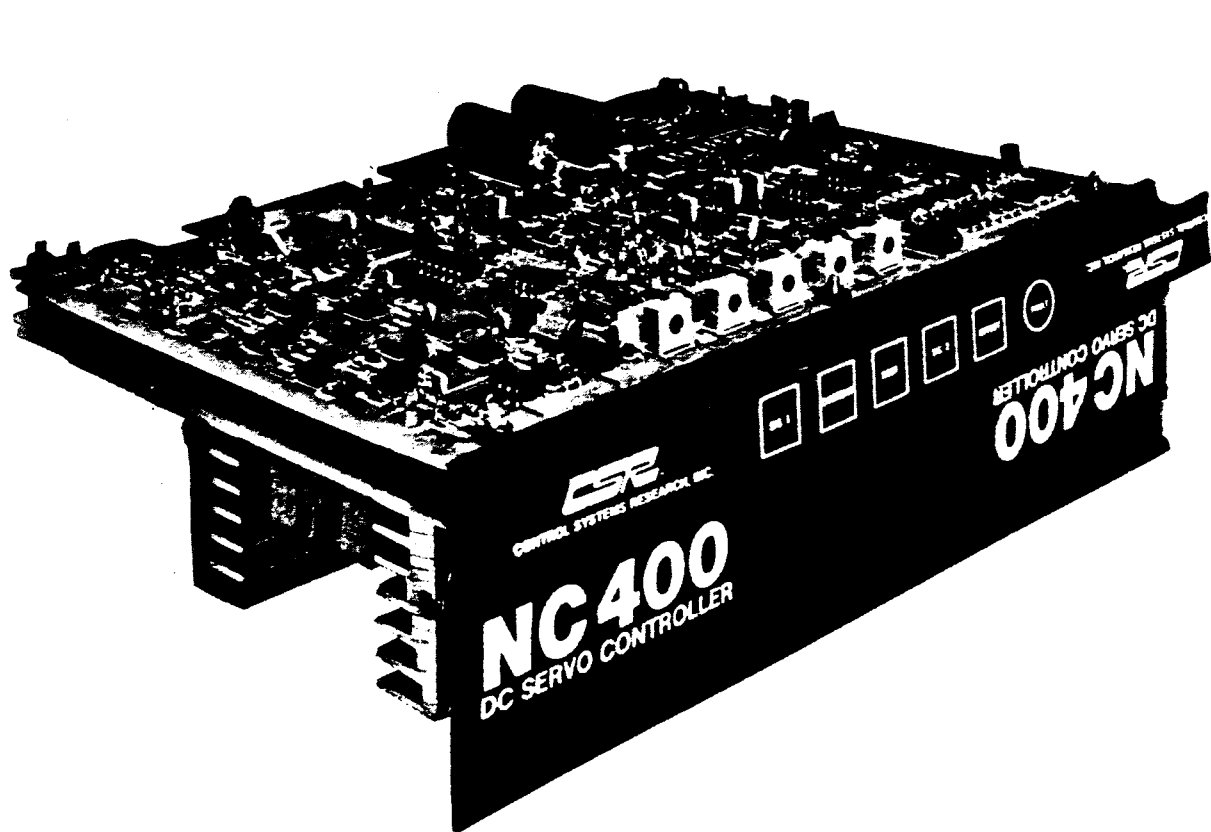


# **OPERATING AND SERVICE MANUAL NC400 SERIES SERVO CONTROLLER**

**MA1229 REV.B**



## NC 400 CARD AMPLIFIER

Operating and Service Manual  
NC400 Series Servo Controllers  
(Preliminary)

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## CHAPTER I

### 1.0 The NC400 Series DC Servo Controllers

#### 1.1 Introduction

Three servo controller models, NC407, NC414 and NC421, and associated equipment assemblies comprise the NC400 Series. These controllers operate from a 100VDC bus and range in peak output currents from 15 to 45 amperes.

These controllers are true plug-in card assemblies and do not require that any wires be detached in order to remove them from their mounting, making replacements or exchanges extremely easy and absolutely foolproof.

The NC400 Series are switch-mode controllers employing rugged power switching transistors, resulting in reliable, efficient and smooth power transfer from the DC supply to the motor load. In fact, average load current form factors are normally lower than 1.01; hence, nearly pure DC current flows in the motor. As a result, substantially more power is obtained from SCR - rated motors, allowing in many cases a reduction of frame size with consequent cost savings.

In addition, an order of magnitude increase in closed-loop velocity and position servo performance is afforded by the high system bandwidths achievable using the NC400 Series.

Besides the three identically-sized servo controller card assemblies, the NC400 Series also offers additional, complementary assemblies (Dual-Axis Card Assembly) in which to mount the controllers for either panel or rack mounting. In addition, both single and three phase Power Supply assemblies are available to provide up to 6KW of power to the controllers. Detailed descriptions of these components, as well as others, are provided in later sections of this manual.

## 1.0 The NC400 Series DC Servo Controllers (Continued)

### 1.1 Introduction (Continued)

The following sections of this manual detail installation, operating and maintenance procedures for the NC400 Series and have, as well, sections covering aspects of the theory of operation of the controllers and basic applications information.

### 1.2 Receiving and Handling

Upon delivery of the equipment, thoroughly inspect the shipping containers and contents for indications of damage incurred in transit. If any of the items called for in the bill of lading or express receipt are damaged or the quantity is short, do not accept them until the freight or express agent makes an appropriate notation on your freight bill or express receipt. If any concealed loss or damage is discovered later, notify your freight or express agent within 15 days of receipt and request that he or she make an inspection.

Claims for loss or damage in shipment must not be deducted from your invoice, nor should payment be withheld pending adjustment of any such claims.

Store the equipment in a clean, dry area. It is advisable to leave the equipment in its shipping container until ready for use.

Procedures for returning equipment to the factory, for any reason, are detailed in later sections of this manual.



## CHAPTER II

### 2.0 Specifications

#### 2.1 Servo Controller Specifications

1) DC Bus Voltage (nominal):	+100VDC		
2) Maximum Output Voltage:	+95		
3) Output Current:			
	<u>NC407</u>	<u>NC414</u>	<u>NC421</u>
Peak (5 sec. max)	<u>+15A</u>	<u>+30A</u>	<u>+45A</u>
RMS	<u>+7A</u>	<u>+14A</u>	<u>+21A</u>
Continuous	<u>+7A</u>	<u>+14A</u>	<u>+21A</u>
4) Horsepower Rating (nominal):			
	<u>NC407</u>	<u>NC414</u>	<u>NC421</u>
Peak	1.5	3.0	4.5
Continuous	0.7	1.4	2.1
5) Power Input Voltages:	+100VDC		
	36VAC (center-tapped) @ 0.27		
6) Power Section Bandwidth:	Small Signal: 0 to 1000Hz		
	Large Signal: 0 to 100Hz		
7) Deadband:	Zero		
8) Efficiency:	85%		
9) Current Limit Range:	NC407: <u>+3A</u> to <u>+15A</u>		
	NC414: <u>+6A</u> to <u>+30A</u>		
	NC421: <u>+9A</u> to <u>+45A</u>		
10) Form Factor (Note 1):	1.01		
11) Gain (Note 2):			
	<u>NC407</u>	<u>NC414</u>	<u>NC421</u>
Input 1:	0 to	0 to	0 to
	5000A/V	10,000A/V	15,000A/V
Input 2:	130 to	260 to	400 to
	1300A/V	2600A/V	4000A/V
12) Gain Linearity:	<u>+5%</u>		
13) Drift (Referred to Input):	10 $\mu$ V/ $^{\circ}$ C		
14) Offset	Adjustable to zero		

## 2.0 Specifications (Continued)

### 2.1 Servo Controller Specifications (Continued)

- |                             |                                     |
|-----------------------------|-------------------------------------|
| 15) Input Resistance (min.) | Input 1: 10K Ohms<br>(Differential) |
|                             | Input 2: 10K Ohms                   |
| 16) Temperature Range:      |                                     |
| Operating:                  | 0°C to +50°C                        |
| Storage:                    | -30°C to +65°C                      |

### ADDITIONAL FEATURES

- |   |  |
|---|--|
| 1) Auxiliary Outputs:                         |  |
| a) Load Current Analogue:                     | 1.6A/V (NC407), 3.3A/V (NC414)<br>4.8A/V (NC421)   |
| b) Reference Voltages:                        | +15VDC @25MA   |
| c) Fault Indication:                          | Open-Collector Transistor<br>Output and PCB LED Indicator  |
| d) RMS Over-Current or Over-Temp. Indication: | Open-Collector Transistor<br>Output with 1.5K ohm Pull-Up<br>to Internal +15VDC  |
| 2) Auxiliary Inputs:                          | Positive Current Inhibit<br>Negative Current Inhibit<br>Enable (short-to-enable)   |
| 3) Protection Circuits:                       | Over-Temperature<br>Over-Voltage<br>Over-Current (RMS)<br>Short-Circuit Across Armature<br>Short-Circuit to Ground -<br>either armature lead |

NOTE 1: At rated continuous current and load inductance of 7A,  
2.9 mH (NC407; 14A, 1.45 mH (NC414); 21A, 1.0mH (NC421)

NOTE 2: Gain ranges shown are for the standard preamplifier  
configuration.

## 2.0 Specifications (Continued)

### 2.2 Power Supply Specifications

#### 2.2.1 Single Phase Power Supplies

- 1) AC Input Voltage: 144VAC, center-tapped  
(nominal, no-load)
- 2) DC Output Voltage; +100VDC  
(nominal, no-load)
- 3) Power Rating: 4.0 KW (max. continuous)
- 4) Transformer/Supply Regulation:

<u>Transformer</u>	<u>No-Load</u>	<u>@Rated PWR</u>	<u>Ripple Volts</u>
T0073	+100VDC	+84VDC	5VP-P
T0074	+100VDC	+82VDC	8VP-P
T0075	+100VDC	+82VDC	12VP-P
T0076	+100VDC	+82VDC	16VP-P

- 5) Cooling: Convection

#### 2.2.2 Three Phase Power Supplies:

- 1) AC Input Voltage: 72VAC line-to-line  
(nominal, no-load) 120VAC @ 1A
- 2) DC Output Voltage: +100VDC  
(nominal, no-load)
- 3) Power Rating: 6.0 KW (max. continuous)
- 4) Transformer/Supply Regulation:

<u>Transformer</u>	<u>No-Load VDC</u>	<u>@Rated PWR</u>	<u>Ripple Volts</u>
T0077	+100VDC	+90VDC	2VP-P
T0078	+100VDC	+90VDC	3VP-P
T0079	+100VDC	+88VDC	4VP-P

- 5) Cooling: Forced Air

## 2.0 Specifications (Continued)

### 2.3 Shunt Regulator Specifications:

#### 1) Peak Power Dissipated:

A1528	1000W
-------	-------

A1529	2000W
-------	-------

#### 2) Continuous Power Dissipated:

A1528	100W
-------	------

A1529	200W
-------	------

#### 3) Thresholds:

Cut-In :	117 - 118 V
----------	-------------

Cut-Out:	112 - 113 V
----------	-------------

## CHAPTER III

### 3.0 Assembly and Terminal Descriptions

#### 3.1 Servo Controller Assemblies: NC407, NC414, NC421

Each of the three servo controller card assemblies A1519 (NC407), A1520 (NC414) and A1521 (NC421) consists of two pcb cards --- a Signal Electronics Card and a Power Electronics Card --- mated together with a plastic handle extrusion to form a complete controller. Only the Power Electronics Card is different in the three different models.

The controller is a true plug-in unit. When inserted into a Dual-Axis Card Assembly, the Signal Electronics Card mates with a 24 pin card edge connector carrying all signals; while the Power Electronics Card mates with a special power card edge connector, through which all power connections are made.

The following is a description of each of the 24 signal inputs and outputs available at A2 on the Signal Electronics Card, and each of the 4 power inputs and outputs available on the Power Electronics Card (refer to Figure 3.1.)

<u>Dual-Axis Card Assy</u>	<u>Servo Controller Assembly</u>	<u>Terminal Description</u>
TB1-1 or TB2-1	A2-10	<u>NON-INVERTING SIGNAL INPUT NO. 1:</u>  Non-inverting signal input point for signal input No. 1, when employing differential input stage. Also can be used as signal No. 3 input point when not employing differential input stage (see Section 5.2). Input impedance is 10K $\Omega$ nominal.

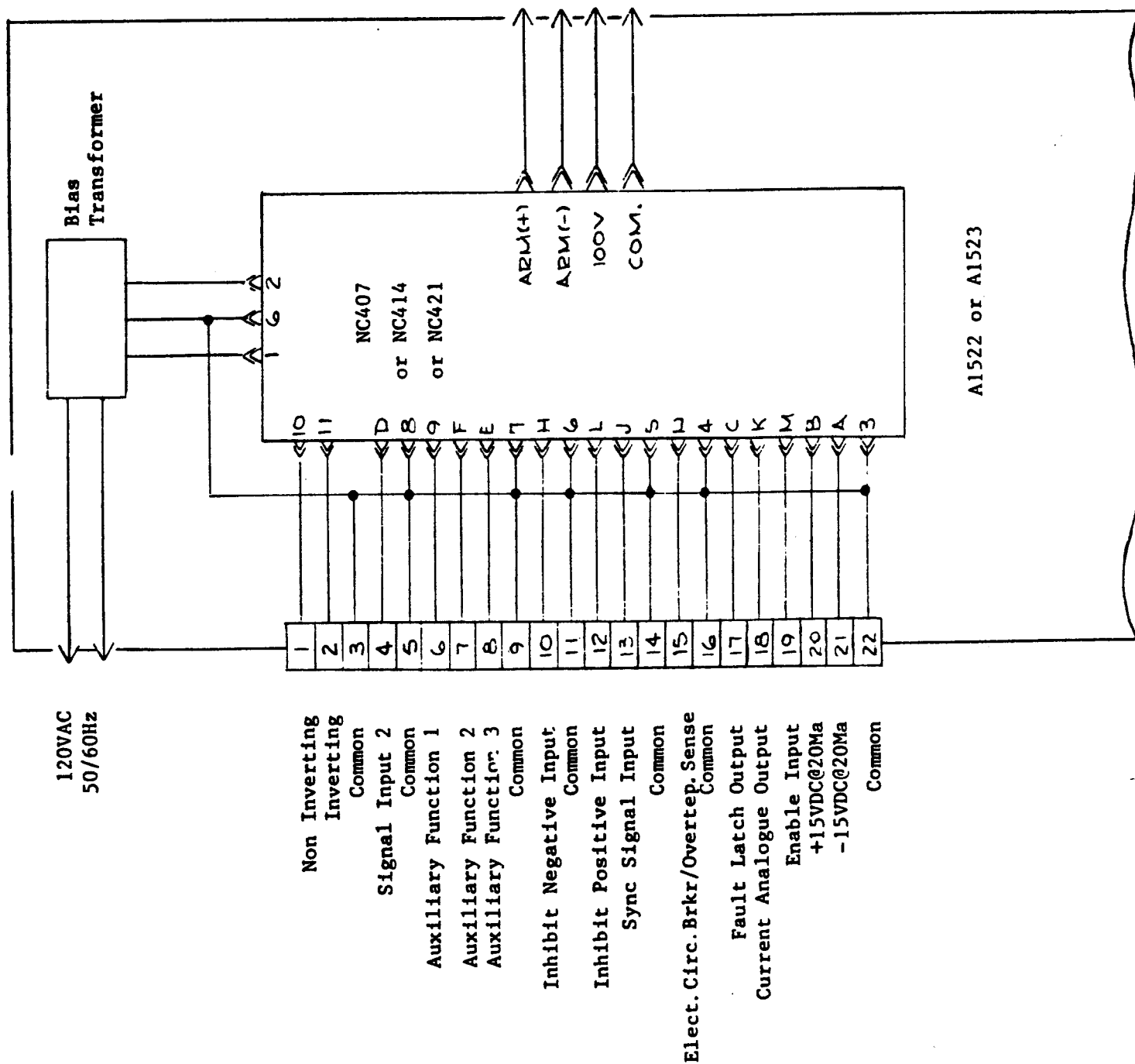


Figure 3.1: Servo Controller Input and Output Designations

### 3.0 Assembly and Terminal Descriptions (Continued)

#### 3.1 Servo Controller Assemblies: NC407, NC414, NC421 (Cont)

<u>Dual-Axis Card Assy</u>	<u>Servo Controller Assembly</u>	<u>Terminal Description</u>
TB1-2 or	A2-11	<u>INVERTING SIGNAL INPUT NO. 1:</u> Inverting signal input No. 1, when employing differential input stage. Input impedance is 10K $\Omega$ nominal. Gain is adjusted by R94 (SIG. 1 potentiometer) at the top of the Signal Electronics Card. CW rotation increases the signal level.
TB1-3,5,9, 11,14,16,22 or TB2-3,5,9, 11,14,16,22	A2-3,4, 5,6,7,8	<u>SIGNAL COMMON:</u> A number of signal common connec- tion points are provided. The sig- nal commons are tied internally on the NC400 Series to the power common.
TB1-4 or TB2-4	A2-D	<u>SIGNAL INPUT NO. 2:</u> Non-differential signal input terminal Gain set using R91 (SIG. 2) poten- tiometer at the top of the Signal Electronics Card. CW adjustment increases the signal level.

### 3.0 Assembly and Terminal Descriptions (Continued)

#### 3.1 Servo Controller Assemblies: NC407, NC414, NC421 (Cont)

<u>Dual-Axis Card Assy</u>	<u>Servo Controller Assembly</u>	<u>Terminal Description</u>
TB1-6 or TB2-6	A2-9	<u>AUXILIARY FUNCTION No. 1:</u> Auxiliary Function 1, 2 and 3 terminals allow the interposition of additional, external circuits in the signal path of the Servo Controller. For example, an external current-limit circuit can be placed between Auxiliary Function terminals 1 and 2 (jumper J4 must be removed). Section 5.2 provides further details.
TB1-7 or TB2-7	A2-f	<u>AUXILIARY FUNCTION No. 2.</u> Used with Aux. Function 1 above, or Aux. Function 3 below to implement special signal processing functions provided by external circuitry. For example, one can interpose a current-limit versus motor speed circuit between the preamplifier and power sections of the controller, using Auxiliary Function No. 2 and No. 3 terminals (jumper J3 must be removed). See Section 5.2 for further details.



### 3.0 Assembly and Terminal Descriptions (Continued)

#### 3.1 Servo Controller Assemblies: NC407, NC414, NC421 (Cont)

<u>Dual-Axis Card Ass'y</u>	<u>Servo Controller Assembly</u>	<u>Terminal Description</u>
TB1-8 or TB2-8	A2-E	<u>AUXILIARY FUNCTION NO.3:</u> Used with Auxiliary Function No.2, above, to implement special signal processing functions. See above and Section 5.2 for details.
TB1-10 or TB2-10	A2-H	<u>INHIBIT POSITIVE:</u> A contact closure or suitable active device capable of sinking a peak current of 20MA and having an off- set or saturation characteristic of less than 0.6V, must be present and closed between the Inhibit Positive terminal and signal common to allow normal controller operation in the positive direction. Positive direc- tion means current flow from the Armature (+) to Armature (-) ter- minals. A delay of approximately 30 msec occurs between inhibit activation and cessation of current flow.
TB1-12 or TB2-12	A2-L	<u>INHIBIT NEGATIVE:</u> Same function as Inhibit Positive above, except that, when activated, current is inhibited from flowing in the negative direction, that is, from Armature (-) to Armature (+).

### 3.0 Assembly and Terminal Descriptions (Continued)

#### 3.1 Servo Controller Assemblies: NC407, NC414, NC421

<u>Dual-Axis Card Assy</u>	<u>Servo Controller Assembly</u>	<u>Terminal Description</u>
TB1-13 or TB2-13	A2-J	<u>SYNC SIGNAL INPUT:</u> This input provides a means of synchronizing the switching frequencies of the controller and other controllers or devices, by injection of a triangle-wave modulation signal from an external source. The injected signal should have an amplitude of from 18 to 20 volts peak-to-peak and a frequency in the range 3 to 6 KHZ. Jumper J1 must be removed when using an external synchronizing signal.
TB1-15 or TB2-15	A2-N	<u>Electronic Circuit Breaker/ Overtemperature Indication:</u> A signal low( $\leq 0.3V$ ) is present at this terminal with respect to signal common during normal controller operation. Up to 10MA of current can be sunk by this circuit. If either the Electronic Circuit Breaker protection circuit or the heat sink over-temperature sensor should activate, this indicator terminal is pulled to +15K VDC through a 1.5K $\Omega$ resistor.

### 3.0 Assembly and Terminal Descriptions (Continued)

#### 3.1 Servo Controller Assemblies: NC407, NC414, NC421

<u>Dual-Axis Card Assy</u>	<u>Servo Controller Assembly</u>	<u>Terminal Description</u>
TB1-17 or TB2-17	A2-C	<u>FAULT LATCH OUTPUT:</u> During normal controller operation a signal low ( $\leq 0.3V$ ) is present at this terminal. Up to 20MA can be sunk. If a fault condition is detected, such as a shorted armature in the motor load, the internal fault latch is set, the controller is disabled and the Fault Latch Output goes to an open state. Pull-up must be provided by external means, as this circuit is an open collector in the tripped state.
TB1-18 or TB2-18	A2-K	<u>CURRENT ANALOGUE OUTPUT:</u> An analogue of load current is available at this terminal. The scale factor is such that $9.3V \pm 10\%$ represents rated peak controller current. The source impedance at this terminal is the equivalent of $2.7K\Omega$ and $0.1 \mu F$ in parallel..

### 3.0 Assembly and Terminal Descriptions (Continued)

#### 3.1 Servo Controller Assemblies: NC407, NC414, NC421 (Cont)

<u>Dual-Axis Card Assy</u>	<u>Servo Controller Assembly</u>	<u>Terminal Description</u>
TB1-19 or TB2-19	A2-M	<u>ENABLE:</u> This terminal provides a means of disabling the controller totally, so that the output bridge circuit semiconductors are all in the OFF state and current is not driven in either direction. The controller is disabled whenever this terminal is <u>not</u> connected to signal common. A delay of approximately 30 msec is incurred when the controller is disabled. Virtually no delay occurs when the controller is enabled.
TB1-20 or TB2-20	A2-B	<u>+15VDC BIAS VOLTAGE:</u> A source of both positive and negative 15VDC bias voltage is provided by the NC400 Series servo controllers and made available at this terminal and the one below. Current draw should not exceed 25 MA. Ripple and noise are less than 50 MV peak-to-peak. These voltages can be used to power auxiliary function circuits or provide reference voltages. See Section 5.3 for further details.
TB1-21 or TB2-21	A2-A	<u>-15VDC BIAS VOLTAGE:</u> See above for details.

### 3.0 Assembly and Terminal Descriptions (Continued)

#### 3.1 Servo Controller Assemblies: NC407, NC414, NC421 (Cont)

<u>Dual-Axis Card Assy</u>	<u>Servo Controller Assembly</u>	<u>Terminal Description</u>
	A2-1 A2-2	<u>36VAC INPUT:</u> A source of 36 VAC, center-tapped, at 0.2 amperes maximum is required at these terminals to provide the low level bias voltages for the controller. The center tap is connected to any of the signal common terminals but preferrably to terminal A2.6.
-----		
COMMON	A1-1	<u>POWER COMMON:</u> Terminal for connection of the nega- tive or common line for the 100VDC power bus from the power supply.
+100VDC	A1-2	<u>+100VDC BUS:</u> Terminal for connection of the posi- tive +100VDC line from the power supply. Connection to this terminal and the one above (common) is made through 0.25" FASTON terminals on the Dual- Axis Card and through a special power board edge connector (AMP No. 530521) to the controller assembly.

### 3.0 Assembly and Terminal Descriptions (Continued)

#### 3.1 Servo Controller Assemblies: NC407, NC414, NC421 (Cont)

<u>Dual-Axis Card Assy</u>	<u>Servo Controller Assembly</u>	<u>Terminal Description</u>
ARM (+)	A1-3	<u>ARMATURE (+):</u> Terminal for connection of the positively defined armature (load) lead.
ARM (-)	A1-4	<u>ARMATURE (-):</u> Terminal for connection of the negatively defined armature (load) lead. As with the power common and +100VDC connections, the armature (+) and (-) connections are made through FASTONS and the special four terminal power board edge connector mentioned above.

#### 3.2 Dual-Axis Card Assemblies. A1522, A1523

A single card, available in two versions, one for rack and one for panel mounting, serves as the holder and connection means for the servo controller cards.

This Dual-Axis Card accommodates one or two controller cards. Each controller card plugs into a set of two card edge connectors, one for signal and one for power voltages. Signal wire connections are made to the Dual-Axis Card Assembly through two 22 pin terminal strips, designated TB1 and TB2, one strip for each axis controller.

### 3.0 Assembly and Terminal Descriptions (Continued)

#### 3.2 Dual-Axis Card Assemblies. A1522, A1523 (Cont)

Power wiring connections are made to 0.25" male FASTON terminals. Two groups of four terminals each are provided, one group for each axis controller.

The various terminal designations and descriptions are given in the previous Section, 3.1. The Dual-Axis Card also contains a cooling fan, bias voltage transformers and fusing for the DC bus inputs and the 120VAC input.

Consult the outline drawings in Section A-1 for further details of this assembly.

#### 3.3 Single-Phase Power Supply Assemblies: A1524 and A1525

A single printed circuit card, the same size as the Dual-Axis card, is employed for both the single and three phase power supply assemblies for the NC400 Series. As with the Dual-Axis Card, both panel and rack mounting versions are available.

The single phase versions A1524 (panel) and A1525 (rack), when used with the appropriate transformer, can provide up to 4.0KW of average continuous power output (See Table 1). The nominal no-load output bus voltage is +100VDC.

AC input connections are made to three screw terminals designated AC1, AC2 and AC3. AC2 is the center-tap connection point.

A total of 12 power output terminals (0.25" male FASTON), six for the power commons and six for the +100VDC connections, are provided.

Each single-phase power supply assembly has a total of 14,000  $\mu$ F (nominal) of filtering. In addition, where required, an optional Shunt Regulator Assembly (See Section 3.5) can be added to the supply by making only two connections.

### 3.0 Assembly and Terminal Descriptions (Continued)

#### 3.4 Three-Phase Power Supply Assemblies: A1526 and A1527

Up to 6.0 KW of average continuous power output can be obtained from each of the two versions, A1526 (panel) and A1527 (rack), of the three-phase power supply assemblies for the NC400 Series (See Table 1).

Unlike the single-phase versions, the three-phase assemblies contain a cooling fan to cool the three-phase rectifier assembly.

Three-phase line connections are made to the three screw terminals AC1, AC2 and AC3. DC power output is available from the 12 FASTON terminals described above in Section 3.3.

#### 3.5 Shunt Regulator Assemblies: A1528 and A1529

As an option, a Shunt Regulator Card can be added to either the single or three phase Power Supply Assemblies. This card regulates the DC bus voltage during periods of regeneration (motor deceleration), when energy returned to the power supply filter capacitor exceeds that supplied.

The resultant voltage build-up on the capacitors activates the Shunt Regulator Card, once a nominal voltage level of 115VDC is exceeded.

Two versions of the regulator are available. The A1528 dissipates 1000 watts peak and 100 watts continuous, while the A1529 dissipates 2000 watts peak and 200 watts continuous.

Both the A1528 and A1529 are the same size, mount in the same manner as the power supply rectifier assembly, and are connected using just two jumper wires supplied with each regulator card.



### 3.0 Assembly and Terminal Descriptions (Continued)

#### 3.5 Shunt Regulator Assemblies: A1528 and A1529 (Continued)

The upper threshold or trip point on each regulator card is factory set and should not require adjustment.

Connection is made to two 0.25" male FASTON terminals on the power supply assembly card. These terminals are designated REG (+) and REG (-), and mate with similarly designated terminals on the regulator card using the jumper wires supplied.

See Section A.1 for further details.

#### 3.6 Rack Panel Assemblies: A1516 and A1518

The Rack Panel Assembly consists simply of a flat, aluminum plate punched to mount to a standard 19" rack. The Rack Panel Assembly can accommodate two assemblies such as the Dual-Axis Card Assembly, which would provide controller card slots for a four axis system.

Alternately, a Power Supply Card Assembly could be substituted for one of the Dual-Axis Assemblies, providing a two-axis system with power supply.

Of course, other combinations are possible, and in fact, the A1518 assembly includes a blank plate, used to cover the unused access hole, should only a single assembly be used with the rack panel.

All required hardware items are supplied with either of the two Rack Panel Assemblies. If desired, CSR can provide assembled Rack Panel, Dual-Axis and Power Supply systems.

See Section A.1 for further information.

### 3.0 Assembly and Terminal Descriptions (Continued)

#### 3.7 Power Transformers

A group of seven standard power transformers are available to be used with the Power Supply Assemblies. Four single-phase transformers provide power output ratings from 1.0 to 4.0 KW. Three three-phase transformers provide 2.0, 4.0 and 6.0 KW of continuous power output.

The single-phase designs have a 144VAC, center-tapped secondary, and a dual primary of 120VAC. All the voltages are no-load values.

The three-phase designs all have delta-connected secondaries of 72VAC line-to-line; a separate 120VAC, 250VA single-phase secondary for fan and bias circuits; and dual three-phase primaries that can be connected for either 240VAC or 480VAC.

Table 1 lists the appropriate power transformer and power supply assembly combinations, while Section A.1 contains outline drawings of the various transformers. All transformers listed are 60HZ designs. For 50HZ units or other primary voltages contact the factory or one of the agents listed at the end of this manual.

AVERAGE POWER	NO. OF PHASES	TRANSFORMER REQUIRED	POWER SUPPLY ASSEMBLY	
			Rack Mtg	Panel Mtg
1.0 KW	1	T0073	A1525	A1524
2.0 KW	1	T0074	A1525	A1524
3.0 KW	1	T0075	A1525	A1524
4.0 KW	1	T0076	A1525	A1524
5.0 KW	3	T0077	A1527	A1526
6.0 KW	3	T0078	A1527	A1526
7.0 KW	3	T0079	A1527	A1526

Table 3.1: Power Supply Combinations

## CHAPTER IV

### 4.0 Installation Procedures

#### 4.1 General Precautions

The general installation procedures are:

1. Equipment ambient temperatures should not exceed 50°C (122°F).
2. Equipment operational altitude should not exceed 6000 feet above sea level.
3. The equipment atmosphere should be free of highly flammable or combustible vapors, corrosive chemical fumes, oil vapor, steam, excessive moisture, and particulants.

#### 4.2 Panel Mounted Assemblies

The panel-mounting versions of the NC400 Series assemblies can be mounted on either horizontal or vertical surfaces. The plastic mounting rails on each of the assemblies provide a convenient and consistent mounting means for each of the panel mounted units.

Recommended mounting hardware is 10-32 or 1/4-20 or M-6 with appropriate flat and lock washers.

During panel layout, allow sufficient clearance between assemblies and adjacent components for wire ways and access to connectors, terminals and fuses located on the assemblies. Also, locate the Power Supply Assemblies centrally with respect to the Dual-Axis Card Assemblies. This will aid in keeping power wiring lead lengths to a minimum, which, in turn, will obviate the need for additional bus smoothing filter capacitors (See Section 4.4.1).

## 4.0 Installation Procedures (Continued)

### 4.2 Panel Mounted Assemblies (Continued)

Consult the outline and application drawings contained in Section A.1 for further information.

### 4.3 Rack Mounted Assemblies

Three assemblies, the A1523 Dual-Axis Card Assembly, the A1525 Single-Phase and A1527 Three-Phase Power Supply assemblies, A1516 and A1518, available in the NC400 Series, are specially designed to mate with the Dual-Axis and Power Supply Assemblies to form complete rack panel units. If desired, CSR can supply completely assembled rack units ready for mounting.

The various rack assemblies are designed to accept wiring from the rear. Servo controller assemblies, however, are inserted from the front in the same manner as with the panel mounted versions of the NC400 Series.

A total of 8 screws, four on each side, are required to mount the A1516 and A1518 panels to a suitable rack.

If the power supply assembly is located at a distance from the Dual-Axis Card assemblies so that power wire lengths are greater than four feet, it is advised that an auxiliary bus smoothing capacitor be mounted and wired to the Dual-Axis Assembly. See Section 4.4.1 for further details.

Section A.1 contains further information regarding rack mounting of the NC400 Series equipment.

#### 4.0 Installation Procedures (Continued)

##### 4.4 Wiring

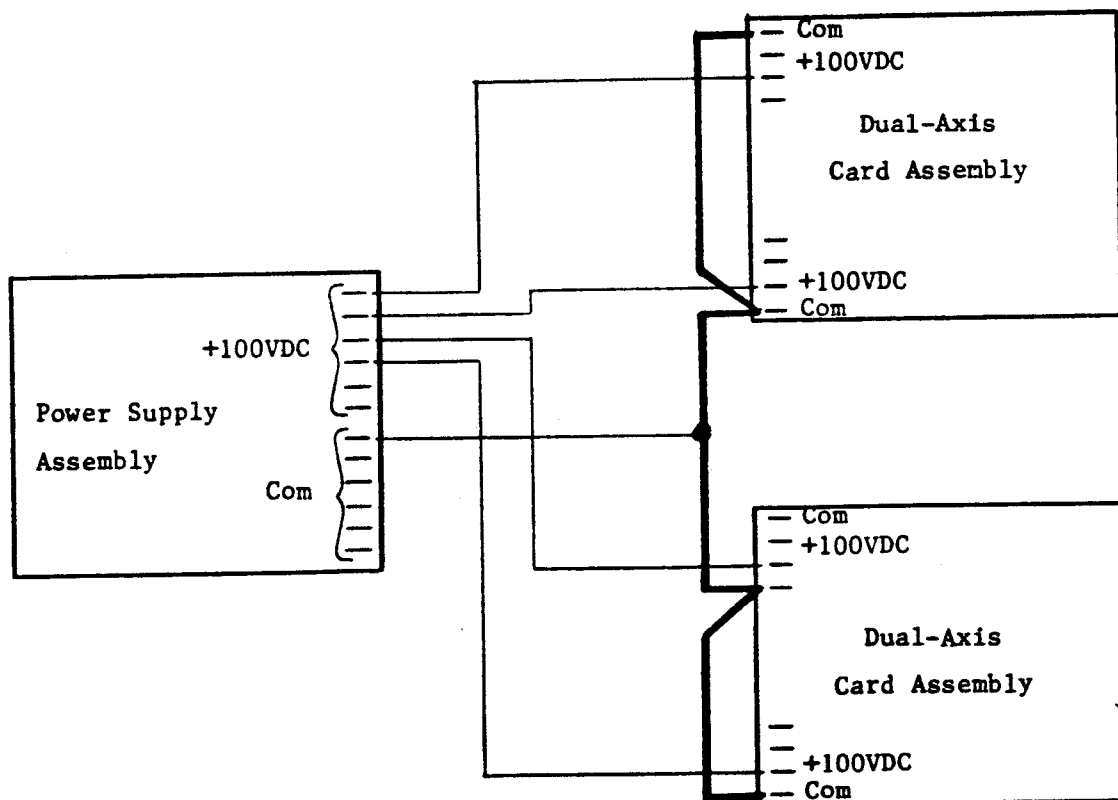
###### 4.4.1 Power Wiring

All power wiring for the armature and power supply connections should be 12 guage ( $3.309 \text{ mm}^2$ ), Machine Tool Wire (MTW), or equivalently rated wire. The wire used for the 120VAC supply for the cooling fan and bias circuits can be 16 guage ( $1.309 \text{ mm}^2$ ).

It is suggested that the armature circuit wires be twisted to minimize the loop area in the armature circuit. This will help to reduce radiated electrical noise from the servo controllers. When possible, the power supply wires should also be twisted.

Wiring between the transformer secondary and the single-phase Power Supply Assemblies should be 10 guage ( $5.261 \text{ mm}^2$ ) or larger (MTW). Secondary side wiring for the three-phase power supplies should also be 10 guage.

To minimize cross talk between controllers powered by the same power supply, it is advisable in some cases to "strap" the power commons at the controllers (Dual-Axis Card Assemblies) and use a single common return line to the power supply. Figure 4.1 illustrates this technique.



**FIGURE 4.1: Technique for Cross-Talk Reduction by Common Strapping**

## 4.0 Installation Procedures (Continued)

### 4.4 Wiring

#### 4.4.2 Signal Wiring and Shielding

All signal and limit circuit wiring need not be larger than 20 guage ( $0.518 \text{ mm}^2$ ). For signal circuits, including the tachometer, twisted-shielded pair wire should be employed.

Proper termination of shielded cables is important in order to avoid creating ground loops or otherwise degrading the noise immunity of the servo controller. In general, cable shields should be terminated at one end only. The other end is left floating. In most applications satisfactory noise immunity will be realized with the signal line shields terminated at the servo controller, to the controller signal common terminals. In some cases, however, terminating the individual shields at the respective signal sources will yield better noise immunity.

In systems particularly sensitive to electrical noise, use of shielding for the armature wiring may be required.

It is important to maintain the continuity of cable shields through any intervening connectors and/or terminal blocks. Also, attempt to minimize the length of unshielded cable at these interconnections.

#### 4.4.3 Earth (Ground) Connections

A high quality earth connection should be made to the common of the power supply. An unused FASTON terminal on the Power Supply Assembly can be used for this purpose. Alternately, connection can be made to the center-tap terminal on single-phase transformers, although this is not recommended, if the transformer is located at a distance of more than a few feet from the Power Supply Assembly.



#### 4.0 Installation Procedures (Continued)

##### 4.5 Ancillary Components

###### 4.5.1 Bus Filter Capacitor

Each NC400 Series servo controller contains a small-valued bus filter capacitor. Because of its value, this capacitor is limited in its ability to provide the required bus smoothing for proper operation of the controller, when the wire lengths between the power supply and servo controller exceed approximately four feet.

In most cases this requirement can be met, but, when it cannot, it is recommended that an auxiliary bus smoothing capacitor be added. The capacitor should be located in close proximity to the Dual-Axis Card Assembly, near the end of the unit containing the power FASTON terminals. For rack mounted units, a Capacitor Mounting Assembly A1603 can be supplied by CSR, if desired.

When the auxiliary bus smoothing capacitor is supplied by CSR, a unit having 3500 $\mu$ F of capacitance and a voltage rating of 150W VDC is provided.

###### 4.5.2 Armature Inductor

The value of the load inductance determines the peak-to-peak ripple current in the load. For this reason, minimum load inductance values are specified for the NC400 Series controller models. Keeping the total load inductance -- motor inductance plus any added external inductance -- equal to or greater than the values specified will insure that the form factors do not exceed 1.01, and that the controller functions normally otherwise.

#### 4.5.2 Armature Inductor (Continued)

Table 4.1 lists the recommended minimum load inductance for the three NC400 Series controller models, and Table 4.2 lists several standard inductors available from CSR, that can be used as auxiliary load circuit inductors.

To determine if a load inductor is required and what its value should be, use the following equation:

$$L_{AUX} \geq L_{MIN} - L_{MOTOR}$$

where  $L_{AUX}$  is the required auxiliary load circuit inductance, and  $L_{MIN}$  is minimum specified load inductance for a particular controller. Obviously, if the calculated difference is zero or negative in value, no auxiliary inductor is required.

Model No.	Minimum Load Inductance $L_{MIN}$
NC407	2.9 mh
NC414	1.45 mh
NC421	1.0 mh

Table 4.1: NC400 Series Minimum Load Inductance Values.

INDUCTOR PART NO.	NOM. VALUE	RATED CURRENT	PEAK CURRENT
L0004	1.5 mh	20A	40A
L0005	1.5 mh	30A	60A
L0007	1.5 mh	10A	30A
L0009	1.0 mh	10A	30A
L0015	0.5 mh	25A	75A
L0017	2.0 mh	10A	30A

Table 4.2: Standard Inductors for use as  $L_{AUX}$

#### 4.5.3 Load Contactor

It is a requirement in many applications that a motor load, or "M" contactor be used to completely disconnect the motor from the controller, whenever an emergency stop or power-down situation arises. Additionally, a dynamic braking resistor is often employed with such a contactor to bring the motor to a quick halt following contactor denenergization.

Most DC contactors, such as the Ward Leonard No. 7000-2140-11, that are rated to handle the peak controller current during contact breaking, can be used.

A typical application employing such a load contactor is shown in Figure 4.2. The DBR (dynamic braking resistor) should be chosen so that the total circuit resistance, DBR plus motor armature resistance, limits the current to less than the demagnetization current for the motor.

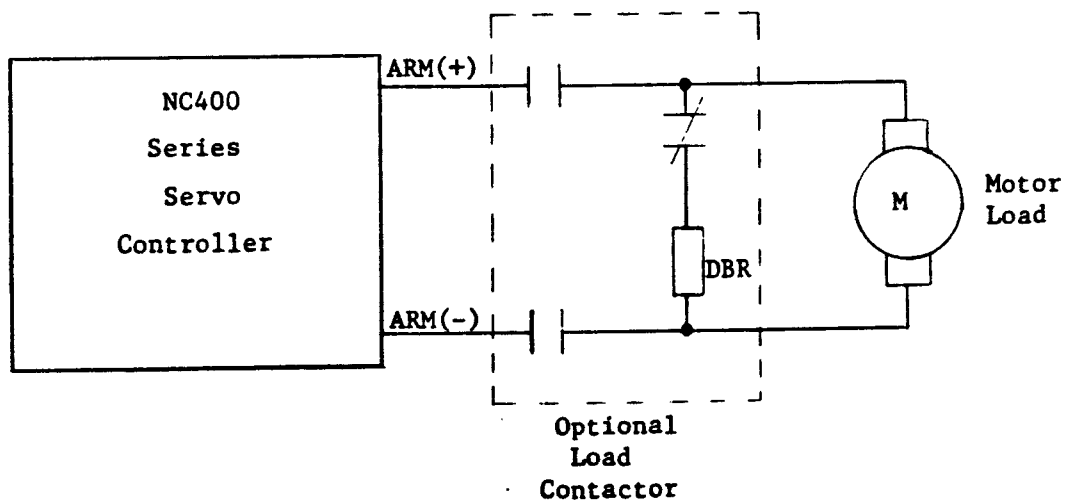
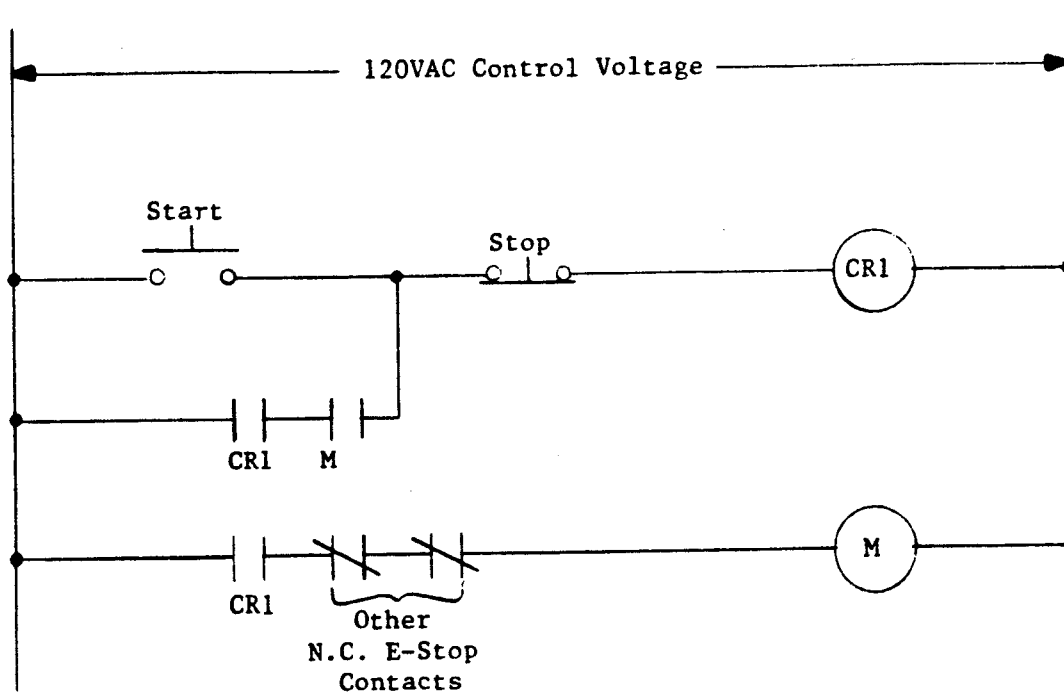


Figure 4.2: Application of Optional Load Contactor.

## CHAPTER V

### 5.0 Set-Up Procedures

#### 5.1 Power Supply Tests

With all installation and wiring finished, perform the following power supply tests:

1. Remove all servo controllers from their respective Dual Axis Card Assemblies.
2. Remove one lead of the Shunt Regulator Cards, if used, and tape it securely away from exposed circuitry and grounded chassis parts.
3. Momentarily apply AC power to the power transformers, including the 120VAC power for the fans and bias transformers. Measure the voltage between the +100VDC and Common terminals on the Dual-Axis Assemblies. The polarity should be correct and the voltage magnitude between 90 and 110VDC.
4. Again apply power. Check that all cooling fans are operating and that between 105 and 125VAC is measured between the 120VAC FASTON terminals on the Dual-Axis Card Assemblies.
5. With power removed and sufficient time (15 seconds or longer) elapsed for discharge of the supply capacitors, reconnect the leads of the Shunt Regulator Cards removed in (2) above.

#### 5.2 Servo Controller Set-Up Procedures

##### 5.2.1 Bridge Resistance Checks

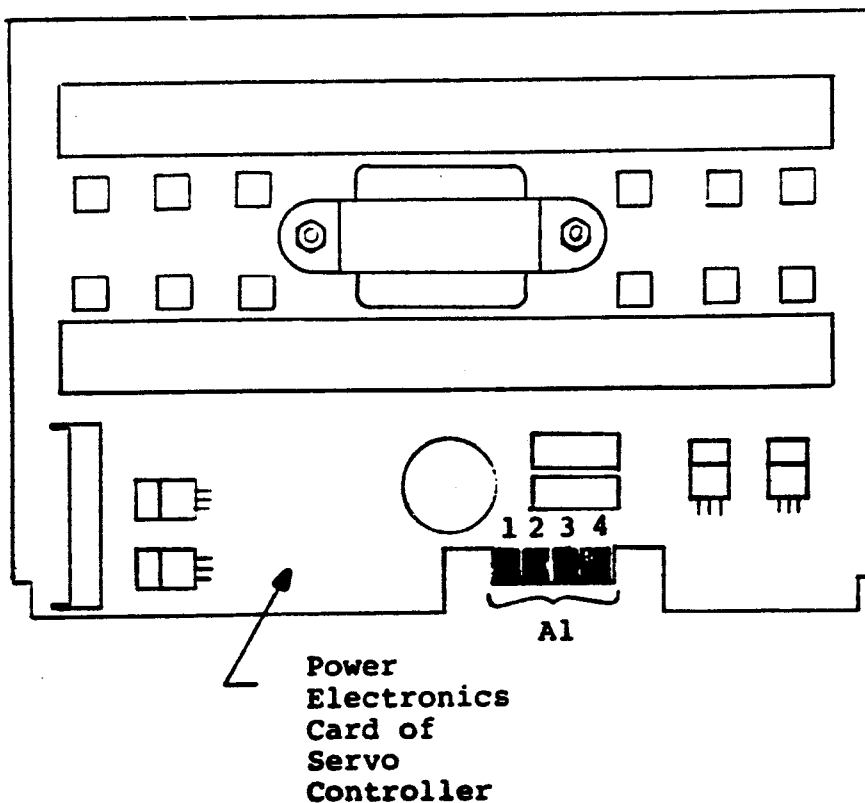
Before insertion of a new or repaired servo controller into the Dual-Axis card Assembly, make the following power section resistance check.

### 5.2.1 Bridge Resistance Checks (Continued)

Using a V-O-M (Volt-ohm meter), make the resistance measurements shown below:

Test Points		Measurement Value
Pos. Lead	Neg. Lead	
A1-2	A1-3	$\geq 2K\Omega$
A1-2	A1-4	$\geq 2K\Omega$
A1-3	A1-1	$\geq 2K\Omega$
A1-4	A1-1	$\geq 2K\Omega$
A1-2	A1-1	$\geq 2K\Omega$
A1-1	A1-2	$\leq 30\Omega$

Table 5.1: Power Section Resistance Test Values



### 5.2.1 Bridge Resistance Checks (Continued)

Consult the fault determination procedures in Chapter VII, if discrepancies are found in these measurements.

**IMPORTANT:** Each servo axis should be completely tested for proper operation before the next axis controller is inserted into the Dual-Axis Card and placed in service.

Insert the first servo controller to be set-up into the appropriate slot in the Dual-Axis Card Assembly.

### 5.2.2 Polarity (Direction) Determination

The polarity of the NC400 Series servo controllers is such that a positive input signal on the inverting signal input terminal results in a positive voltage at the ARM (+) terminal with respect to the ARM (-) terminal.

If the motor and tachometer polarities are known, proper connection to the controller can be made. A positive input signal should produce motor rotation that yields a positive tachometer feedback signal at input No. 2.

If the motor/tachometer polarities are not known, it is advisable to establish same before proceeding with the controller set-up. To establish motor/tachometer polarity use the following procedure:

1. Connect the motor through a switch directly to the +100VDC power supply.

**CAUTION:** EXTREME CARE MUST BE EXERCISED WHEN APPLYING THIS PROCEDURE TO MACHINE-MOUNTED MOTORS TO AVOID INCURRING DAMAGE TO THE MACHINE, DRIVE COMPONENTS AND/OR MOTOR.

### 5.2.1 Bridge Resistance Checks (Continued)

2. Apply power and momentarily close the switch. Note the direction of motor rotation and the relative polarities of the motor voltage and the tachometer voltage.
3. Connect the motor and tachometer leads to the controller keeping in mind the desired motor direction and polarities.

### 5.2.3 Enable and Inhibit Circuit Tests

For an NC400 Series servo controller to be fully operational, logic zeros must be present at each of the Positive and Negative Inhibit and Enable terminals.

When only contact closures are used to realize these functions, a V-O-M or similar instrument can be used to check for proper closures at the appropriate terminals.

When active devices are employed to provide the Inhibit and Enable functions, a different test using the V-O-M must be made. Remove the DC bus fuse on the Dual-Axis Card Assembly for the controller to be checked and proceed as follows.

For each of the inhibits and enable, in turn, measure the voltage present at the appropriate terminal, when, first, system power is applied, and, second, the function (inhibit or enable) is cycled from the active mode to the inactive mode.

During the inactive mode, a logic zero ( $\leq 0.3V$ ) should appear at the desired function's terminal; while a logic high (5.0V nominal for Enable; 1.5V nominal for either Inhibit) should appear during the active mode.

Replace the DC bus fuse after making these tests.



#### 5.2.4 Potentiometer Adjustments

Each NC400 Series servo controller contains five adjustment potentiometers located at the top of the Signal Electronics Card. Normally, only these five potentiometers need to be adjusted during the set-up procedure. The adjustment procedure for each is explained in the following sections.

Before the adjustment procedure is carried out, one must establish that the servo controller is properly attached to the motor load and is otherwise functioning normally, although perhaps not optimally.

Assuming the procedures in the preceding sections were carried out successfully, momentarily apply power to the controller without any signal command applied. All fuses should be in place and all signal and load connections made at this time.

If upon application of power, the motor rapidly accelerates, a runaway condition exists, due, most likely, to a reversal of either the motor or tachometer polarities. Repeat the procedure in Section 5.2.2, if this is the case.

If the motor and tachometer are properly connected, and the controller is functioning normally otherwise, the motor shaft should remain stationary, or at most drift slightly in either direction, when power is applied.

##### 5.2.4.1 Offset Adjustment

With conditions as above, adjust the OFFSET potentiometer R90 until any rotation of the motor shaft ceases. Then, with power to the controller OFF, obtain a zero speed command on the signal command line, and connect the signal lead to the controller.

#### 5.2.4.1 Offset Adjustment (Continued)

Reapply power and again adjust the OFFSET potentiometer for a static motor shaft condition.

If the OFFSET potentiometer has insufficient range, a lower value of resistance can be substituted for R73 to obtain a wider offset adjustment range. See Figure 5.3 for the location of R73 and other adjustment components on the Signal Electronics Card.

#### 5.2.4.2 Current Limit Adjustment

Each NC400 Series servo controller contains a CURRENT LIMIT adjustment potentiometer R93 that is used to set the peak magnitude of current supplied by the controller. The adjustment range is from 100% to approximately 20% of peak rated current.

As mentioned earlier in Section 3.1 an external current limit function can be added by using the Auxiliary Function No. 1 and No. 2 terminals. Figure 5.2 depicts a means of implementing an external current limit using only a potentiometer. When using such a scheme, the jumper J4 on the Signal Electronics Card must be removed. This jumper can be removed by simply cutting its ends flush with the pcb. The two solder terminals supporting J4 can be used if it is ever desired to reinstall this jumper.

If peak current from the controller is desired, simply adjust the CURRENT LIMIT potentiometer full CCW. If a lower value of peak current is required, use the following procedure:

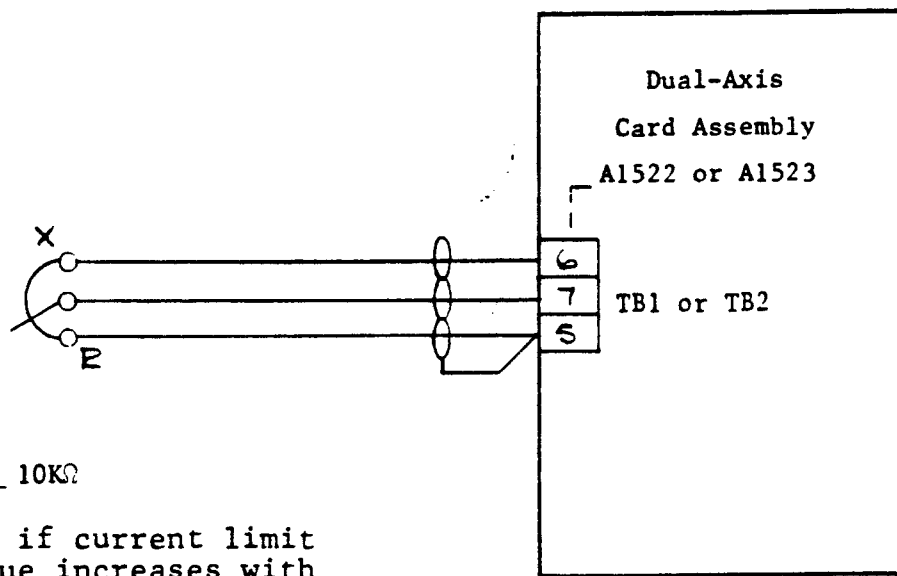
#### 5.2.4.2 Current Limit Adjustment (Continued)

1. Set R93 to full CW.
2. Apply power.
3. Apply a low frequency (0.5Hz), 5 to 15V, bi-directional, square wave signal to the velocity command input (usually Signal Input No. 1)

NOTE: Before applying this test signal, check that R94, the Signal No. 1 gain potentiometer is at approximately midrange; R92, the Servo Response potentiometer is at or near the CCW position; and R91, the Signal No. 2 potentiometer is at the full CW position if the tachometer signal is returned to this input.

While the test signal is applied and the controller operational, monitor the Current Analogue Output at the Dual-Axis Card Assembly terminal TB1-18 (or TB2-18) with an oscilloscope. Peak current is represented at this terminal by a voltage magnitude of  $9.3V \pm 10\%$ . Set the CURRENT LIMIT potentiometer to the desired current level by slowly adjusting it toward the CCW position until the desired level is achieved.

For example, if it is desired to limit the peak current of an NC421 to 35A, the CURRENT LIMIT potentiometer would be adjusted CCW until a peak voltage magnitude of  $(35/45) \times 9.3 \approx 7.2V$  is noted on the Current Analogue Monitor during motor reversals.



$$5K\Omega \leq R \leq 10K\Omega$$

X = CW, if current limit  
value increases with  
CW rotation

X = CCW, if current limit  
value decreases with  
CW rotation

Figure 5.2: Method of Implementing External Current Limit Control.

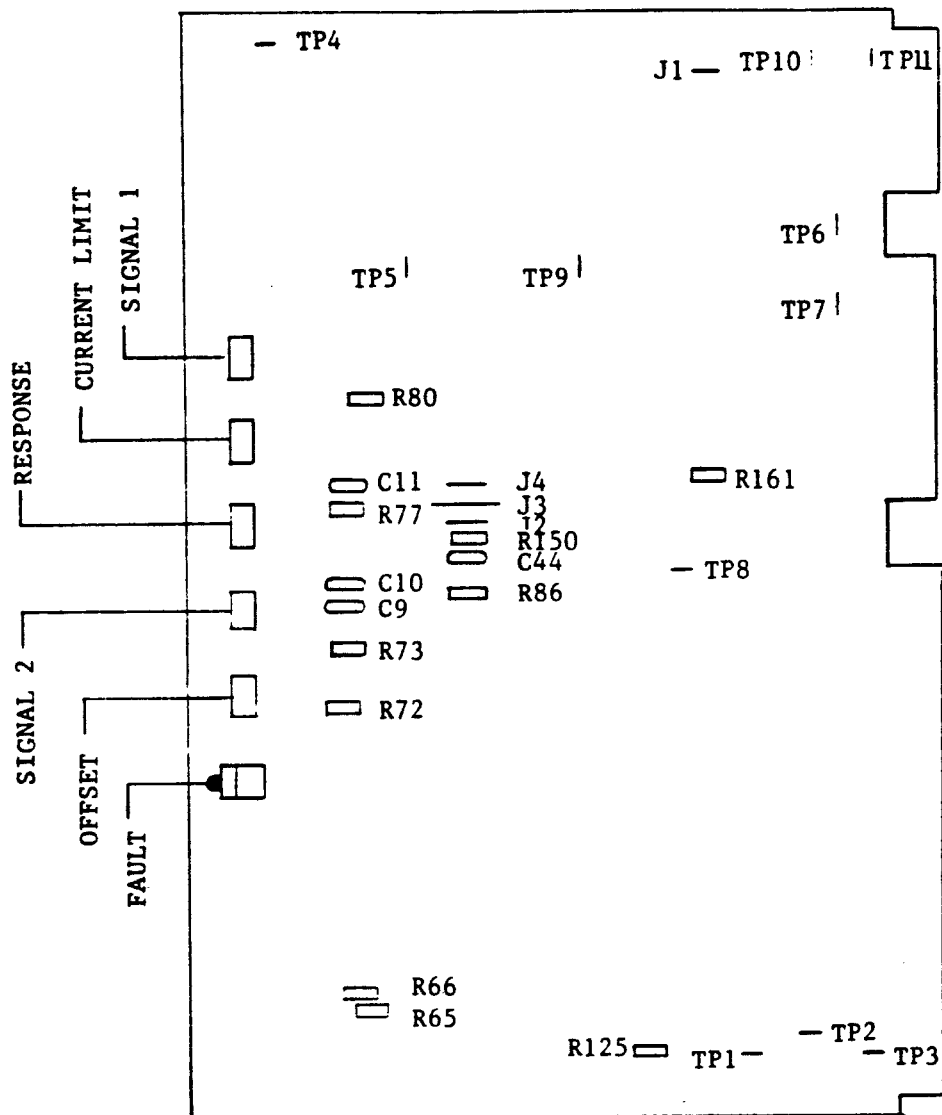


Figure 5.3: Component Locations on NC400 Series Signal Electronics Card.

#### 5.2.4.3 Scale Factor Adjustment

In the standard version of the NC400 Series controller, two scale factor adjustment potentiometers are provided in the preamplifier section of the controller. R94 adjusts the scale factor for Input No. 1, while R91 is used to adjust the scaling of Input No. 2.

Both of these potentiometers are located at the top of the Signal Electronics Card. Both potentiometers are adjusted CW to increase scaling.

The normal velocity loop scaling procedure is as follows:

1. Adjust R91 (SIG. 2) full CW.

NOTE: This procedure assumes the tachometer signal is input Signal No. 2.

2. Adjust R94 (SIG. 1) full CCW.
3. Input a DC level (or low frequency square wave signal) to Input No. 1 having a magnitude equal to the maximum velocity command signal magnitude.
4. Apply power to the controller and monitor the tachometer signal magnitude using a V-O-M or oscilloscope. The oscilloscope is preferred, if a square wave signal is being used.
5. Gradually adjust R94 (SIG. 1) CW until the desired maximum motor speed is attained. The tachometer scale factor in volts/rad/second or volts/1000 rpm must be known in order to make this adjustment. Most tachometers supplied by CSR are scaled at 7.0V/K rpm.
6. If desired maximum speed is not attained with the Signal 1 scale factor potentiometer full CW, then gradually adjust R91 (SIG. 2) CCW until desired motor speed is reached.

#### 5.2.4.3 Scale Factor Adjustment (Continued)

In some cases three input signals, including the tachometer signal, must be summed into the controller. In this case the non-inverting input of Signal Input No. 1 is used as the third input point. Also, jumper J2 (see Figure 5.3 for location) is removed, and C44 and R162 are chosen and soldered in place.

The value of R162 is selected first. In this case the scale factor potentiometers R94 and R91 are adjusted in much the same manner as described above, but R162 is selected using a resistor substitution box or similar instrument. The total input resistance for the third input becomes  $R_{162} + R_{81}$ . R81 is normally  $10K\Omega \pm 1\%$ , but can be changed, if desired.

Then the noise filter capacitor C44 is selected for a desired 3dB cutoff frequency  $f_0$  using the following equation:

$$C_{44} = \frac{1}{2\pi f_0 R_p}$$

where  $R_p$  is the parallel combination of R162 and R81.

Section 6.2 provides further details regarding the three input version of the Preamplifier Section.

#### 5.2.4.4 Servo Response Adjustment

The NC400 Series servo controllers contain a unique, adjustable servo response or servo stability adjustment potentiometer R92. This potentiometer is located at the top of the Signal Electronics Card and is labeled RESP.

#### 5.2.4.4 Servo Response Adjustment (Continued)

In most applications it is necessary to adjust only this potentiometer to achieve optimum response. The adjustment procedure is as follows:

1. Provide the controller with a low frequency, bi-directional square-wave velocity command (a 0.5Hz,  $\pm 5.0V$  waveform is often employed).
2. Apply power to the controller, and while monitoring the tachometer signal\*, gradually adjust the RESP potentiometer R92 from the CCW toward the CW position. Optimum response (critically-damped) should be achieved at some position before reaching full CW on R92. Figure 5.4 illustrates the types of waveforms observed for various settings of R92.

#### 5.2.5 Compensation Component Changes

In some applications, especially those where the load inertia is much smaller or larger than normally encountered, the standard compensation components values of  $0.047\mu F$  for C10 and  $150K\Omega$  for R77 may not allow of an optimum setting of the RESPONSE potentiometer R92. In fact, the velocity loop may be unstable for any setting of R92.

In these cases different values for C10 and R77 must be chosen. The following procedure can be used to select these values:

1. Short circuit C10 with a short jumper wire.
2. Replace R77 with a resistor substitution box. Initially set the box resistance at  $10K\Omega$ .
3. Set R92, the RESPONSE potentiometer to approximately midrange.

---

\*If the tachometer signal is excessively noisy, the filter network depicted in Figure 5.5 can be used to obtain a cleaner signal waveform.



#### 5.2.5 Compensation Component Changes (Continued)

4. Input a 0.5Hz, 2V bi-directional square wave velocity command signal to the controller.
5. Apply power, and while monitoring the tachometer signal, gradually increase the value of the box resistance until optimum response as depicted in Figure 5.4 is achieved.
6. Substitute the closest standard value discrete resistor for R77 and remove the resistor substitution box.
7. Remove the shorting jumper across C10, and again check the response using the squarewave test signal. If near optimum results are obtained, trim the response using the RESPONSE potentiometer R92 for the optimum.
8. If step 7 does not yield satisfactory results, substitute a larger value than 0.047  $\mu$ F, if unacceptable overshooting has been noted; or substitute a smaller value than 0.047 $\mu$ F, if the response is overdamped. Reiteration of this procedure should yield an optimum choice for C10.
9. Finally, select a new value of C11 -- normally 0.0022 $\mu$ F-- so that the time constant of R77·C11 remains approximately as it was with the standard value of R77.

Consult Section 6.2 for further details regarding the compensation components.

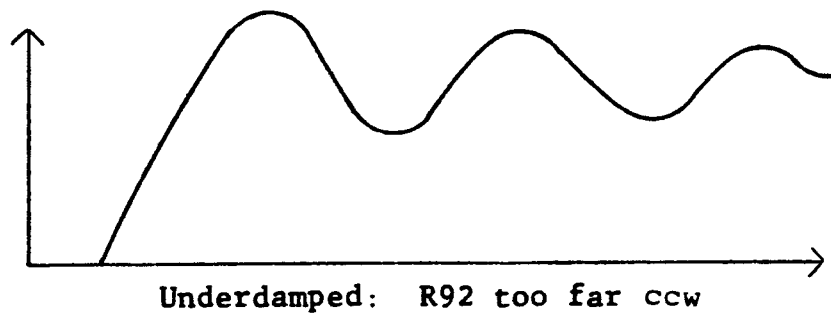
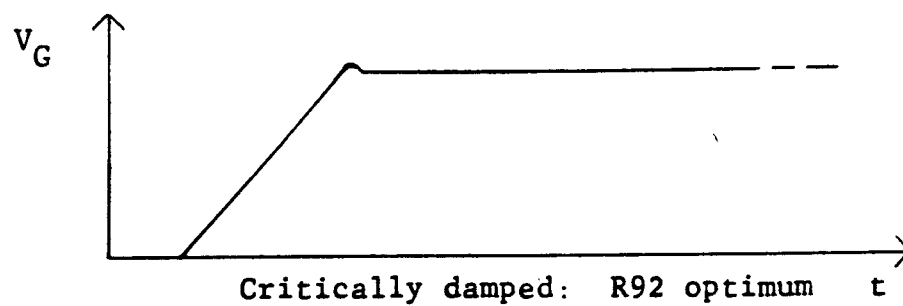
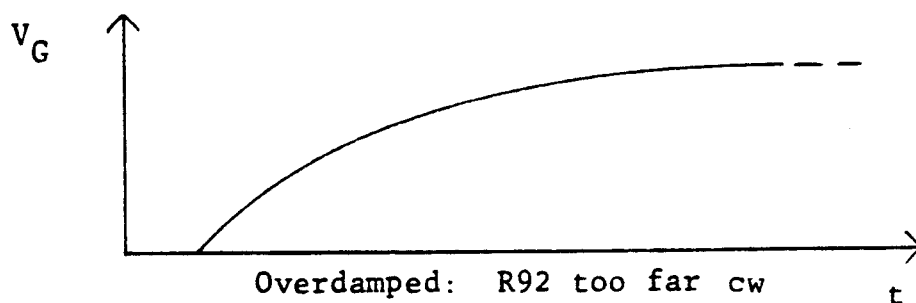
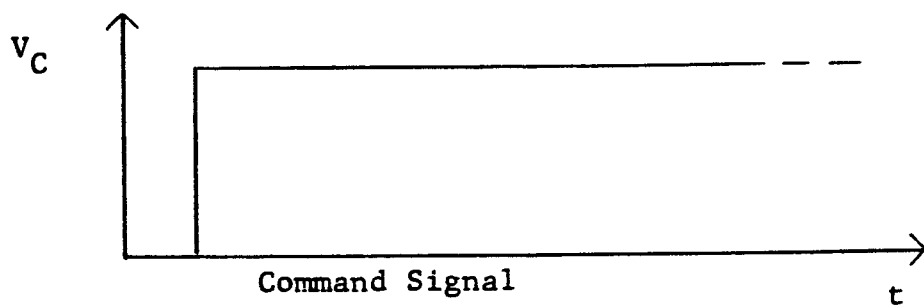
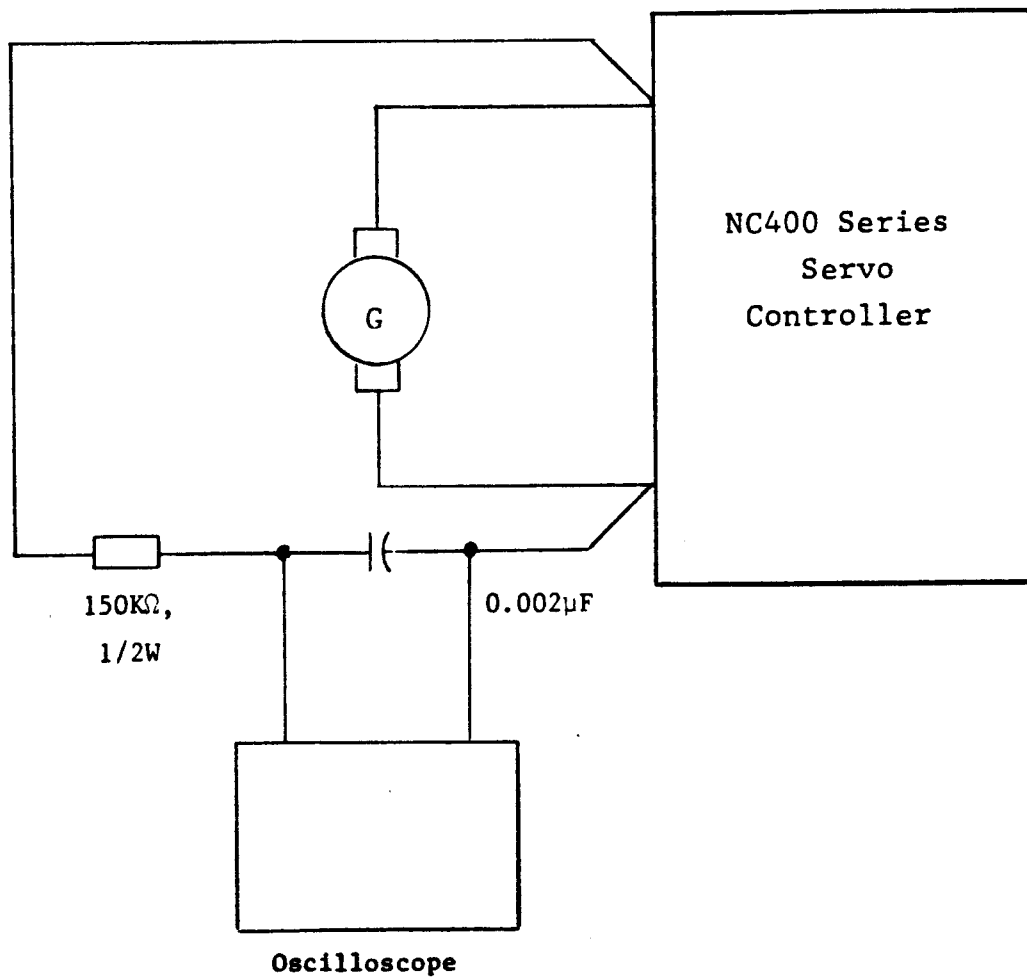


Figure 5.4: Typical Velocity Response Waveforms.



**Figure 5.5: RC Filter Network for Reducing Tachometer Electrical Noise.**

#### 5.2.6 Electronic Circuit Breaker Trip Adjustment

The Electronic Circuit Breaker section of each NC400 Series Servo Controller performs a function similar to an armature circuit fuse or electro-mechanical circuit breaker.

This circuit senses output current flow with time and after a given time disables the controller when output current exceeds the rated current for the controller.

Unlike a fuse or actual circuit breaker, the connection between the motor and controller is not physically broken, instead the controller is disabled using the fault latch circuit. If a physical break between controller and motor is required, a load contactor should be used, as described in Section 4.5.3.

The trip-point versus current level for the Electronic Circuit Breaker is given in Figure 5.6. The nominal trip time at peak current is 5 seconds. This is normally acceptable for most applications and most motors. If however, a short thermal time constant motor is employed in the application, the time constant of the Electronic Circuit Breaker circuit should be changed.

This is best accomplished through experimentation, using a resistor substitution box for resistor R66. By making R66 a lower value, a faster trip versus current curve will result.

A procedure for adjusting the trip point follows:

1. Mechanically lock the rotor of the motor.
2. Set the value of R66 low, say 10K $\Omega$ .
3. Apply a small velocity command to the controller.
4. Apply power to the controller and time the interval between application of power and the trip of the Electronic Circuit Breaker circuit.

#### 5.2.6 Electronic Circuit Breaker Trip Adjustment (Cont)

IMPORTANT: Resistor R161 should be in place for this test so that the Electronic Circuit Breaker circuit disables the controller. If R161 has been removed, it should be replaced for this procedure (standard value is  $10K\Omega$  )

5. If the interval measured in step 4 is less than that desired, increase the value of R66 and repeat step 4 until the desired trip time at the desired peak current is attained.
6. Replace the substitution box with the value selected in step 5.
7. Recheck for proper trip time.

If the decay/reset time of the Electronic Circuit Breaker circuit is too long the value of R65 (standard value  $2M\Omega$ ) can be made smaller. Likewise, if the decay/reset time is too short, a larger value of R65 should be used.

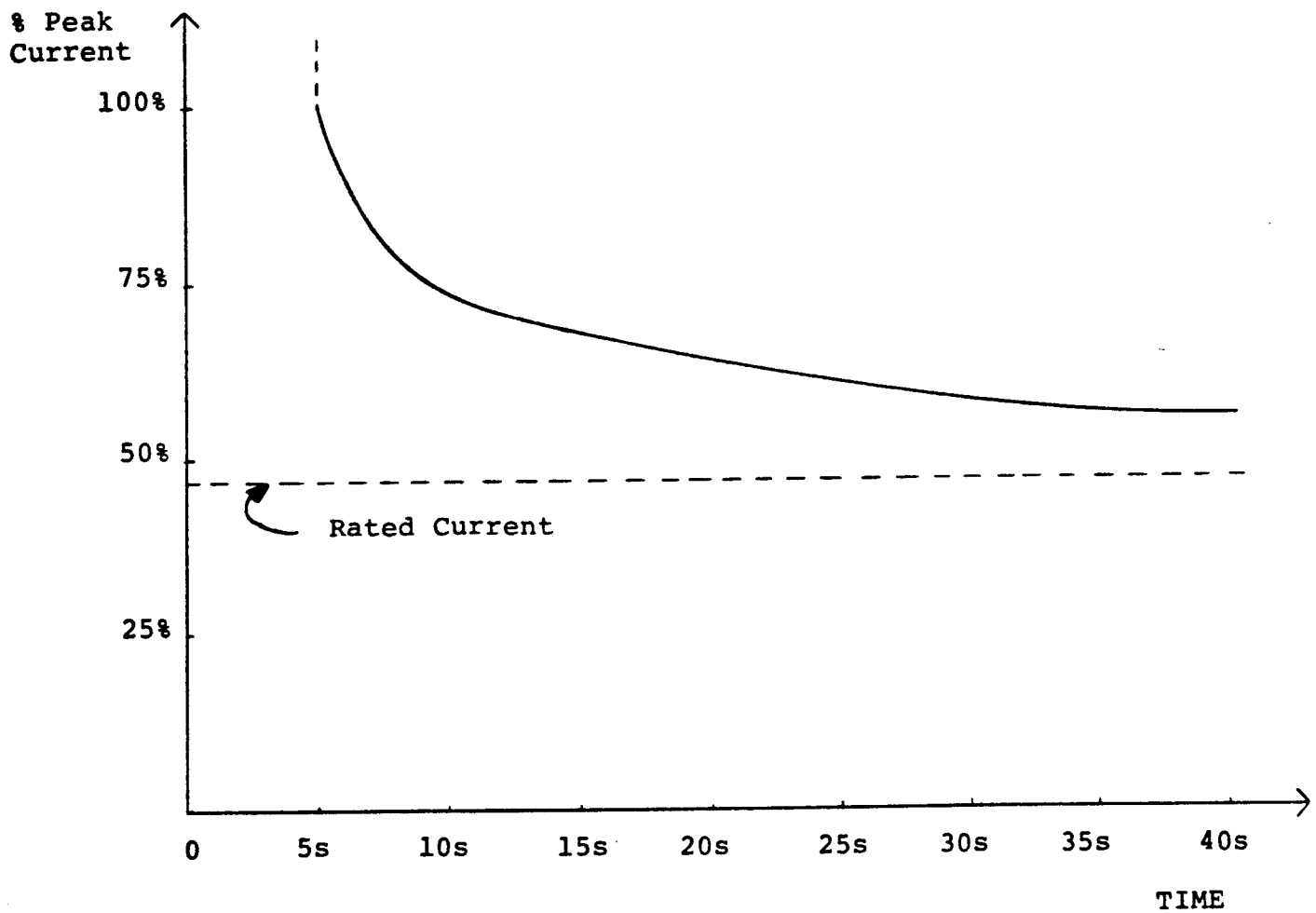


Figure 5.6: Electronic Circuit Breaker Trip Curve for Continuous Output Currents.

## CHAPTER VI

### 6.0 THEORY OF OPERATION

#### 6.1 Power Section Operation

The NC400 Series controllers are switching-mode servo controllers in which the power semiconductors are either in saturation or cut-off. This results in highly efficient controller operation since very little power is dissipated within the semiconductors in either of these two states.

Power transistor switches are employed as the output semiconductors in the NC400 Series. This results in less complicated output circuitry and a more refined, predictable control of load power than is obtainable with silicon controlled rectifiers.

The particular switching technique employed in the NC400 Series is a patented concept commonly known as TWO-STATE MODULATION.\* This technique, pioneered by CSR for DC motor control, has advantages over other switching techniques such as pulse-width modulation (PWM). Some of these advantages will be described in the following discussion of the basic operation of the NC400 Series servo controllers.

Figure 6.1 presents a basic functional block diagram representative of the NC400 Series circuitry. This block diagram is employed to explain the functioning of the various circuits.

Initially, incoming signals are processed in the pre-amplifier section, where servo compensation normally takes place. A detailed description of the preamplifier section is presented in Section 6.2.

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\* US Patent No. 3,294,981

## 6.1 Power Section Operation (Continued)

The resultant signal A is then combined algebraically with a feedback signal B, which is representative of the current flowing in the load, and a relatively high, fixed frequency triangle waveform signal C.

The resulting error signal  $A + B + C$  is applied to the Two-State circuit, the output of which is a square wave signal having the appropriate pulse-width and frequency modulation characteristics for the particular load and command conditions at that instant.

The output D of the two-state circuit is applied to identical sections containing delay and driver circuitry, as well as interfacing circuitry for the limit and protection circuits. As inversion takes place previous to one of the Delay/Driver sections, however. This inversion is necessary in order to have proper signal phasing in the output section.

The output section is a bridge, shown in simplified form in Figure 6.1, consisting of paralleled output transistors (for simplicity only one transistor per quadrant is shown in Figure 6.1) and fast recovery, free wheeling diodes in each quadrant. Emitter resistors are employed with each output transistor to enhance current sharing.

Unlike linear amplifiers, where a small "idling" or common-mode current is necessary to eliminate cross-over distortion, common-mode conduction or switch-through must be avoided in switching amplifiers. This condition arises because of the unequal turn-on and turn-off times of transistors; the turn-off time being longer than the turn-on time. In the NC400 Series precise turn-on delay times are effected in the Delay/Driver sections so that, for example, Q1 has sufficient time to turn off before Q2 is allowed to turn on.



## 6.1 Power Section Operation (Continued)

The use of the bridge output section in the NC400 Series provides for full four quadrant dynamic motor operation. Hence, the controller is capable not only of delivering power to the motor, but also of removing power from the motor (regenerative action) during periods of deceleration.

Load current in the bridge output section is through Q1 - Load - Q4 or through Q3 - Load - Q2. That is, current conduction is always diagonal in the bridge; the destructive condition of having Q1 and Q2 or Q3 and Q4 ON simultaneously, is disallowed by the logic of the low level circuitry.

The load current is sampled by resistors  $R_s$  in each leg of the bridge. When the resultant signals J and K are combined differentially by the current feedback amplifier, a signal B results which is representative of the actual armature current.

This current feedback loop provides the NC400 Series servo controllers with several advantages. First, precise, adjustable current limiting is achieved simply by limiting the peak voltage magnitude at point A in Figure 6.1.

Second, the current feedback configuration makes the amplifier appear to the load as a controlled current source; hence, the effect of the motor L/R time constant is substantially reduced. This is especially desirable in high response servo drive applications.

Finally, the effects of low armature resistances or variations of armature resistance due to heating will not impair the performance of the NC400 Series controllers.

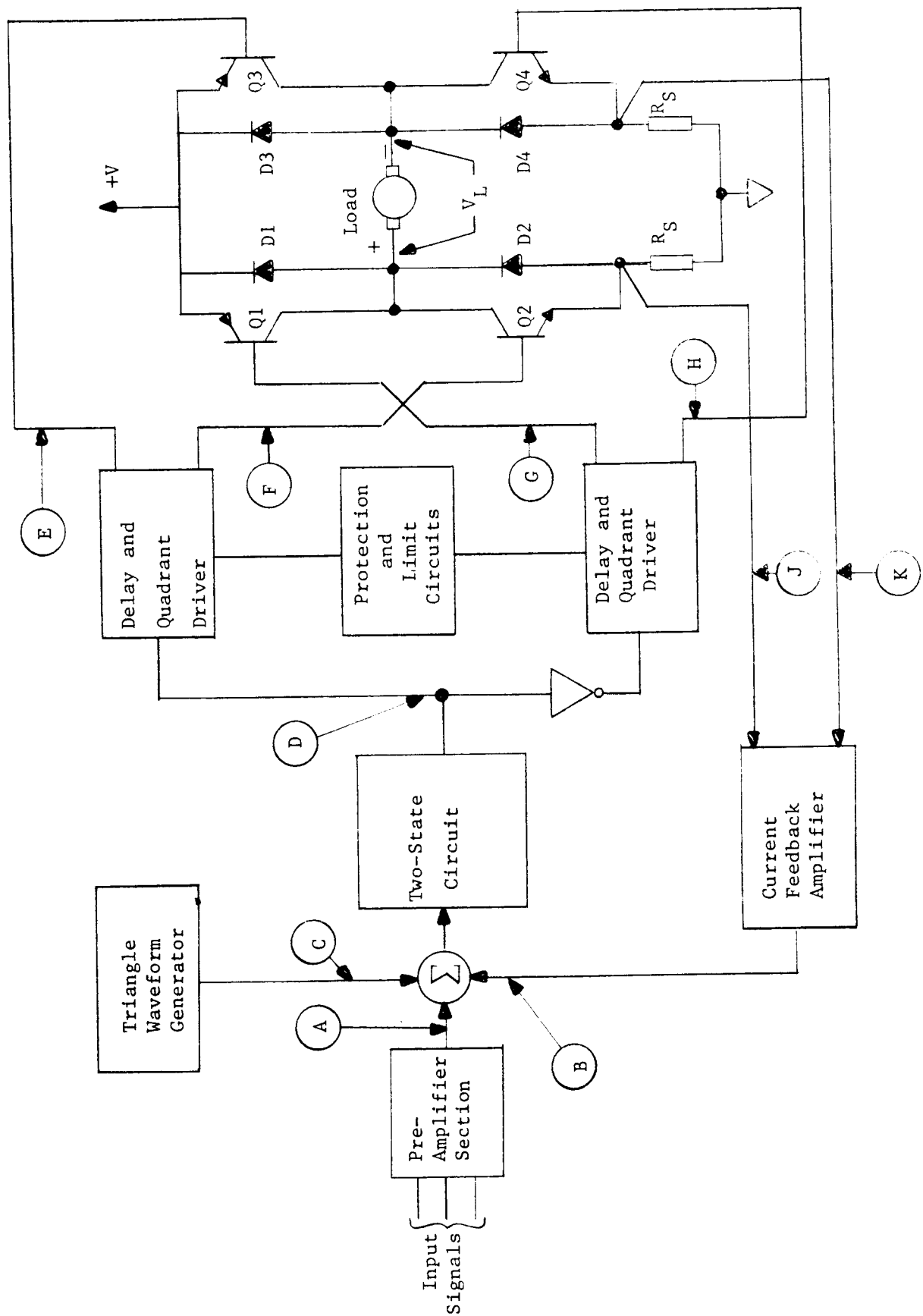


FIGURE 6.1: SIMPLIFIED FUNCTIONAL BLOCK DIAGRAM: NC400 SERIES

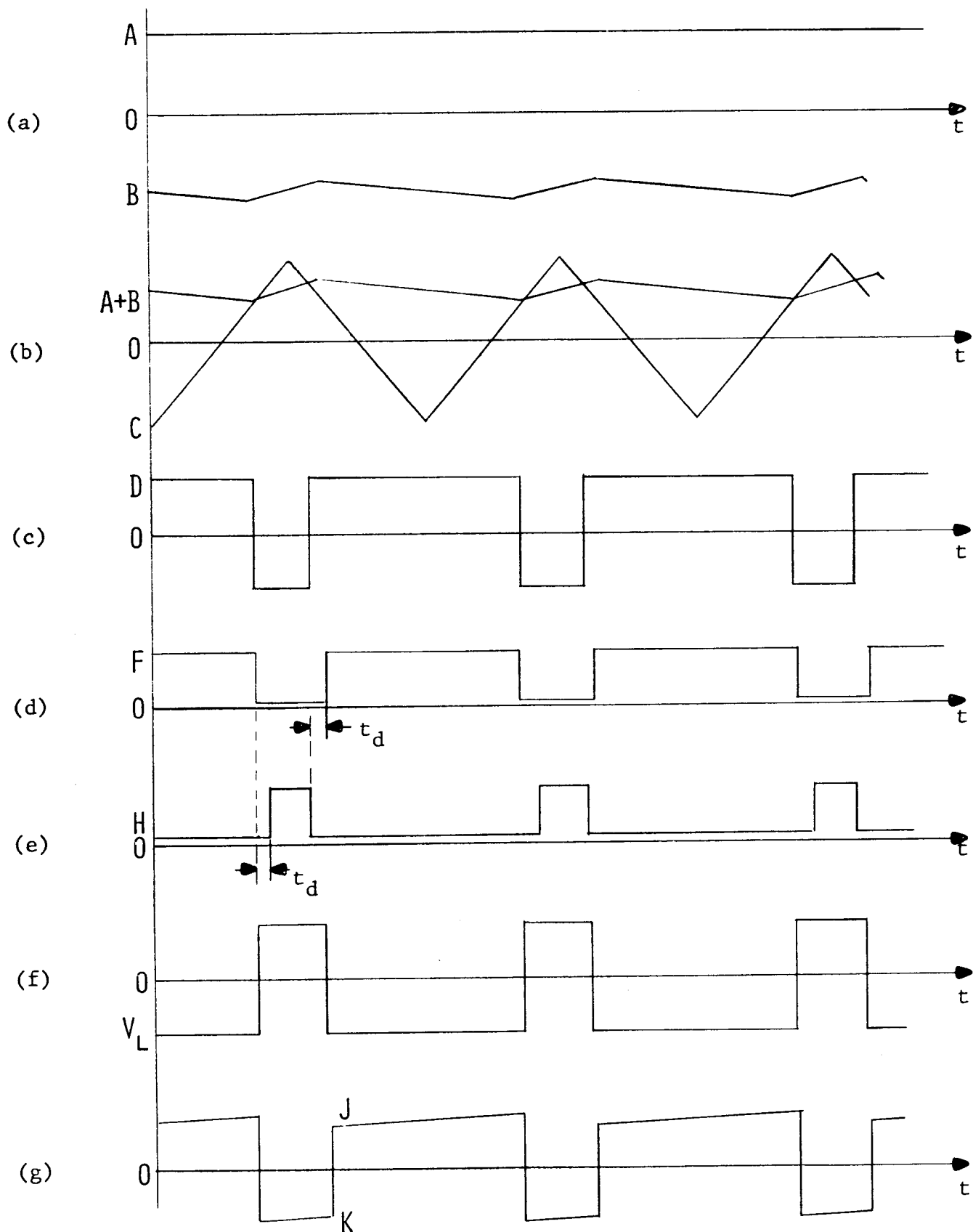


FIGURE 6.2: WAVEFORMS FOR FIGURE 6.1

## 6.1 Power Section Operation (Continued)

Figure 6.2 is a set of idealized waveforms that appear at the various points in Figure 6.1. The waveforms are not to scale and certain waveforms have been exaggerated for clarity. The waveforms are, however, in proper time sequence. Also, Figure 6.2 represents a specific case of input excitation, namely a DC level at point A.

Figure 6.2 (a) depicts the input command signal to the power section appearing at point A in Figure 6.1, and the feedback signal B representing the current flow in the load circuit.

These two signals are combined with the triangle waveform C as shown in Figure 6.2 (b). For clarity, Signals A and B are shown combined, and their sum plotted against waveform C.

The resultant waveform  $A + B + C$ , when applied to the two-state circuit, produces the waveform D, shown in Figure 6.2 (c). This waveform contains the pulse-width and frequency modulation information required to satisfy the input and load conditions at any instant of time.

Waveform D when applied to the remaining delay and quadrant driver sections produces the necessary drive signals at points E, F, G and H for the controller's output quadrants represented by Q1 through Q4 in Figure 6.1. Figure 6.2 (d) and (e) depict the two lower quadrant drive signals F and H. The two upper quadrant signals E and G are not shown since they are similar (when shown with respect to +V) to F and H, respectively.

## 6.1 Power Section Operation (Continued)

Note the effect of the delay times on waveforms F or H in Figure 6.2. After either F or H goes to zero, a delay time  $t_d$  ensues before H or F, respectively, goes on. This delay ensures that common-mode conduction in the output section does not occur.

Figure 6.2 (f) shows the load voltage  $V_L$ . The effect of the delay times  $t_d$  is not apparent in  $V_L$ , because an inductive load such as a motor will cause current to "free-wheel" through diodes D1, D4 and D2, D3. Therefore, when Q2 and Q3 are turned OFF, the load voltage abruptly changes polarity, despite the fact that Q1 and Q4 have not yet been turned ON.

In Figure 6.2 (g), waveforms J and K represent the two constituent parts of the load current, transistor and diode, sampled by identical resistors  $R_s$  in Figure 6.1. These signals are added differentially and scaled to form waveform B, the current feedback signal.

As can be seen from Figure 6.2, if the virtual signal  $A+B$  were large enough to exceed the peak value of C, the controller would cease to switch at the rate determined by the period of the triangle waveform, and the process would no longer be pulse-width modulation.

In the NC400 Series controllers this fact is used to advantage to provide better dynamic response and higher motor speeds than are obtainable with the PWM approach. Greater than 100% modulation allows the load current during transient intervals to slew at a rate limited only by load circuit parameters.

## 6.1 Power Section Operation (Continued)

In addition, load current regulation is enhanced by maintaining a low ratio of triangle waveform amplitude to combined signal amplitude  $A+B$  -- a situation not possible when employing PWM, due to the constraint of maintaining less than 100% modulation at all times.

Finally, higher motor speeds are realizeable with the NC400 Series controllers than with PWM controllers, since again, the constraint of less than 100% modulation for the PWM approach implies that an average load voltage less than full supply bus can be applied to the motor when full speed is commanded.

## 6.2 Preamplifier Section Operation

Each NC400 Series servo controller contains a pre-amplifier section, shown schematically in Figure 6.3, that can be employed to sum velocity command and tachometer feedback signals, and provide the necessary servo compensation and gain adjustments, resulting in stable, optimum servo operation.

The preamplifier employs two integrated circuit operational amplifiers as the active components. These amplifiers have high DC gain along with good temperature and frequency stability characteristics.

One amplifier IC6 is configured as a differential stage with unity gain. The purpose of this stage is to isolate the command signal source from the signal common of the controller. This minimizes cross-talk between controllers operated from the same DC power supply.

## 6.2 Preamplifier Section Operation (Continued)

The second amplifier IC5 sums the inputs from the differential stage, the input No. 2 signal and the offset voltage from potentiometer R90. IC5 also provides the required servo compensation and current limiting functions.

The following sections explain in detail the function of the various component groups in the preamplifier section.

### 6.2.1 Frequency Response Analysis

The preamplifier section of the NC400 Series servo controller is configured with two feedback paths. One in the form of a resistive tee network controls the DC gain of the preamplifier. The other network consisting of C10, R77 and potentiometer R92 controls the AC gain.

Using the tee network consisting of R76, R86 and R87 obviates the need for high valued resistors in the DC feedback network. The equivalent value of the tee network is given by the expression:

$$R_f \approx \frac{R_{76} \cdot R_{87}}{R_{86}}$$

If the standard values employed in the NC400 are substituted into this expression, a value of 100 MΩ results.

The resistor  $R_{86}$  is mounted on solder terminals and can be changed, if one desires to alter the DC gain of the preamplifier. Increasing the value of  $R_{86}$  lowers the gain, while decreasing  $R_{86}$  increases the gain. Note that if no DC feedback is desired,

### 6.2.1 Frequency Response Analysis (Cont)

such as would be the case if the preamplifier is to be a pure integrator, a short circuit should be substituted for  $R_{86}$ .

The higher frequency (AC) gain of the preamplifier is a function of the components  $C_{10}$ ,  $R_{77}$  and the setting of  $R_{92}$ , the RESPONSE potentiometer. These components form a variable lag-lead network. As can be seen from Figure 6.3, setting  $R_{92}$  full CW removes the AC feedback network and no lag in the response occurs. The gain is then flat with frequency, being determined by the DC feedback components; but it does begin to roll-off in the vicinity of 1000 Hz due to the combined effects of the input filter network and the response characteristics of the operational amplifier IC5.

Maximum AC feedback is obtained with  $R_{92}$  set full CCW. This results in a lag frequency of approximately 0.034 Hz. The lead frequency remains constant for all settings of  $R_{92}$  and is approximately 23 Hz. These values are calculated from the following expression for the frequency response of the preamplifier using the standard values for the components.

$$G_1(s) \approx \frac{R_f}{R_{89} + R_{75}} \left[ \frac{1 + sC_{10}R_{77}}{1 + sC_{10}R_{77} \left( 1 + \frac{R_{76}R_{87}}{R_{86}R_{77}} \theta \right)} \right]$$

This is the gain expression for Input No.1. The effect of the scaling potentiometer  $R_{94}$  (SIG. 1) is not included; it is, of course, a factor between 0 and 1.0 multiplying the above expression, and is linearly related to the setting of  $R_{94}$ . At CCW the factor is 0, and at the CW position the factor is 1.0.



### 6.2.1 Frequency Response Analysis (Cont)

The differential amplifier introduces another inversion into the above equation, so that signals applied to the inverting terminal of the amplifier actually experience no net phase inversion in passing through the preamplifier.

The gain expression for Input No. 2 is as follows:

$$G_2(s) \approx - \frac{0.87 R_f}{R_{166}} \left[ \frac{1 + sC_{10}R_{77}}{1 + sC_{10}R_{77} \left( 1 + \frac{R_{76}R_{87}}{R_{86}R_{77}} \right)} \right]$$

The presence of the factor 0.87 is due to the effects of the input filter and attenuator network at Input No. 2. The scaling potentiometer R91 (SIG.2) acts to scale the above expression from a low at the CCW position of 0.08 to the high value of 0.87 at the CW position.

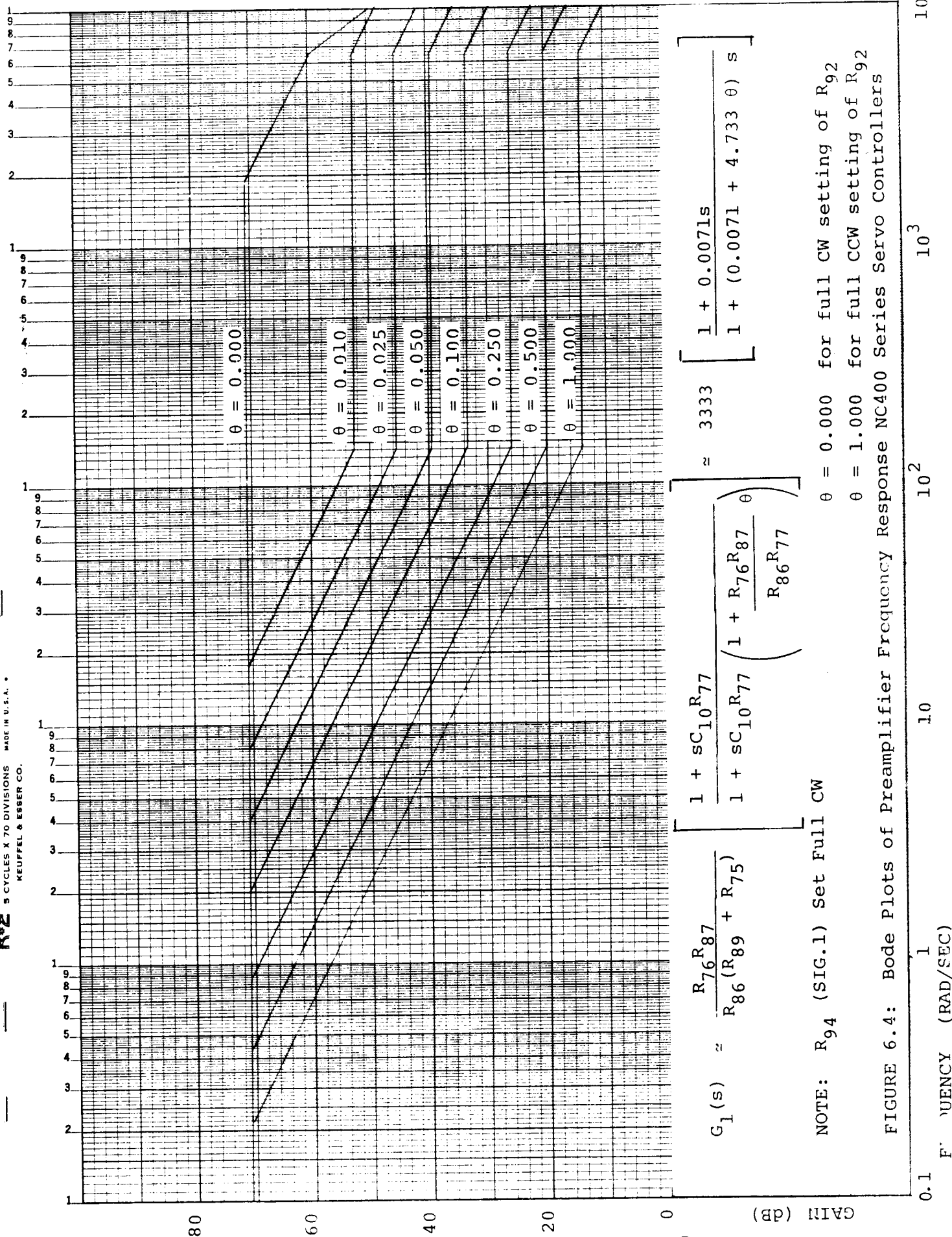
Figure 6.4 is a graph (Bode plot) of the gain expression  $G_1(s)$ . This graph is actually a family of asymptotic curves indicating the manner in which the preamplifier's frequency response is altered by R92, the RESPONSE potentiometer.

### 6.2.2 The Offset Circuit

The offset potentiometer R90 is connected between the plus and minus 15V bias supplies; and, hence, any voltage between these extremes can be applied to  $R_{73}$ , the offset summing resistor.

Hence, with up to 1.5  $\mu$ A injected through  $R_{73}$





### 6.2.2 The Offset Circuit (Cont)

into the preamplifier, one can null up to  $\pm 45$  mV of offset an Input No.1, or  $\pm 170$  mV at Input No.2. If this offset nulling range is insufficient,  $R_{73}$  can be lowered in value.  $R_{73}$  is mounted on solder terminals to facilitate this change.

### 6.2.3 The Current Limit Circuit

The potentiometer R93 in conjunction with zener diodes Z1 and Z2 and resistor R79 form the current limit circuit in the NC400 Series servo controller. The diodes limit the output voltage from IC5 to approximately  $\pm 10.7$  volts. This peak value is then divided by R93, the CURRENT LIMIT potentiometer, and R79.

In the standard form, where J4 and J3 are in place and no auxiliary functions are used, the wiper voltage at R93 is applied to the power section of the controller and is, in fact, the current command, since the power section is configured as a transconductance amplifier, yielding peak current output with approximately 10 volts input.

The wiper voltage of R93 is also returned to the input of IC5 through the feedback network. Because of this the dividing effect of R93 does not effect signal voltages between the current limit extremes. Also, the output impedance of the preamplifier is not appreciably affected by the presence of R93.

### 6.2.3 The Current Limit Circuit (Cont)

Component positions are available for two resistors R78 and R88 to be used in applications, where a fixed current limit is required. For these cases R93 is removed and two appropriate values for R78 and R88 are substituted.

Also, where an external, remote current limit is to be employed J4 should be removed from the controller and the auxiliary Function 1 and 2 input terminals used to carry the external signals. Section 5.2.4.2 provides further details on this current limit method.

### 6.2.4 Three Signal Input Version

When three signals must be summed into the preamplifier section, the non-inverting input of the differential amplifier is converted into a direct third input.

To accomplish this, jumper J2 is removed, and components are selected for R162 and C44 and, if desired, for R81. The resulting third input has the following gain expression:

$$G_3(s) \approx \frac{R_f}{R_{81} + R_{162}} \left[ \frac{1 + sC_{10}R_{77}}{1 + sC_{10}R_{77} \left( 1 + \frac{R_{76}R_{87}}{R_{86}R_{77}} \right)} \right]$$

Note that no potentiometer is employed with the third input to provide variable scaling, instead the gain (dc) is fixed by the selection of R81 and R162.

#### 6.2.4 Three Signal Input Version (Cont)

Once R81 and R162 are selected, the value of C44 is selected to provide a frequency break near 1000Hz. The value of C44 can be calculated approximately using the following expression:

$$C44 \approx \frac{R_{81} + R_{162}}{6280 (R_{81} \cdot R_{162})}$$

It should be noted that in creating the third input, the signal isolating properties of the differential amplifier stage IC6 are lost. The IC6 stage now becomes a gain-of-one inverter for input no. 1.

#### 6.2.5 Miscellaneous Comments

The components R72 and C9, which in the standard form of the preamplifier are not used, can be employed to provide a response lead network for input no. 2. This could prove to be beneficial when, for example the tachometer signal is returned to input no. 2.

Determination of the values of R72 and C9 is best done empirically. Note that the input no. 2 scaling potentiometer R91 divides the voltage applied to R160 only and not that applied to R72 and C9.

In addition, a capacitor C11, placed in parallel with R77, can be selected to minimize noise carried on the input signals. This is especially beneficial when employing motors, such as the so-called "disc" motors, where a significant degree of electromagnetic coupling is present between the tachometer and motor armatures. This results in a noise signal, based on the switching waveform of the controller, being amplified by the preamplifier, and if strong enough, overcoming the

#### 6.2.5 Miscellaneous Comments (Cont)

normal triangle modulation signal. This can result in an unstable condition in the controller.

A value of  $0.0022\mu\text{F}$  is used for  $C_{l1}$  in the standard configuration. If  $C_{l1}$  is changed, especially to a larger value, the effect on the dynamic performance of the controller should be scrutinized carefully.

### 6.3 Protection Circuit Operation

The NC400 Series has several protection features which act to protect the controller from conditions that, if left unchecked, could cause catastrophic damage.

Most of these protection features are designed into the Servo Controller assemblies. One circuit, the (optional) Shunt Regulator, can be considered a protection device, since it regulates the DC bus during periods of regeneration. The servo controllers do have a secondary high bus voltage sensing circuit, though; so that even if the Shunt Regulator is not present the controller will act to protect itself.

In the following sections the functioning of each of the protection circuits is explained in detail.

#### 6.3.1 Thermal Sensor

Attached to one of the heat sinks on each NC400 Series servo controller is a bi-metallic thermal sensor. This sensor is intended primarily to sense the loss of fan cooling or excessively high ambient temperatures.

The sensor's contacts are connected in series with the transistor switch employed as the output device of the RMS Overcurrent Circuit.

If either the thermal switch or transistor switch opens, a logic high will appear at terminal N on the servo controller's signal connector (TB1-15 or TB2-15 on the Dual-Axis Card Assembly terminal strips). This point is pulled to +15VDC through a 1.5K $\Omega$  resistor.

If R161 (10K $\Omega$ ) is in place, the controller's fault latch will also be SET under the above conditions, and the controller will automatically be disabled.



### 6.3.2 Electronic Circuit Breaker Circuit

The current feedback signal, representing armature current, is fed to the Electronic Circuit Breaker Circuit, which senses that a current above the rated current of the controller is being outputted to the load. After a given time interval at the excessive level, the circuit turns OFF the output transistor switch mentioned in Section 6.3.1, and a logic HIGH appears at terminal N on the servo controller's signal terminal strip.

The Electronic Circuit Breaker Circuit consists of an absolute value section that converts the dual-polarity current feedback signal to a unipolar signal. This section is followed by a three section squaring circuit, and then an integrator section.

The output of the integrator is applied to a fixed reference comparator which drives the output transistor switch.

The integrator section contains a dual time constant network. The time constant for the rising current is longer than that for the falling current condition, since this better approximates heating in a motor load. Section 5.2.6 contains further information on this circuit.

### 6.3.3 Overvoltage Sense Circuit

As mentioned in the opening paragraphs of this section, an Overvoltage Sense Circuit is present in the NC400 Series servo controllers, to sense an excessively high DC bus condition (122V or greater), and act to disable the controller.

### 6.3.3 Overvoltage Sense Circuit (Continued)

When a high bus condition is sensed, the Overvoltage Sense Circuit sets the fault latch. Of course, the FAULT light-emitting diode will glow indicating shut down. If this condition should occur repeatedly during the beginning of motor deceleration, excessive regenerated energy is indicated, and a Shunt Regulator Assembly A1528 or A1529 (optional) should be installed.

If a Shunt Regulator is being employed, check the fuse in this circuit, if the above conditions are noted, since, most likely, the Regulator has ceased to function.

### 6.3.4 Undervoltage Protection Circuits

Two similar circuits in the NC400 Series servo controllers monitor both the DC bus voltage and the +15VDC bias voltage. If either of these two circuits senses a voltage too low to maintain proper controller operation, the controller is disabled; but only until proper voltage levels are restored, then the controller is enabled again.

These two circuits also function to properly sequence turn-on of the controller, when power is first applied.

The enable-threshold for the +15VDC bias sense circuit is approximately 13V, while that of the bus sense circuit is approximately +55VDC. At these voltage levels and above normal operation can take place, and so the controller is enabled upon reaching these voltages.

#### 6.3.5 Primary Overcurrent Sense Circuit

The NC400 Series servo controllers contain two overcurrent sense circuits, primary and secondary. The primary circuit employs the principal of inductive voltage division and the transformer effect to sense potentially catastrophic conditions such as a ground short to armature.

The circuit consists of a special transformer containing two identical primary windings and a secondary winding that is connected to low level processing circuitry.

The primary windings are designed to have sufficient inductance, so that the rate of rise of current, should the entire 100V bus voltage be placed across it, will be low enough to allow sufficient time for the controller to disable itself.

Under normal conditions of operation, the load inductance will be many times larger than either of the primary windings of the special transformer mentioned above. One primary winding is placed between each output of the controller and the load. Most of the voltage appears across the load inductance; and, hence, very little voltage is induced in the transformer's secondary winding.

When a short circuit occurs, most of the voltage appears across one or both of the primary windings, which induces a proportionately larger voltage in the transformer's secondary.

This higher secondary voltage is sufficient to exceed the threshold of the low level processing circuit, and the fault latch is set, which disables the controller.

#### 6.3.6 Secondary Overcurrent Sense Circuit

The secondary overcurrent sense circuit monitors the voltage drop across the emitter resistors of transistors in the upper quadrants of the NC400 Series servo controllers.

If the primary overcurrent sense circuit should fail to recognize a potentially catastrophic overcurrent condition, or if an internal short-circuit should develop within the controller, the secondary overcurrent circuit will sense the condition and set the fault latch, which disables the controller.

The secondary overcurrent sense circuit is not as fast acting as the primary circuit, and, in fact, a higher than peak current must appear in the emitter resistor being monitored by this circuit before any action is taken to disable the controller.

#### 6.3.7 Shunt Regulator Option

As an option, a Shunt Regulator Assembly can be added to either the single phase or three phase Power Supply Assemblies. Two versions of the Shunt Regulator are available; one can dissipate 1000 watts peak and 100 watts continuously (A1528), while the other can handle 2000 watts and 200 watts, respectively (A1529).

The Shunt Regulator Assemblies are switching types, wherein dissipative elements (resistors) are switched across the DC bus, whenever the voltage reaches a predetermined level. The switching elements employed are transistors, identical to those used in the output sections of the servo controllers.

The function of the Shunt Regulator is to regulate the voltage of the DC bus during periods of motor deceler-

### 6.3.7 Shunt Regulator Option (Cont)

ation, when there is a net energy outflow from the motor to the controller.

The controller handles this reverse energy just as efficiently as it provides energy to the motor, hence, most of the energy is passed through the controller to the power supply, where the returning energy charges the filter capacitors above their normal voltage level, as determined by the AC incoming voltage.

When the capacitor charge-up reaches a level between 118 and 120V, the Shunt Regulator begins its regulating action. The bus is regulated to this range until regeneration ceases.

Deciding if a regulator is required in a particular application, is best done empirically, using the actual system as a test-bed. The Shunt Regulator Option can be added at any time to the Power Supply Assembly, merely by making two FASTON type connections. Hence, these units can be added in the field, whenever required.

On multiple-axis systems, if it is always the case that the other axes are taking power from the supply when a particular axis is regenerating, then the Shunt Regulator is probably not required.

As a design aid, the following information is provided so that one may estimate if a regulator will be required in a particular case.

### 6.3.7 Shunt Regulator Option (Cont)

It can be shown\* that, neglecting friction and other secondary power loss mechanisms, the total energy returned to the power supply during a deceleration period is given by the equation:

$$E_R = (104.7) \frac{JN}{K_T} \left[ \frac{NK_E}{2} + \frac{I_D^2 R_A^2}{2NK_E} - I_D R_A \right]$$

Where  $J$  = total load inertia (in-lb-sec<sup>2</sup>)  
 $K_T$  = motor torque constant (in-lb/amp)  
 $K_E$  = motor back emf constant (V/Krpm)  
 $N$  = motor speed at the beginning of the deceleration period (Krpm)  
 $I_D$  = magnitude of the deceleration current (A)  
 $R_A$  = total armature circuit resistance ( $\Omega$ ).

Once this energy value has been calculated, the required capacitance needed to store the energy can be found from the expression:

$$C \geq \frac{2E_R}{2300} \text{ farads.}$$

When the single or three phase Power Supply Assemblies in the NC400 Series are used, the value of  $C$  is fixed and the maximum allowable energy can be found. The following inequality results:

$$E_R \leq 16 \text{ joules.}$$

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\* "The Regeneration Energy Phenomenon in Pulse-Width Modulated DC Servo Systems," R. Schmidt, Proceedings of the Sixth Symposium, Incremental Motion Control Systems and Devices.

#### 6.3.7 Shunt Regulator Option (Cont)

This is a maximum guaranteed value using worst-case values for the various parameters.

Additional capacitance, added to the power supply, is not recommended due to the higher surge currents that must be handled by the recifiers and other components during power-up.

## CHAPTER VII

### 7.0 Maintenance, Repair and Warranty

#### 7.1 Maintenance Procedures

The NC400 Series servo controllers and auxiliary assemblies have been designed to be virtually maintenance-free. It is only necessary periodically to check the condition of the fuses and cooling fans and to look for accumulations of dust and dirt on the heat sinks and printed circuit boards.

If heavy deposits of dust or particulants are formed, the controller should be removed from its mounting, thoroughly but carefully cleaned, then remounted and returned to service. No readjustment of the controller's potentiometers should be necessary, if care is used in the cleaning procedure.

Some residue from vapors in the controller's environment may form semi-conductive film on the printed circuit boards and other components, which will impair the operation of the units. If any film residue is noted on the boards during inspection, the boards should be individually washed in a suitable chemical cleaning agent such as a fluoro-carbon degreaser. Care should be taken to prevent cleaning agents from washing the thermal grease from behind the power transistors mounted to the heat sinks; and the plastic backing bar behind the potentiometers should be removed before cleaning with a solvent-type cleaning agent.

#### 7.2 Fault Determination Procedures

If abnormal operation occurs, a number of checks and tests can be made to determine the area of the system in which the fault lies.



### 7.2.1 In-System Check

Check the following items before removing any controllers, wires or other items from the system.

1. Overload Devices: Check all fuses, contactors and breakers for a blown or tripped condition. If one or more of these devices in the bus circuits are blown (or tripped), perform the controller quadrant resistance tests before attempting to reapply power.
2. Wiring: Are all wires to be connected to the controller's terminal connections actually in place, in the correct positions, and tightly secured?
3. Limit Circuits: Check all limit and other disable switches and wiring for proper operation. Check the external function circuits, such as external current limit, if present, for correct operation and connection.
4. Input Signals: Are input signals actually reaching the controller? Are they correct in polarity and magnitude? Are the polarities of the motor and tachometer correct? This latter check is especially important if there has been a motor replacement. A runaway condition is cause for close scrutiny of polarities.
5. Fault Characteristics: It is especially important to note the characteristics of a unit that demonstrates erratic or faulty operation. For example, does the system respond to commands in only one direction; is there insufficient torque, but otherwise normal operation, does the system function

### 7.2.1 In-Systems Check (Cont)

normally for certain periods of time?

These characteristics can prove quite valuable in diagnosing probable causes of failure, especially if it becomes necessary to contact service or factory personnel.

### 7.2.2 Out-of-System Checks

#### 7.2.2.1 Quadrant Resistance Tests

Output section failures usually are caused by damage to one or more output bridge transistors. This damage is usually indicated by abnormal resistance readings when checking the four output section quadrants with a V-O-M or similar instrument.

For this test repeat the procedure given in Section 5.2.1. Abnormal readings allow one to pinpoint the particular quadrant(s) in which damaged devices are present.

It is normally advisable that you return at least the Power Electronics Card for factory repair. However, if you desire to replace damaged power section components, the spare parts list carries parts numbers for the power devices used.

#### 7.2.2.2 Signal Electronics Card Tests

A number of test points are available on the Signal Electronics Card part of the NC400 Series servo controllers, to allow checks to be made for proper operation of the various functional areas of this card.

#### 7.2.2.2 Signal Electronics Card Tests (Cont)

Figures 7.1, 7.2 and 7.3 depict waveforms at the various test points for the condition of no input signals present. As a precaution Auxiliary Function terminal 3 should be jumpered to signal common when checking these waveforms.

Also, if the Power Electronics Card is suspected of being damaged in any way, it is best to separate it from the Signal Electronics Card before making the above measurements.

Before using an oscilloscope to observe the waveforms in Figures 7.2, 7.2 and 7.3, measure first the 15 volt bias supplies at TP1 (+15VDC) and TP3 (-15VDC) with respect to common (TP2). The normal range is 14.25 to 15.75 volts.

If abnormal waveforms are observed at TP9 and TP5 in Figure 7.3, the fault latch or undervoltage protection circuit may be the cause. This can be checked by measuring the voltage at TP8 with respect to common. This voltage is normally 0.5 to 0.8 volts for a fault and 0.1 and 0.2 volts when the controller is enabled.

Each of Figure 7.1, 7.2 and 7.3 indicates the particular active component(s) that could cause an improper waveform at the particualr test point being observed.

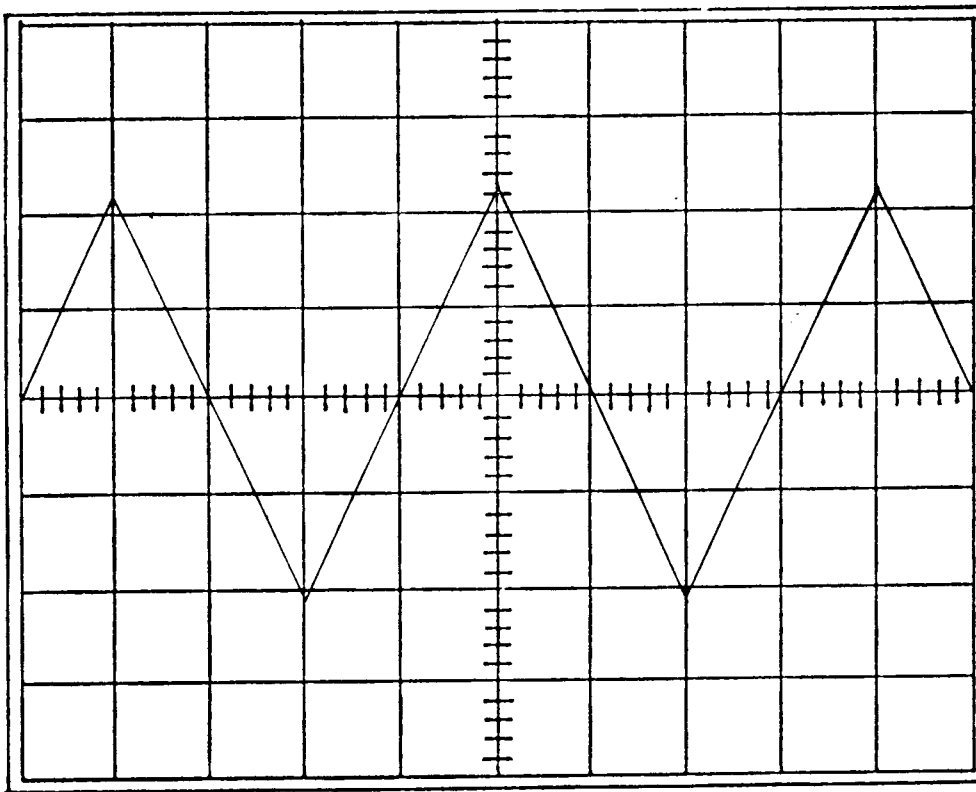


Figure 7.1: Triangle-Wave Generator: TP4  
 Horizontal: 50 $\mu$ s/div  
 Vertical: 5V/div  
 Devices: IC7, IC8

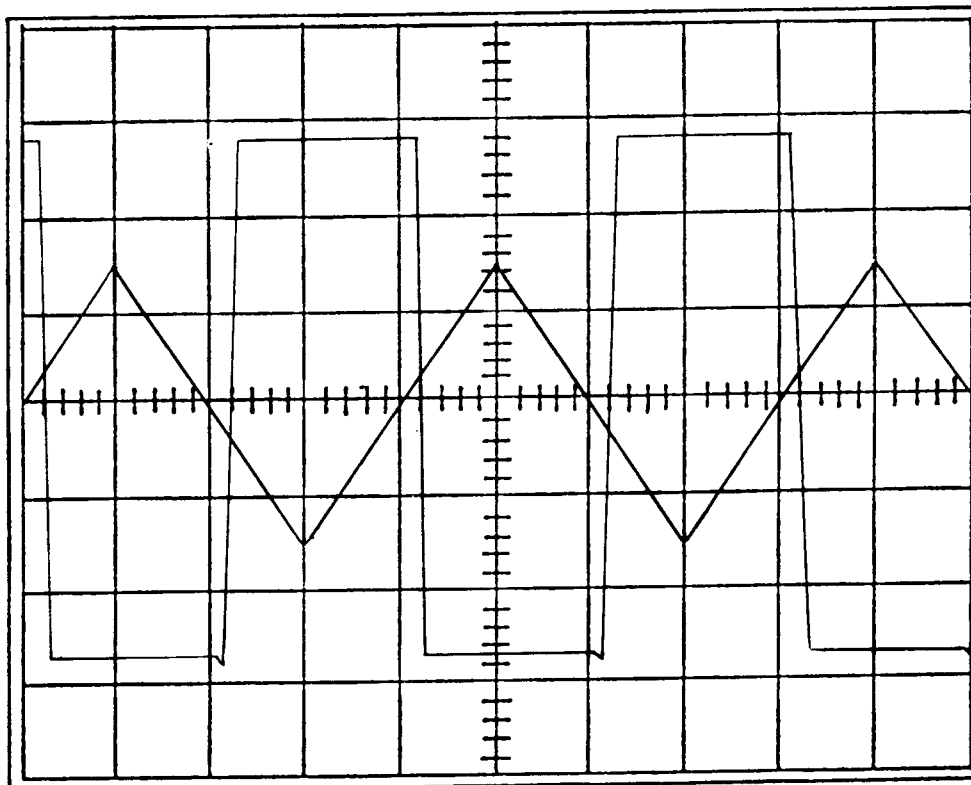


Figure 7.2: Comparator: TP6 TP7  
 Horizontal: 50 $\mu$ s  
 Vertical: 0.5V/div, 5V/div  
 Devices: IC10

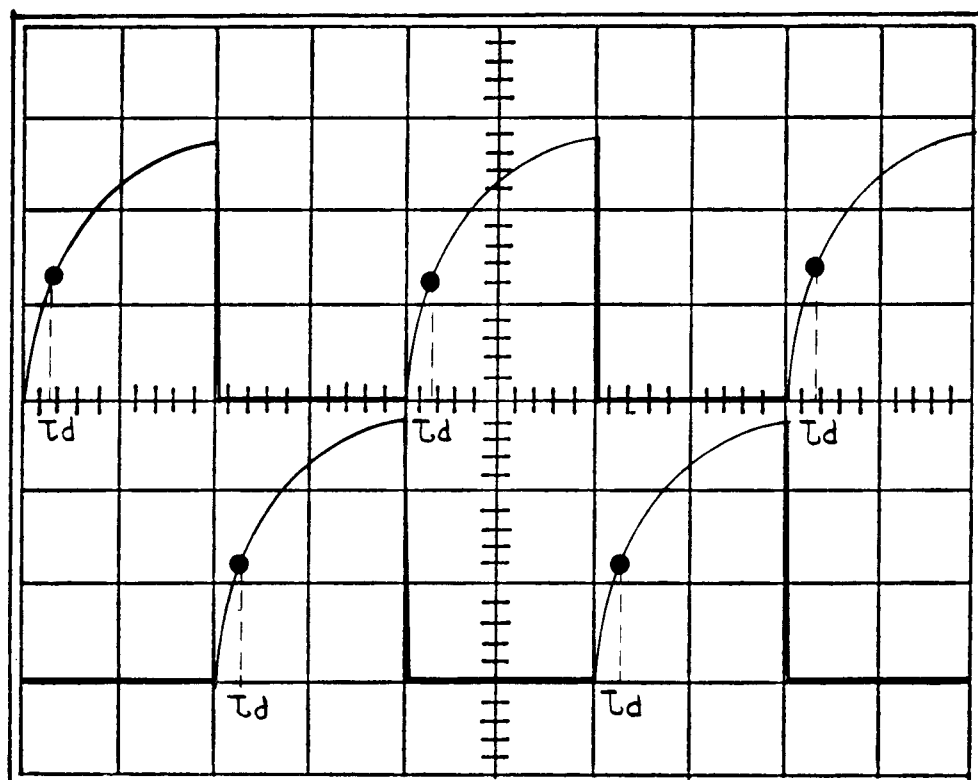


Figure 7.3: Delay Sections: TP5, TP9  
Horizontal: 50 $\mu$ s  
Vertical: 5V/DIV, 5V /DIV  
Devices: IC9, Q32, Q34, Q35  
 $\tau_d$ : 18 $\pm$ 2msec.

### 7.2.2.3 Preamplifier Section Tests

With the load disconnected from the controller, connect a very low level sinusoidal test signal differentially to the inverting/non-inverting terminals of the preamplifier.

The frequency of the test signal can be varied over as wide a range as desired in order to check response. With the RESPONSE potentiometer R92 set full CW, the response should exhibit a break between 500 and 1000Hz.

Check the operation of the SIG.1 scaling potentiometer R94. Varying this potentiometer sufficiently CW should cause saturation of IC5 with attendant clipping of the waveform at the positive and negative extremes.

Also, check the operation of the CURRENT LIMIT potentiometer R93. Set full CW, the clipping voltage at J4 and J3 (if in place) should be approximately 2 volts. Setting R93 full CCW should produce approximately 10.7 volts clipping level.

Finally, move the test signal to the single-ended input number 2 and check for proper operation of SIG.2 scaling potentiometer R91.

If, during the preceding tests the DC gain has been found too high to allow meaningful tests to be made, one can clip one end of R86, the DC gain setting resistor, to obtain a lower DC gain. This will, however, affect the frequency response break point measurements.

### 7.3 Factory Repair

If it is necessary to return an NC400 Series assembly for repair, the following procedure should be followed:

1. If the assembly has been disassembled, reassemble it, making certain that all hardware is in place.
2. Tag the assembly with the following:
  - a) Serial number and assembly number.
  - b) Company and company representative returning the item.
  - c) Date the item was returned.
  - d) Any pertinent, helpful information regarding the malfunction.
3. Carefully package the assembly and apply appropriate cautionary stickers (e.g. FRAGILE).

NOTE: CSR does not recommend returning items in original shipping containers, unless the integrity of these containers was maintained during the original transit.

4. Obtain a Return Authorization Number by contacting the Customer Service Department at the factory or at an authorized repair station. This number should appear on all paperwork regarding the unit and on the outside of the package containing the assembly.
5. Return the items by the best means consistent with your requirements for a timely return of the equipment.

## 7.4 Spare Parts

The NC400 Series equipment is, for the most part, complex electronic equipment, and repair requires a thorough understanding of electronics principles and a full complement of electronic test equipment.

For most users, the best solution is to return any equipment to CSR for repair. In this case only Level A maintenance components are required.

If component level repair is attempted, Level 2 maintenance components will most likely be required and should be stocked. All spare parts should be ordered directly from the Customer Service Department.

### 7.4.1 Level 1 Maintenance Spare Parts

1. NC407: MDA10 fuse, (1) per unit.
2. NC414: MDA20 fuse, (1) per unit.
3. NC421: MDA20 fuse, (1) per unit.
4. Misc: Cooling fan, Howard No. 3450  
or equivalent, (1) per four fan  
cooled assemblies
5. Misc: MDX 1 fuse, (1) per two fan cooled assemblies.

### 7.4.2 Level 2 Maintenance Spare Parts

1. NC407 Power Electronics Card (A1536):
  - (2) Q0023 Output Transistor (CSR)
  - (2) Q0024 Output Transistor (CSR)
  - (2) Q0036 Driver Transistor (CSR)
  - (2) Q0037 Driver Transistor (CSR)
  - (4) CP5-0.1 0.1  $\Omega$ , 5W Resistor (Dale)
  - (1) A115B Diode (General Electric)



#### 7.4.2 Level 2 Maintenance Spare Parts (Cont)

##### 2. NC414 Power Electronics Card (A1537):

- (4) Q0023 Output Transistor (CSR)
- (4) Q0024 Output Transistor (CSR)
- (2) Q0036 Driver Transistor (CSR)
- (2) Q0037 Driver Transistor (CSR)
- (6) CP5-0.1 0.1  $\Omega$ , 5W Resistor (Dale)
- (2) A115B Diode (General Electric)

##### 3. NC421 Power Electronics Card (A1538):

- (6) Q0023 Output Transistor (CSR)
- (6) Q0024 Output Transistor (CSR)
- (2) Q0036 Driver Transistor (CSR)
- (2) Q0037 Driver Transistor (CSR)
- (8) CP5-0.1 0.1  $\Omega$ , 5W Resistor (Dale)
- (3) A115B Diode (General Electric)

##### 4. Signal Electronics Card (A1541):

- (2) 741TC Op. Amp. (Fairchild)
- (2) MPS5172 Small Signal Transistor  
(Motorola)
- (2) 63X103 10K $\Omega$  potentiometer  
(Spectrol)
- (1) 63X202 2K $\Omega$  potentiometer  
(Spectrol)
- (1) MC681P Hex Inverter  
(Motorola)
- (1) MC7815CP +15V Regulator (Motorola)
- (1) MC7915CP -15V Regulator (Motorola)
- (2) IN758A 10V Zener Diode (Motorola)

##### 5. Single Phase Power Supply (A1524, A1525):

- (1) R4050270 Rectifier (Westinghouse)

#### 7.4.2 Level 2 Maintenance Spare Parts (Cont)

##### 6. Three Phase Power Supply (A1526, A1527):

(3) R4040270 Rectifier (Westinghouse)

(3) R4050270 Rectifier (Westinghouse)

#### 7.5 - Warranty

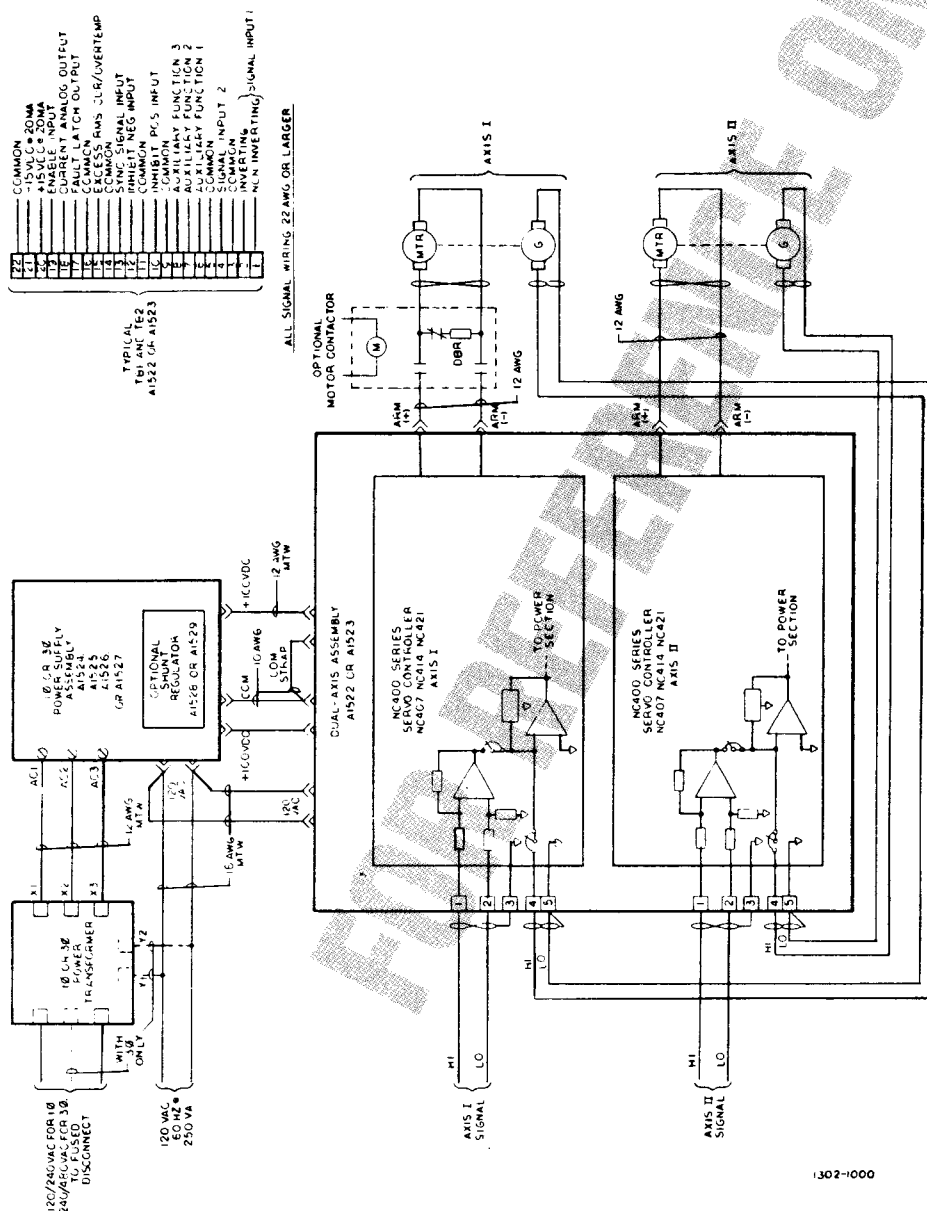
CSR warrants the NC400 Series Equipment to be free from defects in material and workmanship, under normal conditions of use and service, for a period of (1) year after shipment to the original purchaser. CSR's obligation under this warranty is expressly limited to making good at CSR's plant on equipment authorized by CSR to be returned, freight prepaid, for repair or replacement, after examination to CSR's satisfaction that the equipment involved is defective and has not been subject to misuse, negligence, accident, or failure to follow the appropriate operating manual. THERE ARE NO IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE THAT APPLY TO THIS SALE. CSR makes no warranty whatsoever in respect to equipment and components or systems not manufactured by it. When permitted by its suppliers, CSR will transfer to Purchaser any warranties as may be offered by such suppliers to purchasers from CSR. This warranty is expressly made in lieu of all other warranties, express or implied, and CSR shall, under no circumstances, be liable for any direct, indirect, special or consequential damages, expenses, or losses resulting from operation of or defects in the equipment covered hereby.

## 7.6 Authorized Repair Agents

1. USA  
Control Systems Research, Inc  
632 Fort Duquesne Boulevard  
Pittsburgh, PA 15222  
  
ATTN: CUSTOMER SERVICE DEPARTMENT
2. European  
CONTRAVES ANTRIEBSTECHNIK AG  
CSR Product Line  
CH-8105 Regensdorf  
Pumpwerkstrasse 23  
Switzerland
3. United Kingdom  
CONTRAVES INDUSTRIAL PRODUCTS LTD.  
Times House, Station Approach  
Ruislip, Middlesex HA4 8LH  
England

## Appendix

REVISIONS		
LTR.	DESCRIPTION	DATE APPROVED

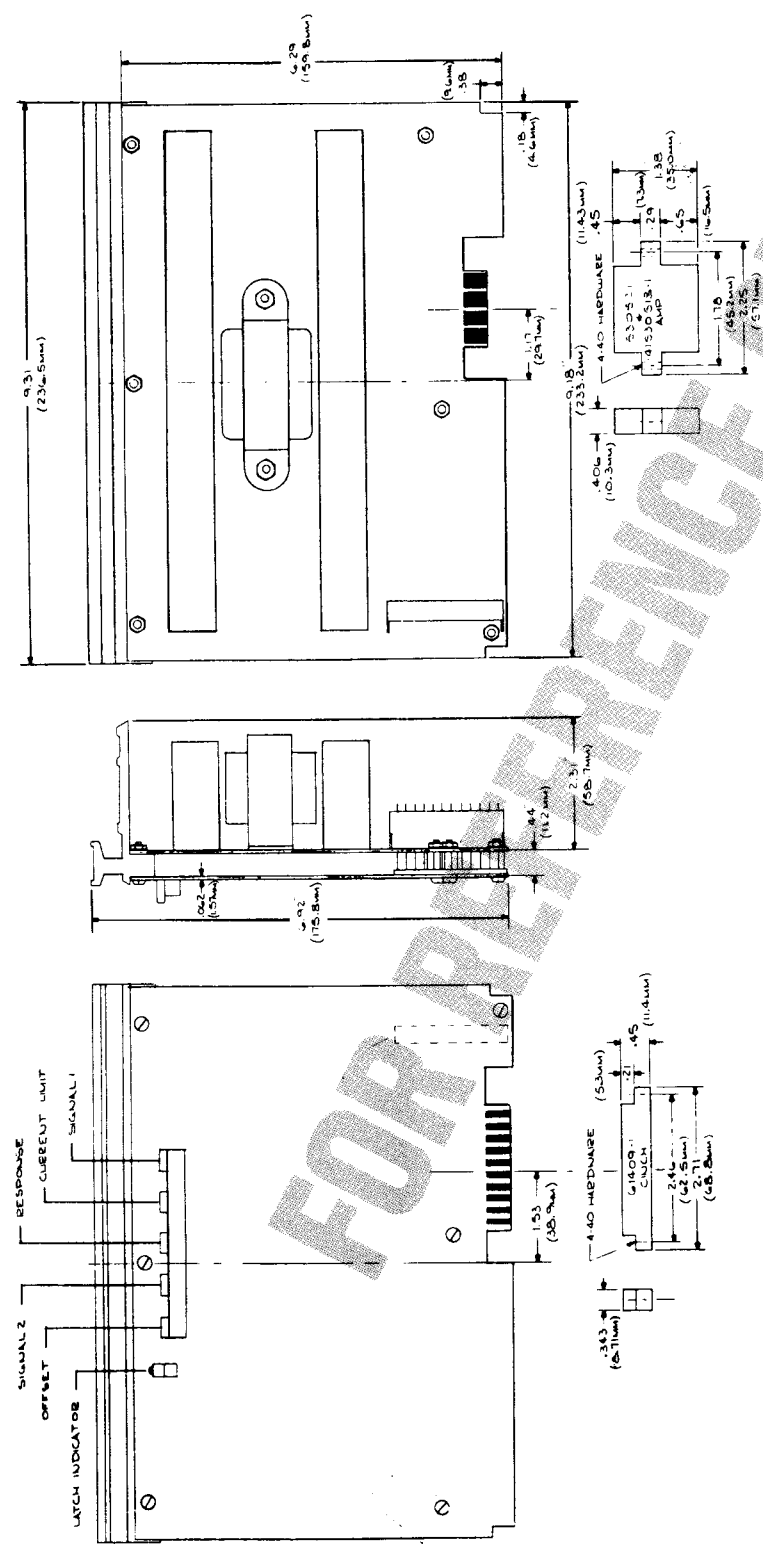


NO.	DESCRIPTION		NOTES
1	TITLE		CONTROL SYSTEMS RESEARCH, INC. PITTSBURGH, PENNSYLVANIA
2	SYSTEM		SYSTEM CONNECTION DIAGRAM
3	INC 400		SERIES
4	SIZE		SIZE CODE
5	D		30173
6	SCALE		SCALE
7	SHEET		SHEET 1 OF 1

PROTOTYPE	PRE-PROD	PRODUCTION	USED ON	FINISH TREATMENT		TOLERANCES EXCEPT AS NOTED	DWN	Q	TYPICAL 2 AXIS SYSTEM
				FINISH	NOTED				
				✓					
						XX 2.01	CHK	1/16	
						ANG. 0° 30'	DRAW	3/16	
						PRAC. 1/64	ENG.	1/16	
							APVD	3/16	
							Q.C.	1/16	
						MATERIAL	DESCRIPTION		

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REVISIONS		DATE	APPROVED
REV	DESCRIPTION		



CONNECTORS SHOWN FOR REFERENCE ONLY		NOTES	
NO	DESCRIPTION	CHK	DATE
		CHK	11/11/11
		DSGN	11/11/11
		ENG	11/11/11
		APD	11/11/11
		Q.C.	11/11/11
TITLE		DESCRIPTION	
U400 SERIES SERVO CONTROLLER		OUTLINE	
SIZE CODE BENT	DWG. NO.		
D 3073	1291-3000		
SCALE	REV.	SHEET 1 OF 1	
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PROTOTYPE	PRE-PROD.	PRODUCTION	USED ON
<p>TOLERANCES EXCEPT AS NOTED</p> <p>XX 2 01 ANG 0 30</p> <p>XX 2 005 FINC 1/44</p> <p>MATERIAL</p> <p>RHS FINISH</p> <p>EXCEPT AS NOTED</p>			



MONITOR WITH 10-32 HARDWARE

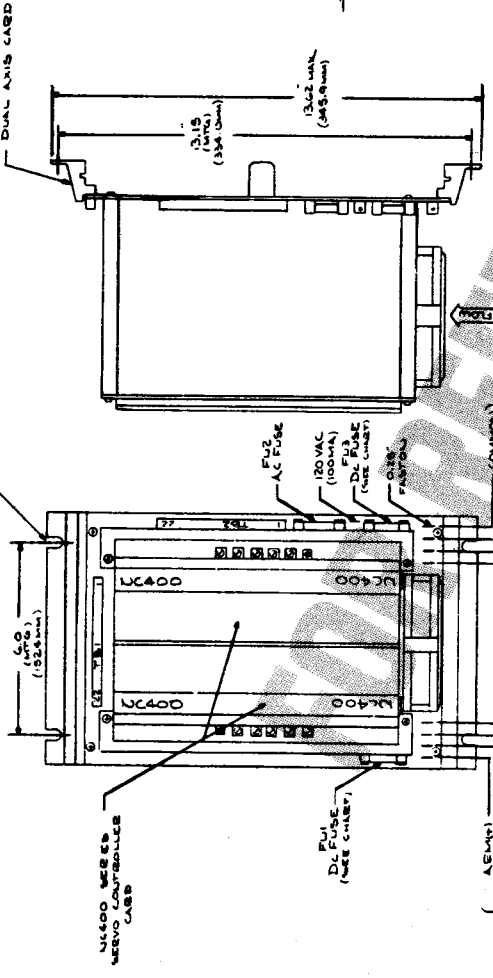
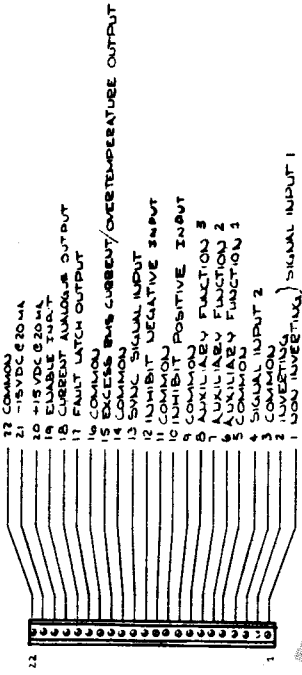


TABLE 2  
CUSTOMER CONNECTIONS



CONTROLLED	AXIS	FUSE	TYPE	WPG
UC407	AXIS 1	FU1	MDA-10	
	AXIS 2	FU2	MDA-10	
NC414	AXIS 1	FU1	MDA-30	BUSBAR
	AXIS 2	FU2	MDA-30	
NC421	AXIS 1	FU1	MDA-30	
	AXIS 2	FU2	MDA-30	

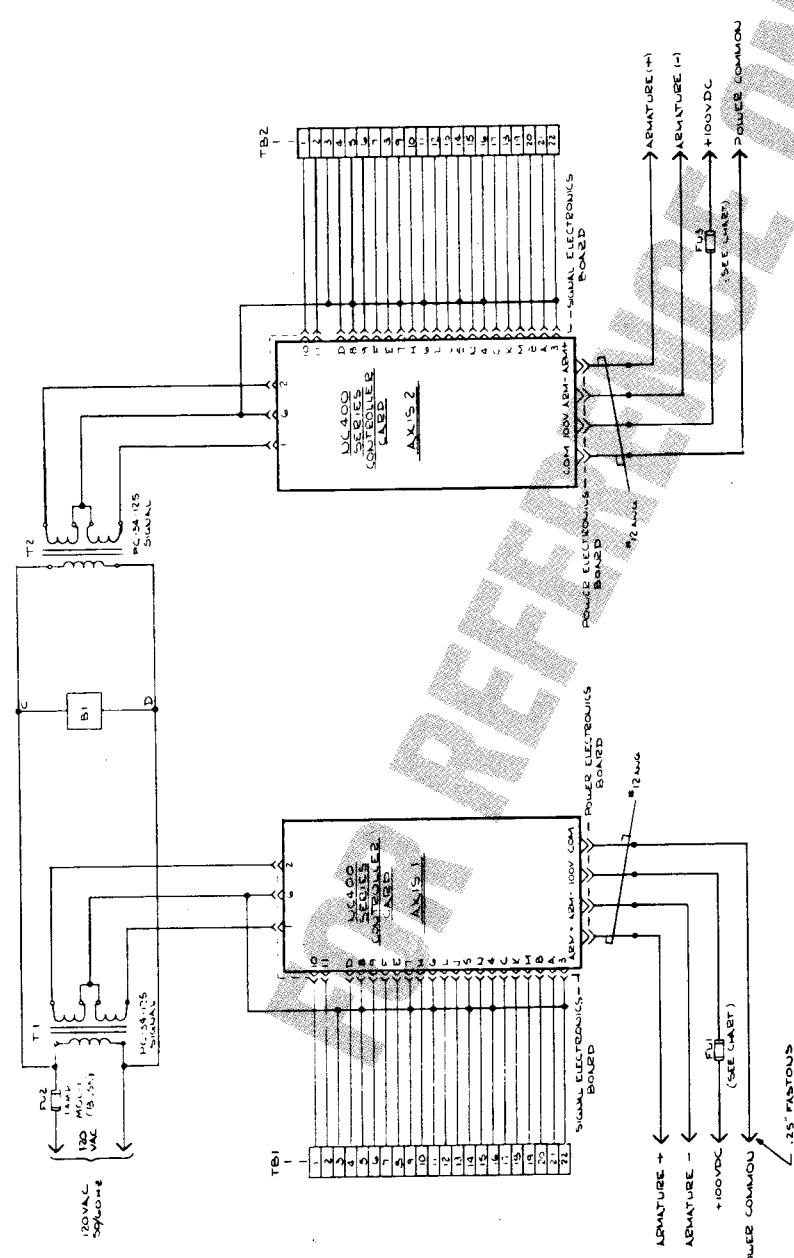
1. NC400 SERVO SERVO CONTROLLER CARDS ARE SUPPLIED IN QUANTITIES OF 1000

CONTROL SYSTEMS RESEARCH, INC. PITTSBURGH, PENNSYLVANIA		DATE: 1/1/77		REV: 1/1/77	
DUAL AXIS CARD		DATE: 1/1/77		REV: 1/1/77	
NC400 SERIES		DATE: 1/1/77		REV: 1/1/77	
PAUCEL MOUNT VERSION		DATE: 1/1/77		REV: 1/1/77	
SHEET: 3 OF 3		DATE: 1/1/77		REV: 1/1/77	
D 30073		DATE: 1/1/77		REV: 1/1/77	
OUTLINE		DATE: 1/1/77		REV: 1/1/77	
TOLERANCES EXCEPT AS NOTED		DATE: 1/1/77		REV: 1/1/77	
XX 2.01		DATE: 1/1/77		REV: 1/1/77	
XX 1.005		DATE: 1/1/77		REV: 1/1/77	
XX 1/4		DATE: 1/1/77		REV: 1/1/77	
MATERIAL		DATE: 1/1/77		REV: 1/1/77	
FINISH		DATE: 1/1/77		REV: 1/1/77	
TREATMENT		DATE: 1/1/77		REV: 1/1/77	
PROVIDE		DATE: 1/1/77		REV: 1/1/77	
APPLICATION		DATE: 1/1/77		REV: 1/1/77	
USED ON		DATE: 1/1/77		REV: 1/1/77	
INSTRUCTIONS		DATE: 1/1/77		REV: 1/1/77	
DATE: 1/1/77		DATE: 1/1/77		DATE: 1/1/77	
REV: 1/1/77		REV: 1/1/77		REV: 1/1/77	

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LTR	REVISIONS		DATE APPROVED
	DESCRIPTION		



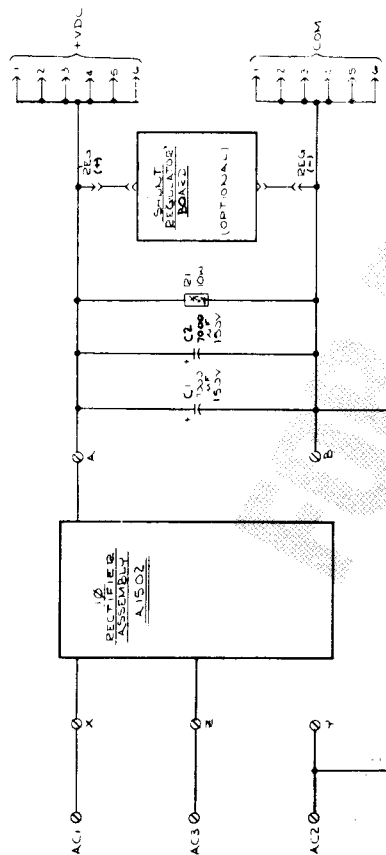
CONTROLLER	AXIS	FUSE	TYPE	WPG
UC407	AXIS 1	F-1	MDA-10	
UC407	AXIS 2	F-2	MDA-10	
UC414	AXIS 1	F-3	MDA-30	BUSHMAN
UC414	AXIS 2	F-4	MDA-30	
UC421	AXIS 1	F-5	MDA-30	
UC421	AXIS 2	F-6	MDA-30	

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TOLERANCES EXCEPT AS NOTED		CHK 12/11/73	DESIGN 12/11/73	ENG 12/11/73	APP'D 12/11/73	QC 12/11/73
XX 2.01	ANG. 0.30					
XXX 2.005	FRAC. 1/64					
MATERIAL		DESCRIPTION				
A1515		SCHEMATIC				
FINISH		TREATMENT				
A1515		USED ON				
PRE-PROD.		PRODUCTION				
PHOTOGRAPH		APPLICATION				

CONTROL SYSTEMS RESEARCH, INC. PITTSBURGH, PENNSYLVANIA	
TITLE DUAL AXIS CARD UC400 SERIES BACK MOUNT VERSION	
SIZE CODE IDENT	DWG NO.
D 30173	A1523
SCALE	REV
	SHEET 1 OF 3





THREE PHASE POWER SUPPLY

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REV	DESCRIPTION	DATE	APPROVED

1/8" 500 SEC. RECTIFIER ASSEMBLY

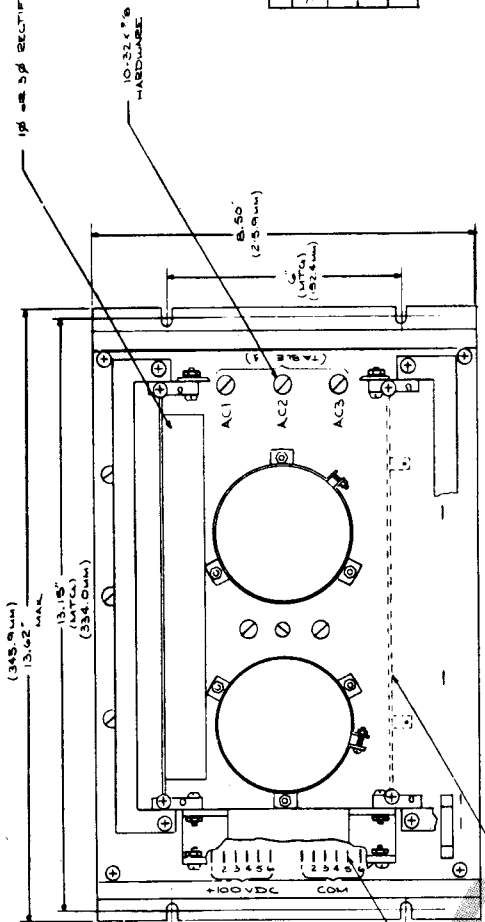
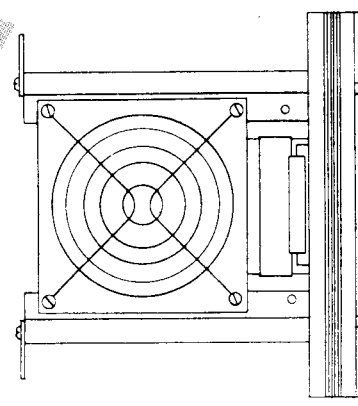
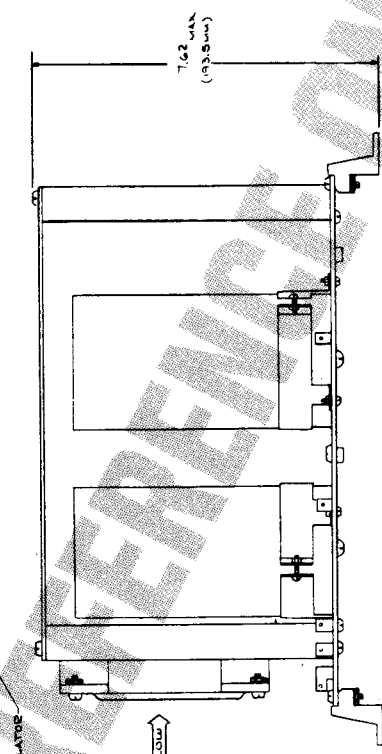


TABLE 1

AC POWER INPUT	SUPPLY CONFIGURATION
TERM	12" 11" 3" 11" 11"
AC1	10 VAC
AC2	10 VAC
AC3	10 VAC

1. VOLTAGES SHOWN ARE NO LOAD AC.  
2. VOLTAGES ARE LINE TO LINE.



NO	DESCRIPTION	NOTES
1	SINGLE PHASE UNITS REQUIRE NO FAN	

CONTROL SYSTEMS RESEARCH, INC. PITTSBURGH, PENNSYLVANIA	
TITLE POWER SUPPLY PANEL MOUNT VERSION	
SIZE CODE IDENT	DWG NO.
D 30173	1293-3000
SCALE	REV
OUTLINE	
TOLERANCES EXCEPT AS NOTED DIM. 1/16" 1/32" 1/64" ANG. 0° 30' FRACTION 1/4" 1/8" 1/16" 1/32" 1/64"	
MATERIAL FINISH EXCEPT AS NOTED	
PROTOTYPE PRE-PROD. PRODUCTION APPLICATION USED ON	
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REV	DESCRIPTION	DATE	APPROVED

10-32 x 1/4" SELF-LOCKING NUTS

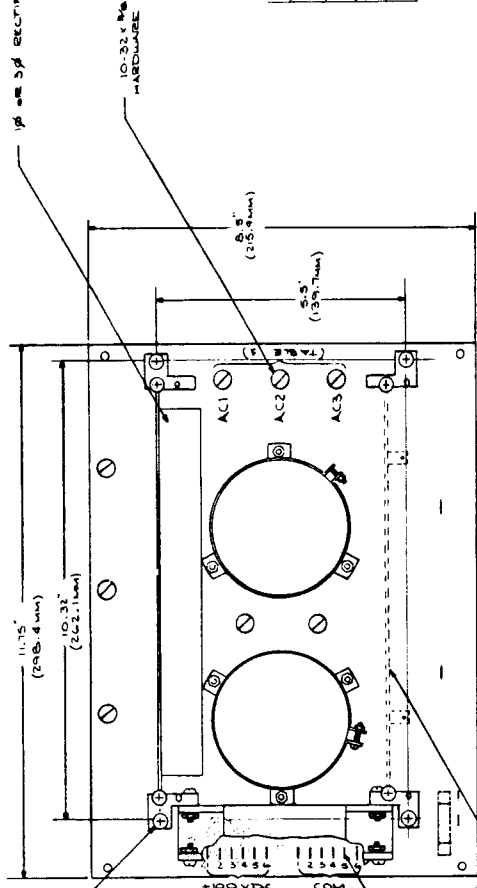
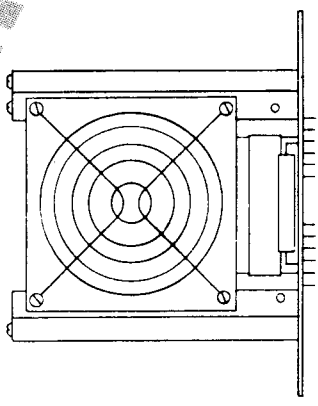
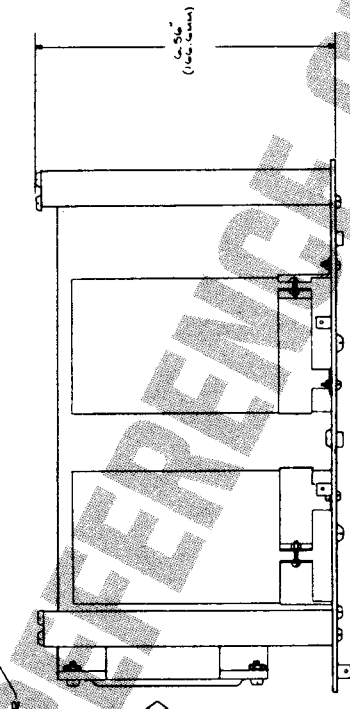


TABLE 1

TERM	AC POWER INPUT
1	3 PHASE
AC1	PHASE 1 TO VAC
AC2	PHASE 2 TO VAC
AC3	PHASE 3 TO VAC

1. VOLTAGES SHOWN ARE  
2. VOLTAGES ARE LINE TO  
LINE



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PROTOTYPE	PRE-PROD.	PRODUCTION	USED ON

FINISH	EXCEPT AS NOTED

TOLERANCES	EXCEPT AS NOTED

CHK	DATE	BY

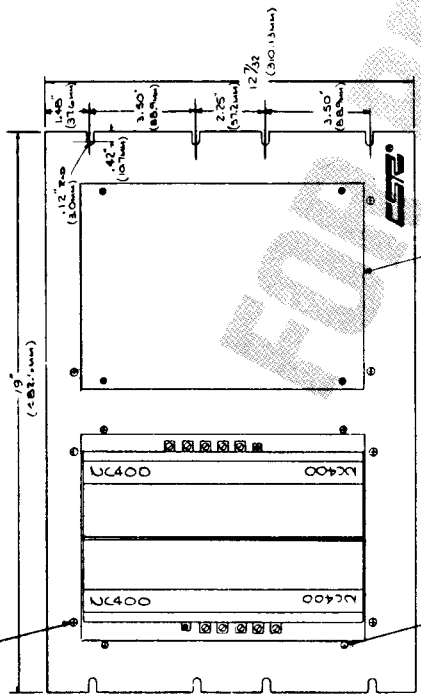
DESCRIPTION	NO.

COVER	DESCRIPTION

REV	DESCRIPTION	DATE	APPROVED

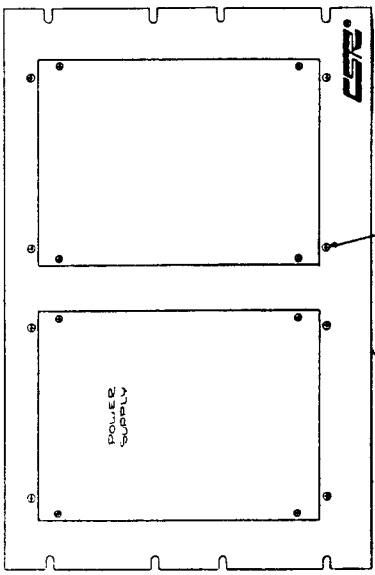
REMOVE 8-32X1/2 BLACK PHILLIPS HD SCREWS FROM FRONT OF DUAL AXIS CARD OR POWER SUPPLY - USE TO MOUNT FRONT PANEL AS SHOWN

FRONT VIEW: DUAL AXIS CARD

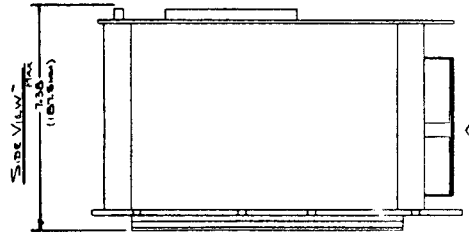


4-40X4 BLACK PHILLIPS HD SCREWS & 4 NUT STAB WASHERS

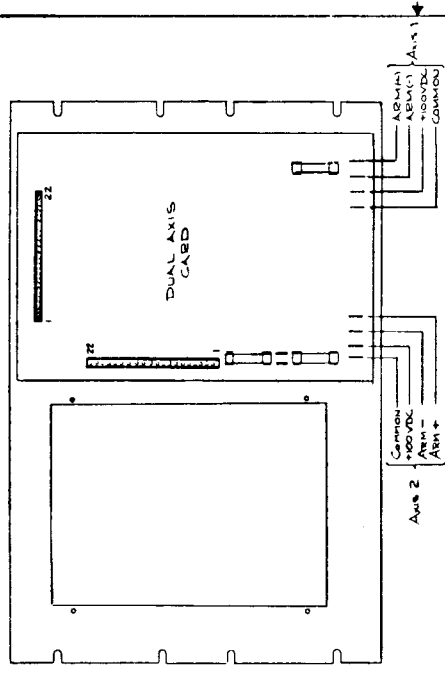
FRONT VIEW: (1) POWER SUPPLY



8-32X3/8 BLACK PHILLIPS HD SCREWS & 8 NUT STAB WASHERS - 8 8-32 HEX NUTS



SIDE VIEW



1. THIS ASSEMBLY CONSISTS OF DUAL COVER PLATE & MOUNTING. ONLY COVER PLATE & MOUNTING ARE SEPARATE ASSEMBLIES.
2. DUAL AXIS CARD OR POWER SUPPLY CAN BE MOUNTED ON EITHER LEFT OR RIGHT SIDE OF PANEL.

NO	DESCRIPTION	NOTES
1	THIS ASSEMBLY CONSISTS OF DUAL COVER PLATE & MOUNTING. ONLY COVER PLATE & MOUNTING ARE SEPARATE ASSEMBLIES.	
2	DUAL AXIS CARD OR POWER SUPPLY CAN BE MOUNTED ON EITHER LEFT OR RIGHT SIDE OF PANEL.	

TOLERANCES		EXCEPT AS NOTED	
DIM	FIN	XX ±.01	ANG 0° 30'
CH	CH	XX ±.005	PMAC 1/64
APD	APD		
OC	OC		
MATERIAL		FINISH	
		FINISH	EXCEPT AS NOTED
		TREATMENT	
		USED ON	
		PRE-PROD	PRODUCTION
		APPLICATION	
		PROTOTYPE	

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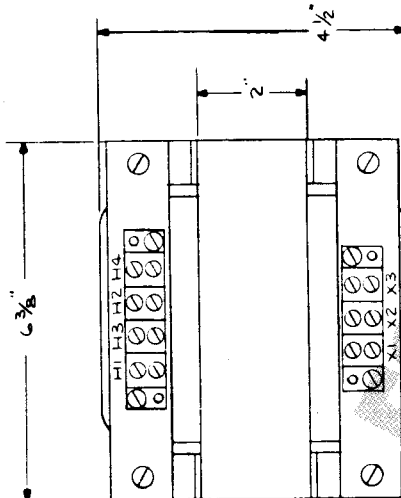
SIZE CODE	IDENT	DWG NO	A1513
D	30173	REV	
SCALE			
SHEET 1 OF 2			

CONTROL SYSTEMS RESEARCH, INC.	
PITTSBURGH, PENNSYLVANIA	
TITLE	
BACK PANEL ASSEMBLY	
WITH COVER PANEL	

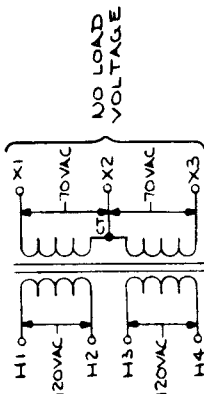


REVISIONS		DATE	APPROVED
LTR.	DESCRIPTION		

# OUTLINE



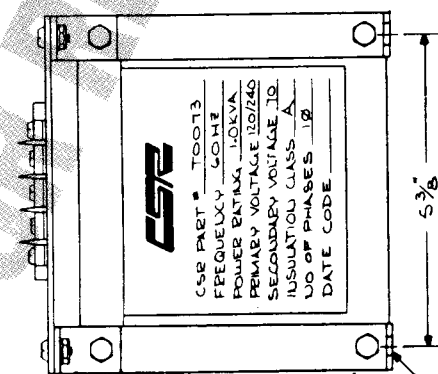
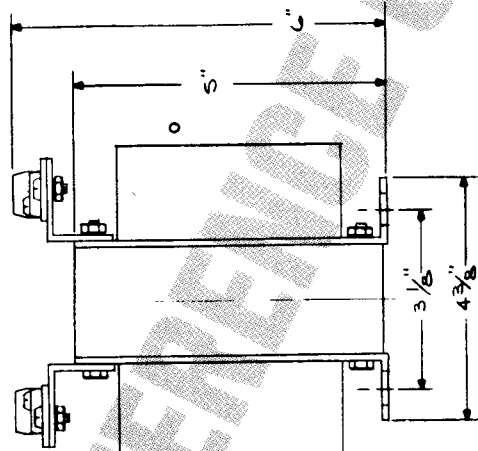
## SCHEMATIC



NO LOAD VOLTAGE

- POWER RATING - 1.1KVA
- FREQUENCY - 60 HZ ONLY
- CORE - 29 GAUGE MG GRAIN ORIENTED SILICON STEEL
- INSULATION - CLASS A OR BETTER
- HI-POT TEST - 3KVAC FOR 5 SEC. WDG TO WDG & WDG TO CORE
- TERMINATIONS - BARRIER TERM STRIPS, (1) FOR PRIMARY, (1) FOR SECONDARY

- MARKINGS - CONNECTIONS INDICATED NEAR OR ON TERM. STRIPS
- RATING & VOLTAGE INFORMATION LISTED ON WRAPPER AS INDICATED
- FINISH - VARNISH IMPREGNATION; NO VARNISH ACCUMULATION ON MOUNTING SURFACES



MOUNTING SLOT 9/32 X 9/16

NO.		DESCRIPTION		NOTES	
		CONTROL SYSTEMS RESEARCH, INC.		PITTSBURGH, PENNSYLVANIA	
		TITLE		TRANSFORMER	
		SIZE CODE IDENT. DWG. NO.		C 30173	
		SCALE		REV.	
		SHEET 1 OF 1			

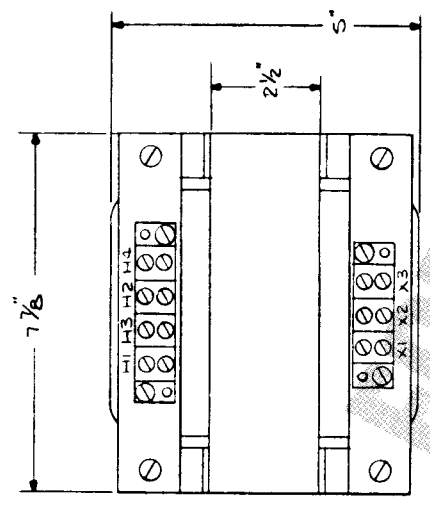
  

DWN.		CHK.		DSCN.		ENG.		APVD.		Q. C.		DESCRIPTION	
2-25-78		3/1/78		3/1/78		3/1/78		3/1/78		3/1/78		OUTLINE SCHEMATIC	

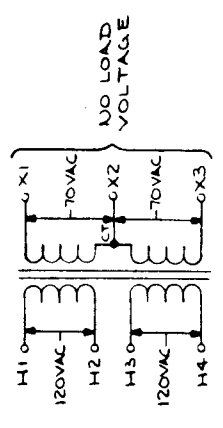


REVISIONS		DATE	APPROVED
LTR.	DESCRIPTION		

OUTLINE



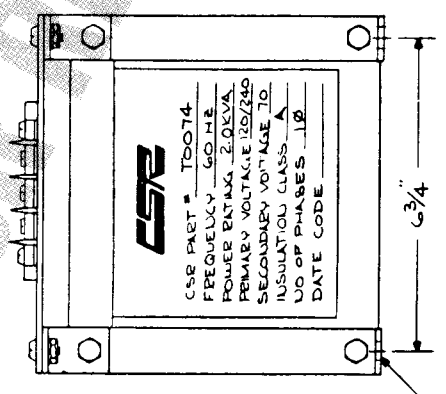
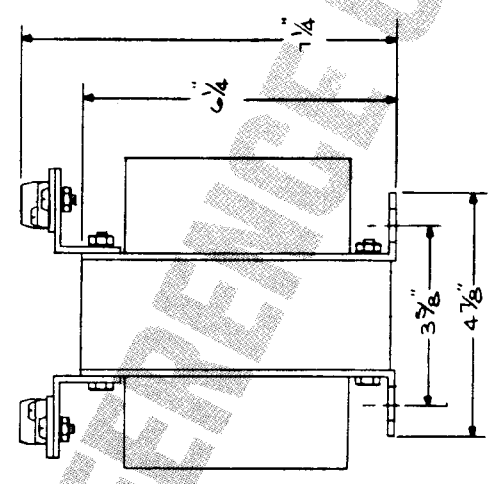
SCHEMATIC



POWER RATING - 2.2 KVA  
FREQUENCY - 60 HZ ONLY  
CORE - 29 GAUGE MG  
 GRN ORIENTED  
 SILICON STEEL  
INSULATION - CLASS A OR  
 BETTER  
HI-POT TEST - 3 KVAC FOR S  
 SEC, WDG TO  
 WDG & WDG TO  
 CORE  
TERMINATIONS - BARRIER TERM  
 STRIPS, (1) FOR  
 PRIMARY, (1) FOR  
 SECONDARY

MARKINGS - CONNECTIONS  
 INDICATED NEAR  
 OR ON TERM. STRIPS  
 - RATING & VOLTAGE  
 INFORMATION  
 LISTED ON WRAPPER  
 AS INDICATED

FINISH - VARNISH  
 IMPREGNATION; NO  
 VARNISH  
 ACCUMULATION  
 ON MOUNTING  
 SURFACES



NO.		DESCRIPTION		NOTES	
		CONTROL SYSTEMS RESEARCH, INC. PITTSBURGH, PENNSYLVANIA			
		TITLE TRANSFORMER			
SIZE CODE IDENT.		DWG. NO.	TOO74		
C		30173			
SCALE		REV.	SHEET 1 OF 1		

TOLERANCES EXCEPT AS NOTED		DWN. CHK.		2-25-73	
XX ±.01	ANG. 0° 30'	DESIGN	3/2/74	3/2/74	
XXX ±.005	FRAC. 1/64	ENG.	3/2/74	3/2/74	
		APVD.	3/2/74	3/2/74	
		Q. C.			

MATERIAL		DESCRIPTION	
RMS FINISH	✓	OUTLINE & SCHEMATIC	
TREATMENT			

PROTOTYPE	PRE-PROD.	PRODUCTION	USED ON

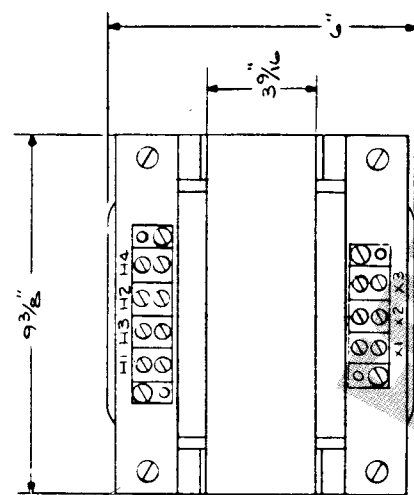
APPLICATION	

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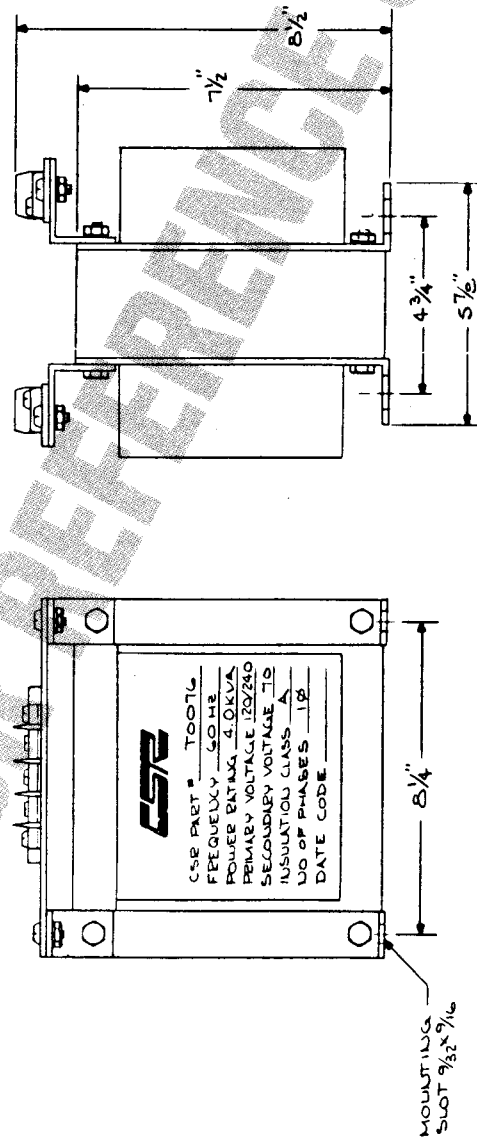
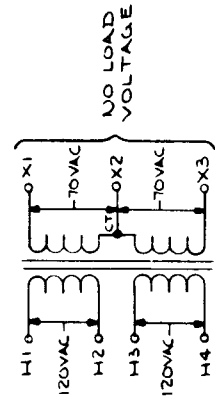


REVISIONS		
LTR.	DESCRIPTION	DATE APPROVED

# OUTLINE



## SCHEMATIC



POWER RATING - 4.4KVA  
FREQUENCY - 60 HZ ONLY  
CORE - 24 GAUGE MG GRAIN ORIENTED SILICON STEEL  
INSULATION - CLASS A OR BETTER  
HI-POT TEST - 3KVAC FOR 5 SEC. WDG TO WDG & WDG TO CORE  
TERMINATIONS - BARRIER TERM STRIPS, (1) FOR PRIMARY, (1) FOR SECONDARY

MARKINGS - CONNECTIONS INDICATED NEAR OR ON TERM. STRIPS  
 - RATING & VOLTAGE INFORMATION LISTED ON WRAPPER AS INDICATED

FINISH - VARNISH IMPREGNATION; NO VARNISH ACCUMULATION ON MOUNTING SURFACES

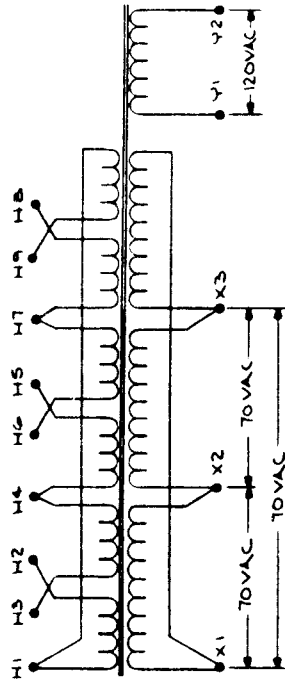
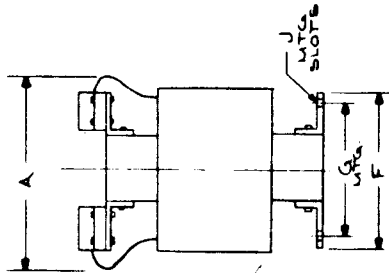
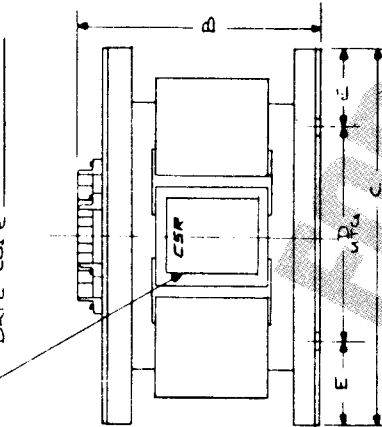
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DWN. CHK. 2-25-75 3/27/71		DWN. CHK. 3/27/71 3/27/71		DWN. CHK. 3/27/71 3/27/71	
DGN. 3/27/71		DGN. 3/27/71		DGN. 3/27/71	
ENG. 3/27/71		ENG. 3/27/71		ENG. 3/27/71	
APVD. 3/27/71		APVD. 3/27/71		APVD. 3/27/71	
Q. C.		Q. C.		Q. C.	
TOLERANCES EXCEPT AS NOTED		TOLERANCES EXCEPT AS NOTED		TOLERANCES EXCEPT AS NOTED	
XX ±.01		XX ±.01		XX ±.01	
XXX ±.005		XXX ±.005		XXX ±.005	
ANG. 0° 30'		ANG. 0° 30'		ANG. 0° 30'	
FRAC. 1/64		FRAC. 1/64		FRAC. 1/64	
MATERIAL		MATERIAL		MATERIAL	
RMS FINISH		RMS FINISH		RMS FINISH	
EXCEPT AS NOTED		EXCEPT AS NOTED		EXCEPT AS NOTED	
TREATMENT		TREATMENT		TREATMENT	
PROTOTYPE	PRE-PROD.	PRODUCTION	USED ON	APPLICATION	

CONTROL SYSTEMS RESEARCH, INC. PITTSBURGH, PENNSYLVANIA		TITLE TRANSFORMER	
SIZE CODE IDENT. DWG. NO. C 30173		TOO76	
SCALE		REV.	
SHEET 1 OF 1			

SERIAL TAG PROVIDES

CSR PART #  
FREQUENCY 60 HZ  
POWER RATING  
PRIMARY VOLTAGE 240/480VAC  
SECONDARY VOLTAGE 70VAC L-L  
INSULATION CLASS  
NO. OF PHASES 3Ø  
DATE CODE



DIMENSIONS										
KVA	A	B	C	D	E	F	G	H	I	J
2.2	7 1/2	9	12	5	3 1/2	5 1/4	3 1/2	3 1/2	3 1/2	3 1/2
4.4	11	8 1/2	13	6	3 1/2	5 1/4	3 1/2	3 1/2	3 1/2	3 1/2
6.6	12	12 1/4	14 3/4	8	4 1/4	5 1/2	3 1/2	3 1/2	3 1/2	3 1/2

HIGH VOLTAGE	CONNECT	LINE'S ON
240VAC	H1 TO H3 TO H8 H2 TO H4 TO H9 H3 TO H1 TO H7	H1 H4 H7
480VAC	H2 TO H3 H3 TO H4 H8 TO H9	H1 H4 H7

- 3 INSULATION CLASS A OR BETTER  
H1 POT TEST: 3KV FOR 5 SEC WDG  
TO WDG & WDG TO CORE
- 2 41, Y2 RATING > 200 VA
- 1 SECONDARY VOLTAGES ARE  
NO LOAD VALUES

NO. DESCRIPTION

NOTES

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PROTOTYPE		PRE-PROD.		PRODUCTION		USED ON		APPLICATION		SCALE		REV.		SHEET 1 OF 1					