase in current will cause a decrease in the output according to the sensitivity of the sensor being used. It is buffered by a non-inverting OP- AMP. A2-A on the IFB board and A1-B on RELAY board.

The buffered signal is conducted to the CONTROL board where it can be monitored at TP9 (O). Here it is summed at A5-C with a negative polarity OFFSET voltage to make the no-load signal equal to zero. This signal can be monitored at TP7 (P). The next stage, A6-A uses the I CAL pot and factory installed "model scaling" zero Ohm resistors to select the gain of the amplifier depending on the full load current rating of the drive and the rating of the sensor. Its output can be measured at TP18 (Q). See TABLE 7 for drive current rating and "model scaling" resistor location on the CONTROL board.

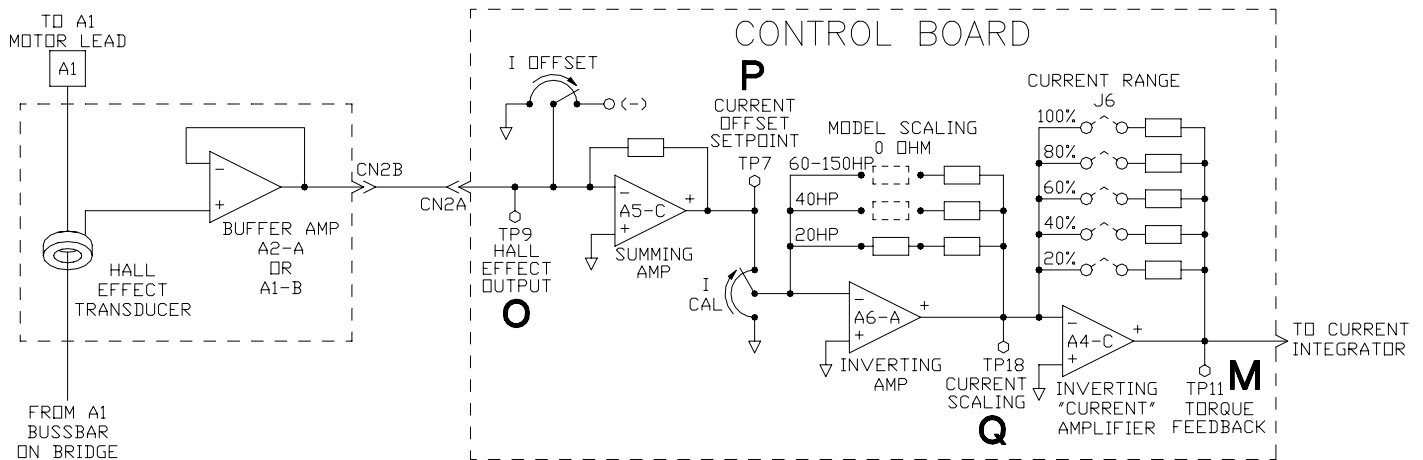


FIGURE 10

TABLE 7: CURRENT SENSOR/SCALING RESISTOR

DRIVE MODEL NO.	MODEL FULL LOAD RATING	CURRENT SENSOR VENDOR P/N	SENSOR SENSITIVITY	ZERO Ohm LOCATION
CDC320-000	36 AMPS	CSLA1DJ	13.2 m V/AMP	R1
CDC340-000	71 AMPS	CSLA1DJ	13.2 m V/AMP	R2
CDC360-000	107 AMPS	CSLA1DJ	13.2 m V/AMP	R3
CDC375-000	140 AMPS	CSLA1DK	9.1 m V/AMP	R3
CDC3150-000	256 AMPS	CSLA1EL	5.6 m V/AMP	R3



The combination of sensor rating and selected gain are used to give a scaled current feedback equal to +5.0 VDC at the full load rating of a particular control model. The next stage, A4-C, uses the programming jumper J6 to allow amplification of the current signal in 20% increments to scale operation of the current related circuits according to the rating of the motor used. Refer to TP11 (M) and FIGURE 11 & 12 for typical waveforms under no load and full load conditions.

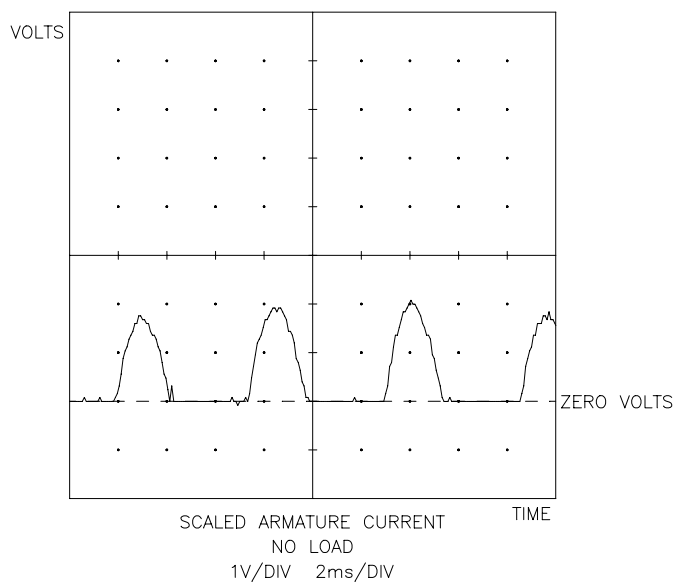
For example: The CDC320-000 drive listed in TABLE 7 as a full load rating of 36 amperes or 10 horsepower with a 240 VDC motor. When the drive is used with a 10 HP motor, J6 – 100% position is used. If used with a 28.1

ampere 7.5 HP motor, 28 divided by 36 equals approximately 78% so the closest range, 80%, should be selected. This will make the current amplifier signal – measured at TP11 (M) – equal to +5.0 VDC at a armature current of 28.8 amperes.

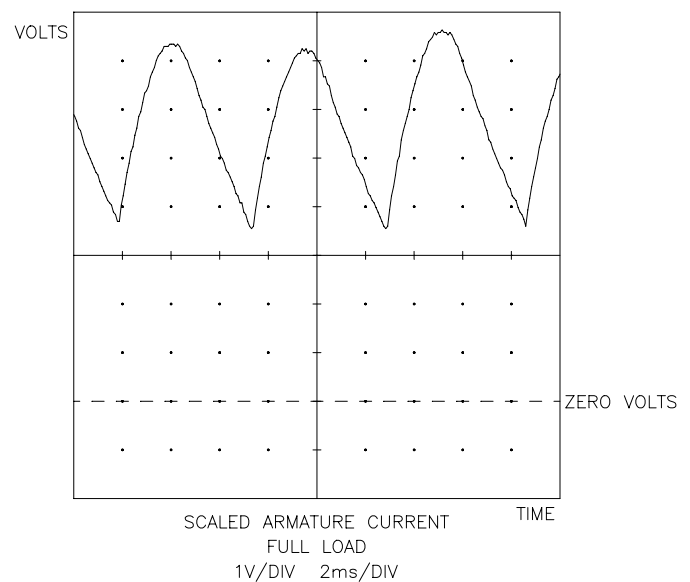
Accurate adjustment of the I OFFSET and I CAL pots is critical to proper operation of the current feedback and protection circuits. These pots are factory adjusted and sealed. Should they require readjustment, refer to SECTION 7 for calibration instructions.

### ARMATURE VOLTAGE SENSING

The armature voltage sensing circuit uses high impedance, exactly 9.4 megohms, for



**FIGURE 11**



**FIGURE 12**

isolation. 9.4 megohms is the total of two series connected resistors in each of the A1 and A2 sensing inputs. Refer to FIGURE 13. The A2 signal is detected by R8 on the FUSE board. It passes through the POWER/TRIGGER board to R4 on the CONTROL board. The A1 signal is detected by R4 on the POWER/TRIGGER board and is connected to R18 on the CONTROL board.

On the CONTROL board R4 and R18 are inputs to the A1-A differential amplifier. The output of A1-A is 4.59 VDC at 240 VDC armature and 9.57 VDC at 500 VDC armature. Programming jumper J2 selects the gain of A1-D to give 7.7 VDC output – measured at TP10(G) – when at the respective full rated armature voltage. This scaled armature voltage is used for the zero speed circuit input

– see SECTION 6.10 - and as input to the armature feedback circuit.

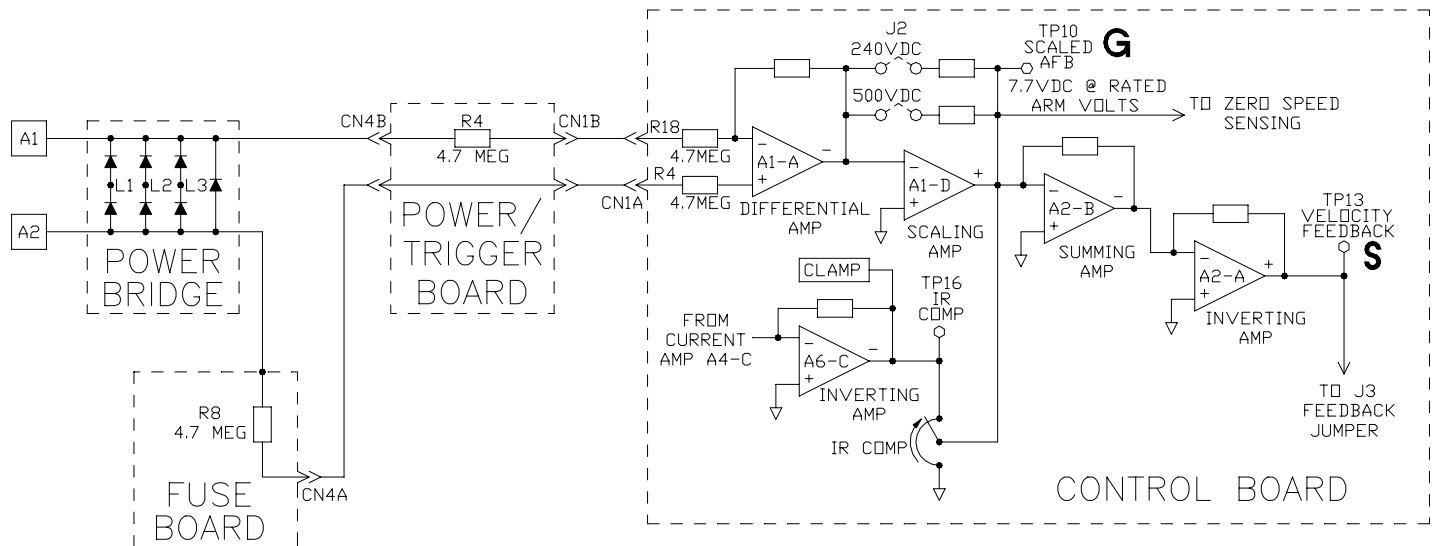
### **ARMATURE FEEDBACK (AFB)**

The counter EMF voltage generated by a motor armature is not an ideal velocity feedback because IR losses in the armature cause speed to drop as load increases – with armature voltage held constant. To compensate for the losses, the IR COMP pot and circuit uses some of the armature load signal from the current amplifier to subtract from the armature feedback voltage. See FIGURE 13. The reduction in feedback acts the same as an increase in velocity reference

and will cause an increase in armature voltage with an increase in load to keep the speed constant. A2-B sums the scaled armature voltage with inverted current amplifier, A4-C, output via A6-C. A6-C has a FET clamp to disable it in a stop condition. The output of A2-B goes through the A2-A inverter stage before connecting to the J3 feedback selection jumper. This signal can be monitored at TB13 (S).

### **TACHOMETER FEEDBACK (TFB)**

Another velocity feedback mode selectable by J3 is TACHOMETER FEEDBACK, TFB. Refer to FIGURE 14. An AC or DC



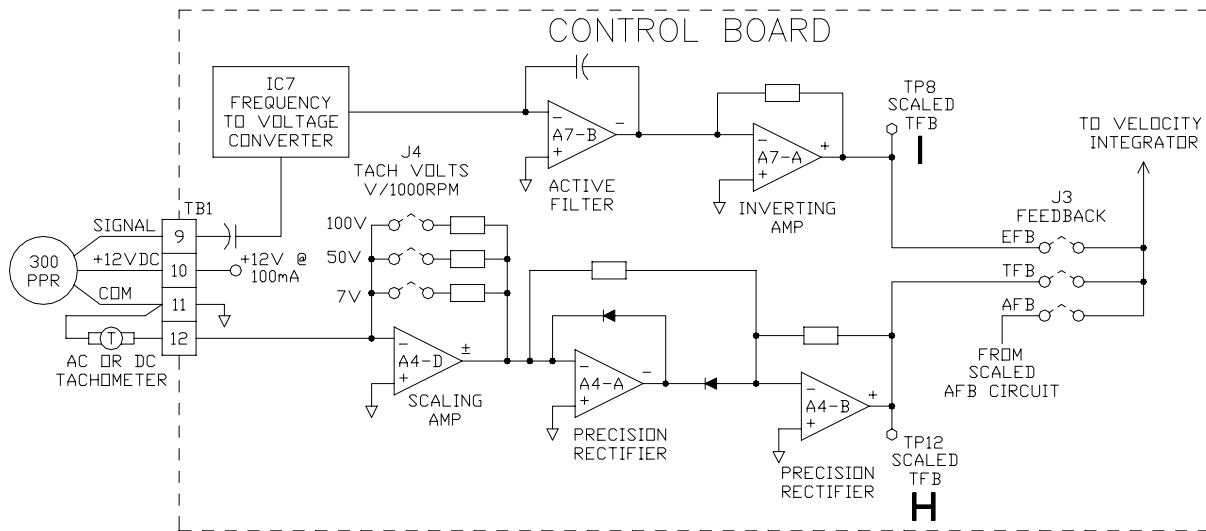
**FIGURE 13**

tachometer output can be connected to TB1-12 and common. The tach voltage is noise decoupled and applied to the A4-D amplifier where the gain is set by jumper J4. The labeling of J4 refers to the rating per 1000 RPM of DC tachometers. 45 VAC and 90 VAC tachometers can be used with the 50 and 100 V jumper positions. The jumper is set to scale the full speed tach voltage to 7.7 VDC. Following the scaled signal, A4-A and A4-B

form a precision rectifier circuit which always keeps the output polarity positive – regardless of input polarity. The output can be measured at TP12 (H).

### **ENCODER FEEDBACK (EFB)**

A 12 VDC 300 PPR encoder connected to TB1-9 can also be selected by J3 in the EFB position – reference FIGURE 14. 1750 RPM equates to 8750 Hz input which is processed



**FIGURE 14**

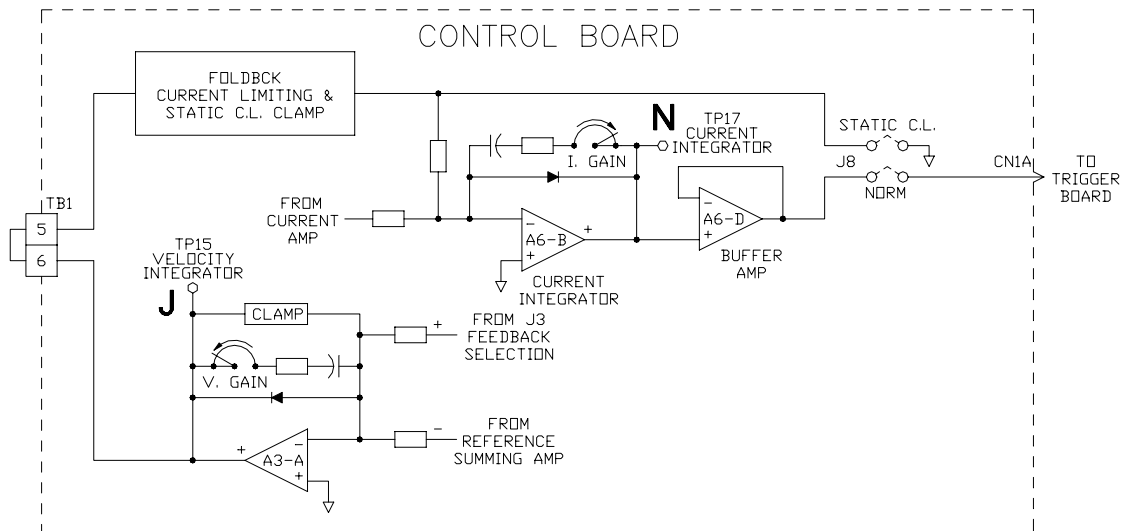
by IC7, a frequency to voltage converter. IC7 sources a current signal into A7-B, an active filter circuit, and then through an inverting amplifier, A7-A where we can see 7.7 VDC on TP8 (I) at 1750 RPM.

### 6.7 VELOCITY AND CURRENT LOOPS

Speed regulation and current regulation are critical operations performed within CHOICE drives by individual "loop" control circuits. They are known as velocity or current loops because the circuits actively use a feedback signal that is "looped around" or fed back for comparison to the reference. Faster response

and improved speed and torque regulation are the results.

Both the velocity and current loops use a hybrid or stepped integrator OP-AMP circuit. Refer to FIGURE 15. They operate with a rate of integration determined by the resistor and capacitor values at the input and in the amplifier feedback loop. They additionally have a pot in series with the loop capacitor that causes the circuit to initially respond like a summing amplifier. The amplifier action causes an initial step in output based on the predominate input signal and gain setting and then it integrates up or down based on continuing conditions. Thus, the response of



**FIGURE 15**

the circuit can be altered by changing the size of the step taken.

### VELOCITY INTEGRATOR

A3-A is the velocity integrator and includes the VOLTAGE (VELOCITY) GAIN pot in its feedback loop. It receives reference input from the A3-C amplifier – see SECTION 6.5 - and feedback from the velocity signal selected by J3 – see SECTION 6.6. The output is based on the initial difference between these two inputs and the continuing level required to minimize the difference. It therefore equates to the torque required by the motor to make the velocity feedback equal to the velocity reference and is used as the reference to the current loop. It can be monitored at TP15 (J) or at TB1-6 where it is normally jumpered to the current loop input at TB1-5.

### CURRENT INTEGRATOR

The current integrator, A6-B, uses the CURRENT (TORQUE) GAIN pot in its feedback loop. Its reference normally comes from the velocity loop as described above and is trimmed by the CURRENT LIMIT pot to limit the highest current level demanded. Additional circuitry senses this signal and can limit it and cause a fault condition if the level is excessive for too long of a time period. See SECTION 6.8 for details on these functions. The feedback is from the current amplifier. The output is based on the initial difference between these inputs and the continuing level required to minimize the difference between them. The output directly controls the trigger circuit and relates to the triggering or conduction angle of the SCRs necessary to produce an armature current feedback equal to the current demand.

**NOTE: For special applications such as center winders that require direct torque control of the motor, the current loop input at TB1-5 can be connected to an alternate source of reference. The velocity loop section will be non-functional and the drive**

**will have no adjustable maximum speed or armature voltage.**

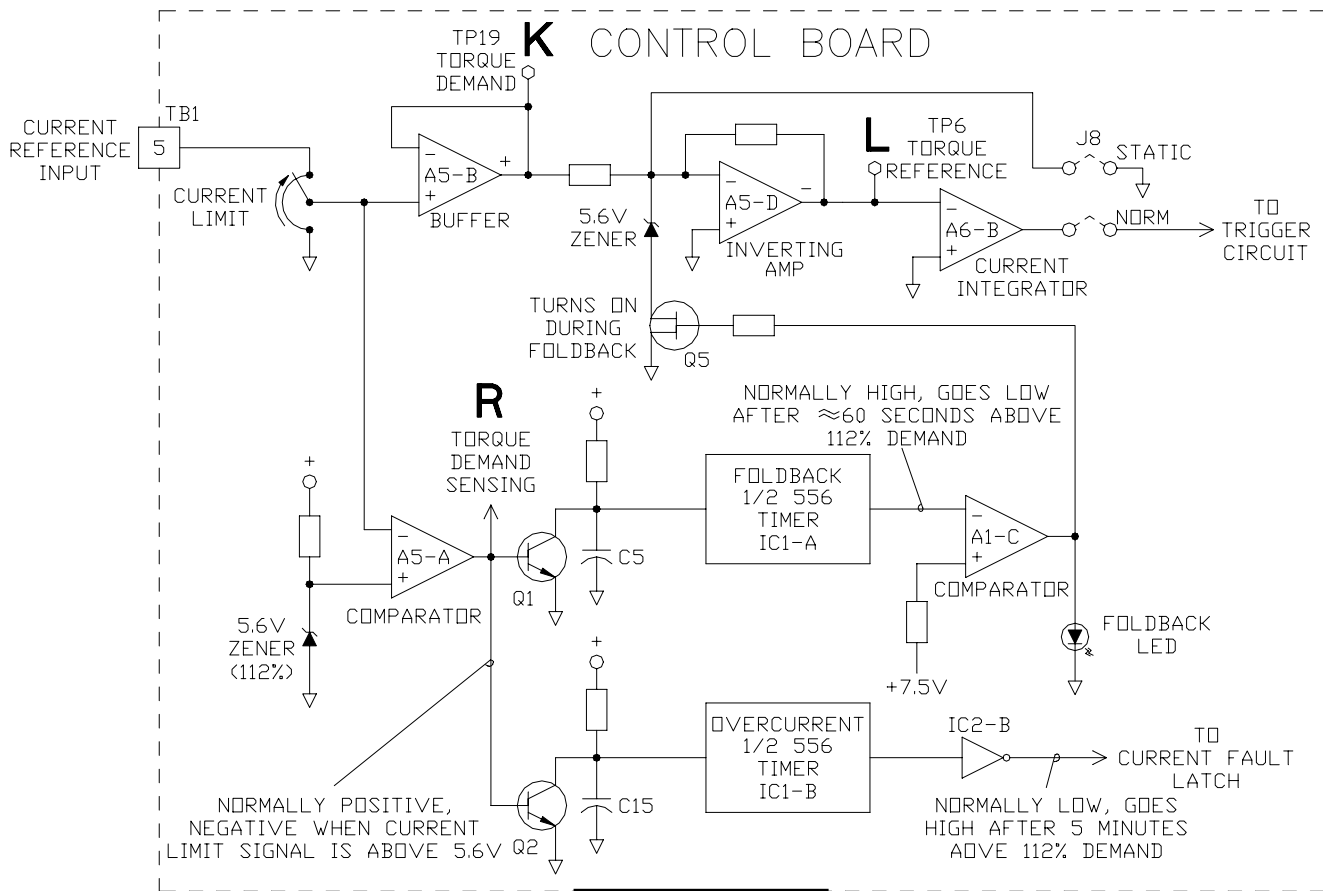
## **6.8 STATIC CURRENT LIMIT AND OVERCURRENT FUNCTIONS**

### FOLDBACK

Refer to FIGURE 16. The current demand signal from the Current Limit pot goes to a demand level sensing circuit, A5-A, and to a buffer stage, A5-B. The buffer output can be measured at TP19 (K) and is connected to a 5.6 volt zener that can be switched into operation by transistor Q5 and comparator A1-C. The signal then is inverted by A5-D and can be monitored at TP6 (L) before being applied to the integrator, A6-B.

At the sensing circuit, the demand signal is compared to a 5.6 zener volt level which is equivalent to 112% current signal - refer to ARMATURE CURRENT SENSING in SECTION 6.6. The comparator output, measured at DCM check point R, is used to control two current related protection circuits. FOLDBACK and OVERCURRENT FAULT.

The FOLDBACK circuit uses IC1-A,  $\frac{1}{2}$  of a 556 dual timer, to control the amount of time the drive has exceeded 112% or rated armature current. After 60 seconds, the drive will enter the FOLDBACK mode and clamp the output to a maximum of 112%. Normally the timer output is triggered into a high state upon power up. This high level exceeds the positive voltage divider level on the non-inverting input of comparator A1-C and causes it to stay at a negative saturation level. When the demand voltage level into the inverting input of A5-A exceeds the 5.6 VDC level on the non-inverting input, the output switches negative and turns off transistor Q1 which was clamping the timing capacitor C5. If the demand has exceeded 112% for approximately 60 seconds, C5 completes its charge and drives the timer output low. The low level causes A1-C and Q5 to switch the 5.6 volt zener into operation



**FIGURE 16**

which now limits the current reference at TP6 (L) to 112%.

### **OVERCURRENT FAULT**

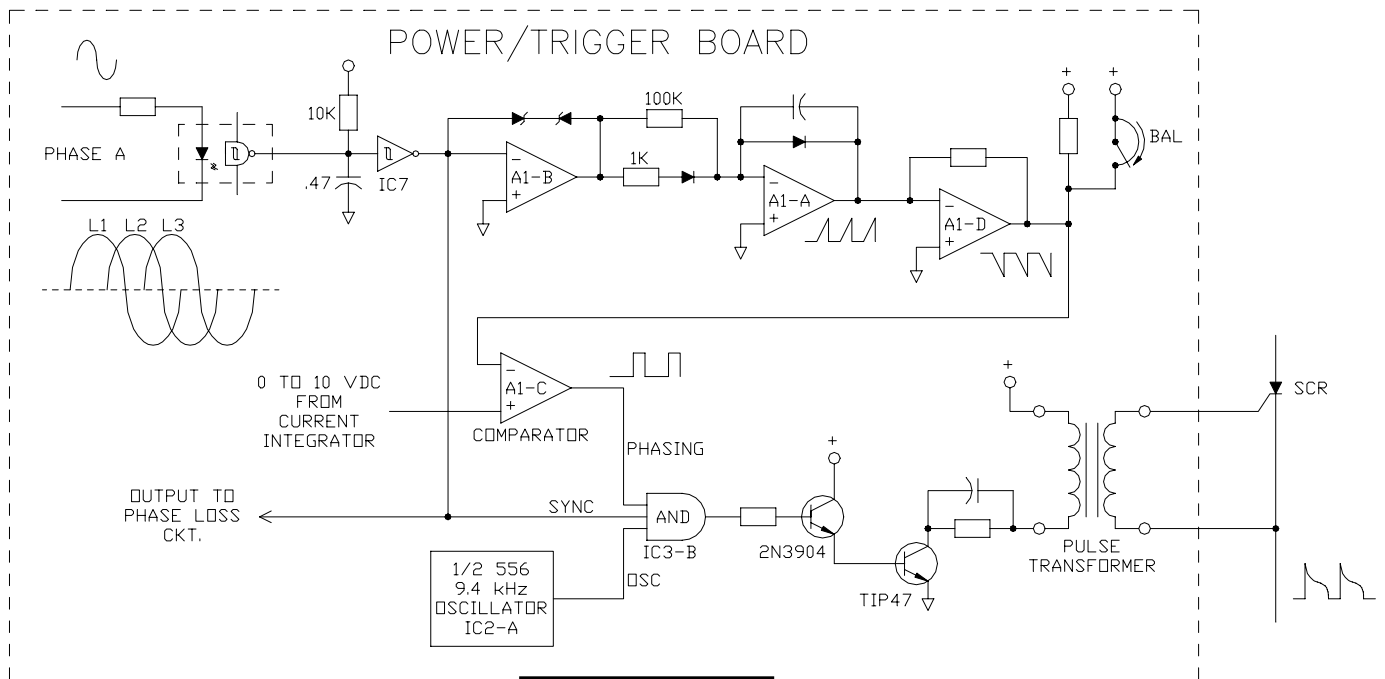
The OVERCURRENT FAULT circuit is similar to the FOLDBACK circuit. Transistor Q2 and timer IC1-B are controlled by the demand sensing circuit in the same way except that the 112% level must be exceeded for five minutes before the timer output drops low. A stage of the hex inverter, IC2, inverts this logic to set the fault latch output high. Refer to SECTION 6.11 for more information on the fault circuits.

**NOTE: The timers for FOLDBACK and OVERCURRENT FAULT operate when the current demand has exceeded 112% continuously for their respective time periods. During time-out, a dip below 112% demand will reset the timers and start the timing cycle over again. A decrease below**

**112% automatically brings the control out of a FOLDBACK condition. OVERCURRENT FAULT though is a latch function and must be reset.**

### **STATIC CURRENT LIMIT**

The STATIC CURRENT LIMIT feature is programmable with J8 on the CONTROL board. See FIGURE 16. This feature allows setting the level of current limiting statically or without actually supplying armature current to the motor. As detailed in previous sections, control of motor current is based on calibration to give a scaled 5.0 VDC current amplifier signal at 100% of the programmed current range. Selection STATIC C. L. with J8 will disable the current loop and trigger circuit. Then starting the control with the speed reference turned up will cause velocity integrator to saturate demanding maximum torque – which can be trimmed to the desired current limit level by monitoring TP19 (K).



**FIGURE 17**

This level is factory set to 7.5 VDC which equates to 150% current.

## 6.9 TRIGGER CIRCUIT

The trigger circuit accepts a voltage command from the current integrator - see SECTION 6.7 and 6.8 - to control the conduction angle of the SCRs. The voltage is applied to three identical circuits - one for each SCR. Each circuit uses all four sections of a quad OP-AMP - either A1, A2, or A3. The A1 section is described here and shown in FIGURE 17.

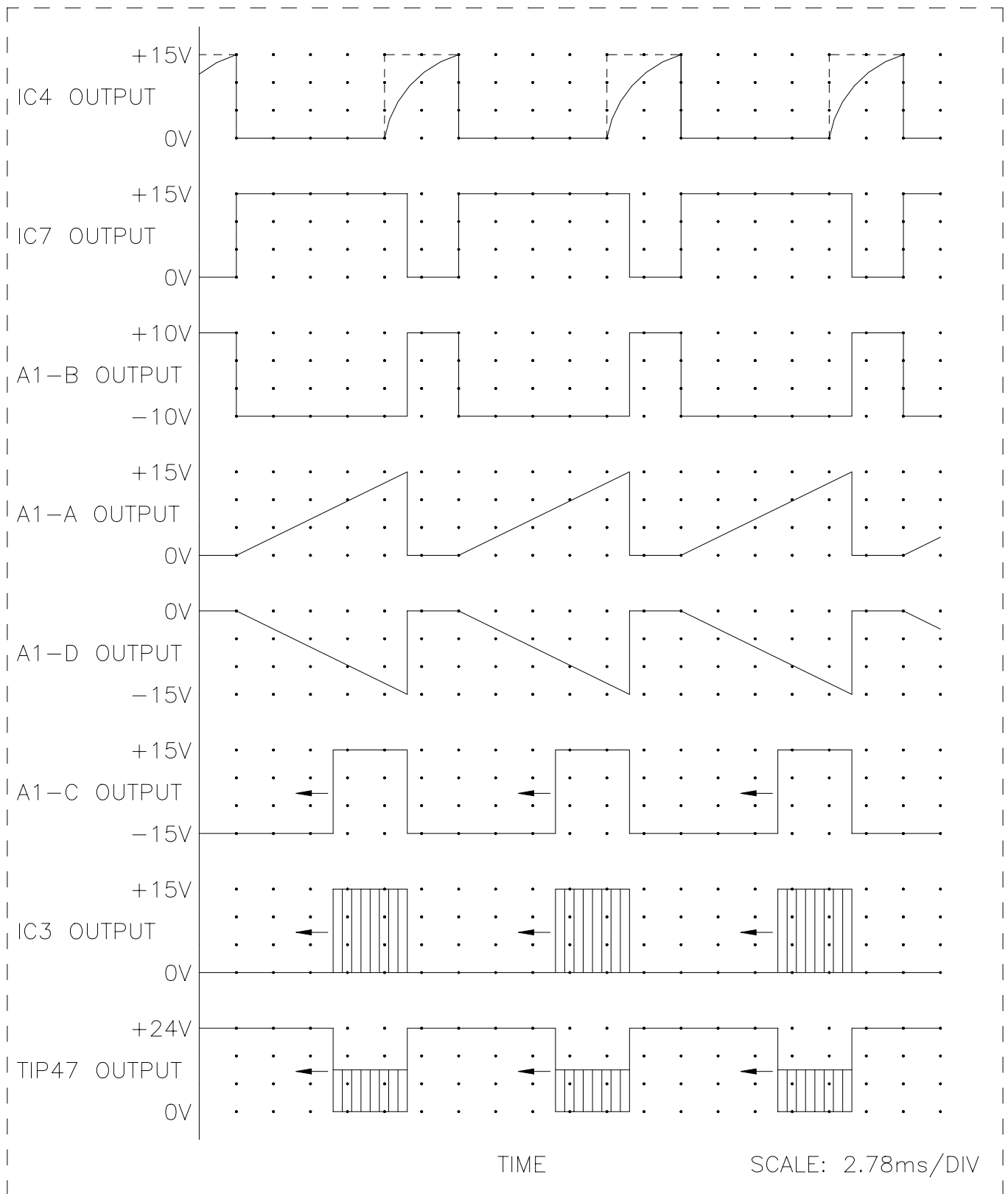
Each circuit is synchronized with one phase of the three phase line by use of line sensing optoisolators - see FIGURE 9 in SECTION 6.6. All circuits are connected to a common oscillator which generates a 9.4 kHz "multipulse" gating frequency for the SCR's. The oscillator, 1/2 of 556 dual timer IC2-A, is turned on by FET Q1 when it is turned off by one of the operating mode control signals. See SECTION 6.10 for a discussion on the various operating mode control signals.

Each optoisolator output is a "sync pulse" that is low for time equal to 2/3 of the line frequency period - 11.1 msec for a 60 Hz line and 13.3 msec for a 50 Hz line. It would appear initially that the "on" time period should be for 1/2 of the line period but we see additional time at the beginning of our sync signal from our main phase optoisolator photo-diode conducting in series with one of the other photo-diodes. The additional time is irrelevant because the power bridge SCR's and diodes are biased by the phase to phase voltage potentials instead of just the line to line potentials sensed by the optoisolators. This difference in phasing requires that the signal be delayed or phase shifted > 1.3 msec by the 10k Ohm/.47 uF R/C network at each isolator output. The effect of the capacitor can be seen on the rising edge of each pulse; refer to FIGURE 18. The result is a logic level low pulse in sync with the AC voltage forward biasing the SCR.

The sync signal is squared up and inverted by an IC7 schmidt trigger gate and applied to IC3-B, a three input AND gate, and to the input of the conduction angle or phasing control circuit. It is additionally applied to the PHASE LOSS circuit which is explained in SECTION 6.11. The AND gate requires the presence of the sync, oscillator and phasing signal to drive the output section of the trigger current. The phasing signal is controlled by the output of the current integrator and is produced in the following manner.

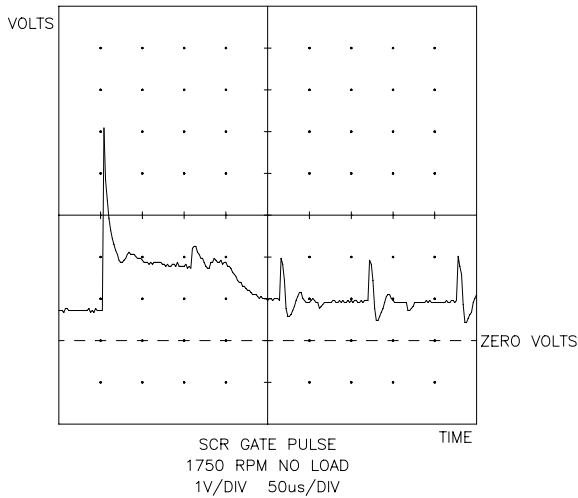
The A1-B OP AMP section inverts and clips the sync pulse to 10.6 VDC. The output charges the A1-A section integrator capacitor slowly through a 100K Ohm resistor. The result is a positive polarity triangle wave with a linear charge ramp and sharp cutoff. It is inverted to negative by the A1-D section amplifier and then summed with a slightly greater positive bias at the A1-C section so that the output is normally saturated negative polarity. If a portion of the triangle wave is high enough in negative polarity, it overcomes the positive bias and causes the amplifier output to saturate positive. This occurs at a point coinciding with the peak of the triangle and stays high for that portion of the triangle ramp that exceeded the positive bias.

A similar output occurs when the positive output from the current integrator is applied to the non-inverting input of the section A1-C comparator. The signal adds to the effect of the triangle wave-shifting the output positive where it coincides with the peak and slope of the waveform. In this fashion, the current integrator output controls the width of the gating signal and therefore the SCR conduction time for each cycle of the AC line. The variable width conduction pulse is modulated by the oscillator output at the IC3 3-input AND gate. A series pass 2N3904 transistor amplifies the gate current to drive a TIP47 transistor into saturation. This TIP47 sinks current through a parallel resistor/capacitor network and the primary of the trigger transformer to induce a gate pulse on the secondary. The initial pulse of current through the capacitor and then mainly through the primary is high due to current flow through the capacitor and then mainly through the resistor since the capacitor does not have time to completely discharge at the 9.4 KHz rate. Refer to FIGURE 18 for a timing diagram of the POWER/TRIGGER board signals and FIGURES 19 & 20 for typical SCR gate pulse with the drive at no load and full load.

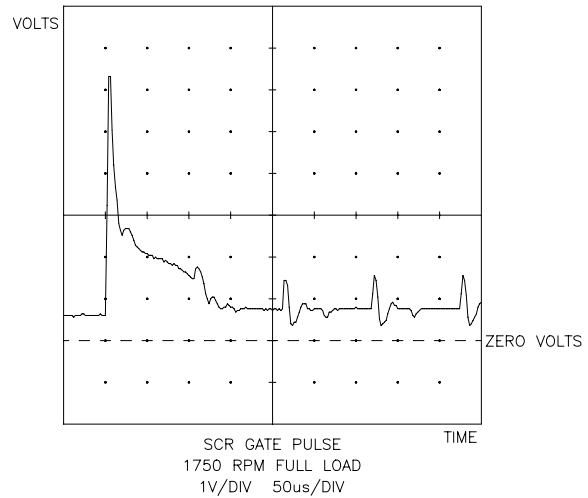


**FIGURE 18**





**FIGURE 19**



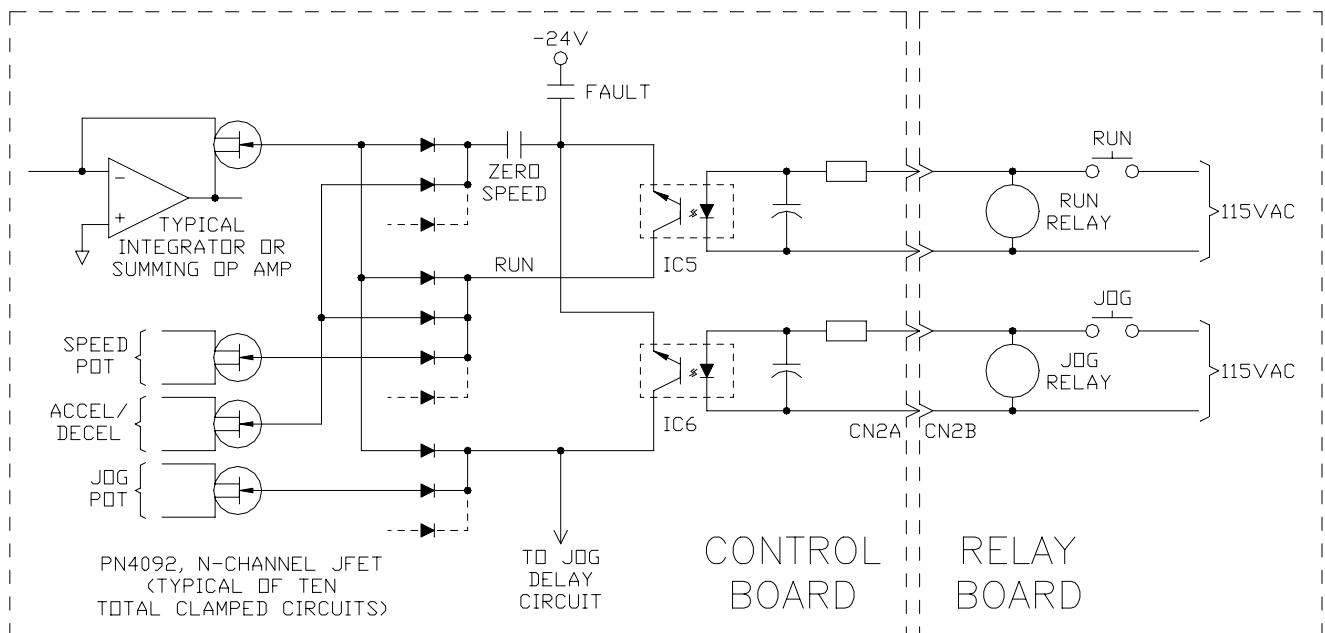
**FIGURE 20**

## 6.10 SPECIAL SIGNALS AND CIRCUIT FUNCTIONS

### OPERATING MODE CONTROL

As covered in SECTION 6.3, RUN and JOG operating modes are commanded by 115 VAC relay logic on the RELAY board. A third operating mode controlled by the ZERO SPEED circuit on the CONTROL board takes

over from the RUN mode when the RAMP STOP pushbutton has been depressed. The mode commands are interfaced with various electronic reference and controlling with various electronic reference and controlling circuits as depicted in FIGURE 21. There are ten of these circuits – listed in TABLE 8 – that are shut off or clamped by FETs (field effect transistor) when not turned on or released by the mode control signals as shown in the table.



**FIGURE 21**

The PN4092 FETs that are used are on or clamping when their gates are at positive or zero volts potential. They are turned off by the application of the -24 VDC through the "steering" diode as shown in the figure.

MODE	SPD POT	JOG POT	ACCEL DECEL	MIN SPD	SUM POT	VEL SET	IR COMP	VEL INT	CURR INT	9.4 KHz OSC
RUN	•	<b>X</b>	•	•	•	•	•	•	•	•
JOG	<b>X</b>	•	<b>X</b>	•	•	•	•	•	•	•
ZERO SPD	<b>X</b>	<b>X</b>	•	•	•	•	•	•	•	•

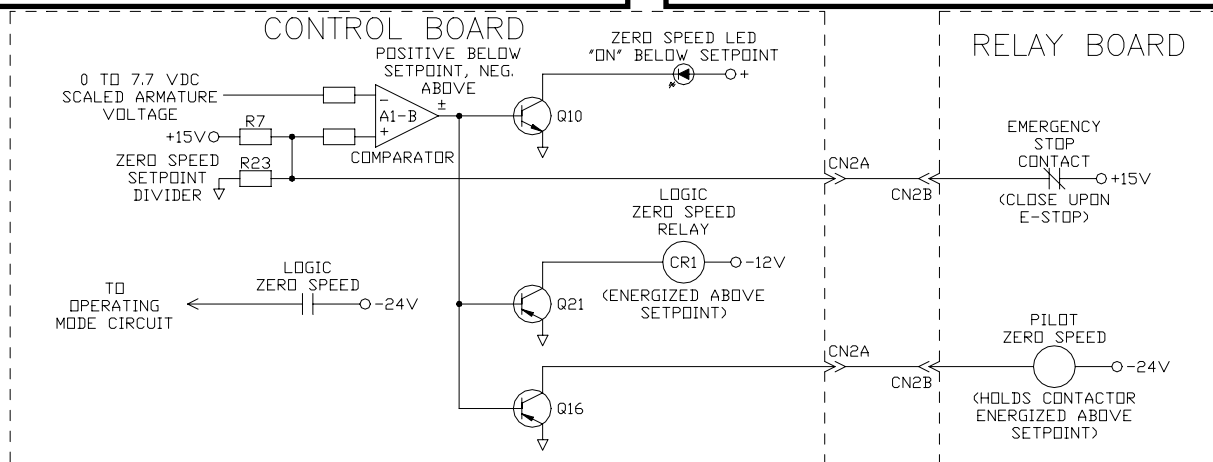
"•" indicates that the respective circuit be turned on by the MODE control signal.

"**X**" indicates that it has no effect.

### **ZERO SPEED FUNCTION**

A typical operation in the RUN mode would de-clamp all of the circuits and signals except for the JOG pot. When above 6% motor speed, depressing the RAMP STOP button will cause the drive to drop out of the RUN mode and continue in the ZERO SPEED mode. TABLE 8 shows that the SPEED pot is clamped in this mode but

ACCEL/DECEL stays on. Its output will ramp down as controlled by the DECEL pot until the armature voltage falls below 6% armature voltage, the ZERO SPEED setpoint. At this level the ZERO SPEED circuit will de-energize the armature contactor and cause the remaining circuits and signals to be clamped. FIGURE 22 is a simplified schematic of the ZERO SPEED circuit.



**FIGURE 22**

The R7/R23 resistor divider controls the ZERO SPEED setpoint and keeps the output of the A1-B comparator positive when the scaled armature voltage is below 6%. The positive voltage cause Q10 (NPN) to light the ZERO SPEED LED. When the scaled armature voltage exceeds the setpoint, A1-B switches negative and causes Q21 and Q16 (PNP's) to energize their respective relays.

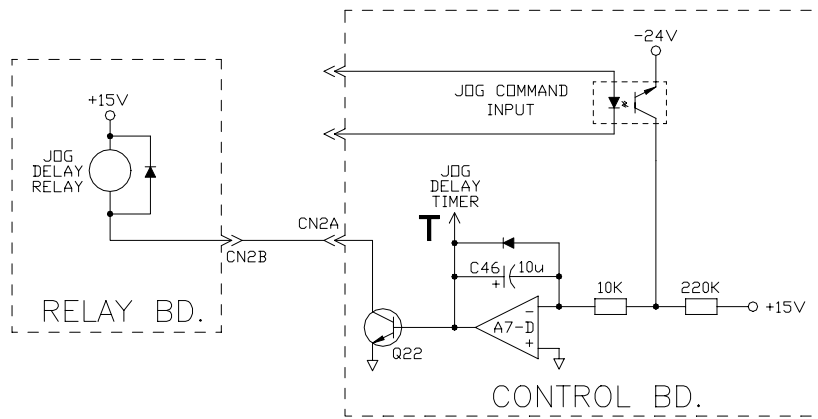
### **JOG DELAY FUNCTION**

This function serves to extend the mechanical life of armature contactors by reducing the number of mechanical operations in an application where a high rate of repeats "jogging" is performed. When the JOG button is pressed and released, the reference is immediately clamped to stop the motor but the contactor is held energized for four seconds.

Pressing the JOG button again within the four second "delay" period will cause the motor to immediately jog and will reset the four seconds delay.

Refer to FIGURE 23. The JOG DELAY relay

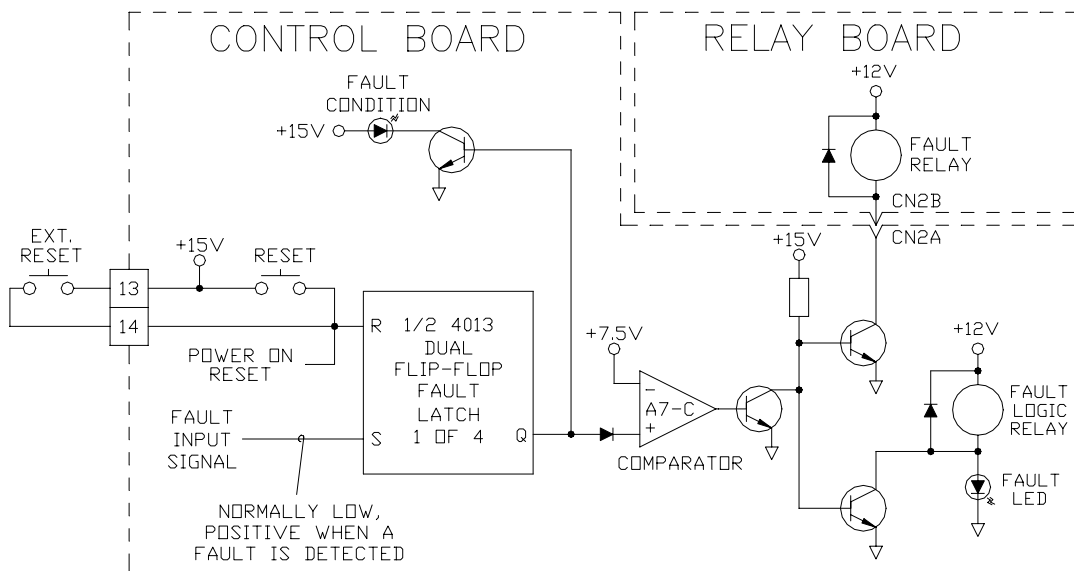
is energized via A7-D when the -24 VDC JOG command input is applied through a 10K Ohm resistor to quickly charge C46. When the command signal is removed, +15 VDC causes slow discharge of the capacitor via a 220K Ohm resistor to produce the delayed drop out



**FIGURE 23**

of the relay. The charge on capacitor C46 can be monitored at DCM check point T.  
**NOTE: the ZERO SPEED and JOG DELAY functions are dependent on the use of a contactor auxiliary contact at TB3-15 and additionally at TB3-18 on reversing models. Delete these contacts to defeat these**

**functions.**  
**6.11 FAULT CIRCUITS**  
 There are four fault conditions on all CHOICE control models.  
 Refer to FIGURE 24.



**FIGURE 24**

Each fault circuit, OVERCURRENT, FIELD LOSS, PHASE LOSS and OVERTEMP, drive a latching circuit which indicates the specific fault and cause operation of the FAULT relays. The latching circuits also maintains the faulted status of the drive until it is reset by the RESET pushbutton on the CONTROL board, an external RESET contact connected to TB1-13 & 14 or by cycling the 115 VAC power to the drive.

The FAULT relays act to shut off the armature voltage output and de-energize the armature contactor. The FAULT LOGIC relay contact, as shown in FIGURE 21, removes the -24 VDC used by the mode control circuitry for de-clamping various circuits. This is explained in SECTION 6.10. The FAULT PILOT relay contact, explained in SECTION 6.3, removes the 115 VAC from the pushbutton operator logic and the contactor.

### OVERCURRENT

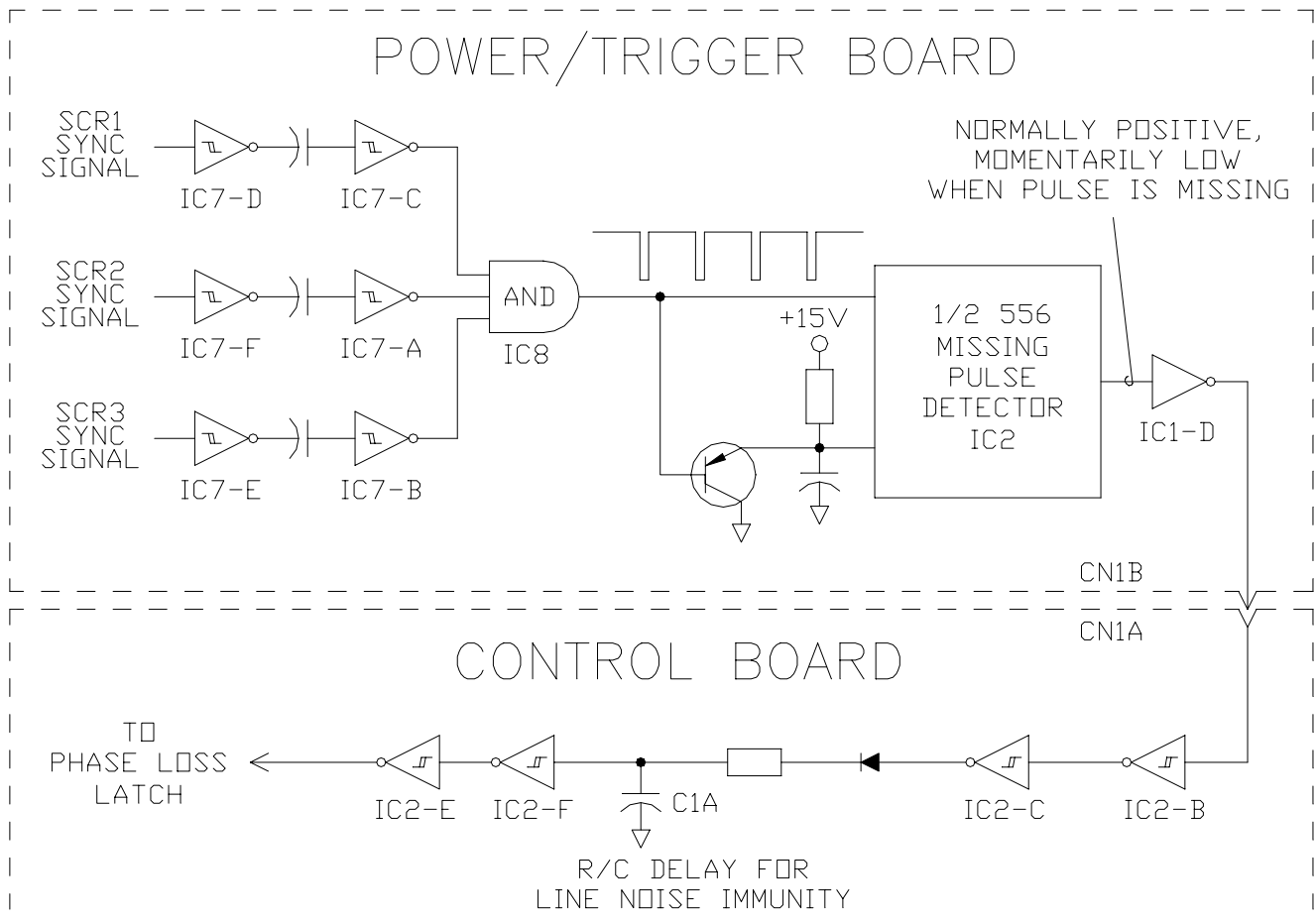
The OVERCURRENT FAULT will occur when the control has continuously demanded more than 112% armature current for five minutes. It acts in concert with the FOLDBACK circuit, and is explained in detail in SECTION 6.8.

### FIELD LOSS

The FIELD LOSS circuit detects the presence of field current flow, not voltage, by the circuit shown in FIGURE 1. SECTION 6.2 gives an explanation of this circuit.

### PHASE LOSS

The PHASE LOSS circuit is shown in FIGURE 25. Each phase of the line supply is detected through the use of optoisolators as shown in FIGURE 9 in SECTION 6.6. The sync pulses from this circuit are described with the trigger circuit in SECTION 6.9.



**FIGURE 25**

The three 50 or 60 Hz (depending on line frequency) sync signals maintain their 120 degree phase relationship through the IC7 schmidt trigger logic gates and are converted to narrow pulse by capacitive coupling to the input of additional IC7 gates. The three sets of pulse are all added by the IC8 AND gate to give a regular pulse train at three times the line voltage frequency. Each pulse then coincides with one cycle of one of the input phases.

½ of IC2, a 556 dual timer, is used as a missing pulse detector, and monitors the pulse train. When powered up, IC2 begins a timing cycle and the output goes high. The train of input pulses continually resets and re-triggers the timer so that it normally cannot complete a timing cycle. One missing pulse gives enough time for a cycle to complete. If this happens, IC2 output goes low and is inverted by the IC1 gate. A high level from IC1 then signals a delay circuit that a sync pulse is missing.

Experience has shown us that normal industrial line supplies and branch circuits are constantly being subjected to notches or "hole in the line". The delay circuit provides immunity from such intermittent and short losses of line voltage that do not adversely

affect drive operation. A capacitor charge must build up from repeated loss of line for a time equal to about 3 cycles or 50 – 60 milliseconds before reaching the level necessary to operate the fault latch, ½ of IC3. Several IC2 inverter gates are used to square up the signal from the detector and into the latch.

**OVERTEMP**

OVERTEMP operates from a thermostat switch located on the power bridge heatsink. The 77 degrees Centigrade rating and the placement of the thermostat cause it to open if the temperature on the base of the SCR/DIODE modules exceeds 85 degrees Centigrade. The size of the heatsink and fan forced ventilation on some models will permit continuous operation at full armature current rating in a 55 degree ambient without this happening.

NOTE: The 55 degree rating refers to the ambient temperature around the heatsink. An totally enclosed drive is specified with a maximum of 40 degrees ambient outside the enclosure to allow for heat trapped within the enclosure.

**7 Drive Programming & Calibration**

**7.1 ADJUSTMENT AND PROGRAMMING PRESETS**

CAROTRON CHOICE® controls are all functionally tested and calibrated with motor loads and should require further calibration only to tailor operation for a specific application. The adjustment presets are listed in the event that the condition of the control and its adjustments are unknown or in doubt.

**Potentiometer Presets**

- Min Speed.....full CCW
- Max Speed.....mid-range

- Jog Speed.....full CCW
- Sum Trim.....full CCW
- Accel.....mid-range
- Decel.....mid-range
- Voltage Gain.....1/3 CW
- Current Gain.....1/3 CW
- IR Comp.....full CCW
- Current Limit.....mid-range
- Current Offset.....Do not adjust-Refer to SECTION 7.2 if altered
- Current Cal.....Do not adjust-Refer to SECTION 7.2 if altered

### Programming Jumper Presets

Jumpers J1, J2, J4, J6 & J7 should be placed in the positions appropriate to the line, motor and feedback device rating. J3 should be placed initially in the AFB position until proper encoder or tachometer operation is verified. Place Jumper J8 in the NORMAL position.

Jumper J5 will be placed according to the specific application requirements.

## 7.2 CALIBRATION AND FINE TUNING

### CURRENT OFFSET & CURRENT CAL

These two adjustments are preset at the factory to give a calibrated current amplifier signal versus armature current signal. These adjustments are critical to all current related functions, i.e. current feedback, current feedback, current limiting, IR Compensation current foldback, and overcurrent fault.

**WARNING!!! Altering the factory settings of these pots may result in loss of protection and overload operation of the control and motor.** If the adjustments are unknown or in doubt, the following procedure can be used to calibrate the control.

Disconnect the F1 and F2 field terminals from the control, and place jumper J1 in the BYPASS position. Connect an ammeter in series with the armature leads. Apply power to the control. With jumper J6 in the 100% position, monitor TP11 (M), and adjust the I (Current) OFFSET pot P3 to read +5 mV or +.005 VDC.

Adjust the external speed pot to approximately 20% and the CURRENT LIMIT pot P9 fully CCW. Run the control, while still monitoring TP11 (M). Slowly adjust the CURRENT LIMIT pot P9 CW until 1.0 VDC is reached at TP11 (M). Since all current signals are scaled to 5 VDC at 100% of the jumper J6 range, the 1.0 VDC level corresponds to 20%. Slowly adjust the I (CURRENT) CAL pot P6 until the ammeter

reads 20% of the rated armature current of the control. Please note that CW rotation will decrease armature current while CCW rotation will cause an increase.

Example: A CDC320-000 has a maximum rating of 37 A. Adjust P9 until TP11 (M) reads 1 VDC. Adjust P6 until the ammeter reads 7.4 ADC, 20% of 37 A.

**WARNING!!! Do not exceed the maximum current rating of the ammeter.** On higher current drives it may also be necessary to tap armature current down in order not to exceed smaller ammeter current ratings. This is done by moving jumper J6 to a lower percentage and adjusting P6 to a lower percentage.

Example: A CDC3150-000 has a maximum rating of 256 A. In the above example, P6 would then be adjusted until the ammeter would read 51.2 ADC. However, if jumper J6 was placed in the 20% range instead of the 100% range, P6 would have to be adjusted to only 10.2 ADC, 20% of 51.2 ADC.

After calibration, remove power and reconnect the field and armature wires as before. Return J1, J6 and P9 to their previous positions.

### BAL 1 & BAL 2

These two adjustments are preset at the factory to equalize the conduction angle of the 3 SCRs and the loading of the 3 phase AC line input. The BAL 1 pot is used to adjust SCR1 while the BAL 2 pot is used to adjust SCR2. These two adjustments are used to equalize their conduction angles with SCR3, which is not adjustable. If these adjustments are unknown or in doubt, the following procedure can be used to balance the SCRs. An oscilloscope and /or ammeter(s) will be required to balance the SCRs.

The SCRs can be balanced in one of two ways. The first option is to balance the conduction angle or "on time" of each SCR.

This is best done by viewing the armature output (A1 with respect to A2) with an oscilloscope.

**WARNING!!! High voltage potentials are present on the armature. Do not connect any grounded instrument to the CHOICE control. Please follow the oscilloscope manufacturer's recommendations on measuring high voltage potentials not referenced to earth or machine ground.**

Turning the BAL 1 pot CW will increase the conduction angle of SCR1. Notice as the conduction angle is increased on SCR1, the other two SCR conduction angles are decreased to keep the armature output current the same. Likewise, if SCR2 is increased, the conduction angles of SCR1 and SCR3 are decreased. Since each balance pot affects all 3 SCRs, both balance pots will have to be adjusted in conjunction with each other. Alternately adjust each balance pot until all 3 SCR conduction angles are equal.

The second option is to balance the currents of the 3 phase AC line inputs. This is best done by using ammeters to measure the current in each phase. If the 3 AC line phase voltages are equal, balancing of the conduction angles as described above would also equalize the 3 phase line currents. However, if the 3 phase AC line voltages are not equal, balancing of the conduction angles will not produce equal currents in the 3 phase AC lines. Simply adjust the balance pots as described in the above procedure while monitoring the AC line currents. As above, each balance pot affects the line currents of all 3 phases. Alternately adjust each balance pot until all 3 AC line phase currents are equal.

### **VOLTAGE GAIN & CURRENT GAIN**

The VOLTAGE and CURRENT adjustments, P2 & P5, as preset by CAROTRON will provide stable and responsive performance under most load conditions. When required, the drive performance can be optimized for a particular

application or to correct undesirable operation by use of these adjustments. The adjustments are complex though and can adversely affect operation if not properly set. In general, the settings that give the most stable operation do not always give the fastest response. Problems correctable by these pots can usually be separated into those related to stability of steady state operation; i.e., constant speed and load conditions; and those that occur with speed or load changes that are related to balanced operation of the SCR power bridge. Refer to the following guidelines when re-adjustment is required.

When instability is observed, it should first be evaluated as a possible load induced condition. Cyclic variation in armature current and in motor speed can indicate mechanical coupling or machine loading conditions. If mechanically induced, the instability repetition rate or frequency can usually be related to a motor or machine rotation rate or loading cycle. In this situation, the instability frequency will change in coincidence with any motor speed change.

Instability in the control output due to incorrect adjustment would usually be present over a range of speed and would not usually change frequency in coincidence with speed. Because the response of the control can sometimes be altered to partially compensate for mechanically induced instability, it is sometimes difficult to determine if the load change is affecting control output stability or if control output is affecting the load stability. De-coupling the load can help make this determination.

If fuse blowing or tripping of breakers should occur, it may be due to unbalanced operation of the power bridge. This would usually be noticeable when rapid changes in output or surges of torque are being called for as opposed to steady state operation. Examples would be when quickly accelerating a load up to speed, or when a load is suddenly applied.

Typically the setting that provide the most stable and balanced bridge operation under all conditions do not give the fastest response.

To prevent confusion and minimize anxiety when making loop adjustments, use the following guidelines:

1. Make sure the problems are not due to things other than adjustment. Operation similar to that can be caused by but are not limited to the following problems.
  - Leakage due to insulation breakdown in the motor. A motor with insulation breakdown may operate fine when cool or at light loads but may cause problems when conditions change.
  - Improper wiring of the motor. Does the motor have a SERIES armature winding? If it does, its polarity is critical. Are the field windings connected correctly? Most motors used with CHOICE<sup>®</sup> drive models have dual field windings that must have the same polarity to work properly.
  - Incorrect armature current scaling. Has the proper motor current range been selected by J6 on the CONTROL board? The scaled current range of the control must match the nameplate current rating of the motor.
  - If used, is the velocity feedback tachometer or encoder selected, connected and scaled properly?
  - If in armature feedback, is the IR COMP adjusted too high?
  - Is the speed reference to the control a stable, noise free signal?
2. Know what your starting point is before making an adjustment.
3. Make only one adjustment at a time. If an adjustment has no affect or appears not to help, be sure to return it to its starting point before making any other adjustment.
4. When loop adjustments are required, start first with the I (current) loop adjustment.

### **IR COMP**

The IR COMP is functional only in the AFB mode and is used to keep motor speed from decreasing as load is increased. Adjustment is best done when the motor or machine can be loaded normally. If the motor is normally operated at a particular speed, adjust the IR COMP while running at that speed. If the motor operates under load over a wide speed range, pick a speed near mid-range to make the adjustment. Adjust as follows:

Operate the unloaded motor at the normal or mid-range speed and note the exact speed. While still monitoring speed, apply normal load. The reduction in speed of a fully loaded motor will usually fall between 2 and 13% of rated or "Base" speed. Slowly increase the IR COMP adjustment clockwise until the loaded speed equals the unloaded speed measured in the previous step. Making this adjustment may now cause the unloaded speed to be slightly higher. Repeat this procedure until there is no difference between loaded and unloaded speed levels.

Use care not to set the adjustment too high or speed may increase with load and instability may result.

**NOTE: For this adjustment, do not use SCALED ARMATURE VOLTAGE to measure speed. Armature voltage is not an exact indication of loaded motor speed!**



## 8

# Component Testing

### Fuses

Due to other circuit paths that may interfere with measurements, it is not recommended that fuses be tested with an Ohmmeter while still in the circuit. Remove the fuse, and then check the resistance with an Ohmmeter. A fuse may also be checked by applying power to the drive and carefully measuring the voltage across the fuse. Remember that a good fuse will not have a voltage drop, while a blown fuse will.

### SCRs

The power devices may be tested with a meter and a small (1.5 or 9 VDC) battery. First remove the component to be tested from the circuit, and simply measure the resistance from the anode to the cathode to check for a shorted SCR. Depending on the current rating of the SCR model, a good SCR will read anywhere from approximately 400k Ohms to an open circuit. Set the meter to the diode check and once again read across the anode

and cathode terminals. Place the positive meter probe on the anode and the common or negative meter probe on the cathode. Connect the negative of the battery to the cathode terminal. Momentarily connect the positive battery lead to the gate terminal. The diode check voltage should read around 0.6 to 0.7 VDC. Note that the SCR may not latch into conduction due to the small amount of current being supplied by the meter.

### DIODES

Remove the component to be tested from the circuit, and simply measure the resistance from the anode to the cathode to check for a short. Set the meter to the diode check and read across the anode and cathode terminals. Place the positive meter probe on the anode and the common or negative meter probe on the cathode. The diode check voltage should read around 0.6 to 0.7 VDC.

## 9

# Troubleshooting

When trouble shooting a control problem, the first step is to eliminate the motor. This can be done best by substituting another motor or a "dummy" load and checking to see if the problem still persists. An emergency "dummy" load can be created by placing two 115 VAC light bulbs in series for 230 VAC operation, or 4 in series for 460 VAC operation. Higher wattage loads will perform better as dummy loads.

**NOTE; The control must be operated in armature feedback when dummy load are used.**

### *Drive blows fuses on power up*

- A drive that blows fuses when applying the 3 phase power likely has a shorted SCR or diode in the armature or field supply bridges. Refer to SECTION 8 for information on testing these devices.
- A shorted motor or shorted wiring to the motor can be checked best with a megger. A Ohmmeter may also be used, but it may not be able to detect high resistance paths to ground that may break down at rated operating voltage.
- Disconnect the motor from the control. Measure the resistance from each motor terminal to machine or earth ground. Place your Ohmmeter in the RX 100k or greater scale, and be suspicious of any reading less than 500k Ohms.

- Shorted or excessively loaded control voltage transformer. The 115 VAC secondary must be rated to handle any customer added auxiliary loads in addition to the normal requirements of the control.

***Drive blows fuses when entering RUN or JOG mode.***

- Check the 3 phase supply voltage. Voltage in excess of 506 VAC may cause random fuse blowing Reduce the supply to approximately 460 VAC.
- Improper operation of the armature contactor may cause the CHOICE<sup>®</sup> drive to have improper start up. This can happen when the external armature contactor is not being controlled by the internal CHOICE<sup>®</sup> relay logic. The normal start up procedure should assure that the contactor is energized before the control loops are enabled. Likewise, the control loops should be allowed to clamp before opening the contactor.
- Shorted or excessively loaded control voltage transformer. The 115 VAC secondary must be rated to handle any customer added auxiliary loads in addition to the normal requirements of the control. The external armature contactor inrush adds to this load upon start-up.
- Transient induced uncontrolled gating of the SCR's. The coils of electromechanical devices such as relays and solenoid that are energized when the drive is started should have transient suppressors. This is achieved by placing MOV's or snubbers in parallel with the coil. All internal relay coils on CHOICE<sup>®</sup> drives are suppressed.

***Drive will not RUN or JOG (RUN and JOG LEDs will not light)***

- Check 115 VAC power at TB2-2 & 3 on the FUSE board. If not present, check control voltage transformer and primary supply from two of either FU4, FU5, or FU6 on the FUSE board.
- Check 115 VAC power at TB3-20 & 21. If not present, check FU1 on the FUSE board and check status of FAULT LEDs.

- Observe the ZERO SPEED LED. It should be "on" when the motor is stopped. If not, the ZERO SPEED relay may locking out the run commands due to SCR leakage voltage appearing at the power bridge output. Refer to drawing A10552. The 40K Ohm 10 watt resistor connected across the armature busbars may be open.
- Verify proper operation of RUN and JOG contacts.
- Check power supplies (Refer to SECTION 10). The power supply is fused by FU1 on the POWER SUPPLY board.

***Drive will not RUN or JOG (Run and Jog LEDs will light)***

- Check power supplies (Refer to SECTION 10).
- Verify presence of signal at TOTAL REFERENCE SETPOINT at TP14 (F). If not present, check input at TB1-2 or 7 depending on speed pot or summing input operation.
- Verify that the CURRENT LIMIT pot is not adjusted too low.

***Motor runs too fast or runs away***

- Lack of velocity feedback can cause run-away and insufficient feedback can cause excessive speed.
- Check position of J6 according to motor armature nameplate rating. The SCALED ARMATURE VOLTAGE, TP10 (G) should measure about 7.7 VDC at rated armature output, either 240 or 500 VDC.
- Tachometer feedback (TFB) or encoder feedback (EFB) signals can be monitored at TP12 (H) and TP8 (I), respectively, while the control is operated in armature feedback (AFB). Each signal should measure about 7.7 VDC at rated armature output. Check tightness of the coupling. For TFB, verify the position of J4 matches the voltage rating of the tachometer used, and for used, and EFB, confirm use of a 300PPR encoder.

- Check level to TOTAL REFERENCE SETPOINT, TP14 (F). Too high a setting of the MAX SPEED pot or excessive summing input signals can cause outputs over 100%.
- Overspeed when in armature feedback can be caused by improperly wired or defective motor fields. Make sure the polarities of multi-winding fields are correct. Refer below for correct field connections.

***Motor runs too slow***

- Excessive velocity feedback from incorrect programming of J2 or J4 and/or encoder with higher than 300PPR used as feedback. Monitor SCALED ARMATURE, SCALED TACH, or SCALED ENCODER at TP10 (G), TP12 (H), or TP8 (I), respectively, to verify 7.7 VDC at rated speed of motor.
- Excessive loading of the motor or wrong current range programmed by J6. Monitor CURRENT FEEDBACK signal at TP11 (M), and check for 5.0 VDC level at 100% or range selected by J6. Over-loading the motor for 60 seconds will cause FOLDBACK which may limit the motor speed.

***Motor drops in speed when loaded***

- Excessive loading of the motor or wrong current range programmed by J6. Monitor CURRENT FEEDBACK signal at TP11 (M), and check for 5.0 VDC level at 100% of range selected by J6.
- Operating in armature feedback and not compensating for IR losses in motor. Refer to SECTION 7.2 for adjusting the IR COMP pot.

***Motor draws a high level of armature current, but will not produce rated torque***

- One of the dual field winding polarities may be reversed. When connecting the field in a low voltage operation (150VDC), the field windings should be connected in parallel. The F1 and F3 (positive polarity) leads should be connected together, and the

F2 and F4 (negative polarity) leads should be connected together. For high voltage operation (300 VDC), the field windings should be connected in series. The F2 and F3 leads only should be connected together with F1 as positive and F4 as negative inputs.

- If the field polarity is unknown or in doubt, a simple test with a voltmeter and a small battery (1.5 or 9 VDC) can be used to determine the proper polarity. Disconnect all wires from the motor, and connect the voltmeter across one of the field windings. Connect the negative battery terminal to one lead of the other field winding to the positive battery terminal to one lead of the other field winding. Momentarily connect the other field winding to the positive battery terminal. If the voltage on the field winding initially goes positive and then swings negative, the field leads connected to the positive battery terminal and the positive leads of the voltmeter have the same polarity. If the voltage first swings negative and then positive, reverse one of the connections.

**WARNING! When using a battery as described above, the inductance of the field can produce a voltage shock when connections are made and broken.**

***Motor is unstable and becomes worse when load is applied***

- The series field may be connected incorrectly. Only non-regenerative drives should use the series field (S1 and S2) by placing it in series with the armature windings. The polarity of the F1 lead and the S1 lead should always be the same. Changing the direction of motor rotation by reversing the armature leads with contactors should not reverse the series field winding.
- Voltage and/or current loops not adjusted properly.

Many signals on the CHOICE<sup>®</sup> drive can easily be monitored by test points on the various PC boards. Most of these signals on the CONTROL board are also easily accessible via CAROTRON'S DCM100-000.

### CONTROL BOARD

**NOTE:** Letters refer to DCM100-000 Check Points.

<b>A</b>	Parameter:	Unregulated power supply
TP2	Level/range:	+24 VDC, ±3.0 VDC
	Condition:	Can vary ±3.0 VDC with Line and load Fluctuation
<b>B</b>	Parameter:	Unregulated power supply
TP4	Level/range:	24 VDC, ±3.0 VDC With line and load Fluctuations
<b>C</b>	Parameter:	Regulated power supply
TP3	Level/range:	+15 VDC, ±0.75 VDC
	Condition:	Fixed within line Variation of ±10%
<b>D</b>	Parameter:	Regulated power supply
TP5	Level/range:	-15 VDC, ±0.75 VDC
	Condition:	Fixed within line variation of ±10%
<b>E</b>	Parameter:	Accel/Decel output
	Level/range:	0 to +10.0 VDC
	Condition:	Equal to speed setting After ramp time 0 VDC = 0% speed reference +10 VDC = 100% speed reference
<b>F</b>	Parameter:	Total reference (velocity) setpoint
TP14	Level/range:	0 to -10.0 VDC
	Condition:	Sum of all reference

signals reference  
0 VDC = 0% speed reference  
-10 VDC = 100% speed reference

<b>G</b>	Parameter:	Scaled armature voltage
TP10	Level/range:	0 to +7.7 VDC
	Condition:	0 VDC = 0% armature Output voltage +7.7 VDC = 100% armature output voltage
<b>H</b>	Parameter:	Scaled tachometer voltage (when used)
TP12	Level/range:	0 to +7.7 VDC
	Condition:	0 VDC = 0% motor speed +7.7 VDC = 100% motor speed
<b>I</b>	Parameter:	Scaled encoder Voltage (when used)
TP8	Level/range:	0 to +7.7 VDC
	Condition:	0 VDC = 0% motor Speed +7.7 VDC = 100% motor speed
<b>J</b>	Parameter:	Velocity integrator Output
TP15	Level/range:	0 to 13.5 VDC
	Condition:	Load and speed Dependent 200 RPM N.L.=+0.44 VDC 200 RPM F.L.=+8.8 VDC 1750 RPM N.L.=+0.44 VDC 1750 RPM F.L.=+8.9 VDC Motor stalled or current limited = +13.5 VDC

**K** Parameter: Torque demand  
 TP19 Level/range: 0 to +8.0 VDC  
 Condition: Load dependent  
 +5.0 VDC = 100%  
 current demand  
 +7.5 VDC = 150%  
 current demand

**L** Parameter: Torque reference  
 TP6 Level/range: 0 to -8.0 VDC  
 Condition: Load dependent unless  
 Limit by foldback or  
 Current limit functions  
 -5.6 VDC = 112%  
 foldback level  
 -7.5 VDC = 150%  
 current demand

**M** Parameter: Torque feedback  
 TP11 Level/range: 0 to +7.5 VDC  
 Condition: Load dependent  
 +5.0 VDC = 100% of J6  
 current range  
 +7.5 VDC = 150% of J6  
 current range

**N** Parameter: Current integrator output  
 TP17 Level/range: 0 to +6.25 VDC  
 Condition: Load & speed dependent  
 200 RPM N.L. = +4.34  
 VDC  
 200 RPM F.L. = +4.56  
 VDC  
 1750 RPM N.L. = +5.22  
 VDC  
 1750 RPM F.L. = +6.25  
 VDC

**O** Parameter: Hall effect output  
 TP9 Level/range: MV/Ampere-see  
 TABLE 7  
 Condition: Signal decreases with  
 Armature current  
 Increase  
 Output is model  
 Dependent:  
 Approximately 7.6 to  
 8.2 VDC at 0 amps.

Current decreases about  
 1.3 – 1.4 VDC at full  
 load

**P** Parameter: Current offset setpoint  
 TP7 Level/range: 0 to 1.0 VDC  
 Condition: Offsets hall effect output  
 At O armature current  
 Factory setting, DO  
 NOT ADJUST, See  
 SECTION 7.2

**Q** Parameter: Current scaling  
 TP18 Level/range: 0 to -5.0 VDC  
 Condition: Signal proportional  
 To armature current  
 -5.0 VDC = 100%  
 model rated load  
 current  
 Factory setting, DO  
 NOT ADJUST, See  
 SECTION 7.2

**R** Parameter: Torque demand sensing  
 Comparator  
 Level/range: +13 VDC ±1.5 VDC  
 (before foldback)  
 Condition: Controls feedback and  
 Over current fault  
 circuits  
 $\geq 112\%$  current demand = -13.0 VDC ±1.5  
 VDC

**S** Parameter: Velocity feedback  
 TP13 Level/range: +7.7 VDC at full motor  
 Speed  
 Condition: Signal composed of  
 Armature voltage  
 Feedback minus IR  
 Compensation signal

**T** Parameter: Jog delay timer signal  
 Level/range: -5.0 VDC ±0.2 VDC  
 Or +13.5 VDC  
 Condition: Provides contactor  
 delayed  
 Drop out on jog –  
 Approximately 4  
 Seconds

	Jogging = +13.5 VDC
	After contactor delay =
	-6.0 VDC
TP1	Parameter: Circuit common

TP16	Parameter: IR Comp
	Level/range: 0 to -2.0 VDC
	Condition: Load and speed dependant

# 11 Replacement Parts & Component Substitution

## 11.1 COMPONENT SUBSTITUTION

Many components of a CHOICE<sup>®</sup> drive are interchangeable with other CHOICE<sup>®</sup> models. The following section lists CAROTRON's part numbers and the manufacturer's part number (if applicable) of the drive's major components. This section can be used to order additional parts or to determine if a component from one drive may be substituted on another.

If needed, the CONTROL board can be modified with minimal effort to operate any model. The location of a zero Ohm resistor in position R1, R2, or R3 determines the CONTROL board model. Simply remove the zero Ohm resistor, and replace it in the correct location. Please refer to TABLE 7 for placement. The FUSE boards for all models are identical, except for the wire lengths and lug sizes. The CDC3150-000 FUSE board requires longer wire lengths and larger ring lugs than the other models

ALL SCR/DIODE isolated power modules are rated at 1400 volts repetitive peak off state and inverse voltage and have 1000 volts/microsecond dv/dt. There are 3 each per model. The power modules listed in SECTION 11.5 are pin-for-pin compatible with all CHOICE<sup>®</sup> drives. Consult the factory for assistance in making substitutions with components other than the recommended spares listed below in SECTION 11.5.

A higher rated current and/or voltage

component may be substituted for any power component. For example, the CDC320-000 model uses a 25 ampere, 1400 volt SCR/DIODE module. If this module is not available, a 55 ampere 1400 volt or a 25 ampere 1600 volt SCR/DIODE module could be substituted. NOTE: A higher current rated module will normally require a higher latching current for the device to operate correctly. Under light load conditions, this may cause the SCR to momentarily drop out of conduction or to not conduct at all. However, this problem is easily eliminated by the application of load and/or choosing a substitute device with a minimal difference in the current rating.

## 11.2 PRINTED CIRCUIT ASSEMBLIES

### CONTROL BOARD

Model CDC320-000.....	D10485-001
Model CDC340-000.....	D10485-002
Models CDC360-000 – CDC3150-000.....	.....D10485-003

### RELAY BOARD

Model CDC320-000-CDC360-000.	.....D10488-000
Model CDC375-000.....	D10488-001
Model CDC3150-000.....	D10488-002

### FUSE BOARD

Model CDC320-000- CDC375-000.....	.....D10491-000
Model CDC3150-000.....	D10491-001

**POWER/TRIGGER BOARD**

All model .....D10494-000

**IFB (CURRENT FEEDBACK BOARD)**

Model CDC3150-000 only.....C10748-003

**11.3 CONNECTOR /CABLE  
ASSEMBLIES**

**SAME FOR ALL MODELS**

Cable 1.....A10527-000

Cable 2.....A10528-000

Cable 4.....A10530-000

**MODEL DEPENDENT**

**Cable 3**

Models CDC320-000 – CDC375-000.....  
.....A10529-000

Model CDC3150-000.....A10805-000

**Cable 5**

Model CDC320-000 – CDC375-000  
.....A10531-000

Model CDC3150-000.....A10806-000

**Cable 6**

Models CDC320-000 – CDC375-000  
.....A10532-000

Model CDC3150-000.....A10807-000

**Cable 7**

Model CDC3150-000 only.....A10808-000

**11.4 FUSES**

**SAME FOR ALL MODELS**

FU1: 5 ampere, 250 VAC, dual element, time delay located on the FUSE board

CAROTRON.....FU1005-01

BUSSMANN.....MDA-5

LITTELFUSE.....326005

FU2, FU3: 10 ampere, class CC, time delay, 500 VDC located on the FUSE board

CAROTRON.....FUS1012-00

LITTELFUSE.....CCMR-10

FU4-FU6: 10 ampere, dual element, time delay, 500 VAC located on the FUSE board

CAROTRON.....FUS1008-03

BUSSMANN.....FNQ-10

LITTELFUSE.....FLQ-10

**MODEL DEPENDENT**

FU7, FU8, FU9 current rating per model, 500 VDC semiconductor types

Model CDC320-000: 50 ampere

CAROTRON.....FUS1009-00

BUSSMANN.....FWH50

SHAWMUT.....A50QS50-4

LITTELFUSE.....L50S50

Model CDC340-000: 100 ampere

CAROTRON.....FUS1009-01

BUSSMANN.....FWH100

SHAWMUT.....A50QS100-4

LITTELFUSE.....L50S100

Model CDC360-000: 150 ampere

CAROTRON.....FUS1009-02

BUSSMANN.....FWH150

SHAWMUT.....A50QS150-4

LITTELFUSE.....L50S150

Model CDC375-000: 175 ampere

CAROTRON.....FUS1009-03

BUSSMANN.....FWH175

SHAWMUT.....A50QS175-4

LITTELFUSE.....L50S175

Model CDC3150-000: 350 ampere

CAROTRON.....FUS1009-04

BUSSMANN.....FWH350

SHAWMUT.....A50QS350-4

LITTELFUSE.....L50S350

**11.5 POWER COMPONENTS**

Freewheeling (flyback) diode: 1 per model

Models CDC320-000 – CDC375-000: 80 ampere

CAROTRON.....PMD1011-00

SEMIKRON.....SKKE81/14

IR.....IRKE81-14

Model CDC3150-000: 165 ampere  
 CAROTRON.....PMD1015-00  
 AEG/EUPEC.....D171N1400K  
 IR.....IRKE166-1400

SCR/DIODE: 3 per model

Model CDC320-000: 25 ampere  
 CAROTRON.....PMD1010-02  
 AEG/EUPEC.....TD25N1400KOF  
 SEMIKRON.....SKKH26/14E  
 IR.....IRKH26/14-S90

Model CDC340-000: 55 ampere  
 CAROTRON.....PMD1010-01  
 AEG/EUPEC.....TD56N1400KOF  
 SEMIKRON.....SKKH56/14E  
 IR.....IRKH56/14-S90

Model CDC360-000: 90 ampere  
 CAROTRON.....PMD1010-00  
 AEG/EUPEC.....TD92N1400KOF  
 SEMIKRON.....SKKH91/14E  
 IR.....IRKH91/14-S90

Model CDC375-000: 105 ampere  
 CAROTRON.....PMD1010-00  
 AEG/EUPEC.....TD105N1400KOF  
 SEMIKRON.....SKKH105/14E

Model CDC3150-000: 135 ampere  
 CAROTRON.....PMD1014-03  
 AEG/EUPEC.....TD142N1400KOF  
 IR.....IRKH136-14S90

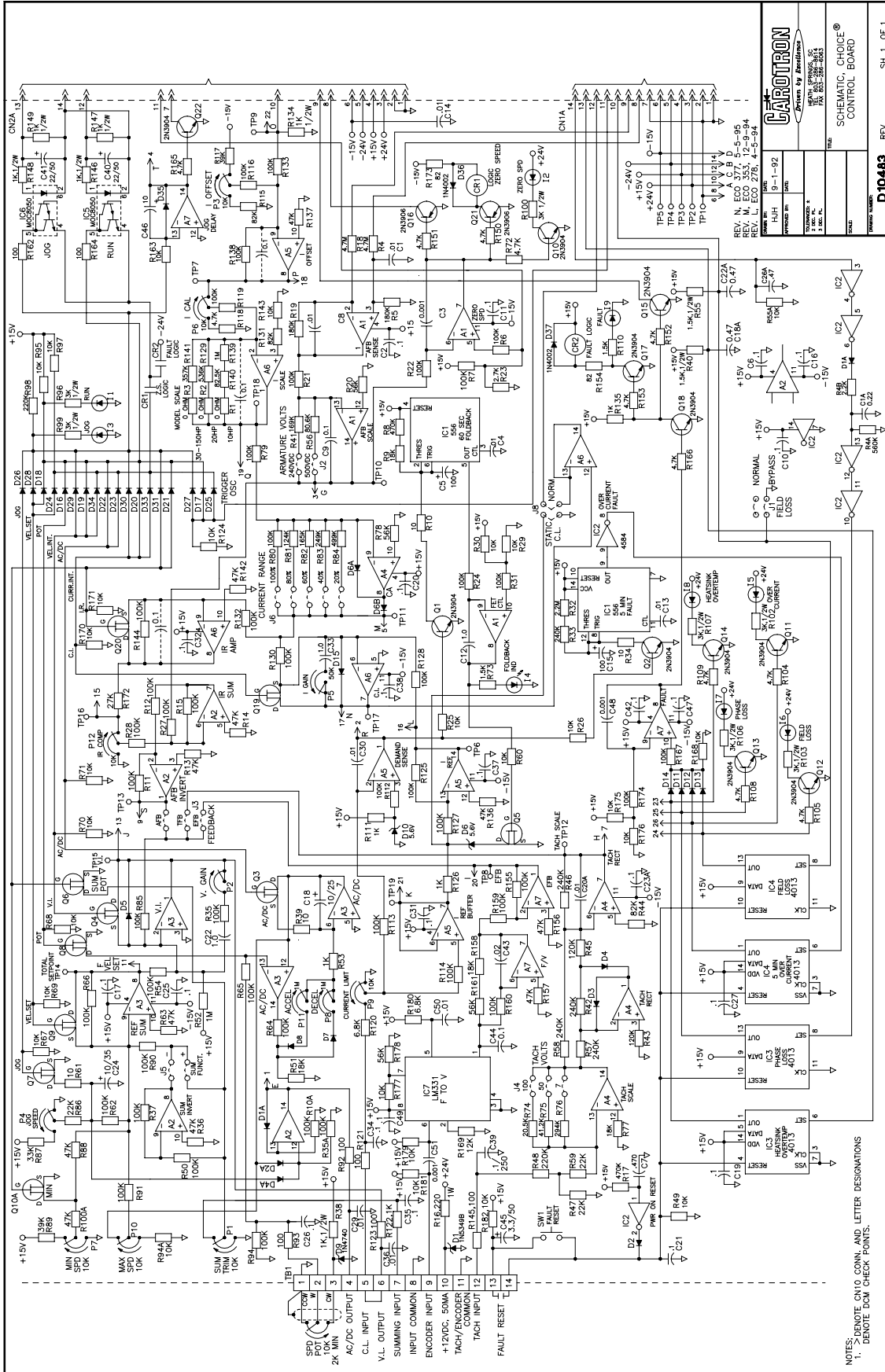
**FIELD SUPPLY**

The field supply uses the same power components for all models.

DB1 & DB2, diode doubler, 25 ampere, 50 V,  
 2 per model:

CAROTRON.....PMD1009-00  
 EDI.....FPID2505  
 HV.....CSB2505





**LAPTRON**  
 SYSTEMS & ASSOCIATES  
 1000 W. 10th St. #100  
 Los Angeles, CA 90015  
 (213) 475-1000

REV. N. ECO 377, 5-5-84  
 REV. L. ECO 278, 4-5-84  
 REV. M. ECO 279, 4-5-84

FORM NO. 100 9-1-82

DATE: \_\_\_\_\_  
 DRAWN BY: \_\_\_\_\_  
 CHECKED BY: \_\_\_\_\_  
 APPROVED BY: \_\_\_\_\_

SCHEMATIC, CHOICE®  
 CONTROL BOARD

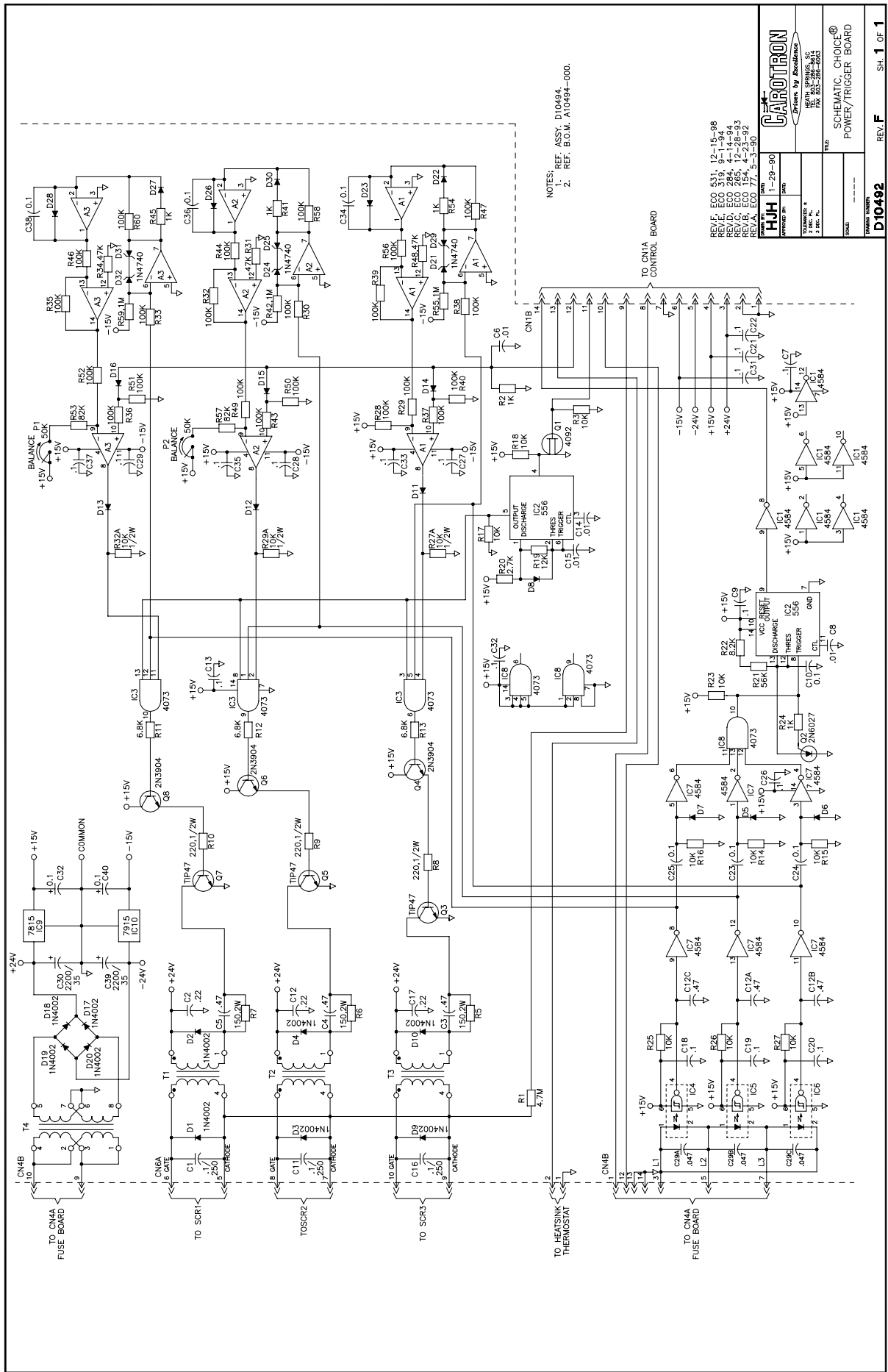
FIGURE NUMBER: \_\_\_\_\_

REV. \_\_\_\_\_

D10483 REV. \_\_\_\_\_

SH. 1 OF 1

NOTES:  
 1. > DENOTE ON/OFF, AND LETTER DESIGNATIONS  
 2. DENOTE DCM CHECK POINTS.



NOTES:  
 1. REF. ASSY. D10494.  
 2. REF. B.O.M. A10494-000.

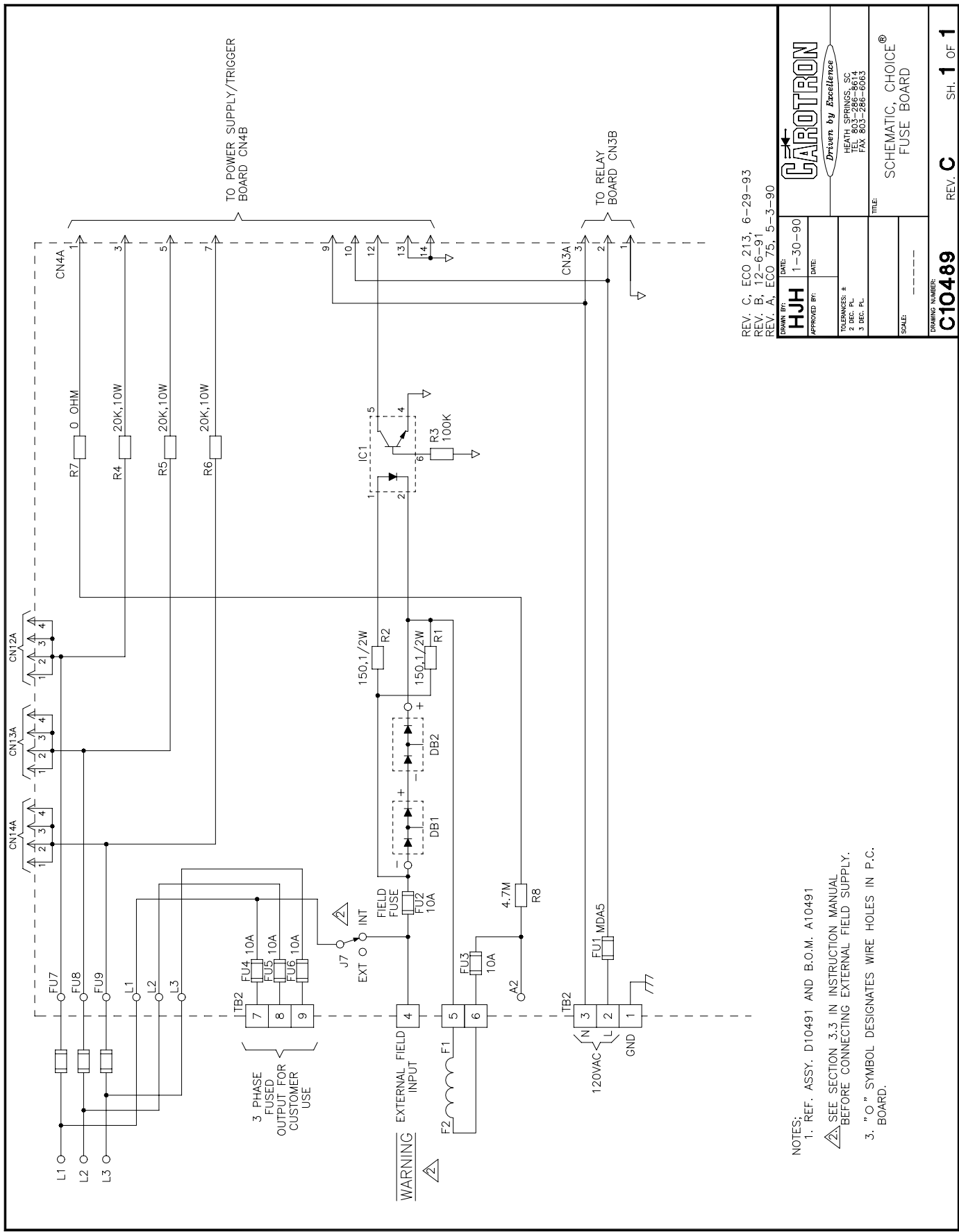
REV. F. ECO 531, 12-15-96  
 REV. E. ECO 294, 4-14-94  
 REV. C. ECO 265, 12-28-93  
 REV. B. ECO 174, 5-23-92  
 REV. A. ECO 174, 5-23-92

**PAROTRON**  
 Division of BENTON & BOWLES  
 1000 SPRING ST.  
 ST. LOUIS, MO 63102-3800

APPROVED BY: \_\_\_\_\_ DATE: \_\_\_\_\_  
 DRAWN BY: \_\_\_\_\_ DATE: \_\_\_\_\_  
 CHECKED BY: \_\_\_\_\_ DATE: \_\_\_\_\_  
 TOTAL: \_\_\_\_\_

FIELD: \_\_\_\_\_  
 SCHEMATIC CHOICE®  
 POWER/TRIGGER BOARD

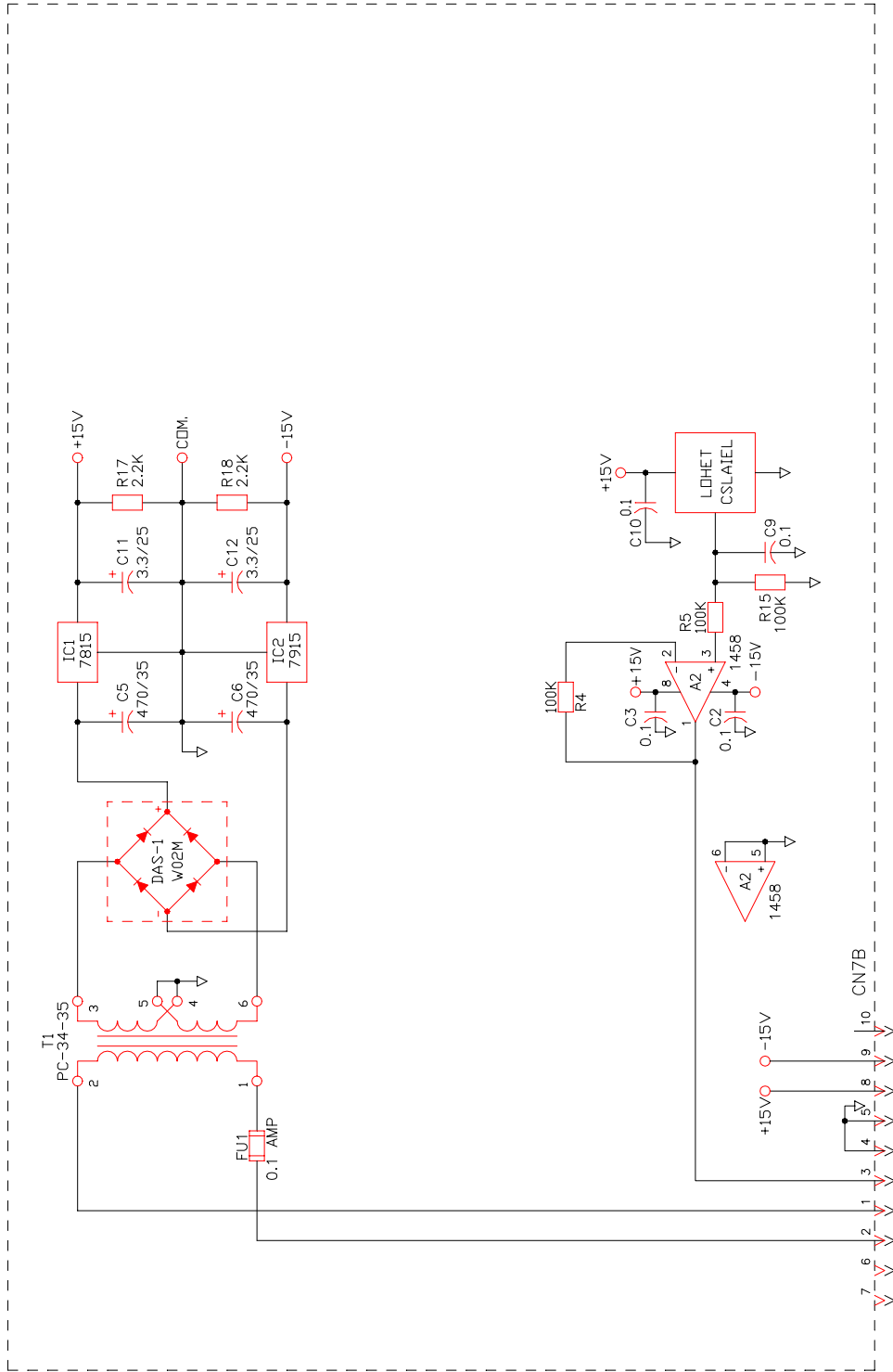
FORM NO. \_\_\_\_\_  
 D10492 REV. F SH. 1 OF 1



REV. C, ECO 213, 6-29-93  
 REV. B, 12-6-91  
 REV. A, ECO 75, 5-3-90

<i>Driven by Excellence</i>	
HEATH SPRINGS, SC TEL. 803-286-8614 FAX 803-286-8063	
TITLE: SCHEMATIC, CHOICE® FUSE BOARD	
SCALE: -----	
DRAWING NUMBER: <b>C10489</b>	REV. <b>C</b>
SH. <b>1</b> OF <b>1</b>	

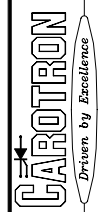
- NOTES:
1. REF. ASSY. D10491 AND B.O.M. A10491
  2. SEE SECTION 3.3 IN INSTRUCTION MANUAL BEFORE CONNECTING EXTERNAL FIELD SUPPLY.
  3. "O" SYMBOL DESIGNATES WIRE HOLES IN P.C. BOARD.



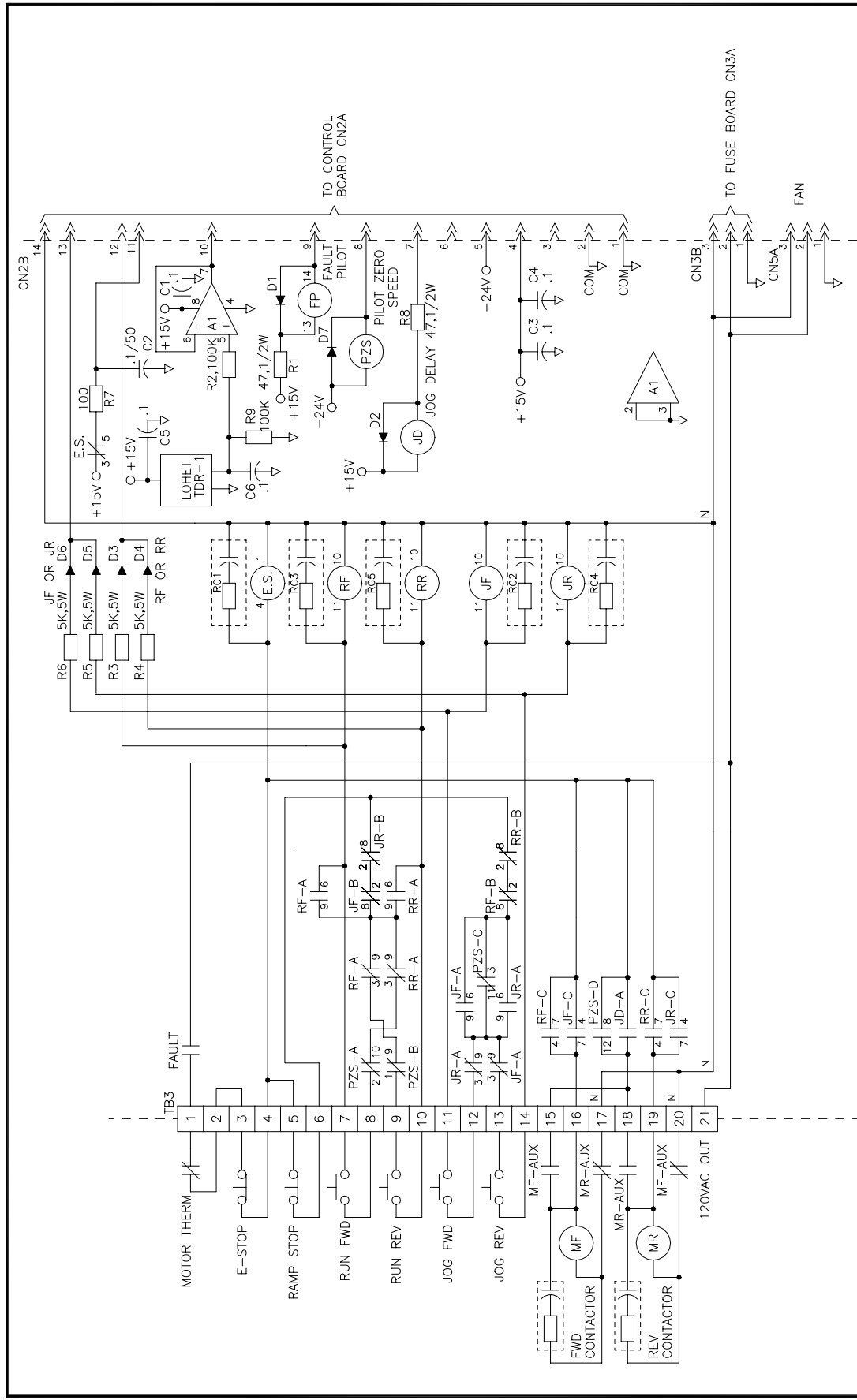
NOTES:  
1. REF. ASSY. C10748-003.

REV. A, ECO 165, 6-29-92

DRAWN BY: <b>HJH</b>	DATE: 12-3-91
APPROVED BY:	DATE:
TOLERANCES: 1 2 DEC. PL. 3 DEC. PL.	
TITLE: SCHEMATIC; CHOICE® IFB BOARD	
SCALE: ---	
DRAWING NUMBER: <b>C10815</b>	REV. <b>A</b> SH. <b>1</b> OF <b>1</b>



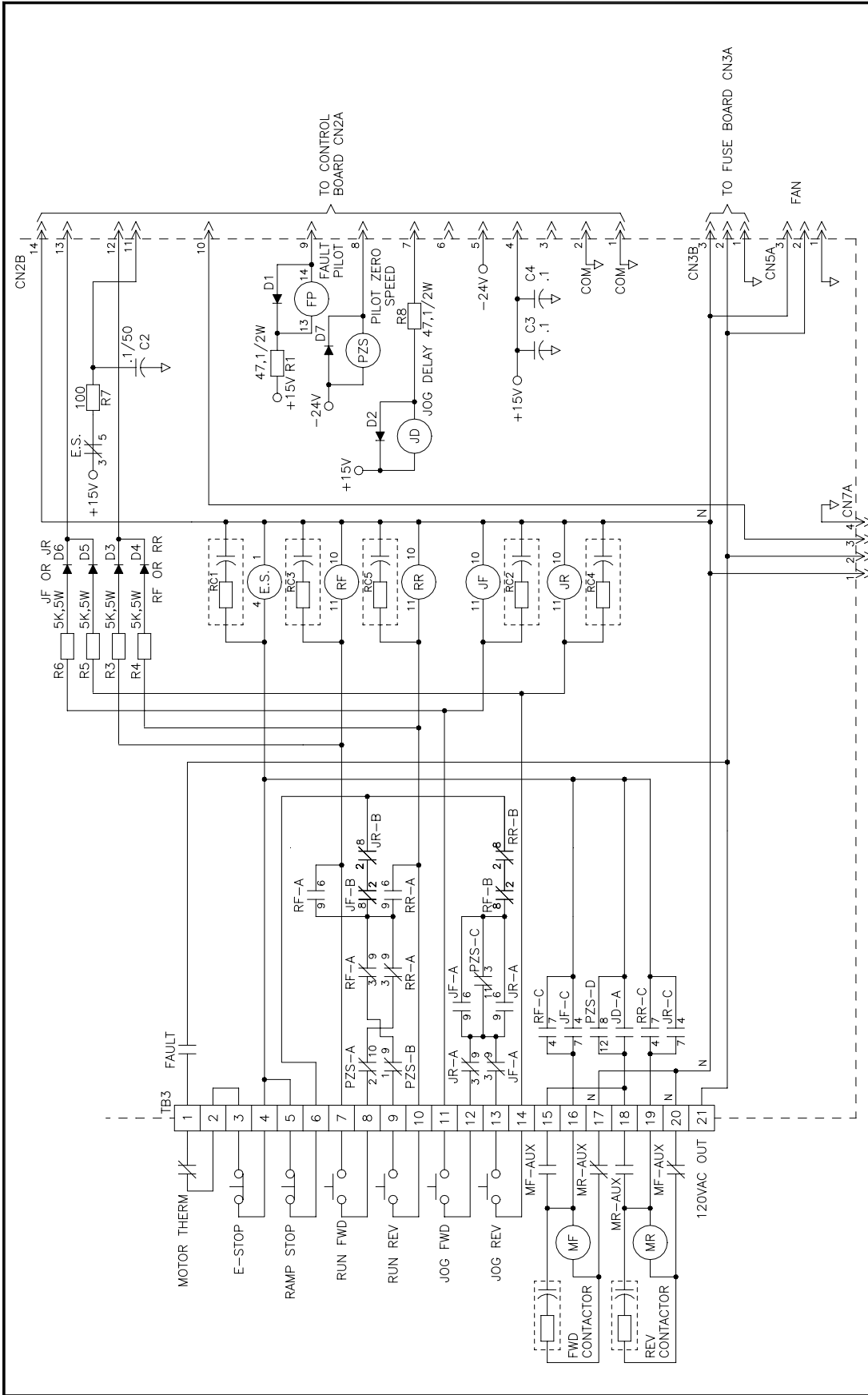
HEATH SPRINGS, SC  
803-286-6063  
FAX 803-286-6063



NOTES:  
 1. REF. ASSY. D10488-000 AND B.O.M. A10488-000 FOR CDC320-CDC360  
 2. REF. ASSY. D10488-001 AND B.O.M. A10488-001 FOR CDC375


DRAWN BY: <b>HJH</b>	DATE: 6-11-90
APPROVED BY:	DATE:
REVISIONS: # 1 DEC. 90 2 DEC. 91 3 DEC. 91	
TITLE: SCHEMATIC CHOICE® RELAY BOARD MODELS CDC320-CDC375	
DRAWING NUMBER: <b>C10486</b>	

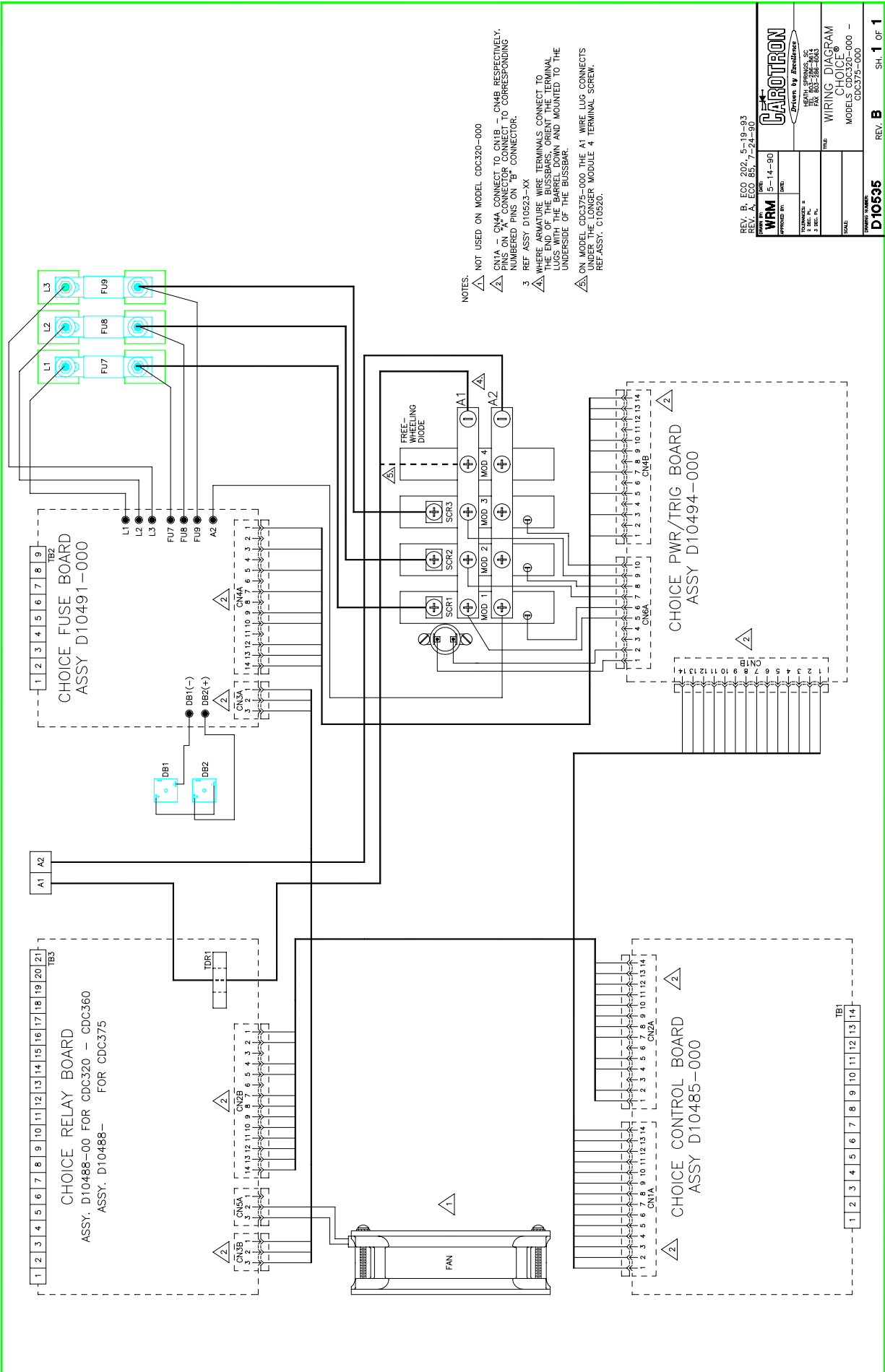
REV. B, ECO 133, 10-17-91  
 REV. A, ECO 81, 6-26-90



DRAWN BY: <b>HJH</b>	DATE: 10-17-91
APPROVED BY:	DATE:
TOLERANCES: # 2 DEC. PL. 3 DEC. PL.	
TITLE: SCHEMATIC CHOICE® RELAY BOARD MODEL CDC3150-000	
SCALE:	
DRAWING NUMBER: <b>C10793</b>	
REV. <b>1</b> OF <b>1</b>	

NOTES:  
 1. REF. ASSY. D10488-002 AND B.O.M. A10488-002.

  
 Driven by Excellence  
 HEATH SPRINGS, SC  
 TEL 803-286-8614  
 FAX 803-286-8063



NOTES:

- △ NOT USED ON MODEL CDC320-000
- △ CN1A - CN4A CONNECT TO CN1B - CN4B RESPECTIVELY. PINS ON 'A' CONNECTOR CONNECT TO CORRESPONDING NUMBERED PINS ON 'B' CONNECTOR.
- 3 REF ASSY D10523-XX
- △ WHERE ARMATURE WIRE TERMINALS CONNECT TO END OF THE BUSBAR, ORIENT THE TERMINAL LUGS TO THE BOARD AND MOUNTED TO THE UNDERSIDE OF THE BUSBAR.
- △ ON MODEL CDC375-000 THE #1 WIRE LUG CONNECTS UNDER THE LONGER MODULE #1 TERMINAL SCREEN. REF ASSY. C10520.

REV. B, EGO 202\_5-14-93  
REV. A, EGO 657\_2-24-90

FORM NO. WRM 5-14-90

APPROVED BY: [Signature]

DATE: [Blank]

BY: [Blank]

3 DEC. 93

2 DEC. 93

1 DEC. 93

DATE: [Blank]

SCALE: [Blank]

DRIVING NAME: [Blank]

REV. B

SH. 1 OF 1



Driven by Ametek

HEATH SPINDLE CO

1000 W. 10th St.

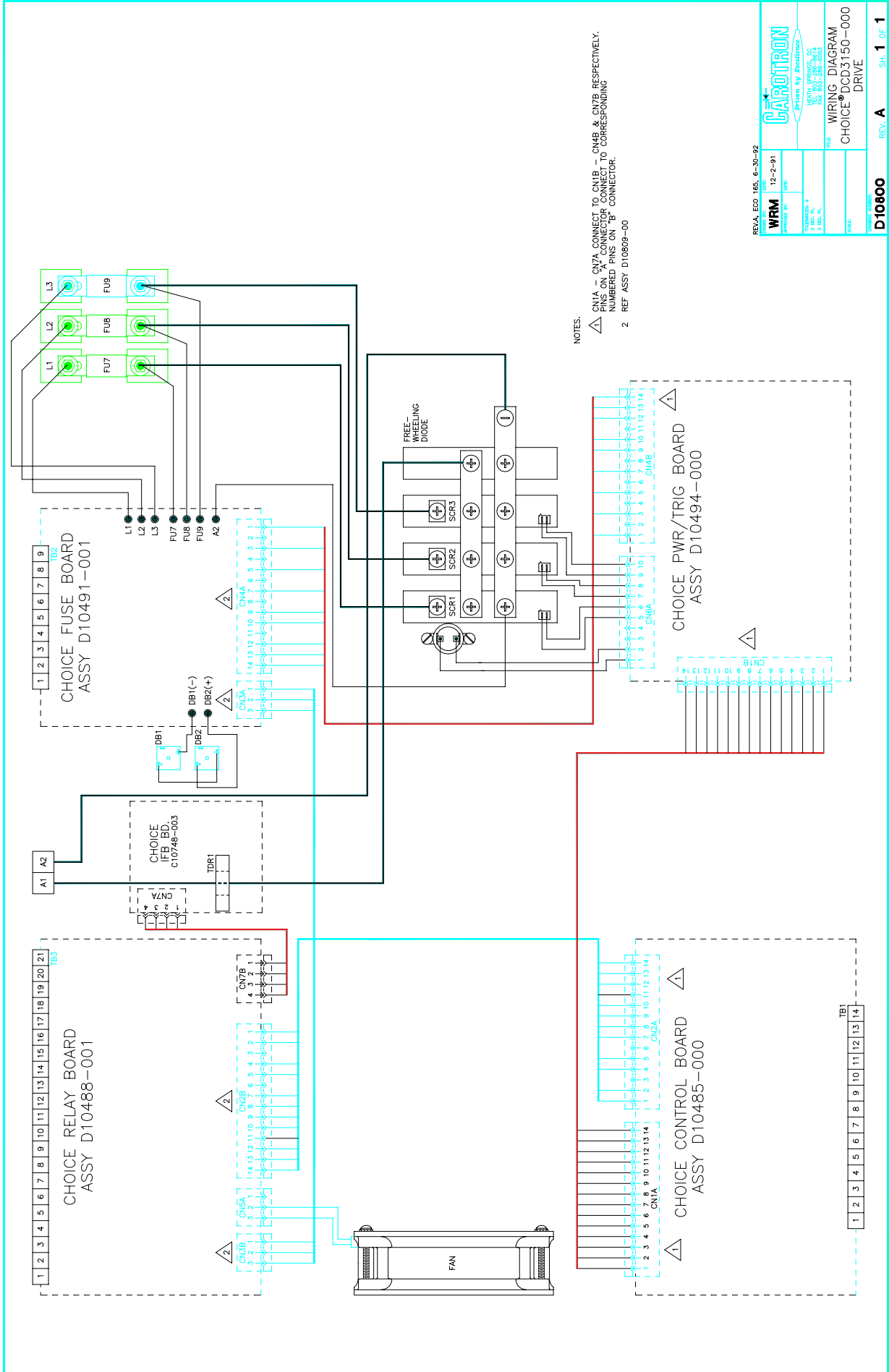
PA 302-388-6043

WIRING DIAGRAM

CHOICE

MODELS CDC320-000 -

CDC375-000



NOTES:

- 1. CN1A - CN1B CONNECT TO CN1B - CN14B & CN17B RESPECTIVELY. CN1A OR CN1B OR CN17B CONNECT TO CORRESPONDING NUMBERED PINS ON CN1D CONNECTOR.
- 2. REF ASSY D10809-00

REV. EDD 165 6-30-92

**WFRM** 12-2-91

DATE: 12-2-91

DESIGNED BY: [Blank]

DRIVEN BY: [Blank]

SCALE: [Blank]

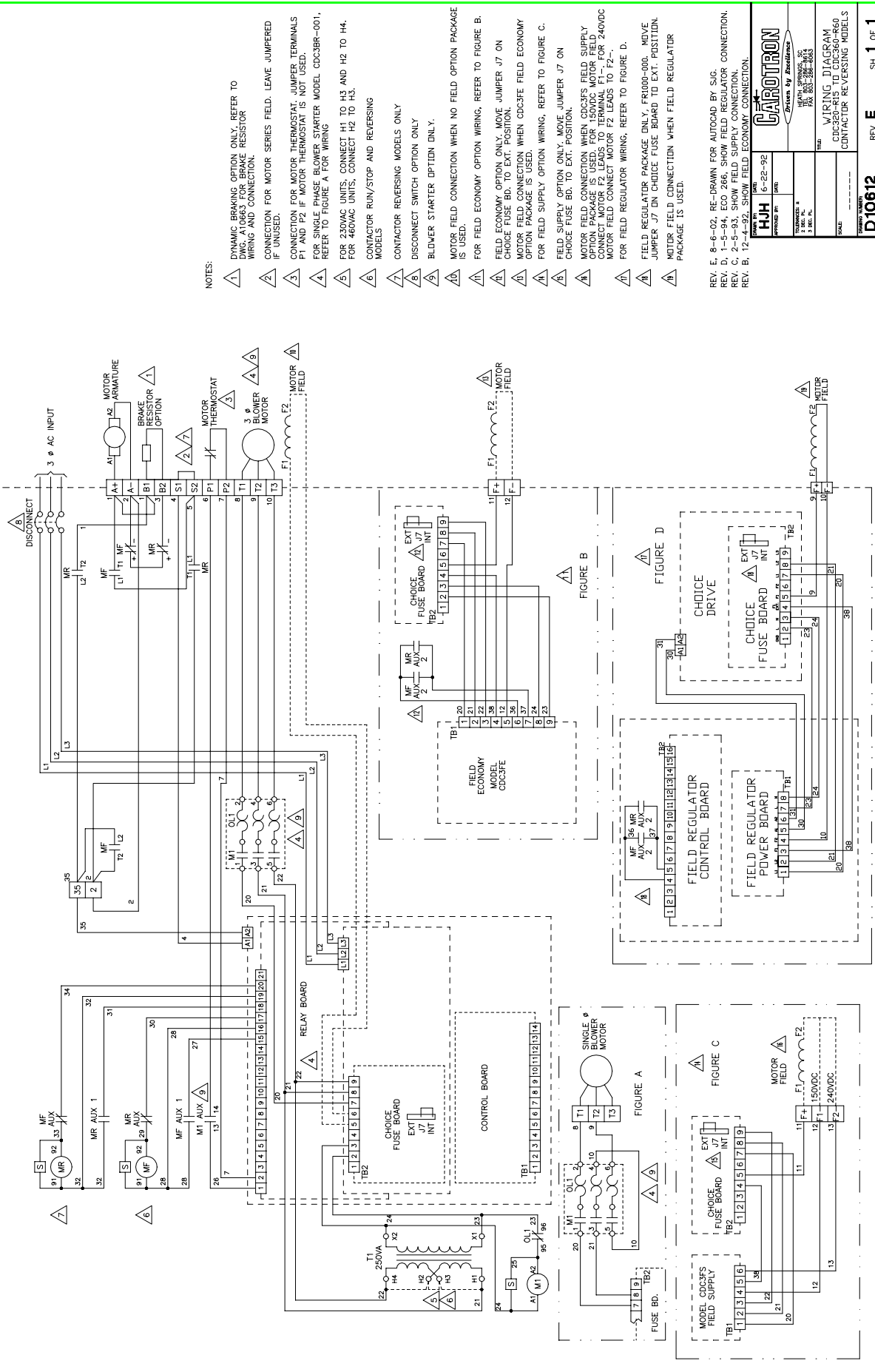
**CAROTRON**  
 Precision Air Resistance

NEW YORK, N.Y. 10017-2100  
 TEL: 212-351-3000  
 FAX: 212-351-3001

FILE: WIRING DIAGRAM  
 CHOICE®DCJ3150-000  
 DRIVE

**D10800** REV. A SH. 1 OF 1





**NOTES:**

- 1. DYNAMIC BRAKING OPTION ONLY. REFER TO DWG. A10663 FOR BRAKE RESISTOR WIRING AND CONNECTION.
- 2. CONNECTION FOR MOTOR SERIES FIELD. LEAVE JUMPERED IF UNUSED.
- 3. CONNECTION FOR MOTOR THERMOSTAT. JUMPER TERMINALS P1 AND P2 IF MOTOR THERMOSTAT IS NOT USED.
- 4. FOR SINGLE PHASE BLOWER STARTER MODEL CDC3BR-001, REFER TO FIGURE A FOR WIRING.
- 5. FOR 230VAC UNITS, CONNECT H1 TO H3 AND H2 TO H4. FOR 460VAC UNITS, CONNECT H2 TO H3.
- 6. CONTACTOR RUN/STOP AND REVERSING MODELS.
- 7. CONTACTOR REVERSING MODELS ONLY.
- 8. DISCONNECT SWITCH OPTION ONLY.
- 9. BLOWER STARTER OPTION ONLY.
- 10. MOTOR FIELD CONNECTION WHEN NO FIELD OPTION PACKAGE IS USED.
- 11. FOR FIELD ECONOMY OPTION WIRING, REFER TO FIGURE B.
- 12. FIELD ECONOMY OPTION ONLY. MOVE JUMPER J7 ON CHOICE FUSE BD. TO EXT. POSITION.
- 13. MOTOR FIELD CONNECTION WHEN COC3FE FIELD ECONOMY OPTION PACKAGE IS USED.
- 14. FOR FIELD SUPPLY OPTION WIRING, REFER TO FIGURE C.
- 15. FIELD SUPPLY OPTION ONLY. MOVE JUMPER J7 ON CHOICE FUSE BD. TO EXT. POSITION.
- 16. MOTOR FIELD CONNECTION WHEN COC3FE FIELD SUPPLY OPTION PACKAGE IS USED. FOR 150VDC MOTOR FIELD CONNECT MOTOR F2 LEADS TO TERMINAL F1-. FOR 240VDC MOTOR FIELD CONNECT MOTOR F2 LEADS TO F2-.
- 17. FOR FIELD REGULATOR WIRING, REFER TO FIGURE D.
- 18. FIELD REGULATOR PACKAGE ONLY. FR1000-000. MOVE JUMPER J7 ON CHOICE FUSE BOARD TO EXT. POSITION.
- 19. MOTOR FIELD CONNECTION WHEN FIELD REGULATOR PACKAGE IS USED.

REV. E, 8-6-92 RE-DRAWN FOR AUTOCAD BY S.G.  
 REV. D, 1-5-94, ECO 266, SHOW FIELD REGULATOR CONNECTION.  
 REV. C, 2-5-93, SHOW FIELD SUPPLY CONNECTION.  
 REV. B, 12-4-92, SHOW FIELD ECONOMY CONNECTION.

DATE	REV.	BY	DESCRIPTION
11/15/92	1	HJH	6-22-92
12/15/92	2	HJH	11-15-92
1/5/94	3	HJH	ECO 266
2/5/93	4	HJH	ECO 266
12/4/92	5	HJH	ECO 266

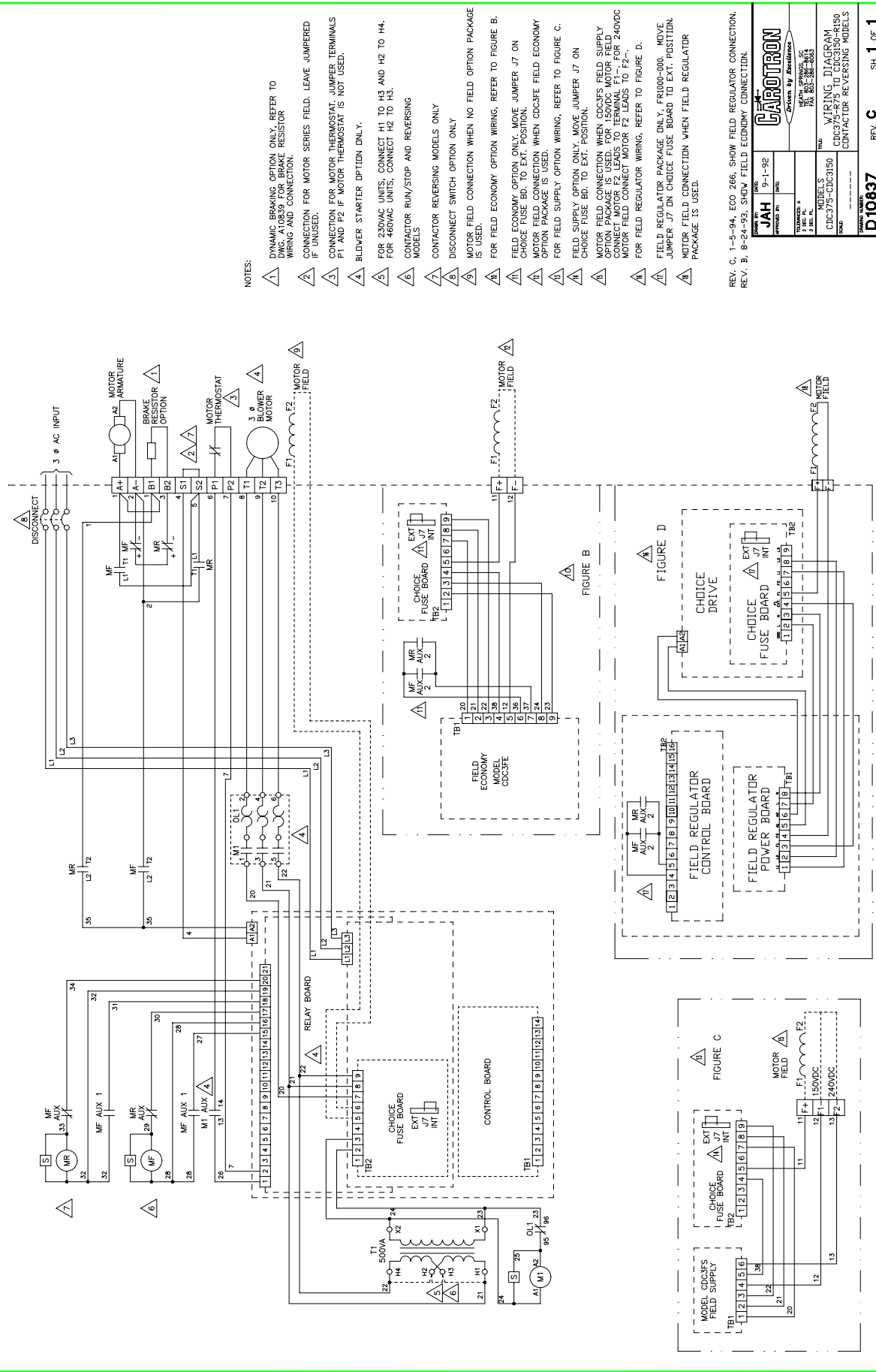
**DRIVEN BY ASSISTANCE**

**CAROTRON**  
 1100 W. 20TH ST. S.W.  
 DENVER, CO 80202-1003  
 TEL: 303-733-8000  
 FAX: 303-733-8003

**WIRING DIAGRAM**  
 CDC360-R15 TO CDC360-R60  
 CONTACTOR REVERSING MODELS

STANDARD VALUE

**D10612** REV. E SH. 1 OF 1

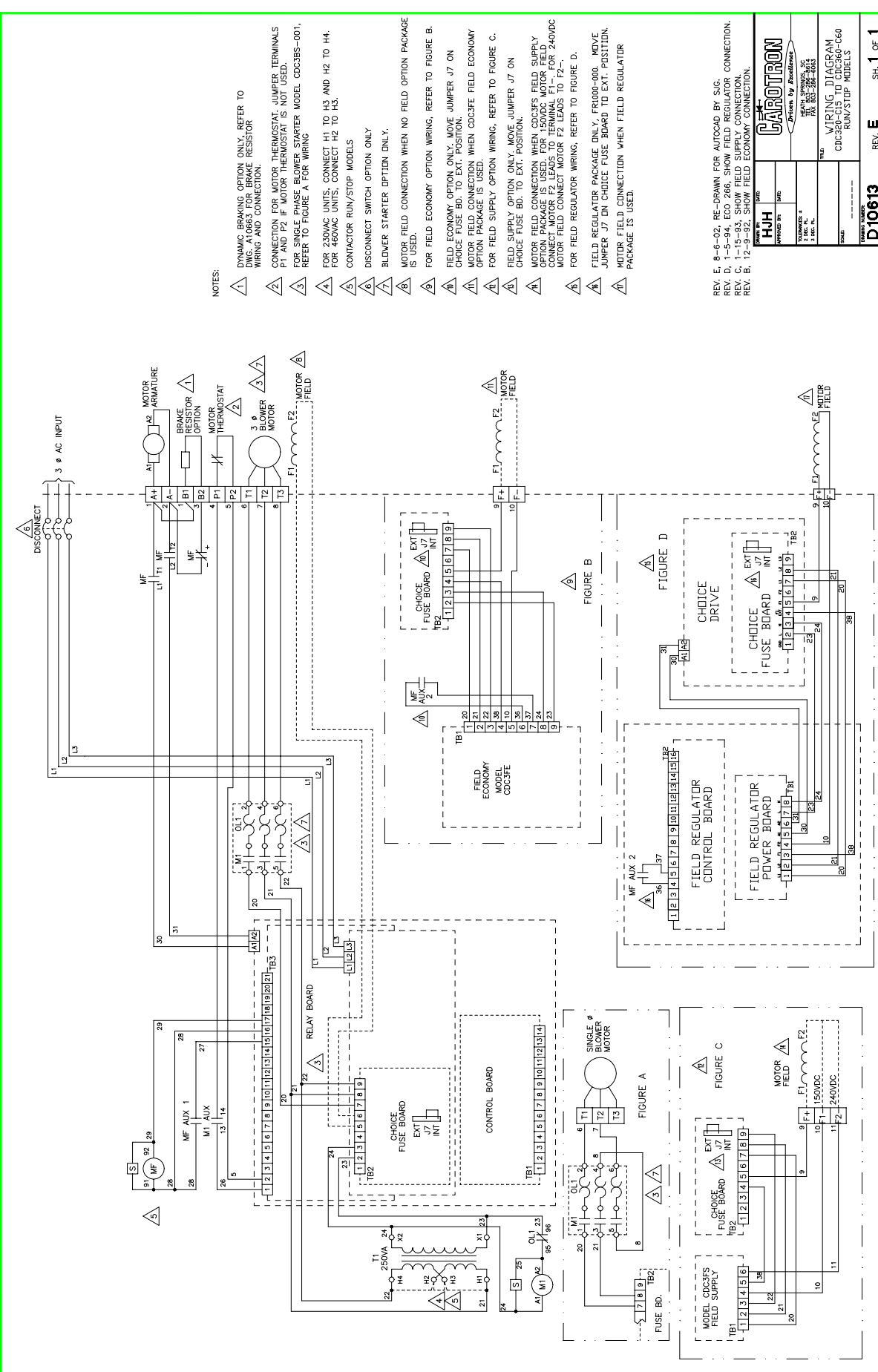


NOTES:

- △ 1. DYNAMIC BRAKING OPTION ONLY. REFER TO DWG. A10839 FOR BRAKE RESISTOR WIRING AND CONNECTION.
- △ 2. CONNECTION FOR MOTOR SERIES FIELD. LEAVE JUMPERED IF UNUSED.
- △ 3. CONNECTION FOR MOTOR THERMOSTAT. JUMPER TERMINALS P1 AND P2 IF MOTOR THERMOSTAT IS NOT USED.
- △ 4. BLOWER STARTER OPTION ONLY.
- △ 5. FOR 230VAC UNITS, CONNECT H1 TO H3 AND H2 TO H4. FOR 480VAC UNITS, CONNECT H2 TO H3.
- △ 6. CONTACTOR RUN/STOP AND REVERSING MODELS.
- △ 7. CONTACTOR SWITCH OPTION ONLY.
- △ 8. DISCONNECT SWITCH OPTION ONLY.
- △ 9. MOTOR FIELD CONNECTION WHEN NO FIELD OPTION PACKAGE IS USED.
- △ A. FOR FIELD ECONOMY OPTION WIRING, REFER TO FIGURE B.
- △ B. FIELD ECONOMY OPTION ONLY. MOVE JUMPER J7 ON CHOICE FUSE BD. TO EXT. POSITION.
- △ C. MOTOR FIELD CONNECTION WHEN COCSE FIELD ECONOMY OPTION PACKAGE IS USED.
- △ D. FOR FIELD SUPPLY OPTION WIRING, REFER TO FIGURE C.
- △ E. FIELD SUPPLY OPTION ONLY. MOVE JUMPER J7 ON CHOICE FUSE BD. TO EXT. POSITION.
- △ F. COCSE FIELD SUPPLY OPTION ONLY. CONNECTION WHEN L500C-MOTOR FIELD CONNECT MOTOR F2 LEADS TO TERMINAL F1. FOR 240VDC MOTOR FIELD CONNECT MOTOR F2 LEADS TO F2.
- △ G. FOR FIELD REGULATOR WIRING, REFER TO FIGURE D.
- △ H. FIELD REGULATOR PACKAGE ONLY. FR1000-000. MOVE JUMPER J7 ON CHOICE FUSE BOARD TO EXT. POSITION. PACKAGE IS USED.
- △ I. MOTOR FIELD CONNECTION WHEN FIELD REGULATOR PACKAGE IS USED.

REV. C, 1-5-94, ECO 266, SHOW FIELD REGULATOR CONNECTION.  
 REV. B, 8-24-93, SHOW FIELD ECONOMY CONNECTION.

REV. 27-1-92	<p>CABOTRON          FIELD SUPPLY &amp; REVERSING          1001 N. 12th St., Suite 200          Phoenix, AZ 85015</p>
DATE: 27-1-92	
BY: JAH	
MODEL: C10375-CDC150	TITLE: WIRING DIAGRAM PART: C10375-CDC150 CONTRACTOR REVERSING MODELS
<b>D10837</b>	

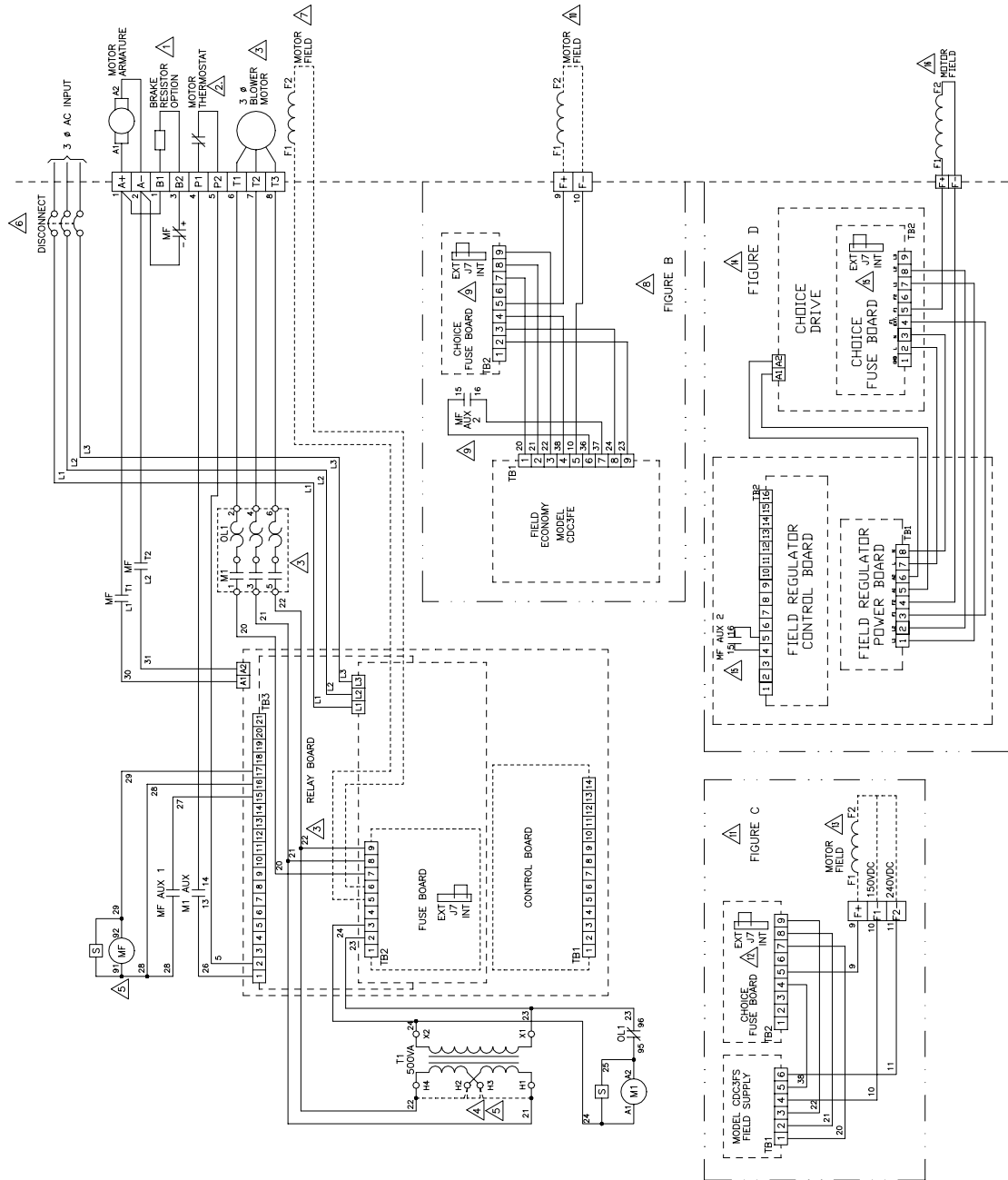


**NOTES:**

- △ DYNAMIC BRAKING OPTION ONLY. REFER TO DIMS. A10663 FOR BRAKE RESISTOR WIRING AND CONNECTION.
- △ CONNECTION FOR MOTOR THERMOSTAT. JUMPER TERMINALS P1 AND P2 IF MOTOR THERMOSTAT IS NOT USED.
- △ FOR SINGLE PHASE BLOWER STARTER MODEL C0C3B5-001, REFER TO FIGURE A FOR WIRING.
- △ FOR 230VAC UNITS, CONNECT H1 TO H3 AND H2 TO H4.
- △ FOR 460VAC UNITS, CONNECT H2 TO H3.
- △ CONTACTOR RUN/STOP MODELS
- △ DISCONNECT SWITCH OPTION ONLY
- △ BLOWER STARTER OPTION ONLY.
- △ MOTOR FIELD CONNECTION WHEN NO FIELD OPTION PACKAGE IS USED.
- △ FOR FIELD ECONOMY OPTION WIRING, REFER TO FIGURE B.
- △ FIELD ECONOMY OPTION ONLY. MOVE JUMPER J7 ON CHOICE FUSE BOARD TO EXT. POSITION.
- △ MOTOR FIELD CONNECTION WHEN C0C3FE FIELD ECONOMY OPTION PACKAGE IS USED.
- △ FOR FIELD SUPPLY OPTION WIRING, REFER TO FIGURE C.
- △ FIELD SUPPLY OPTION ONLY. MOVE JUMPER J7 ON CHOICE FUSE BD. TO EXT. POSITION.
- △ MOTOR FIELD CONNECTION WHEN C0C3FS FIELD SUPPLY MODEL C0C3FS-001 IS USED. CONNECT MOTOR F2 LEADS TO TERMINAL F1. FOR 244VDC MOTOR FIELD CONNECT MOTOR F2 LEADS TO F2-.
- △ FOR FIELD REGULATOR WIRING, REFER TO FIGURE D.
- △ FIELD REGULATOR PACKAGE ONLY. FR1000-000. MOVE JUMPER J7 ON CHOICE FUSE BOARD TO EXT. POSITION.
- △ MOTOR FIELD CONNECTION WHEN FIELD REGULATOR PACKAGE IS USED.

REV. E, 8-6-02. RE-DRAWN FOR AUTOCAD BY S.G.  
 REV. D, 1-5-94. ECO 286. SHOW FIELD REGULATOR CONNECTION.  
 REV. C, 1-15-93. SHOW FIELD SUPPLY CONNECTION.  
 REV. B, 1-2-92. SHOW FIELD ECONOMY CONNECTION.

	HEAVY SPRINGS, SC P.O. BOX 288 28000
TITLE: WIRING DIAGRAM C0C3B5-001 TO C0C3B5-C60 RUN/STOP MODELS	
DRAWN BY:	CHECKED BY:
DATE:	DATE:



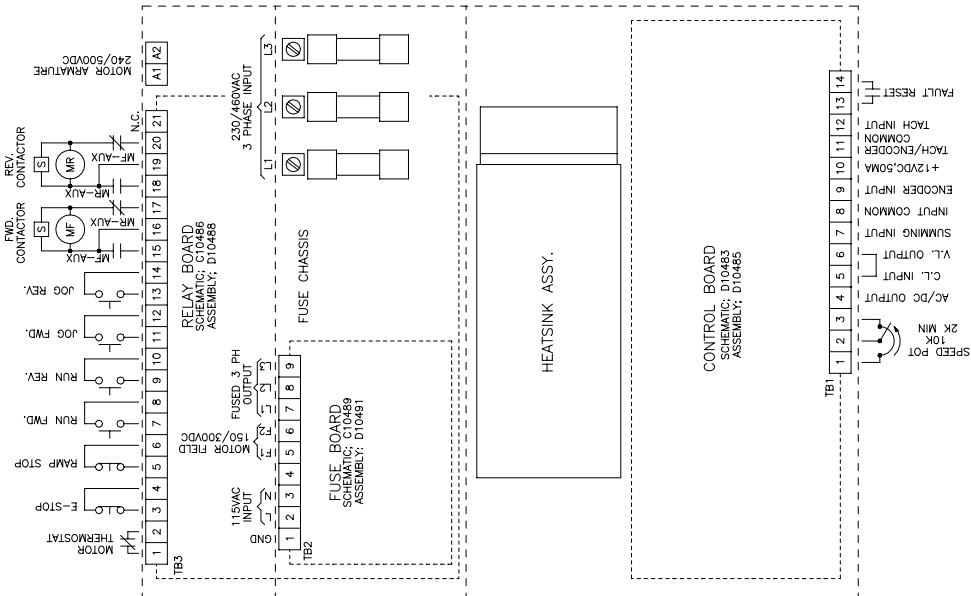
- NOTES:
- 1. DYNAMIC BRAKING OPTION ONLY. REFER TO DWG. A10839 FOR BRAKE RESISTOR WIRING AND CONNECTIONS.
  - 2. CONNECTION FOR MOTOR THERMOSTAT. JUMPER TERMINALS P1 AND P2 IF MOTOR THERMOSTAT IS NOT USED.
  - 3. BLOWER STARTER OPTION ONLY
  - 4. FOR 230VMS UNITS, CONNECT H1 TO H3 AND H2 TO H4. FOR 460VAC UNITS, CONNECT H2 TO H3.
  - 5. CONTACTOR RUN/STOP MODELS
  - 6. DISCONNECT SWITCH OPTION ONLY
  - 7. MOTOR FIELD CONNECTION WHEN NO FIELD OPTION PACKAGE IS USED.
  - 8. MOTOR FIELD CONNECTION WHEN FIELD OPTION PACKAGE IS USED.
  - 9. FOR FIELD ECONOMY OPTION WIRING, REFER TO FIGURE B. CHOICE FUSE BD. TO EXT. POSITION.
  - 10. FIELD ECONOMY OPTION ONLY. MOVE JUMPER J7 ON CHOICE FUSE BD. TO EXT. POSITION.
  - 11. MOTOR FIELD CONNECTION WHEN CDC3FE FIELD ECONOMY OPTION PACKAGE IS USED.
  - 12. FOR FIELD SUPPLY OPTION WIRING, REFER TO FIGURE C. CHOICE FUSE BD. TO EXT. POSITION.
  - 13. FIELD SUPPLY OPTION ONLY. MOVE JUMPER J7 ON CHOICE FUSE BD. TO EXT. POSITION.
  - 14. MOTOR FIELD CONNECTION WHEN CDC3FS FIELD SUPPLY OPTION PACKAGE IS USED. FOR 150VDC MOTOR FIELD CONNECT MOTOR F2 LEADS TO TERMINAL F1--FOR 240VDC MOTOR FIELD CONNECT MOTOR F2 LEADS TO F2--.
  - 15. FOR FIELD REGULATOR WIRING, REFER TO FIGURE D.
  - 16. FIELD REGULATOR PACKAGE ONLY. FRC008-000. MOVE JUMPER J7 ON CHOICE FUSE BOARD TO EXT. POSITION
  - 17. MOTOR FIELD CONNECTION WHEN FIELD REGULATOR PACKAGE IS USED.

REV. 5, 1-5-84, EGO 268, SHOW FIELD REGULATOR CONNECTION.  
 REV. 6, 8-24-83, SHOW FIELD ECONOMY CONNECTION.

<b>JAH</b>	DATE	1-16-92
ISSUED BY	DATE	
DESIGNED BY	DATE	
MODELS	TIME	
CDC375-CDC3150		
WIRING DIAGRAM		
CDC375-C75 TO CDC3150-C150		
RUN/STOP MODELS		
FORM NO. 100		

**Garatron**  
 Drives by Resistance  
 HEAVY DUTY, 50  
 AMP, 240VAC, 60Hz

**D10838** REV. B SH. 1 OF 1



CONNECTION DIAGRAM

DATE	3-28-90
DESIGNED BY	HJH
APPROVED BY	_____
DATE	_____
REVISED BY	_____
DATE	_____
SCALE	_____
DRAWING NUMBER	D10521
REV.	A
SH.	1 OF 1

**CAROTRON**  
Driven by Ametron

HEATH STREET, ST. LOUIS, MO. 63103  
TEL. 314-863-2800  
FAX 314-863-2803

CONNECTION DIAGRAM  
CHOICE CONTROL

**NOTES:**

# Standard Terms & Conditions of Sale

## 1. General

The Standard Terms and Conditions of Sale of Carotron, Inc. (hereinafter called "Company") are set forth as follows in order to give the Company and the Purchaser a clear understanding thereof. No additional or different terms and conditions of sale by the Company shall be binding upon the Company unless they are expressly consented to by the Company in writing. The acceptance by the Company of any order of the Purchaser is expressly conditioned upon the Purchaser's agreement to said Standard Terms and Conditions. The acceptance or acknowledgement, written, oral, by conduct or otherwise, by the Company of the Purchaser's order shall not constitute written consent by the Company to addition to or change in said Standard Terms and Conditions.

## 2. Prices

Prices, discounts, allowances, services and commissions are subject to change without notice. Prices shown on any Company published price list and other published literature issued by the Company are not offers to sell and are subject to express confirmation by written quotation and acknowledgement. All orders of the Purchaser are subject to acceptance, which shall not be effective unless made in writing by an authorized Company representative at its office in Heath Springs, S.C. The Company may refuse to accept any order for any reason whatsoever without incurring any liability to the Purchaser. The Company reserves the right to correct clerical and stenographic errors at any time.

## 3. Shipping dates

Quotation of a shipping date by the Company is based on conditions at the date upon which the quotation is made. Any such shipping date is subject to change occasioned by agreements entered into previous to the Company's acceptance of the Purchaser's order, governmental priorities, strikes, riots, fires, the elements, explosion, war, embargoes, epidemics, quarantines, acts of God, labor troubles, delays of vendors or of transportation, inability to obtain raw materials, containers or transportation or manufacturing facilities or any other cause beyond the reasonable control of the Company. In no event shall the Company be liable for consequential damages for failure to meet any shipping date resulting from any of the above causes or any other cause.

In the event of any delay in the Purchaser's accepting shipment of products or parts in accordance with scheduled shipping dates, which delay has been requested by the Purchaser, or any such delay which has been caused by lack of shipping instructions, the Company shall store all products and parts involved at the Purchaser's risk and expense and shall invoice the Purchaser for the full contract price of such products and parts on the date scheduled for shipment or on the date on which the same is ready for delivery, whichever occurs later.

## 4. Warranty

The Company warrants to the Purchaser that products manufactured or parts repaired by the Company, will be free, under normal use and maintenance, from defects in material and workmanship for a period of one (1) year after the shipment date from the Company's factory to the Purchaser. The Company makes no warranty concerning products manufactured by other parties.

As the Purchaser's sole and exclusive remedy under said warranty in regard to such products and parts, including but not limited to remedy for consequential damages, the Company will at its option, repair or replace without charge any product manufactured or part repaired by it, which is found to the Company's satisfaction to be so defective; provided, however, that (a) the product or part involved is returned to the Company at the location designated by the Company, transportation charges prepaid by the Purchaser; or (b) at the Company's option the product or part will be repaired or replaced in the Purchaser's plant; and also provided that (c) the Company is notified of the defect within one (1) year after the shipment date from the Company's factory of the product or part so involved.

The Company warrants to the Purchaser that any system engineered by it and started up under the supervision of an authorized Company representative will, if properly installed, operated and maintained, perform in compliance with such system's written specifications for a period of one (1) year from the date of shipment of such system.

As the Purchaser's sole and exclusive remedy under said warranty in regard to such systems, including but not limited to remedy for consequential damages, the Company will, at its option, cause, without charges any such system to so perform, which system is found to the Company's satisfaction to have failed to so perform, or refund to the Purchaser the purchase price paid by the Purchaser to the Company in

regard thereto; provided, however, that (a) Company and its representatives are permitted to inspect and work upon the system involved during reasonable hours, and (b) the Company is notified of the failure within one (1) year after date of shipment of the system so involved.

The warranties hereunder of the Company specifically exclude and do not apply to the following:

a. Products and parts damaged or abused in shipment without fault of the Company.

b. Defects and failures due to operation, either intentional or otherwise, (1) above or beyond rated capacities, (2) in connection with equipment not recommended by the Company, or (3) in an otherwise improper manner.

c. Defects and failures due to misapplication, abuse, improper installation or abnormal conditions of temperature, humidity, abrasives, dirt or corrosive matter.

d. Products, parts and systems which have been in any way tampered with or altered by any party other than an authorized Company representative.

e. Products, parts and systems designed by the Purchaser.

f. Any party other than the Purchaser.

The Company makes no other warranties or representation, expressed or implied, of merchantability and of fitness for a particular purpose, in regard to products manufactured, parts repaired and systems engineered by it.

## 3. Terms of payment

Standard terms of payment are net thirty (30) days from date of the Company invoice. For invoice purposed, delivery shall be deemed to be complete at the time the products, parts and systems are shipped from the Company and shall not be conditioned upon the start up thereof. Amounts past due are subject to a service charge of 1.5% per month or fraction thereof.

## 6. Order cancellation

Any cancellation by the Purchaser of any order or contract between the Company and the Purchaser must be made in writing and receive written approval of an authorized Company representative at its office in Heath Springs, S.C. In the event of any cancellation of an order by either party, the Purchaser shall pay to the Company the reasonable costs, expenses, damages and loss of profit of the Company incurred there by, including but not limited to engineering expenses and expenses caused by commitments to the suppliers of the Company's subcontractors, as determined by the Company.

## 7. Changes

The Purchaser may, from time to time, but only with the written consent of an authorized Company representative, make a change in specifications to products, parts or systems covered by a purchase order accepted by the company. In the event of any such changes, the Company shall be entitled to revise its price and delivery schedule under such order.

## 8. Returned material

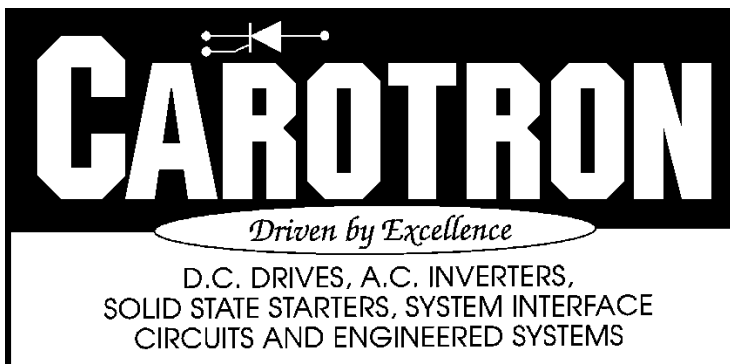
If the Purchaser desires to return any product or part, written authorization thereof must first be obtained from the Company which will advise the Purchaser of the credit to be allowed and restocking charges to be paid in regard to such return. No product or part shall be returned to the Company without a "RETURN TAG" attached thereon which has been issued by the Company.

## 9. Packing

Published prices and quotations include the Company's standard packing for domestic shipment. Additional expenses for special packing or overseas shipments shall be paid by the Purchaser. If the Purchaser does not specify packing or accepts parts unpacked, no allowance will be made to the Purchaser in lieu of packing.

## 10. Standard transportation policy

Unless expressly provided in writing to the contrary, products, parts and systems are sold f.o.b. first point of shipment. Partial shipments shall be permitted, and the Company may invoice each shipment separately. Claims for non-delivery of products, parts and systems, and for damages thereto must be filed with the carrier by the Purchaser. The Company's responsibility therefor shall cease when the carrier signs for and accepts the shipment.



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