

1395 Troubleshooting Guide

Malfunctions Not Indicated by a Fault

General

Some drive malfunctions or operating difficulties do not induce drive fault responses. In some cases the drive is simply not doing what the user desires and a general guide to help determine what is required for the desired response is given here. Each section below will deal with either the function block that is causing the malfunction or in some cases the board related circuits that may effect the desired response.

Logic Control Malfunctions

The Logic control function block is used to command the drive to perform various operations. These include Start, Stop, Jog, etc. The “Logic Command” parameters 150, 151, and 152 are the configuration sink parameters where the commands are specified. The logic bit assignments for all logic commands are identical. Each of these logic command parameters has an assigned order of priority.

Parameter 152 has the highest priority. If Command Enable (Bit 8) is set all other logic command parameters are overridden. An exception is the STOP request (Bit 11) which is always active in every logic parameter at all times. Parameter 152 is the logic command linked to the Bulletin 1300 Programming Terminal and is used when the programming terminal has LOCAL Control.

Parameter 150 is the second highest priority. If bit 8 in parameter 152 is clear and bit 8 is set in parameter 150, then parameter 150 issues the logic commands. If bit 8 of parameters 152 and 150 are clear, then control reverts to the lowest priority logic command, parameter 151. Parameter 150 and 151 can be linked to any adapter's source configuration parameters. It is important to understand which logic command has control to achieve proper operation.

The 1395 maintains status bits in parameter 100 “Logic Status” which indicates which logic command is presently active. Bits 2 and 3 are used to report which of the logic commands are active. Table 3-A lists the bit definitions:

Table 3.A
Parameter 100 Bit Status Definitions

| Bit 3 | Bit 2 | Definition |
|--------------|--------------|--|
| 0 | 1 | Parameter 150 “Logic Command 1” Active |
| 1 | 0 | Parameter 151 “Logic Command 2” Active |
| 1 | 1 | Parameter 152 “Logic Command 3” Active |

A list of logic control malfunctions, symptoms, and possible causes and solutions is provided below:

Malfunction: Drive Will Not Start.

Symptom: External Start Command issued, corresponding bit in Logic Command does not change states.

Solution: External wiring to the adapter or the PLC program is setting the wrong bit. Look for other bits toggling in the Logic Command when initiating the START command. The Discrete adapters digital inputs are programmable to any of the 16 bit positions. Verify that the inputs are properly linked to the desired bits of the logic command.

Solution: An incorrect configuration link may exist. Check the source parameter from the adapter in the drive to determine if the correct bit is being set. If it is, check that the source parameter is linked to the proper sink parameter.

Symptom: External Start Command issued, proper bit is set in Logic Command.

Solution: Check the READY status bit in parameter 100 “Logic Status” is set to 1. The drive will not start if the ready bit is set to 0. Any of the following conditions will cause the READY bit to be set to 0: A fault, ECOAST string open, any stop bit in any of the three logic commands is set or Armature Voltage is greater than 10% of rated.

Solution: ECOAST string is open preventing the drive from starting. Check ECOAST status parameter 101 Bit 1 when VP faults are selected (parameter 630 = 1). Close ECOAST string prior to issuing the START command.

Solution: A STOP bit is set in one of the three Logic Commands. Check parameters 150, 151, and 152 bit 11 for a set condition. If the bit is set, determine the cause, as the drive will not allow a START if any STOP bit is set.

Solution: The Bulletin 1300 Programming Terminal has LOCAL control. Check parameter 152 bit 8. If set, the Programming terminal has control, release LOCAL control at the terminal.

Solution: The wrong Logic Command is selected. If bit 8 in parameter 152 is clear and bit 8 is set in parameter 150, then parameter 150 issues the logic commands. If bit 8 of parameters 152 and 150 are clear then control reverts to the lowest priority logic command, parameter 151, regardless of the status of bit 8 in parameter 151.

Solution: The drive is executing a CLEAR FAULT. If bit 14 in Logic Command is set, the drive will execute a Clear Fault until the bit is cleared. A start command will not be acknowledged when a CLEAR FAULT is active.

Solution: Contactor wiring is incorrect. If external circuitry is not required, verify that a jumper is present between TB2-8 & 9 (Series A) or TB2-6 & 7 (Series B 3.6 - 110A).

Symptom: Drive starts but stops immediately.

Solution: An incorrect START type is selected in parameter 624 “Maintained Start”. If parameter 624 = 1 the start command must be maintained. If the START is removed, the drive will initiate a “Controlled Stop”. If parameter 624 = 0, the Start command will be treated as a momentary type input (rising edge triggered) and a STOP command is required to stop the drive.

Malfunction: Drive Stops even though No STOP Command was Issued.

Symptom: STOP (bit 11) is set in one of the logic commands.

Solution: A safety system external to the drive is issuing a STOP command. This could be coming through any of the Adapters.

Solution: The STOP key on the Bulletin 1300 Programming Terminal was pressed which will stop the drive regardless if LOCAL mode is active.

Symptom: No STOP bits were set, drive stopped.

Solution: ECOAST string was opened during operation. ECOAST string must be closed prior to attempting to restart the drive.

Solution: A drive fault was detected and stopped the drive. Examine the Fault Queue to determine the exact cause.

Malfunction: Contactor Remains Closed After A STOP Command.

Symptom: Same

Solution: The Close Contactor (bit 13) is set in the logic command. Determine what is activating this bit and correct.

Link / Configuration Parameter Malfunctions

The configuration parameters determine where and how the real-time Input and Output signals will be used by the 1395 drive. These types of problems can usually be avoided if the Start-up Procedure is closely followed and the application is well defined. Often the problem can be tracked to a parameter entry error during programming.

Malfunction: An error in the configuration of the drive often exhibits itself in sink parameters not reflecting the desired input signals from the source parameters.

Solution: The easiest way to troubleshoot this type of problem is to start examining the source parameter closest to the actual input. In the case of a signal coming from one of the adapters, verify that the source parameter data is correct. If it is not, the problem exists between the origin of the signal and the Adapter Board.

Solution: If the adapter's source parameter is correct then check the sink parameter that is linked to it. The data should be exactly the same, taking into account any unit conversions that may exist. If the data is not exact, a problem in the configuration links exist. This methodology can be used to track data throughout the 1395 drive.

Solution: If the 1395 has experienced a Hard or Soft Fault, the System Processor will not process configuration links that direct data transfer to, or from, a processor that is faulted. The same is true if an attempt to direct data to an adapter board that is not mounted is attempted.

Velocity Control Malfunctions

Velocity control is the function block which controls the direction and velocity of the motor. This function block has many set-up and configuration parameters which can affect the operation and performance of the drive. It deals not only with velocity regulation but with torque regulation and most motor related functions. It is important that the Start-up procedure has been properly performed before attempting these troubleshooting techniques.

Below is a list of malfunctions, symptoms, and possible solutions.

Malfunction: The motor is rotating at the wrong velocity

Symptom: The motor velocity is incorrect, but remains constant during varying loads.

Solution: The velocity reference selected is incorrect. The initial velocity reference to the drive is selected in the Logic Command word. Bits 0-2 select the reference to be used. Control of the reference selection is made in the active Logic Command word. Logic Command Velocity Reference Selection is shown in Table 3-B:

Table 3.B
Logic Command Definitions

| Bits | 2 | 1 | 0 | Definition | Associated Parameter |
|------|---|---|---|-----------------------------|----------------------|
| | 0 | 0 | 0 | External Velocity Reference | 154 |
| | 0 | 0 | 1 | Preset Speed 1 | 633 |
| | 0 | 1 | 0 | Preset Speed 2 | 634 |
| | 0 | 1 | 1 | Preset Speed 3 | 635 |
| | 1 | 0 | 0 | Preset Speed 4 | 636 |
| | 1 | 0 | 1 | Preset Speed 5 | 637 |

Solution: The External Velocity Reference is correctly selected, but the value reflected in the configuration parameter 154 "Vel Ref Whole" is incorrect. The user supplied reference from one of the adapter boards must be correctly linked to parameter 154.

Solution: Verify that the configuration links are correctly entered. If parameter 154 is linked to an analog input parameter on the Discrete Adapter, verify that the scaling and offset parameters are properly calibrated for that analog input channel. Also verify that the analog signal being input to the board is correct. For more information refer to the Discrete Adapter Malfunctions section of this chapter.

Solution: If the Preset speed value is correct, verify that the velocity limits are not clamping the reference. Parameter 608 "Fwd Speed Lim" determines the forward velocity reference clamp and parameter 607 "Rev Speed Lim" determines the reverse

velocity clamp. The velocity reference, parameter 102, will be clamped at these limits even if the preset or external velocity reference is higher.

Solution: If parameter 106 “Velocity Fdbk” does not reflect the actual motor velocity as measured by a hand tach or other independent measuring device. The scaling of the velocity feedback is incorrect. Verify that parameter 621 “Fdbk Device Type” reflects the proper velocity feedback device being used.

- 0 = Encoder Feedback Selected
- 1 = Armature Voltage Feedback Selected
- 2 = Analog Tachometer Selected
- 3 = No Feedback Device Selected

Solution: If Encoder Feedback is selected, verify that parameter 609 “Encoder PPR” correctly reflects the pulses/rev rating of the device being used.

Solution: If Armature Voltage Feedback is selected verify that parameter 610 “Rated Motor Volt” and parameter 606 “Base Motor Speed” are correctly entered according to the motor nameplate data. Also verify that parameter 739 “K Arm Volts” is properly scaled to the drive voltage rating. Verify that the field is functioning properly by checking that parameter 612 “Rated Fld Mtr Cur” reflects the rated field current on the motor nameplate. Enter the fields bridge rating as determined by the jumper setting on the Feedback board and the drive nameplate rating, in parameter 616 “Rated Fld Brdg I”. The field bridge jumper should select the current rating that is just above the motor field rating.

Solution: If an analog tachometer is used, verify that the offset and scaling parameters associated with the adapter's analog input channel are correctly set-up.

Symptom: The motor velocity decreases when the load on the motor increases. Torque varies proportional to the load.

Solution: The Droop function is incorrectly activated or set-up. Droop allows the velocity to decrease as a function of load torque. As the load on the motor increases the final velocity reference will decrease based on the values of the set-up parameters for the droop function. If parameter 103 is equal to the desired velocity reference but parameter 104 “Final Vel Ref” is not, then the Droop control is affecting the reference. Parameter 657 “Droop Percent” sets the reduction in velocity, in percentage of base speed, that will occur at rated load. Parameter 658 “Droop Filter” determines the gain of a low pass filter which effects the response of the reduction in velocity due to an increase in load.

Symptom: The motor velocity decreases due to insufficient motor torque being commanded for the load present. Torque command remains constant or decreases.

Solution: The torque taper control may be limiting the torque command. Torque taper is used to reduce the current limit as a function of speed. Set-up is accomplished through parameter 665 “Strt Taper Speed” which sets the velocity at which the maximum torque will begin to be limited. Parameter 666 “End Taper Speed” which set the velocity where the maximum torque will be fully limited, and parameter 667 “Min Taper Cur” which sets the maximum torque level at end taper speed. Verify that this function is properly set-up and not interfering with normal operation.

Symptom: The motor velocity decreases due to insufficient armature current being output to the motor. The torque command accurately reflects the output from the velocity regulator but the corresponding armature current reference remains constant or decreases.

Solution: The armature current reference, parameter 111 “Arm Current Ref” is being limited by the forward or reverse armature current bridge limits. Parameter 663 “Fwd Brdg Cur Lim” specifies the forward bridge limit while parameter 664 “Rev Brdg Cur Lim” specifies the limit for the reverse bridge. Verify that these parameters are properly set-up to allow for normal operation.

Solution: The motor or bridge set-up parameters are incorrectly entered. Verify that parameter 611 “Motor FLA” and parameter 615 “Rated Arm Brdg I” are properly entered. These effect the scaling of torque command to armature current reference.

Malfunction: Motor accelerates or decelerates incorrectly.

Symptom: Motor accelerates too fast for application.

Solution: The ramp control is disabled in the active Logic Command. Bit 5 must be cleared for the ramp control to function.

Solution: Parameter 651 “Accel Time” is too small. This parameter specifies the Accel rate as the total time to accelerate from 0 to base speed.

Solution: Parameter 663 “Fwd Brdg Lim” is set too high. This parameter controls the armature current output during acceleration which directly controls maximum torque available.

Solution: If the motor is accelerating under the JOG command verify that the JOG ramp enable is set. The ramp enable for JOG is activated through parameter 626 “Jog Ramp Enable”. If parameter 626 is set to 1, the programmed ramp rates will be used. If parameter 626 is set to 0, no ramp will be implemented during JOG commands.

Symptom: Motor accelerates too slow for application.

Solution: Parameter 651 “Accel Time” is too large. This parameter specifies the Accel rate as the total time to accelerate from 0 to base speed.

Solution: The ramp control is enabled in the active Logic Command. If no ramp control is desired, bit 5 in the active Logic Command must be set for the ramp control to be by-passed.

Solution: Parameter 663 “Fwd Brdg Lim” is set too low. This parameter controls the armature current output during acceleration which directly controls maximum torque available.

Solution: The torque taper control may be limiting the torque command. Torque taper is used to reduce the current limit as a function of speed. Its set-up is accomplished through parameter 665 “Strt Taper Speed” which sets the velocity at which the maximum torque will begin to be limited. Parameter 666 “End Taper Speed” which sets the velocity where the maximum torque will be fully limited, and parameter 667 “Min Taper Cur” which sets the maximum torque level at end taper speed.

Solution: Insufficient torque may be available due to improper field set-up. The motor field parameters must be properly set up to obtain maximum available torque. Verify that the field control is properly calibrated.

Solution: If the motor is accelerating under the JOG command verify that the JOG ramp enable is set. The ramp enable for JOG is activated through parameter 626 “Jog Ramp Enable”. If parameter 626 is set to 1, the programmed ramp rates will be used. If parameter 626 is set to 0, no ramp will be implemented during JOG commands.

Symptom: Motor decelerates too fast for application.

Solution: The ramp control is disabled in the active Logic Command. Bit 5 must be cleared for the ramp control to function.

Solution: Parameter 652 “Decel Time” is too small. This parameter specifies the Decel rate as the total time to decelerate from base speed to zero.

Solution: Parameter 664 “Rev Brdg Lim” is set too high. This parameter controls the armature current output during deceleration which directly controls maximum torque available.

Solution: If the motor is decelerating under the JOG command verify that the JOG ramp enable is set. The ramp enable for JOG is activated through parameter 626 “Jog Ramp Enable”. If parameter 626 is set to 1, the programmed ramp rates will be used. If parameter 626 is set to 0, no ramp will be implemented during JOG commands.

Symptom: Motor decelerates too slow for application.

Solution: Parameter 652 “Decel Time” is too large. This parameter specifies the decel rate as the total time to decelerate from base speed to zero.

Solution: The ramp control is enabled in the active Logic Command. If no ramp control is desired, bit 5 in the active Logic Command must be set for the ramp control to be by-passed.

Solution: Parameter 664 “Rev Brdg Lim” is set too low. This parameter controls the armature current output during deceleration which directly controls maximum torque available.

Solution: The torque taper control may be limiting the torque command. Torque taper is used to reduce the current limit as a function of speed. Its set-up is accomplished through parameter 665 “Strt Taper Speed” which sets the velocity at which

the maximum torque will begin to be limited. Parameter 666 “End Taper Speed” which set the velocity where the maximum torque will be fully limited, and parameter 667 “Min Taper Cur” which sets the maximum torque level at end taper speed.

Solution: Insufficient torque may be available due to improper field set-up. The motor field parameters must be properly set up to obtain maximum available torque. Verify that the field control is properly calibrated.

Solution: If the motor is decelerating under the JOG command verify that the JOG ramp enable is set. The ramp enable for JOG is activated through parameter 626 “Jog Ramp Enable”. If parameter 626 is set to 1, the programmed ramp rates will be used. If parameter 626 is set to 0, no ramp will be implemented during JOG commands.

Malfunction: The motor velocity is not controlled and excessive velocity occurs.

Symptom: The motor velocity is excessive and parameter 106 “Velocity Fdbk” remains constant or near zero.

Solution: The velocity feedback device is incorrectly selected. Verify that parameter 621 “Fdbk Device Type” reflects the proper velocity feedback device being used.

- 0 = Encoder Feedback Selected
- 1 = Armature Voltage Feedback Selected
- 2 = Analog Tachometer Selected
- 3 = No Feedback Device Selected

Solution: If Encoder Feedback is selected and the device has malfunctioned, or no device is connected, or the wrong encoder PPR is entered in Param 609, the motor will accelerate uncontrollably and fault on VP-10 Feedback Loss.

Solution: If Armature Voltage Feedback is selected, the motor should only runaway if an internal component malfunctions. The armature voltage is sensed at the DC contactor connections. It is then scaled on the Feedback Board and measured on the Main Control Board.

Solution: If an analog tachometer is selected and the device has malfunctioned or is not connected, the motor will accelerate uncontrollably and fault. Also if the scaling is incorrect, or the analog input signal from the tach is over voltage, the motor will accelerate uncontrollably.

ATTENTION:

If no Feedback Device is selected, uncontrollable acceleration of the motor could occur. This is a potentially dangerous situation because the Drive will not trip on a Feedback Loss fault. Parameter 621 must only be set to (3) when operating the Drive as an external torque regulator, in follower type applications.

Symptom: The motor accelerates uncontrollably and parameter 106 “Velocity Fdbk” has the wrong polarity for the direction commanded.

Solution: The field polarity and the direction information from the encoder must match for proper control. Forward direction of the motor is defined as positive armature voltage +A1 / -A2 and phase A must lead phase B of the encoder for CCW rotation as viewed from the commutator end of the motor. Forward direction can be defined as CW rotation by switching the polarity of the field connections and by switching one encoder signal pair. The same holds true for an analog tachometer. The polarity- of the tach signal must match the polarity of the armature voltage. Forward rotation can be defined as either CW or CCW depending on the polarity of both signals.

Symptom: The motor accelerates uncontrollably with the motor turning in the same direction as the velocity command.

Solution: Switch the encoder signal pairs or the analog tach polarity. Then verify that parameter 107 “Position Feedback” counts up to a higher value as the motor is rotated in the forward direction.

Symptom: The motor runs away with the motor turning in the opposite direction as the velocity command.

Solution: Verify that parameter 107 “Position Feedback” counts up to a higher value when the motor is rotated in the forward direction. If it does, reverse the polarity of the field connections.

Malfunction: The motor turns at the correct speed, but rotates in the wrong direction.

Symptom: Parameter 107 counts down to a lower value when the motor is rotated in a forward direction.

Solution: Reverse both the encoder signal pairs/analog tach polarity and the polarity of the field connections.

Malfunction: The motor over/undershoots the target velocity.

Symptom: Excessive overshoot of the target velocity is evident when the velocity is stepped and overshoots to a speed faster/slower than commanded. The regulator then compensates and velocity swings back the other way, sometimes oscillating several cycles before achieving a constant velocity. When approaching zero speed the velocity may actually pass through zero speed and rotate in the opposite direction until zero speed is achieved.

Solution: Excessive overshoot usually indicates that the velocity loop is tuned incorrectly. The gains of the velocity loop, the actual values of, and the ratio between, KP and KI are incorrect, or the feed forward term (KF) is too high. Decreasing KI or increasing KP should reduce the amount of overshoot. Tune the velocity loop using Autotune. By decreasing parameter 661 “KF Velocity Loop” the feed forward term will be increased which will reduce overshoots but also decrease the gain of the loop in respect to velocity reference. The response to a load disturbance is unaffected by KF. Refer to the Start-up Procedure for more information. If the problem occurs when approaching zero speed it may help to increase parameter 710 “Zero Speed Tol”. This will cause the drive to cease regulation sooner and allow the motor to coast to a smooth stop. Refer to the Start-up Procedure for more information.

Symptom: Excessive undershoot of the target velocity is evident when the velocity is stepped and does not reach the target velocity in the desired time.

Solution: Excessive undershoot usually indicates that the velocity loop is tuned incorrectly. The gains of the velocity are too low or the Feedforward Term (KF) is too low. Increasing parameters 659 “KI Velocity Loop” and 660 “KP Velocity Loop” will increase the gain of the system to allow a faster response to variations in velocity feedback. By increasing parameter 661 “KF Velocity Loop” the feedforward term will be decreased which will reduce undershoots but also increase the gain in respect to the velocity reference. Refer to the Start-up Procedure for more information.

Velocity Feedback Device Malfunction

Velocity Feedback Device malfunctions can be difficult to diagnose and correct. In this section troubleshooting techniques dealing with each type of velocity feedback device will be explained.

Encoder Device Failure

The encoder feedback device is mounted on, or near the motor and is mechanically coupled to the motor shaft. It senses motor rotation and outputs a dual channel quadrature output waveform. The 1395 requires that the encoder output be differential line drivers at 5-12V signal levels. Channel A and Channel B are square wave type outputs that are 90 Degrees out of phase. When rotating in the CCW direction, as viewed from the commutator end, Channel A leads Channel B (Waveform 1). Each differential channel has an inverted and non-inverted signal, for example A and A(NOT) (Waveform 3).

The encoder requires a power supply. The 1395 provides a + 12V isolated supply capable of 500mA of current with a current foldback feature that protects the power supply should the current draw exceed 500mA. If different power supply requirements exist for the chosen feedback device, the supply must be provided external to the 1395 drive. It is important that the Start-up Procedure has been properly performed before attempting these troubleshooting techniques.

Test points on the Main Control Board (TP12 - Encoder Phase B (ENCB) and TP15 - Encoder Phase A (ENCA)) can be used to monitor the frequency and phase relationships of the encoder. An oscilloscope should be used to monitor these signals with respect to AGND (TP57). The waveforms should be logic level signals, 0 to 5V square-waves.

ATTENTION:

Extreme care must be used when probing the m test points on any board. Improper techniques may result in damage to the circuit and personal injury. Do Not attempt probe tests that are not listed here. Damage to extremely sensitive circuits may cause unpredictable drive operation and unintended motor rotation.

The frequency is proportional to speed and the pulse rate of the encoder, referred to as the “Pulse/Rev” rating on the nameplate. The speed of the motor can be calculated by: $\text{Speed (RPM)} = [\text{Frequency (Hz)} \times 60] / [\text{Pulses/Revolution}]$.

The direction of rotation is determined by the phase relationship of ENCA to ENCB. ENCA and ENCB should always be 90 Degrees out of phase with each other. If ENCA leads ENCB by 90 Degrees then the direction of rotation is defined as forward. If ENCB leads ENCA by 90 Degrees then the direction of rotation is defined as reverse. Waveform 1 shows forward rotation with ENCA as the top waveform. Waveform 2 is reverse rotation with ENCA as the top waveform.

The following is a list of final functions, symptoms, and possible solutions.

Malfunction: The drive faults on “VP-10 Feedback Loss”. This indicates that the measured velocity from the encoder is less than the level programmed in parameter 732 “Tach Loss Vel” and the velocity calculated from the CEMF of the motor is greater than the level programmed in parameter 731 “Tach Loss CEMF”.

Symptom: The velocity feedback is not being registered because jumpers on the Main Control Board are selected incorrectly for the encoder in use. Verify that the jumper selection for the encoder output voltage on the Main Control Board is correct.

Solution: For 5V differential encoders J8, J9, and J10 should be in position 1-2. For 12V differential encoders J8-J10 should be in position 2-3.

Symptom: The encoder feedback device is inoperative due to lack of encoder power supply. Measure the encoder power supply from the 1395 drive by measuring from TB3-13 (+) to TB3-14 (-) with a DVM. The voltage level should be +12V, +/- 10%.

Solution: If the supply is near zero remove all power to the drive. Disconnect the encoder supply connections at TB3-13 and TB3-14. Apply power and repeat the measurement. If the supply is restored to its proper level the encoder power supply foldback circuit was activated. Remove all power to the drive and connect the supply connections to the encoder. If upon applying power, the supply again folds back, excessive current draw is occurring. This could be due to shorted supply connections or a damaged encoder. Check all wiring between the 1395 terminal strip and the encoder. If the wiring is functional, replace the encoder. If the supply remains low even after the encoder is disconnected, replace the Main Control Board.

Symptom: The encoder output signals are lost due to a malfunction of the line drivers in the encoder device.

Solution: Measure the encoder output signals at the 1395 terminal strip. Place a scope probe at TB3-17 and at TB3-18 and reference them to TE. These signals represent the differential channel outputs for phase B. TB3-17 is inverted and TB3-18 is non-inverted. Rotate the shaft of the motor, either by mechanical means or under armature voltage feedback control. The resulting waveform should be similar to Waveform 3. If the proper signal is not observed, replace the encoder. Note: If using armature voltage feedback to troubleshoot the encoder, the set-up procedure for armature voltage feedback must be performed first for proper operation. Use the same method to check phase A of the encoder output. Place a scope probe at TB3-19 and TB3-20 and reference them to TE. TB3-19 is inverted and TB3-20 is non-inverted. Rotate the shaft of the motor, either by mechanical means or under armature voltage feedback control. The resulting waveform should be similar to Waveform 3. If the proper signal is not observed, replace the encoder.

Symptom: The encoder output signals are present at TB3, but the quadrature relationship is incorrect between phases A and B.

Solution: Open the drive door and lower the Main Control Board assembly. Locate test points TP12 and TP15 on the left side of the board near U13. TP12 is the phase B signal and TP15 is the phase A. Verify that proper quadrature exists between A and B. Rotate the motor in the CCW direction, as viewed from the commutator. The resulting waveform should be similar to Waveform 1 shown in Figure 3-1. If the encoder signals are in phase or 180 Deg out of phase, check the wiring to ensure that the signal lines are not shorted. If the wiring is functional replace the encoder.

Symptom: Encoder output signals present at TB3, not present on Main Control Board. Encoder interface failure.

Solution: Replace the Main Control board.

Figure 3.1
Waveform 1 - Encoder Phases A (TP15)
and B (TP12), Forward (CCW)

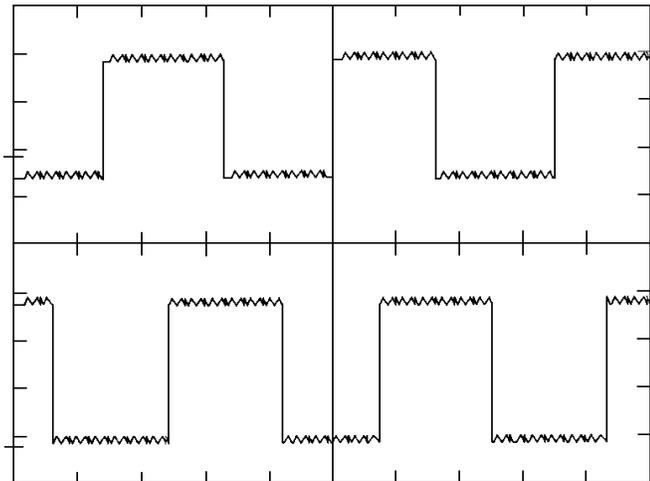


Figure 3.2
Waveform 2 - Encoder Phases A (TP15)
and B (TP12), Reverse (CW)

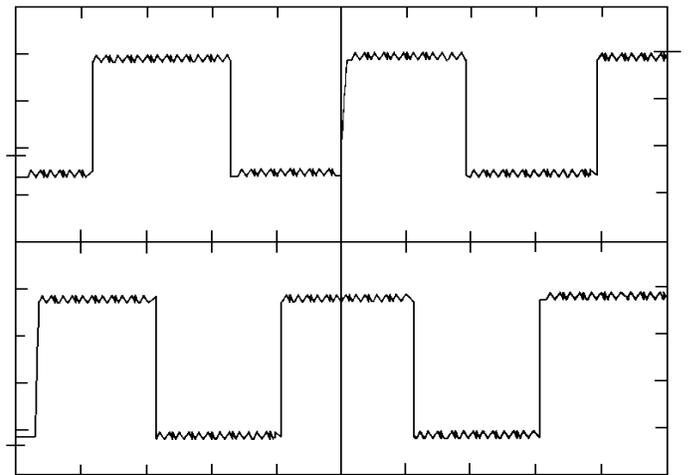


Figure 3.3
Waveform 3 - Encoder Signals A (TB3-20)
and A (NOT) (TB3-19)

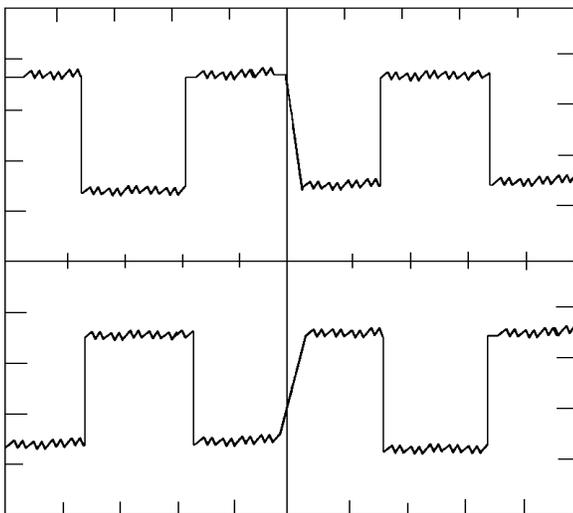
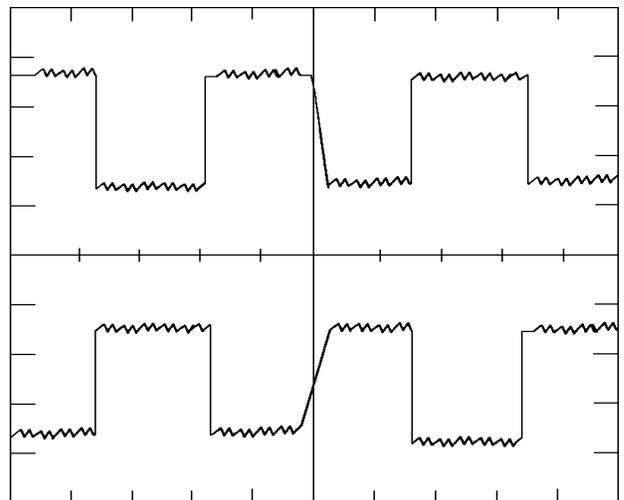


Figure 3.4
Waveform 4 - Encoder Signals B (TB3-18)
and B (NOT) (TB3-17)



Analog Tachometer Malfunction

The analog tachometer device generates a DC voltage that is direction sensitive and proportional to speed. The tach output must be connected to an analog input channel on the Discrete Adapter Board. Most industrial tachs have an output greater than the +/- 10V range of the analog inputs. The tach output must be scaled down, by an external voltage divider network (see Figure 6.22).

Below is a list of malfunctions, symptoms, and possible solutions.

Malfunction: Drive faults on “VP-10 Feedback Loss”. This indicates that the measured velocity from the tachometer is less than the level programmed in parameter 732 “Tach Loss Vel” and the velocity calculated from the CEMF of the motor is greater than the level programmed in parameter 731 “Tach Loss CEMF”.

Symptom: The velocity feedback is not being registered in parameter 156. Rotate the shaft of the motor, either by mechanical means or under armature voltage feedback control. Note: If using armature voltage feedback to troubleshoot the tach circuit, the set-up procedure for armature voltage feedback must be performed first for proper operation. If the Adapter configuration parameter indicates proper data, an incorrect configuration link is in the drive.

Solution: Verify that the analog input configuration parameter is linked to parameter 154. Also verify that external velocity feedback is selected. Examine parameter 621 “Fdbk Device Sel” to verify its value is 2.

Analog Tachometer Malfunction

The analog tachometer device generates a DC voltage that is direction sensitive and proportional to speed. The tach output must be connected to an analog input channel on the Discrete Adapter Board. Most industrial tachs have an output greater than the +/-10V range of the analog inputs. The tach output must be scaled down, by an external voltage divider network.

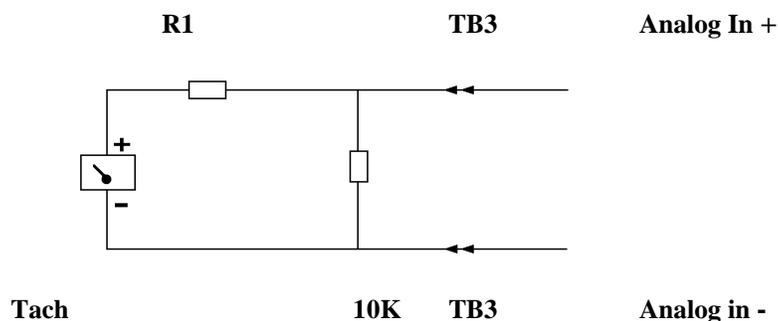
ATTENTION:

Connecting a Tach which has an output range greater than +/-10V directly to the analog input channel can severely damage the adapter card.

The tach signal then must be scaled in the adapter card to determine the proper relationship of output voltage/motor velocity to Base Speed in Drive units. This scaled configuration data must then be linked to Parameter 156 “Tach Velocity”. Many problems relate to the scaling of the tach signals. Below is a procedure for checking the scaling of the analog tach feedback for proper drive operation.

1. Determine the Volts/RPM rating of the tach. It is usually on the tach nameplate. Multiply this rating times the absolute maximum speed the motor will be commanded to accelerate to. (This value should also be programmed in Parameter 607 “Rev Speed Lim” and 608 “Fwd Speed Lim” to ensure the velocity command will be properly clamped).
2. This Max Volts output must be scaled to a level within the +/- 10V analog input channel range. This can be accomplished by using a voltage divider that will take the Max Volts output and scale it to a maximum 9V input. This allows for protection against 10% overshoot.

20K Adapter Board Input Impedance



This circuit uses a 10K resistor across the input channel and R1 represents the dropping resistor for the scaling network. To determine the value of R1 use the following equation:

$$\frac{(\text{Max Volts output}) \times 620}{9V} - 6250 = R1$$

3. The analog input channel on the adapter board must now be scaled to represent an accurate velocity feedback signal. First determine the analog input signal for base speed. Parameter numbers are given in () where applicable

$$\frac{\text{Base Motor Speed (606)} \times 9V}{\text{Max Speed}} \quad \text{Base Speed Input}$$

4. This input voltage at base speed is then converted to raw Adapter units according to the equation given here.

$$\frac{\text{Base Speed Input} \times 2048}{10} \quad \text{Raw Adapter Units}$$

5. The Raw Adapter units are then used to determine the correct scaling parameter value according to the equation shown here

$$\frac{4096}{\text{Raw Adapter Units}} \quad \text{Scaling Parameter Value}$$

6. The scaling parameter value should then be entered into the associated analog input scaling set-up parameter. This procedure should be correct to within 5%. Verify that the scaling is correct by measuring the actual motor velocity with a hand tachometer. Fine tune the scaling by adjusting the appropriate value to minimize any error.
7. Any drift at zero speed can be virtually eliminated by adjusting the offset parameter associated with the channel in use.

Below is a list of malfunctions, symptoms, and possible solutions.

Malfunction: Drive faults on “VP-10 Feedback Loss”. This indicates that the measured velocity from the tachometer is less than the level programmed in parameter 732 “Tach Loss Vel” and the velocity calculated from the CEMF of the motor is greater than the level programmed in parameter 731 “Tach Loss CEMF”.

Symptom: The velocity feedback is not being registered in parameter 156. Rotate the shaft of the motor, either by mechanical means or under armature voltage feedback control. Note: If using armature voltage feedback to troubleshoot the tach circuit, the set-up procedure for armature voltage feedback must be performed first for proper operation. If the Adapter configuration parameter indicates proper data, an incorrect configuration link is in the drive.

Solution: Verify that the analog input configuration parameter is linked to parameter 154. Also verify that external velocity feedback is selected. Examine parameter 621 “Fdbk Device Sel” to verify its value is 2.

Symptom: Adapter configuration parameter indicates no velocity feedback. Tach signal incorrectly connected to 1395.

Solution: Verify that the tach signal is present at the TB3 terminals which correspond to the desired analog input channel. If it is not, then check all wiring and connections that exist between the 1395 and the tachometer. If the wiring is functional replace the tachometer. If the signal is present at TB3, verify the scaling and offset parameters associated with the selected analog input channel.

Malfunction: Velocity control is maintained until the velocity exceeds a certain threshold and the motor accelerates uncontrollably.

Symptom: The velocity feedback is proportional to the velocity of the motor until a certain level is reached and the velocity feedback value is clamped and the motor accelerates uncontrollably.

Solution: The tachometer voltage is exceeding the input voltage range of the analog input channel on the adapter board. When the voltage range is exceeded the feedback data will become clamped and the motor will accelerate uncontrollably. It will be necessary to rescale the voltage divider network, external to the drive, to assure that the tach signal will remain inside the operating range of the analog input channel throughout the entire speed range of the motor.

Malfunction: The motor is rotating at the wrong speed.

Symptom: The velocity feedback viewed in parameter 106 “Velocity Fdbk” does not match the actual velocity of the motor, as measured by independent means (hand tach).

Solution: The scaling of the tach signal must be verified. The first scaling takes place at the voltage divider network which reduces the tach output to a level within the + 10V input range. The second scaling takes place in the adapter board which converts the incoming signal to Drive Units representing motor velocity.

Armature Current Control

Armature current control is performed in the Current processor. Most of the malfunctions that occur produce fault responses that indicate the problem. In some cases improper tuning will cause nuisance faults and abnormal operation to occur. If the armature control parameters are improperly calibrated, malfunctions will occur and possible damage to the drive may occur. Most malfunctions described here will deal with the symptoms the drive will exhibit when the parameters are missadjusted. Following is a list of malfunctions, symptoms, and possible solutions.

Malfunction: **Armature current output is well below rated or well above the rated level. This results in decreased or increased available torque. The velocity control up to and including the commanded torque has been checked and is functioning properly.**

Symptom: The armature current reference is below the level called for by Torque Command. When Parameter 110 “Torque Command” is 100%, Parameter 111 “Arm Current Ref” should reflect the motor's rated armature current. The torque command should remain proportional to the armature current reference from zero to base speed.

Solution: The ratio of torque command to armature current reference is wrong. This ratio is calculated based on Parameters 611 “Motor Arm FLA” and 615 “Rated Arm Brdg 1”. Parameter 611 should reflect the nameplate full load armature current rating of the motor. Parameter 615 should reflect current rating of the Drive as listed on the product label. If either of these parameters is incorrectly entered, the armature current output will be incorrect.

Malfunction: **Measured armature current to the motor does not equal the commanded armature current.**

Symptom: The armature current measured by the clamp on ammeter is not equal to the current reflected in parameter 112 “Arm Current Fdbk”.

Solution: Verify that Parameter 615 reflects the bridge current rating of the Drive as listed in the Start-Up chapter of the Installation Manual. If this value is incorrect the armature current output scaling will be incorrect and the level of the current to the motor will be inaccurate.

ATTENTION:

If a Feedback Board is ever replaced due to a component malfunction, the scaling resistors mounted in TB2 and TB3 will be transferred to the new board prior to installation. If TB2 and TB3 resistors are omitted or improperly installed, the current scaling will be incorrect and damage to the Drive may occur.

Malfunction: **A step in torque command causes the Drive to trip on an overcurrent trip.**

Symptom: A step in torque command results in a excessive pulse of armature current, faulting the Drive.

Solution: The current loop may be improperly tuned. If the gains are too high the step command will cause the current regulator to over react and produce too much current. Tune the Drive to the proper current loop gain using the Autotune procedure.

Solution: Reduce the value of Parameter 668 “dI/dT Limit”. This parameter limits the rate of change allowed for the armature current reference. By reducing this value, the control will increase the armature current reference at a slower rate when given a step torque command.

Solution: Verify that all six pulses are present in the armature current waveform. To monitor the armature current waveform place a scope probe on test point TP5 on the Main Control Board. Reference the scope to TP57 AGND. If one or more are missing, a malfunction in the power structure has occurred, refer to Magnetics/Power Structure section of this chapter for further details on correcting armature bridge malfunctions.

Solution: Check the motor commutator for signs of arcing and excessive, or rough, brush wear. Consult a motor rebuilder.

Malfunction: Drive faults on an overcurrent fault as soon as the contactor closes.

Symptom: Same as symptoms in previous malfunction.

Solution: The current loop may be improperly tuned. If the gains are too high the initial current command will cause the current regulator to over react and command too much current. Tune the drive to a lower current loop gain using the Autotune procedure.

Solution: The armature winding in the motor may be shorted. Check the armature resistance from A1 to A2 and from A1 to PE (ground) and A2 to PE. If necessary, disconnect the motor armature leads from the 1395 and use a Megger to apply high voltage from A1 to PE and from A2 to PE. This will indicate if insulation breakdown has occurred in the motor. If the motor is not shorted, a malfunction has occurred in the armature bridge. Refer to Magnetics / Power Structure section for further details on correcting armature bridge failures.

The following paragraphs describe test points on the Main Control Board that can be used to diagnose armature bridge malfunctions:

ATTENTION:

Extreme care must be used when probing the test points on any board. Improper techniques may result in damage to the circuit and personal injury. Do Not attempt probe tests that are not listed here. Damage to extremely sensitive circuits may cause unpredictable drive operation and unintended motor rotation.

TP2- Armature Current Feedback can be used to monitor the armature current as sensed by the current transformers in the AC lines. These signals are unipolar representations of the armature current. Conduction in either bridge results in a positive waveform in respect to AGND. Either an oscilloscope (preferred) or a DVM can be used to monitor this signal with respect to AGND (TP57). Scaling of the signal is 2V = bridge rated current (Drive nameplate rating). The monitored waveform should have equally spaced pulses at a period of 2.7ms. Waveform 4 represents continuous current conduction. Waveform 5 is discontinuous current conduction

TP21 - Armature Voltage Feedback is sensed at the output side of the DC contactor. It is scaled down to a +/- 10V signal and accurately reflects the voltage waveform across the motor armature. The waveform measured at TP21 is inverted in respect to the actual voltage across A1 to A2. Either an oscilloscope (preferred) or a DVM can be used to monitor this signal with respect to AGND (TP57). It is scaled on the low voltage drive (150- 300V DC) as 1V signal = 65V armature voltage. The high voltage drive (300-500V DC) is scaled as 1V signal = 125V armature voltage. The waveforms shown in Figures 3-5 through 3-11 represent the typical signal that occurs during the four quadrants of bridge operation.

Figure 3.5
Waveform 5 - Armature Current Feedback
(TP2) - Continuous Current

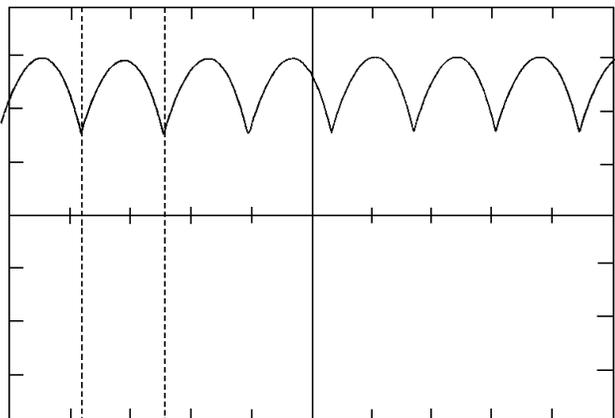


Figure 3.6
Waveform 6 Armature Current Feedback
(TP2) - Discontinuous Current

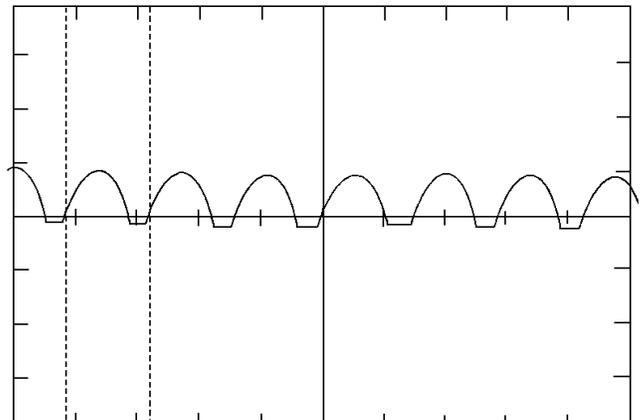


Figure 3.7
Waveform 9 - Armature Voltage Feedback
(TP21) - Motoring Forward

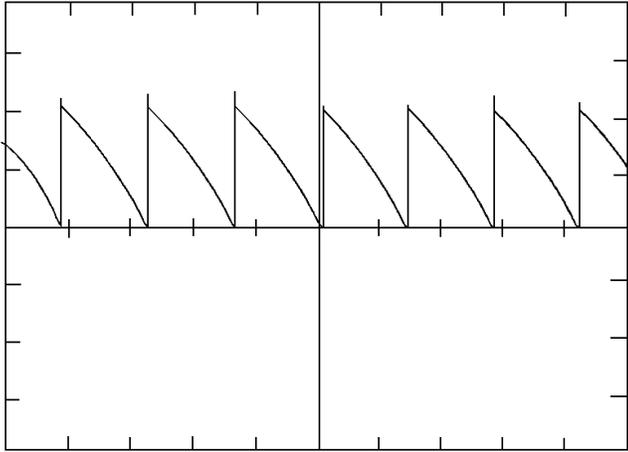


Figure 3.8
Waveform 8 - Armature Voltage Feedback
(TP21) Regen Forward

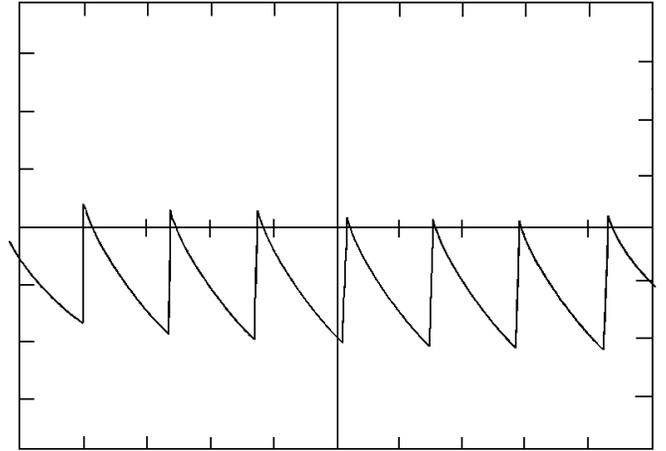


Figure 3.9
Waveform 7 - Armature Voltage Feedback
(TP21) Motoring Reverse

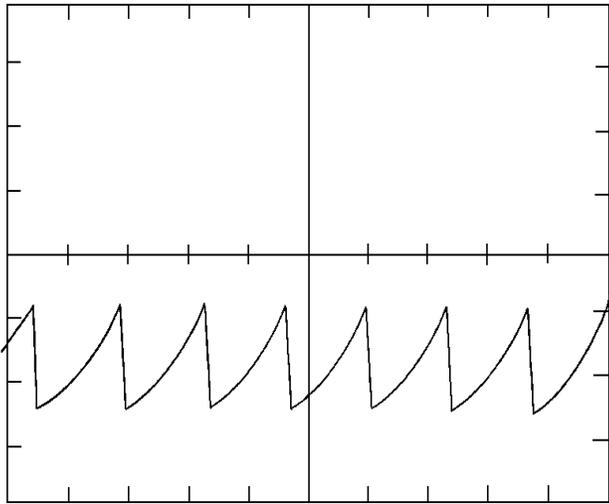


Figure 3.10
Waveform 10 - Armature Voltage Feedback
(TP21) Regen Reverse

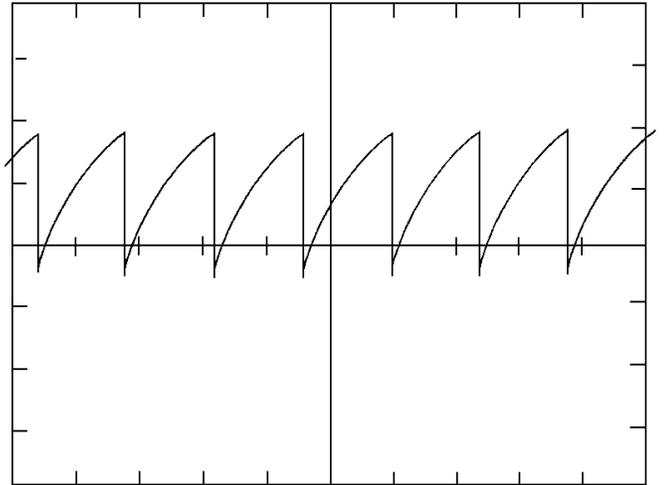
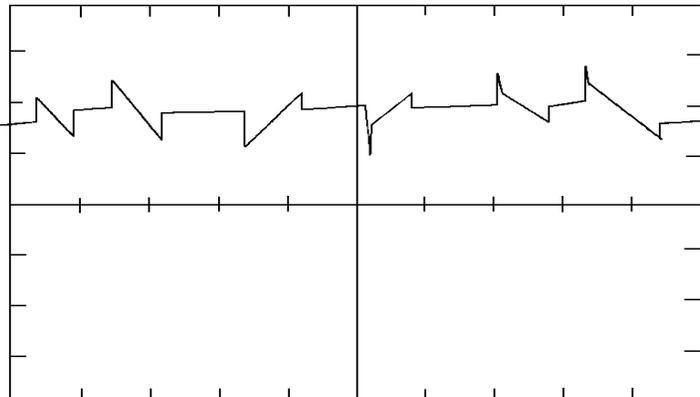


Figure 3.11
Waveform 11 - Armature Voltage Feedback
(TP21) Constant Velocity w/No Load



Field Current Control

Field current control is performed in both the Velocity Processor and the Current Processor. The Velocity Processor controls the field current reference based on velocity, armature voltage, mode of operation, etc. The Current Processor performs the field current regulation based on the reference it receives from the Velocity Processor and the field current feedback measured by the Current Processor. Most control related malfunctions are experienced when initially calibrating the field control for operation below Base Speed. The field must be calibrated for operation in both constant Torque mode and constant Horsepower mode. Constant Torque mode occurs below base speed when the motor has full field current applied and maximum rated torque can be achieved. Constant Horsepower mode occurs above base speed. The field control reduces the field current reference to maintain a constant armature voltage as velocity increases. The torque output decreases with an increase in velocity to maintain a constant horsepower output. This functionality is commonly referred to as "Field Weakening". The following is a list of malfunctions, symptoms, and possible solutions for the field control.

Malfunction: The exterior surface of the motor reaches a high temperature when the motor is stopped.

Symptom: The motor case temperature is excessive while the drive is in a stand-by mode. The drive is powered on, but not enabled.

Solution: The Field Economy function in the drive is not enabled. The Field Economy function reduces the field reference when the motor is stopped to reduce the power in the motor. Bit 0 of parameter 627 "Flux Mode Select" should be set to 1 to enable the Field Economy function. The field flux reference will be reduced to the level specified in parameter 674 "Fld Economy Ref" after the motor has been stopped for a period of time exceeding the value specified in parameter 675 "Fld Economy Dly". A typical value of field economy is 30-50%.

Solution: Setting the field economy too low may cause a drive fault to occur upon starting the drive. This would happen when the field bridge goes into discontinuous conduction when in field economy mode. If this occurs, it will take too long for the field current to increase to the commanded level once a START command is issued and the drive will fault on VP-13 "Motor Field Loss" or VP-36 "Excess Arm Voltage". The field economy reference should be set so the field bridge is in continuous conduction.

Malfunction: The field current and resulting CEMF vary above basespeed with a constant speed reference.

Symptom: With a constant speed reference above base speed, the velocity and field current vary.

Solution: The CEMF regulator is unstable, causing the field current reference to oscillate. The gains of the regulator are determined by parameter 672 "KI Flux" and parameter 673 "KP Flux". Decrease parameter 672 until stable operation is achieved.

Malfunction: Measured field current is not equal to parameter 118 "Fld Cur Fdbk".

Symptom: If the field current measured by the clamp-on ammeter is significantly different (greater than 10%) from the value reported in parameter 118 the field feedback scaling is incorrect.

Solution: Initial calibration of the field control determines the field current below Base Speed. The nameplate rating of both the motor and drive determine the initial scaling calibration. Enter the motor nameplate current rating in parameter 612 "Rated Fld Mtr Cur". Enter the field's bridge rating as determined by the field current jumper J1, not the drive nameplate rating, in parameter 616 "Rated Fld Brdg I". Refer to the Start-Up chapter of the 1395 Installation Manual for values for parameters 612 and 616. If the initial calibration is correct, the Feedback Board may have experienced a failure. This would be typified by the field being phased full on and full current flowing in the motor field circuit. However, no field current feedback would be registered at parameter 118 "Fld Current Fdbk". Replace the Feedback Board, being sure that the burden resistors installed at TB2 and TB3 are of the same value and type as installed in the original board.

Malfunction: The field current reference is not equal to the motor nameplate rating during velocity regulation below base speed.

Symptom: Parameter 117 "Fld Current Ref" is not equal to parameter 612 "Rate Fld Motor Cur". For operation below base speed, these two values should be equal.

Solution: Verify that parameter 676 "Field Flux Ref" is equal to 100%. If it is less than 100% a reduced field current reference will be commanded. Also verify that parameter 115 "Flux Command" is equal to 100%, when parameter 676 is equal to 100%. If it is not, the flux reference select may be improperly programmed. For applications where the velocity processor generates its own field current reference, bit 2 of parameter 627 "Flux Mode Select" should be set to 0. If bit 2 is set to 1,

parameter 159 "Flux Feed Forward" will be used as the field flux reference. Parameter 159 is used when an external field flux reference is brought into the drive, typically under master/follower configurations. Typically in a follower drive (torque regulator) application, the field flux reference will be brought into the follower, from the master drive (velocity regulator). If the unit experiencing the malfunction is a stand alone or master velocity regulator, it will generate a field current reference internally.

Malfunction: The field current feedback is not equal to the field current reference indicating that proper regulation cannot be obtained.

Symptom: Parameter 117 "Fld Current Ref" is not equal to parameter 118 "Fld CurrentFdbk".

Solution: Verify the field voltage rating of the motor and the field voltage rating of the drive under use is compatible. A drive with a 230V AC input rating is capable of a field output of 150V DC, a 380V AC of 250V DC, a 415V AC of 270V DC, and a 460V AC of 300V DC.

Malfunction: The measured motor voltage at base speed, no load, is not equal to the rated nameplate motor armature voltage.

Symptom: The armature voltage measured with a DVM at A1 and A2 of the DC contactor, at base speed with no load applied, is not equal to the value entered at parameter 610 "Rated Motor Volt".

Solution: Fine tune the calibration of the constant field control to match the flux requirements of the motor. The nameplate rating of field current is a general estimate published by the motor manufacturer, if more exact calibration is required perform the following adjustments: Operate the motor at Base Speed velocity, under no load, and place a DVM across the DC contactor at A1 and A2. Verify that parameter 676 "Field Flux Ref" is equal to 100%. Adjust parameter 612 "Rate Fld Mtr Cur" in small increments until the voltage measured at A1 and A2 is equal to the rated armature motor voltage as stated on the motor nameplate. (Increasing parameter 612 will cause the armature voltage to increase). If parameter 612 must be increased to a value greater than parameter 616, the next higher J1 setting on the feedback board must be selected and the value of parameter 616 must be changed to reflect the higher setting. Remove all power to the drive before changing the J1 jumper selection. Verify that the motor rated field is compatible with the drive rating in both voltage and current.

Malfunction: The measured motor voltage above base speed does not remain constant.

Symptom: When the actual motor velocity exceeds the base speed of the motor, the armature voltage continues to vary proportional to velocity.

Solution: Verify that the field weakening enable, bit 1 of parameter 627 "Flux Mode Select" is set to 1. This bit must be set if constant horsepower operation is desired.

Symptom: When the actual motor velocity exceeds the base speed of the motor, the armature voltage varies, but not directly proportional to velocity. The load on the motor is relatively constant.

Solution: Verify that the Field Flux Tune has been executed under Autotune control. This must be performed prior to operating the drive above base speed to ensure that the field control parameters have been set to reflect the flux characteristics of the motor. Autotune will calibrate the field weakening parameters 677 to 685 and enter them into the parameter table. In addition, the CEMF regulator must also be tuned. The CEMF regulator varies the field reference based on the CEMF of the motor being measured. The CEMF regulator will adjust the field reference during operation to maintain a constant Armature voltage. The response of this regulator is controlled by parameter 672 "KI Flux" and parameter 673 "KP Flux". These parameters control the gain of the CEMF regulator. Setting parameter 687 "CEMF Preload" to zero and parameter 627 "Flux Mode Select" bit 5 (CEMF Set) to 1 will disable the CEMF regulator. If bits 4 (Hold) and 5 (Set) in parameter 627 are both set to 0, the CEMF regulator is automatically enabled and uses parameter 610 "Rated Motor Volt" as the reference.

Solution: Verify that the external CEMF regulator control, bit 3 of parameter 627 "Flux Mode Select" is set to 0. If this bit is set to 1, parameter 160 "CEMF Ref" will be used to determine the CEMF regulator reference, instead of the rated motor voltage parameter. Also verify that bits 4 and 5 are set to zero under normal operation. If bit 4 is set to 1 the CEMF regulator will hold its output to the last value before the bit was set. If bit 5 is set to 1 the output of the CEMF regulator will be reset to the value specified in parameter 687 "CEMF Reg Preload". Parameter 686 "Fld Weaken Speed" determines the velocity at which the field weakening function will become active.

Symptom: When the actual motor velocity exceeds the base speed of the motor, the armature voltage varies directly with the load on the motor.

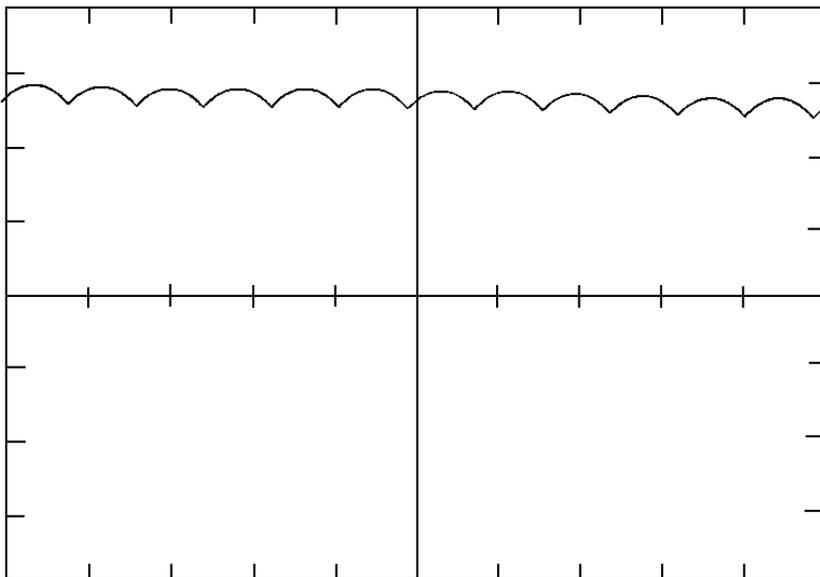
Solution: If the armature voltage changes significantly (greater than 5%) with an increasing load, the armature resistance compensation is too high. Reduce parameter 614 "Arm Resistance". If armature voltage increases significantly with an increasing load, parameter 614 is too low. A typical range is 3 to 10%.

TP25- Field Current Feedback can be used to monitor the field current as sensed by the current transformer FCT. This signal is scaled so that 3V DC = full rating of the bridge as determined by the jumper setting of J1 on the feedback board or the PSI/Switcher based on the HP rating. Either an oscilloscope (preferred) or a DVM can be used to monitor this signal with respect to AGND (TP57). The waveform in Figure 3-12 shows the typical waveform of field current feedback.

ATTENTION:

Extreme care must be used when probing the test points on any board. Improper techniques may result in damage to the circuit and personal injury. Do Not attempt probe tests that are not listed here. Damage to extremely sensitive circuits may cause unpredictable drive operation and unintended motor rotation.

Figure 3.12
Field Current Feedback (TP25) - Continuous Current



Magnetics / Power Structure

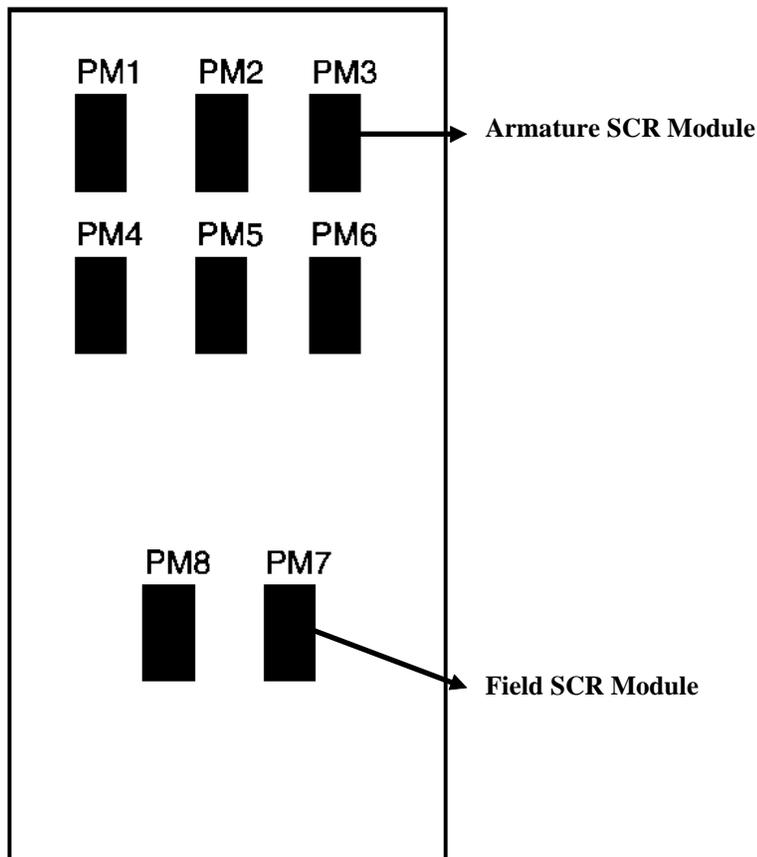
The 1395 drive contains a power structure that has an armature and field supply. The armature supply consists of a three-phase, full wave rectified, dual bridge, capable of four quadrant output. The field supply consists of single phase, full wave rectified bridge. Also associated with the power structure are the low voltage logic power supply and the 24V unregulated power supply, contactor control circuits, and incoming line protection devices. The procedures below are designed to identify damaged components by standard troubleshooting techniques. Note that the troubleshooting information in this section is divided into two sections. All Series A troubleshooting information precedes Series B troubleshooting.

SERIES A
(1 -100 HP 230 VAC)
(2 - 200 HP 460 VAC)

Armature SCR's (Series A)

The 1395, 1-100 HP 230 VAC/ 2 - 200 HP 460VAC, armature supply consists of six dual pack SCR modules mounted on the main heat sink. A malfunction of any of these devices will show itself in either an overcurrent related fault, blown or tripped incoming protection devices, or erratic motor operation. The following procedure can be used if an armature bridge component malfunction is suspected.

1. Disconnect and lock-out ALL incoming voltage sources. Verify that the three-phase high voltage is removed from the incoming protection devices, either F1 - F3 or the main circuit breaker CB1. Also verify that the 115V logic supply and contactor power is removed from TB2-3,4, and 5. If an external field supply is used, verify that it is also removed by checking TB1-1 and 5.
2. Check the Anode to Cathode junction of each SCR module. With a DVM on the 1 Meg ohm scale, measure the resistance across the SCR modules as follows: (Note: Lead orientation is not critical)



SCR Layout Series A

- PM1 - Upper left SCR module;
A1 (Bottom of DC contactor) to L1 (bottom of F1)
- PM2 - Upper middle SCR module;
A 1 (bottom of DC contactor) to L2 (bottom of F2)
- PM3 - Upper right SCR module;
A1 (bottom of DC contactor) to L3 (bottom of F3)
- PM4 - Lower left SCR module;

A2 (bottom of DC contactor) to L1 (bottom of F1)
PM5 - Lower middle SCR module;
A2 (bottom of DC contactor) to L2 (bottom of F2)
M6 - Lower right SCR module;
A2 (bottom of DC contactor) to L3 (bottom of F3)

All resistance's should be 100kohms or greater. If a low resistance is detected replace the affected SCR pack.

3. Check the gate to cathode junction of each SCR module. With the DVM on the 1 K ohm scale, measure resistance of each junction as follows:

(Note lead orientation is not critical)

PM1 - Upper left SCR module;
G1 (Top of left arm/snubber board) to A1 (See above)
G2 (Top of left arm/snubber board) to L1 (See above)
PM2 - Upper middle SCR module;
G1 (Top of middle arm/snubber board) to A1 (See above)
G2 (Top of middle arm/snubber board) to L2 (See above)
PM3 - Upper right SCR module;
G1 (Top of right arm/snubber board) to A1 (See above)
G2 (Top of right arm/snubber board) to L3 (See above)
PM4 - Lower left SCR module;
G1 (Bottom of left arm/snubber board) to A2 (See above)
G2 (Bottom of left arm/snubber board) to L1 (See above)
PM5 - Lower middle SCR module;
G1 (Bottom of middle arm/snubber board) to A2 (See above)
G2 (Bottom of middle arm/snubber board) to L2 (See above)
PM6 - Lower right SCR module;
G1 (Bottom of right arm/snubber board) to A2 (See above)
G2 (Bottom of right arm/snubber board) to L3 (See above)

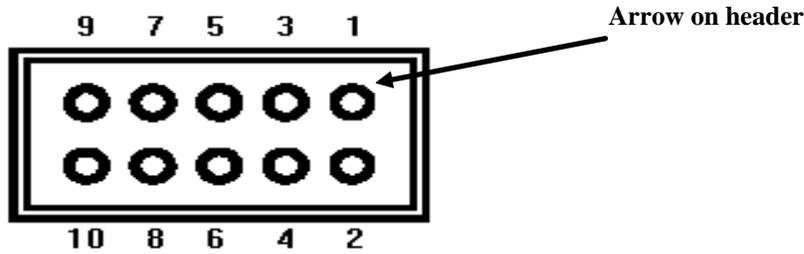
All resistance's should be between 7 to 30 ohms. If a measurement is outside of this range or if one reading deviates significantly from the majority, then module replacement may be necessary.

Armature Pulse / Snubber Boards (Series A)

The Armature Pulse / Snubber Boards provide isolation of the gate pulse firing circuit and also provide DV/DT protection for the SCR modules. A malfunction of these devices will be evident in either an overcurrent related fault, blown or tripped incoming protection devices, or erratic motor operation. Follow the procedure below if a board malfunction is suspected.

1. Disconnect and lock-out ALL incoming voltage sources.(See above)
2. Remove all three Pulse Boards by disconnecting the ribbon cable at J1 and remove the upper and lower gate leads at G1 and G2. Loosen the captive thumb screws designated DCA1, AC, and DCA2. Measure the following resistance's with the DVM on the 200 ohms scale. (Note lead orientation is not critical)

G1 (upper) to DCA1 should be 100 ohms +10%
G1 (lower) to DCA2 should be 100 ohms +10%
G2 (upper) to AC (2L1) should be 100 ohms +10%
G2 (lower) to AC (3L1) should be 100 ohms +10%
D1 (anode) to DCA1 should be 1 to 2 ohms
D2 (anode) to AC (2L1) should be 1 to 2 ohms
D3 (anode) to AC (3L1) should be 1 to 2 ohms
D4 (anode) to DCA2 should be 1 to 2 ohms
J1-1 to J1-8 should be 100 ohms +10% (see below)
J1-2 to J1-8 should be 100 ohms +10% (see below)
J1-3 to J1-8 should be 100 ohms +10% (see below)
J1-6 to J1-8 should be 100 ohms +10% (see below)



J1 Pin Orientation (Top View)

3. If any of these measurements (G1 through J6) are out of tolerance, replace the associated board. If these procedures check out and no apparent discrepancies are found, a potential problem could still exist. If a “breakdown path” has been established from the pulse transformer primary to secondary, it is possible that a malfunction could show itself when the line voltage potential is applied to the power structure. This condition can only be detected by “hi potting” the board at a level of 2500Vrms, and verifying less than 5mA from primary to secondary.

Field SCR's (Series A)

The 1395 field supply consists of two dual pack SCR modules arranged in a single-phase full wave rectifier configuration. Malfunction of any of these components may cause various responses including field and velocity related faults, or blown fuses at F4 and F6. The following procedures can be used if field bridge malfunctions are suspected.

1. Disconnect and lock-out ALL incoming voltage sources. Verify that the 3 phase high voltage is removed from the incoming protection devices, either F1 - F3 or the main circuit breaker CB 1. Also verify that the 115V logic supply and contactor power is removed from TB2-3, 4, and 5 . If an external field supply is used, verify that it is likewise removed by checking TB1-1 and TB1-5
2. Check the Anode to Cathode junction of each SCR module. With a DVM on the 1 Meg ohm scale, measure the resistance across the SCR modules as follows: (Note lead orientation is not critical).

For Low kVA 1395

- Resistance from TB1-1 to TB2-1 should be greater than 500k ohms
- Resistance from TB1-5 to TB2-1 should be greater than 500k ohms
- Resistance from TB1-1 to TB2-2 should be greater than 500k ohms
- Resistance from TB1-5 to TB2-2 should be greater than 500k ohms

If a measurement results in an “infinity” reading, check F4 and F6 for blown fuses.

3. Check the gate to cathode junction of each SCR module. With the DVM on the 1K ohm scale, measure resistance of each junction as follows: (Note lead orientation is not critical). Loosen the four captive thumb screws on the feedback board and lift the board to gain access to the field pulse \ snubber board. Remove the gate leads to the SCR modules. Measure the following resistance's:

PM7 - Left SCR module;

- G1 (left side of fld/snubber board) to TB2-1
- G2 (left side of fld/snubber board) to TB2-2

PM8 - Right SCR module;

- G1 (right side of fld/snubber board) to TB1-5
- G2 (right side of fld/snubber board) to TB1-1

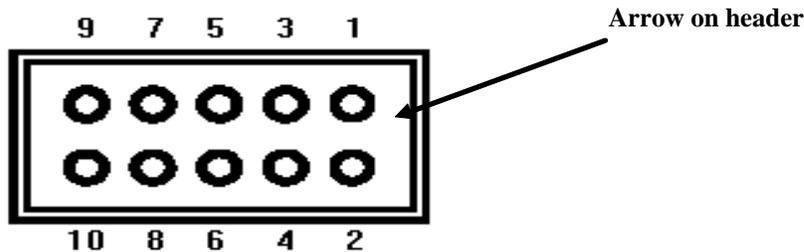
All resistance measurements should be between 15 to 60 ohms. If the measurement is outside of this range or if a significant deviation among devices is measured, module replacement may be necessary.

Field Pulse / Snubber Boards (Series A)

The field pulse / snubber boards provide isolation of the gate pulse firing circuit and also provide DV/DT protection for the SCR modules. A malfunction of these devices will be evident in either an overcurrent related fault, blown or tripped incoming protection devices, or erratic motor operation. Follow the procedure below if a board malfunction is suspected:

1. Disconnect and lock-out ALL incoming voltage sources.(See above)
2. Remove the pulse/snubber board by disconnecting the ribbon cable at J1 and remove the left and right gate leads at G1 and G2. Loosen the captive thumb screws and remove the printed circuit board. Measure the following resistance's with the DVM on the 200 ohms scale. (Note lead orientation is not critical)

L1 to D3 (cathode) should be 100 ohms +/- 10%
L1 to D3 (anode) should be 1 to 2 ohms
F1 to D4 (cathode) should be 100 ohms +/- 10%
F1 to D4 (anode) should be 1 to 2 ohms
L3 to D2 (cathode) should be 100 ohms +/- 10%
L3 to D2 (anode) should be 1 to 2 ohms
F1 to D1 (cathode) should be 100 ohms +/- 10%
F1 to D1 (anode) should be 1 to 2 ohms
J1 - 1 to J1-9 should be 60 ohms +/- 10%
J1 - 1 to J1-10 should be 60 ohms +/- 10%



J1 Pin Orientation (Top View)

If any of these measurements are out of tolerance, replace the associated board. If the above procedure checks out and no apparent discrepancies are found, a potential problem could still exist. If a “breakdown path” has been established from the pulse transformer primary to the secondary, it is possible that a malfunction could show itself when the line voltage potential is applied to the power structure. This condition can only be detected by “hi potting” the board at a level of 2500V rms, and verifying less than 5mA from primary to secondary.

115V Unit Power Supply (Series A)

The 115V Unit Power Supply sources the +5V, +12V, and +12V ISO logic power supplies used on the 1395 printed circuit boards. It is located on the fold down steel bracket, next to the PSI Board. A malfunction of this device will exhibit loss of functionality due to low or non-existent logic supplies, drive fault responses, and erratic operation. Follow the procedure below if a unit power supply malfunction is suspected.

1. Measure the 115V AC source for the power supply. With the DVM on the 200V AC range, measure the voltage across J1-5 and J14 on the PSI Board. (No convenient test points exist on the unit power supply, most measurements will be performed on the PSI board). If 115V AC cannot be detected, check fuse F8 located on the top panel. Remove all power prior to checking the condition of F8.
2. Measure the outputs of the unit power supply. With the DVM on the 20 VDC range, measure the logic supply levels shown in Table 3.C referencing to TP5 (ground).

IMPORTANT:

If necessary, the 5V level can be adjusted with potentiometer R3, located on the Power Supply Board.

Table 3.C
Logic Supply Levels

| Test Point | Voltage | Low Limit | High Limit |
|-------------------|----------------|------------------|-------------------|
| TP1 | +12V DC | +11.85V DC | +13.13V DC |
| TP2 | +5.00V DC | +4.98V DC | +5.02V DC |
| TP4 | -12V DC | -11.85V DC | -13.13V DC |

If no logic voltages can be detected, check the condition of the fuse located on the unit power supply. Remove all power prior to checking the condition of the fuse. If the fuse is not open, replace the unit power supply.

3. Before replacing the unit power supply, disconnect and lock-out ALL incoming voltage sources. Verify that the 3 phase high voltage is removed from the incoming protection devices, either F1-F3 or the main circuit breaker CB1. Also verify that the 115V logic supply and contactor power is removed from TB2-3, 4 and 5. If an external field supply is used, verify that it is likewise removed by checking TB1-1 and TB1-5.

4. Verify that the logic supplies also exist on the Main Control Board at the following test points:

- TP51 - +5V logic supply can be monitored with a DVM. Its signal level should be +5.00V DC +/- 0.02 VDC in respect to TP52.
- TP52 - Digital logic supply common can be monitored with a DVM. Its signal level should be +0V DC in respect to TE. This signal is used as the reference for measuring all isolated signals.
- TP53 - Isolated supply common can be monitored with a DVM. Its signal level should +0V DC in respect to TE. This signal is used as the reference for measuring all isolated signals.
- TP54 - Isolated +12V supply can be monitored with a DVM. Its signal level should be between 11.85 and 13.13 VDC in respect to TP53.
- TP55 - +12V logic supply can be monitored with a DVM. Its signal level should be between 11.85 and 13.13 VDC in respect to TP57.
- TP56 - -12V logic supply can be monitored with a DVM. Its signal level should be between 11.85 and 13.13 VDC in respect to TP57.
- TP57 - Analog supply common can be monitored with a DVM. ITs signal level should be +0VDC in respect to TE. This signal is used as the reference for measuring all analog signals.
- TP58 - +5V isolated supply can be monitored with a DVM. Its signal level should be +5.00V DC +/- 0.02 VDC in respect to TP53.

24V Internal Unregulated Supply (Series A)

The 24V unregulated power supply is used to supply power for SCR gate firing signals, the 24V ECOAST string, the pre-pilot relay, and the “faulted” relay. The components include a step-down transformer located under the top magnetics bracket, the rectifier and filter capacitors that are located on The PSI Board. A failure will exhibit a drive fault CP-15 “24V Power Supply Loss”. Follow the procedure below if a 24V power supply malfunction is suspected.

1. Measure the +24V supply level on the PSI Board. With the DVM on the 200V DC range, measure the potential from TP5 to TP23. The voltage should be 24V DC +/- 6.0 V.

2. Measure the 20V AC source for the 24V supply. With the DVM on the 200V AC range, measure across J2- 9 and J2-10 on the PSI Board. The measured potential should be 20V AC +/- 30%. If no potential is measured, check fuse F7 on the top panel. Remove all power prior to checking the condition of the fuse. If the potential is correct, replace the PSI Board.
3. If after replacing F7, the fuse still opens, replace the stepdown transformer 1PT. It is located on the back side of the magnetics bracket that mounts the incoming protection devices.

Magnetics Bracket Assembly Components

The magnetics bracket is located at the top of the drive. It includes TB1, TB2, F4 through F8, the pilot relay, 24V supply transformer, and 115V distribution block. The following procedures describe the remaining components, not already covered, and how to test them. Disconnect and lock-out ALL incoming voltage sources prior to performing any of the tests below. Verify that the 3 phase high voltage is removed from the incoming protection devices, either F1 - F3 or the main circuit breaker CB 1. Also verify that the 115V logic supply and contactor power is removed from TB2-3,4, and 5. If an external field supply is used, verify that it is likewise removed by checking TB1-1 and TB1-5.

1. Fuses F4 through F6 are 25A rectifier type fuses. These fuses are a rejection style rectifier type fuse and are sensitive to their orientation in the fuse holders. The keyed end must be inserted downward in the fuse holder.
2. Fuse F7 provides protection for the 24V supply transformer. This fuse is a fragile glass type and caution should be exercised when handling it.
3. Fuse F8 provides protection for the 115V circuits. This fuse is a fragile glass type and caution should be exercised when handling it.
4. The pilot relay is located on the backside of the magnetics panel. Remove the wire harness at J1 on the PSI Board. With the DVM on the 20k ohm range, measure the resistance of J1-1 and J1-2 in the harness. It should be 3.5K ohms +/-10%.
5. The thermal switch is mounted in the middle of the main heat sink. In a normal, cool ambient, measure the resistance between TB1-17 and 18 on the Feedback board. The resistance should be less than 2 ohms.

SERIES B

(1 - 30 HP 230 VAC)

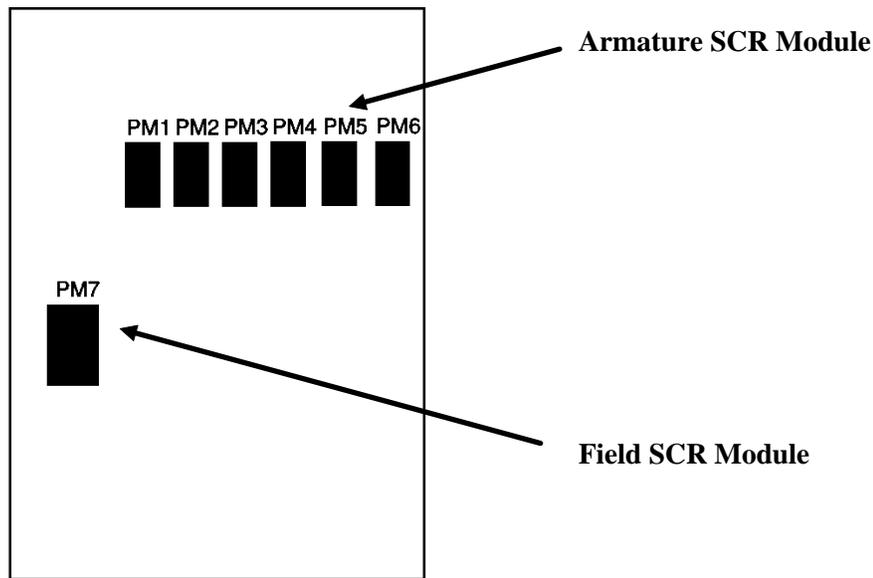
(2 - 60 HP 460 VAC)

Armature SCR's Series B

The 1395, 1-30 HP 230 VAC/ 2 - 60 HP 460VAC armature supply consists of six dual pack SCR modules mounted on the main heat sink. A malfunction of any of these devices will show itself in either an overcurrent related fault, blown or tripped incoming protection devices, or erratic motor operation. The following procedure can be used if an armature bridge component malfunction is suspected.

1. Disconnect and lock-out ALL incoming voltage sources. Verify that the three-phase high voltage is removed from the incoming protection devices, either F1 - F3. Also verify that the 115V logic supply and contactor power is removed from TB2-1, 2, 3. To gain access to the Power Board, swing down and remove PS1/Switcher Board.
2. Check the Anode to Cathode junction of each SCR module. With a DMM on the 1 Megohm scale, measure the resistance across the SCR modules as follows:

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PM1 - left SCR module; to PM2 2nd SCR module
 A1 (bottom of DC contactor) to L1 (bottom of F1)
 A2 (bottom of DC contactor) to L1 (bottom of F1)
 PM3 - 3rd SCR module to PM4 4th SCR module
 A1 (bottom of DC contactor) to L2 (bottom of F2)
 A2 (bottom of DC contactor) to L2 (bottom of F2)
 PM5 - 5th SCR module to PM6 Right SCR module
 A1 (bottom of DC contactor) to L3 (bottom of F3)
 A2 (bottom of DC contactor) to L3 (bottom of F3)

All resistance's should be 100K ohm or greater. If a low resistance is detected, remove the power board and determine which of the power module pair is bad, replace it accordingly.

3. Check the Gate to Cathode junction of each SCR module. With a DMM on the 1K ohm scale, measure the resistance of each junction as follows:

PM1 - left SCR module G1 J15 to A1 and G2 J16 to L1
 PM2 - 2nd SCR module G1 J17 to A2 and G2 J18 to L1
 PM3 - 3rd SCR module G1 J19 to A1 and G2 J20 to L2
 PM4 - 4th SCR module G1 J21 to A2 and G2 J22 to L2
 PM5 - 5th SCR module G1 J23 to A1 and G2 J24 to L3
 PM6 - Right SCR module G1 J25 to A2 and G2 J26 to L3

All resistance's should be between 7 to 30 ohms. If measurement is outside of this range or one reading deviates significantly from the majority, module replacement may be necessary.

Armature Pulse / Snubber Circuits (Series B)

The Armature Pulse / Snubber Circuits located on the power board provide isolation of the gate firing circuit and also provide DV/DT protection for the SCR modules. A malfunction of these devices will be evident in either an overcurrent related fault, blown or tripped incoming protection devices or erratic motor operation. Use the following procedure if a malfunction in this circuitry is suspected.

1. Disconnect and lock out all incoming voltage sources. To Gain Access to the power board, swing down and remove PSI/Switcher Board.
2. Remove the armature gate leads J15 thru J26. Measure the following resistance's with a DMM on the 200 ohm scale.

J15 to A1 (bottom side of contactor) should be 100 ohms +/-10%
J16 to L1 should be 100 ohms +/- 10%
J17 to A2 (bottom side of contactor) should be 100 ohms +/-10%
J18 to L1 should be 100 ohms +/- 10%

J19 to A1 (bottom side of contactor) should be 100 ohms +/-10%
J20 to L2 should be 100 ohms +/- 10%
J21 to A2 (bottom side of contactor) should be 100 ohms +/-10%
J22 to L2 should be 100 ohms +/- 10%

J23 to A1 (bottom side of contactor) should be 100 ohms +/-10%
J24 to L3 should be 100 ohms +/- 10%
J25 to A2 (bottom side of contactor) should be 100 ohms +/-10%
J26 to L3 should be 100 ohms +/- 10%

J6 - 6 to J6 - 1 should be 100 ohms +/- 10%
J6 - 8 to J6 - 1 should be 100 ohms +/- 10%
J6 - 9 to J6 - 1 should be 100 ohms +/- 10%
J6 - 10 to J6 - 1 should be 100 ohms +/- 10%
J6 - 11 to J6 - 1 should be 100 ohms +/- 10%
J6 - 12 to J6 - 1 should be 100 ohms +/- 10%
J6 - 13 to J6 - 1 should be 100 ohms +/- 10%
J6 - 14 to J6 - 1 should be 100 ohms +/- 10%
J6 - 15 to J6 - 1 should be 100 ohms +/- 10%
J6 - 16 to J6 - 1 should be 100 ohms +/- 10%
J6 - 18 to J6 - 1 should be 100 ohms +/- 10%
J6 - 20 to J6 - 1 should be 100 ohms +/- 10%

If any of these measurements are out of tolerance, replace the power board.

Field SCR Module (Series B)

The 1395 Series B field supply consists of a single quad pack SCR module arranged as a single phase full wave rectifier. Malfunction of this component may cause various responses including field and velocity related faults, or blown F1 and F2 fuses. The following procedure can be used if field bridge malfunctions are suspected.

1. Disconnect and lock out all incoming voltage sources. Verify the 3 phase high voltage is removed from the input fuses F1 - F3. Also verify the 115V logic and contactor power are removed from TB2 of the PSI/Switcher board.
2. To gain access to the power board, swing down and remove the PSI/Switcher board.
3. Remove all interconnects to the field bridge.
4. Check the gate to cathode junction of each SCR of the module as follows:

Pin 6 to Pin 3
Pin 7 to Pin 2
Pin 8 to Pin 4
Pin 9 to Pin 2

All resistance measurements should be between 15 and 60 ohms. If outside of this range or if significant deviation between SCR's is measured, module replacement may be necessary.

4. With the DMM on the 2 megohm range, check the anode to cathode junction of each SCR as follows:

Pin 2 to Pin 3 should be greater than 500K ohm.

- Pin 2 to Pin 4 should be greater than 500K ohm.
- Pin 1 to Pin 4 should be greater than 500K ohm.
- Pin 1 to Pin 3 should be greater than 500K ohm.

Field Pulse I Snubber Circuits (Series B)

The field pulse / snubber circuits, located on the power board, provide isolation of the gate firing circuit and also provide DV/DT protection for the SCR modules. A malfunction of these devices will be evident in either an overcurrent related fault, blown or tripped incoming protection devices or erratic motor operation. Follow the procedure below:

1. Disconnect and lock out all incoming voltage sources.
2. To gain access to the power board, swing down and remove the PSI/Switcher board.
3. Remove the gate interconnects between the PCB and field SCR module (J11, J12, J13, J14).
4. Measure the following resistance's with a DMM on the 200 ohm scale.

- TB1-1 (L1) to D7 anode should be 1 to 2 ohms.
- TB1-1 (L1) to D7 cathode should be 100 ohms +/- 10%
- TB1-2 (L3) to D8 anode should be 1 to 2 ohms.
- TB1-2 (L3) to D8 cathode should be 100 ohms +/- 10%
- TB1-3 (F+) to D9 anode should be 1 to 2 ohms
- TB1-3 (F+) to D9 cathode should be 100 ohms +/- 10%
- TB1-3 (F+) to D10 anode should be 1 to 2 ohms
- TB1-3 (F+) to D10 cathode should be 100 ohms +/- 10%
- J6 - 1 to J6 - 19 should be 60 ohms. +/- 10%
- J6 - 1 to J6 - 17 should be 60 ohms. +/- 10%

115V Switching Power Supply (Series B)

The 115V switching power supply sources the +5V, +/-12V, and the +12V ISO logic supplies used on the 1395 printed circuit boards. The power supply circuitry is located on the right side of the PSI/Switcher board. Failure of this circuitry will exhibit loss of functionality due to low or non existent logic supplies, drive fault responses, and erratic operation. Follow the procedure below if a switching power supply malfunction is suspected:

1. Measure the 115VAC source for the power supply. With a DMM on the 200VAC range, measure the voltage across pins 2 and 3 of TB2 on the PSI/Switcher board. If 115V is not detected, check AC source. If 115V is detected, check the condition of F1, in the upper left hand corner of the PSI/Switcher board, and F3, to the left of TB2.
2. Measure the outputs of the supply on the test points located on the right side of the PSI/Switcher board. With a DMM on the 20VDC range, measure the logic supply levels shown in Table 3.D with reference to TP6.

Table 3.D
Logic Supply Levels

| Test Point | Voltage | Low Limit | High Limit |
|-------------------|----------------|------------------|-------------------|
| TP1 | +12V DC | +11.85V DC | +13.13V DC |
| TP2 | +5.00V DC | +4.98V DC | +5.02V DC |
| TP4 | -12V DC | -11.85V DC | -13.13V DC |

If the +5V is outside of the tolerance, adjust the trimmer potentiometer labeled R8 or 5V ADJ until it is inside specified tolerances. No independent adjustment is available for the other outputs.

3. Verify that the logic supplies also exist on the Main Control Board at the following test points:

- TP51 - +5V logic supply can be monitored with a DVM. Its signal level should be +5.00 VDC +/- 0.02VDC in respect to TP52.
- TP52 - Digital logic supply common can be monitored with a DVM. Its signal level should be +0V DC in respect to TE. This signal is used as the reference for measuring all isolated signals.
- TP53 - Isolated supply common can be monitored with a DVM. Its signal level should +0V DC in respect to TE. This signal is used as the reference for measuring all isolated signals.
- TP54 - Isolated + 12V supply can be monitored with a DVM. Its signal level should be between 11.85 and 13.13 VDC in respect to TP53.
- TP55 - +12V logic supply can be monitored with a DVM. Its signal level should be between 11.85 and 13.13 VDC in respect to TP57.
- TP56 - -12V logic supply can be monitored with a DVM. Its signal level should be between 11.85 and 13.13 VDC in respect to TP57.
- TP57 - Analog supply common can be monitored with a DVM. Its signal level should be +0VDC in respect to TE. This signal is used as the reference for measuring all analog signals.
- TP58 - +5V isolated supply can be monitored with a DVM. Its signal level should be +5.00V DC +/- 0.02 VDC in respect to TP53.

24V Unregulated Supply

The 24V unregulated power supply is used to supply power for SCR gate firing signals, the 24V ECOAST string, the pre-pilot relay, and the “faulted” relay. The components include a step-down transformer, rectifiers and filter capacitors located on the upper left side of the PSI/Switcher board. A failure will exhibit a drive fault CP-15 “24V Power Supply Loss”. Follow the procedure below if a 24V power supply malfunction is suspected.

1. Measure the +24V supply level on the PSI/Switcher Board. With a DMM on the 200 VDC range, measure the potential from TP25 to TP6. The voltage should be 24V DC +/- 6.0V.
2. Measure the 20 VAC source for the 24V supply. With a DMM on the 200 VAC range, measure from cathode of D12 to the cathode of D13. The measured potential should be 20 VAC +/- 6 VAC. If no potential is measured check fuse F2 on the PSI/Switcher board. If the AC potential is correct and there was no voltage measured in step 1, replace the PSI/Switcher board.
3. If after replacing F2, the fuse opens again, board replacement may be necessary.

Auto Tuning Malfunctions (Series A & B)

The Autotune function of the 1395 allows the user to tune the current and velocity loops in a minimum amount of time and effort. The Autotune function is executed using the Bulletin 1300 Programming Terminal and the standard logic control, dictated by the application. Most malfunctions that occur are indicated with a fault response from the 1395. The fault messages that are associated with Autotuning are VP-40 through VP- 49 and CP-16, CP-18, CP-90 through CP-121. These fault messages are fully explained in Velocity Processor and Current Processor fault description sections.

Autotune measurement tests require the same considerations that normal operation does. Control of the drive ultimately is executed from the selected Logic Command. The parameters associated with Autotune must be properly programmed. The drive set-up parameters must be accurately programmed (i.e. Base Speed, Rated Armature Current Levels, Rated Field Current Levels, etc.) to allow for controlled and safe operation. All ECOAST and other related protective type circuits must be fully operational before attempting to use Autotune.

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