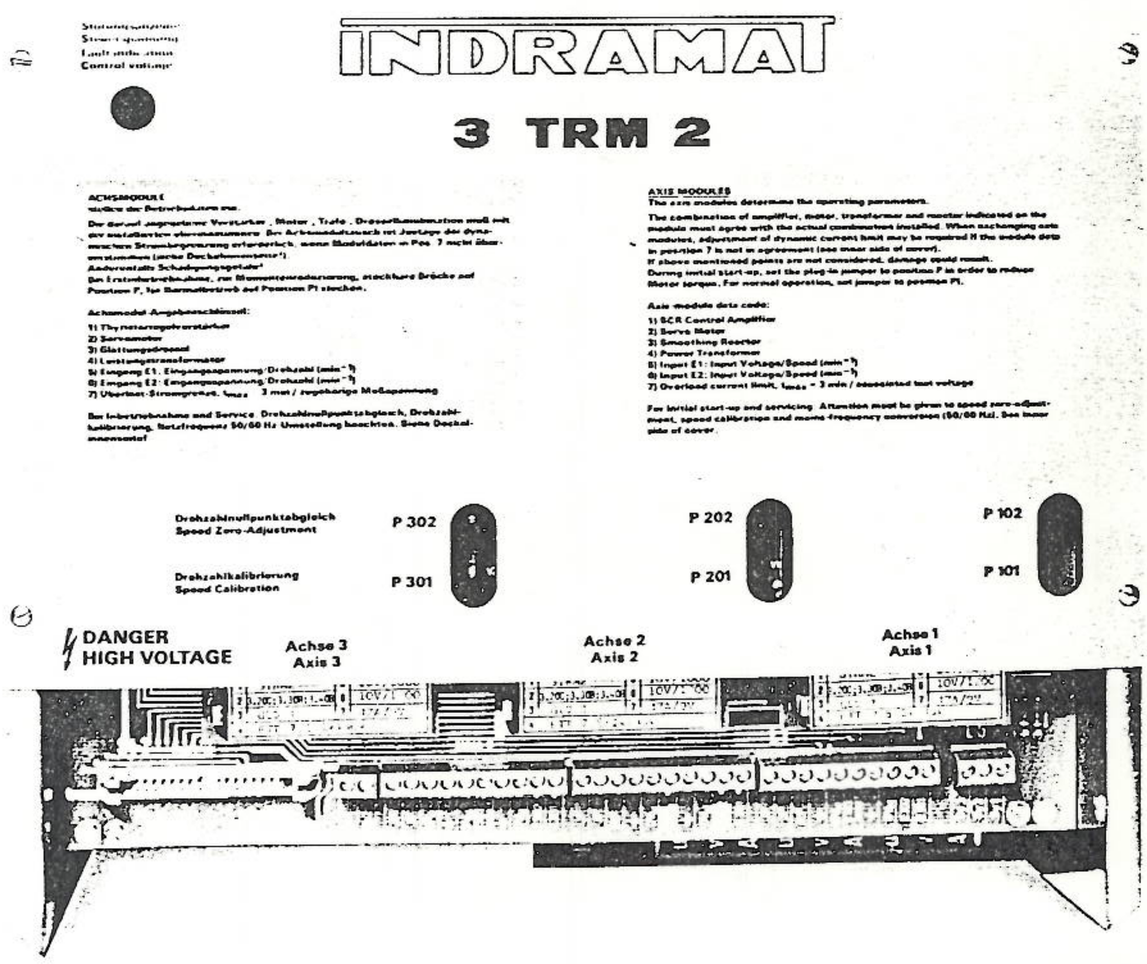
INDRAMAT - Servo Systems

3Axes-Single Phase
Thyristor Control Amplifier

Functional Description and Instruction for Initial Start-Up



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Modular Structured Two-Pulse Control Unit for DC-Servo Motors, Type MDC

Summary

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1. General

The 3 TRM 2 INDRAMAT SCR Control Amplifier is a highly compact single-phase static converter specially designed for three-axes drive systems. The armature-circuit control feature allows continuous driving and braking at changing torque in four-quadrant mode of operation.

The device is especially designed for operation with INDRAMAT Permanent Magnet Direct-Current Servomotors.

The device is constructed in compact cassette-type design with IP 00 type of enclosure for switch-cabinet mounting. The drive interfaces meet the requirements of VDI-Directive 3422.

The following versions of the device are produced: (see table 1)

The standard version of a drive package for 3 axes is composed of the following: (cf. Figure 1a)

1 SCR Control Amplifier 3 TRM 2
3 Single-phase isolating transformers for supplying the power section
3 Reactors for smoothing the armature currents
3 INDRAMAT DC-Servomotors

In special cases use of a single-phase isolating transformer for 3 axes is possible as well (cf. Figure 1b).

The following descriptions refer to INDRAMAT Permanent Magnet Direct-Current Servomotors, as far as the DC motors connected are concerned.

Designation	Symbol [Unit]	Type 3 TRM 2 G 11	Type 3 TRM 2 G 12	Type 3 TRM 2 G 21	Type 3 TRM 2 G 22
Power Supply NT 5		available	—	available	—
Rated AC Supply Voltage*)	U_{Aa} [V]	160 (-ground	160	250	250
Rated DC Output Voltage	U_d [V]	140	140	220	220
Maximum Allowable DC Output Current (3 Axes)	$\Sigma I_{d\,zul.}$ [A]	70	70	70	70
Maximum Allowable DC Output Current (1 Axis)	$I_{d\,zul.}$ [A]	33	33	33	33
Rated Output	P_{Typ} [kVA]	9,8	9,8	15,4	15,4
Power Dissipation	$P_{Verl.}$ [W]	125	90	125	90
Maximum Ambient Temperature	δ [°C]	45	45	45	45
Weight	G [kg]	9,8	6.9	9.8	6.9

U_{Aa} = Maximum allowable rated secondary voltage of transformer, measured between phase and neutral, 10 % overvoltage possible
U_d = Maximum DC output voltage possible (average value) at rated AC supply voltage
$I_{d\,zul.}$ = Allowable continuous RMS-value of DC output current at maximum ambient temperature
P_{Typ} = $U_d \cdot I_{d\,zul.}$
$P_{Verl.}$ = Power dissipation at $I_{d\,zul.}$
*) = 50 Hz or 60 Hz operation, respectively, by choice

Table 1 : 3 TRM 2 Versions

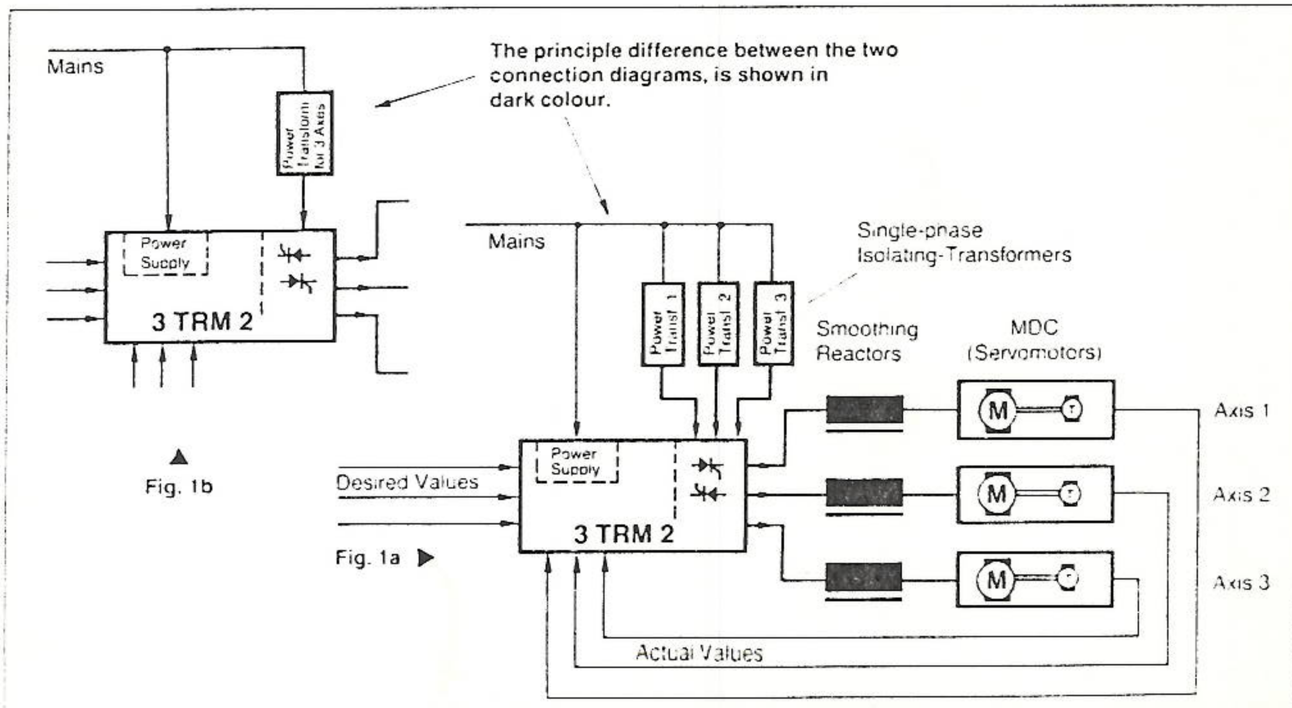


Fig. 1a: Connection Diagram for 3 Drive Axes with 3 Power Transformers
Fig. 1b: Connection Diagram for 3 Drive Axes with 1 Power Transformer

2. Functional Description of SCR Control Amplifier 3 TRM 2

The description refers to the internal circuit diagram and the block diagram (see Documentation). The design of the control section is identical for all 3 axes; therefore the component designations have been chosen in such a way that the first digit indicates the respective axis, e. g. R 243 = Axis 2, Resistor 43.

Based on axis 1 the functioning of the device shall be explained:

The control section for axis 1 essentially consists of:

- Speed Controller V 102
- Speed-dependent Delay-Angle Limiter V 103 (V1, V2 on Axis Module TSS4)
- Linearizing Network (on Axis Module TSS4)
- Dynamic Current Limiter V 107
- Summing Amplifier V 104, V 105
- Control Unit (comprises the Pulse Generator Modules IC 101, IC 102, Pulse Amplifiers T 101, T 102 and Pulse Transformers TR 101, TR 102)

The main assemblies and their functional interrelations are shown in the block diagram (see Documentation).

For setting a speed value a speed-proportional voltage is applied to Speed controller V 102 via the desired-value input E 101 or E 102. The actual speed value is provided by a tacho generator and applied to the speed controller via tacho input E 103. The speed controller forms the difference between the desired and the actual speed value and varies its output voltage accordingly.

The PI-behaviour of the speed controller (resistor and capacitor in the feed-back loop) ensures optimum control without stationary deviation.

The firing-angle limiter limits the output voltage of the speed controller in order to maintain the peak current value and to safeguard the commutation and demagnetization limits of the associated DC motor. This voltage is applied to the pulse generator modules IC 101, IC 102 via the linearizing network and the summing amplifiers V 104, V 105. The firing angle of the SCR unit shifts in accordance with the voltage variations and the output voltage of the device changes. The voltage difference between device output voltage and motor-EMF changes and hence the motor current changes. The resulting motor torque accelerates the mass of the drive unit and it causes a speed variation counteracting, the difference between the desired and the actual values at the input of the controller.

In case the armature current exceeds the preset current limit for an excessive period of time, then the dynamic current limiter starts to act via V 107 and reduces the armature current to the preset limiting value.

The silicon-controlled rectifiers operate with adjustable firing-angle-overlapping to ensure a high degree of drive-rigidity and to make sure that the motor follows immediately the control actions, also at low speed values and at standstill.

2. 1 Speed Controller

An operational amplifier particularly stable with temperature, with a maximum offset-voltage drift of 3 µV/°K only, is used in the speed controller.

The speed-zero adjustment (drive substantially at standstill for desired-value zero) can be performed by means of potentiometer P 102. The external circuitry of the controller ensures optimum control action of the associated drive unit. (for this refer to Chapter 3.6)

2.1.1 Interrelation between Desired-value Voltage and Speed

The desired-value voltage to speed ratio at the desired-value inputs E 101 and E 102 is fixed and indicated on the respective axis module. In case a different ratio is desired, the input resistors (R1 or R2, respectively) must be calculated according to equation (1) and it is recommended to indicate the new desired-value voltage/speed ratio on the axis module under pos. 5 (cf. Chapter 2. 4)

$$\boxed{\text{R1 or R2, respectively} = \frac{U_{desired}}{n} \cdot k \ [\text{k-Ohm}]} \qquad (1)$$

R1 or R2, respectively = input resistor required, in k-Ohms

$U_{desired}$ = desired-value input voltage, in Volts

n = desired speed value, in min^{-1}

k = constant, resulting from the input sensitivity of 0.33 [µA/min]

$$k = 3000 \left[\frac{\text{k-Ohm}}{\text{V} \cdot \text{min}}\right]$$

If, for instance, it is desired that the motor reaches 1000 min^{-1} for a desired-value voltage of 8 V at the input, the following desired-value input resistor is required:

$$R1 = \frac{8}{1000} \cdot 3000 = 24 \ [\text{k-Ohm}]$$

2.2 Speed-dependent Firing-angle Limit

Task:

In order to maintain speed-dependent maximum current values on the one hand and to allow peak current values in the working range on the other hand, the firing-angle can be limited as a function of the speed, according to the commutation characteristic of the associated servomotor. This firing-angle limiting results in a current-speed-diagram in the four quadrants, as shown in Fig. 2.

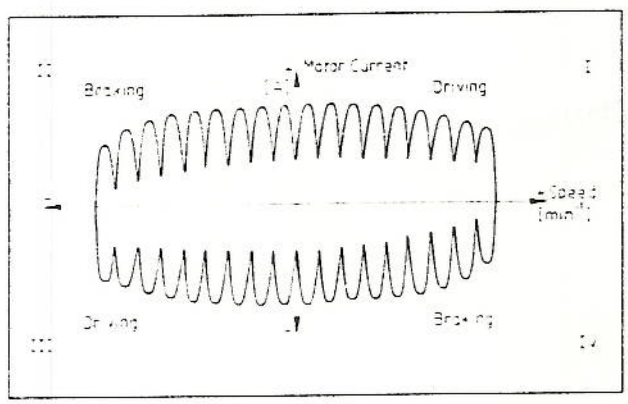


Fig. 2: Current-Speed-Diagram in the Four Quadrants

Performance:

The firing-angle limitation consists of a basic value of freedom, limiting the firing-angle at speed = 0 and the adaptive portion which increases the speed in driving direction with increasing speed, about in the same proportion as the EMF increases. The speed-controller output voltage (U 103) is a measure of the firing-angle.

This output voltage is limited to the basic value of freedom at speed = 0 (as evident from Fig.3). This is achieved via V 102, with the resistor ratio R 12/R 11 for the positive basic value of freedom. The speed-controller output voltage increases by the adaptive portion with increasing speed in the direction of driving current and it decreases accordingly by this portion in the direction of braking current.

2. 3 Linearizing Network

Task:
It equalizes the nonlinearity of the firing-angle versus motor current characteristic and thus allows stable operation with a high degree of drive-rigidity.

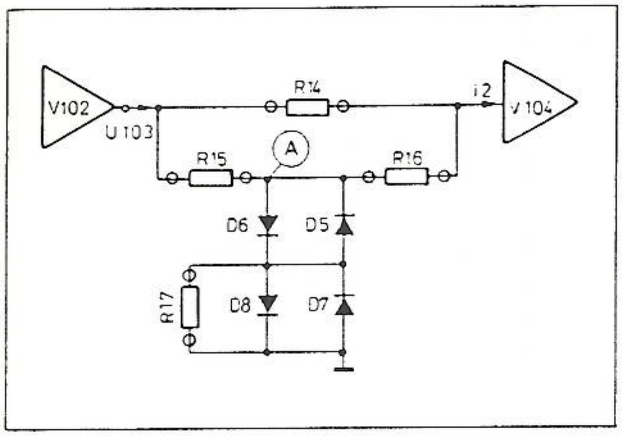


Fig. 4: Linearizing Network

Performance:
The output current i_2 (Fig.4) of the linearizing network is proportional to the firing-angle. The current i_2 increases linearly with the controller output voltage U 103 until at point Ⓐ the threshold voltage of the diode appears. When further increasing U 103 the current remains constant via R 16 and a further increase of i_2 can only be achieved via R 14. This results in a nonlinear relationship between U 103 and i_2 which compensates for the nonlinearity of the firing-angle versus motor current relationship to a large extent.

2. 4 Axis Modul TSS4/XXX

The axis module TSS4 allows optimum adaption of the SCR control amplifier to the associated drive combination. For each combination of motor, transformer and reactor the following assembly wirings are fixed on the TSS4 axis module card:

- The speed-dependent firing-angle limitation
- The speed-controller wiring
- The linearizing network
- The input wiring
  (cf. Block Diagram, Documentation)

The most important information is indicated on the axis-module imprint (cf. Fig 5)

Axis module no.	TSS4/XXX
1) SCR control amplifier	3 TRM 2
2) Servomotor	MDC 10.20 F
3) Smoothing choke	GLD 2
4) Power transformer	ETT 3,5/2x140 V
5) Input E 1:	
Input voltage/speed (min^{-1})	10 V/2000
6) Input E 2:	
Input voltage/speed (min^{-1})	free to choose
7) Overload current limit t_{max} = 3 min/	
associated measuring voltage	30A/5 V

The assembled drive combination and the corresponding wiring of the axis-module card TSS4 are summarised by means of the axis-module number.

2. 5 Summing Amplifiers V 104 and V 105

The current values from the linearizing network, the firing-angle overlapping and the dynamic current limit are summed up in the summing amplifiers and are fed to

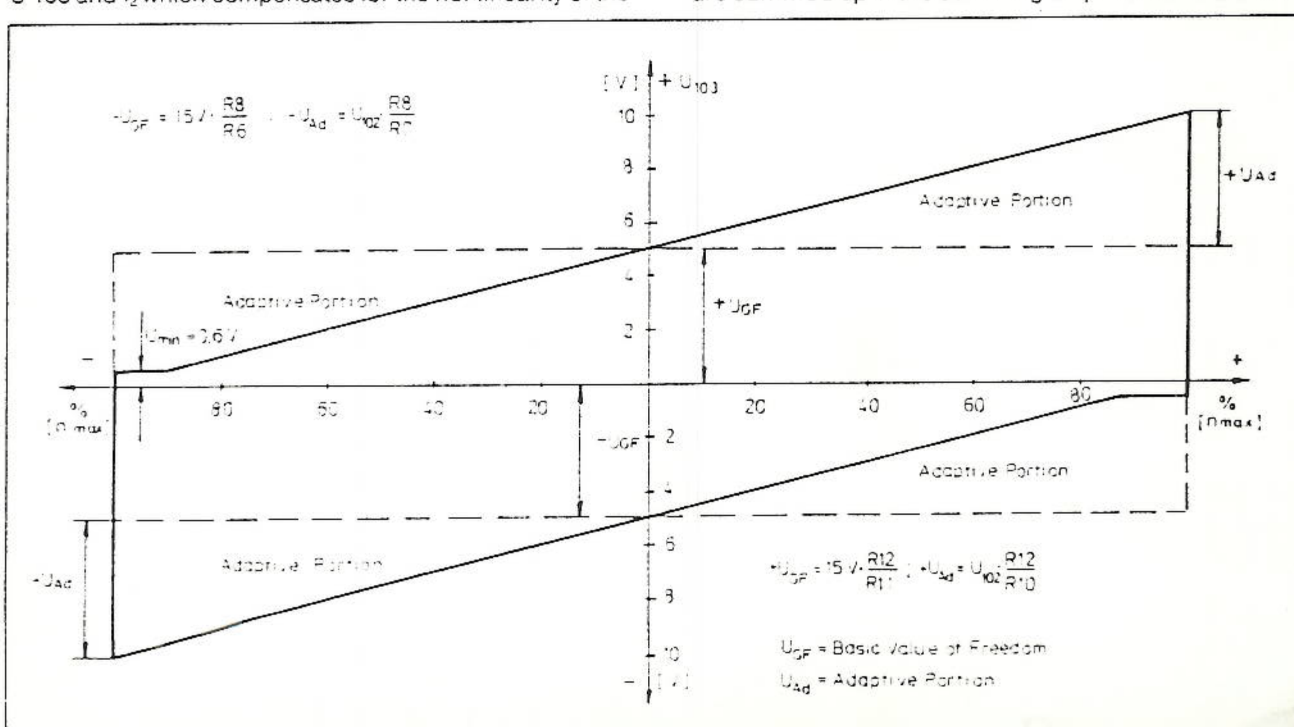


Fig. 3: Output-Voltage Range U 103 of the Speed Controller as a Function of the Speed

the pulse-generator modules IC 101 and IC 102 as a voltage proportional to the firing-angle (cf. Block Diagram, Documentation).

AXIS MODULE		TSS4/XXX	
1	3TRM2	5	10V/2000
2	MDC 10.20 F	6	
3	GLD 2	7	30A/5V
4	ETT 3,5 / 2 x 140 V		

Fig. 5: An Example of Axis Module

2. 6 Control Unit

It consists of the pulse-generator modules, the pulse-amplifier stages and the pulse transformers.

Task:

The control unit transforms the voltage values which are proportional to the firing-angle into trigger pulses synchronized by the mains, similar to an A/D-converter.

Performance:

For that purpose the control unit compares the output voltages of V 104 at test point 109 in IC 101 and of V 105 at test point 110 in IC 102 with the saw-tooth voltage synchronized by the mains. (cf. Block Diagram, Documentation and Fig. 10). As long as the saw-tooth voltage exceeds the output voltage, the corresponding silicon-controlled rectifiers are triggered by means of trigger pulses. IC 101 controls the positive group of SCR's and IC 102 the negative one. One of the trigger pulses is shown in Fig. 6.

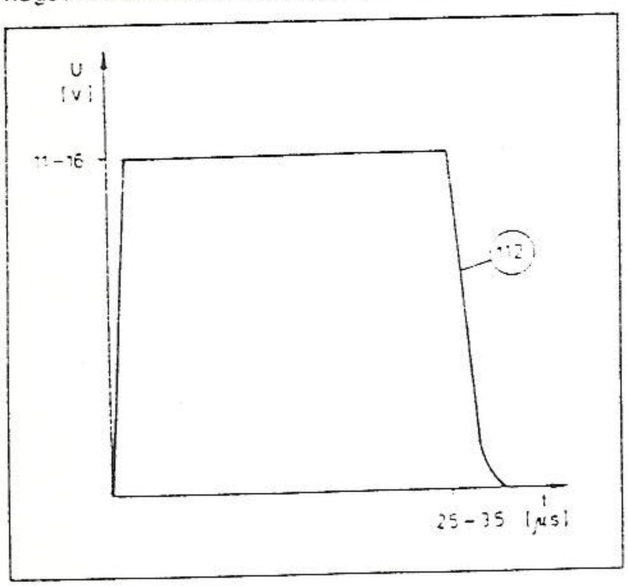


Fig. 6: Output Signals of a Trigger Pulse Generator

2. 7 Dynamic Current Limit

Task:

It allows high accelerating currents limited in time and protects from prolonged exceeding of the fixed current limit.

Performance:

The actual current value is detected via a current transformer and is applied to amplifier V 107. This one compares the current limit setting of potentiometer 104 with the actual current value. (cf. Internal Circuit Diagram, Documentation). In case the actual current value exceeds the current-limit setting, amplifier V 107 integrates towards the negative range, starting from its maximum positive output voltage (13 ... 14 V) and acts upon the summing amplifiers V 104 and V 105 in a limiting manner. The response time is depending, upon exceeding the current limit setting.

At INDRAMAT the current limit setting is adjusted to double the motor current rating and this value is indicated on the respective axis module under position 7 (cf. Fig 5). In case alternate settings are desired, please refer to Chapter 3.8.

Attention:

If a different voltage value is indicated on the axis module under position 7 when exchanging axis modules, the current limit must be readjusted in accordance with the new task. (P 104).

2. 8 Synchronization

The synchronization ensures that the pulse-generator modules in the control unit are able to generate a saw-tooth voltage synchronous with the secondary voltage of the power transformers.

Performance:

On principle the 3 TRM 2 is designed in such a way that either internal or external synchronization is feasible, depending on the type of application. In all these cases the amplifier V 106 (cf. Fig. 7) generates a pulsating DC voltage U 106 (Synchronizing DC) out of the synchronizing AC, which must be in phase with the respective secondary voltage of the power transformer, and this DC is fed to the pulse-generator modules IC 101, IC 102. Thus IC 101 generates the saw-tooth voltage synchronized by the mains, while IC 102 periodically switches the trigger-pulse release.

2. 8. 1 Internal Synchronization

It is only then that internal synchronization is possible, if the power supply transformer in power supply NT 5 as well as the power transformers TR 1, TR 2 and TR 3 are connected to one and the same phase wires. (See Fig. 8)

For internal synchronization of the three axes the jumper Sy must be soldered in. No connection must be made to terminals Sy 1, Sy 2 and Sy 3.

2. 8. 2 External Synchronization

External synchronization is required, if

a.) the 3 TRM 2-version does not include a power supply unit (e.g. Copying Control)

b.) the power transformers are connected to different phase wires, for better load distribution purposes (see Fig. 9)

For external synchronization jumper Sy must be removed. The synchronizing voltages Sy 1, Sy 2, Sy 3, must be in phase-coincidence with the power voltages of the individual axes.

2.9 Firing-Angle Overlapping – Preconduction Current

Task:

The firing-angle overlapping ensures a high degree of drive-rigidity also at low control levels and it avoids additional dead band in the control.

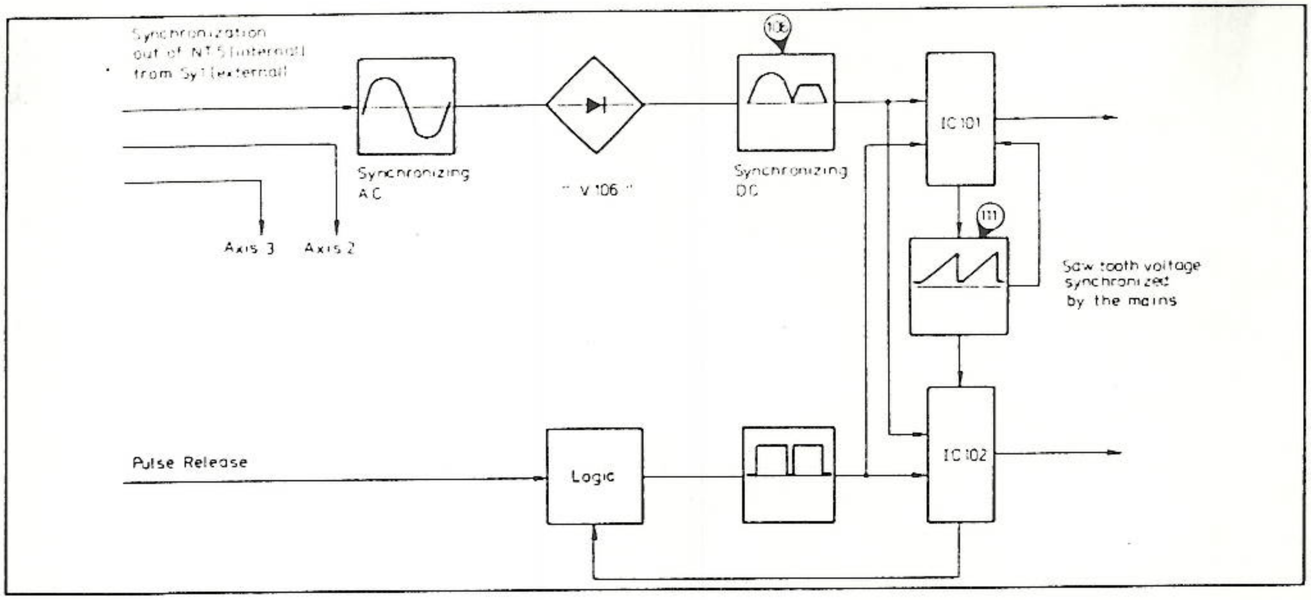


Fig. 7: Synchronization

Performance:

The control voltages U 109 and U 110 (cf. Internal Circuit Diagram) are adjusted by means of trimming potentiometer P 103 in such a way that they sink below the saw-tooth voltage level at a speed-controller output U 103 = 0 V and cause a small firing-angle at the silicon-controlled rectifiers (cf. Fig. 10 c). Due to this the silicon-controlled rectifiers are carrying a preconduction current which flows in the secondary circuit of the transformer. For preconduction-current adjustment refer to Chapter 3.7.

2. 10 Controller and Pulse Release

Task:

These assemblies offer the possibility to lock the entire automatic speed control system externally. The controller release acts upon the speed controller, the pulse release upon the control unit. (cf. Chapter 3.9).

2. 10. 1 Controller Release (RF)

Controller release is effected by applying a voltage (+ 5 V ... + 30 V) to input RF (terminal 3). FET 101 becomes high impedance due to this voltage via comparator V 101 and thus the PI-wiring of speed controller V 102 becomes effective. The controller release is effected without delay and it is cancelled about 220 ms after the signal has been taken away. (cf. Internal Circuit Diagram, Documentation).

2. 10. 2. Pulse Release (IF)

Applying a voltage (+ 5 V ... + 30 V) to terminals 1 and/or 2 (inputs IF) causes pulse release without delay. After taking away the voltage the trigger pulses are blocked with a delay of about 400 ms.

Attention:

The controller and pulse release signals must be issued only if it is secured that there is no permanent blocking of the drive system, e.g. due to a brake held off electrically. The motor does not deliver any torque when the pulses or the controller are inhibited. The drive is free to move, provided it has not been blocked mechanically.

2. 11 Voltage Monitoring System

Task:

The voltage monitoring system switches off the device in case of a control-voltage malfunction, in order to avoid erratic functioning.

Performance:

If there is no malfunction of control voltages (± 15 V), then transistors T1, T2, T3 and T4 are conducting. Relay d1 has pulled up and reports „Readiness for Operation" via a floating contact (normally-open contacts Bb 1 and Bb 2) (cf. Internal Circuit Diagram, Documentation). If now, for instance, the positive control voltage drops below +14.5V, then transistors T1 and T3 are cutting off and the relay drops out. The ready to run contact Bb opens and the light-emitting diode h1 indicates the malfunction, provided the + 24 V voltage is present. At the same time the pulse generator modules are locked.

2. 12 Power Supply

The central power supply unit and the associated transformer are located underneath the swivelling circuit board. The power supply provides the supply voltages for the open and closed loop control sections, the load voltages for triggering the brakes and the synchronizing AC for the control unit for internal synchronization.

Attention:

Connect power-supply transformer and power transformer to the same phase wire in case of internal synchronization.

For further information see IE 71 000.

2.13 Fuses

2.13.1 Control Section

Fine-wire fuses on the power-supply card

e 1, e 2	=	1. 0 A medium-slow for the primary of the power-supply transformer
e 3	=	4. 0 A medium-slow for + 24 V (= + U_L)-Output

2.13.2 Power Section

The necessary fusing for the power section has to be chosen dependent on application. The necessary information for calculation of fuse rating can be found in brochure IE 71 000.

2.14 50/60 Hz Conversion

Solder in the jumpers Br 101, Br 201 and Br 301 for operation with 60 Hz mains frequency (cf. Identification print 3 TRM). Don't insert jumpers Br 101, Br 201 and Br 301 for 50 Hz-operation! Thereafter it becomes necessary to check the firing-angle overlapping. (cf. Chapter 3.7).

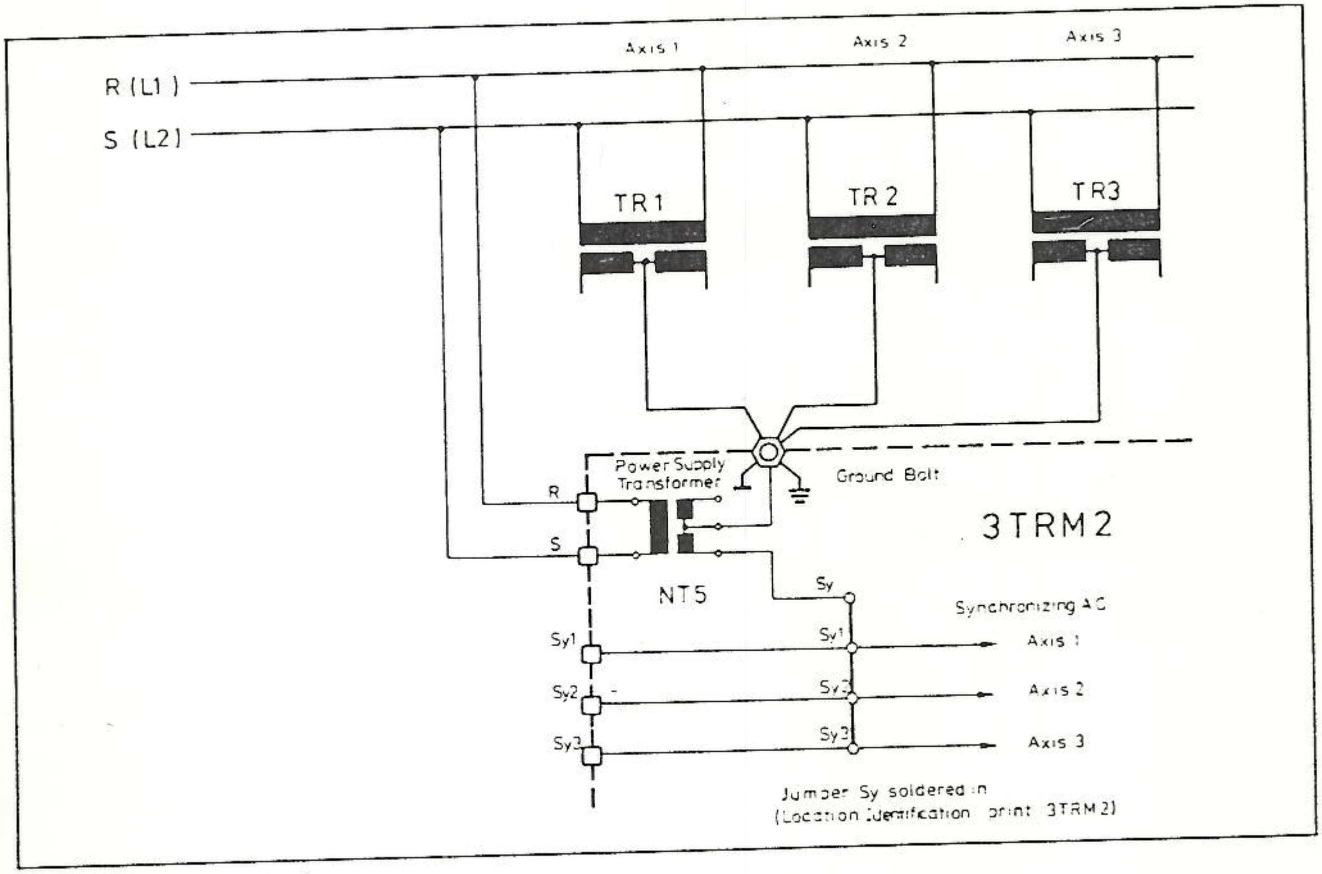


Fig. 8: Internal Synchronization

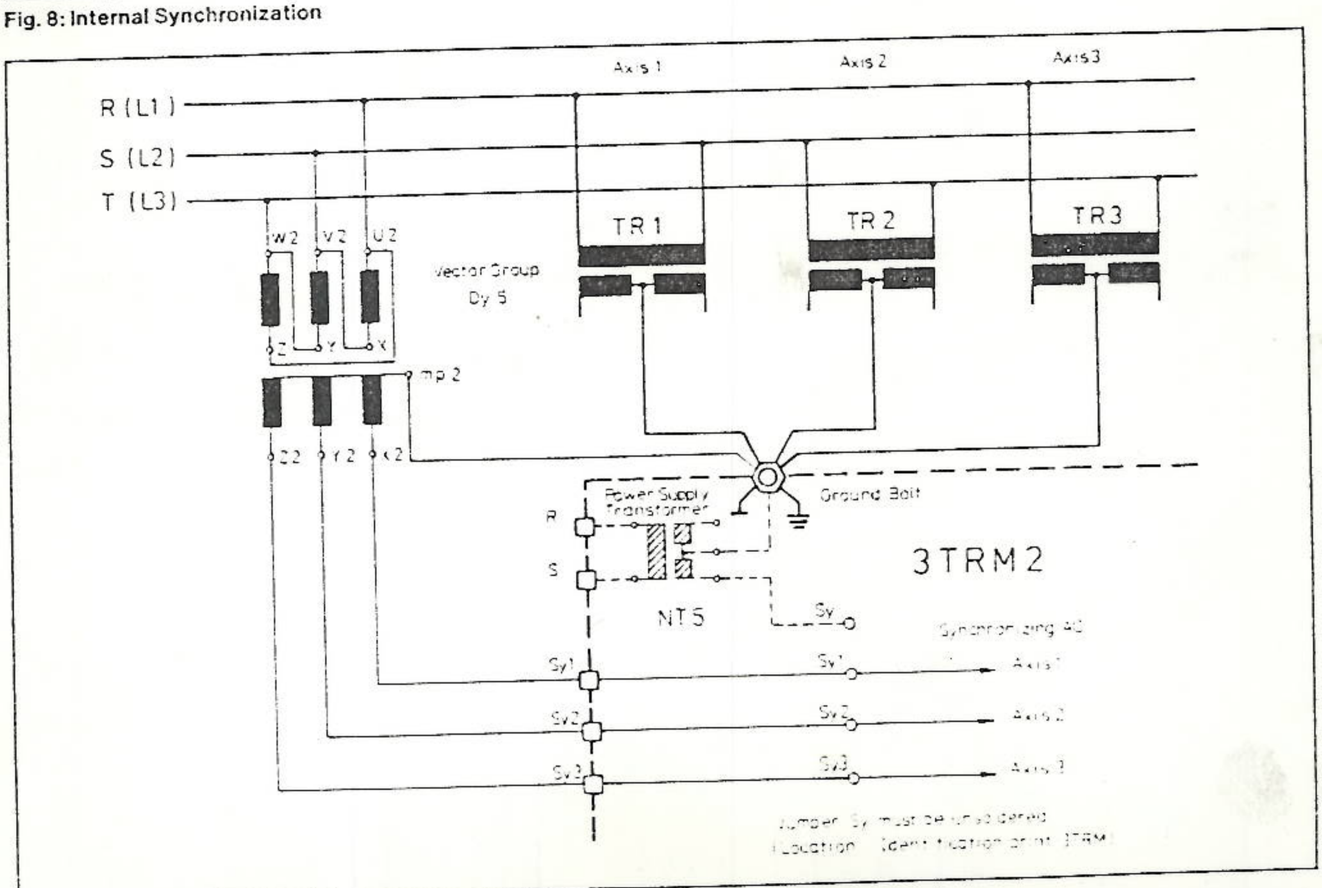


Fig. 9: External Synchronization

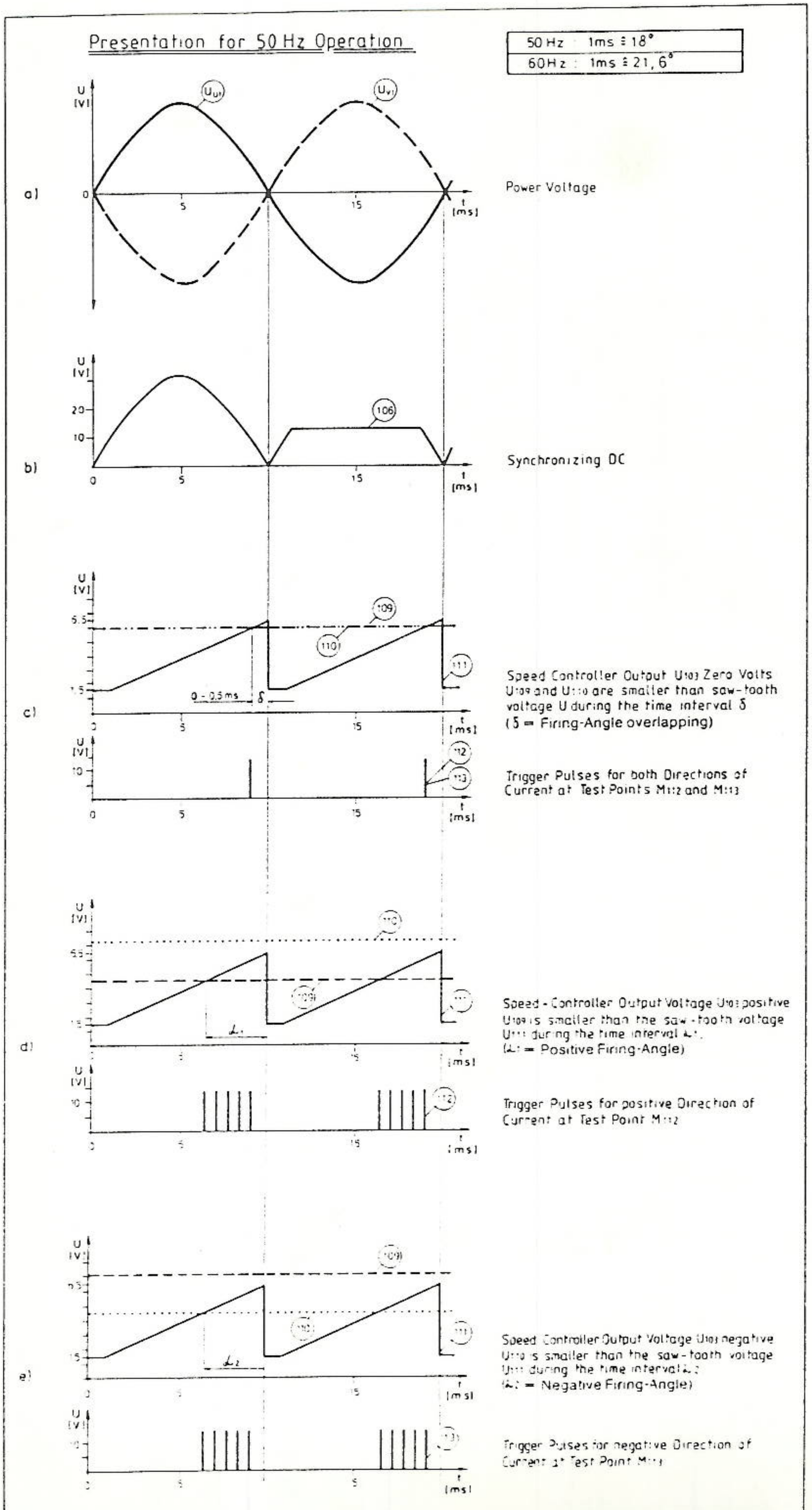


Fig. 10: Transformation of the voltages which are proportional to the firing angle into trigger pulses synchronized with the mains

3. Initial Start-Up

For starting-up the drive combination it is recommended to proceed in accordance with the following description:

3.1 Start-Up Equipment

- Multimeter for DC and AC (with moving-coil instrument movement, centre zero)
- Oscilloscope (floating via isolating transformer)
- Battery supply for adjustable desired-value inputs up to ± 10 V.
- Precision resistor measuring 1 m Ohm (100 A = 100 mV)

3.2 Checks

During the subsequent checks watch that the wires are firmly seated inside the terminals.

1. **External wiring**
   Check that the external wiring is in agreement with the connection diagram.

2. **Protective measure**
   Check that the protective measures stipulated have been adhered to (in particular the non-fused earthed conductor at the ground connections of device, motor, transformer and reactor).

3. **Axis-module data**
   Check that the axis-module data are in agreement with the data of the transformer, motor, amplifier and reactor installed.

4. **Mains supply; mains frequency**
   a) Check that the local mains supply voltage is in agreement with the primary voltages of the transformers (Transformer for Power Supply and Power Section)
   b) Check that the local mains frequency is in agreement with the operating-frequency setting of the amplifier (see Chapter 2.14).

5. **Apply mains supply voltage**
   Apply mains supply voltage to the control section (terminals R-S); Don't switch on the power section.

6. **Error display**
   The error display for measuring voltages must not light up, otherwise recheck the voltage values.

7. **Emergency Off**
   Check the proper functioning of the "Emergency-Off-Chain", in particular the emergency-cutout by means of the safety limit switches.
   Erratic functioning of the drive can not be excluded when the system is in an emergency-off situation. It is therefore necessary to cut off the power. Yet as a result of this cutting-off of the power a controlled braking with minimum braking distance is no longer possible. In order to shorten the braking distance under these circumstances the armature circuit can be short-circuited via a resistor simultaneously with the opening of the power contactor c1. (for details cf. IE 71000). This braking by short-circuiting the armature is speed-dependent and does not ensure any holding torque. If holding back of a braked drive is required (e.g. in the case of vertical axes) a brake lifted electrically must be provided in the motor, or if not available a mechanical brake must be provided.
   In any case an erratic drive motion must be taken into account until the drive has come to a standstill (in an emergency-off situation), and the extent of this motion depends on the kind of malfunction and on the operating condition of the drive at the moment the malfunction occurs. Endangering of personnel due to erratic drive motions must therefore be excluded by means of an overriding safety feature on the equipment side.
   The safety limit switches must be arranged in such a way that the machine is unable to move against fixed stops. The distance between the safety limit switch and the fixed stop must be larger than the braking distance of the drive.

8. **Mechanical Blocking**
   Check that the mechanical blocking is unblocked upon the signals Controller Release and Pulse Release. The drive shaft must be free to move.

3.3 Initial Start-Up, e.g. for Axis 1

1. For the initial start-up it is practical to uncouple the servomotor from the system. In case this proves to be impossible, the proper functioning of the emergency-off circuitry will be of utmost importance. (cf. Chapter 3.2 Emergency-Off).
2. Disconnect the connecting wire for the Pulse Release (IF) at the axes 2 and 3. At axis 1 apply the Controller- and Pulse-Inhibit signal (0 V at terminals IF and RF).
3. Change the plug-in jumpers for motor-torque reduction from position PI to position P.
4. Disconnect all the desired-value inputs of the control on the equipment side from the SCR-Control Amplifier. Connect the battery supply for adjustable desired-value inputs with a maximum of ± 10 V to the desired-value input of axis 1 (and 0 V to terminal 3). The input sensitivity is indicated on the respective axis module following Point 5.
5. Switch on the power supply for the control and the power section.
6. Close the circuit for the controller and the pulse release. Apply a small desired value by means of the battery supply.

Attention:
In case the polarity of the tacho generator is wrong, the drive will now accelerate out of control. Immediately actuate "Emergency-Off" and change the polarity of the tacho generator. In case the polarity is correct the speed of the drive will follow the desired-value input. Change the plug-in jumper of axis 1 from position P back to position PI again.

3.3.1 Speed Calibration

Speed calibration is required for each one of the axes to compensate for tacho-generator tolerances. The adjustment must be performed for initial start-up and when exchanging the motor or when exchanging the tacho-generator only. For this purpose it is practical to operate the drive with a desired-value signal which provides 30 to 100 % of the maximum usable speed (at the given input voltage, speed ratio). For calibration of axis 1 trimming potentiometer P 101 is used, for axis 2 P 201 is used and for axis 3 P 301 is used. The speed value to be set is calculated as follows:

$$n = \frac{U_{desired}}{R1 \text{ or } R2\text{, respectively}} \cdot k\ [min^{-1}] \qquad (2)$$

n = motor speed in min^{-1}
$U_{desired}$ = applied desired-value voltage in V

R1 or R2, respectively = input resistor used, in kOhm

$k = 3000 \left[\frac{kOhm}{V \cdot min}\right]$

Attention:
Speed calibration must not be used to compensate for desired-value tolerances!

3.3.2 Speed Zero-Adjustment P107 MP107

In case the motor is drifting when the desired-value zero is applied to the speed control loop, substantial standstill of the drive can be achieved by adjusting at trimming potentiometer P 102 (Axis 1), P 202 (Axis 2) and P 302 (Axis 3). Possible reasons for a zero drift, amongst other things, are the following: Offset-voltage of the speed controller (is temperature dependent), offset-voltage in the preceding control system, potential differences between NC-ground and measuring zero of the controller.

3.4 Checking the Moment of Load

If the initial operation of the servo drive has been performed with the load uncoupled according to 3.3, then the load can now be coupled after proper functioning has been ascertained. Here again the desired-value signal to be used for the subsequent check is provided by the battery supply.

3.4.1 Motor Torque Measurement with the Aid of Current Consumption

The current consumption of the DC-servomotor is a direct measure of the moment of load.

The factor to be used for converting current into torque values is indicated on the motor identification plate, stated as K_m (Nm/A). Current is measured by measuring the voltage drop across a 1-mOhm-precision resistor connected between motor and Mp. A moving-coil instrument indicates the average value of the current (100 m V = 100 A) to which the current-torque-factor K_m applies (Nm/A).

It should be noted that the voltage drop is measured at the test sockets provided for this purpose within the load terminals.

3.4.2 Base Torque in the Feed Range

Determine the base torque of the load in both directions of motion by measuring the current consumption at maximum speed in the feed range.
For further information, see IE 71 000.

3.4.3 Motor Torque at Rapid Traverse Rate

The current consumption of the motor at rapid traverse rate must not exceed 75 % of the rated current. Some of the reasons for an excessive increase of the torque value at rapid traverse rate are the following:

- Insufficient fluidal balance of weight for vertical axes (Sectional flow area too small)
- Oil-bath gear unit with accumulation of fluid in the gear-tooth system.
- Inadequate restoring of the ball in the nut of the ball screw.

3.5 Adjusting the Balance of Weight

It is practical to adjust the fluidal balance of weight for a vertical machine axis by measuring the motor current in accordance with 3.4.2 and 3.4.3. Perform the adjustment in such a way that the current consumption of the motor during the upwards and downwards motion of the slide shows identical minimum values.

3.6 Checking the Speed Control Loop

The circuitry for the speed controller wired at the factory is generally adequate for the usual operational requirements. A check of controller action and an optimization that might eventually become necessary later on can be performed in accordance with the following guide lines:

Disconnect the desired-value input coming from a control system on the equipment side from the SCR-control amplifier. Connect a battery supply with an adjustable desired-value input of ± 10 V maximum. To avoid excessive speed values the input sensitivity of the axis module used must be taken into account. Appraisal and post-optimization: (see Fig. 11).

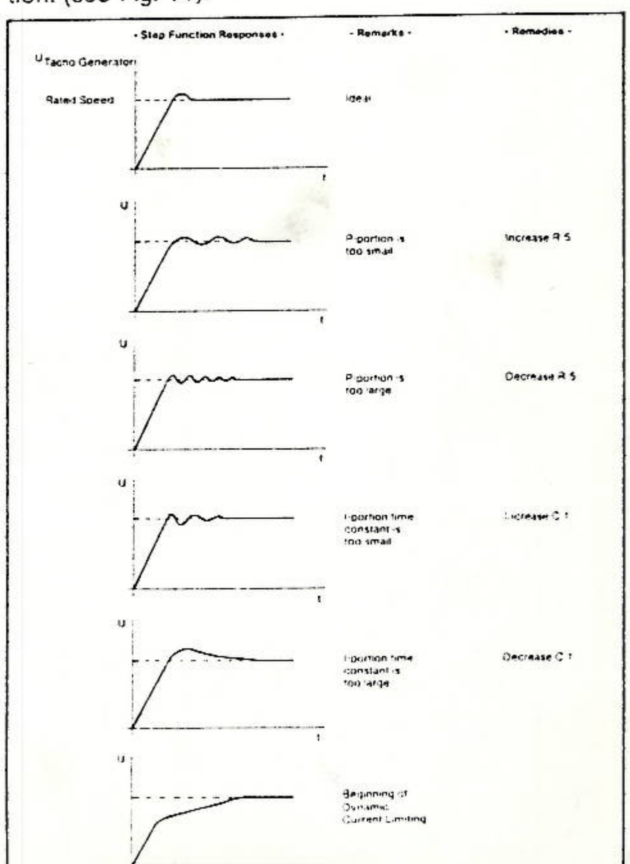


Fig. 11: Characteristics of Speed Control Loop for various PI-Elements

The battery supply must provide a step function signal without overshoots, gaps or ringing as a test signal. The tacho-generator voltage of the drive is recorded, starting at about 10 %, then 50 % and finally 100 % of the amplitude. A series of tests should include at least 5 step-function responses. (There may be differences between individual step responses with regard to ascending wave flank and maximum overshoot depending on the moment the mains supply voltage is gated). For a desired-value input of 10 %, overshoots of 40 % are admissible in the step response, provided in this same series of tests smaller overshoots or less creep behaviour for the wave fronts exist as well.

The Optimization is modified by exchanging the feedback components R 5 and C 1 soldered in on module TSS4. (see Fig. 11).

3.7 Adjustment of Firing-Angle Overlapping and Pre-Current

A pre-current is applied to the secondary circuit of the power transformer in order to achieve maximum drive rigidity and to avoid dead time periods.

This current is adjusted at the SCR-control amplifier at the INDRAMAT-plant prior to delivery of the device.

A check is required when changing over to 60 Hz. Too high a pre-current setting causes strong vibrations when the drive is at a standstill and results in additional warming-up of the power transformer and the motor. Too low a pre-current setting shows itself as "slack" at the motor shaft, i.e. the motor shaft can be rotated for several angular degrees until counter-acting torque is developed.

A check and an adjustment that might eventually become necessary later on can be performed as follows: Adjustment of pre-current: Example for Axis 1 (cf. Fig. 12).

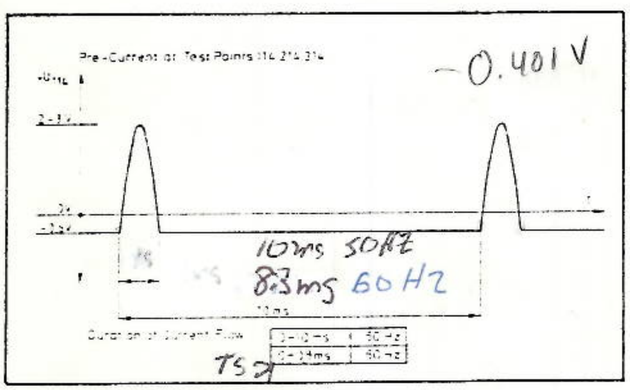


Fig. 12: Limiting Values for Adjustment of Pre-Current

1. Switch off control and load voltages (When using a common power transformer block the pulses for axis 2 and axis 3)
2. Put test point 103 to ground (0 V_M)
3. Connect oscilloscope between 0 V_M and test point 114
   Sweep Time/Div. : 2 ms/Div.
   Voltage Sensitivity/Div. : 1 V/Div.
4. Apply the control and power voltages
5. Release the controller and the pulses
6. The duration of current flow must be in agreement with the data given in Fig. 12; adjust eventually at trimming potentiometer 103.
7. Disconnect test point 103 from 0 V_M

Proceed in a similar manner for axis 2 and axis 3
Axis 2: Test Point 214, Trimming Potentiometer P 203
Axis 3: Test point 314, Trimming Potentiometer P 303

3.8 Adjustment of Dynamic Current Limit

Adjustment of Current Limit:

1. The current limit is factory-adjusted according to the axis-modul data. It is only then that adjustment is required, if the module data in position 7 are not in agreement when exchangig modules or if due to the application a different setting is desired.
2. Adjustment of limiting current can be performed according to diagram. (Fig. 13) It must not exceed the value indicated on the axis module which corresponds to double the average value of the rated motor current. For this purpose adjust the voltage at test point 104 (Axis 1), 204 (Axis 2), 304 (Axis 3) by means of trimming potentiometer P 104 (Axis 1), P 204 (Axis 2), P 304 (Axis 3).

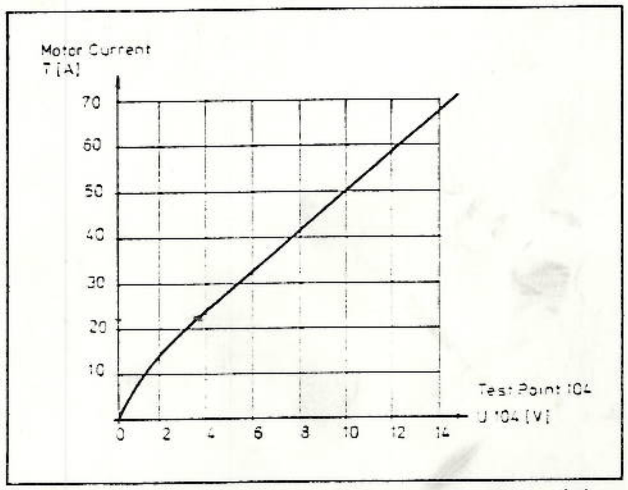


Fig. 13: Limiting Current of the Motor as a Function of the Voltage U 104

3.9 Start-and-Stop Operation of the Servo Drive

The start-and-stop operation, as it is required for the manual mode of operation for instance, requires a specific signal sequence for desired value, for the controller and pulse release, as well as for the braking signal. Figure 14 shows the chronological sequence of the individual functions and signals. The relationships shown will result, provided the control and power voltages are switched on.

The short-time operation against the brake prevents the descending of the slide in the case of axes with suspended loads.

3.10 Interconnection with the Numerical Control

Performance:

The interaction of numerical control, feed drive and of the machine with its position transducer is shown in Fig. 15. On principle two control loops are different, and that is the position-control loop (provided by the desired-position value w and the actual-position value x) on the one hand and the speed-control loop on the other hand (provided by the desired-speed value $v_{desired}$ and the actual-speed value v_{actual}) The numerical control forms the difference x_w (in the position control loop) between the desired-position value w and the momentary actual-position value x. The position deviation x_w multiplied by the K_v-factor results in the desired value $v_{desired}$ for the subordinated speed-control loop and thus causes a motion by means of which the actual-position value x approaches again the desired-position value w. When the slide approaches the desired position the value w - x = x_w becomes smaller and smaller, the slide speed decreases more and more and comes to a standstill for w - x = 0.

3.10.1 Defining the Sense of Control

Basically it must be started from, that the voltage polarity issued by the NC for positive traverse direction must in fact move the machine axis in positive direction with respect to the coordinates of the machine.

Apply this voltage polarity by means of a battery supply to the desired-value input of the control amplifier, after disconnecting the NC-output (= desired-speed value $v_{desired}$). The machine slide must move in positive direction, otherwise change the polarity of armature and tacho generator.

Subsequently check whether the position control system makes a correction for a position deviation. For this purpose connect a DC-voltmeter to the NC-output which had been disconnected and apply a small positive desired-value voltage in order to move the slide.

The voltage at the NC-output of the position control system must become more **negative** in order to make a correction for the position deviation. Otherwise the polarity of the desired speed value must be changed.

Important:
In case servo drive accelerates out of control after closing the position-control loop, the polarity in the position control system will be wrong.

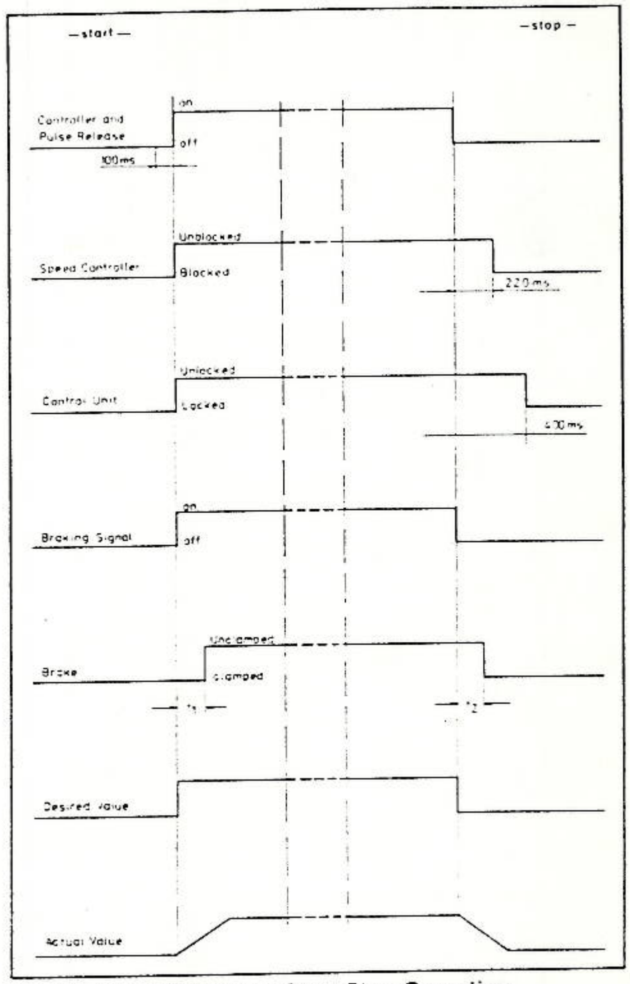


Fig. 14: Signal Sequence: Start-Stop-Operation

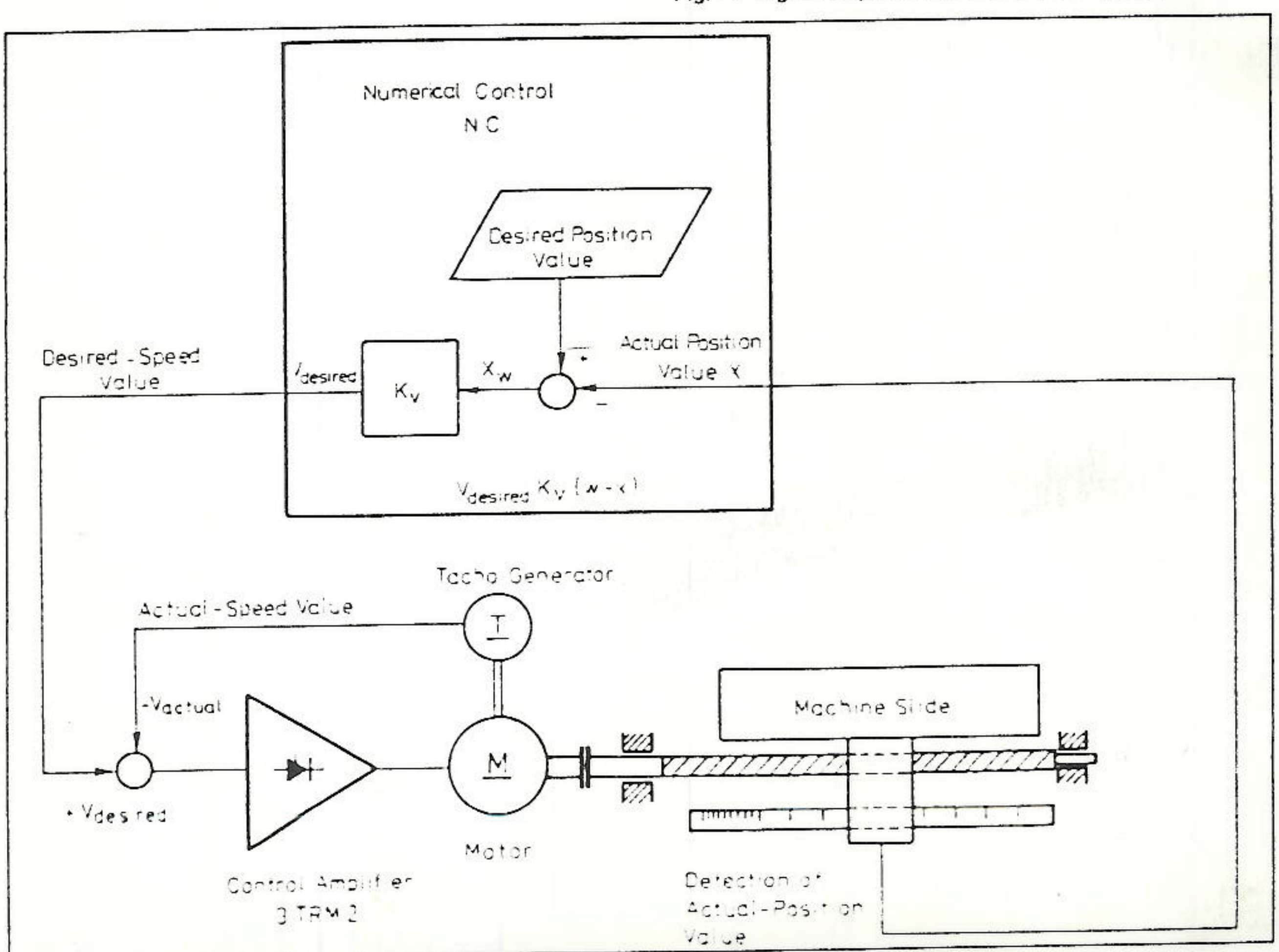


Fig. 15: Functional Diagram of the Position Control System

3.10.2 Harmonic Content of the Desired-Value Signal

The harmonic content of the DC-signal fed out by the numerical control for x_w must not exceed the following values, as a function of the frequency of these harmonics:

$$\boxed{U_{ss} = 0.01 \cdot f \cdot U \quad [V]} \tag{3}$$

U_{ss} = Peak-to-peak value of the superimposed AC, expressed in Volts.
f = Frequency of the harmonics, expressed in Hertz
U = Maximum value of the voltage fed out for x_w, expressed in Volts

In case the harmonic content is higher than the value indicated stability problems must be expected in the control system.

Smoothing, the signal by means of a filter is possible only within certain limits due to the delaying action of the filter in the control loop.

3.10.3 Desired-Value Voltage/Speed Ratio

The input resistor for the x_w-voltage of the numerical control in the control amplifier of the servo drive must always be dimensioned in such a way that the maximum slide speed is reached at 90 % of the maximum NC-output voltage. This measure ensures that the position control remains within the active range in case there are minor overshoots of the NC-output voltage.

Futher information about calculating the required input resistor are given in Chapter 2. 1. 2.

3.10.4 Gain of the Position-Control System – K_v-Factor

The voltage per unit of travel fed out by the numerical control for x_w and the voltage-speed relationship at the servo drive together determine the gain of the position-control system.

The ratio of slide speed v divided by the deviation x_w is understood to be the speed-gain and is called the K_v-factor.

$$\boxed{K_v = \frac{v}{x_w} \left[\frac{m/min}{mm}\right]} \tag{4}$$

v = Speed in m/min
x_w = Position deviation in mm

The slope of the straight line in Fig. 16 corresponds to this K_v-factor.

Proper gain of the position-control system is of utmost importance for the functioning of the system. Too high a gain causes detrimental accelerations, overshoots and instability. Too low a gain causes creeping into position and contour errors for the contouring control system. In the case of a linear gain characteristic the accelerations increase with increasing speed.

$$\boxed{a = v \cdot K_v \left[\frac{m}{s^2}\right]} \tag{5}$$

In order to bring about the proper gain for the position control system it is necessary to know the voltage fed out by the numerical control for x_w per mm of position deviation.

Futheron the maximum value of the voltage fed out must be known.

If generally no information is available about both these values, then these can be determined by means of measurements at the system.

For this purpose a DC-voltmeter is connected to the output of the NC. With the servo drive switched off desired-position values are fed in via the NC in increments of 1. 0 mm, starting with 1. 0 mm. (1; 2; 3; etc.) The position value entered and the voltage fed out by the NC are plotted on a system of coordinates.

If a numerical control system does not feed out a linearly increasing voltage as a function of the position deviation, but the slope of the voltage curve rather flattens with increasing position deviation, then this particular control system features a two gain characteristic. The explanations given for the linear gain characteristic apply in an analogous way for the individual slope sections.

The diagram in Fig. 16 shows the voltage output ususal for x_w of a numerical control system. Mostly 8 ... 12 V DC-output voltage are usal for a deviation of 12 ... 16 mm.

Usual speed-gain values are K_v = 1. 0 ... 2 in the feed range and 0.75 ... 1 in the rapid traverse range. Different gain values for the feed range and for the rapid traverse range are brought about by means of bent characteristics.

3.10.5 Slope, Two Gain Characteristic

Two procedures are usual in order to reach high gain values in the feed range and to avoid nevertheless detrimental accelerations in the rapid traverse range:

1. Slope

For this procedure the numerical control system provides up to the rapid traverse range a gain characteristic, measured in the prescribed way, which corresponds to the gain in the feed range.

During operation the control modifies the desired values above the feed range as a function of time so that excessive accelerations are avoided. When properly set the effect of a two gain characteristic is achieved. It is then that the slope is properly set, when the running-up and braking time for the rapid traverse rate amount to 180 ... 240 ms (this corresponds to K_v = 1,0 . . . 0.75)

2. Two Gain Characteristic

For this procedure the setting is adjusted in such a way that the gain values in both the speed ranges for feed and rapid traverse remain within the above mentioned limits.

The break point of the characteristic should be positioned at about 10 % above the feed range. (See Fig. 16).

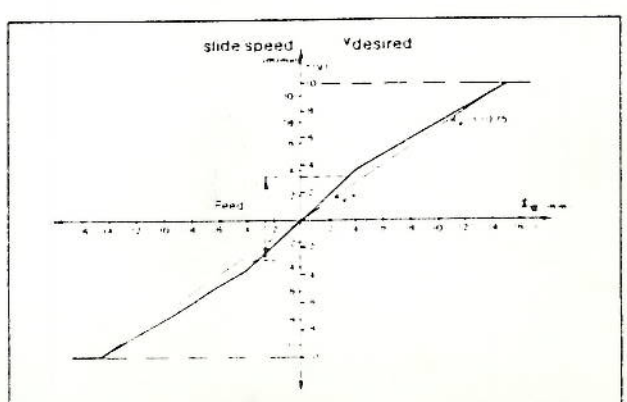


Fig. 16: Kv-Diagram

Type Code

Brief name

3	T	R	M	2	-G	1	1	-W	0/0	0	1/0	0	1/0	0	1/S	0	X	X	X

Number of axes
3 axes = 3

Thyristor Control Amplifier

Construction Type
Module Construction = M

Pulse number
2 pulses / Cycle = 2

Mode of operation
Rectifying operation = G

Series
U_{Aa} = 160 V = 1
U_{Aa} = 250 V = 2

Model
with power supply = 1
without power supply = 2

Type of installation
Wall-type = W

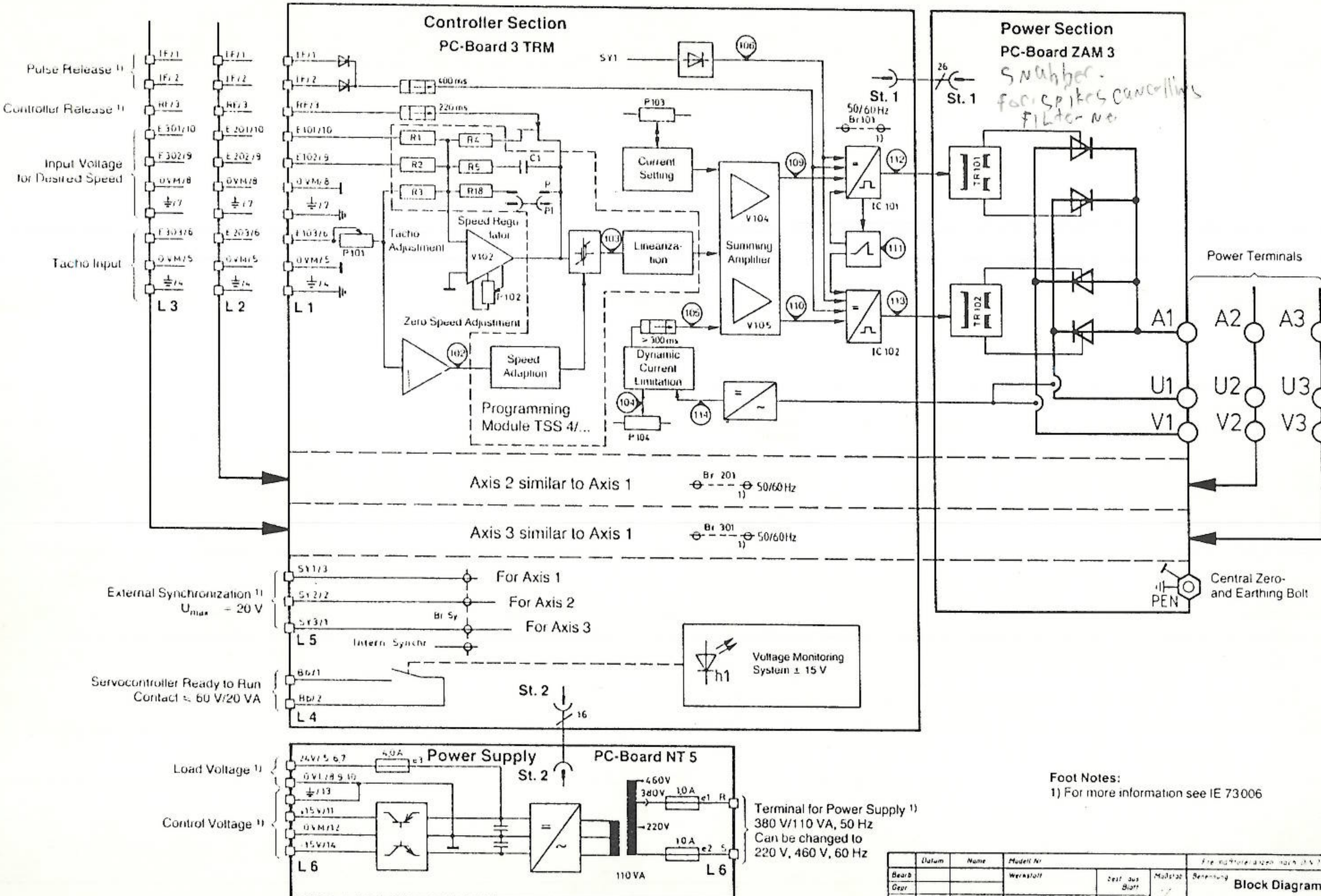
Type of cooling
Natural convection = 0

Adaption module TSS4 [1)]
Identifies the motor
the task and the exact model

- for axis 1
- for axis 2
- for axis 3

Special model [1)]
It is identical with the So
(special number) of the relevant
design list

1) The number is laid down by the manufacturer
If for any model the number is not known, the corresponding part of the code should be given in clear
The determination is effected at he initial construction



Foot Notes:
1) For more information see IE 73006

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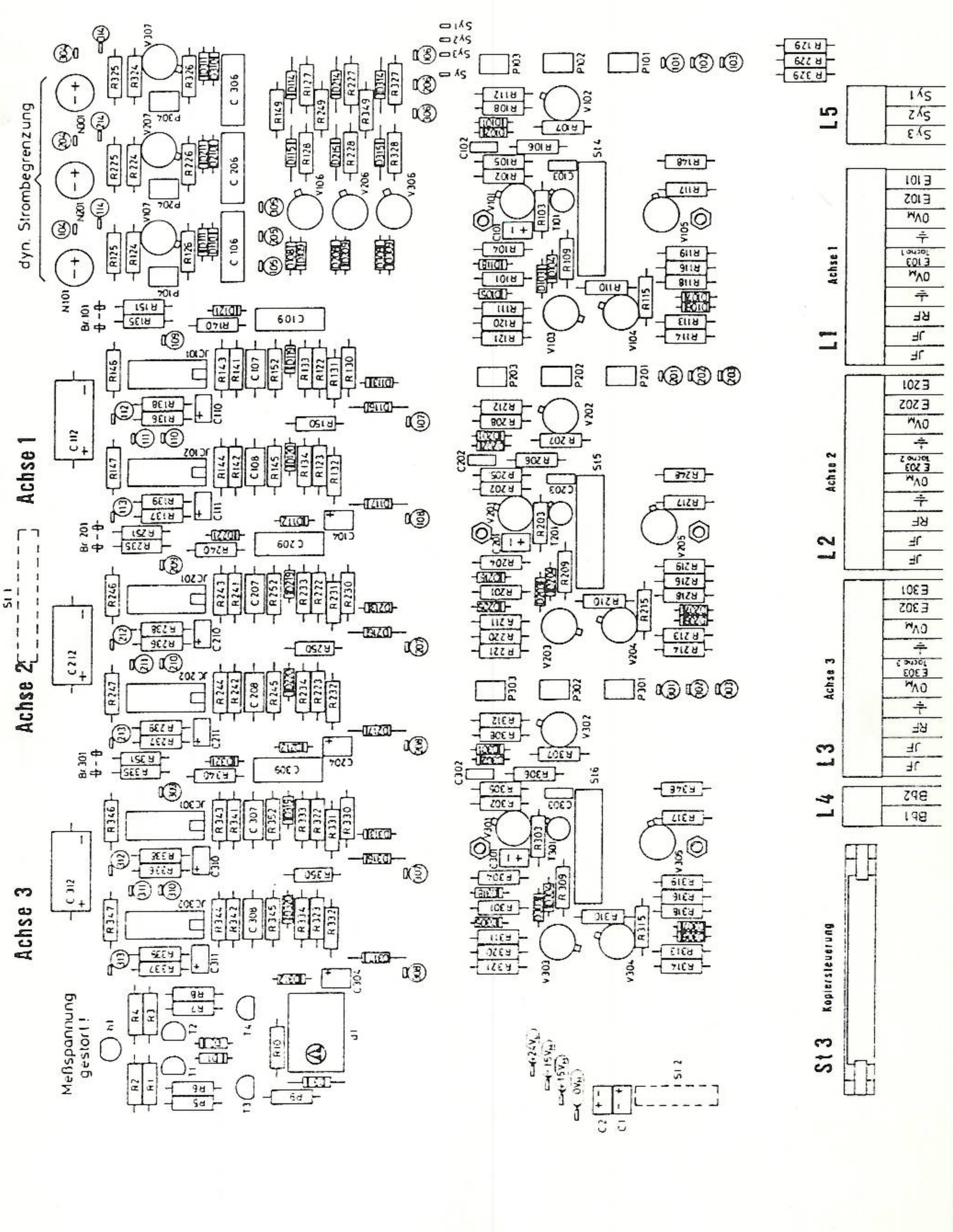
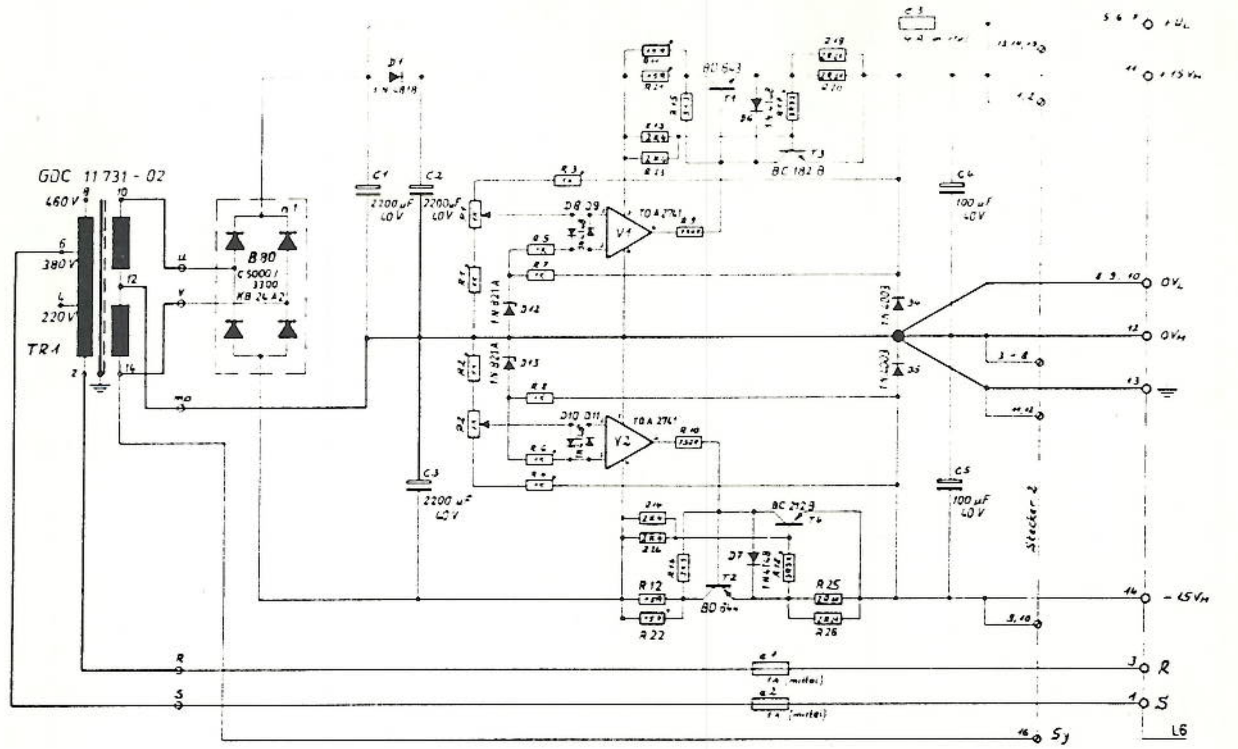
Block Diagram 3 TRM 2

Zeichg. Nr. 109 – 380 – 3603 – 0 E



3 TRM Component Layout

109 – 380 – 1901–5



Explanation of Connections

- ○ Terminal Board 1,5 mm²
- ⊘ Plug 2
- ⊖ Soldering Terminals

Power Supply NT 5
Circuit Diagram

Zeichng. Nr. 109 – 380 – 3402-3 E

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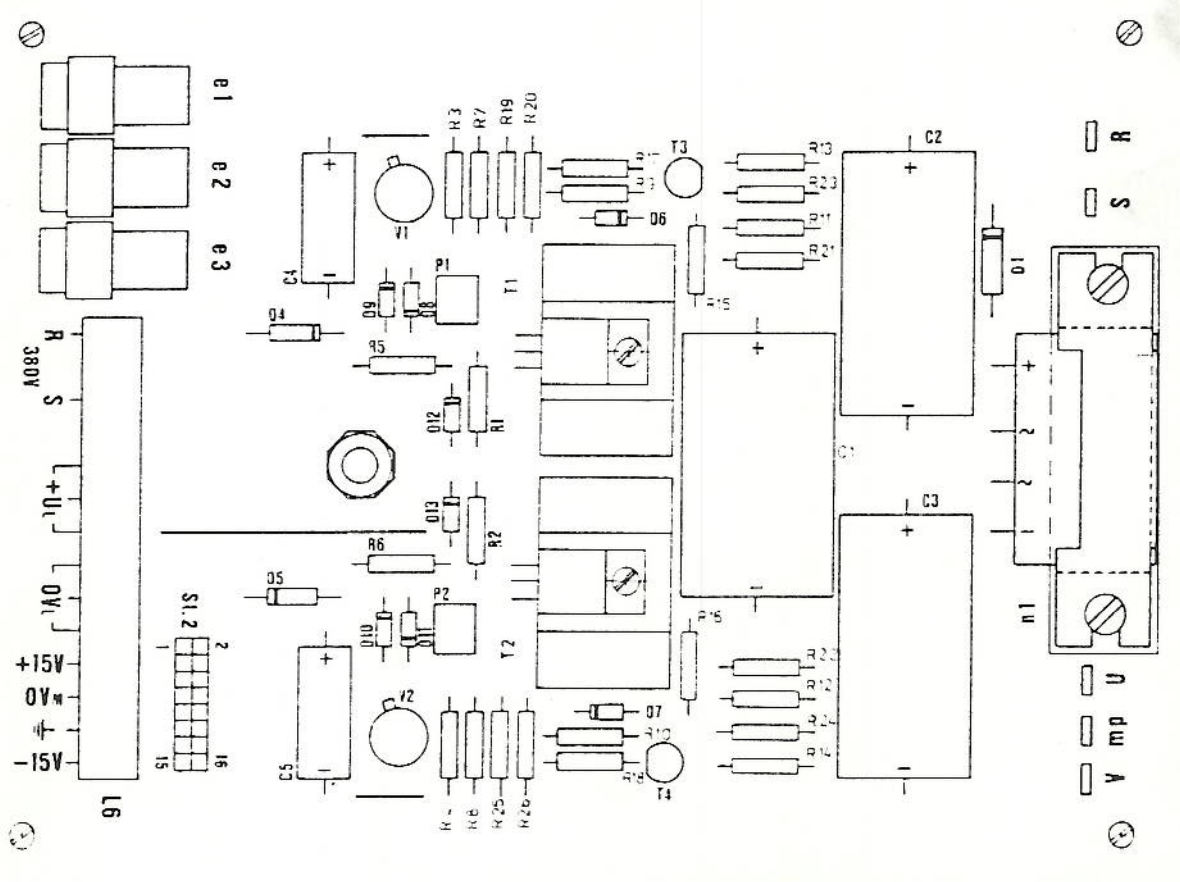
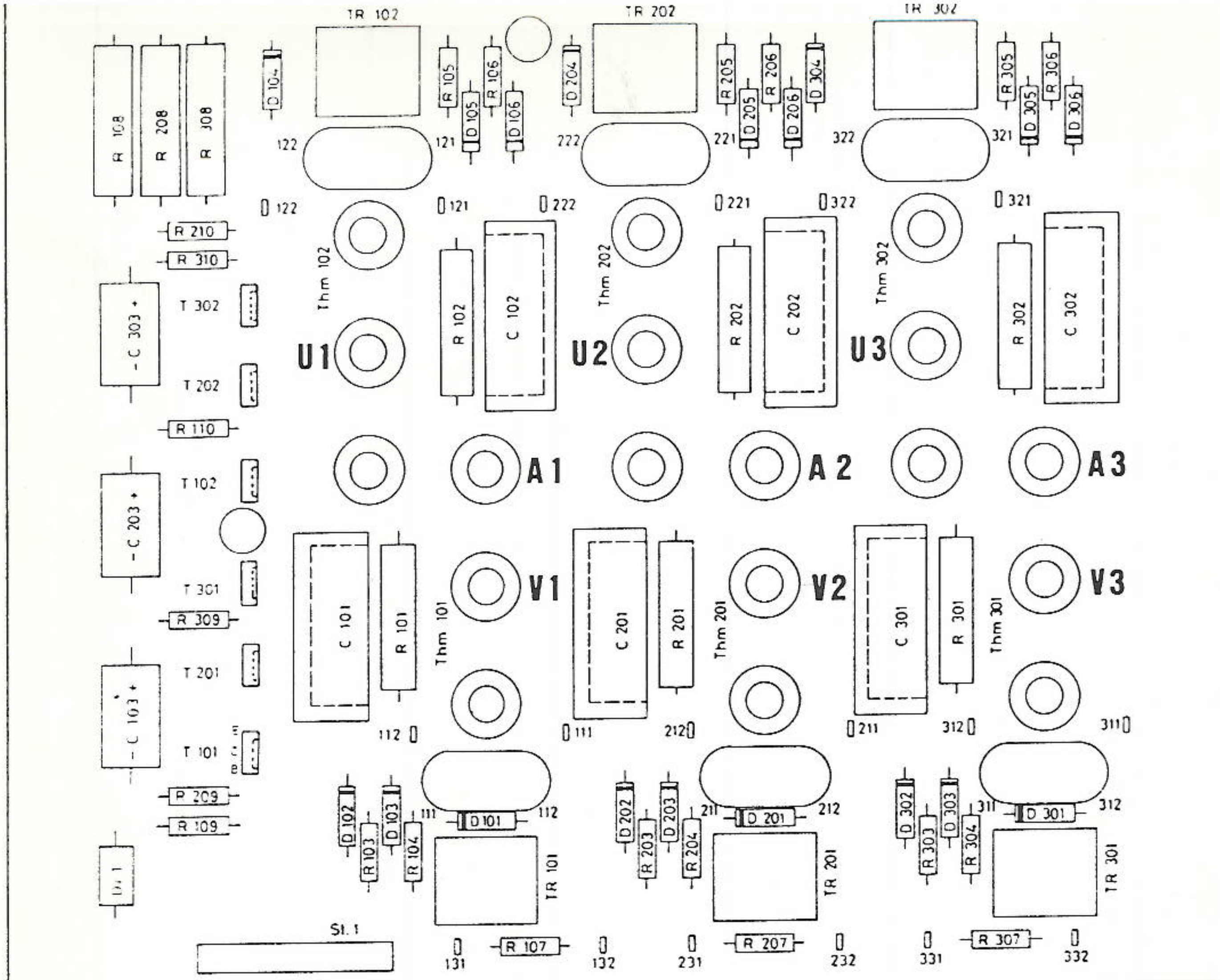
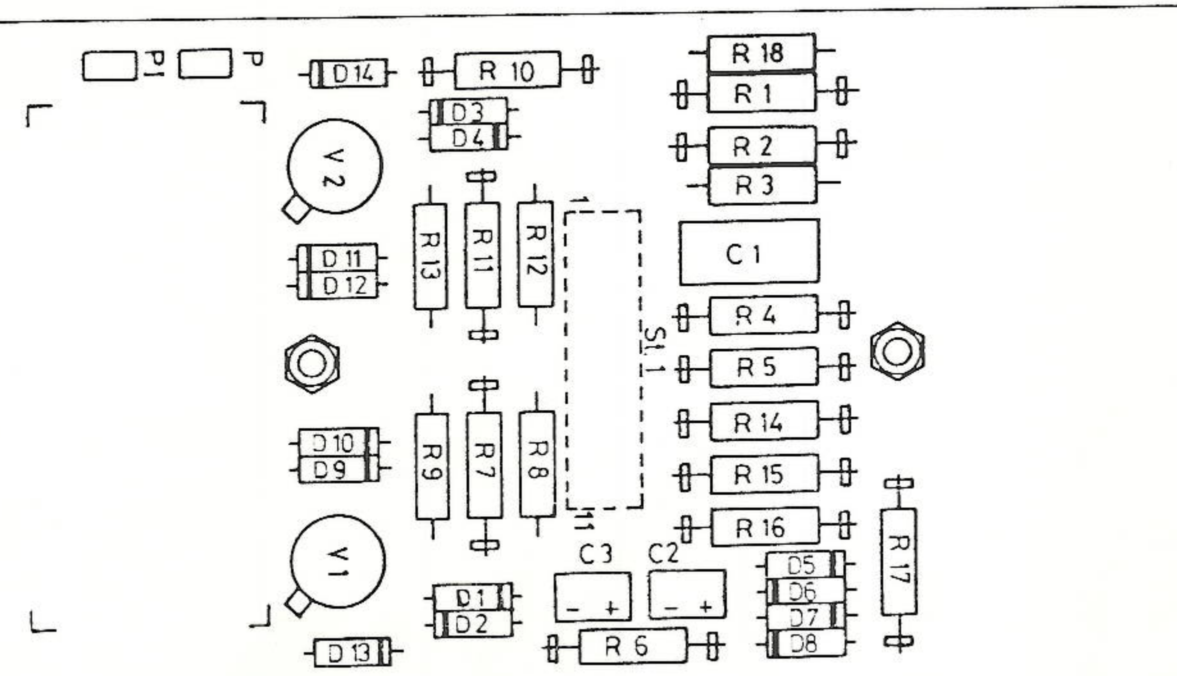


Component Layout NT 5

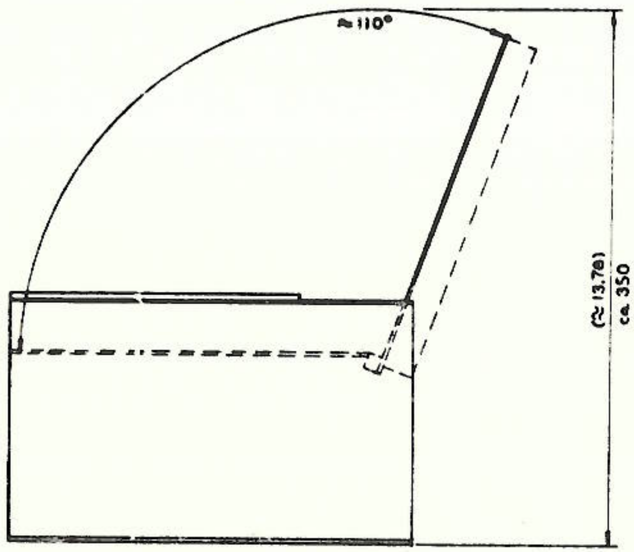
Zeichng. Nr. 109 – 380 – 2904-5

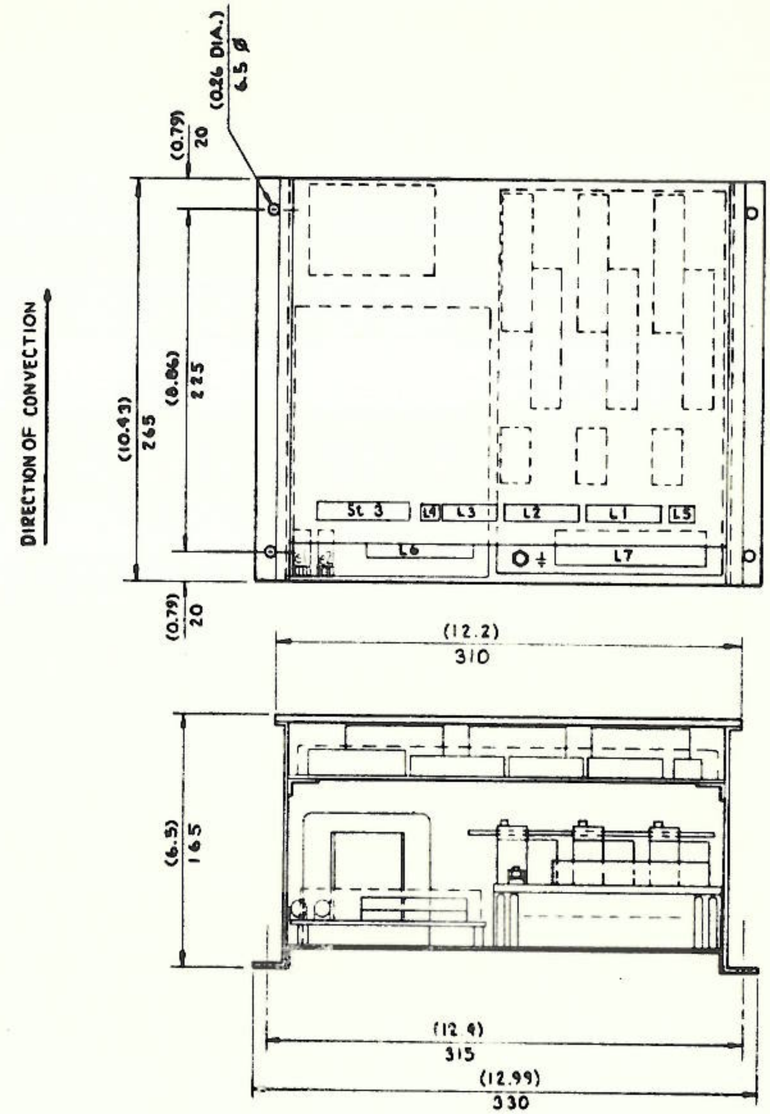


Datum	Name	Modell Nr			Freimaßtoleranzen nach DIN 7168
Bearb. 30.7		Werkstoff	best. aus Blatt	Maßstab	Benennung Component Layout ZAM 3
Gepr.		Fertigmaße	Blatt Nr	/	Zeichg. Nr. 109 – 380 – 2908–2
Norm					
INDRAMAT		Ers. für	d. Ä.-M		Ers. d. / d. Ä.-M



Bearb. 30.7		Werkstoff			Benennung Component Layout TSS4
		Fertigmaße			Zeichg. Nr. 109 – 380 – 4902–2
INDRAMAT		Ers. für			





NOTE: (INCHES) / m.m.

L1 CONTROL INPUTS AXIS 1
L2 CONTROL INPUTS AXIS 2
L3 CONTROL INPUTS AXIS 3
L4 READY FOR OPERATION CONTACT
L5 EXTERNAL SYNCHRONIZATION
L6 POWER SUPPLY TERMINALS
L7 POWER TERMINALS
St3 CONTROL INPUTS TRACER CONTROL

THE REXROTH CORPORATION INDRAMAT DIVISION 248 JAMES ST. BENSENVILLE, ILL. 60106	APPROVED BY DRAWN BY K. DATE 4-28-80 SCALE
OUTLINE DRAWING OF A STRM 2	
	DRAWING NUMBER CM-1007

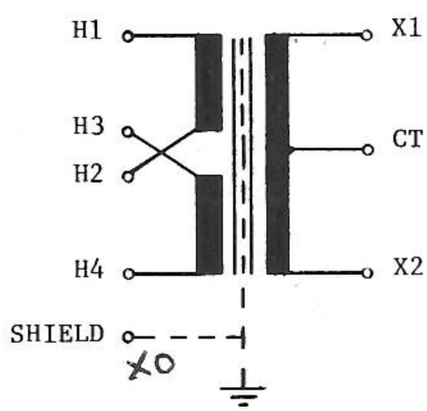
INDRAMAT
Motion Controls for Industry

800/415
3/21/80

TRANSFORMER SPECIFICATION SHEET FOR THE
TRK2 & 3TRM2 SINGLE-PHASE CONTROLLER

DESCRIPTION: Single Phase - 50/60 HZ
240/480 Vac Primary
Center tapped Secondary
4.5-5.5% Secondary Impedance
Core Ground

TYPICAL SCHEMATIC:



MOTOR TYPE	KVA RATING	SECONDARY VOLTS
MDC 10.10H	2.0	90 Volts Per Leg
MDC 10.20F	3.5	140 Volts Per Leg
MDC 10.30D	5.0	140 Volts Per Leg
MDC 10.40C	5.0	140 Volts Per Leg
MDC 3.10C	2.5	75 Volts Per Leg
MDC 3.20C	3.5	120 Volts Per Leg
MDC 3.30B	5.0	140 Volts Per Leg
MDC 3.40B	6.5	140 Volts Per Leg
MDC 8.00B	6.5	120 Volts Per Leg
MDC 8.10B	6.5	140 Volts Per Leg

THE ABOVE DATA IS FOR TYPICAL APPLICATIONS
AND IS SUBJECT TO CHANGE WITHOUT NOTICE.

INDRAMAT GmbH.
Partensteiner Straße 23
D-8770 Lohr a. Main

Postfach 505/506
☎ (09352) 18-40
Tx 689421/689402 (Service)

England:
G. L. Rexroth Ltd.
INDRAMAT Division
23 Castle Street, Cirencester
Gloucestershire, GL 7 1 QF
☎ 0285 - 68671
Tx 43565
B. Hedges

France:
Rexroth Sigma
Division INDRAMAT
136, Rue Perronet
F-92200 Neuilly s/Seine
☎ (1) 7452722
Tx 610694
P. A. Cotte

Sverige:
AB Zander & Ingeströrn
INDRAMAT Division
Box 12088
10223 Stockholm
☎ 08-809000
Tx 10074
V. Jha

España:
Goimendi S. A.
Jolastokieta (Herrera)
Apartado 1137
San Sebastian
☎ 943-393840
Tx 36172
S. Sebastian

Italia:
Rexroth S. p. A.
Divisione INDRAMAT
Via G. Di Vittorio
I-20063 Cernusco S/N
☎ (02) 90365-270
Tx 331695
Dot. ing. M. Tonini

USA:
Rexroth Corporation
INDRAMAT Division
248 James Street
Bensenville Illinois 60106
☎ 3128601010
Tx 206582
R. L. Rickert

Rexroth Corporation
INDRAMAT Division
6230 Cochran Road
Cleveland, Ohio 44139
☎ 2162489062
Tx 980258
R. B. Brennan

India:
Kirloskar Electric Co. Ltd.
Post Box No. 5555,
Malleswaram West,
Bangalore-560055
☎ 35311
Tx 0845-230 & 790
I. N. Mallikarjuna