TYPE 22-1000 THREE PHASE ADJUSTABLE SPEED DRIVE SYSTEMS

DESCRIPTION OF ELECTRICAL OPERATION

I. INTRODUCTION

Type 22-1000 three-phase systems provide a line of controlled-voltage drives for armature excitation of 240/500 volt dc machines from 5 HP to 150 HP. They require 230/460 volt, three phase 50/60 Hertz power and feature front accessibility, high package density, minimum number of adjustments, and NEMA I (drip proof) wall-mounted enclosures or panel-mounted. The system provides 150/300 volt dc field excitation throughout the full horsepower range, with optional Field Crossover for use where extended speed range is desired.

Other options available are Quick-Slowdown and Isolation Panel for isolation of Control and Power circuits.

II. SCOPE OF APPLICATION

The 22-1000 System is a full wave adjustable voltage armature control to be used with motors designed for use with full wave thyristor controls.

Since the System utilizes a semiconverter power circuit (i.e., one-half of the bridge is made up of diodes and one-half consists of silicon controlled rectifiers), single quadrant operation only (rectification) is possible. This means that the motor will coast to a stop when the reference is removed. Regeneration is generally required only when very fast, controlled deceleration is desired. When fast braking is required, dynamic braking is supplied as an option, of if greater control over deceleration is desired, Quick-Slowdown may be required, optionally.

The drive includes as standard a Torque (current) Limit potentiometer, which can be used separately or in conjunction with a Torque Taper (current limit taper) adjust potentiometer for use on winder applications where a constant horsepower characteristic is desired. Maximum and minimum speed limits can also be set via potentiometers in the control cabinets.

When jogging, threading, and/or linear, independently adjustable acceleration and deceleration are desired, accessory kits are available for modification. Anti-plugging is included on all reversing drives to protect motor and control.

Specifications and Ratings of above features are covered in a later section of this I.L.

III. ELECTRICAL DESCRIPTION

The 22-1000 3-Phase Adjustable Speed Drives consists of a 240/500 volt dc motor of the desired horsepower rating. Each Control System consists of a 3 phase, 22-1000 Thyristor Control and an operator's station.

The 22-1000 Thyristor Control, the heart of the system, contains the Controlled TPM Assembly and contactors, shunt, fuses (or breaker), and other optional equipment such as the Test Kit and Linear Accel-Decel. Kit., Quick Slowdown, Isolation Board and Field Crossover.

The Controlled TPM Assembly contains the semiconductor power devices (diodes and thyristors), the RC Suppression Board, and the Controller board, which contains all control circuits, the gate pulse generator circuit, and the gate pulse suppression circuits. Discussion of the Controller board operation is reserved to a later section.

The semiconductor power devices are mounted in heat sinks, which become the supporting structure for the Controlled TPM Assembly above. The power semiconducjtors are wired as in Figure 1 below. The circuit illustrated is that of a 3 phase semiconverter, whose output is variable dependent on the controlled gating applied to the thyristor gate G1, G2 and G3.

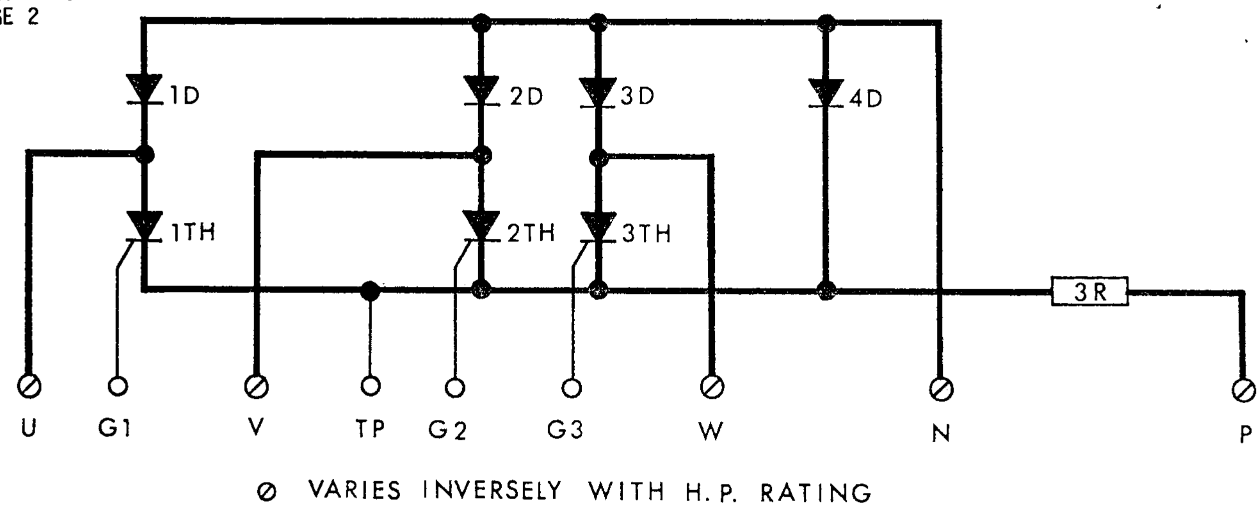


FIG. 1

The heavy lines signify power connections, whereas the light wires are low energy circuits. Consider for a moment that thyristors 1TH, 2TH and 3TH are replaced by power diodes. The familiar full wave rectified waveform of Figure 2 would result across the positive and negative bus terminals (P&N). This bus voltage from now on will referred to as v_b. If i_1 is defined as that current which always flows through the diode replacing 1TH, i_2 as that current flowing through the diode replacing 2TH and i_3 as that flowing through 3TH then currents i_1, i_2, and i_3 will appear as shown in Figure 2, assuming a resistive load.

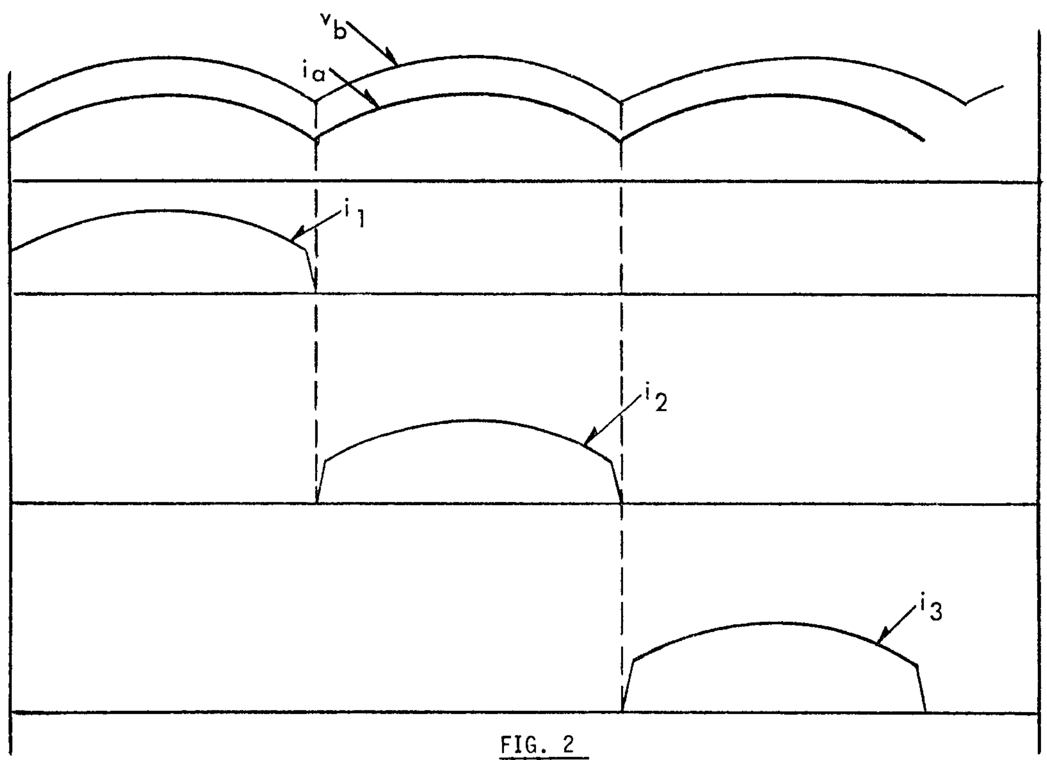


FIG. 2

The sums of currents i_1, i_2, and i_3 is equal to the total rectified current, i_a. A diode conducts in one direction only. In this respect a thyristor is equivalent. But a thyristor can be made to block current in both directions (both polarities), or it can be gated at various times during its positive half-cycle. In Figure 3 a sinewave generator, V_s, is shown connected to a thyristor and load, R_L.

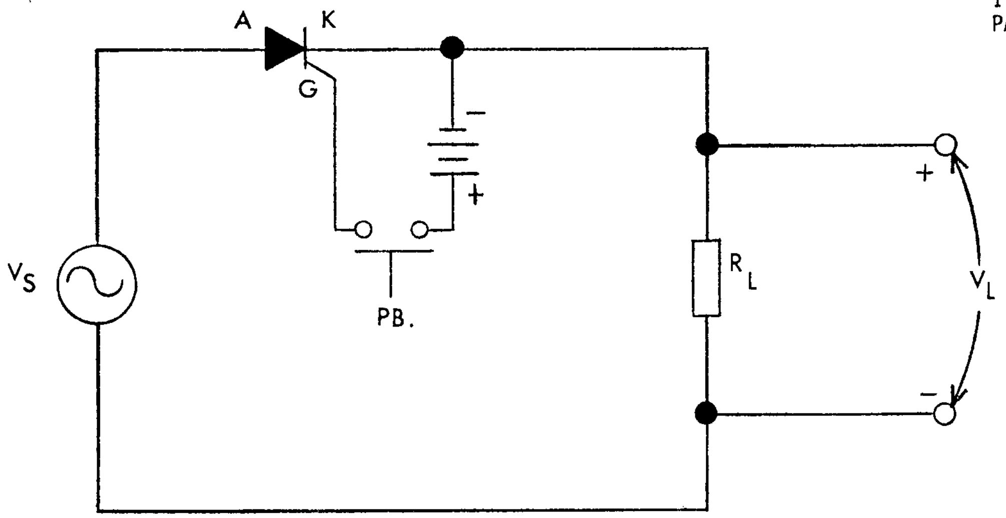


FIG. 3

The anode of the thyristor, (A) must be positive with respect to the cathode, K for conduction to take place. In addition pushbutton (PB) must be closed in order to gate the thyristor. In order for any conduction to take place the pushbutton must be activated sometime during the first (positive) half cycle of V_S. Once gated conduction will continue until current tries to reverse, which will occur when the sign wave of V_S first goes negative, even if the pushbutton is released.

Gating angles, signified as α (alpha), may vary between 0 and 180 degrees of the excitation voltage as shown in Figure 4.

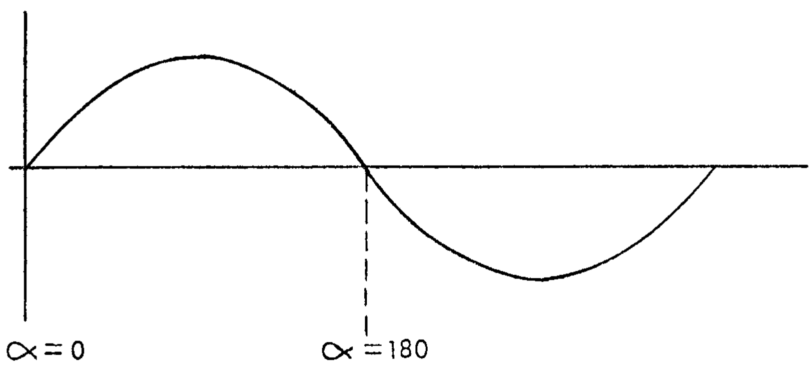
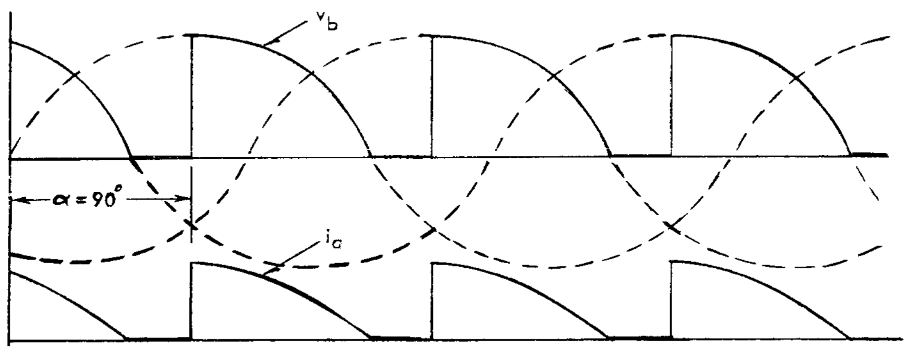


FIG. 4

The load voltage and current would appear as in Figure 5 if a gate pulse were released at $\alpha = 90^0$.

FIG.-5



If an inductive motor load were connected across terminals, P and N, in Figure 1, the armature voltage and current would appear as in Figure 6.

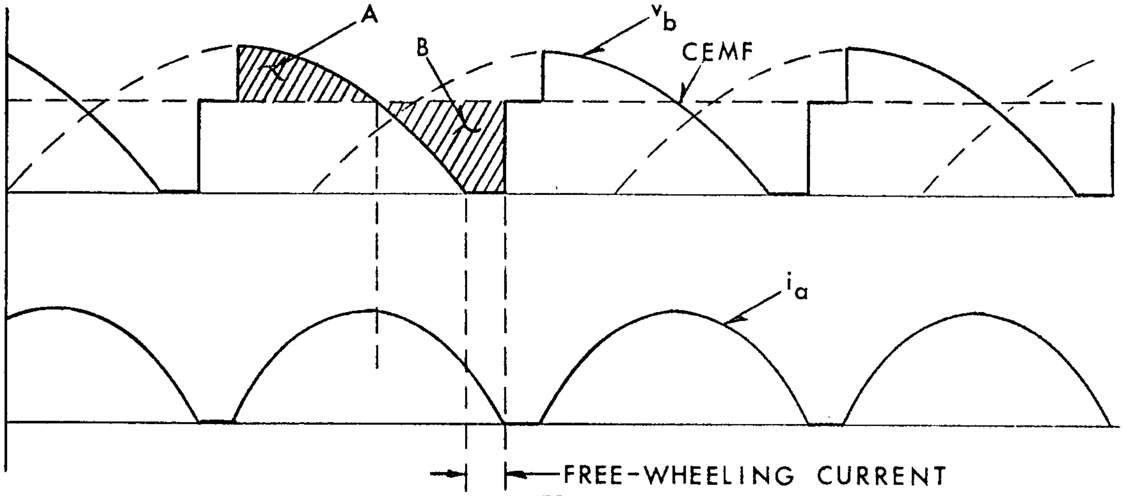


FIG. 6

Conservation of energy requires that areas A and B in Figure 6 be equal, if the resistive losses in the armature are neglected. Since these losses are usually 5% or less, this is a fair approximation. Whenever the current i_a goes to zero notice that the bus voltage v_b snaps up to the value of the motor CEMF. This is understandable, for when current ceases to flow in the TPM and motor armature, the motor is essentially disconnected from the TPM. It can only be reconnected after a gate pulse is sent to the thyristor. If continuous current were the case (i.e., the current never goes to zero) the bus voltage v_b WOULD never be shown equal to the CEMF of the motor for any length of time, and current and voltage waveshapes would appear as in Figure 7.

In a three phase control, however, the chances of observing discontinuous current (Figure 6) are very low. Usually, with a moderate load on the motor continuous current is the case, as shown in Figure 7. The ripple current is lower in a three-phase drive, because there are three applications of line voltage per cycle across the load rather than two. For a given motor, the form factor for any given gating angle is much lower for a three phase bridge than it is for a single phase bridge. Therefore, for any given motor and gating angle the 3-phase bridge exhibits current which has a lower ripple content than the single-phase bridge.

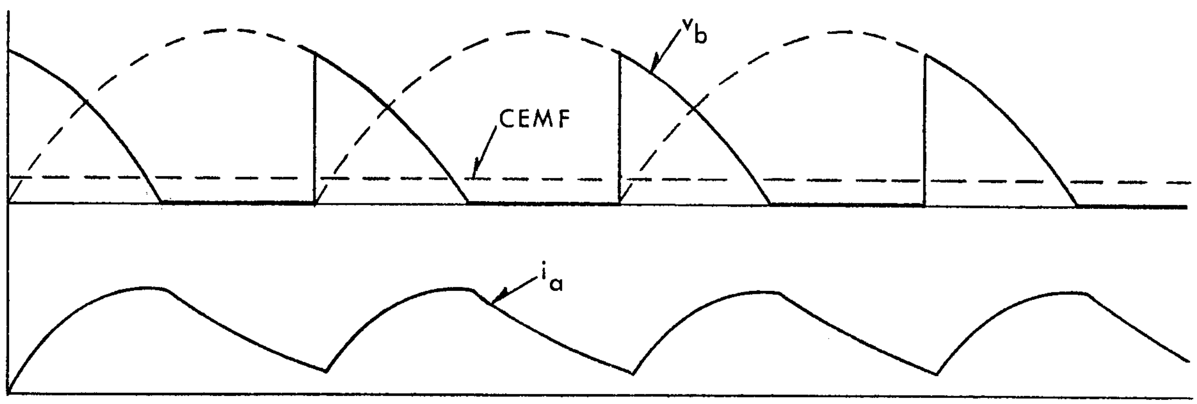


FIG. 7

The question might be posed --- "who cares whether the current is continuous or not?" The answer is Westinghouse cares. Ripple content is proportional to the form factor of the current waveshape. The form factor is defined as the ratio of RMS current to DC current. It is desirable to get the form factor as close to unity as possible, which is to say we would like to have the current as ripple-free as possible. The higher the form-factor of the system, the more power is burned up in the motor armature circuit, TPM. and power connections. When more power in the TPM is consumed, the thyristors and diodes run hotter and the TPM may need to be derated. Also, the efficiency of the system is less. In an attempt to supply more power per dollar to our customer, Westinghouse Motors are recommended, since these motors have fairly high inductances, low-form factors and will result in greater economy of operation.

The type 22-1000 Controlled TPM Assembly supplies half-wave-rectified power to the motor field via bridge diodes 1D and 2D. Diodes 1D and 2D carry both armature and field current as shown in Figure 1. R-C circuits designed to balance voltage between 1TH, 2TH and 3TH equally when they are not conducting are connected from phase to phase. A filter is also used to absorb voltage spikes on the bridge semiconductors. The above filter components are mounted on a separate PC board and jumpered to the Controller board to which the power semiconductors are connected.

The question may arise as to the purpose of the diode, 4D, placed across the armature. Diode 4D is called a freewheeling diode, and its use is necessary in all semiconverter circuits wherever discontinuous current cannot be guaranteed over the full range of gating angle (α). For example, in Figures 6 and 7 where the bus voltage waveform v_b reach zero volts (i.e., at $\alpha = 180^o$), the thyristor and diode last conducting, cease conducting and the stored energy in the motor armature inductance is shunted in the freewheeling diode. The current decays exponentially in the armature and the freewheel diode until it reaches zero, which can be observed in the bottom traces in Figures 6 and 7. If the freewheel diode were not in the circuit, and gate pulses were not to continue, as is the case when a reduction in motor speed is desired, current might half wave through the last conducting thyristor until a gate pulse is received by one of the other thyristors, a condition which may never occur. In some cases gate pulse suppression will occur because safe peak currents are exceeded. At other times, the motor will just continue to run at approximately half speed until the controller tells the motor to run faster and gate pulses are again received by the thyristors.

Resistor (3R) is a combination shunt which supplies current feedback ($-i_a$) to the controller board. Depending on horsepower, various portions of the shunt are utilized so as to always feedback approximately 0.5 volts for 100% rated armature current. When isolation is desired the shunt is replaced by the appropriate transductor assembly, but burden resistors are still chosen to procuce 0.5 volts. for rated motor current.

Type 22-1000 Controller and Gate - The Controller printed circuit board provides all of the dynamic control functions necessary for regulating the TPM. The Controller provides filtered ± 24 VDC power and zener regulated DC power for all Controller and gating functions. In addition, a ± 15 volt regulated power supply is used for references, both on the Controller Board and off the board for feeding reference circuits on the Field Crossover Board when this option is used. This supply should not be used for additional auxiliary circuits.

If the Ramp Function Generator is added as an option, power for it is provided by the Controller via push-on lance terminals and jumpers. In discussing the Controller it is best to start with the innermost functional block in the control loop, namely, the Gate Pulse Generator (G.P.G.). The G.P.G. is really a "sub-circuit" of the Controller board, but a very important one. In Figure 8, it is convenient to show the ±24 volt power supply as well as the G.P.G. Terminals (or points) marked "PSP" refer to + 24 volts, those marked "PSC" refer to "system ground" NOT EARTH GROUND unless the Isolator Board has been incorporated., and "PSN" refers to -24 volts.

The power is received through points "U", "V", and "W" which is applied to the primary windings of transformers 1T, 2T, and 3T, which are connected in delta-star. The use of 3-single phase transformers rather than 1-three phase transformers was preferred because of large cost savings of the power. The secondaries of the transformers are fed to a 6-phase-bridge rectifier made up of diodes 29D through 34D and 3D through 6D. These very same secondaries supply reference timing waves to the input of the gate-pulse-generator circuit (upper half of Figure 8).

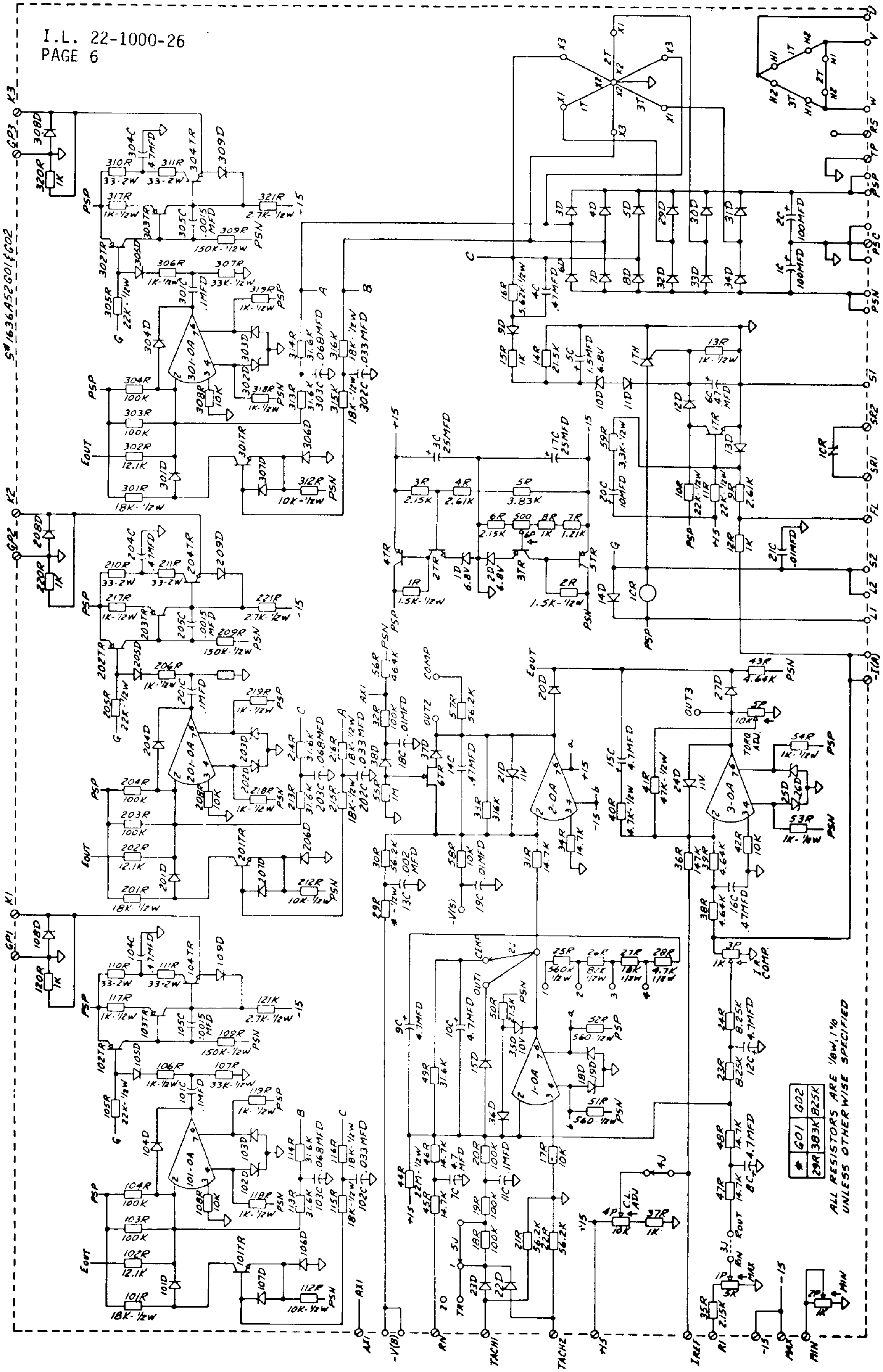


FIG. 8

Gate Pulse Generator (Subcircuit)

A glance at Figure 8 will show 3 identical circuits comprising the G.P.G. Only one will be described since the other two function identically. The timing reference from X3 of transformer 2T is fed to a 30^{o} delay filter comprising resistors 113R, 114R and capacitor, 103C. Since it is necessary to have close tracking of the 3 pulses, this capacitor has a tolerance of ±1%. For convenience, a simplified diagram of Figure 1 is shown repeated in Figure 9.

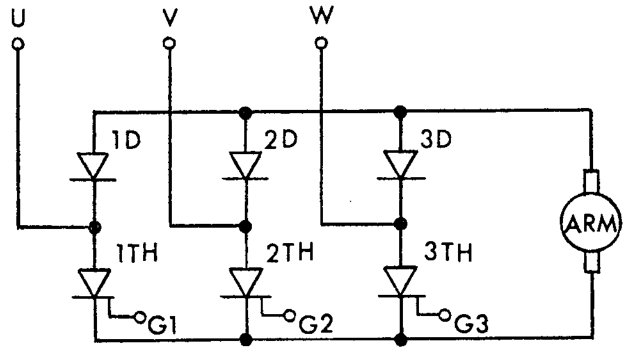


FIG. 9

Since, it is necessary to understand the power commutation process before one can understand gating requirements, a discussion of power commutation process follows. Figure 10 shows the sequence of the excitation voltage (U, V, W) and the corresponding sequence of pulses. Inside the rectangular boxes are the devices which are in conduction at each moment.

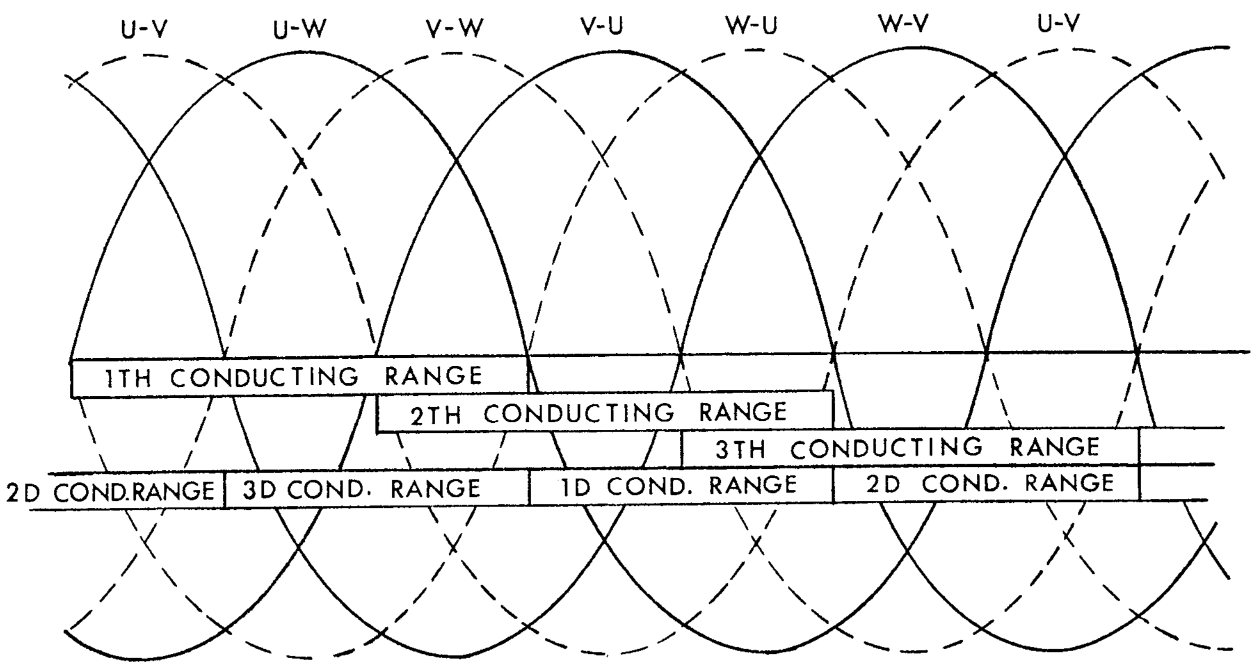


FIG. 10

Though the thyristor conduction periods are shown to overlap, in practice this is not the case. Only 120 degrees conduction is possible. The overlapping was necessary to show the range of possibilities of conduction. For example, 1TH can be gated anytime that the wave U-W is positive. One third of a cycle later (120 deg.) 2TH is gated and any current remaining in 1TH is now commutated to 2TH. It is quite possible for the thyristors and diodes to conduct less than 120 degrees, because the freewheeling diode commutates the current from 3D rather than allowing 1D to do the job.

Since 1TH can be fired only during the time that the voltage (U-W) is positive, we want to use the voltage (U-W) as a reference wave to time pulse #1 (GP1) from the G.P.G. Likewise wave (V-U) becomes a reference wave for GP2, and wave (W-V) is the reference wave for GP3.

Ideally a linear relationship is desired between the input to the GPG (i.e., E_{out} from the operational amplifier circuit) and the Output of the thyristor rectifier. To generate this relationship a Cosine wave must be generated. The gate pulse is timed by shifting the level of the cosine wave with respect to PSC. When the cosine wave crosses zero volts (PSC) in the negative going direction, a pulse is released to the proper thyristor. Figure 11 shows the reference (excitation voltage) voltage (U-W) and the cosine wave biased to gate at α = 180 degrees.

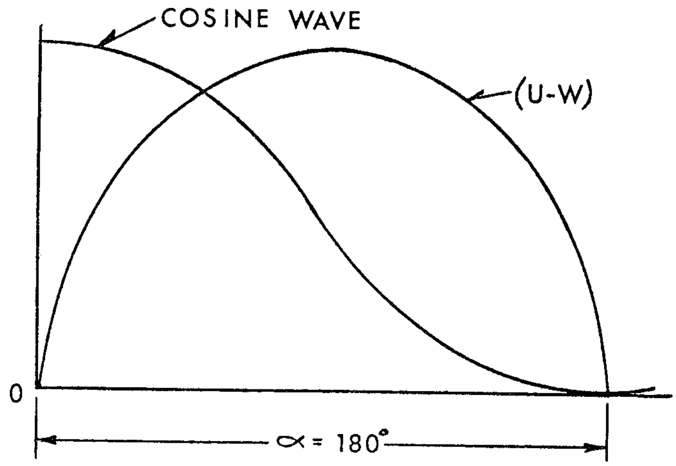


FIG. 11

FIG. 11

The cosine wave, generated by the transformer, 2T, and the input filter on the G.P.G. must be shifted up 5V. as shown in Figure 11 when no voltage is present at E_{out} (See Figure 8). The parallel combination of 103R and 104R performs this function. The voltage, E_{out}, has the limits: -10 volts $\leq E_{out} \leq 0$ volts. When E_{out} is zero Figure 11 results. When E_{out} is -10 volts, it is desirable to approach a gating angle (α) of 0 degrees. This means that the peak-to-peak voltage of the cosine wave should be approximately 10 volts (i.e., equal to the maximum range of E_{out}. The same filter used to shift the 120 degree signal from 2T back 30 degrees also was used to attentuate the 50 volt peak-to-peak signal to 10 volts peak-to-peak. In actual practice it is desirable to limit the advancement of the gating angle (2) to approximately 10 - 12 degrees. One can insure by so doing that gate pulses never disappear, as might be the case if no advance limit were used. The advance limit is accomplished in Figure 8 taking the timing wave from transformer 3T, X3 filtering it with a 12 degree filter 115R, 116R and 102C, and applying this signal to the base of transistor 101-TR. Whenever this delayed timing wave is positive a gate pulse may be released, but a pulse may not be released whenever the timing wave is negative.

The OP-Amp summing junction (101-OA) the cosine wave through 113R, the shifting bias through 103R and 104R, and E_{out} through 102R. It also sums the signal from the collector of 101-TR if this signal is positive enough to forward bias diode 101D. Whenever the net current summed by Amplifier 101-OA is negative, 101-OA's output goes to positive saturation. This signal is in turn, differentiated by capacitor 101C. The resulting sawtooth of duration 1.5 to 2.0 vs. turns off transistor 102TR by forcing its base drive off. This allows the collector of 101TR to drag which in turn allows 103TR to conduct current into the base of 104TR, which supplies gate current to thyristor 1TH of the T.P.M. Diode 108D allows the primary of the pulse transformers (when used) to freewheel current and prevents large negative voltages from being fed to the emitter of 104TR. Capacitor 104C differentiates the leading edge of the gate pulse to insure hard firing of the thyristors.

Gate Pulse Suppression is also a subcircuit of the Controller board. Its operation is based on the tripping of a thyristor (1TH) which pulls the common line connecting 105R, 205R, and 305R to near zero volts. This causes transistors 102TR, 202TR, and 302TR to turn on hard, which blocks further gating.

The thyristor is tripped (or made conductive) only when the instantaneous armature current becomes greater than 400 per cent of rated motor current. Coupled to the gate-pulse-suppression subcircuit is a phase-sequence protection and detection circuit. The voltages on the secondary terminals (X3) of transformers 2T and 3T are fed to an RC network made up of capacitor 4C and resistor 16R which is sensitive to phase rotation. If phase rotation is correct, the voltage built up across capacitor 5C and zener diode 10D is less than the zener's breakdown voltage and no signal is seen at the gate of thyristor, 1TH. If phase rotation is incorrect, or if any of the phases is missing, the voltage will be high enough to break down the zener diode 10D and gate the thyristor, 1TH. Whenever the thyristor is gated (i.e., when gate pulse suppression is activated), the voltage across the coil of relay 1CR and the gate pulse suppression lamp becomes equal to 24 volts, which lights the lamp and picks up the relay. Whenever the relay is picked up, the dc contactors are dropped out and the reference is removed. Complete restarting procedure is then necessary after the cause for gate pulse suppressing has been found, corrected, and the gate pulse reset pushbutton is depressed. Before it was mentioned that this cosine wave was necessary to produce a linear relationship between E_{out} and bus voltage (V_b). The derviation of this relationship follows:

Let E_{out} = peak voltage output of operational amplifier section (i.e., -10 volts).

e_{out} = actual output voltage of operational amplifier circuit.

α = gating angle. (0 to 180 degrees).

V_b = peak bus voltage available.

v_b = bus voltage for a particular gating angle (α).

Then $$\cos(\alpha) = \frac{2e_{out}}{E_{out}} - 1 \qquad \text{I}$$

Since the bus voltage (v_b) relates to α as follows.

$$v_b = V_b \frac{(1 + \cos\ )}{2} \qquad \text{II}$$

Solving for v_b as a function of e_{out}, equation I needs to be solved for α:

$$\alpha = \cos^{-1}\left[\frac{2e_{out}}{E_{out}} - 1\right] \qquad \text{III}$$

Substituting for α above in equation II

$$v_b = \frac{V_b\left[1 + \cos\left\{\cos^{-1}\left(\frac{2e_{out}}{E_{out}} - 1\right)\right\}\right]}{2} \qquad \text{IV}$$

Simplifying eg. IV above:

$$v_b = \left(\frac{V_b}{E_{out}}\right) e_{out}$$

Let $\frac{V_b}{E_{out}}$ = K = gain of the gate pulse generator

Then

$v_b = K \cdot e_{out}$ (i.e., the linear relationship)

OPERATIONAL AMPLIFIER SUBCIRCUITS

In addition to the gate-pulse-generator, power supply, and gate pulse suppression subcircuits, there are three operational amplifier subcircuits of the Controller Board (See Figure 12). Amplifier (1-0A) is associated with the input reference circuit, which is made up of resistors, 35R, 47R, 48R and Pot 1P, 2P which comprise the standard reference circuit. The Operator's Speed pot connects to terminals MAX, R1, and MIN of this circuit. Jumper 3J is replaced by the Ramp Function Generator when this function is desired. Resistors 45R, 48R provide an auxiliary input which is used for the Jog reference when desired. Resistors (8R through 22R, capacitor 11C and 23D and 22D comprise the Tach Feedback circuit. Resistors 23R, 24R and capacitor 12C feedback a portion of the current feedback signal as adjusted by the "IR Compensation" pot, 3P. Diodes 15D, 35D and 36D limit the output of 1-0A to +10.5 volts and -.5 volts, when jumper 2J is tied to "CEMF", the regulator is operated as a gain of one amplifier with a first order lag at 150 ms. When tied to pins 1 through 4 amplifier 1-0A becomes a Speed Controller, with positions 1 and 2 being used for high inertias and positions 3 and 4 being used for low inertia loads (see Specifications and Ratings). Capacitor 9C is on stub terminals in the event that it must be changed to allow an even wider range of gain and lead time constants if necessary.

The output of the Speed or Reference Controller feeds the Voltage Controller 2-0A through 31R where it is summed with the voltage feedback from terminal ($-v_b$) through 29R and 30R. On isolated drives where voltage feedback comes from the voltage sensor through terminal ($-V_S$), feedback to pin $-v_b$ must be removed. Resistor 33R and capacitor 14C provide a voltage loop crossovaer of approximately 200 radians. Diode 21D limits output voltage to +0.5 and -11 volts. The remaining components 6TR,37D, 38D, 55R, 56R, 32R, 57R, and 13C are used with the Quick Slowdown circuit to be discussed later.

The reference means to the Current Controller, 3-0A is comprised of the +15 volt regulated supply, Pot 4P (Current Limit Adjust Pot), 36R and 37R. The feedback comes from the shunt or Isolation board burden resistors to the ($-i_a$) terminal where it is summed with the reference signal through 38R and 39R at 3-0A's summing junction. Rate feedback on the Current Controller is provided by 40R and 15C. D. C. negative feedback provided by 41R and Pot 5P provides the function of **TAPERED** Current Limit, a property useful on winder drives or other constant horsepower applications.

The outputs of the Current and Voltage Controllers are or'd through diodes 20D and 27D, the least negative are becoming the signal, E_{out}, which is fed to the gate pulse generator circuit. The more negative of the two switches into negative limits of (-10 volts). While a controller output is in negative limit it is said to be "out of control", and has no effect upon the bus voltage in any way. When two amplifiers are connected as above, they are said to be connected in parallel, and are referred to as parallel regulators. Such systems can be adjusted to give faster response than multi-loop systems. Because switching between two or more regulators is possible with a parallel regulator system, two different modes of operation are possible. In the 22-1000, 3-phase system the two modes of operation are voltage and current.

REGULATOR ADJUSTMENTS

The minimum and maximum speed adjust pots, briefly mentioned before, are used to set maximum and minimum speed points. The range of adjustment of the speed potentiometer in the operator's station can be adjusted with these pots. Armature resistance drop compensation can be adjusted through use of "I R COMP." potentiometer 3P. An adjustment for limiting the armature current is available called the "Current Limit Adjust" potentiometer 4P in Figure 12. Adjustment of Armature Current is available over the range of 10% to 150% of rated armature current. In addition to adjustment of Current Limit available through 4P, one may remove jumper 4J and adjust current-limit through use of a follow signal entering at the stab terminal connected to resistor 36R. Applications requiring this might be on tension controls. The "Torque Adjust" potentiometer 5P adjusts the amount of negative feedback applied to the Current-Controller. The effect is to reduce the amount of current-limit reference entering the summing function of 3-0A, which is to say the current-limit is lowered as the output of 3-0A increases. The result is a sloped current-limit characteristic as shown in Figure 13.

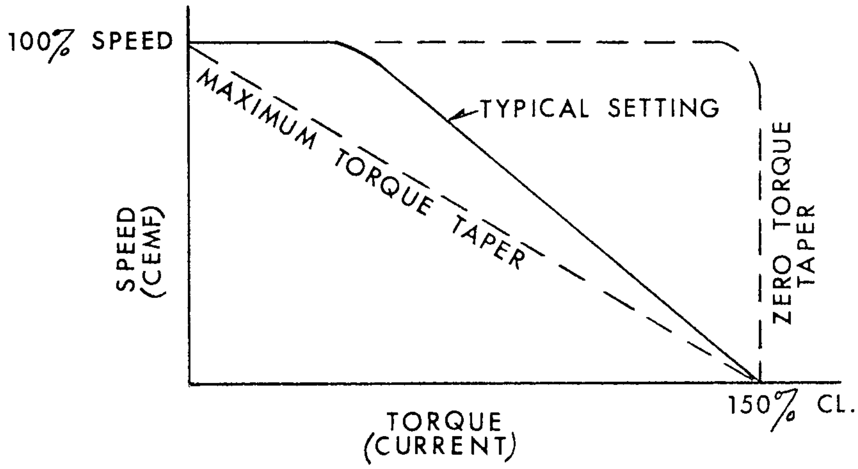


FIG. 13

MAGNETIC LOGIC AND POWER CIRCUITS

Each drive is equipped with a 9-relay logic board, which controls the operation of the dc contactors used for disconnecting the power supply from the motor, dynamic braking and for switching armature leads on REVERSING drives. The contactor in conjunction with the relays on the logic board protect the power supply against high current surges (i.e., plugging when reversing the drive), drop out when the line voltage dips too low for longer than couple of hundreds of a second, and drop out when either the motor is overloaded, gate-pulse suppression is activated due to overcurrents greater than 200% rated current, single-phasing or incorrect phase-rotation.

Logic providing all options is shown on Figure 14 with 9-Relay Logic. The 9-Relay automatic reversing is provided (i.e., by switching the switch, 2 SW, back and forth, the logic cycles the drive automatically). The switch could be replaced by limit switches to perform the same function. A separate potentiometer provides independent adjustment of jog speed. A thread pushbutton and relay, "THRD", and "TH", respectively allow the drive to run at the speed set by the "Min". speed pot on the Controller Board. Pushing the run, "RN", pushbutton automatically sets the drive running at the speed set on the operator's station. Two antiplugging relays provide antiplugging (forward and reverse) and dynamic braking functions and the O. L. relay and G.P.S. relay act to sequence the drive to stop. By adding jumpers 1J and 2J the Ramp Function Generator may be used to provide constant-rate-acceleration and deceleration. See chart Figure 14.

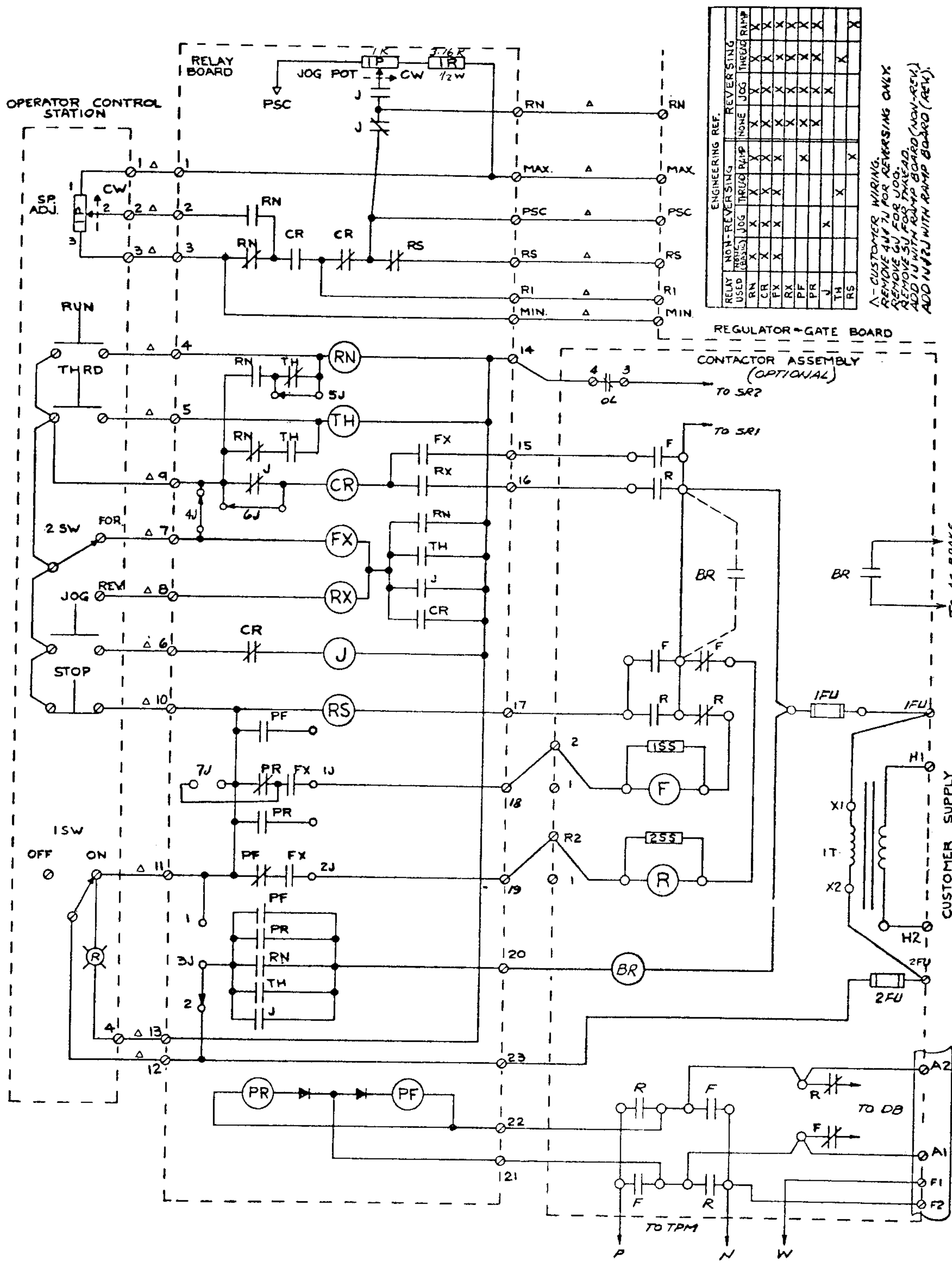
An AC-Mechanical Brake "BR" relay can be provided which allows the drive to be held in place after coming to a stop due to dynamic braking, depending on the location of jumper, 3J. With the jumper in position (2) as shown, the brake will lock onto the motor shaft whenever the motor is at rest, or very near to rest, since PF or PR drop out with about 10 or 11 volts on the armature (of a 240 volt machine). In position (1), if switch 1SW, is switched "off", the mechanical brake will lock in immediately, 1SW acting as an "emergency stop".

OPTIONAL ACCESSORIES

Jog Kit - Consisting of a plug-in relay and a pushbuton and contact block, modifies the system for jogging operation. A speed pot, which adjusts jog speed independently of other speed adjustments, is located on the "9R-Relay board".

Linear Accel-Decel. Kit - This kit consists of 2 relays, 9 jumpers, and appropriate hardware and instructions. This kit allows separately adjustable linear speed ramping rates from 2 seconds to 40 seconds.

Thread Kit - Allows running at the minimum speed setting by simply pushing the "Thread" pushbutton. Returning to run speed is accomplished by pushign the "Run" pushbutton. At anytime one may drop back to thread speed by just pushing the "thread" button again. The "Thread Kit" includes a plug-in relay (relay "THD"), pushbutton and contact block and appropriate instructions.



9 RELAY LOGIC BOARD

FIG. 14

A. C. Brake Kit - Allows the application of a mechanical brake to hold the motor shaft after the shaft has come to rest through dynamic braking. By flipping the "on-off" switch to "off", the brake will engage either immediately, or upon stopping after dynamic braking, depending upon the position of jumper 3J on the relay logic board. The kit includes a "BF" type relay, a plug-in octal pin dc relay (PF), fast-on terminals and other hardware and instructions for mounting. If a 22-1000 Accel-decel. kit has been ordered, the dc octal pin plug-in relay is not necessary, since it is included in the Accel-decel. kit.

Dynamic Braking Kit - is added when quick stopping of the motor is required (i.e., not coasting). Be sure that the proper Dynamic Braking Kit is used, the kits are horsepower rated (i.e., by group number) and should match the motor horsepower rating. Instructions for mounting and wiring are included in each kit. When Quick Slowdown is required, different dynamic braking resistors are generally used. See section on Quick Slowdown.

IV. SPECIFICATIONS AND RATINGS (BASIC CONTROL)

A. Input Voltage: 230/460 Volts AC, +10%, -5%, 50/60 Hertz.

B. Output Voltage: 240/500 Volts DC.

C. Output Current (max. Current-Limit): 150% for 1 minute.

D. Minimum Current-Limit Adjustable to 10% rated dc motor current.

E. Load and Line Regulation: ±1% or less with tachometer feedback.
±2% or less standard.

F. Speed Range: 100/1 with tachometer
30/1 standard.

G. Temperature Range: 0^o to 40^o C outside cabinet.
When not mounted in standard cabinet, the average of the temperatures just above the heat sink assembly and just below the heat sink assembly (with rated current) must not exceed 50^oC.

H. Adjustments:

1. Maximum Speed Pot - 0% to 125%
2. Minimum Speed Pot - 0% to 30%
3. IR Compensation - adjustable from zero to 100% (IR drop at full load not exceeding 24 volts.)
4. Current Limit - adjustable from 10% to 150% of rated motor current.
5. Torque Taper Adjust - zero taper to 150% taper (i.e., 100% speed drop for 150% load change.)
6. Speed Controller Compensation:

position 2J to 1: T_o = 3.00 seconds.

position 2J to 2: T_o = 0.50 seconds.

position 2J to 3: T_o = 0.10 seconds.

position 2J to 4: T_o = 0.02 seconds.

I. Follower Signals*: 0 to -8.1 volts corresponds to 0 to 100% speed.

*Follow signals must be isolated (i.e., not grounded) or else an isolation power transformer feeding the drive must be used, or the Isolation Panel Option used.

J. Linear Accel.-Decel. time: (2-40 Sec. to full speed)

Accel.-decel. times separately adjustable.

K. Gate Pulse Suppression (Instantaneous overcurrent protection).

Permanently set to trip when the peak armature current exceeds 400% of rated dc armature current.

L. Motor Thermal Overload:

Set to protect the motor, based on 115% of motor full load current.

M. Jog Speed (Relay Board):

Adjustable up to 30% motor base speed using 9R - Relay Logic

V. TECHNICAL DESCRIPTIONS AND SPECIFICATIONS FOR OPTIONAL ACCESSORIES FOR THE 22-1000 DRIVE SYSTEMS

FIELD CROSSOVER WITH SPEED REGULATION

DESCRIPTION

This regulator consists of a TPM and Regulator Board Assembly. (See Scheme Fig. 15 & 16). The regulator is designed to regulate for full rated current, whenever speeds less than base speed are desired. Pot 2P adjusts for rated field current by means of comparison with the +15 volt reference on 28R and 29R. The output of the Field Current Controller 6-OA moves in a direction as to insure that approximately -2.0 volts is fed back to the anodes of diodes 11D and 12D.

The output of the Voltage Sensor 4-OA is proportional to the absolute value of the motor armature voltage. The voltage sensor output is fed to gain reducing amplifier (FFG), 5-OA, the output of which is compared with the field current feedback through the diode "O ring circuit" made up of 11D and 12D. The field current is weakened whenever the armature voltage attempts to exceed 240V. or 500V. (i.e., rated armature voltage). When this occurs, diode 11D conducts and diode 12D goes out of conduction. Field current above base speed is therefore regulated by the output signal of 5-OA. When a speed decrease is demanded, any phase-back occurring in the T.P.M., causing the armature voltage to decrease, is corrected for by strengthening the field to raise armature voltage back to 240/500V. Only when the field current (and field current feedback) increases to the full field value (i.e., rated field) is armature voltage allowed to decrease below rated values (i.e., 240/500V). The transistion field control to armature control occurs when diode 12D regains conduction (i.e., field current feedback has sufficiently increased) and 11D drops out of conduction.

SET UP

Current Sensing Resistor jumpers on T.P.M. must be set up to provide between 2 to 6 volts between terminals (-IF) and (PSC) at nameplate rated field current, otherwise pot (2P) will not be able to adjust for rated field current.

The voltage between (+15V) and (PSC) should be exactly +15 volts, or as close to it as possible, otherwise field weakening may be initiated below rated armature voltage. This adjustment is found on the S600 Controller Board, Pot 6P. Minor adjustment *OF* crossover voltage may be accomplished by adjustment of 6P.

Adjust pot 2P to obtain full field current with the motor at rest.

Adjust pot 1P (after 1 through 3 above have been adjusted) to adjust field loss to desired point. This adjustment must be made after twidling of the power supply is finished, for changing the power supply voltage adjustments also modifies the field loss circuit set point.

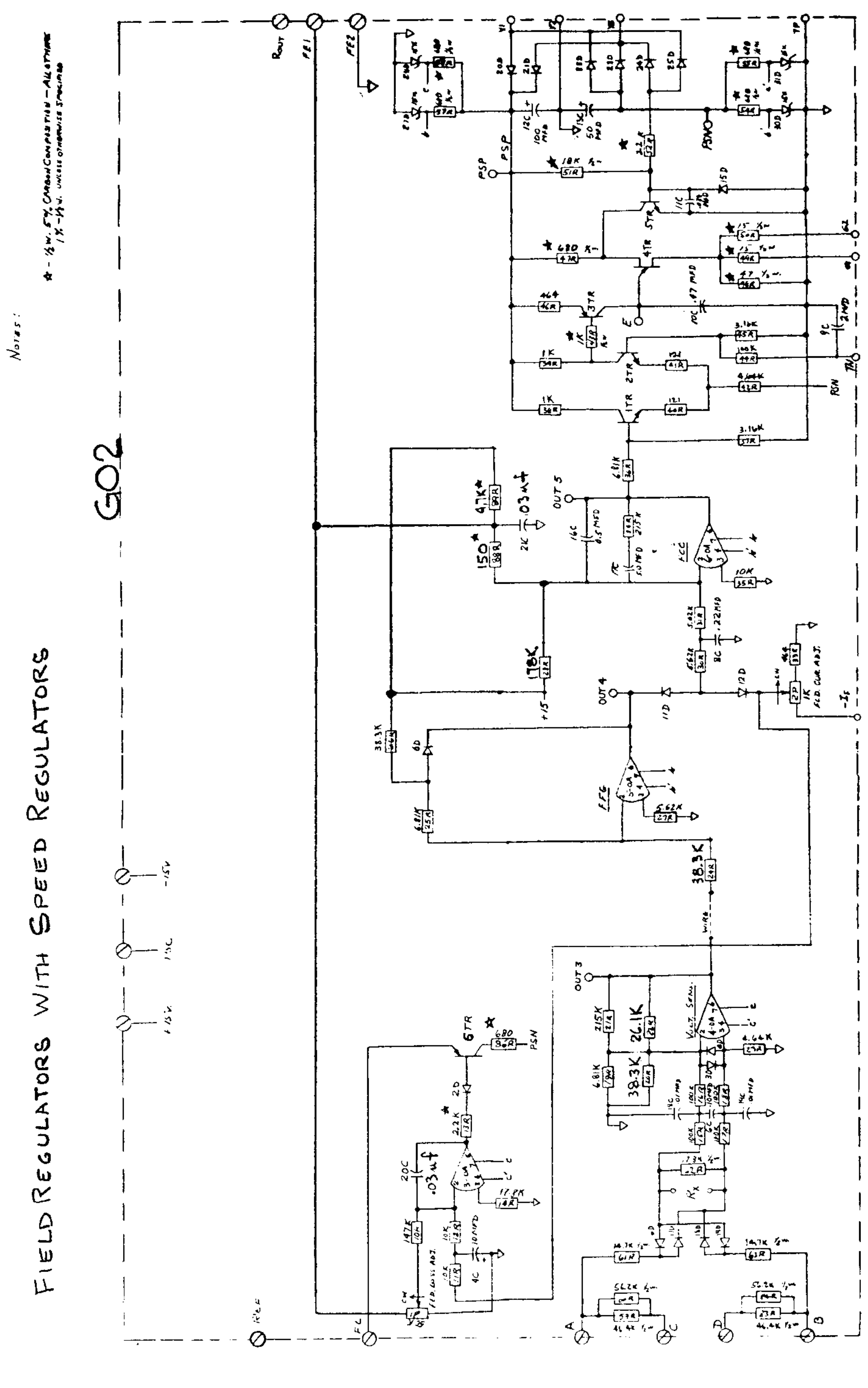


FIG. 15

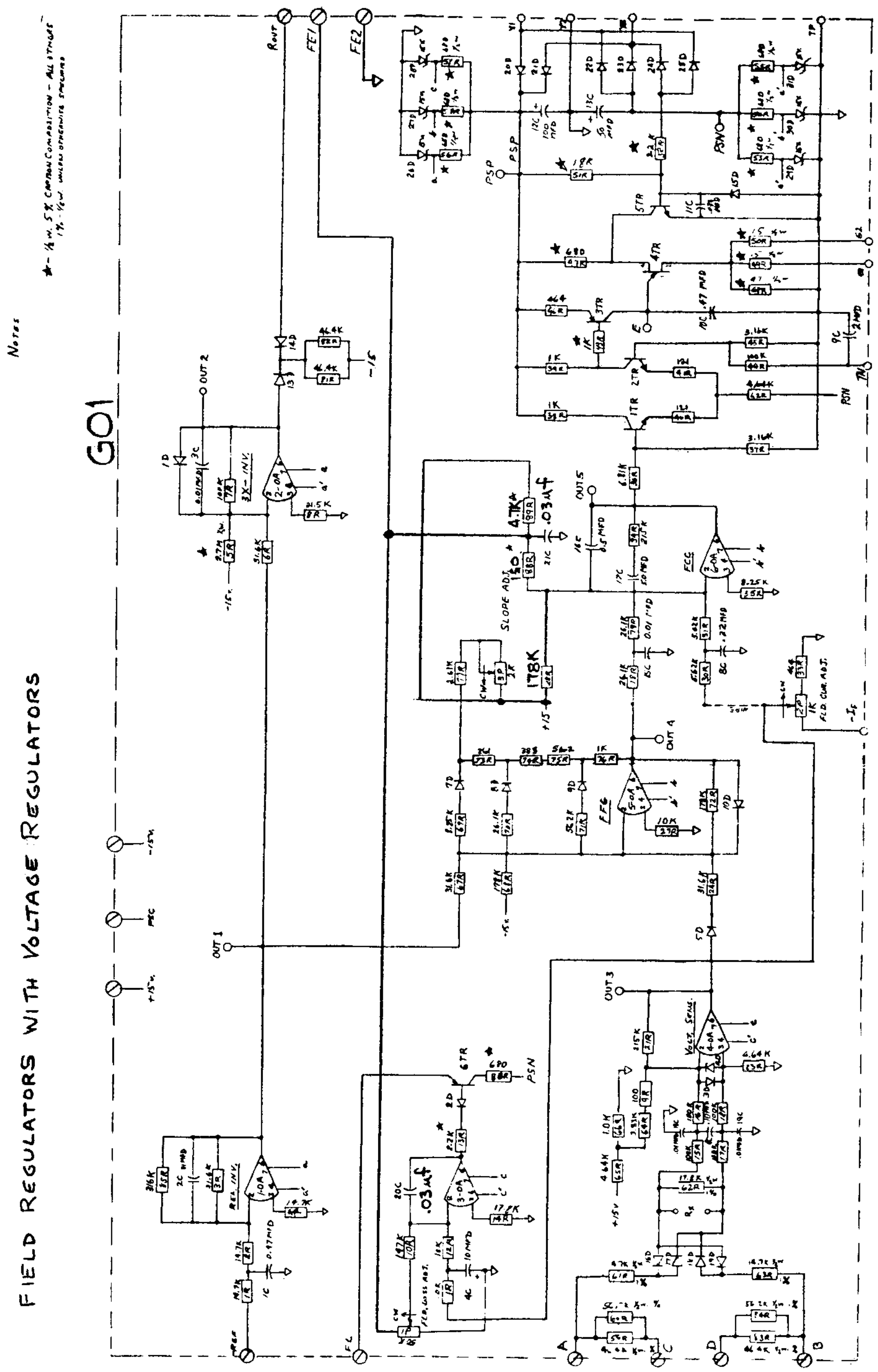

FIELD REGULATORS WITH VOLTAGE REGULATORS
G01
Notes
SLOPE ADJ.
FLD CUR ADJ.
OUT 1
OUT 2
OUT 3
OUT 4
OUT 5
PSP
PSN
FE1
FE2
FCC
FFG

FIG. 16

SET UP (Cont'd)

The tach. voltage per thousand rating of the tach. should be divided by the field range desired (i.e., on a 2 to 1 field range, what was a 100 volt/thousand R.P.M. tach should be a 50 volt/thousand tach. Following this rule means that 8.0 volts reference voltage will produce top speed desired. This then allows standard reference circuits to be used. It also limits the maximum tach voltages to under 200V., allowing standard 200 volt diodes to continue to be used in the tach feedback circuit.

SPECIFICATIONS

CROSSOVER VOLTAGE	-	240 VDC/500 VDC +5%
MAXIMUM FIELD CURRENT	-	22 Amps DC.
FIELD LOSS ADJUST	-	0 - 100% Rated
AC LINE VOLTAGE	-	230 VAC ±10%, 50/60 Hz.
FIELD RANGE	-	3 to 1 (4 to 1 Special)

FIELD CROSSOVER WITH VOLTAGE REGULATORS

DESCRIPTION (See Scheme Fig. 15 & 16)

This regulator is similar to the Field Crossover Speed Regulator, except that no tachometer is necessary and additional components on the regulator board are necessary. These additions are the Reference Inverter, 1-OA, the 3X inverter, 2-OA and a variation of 5-OA (i.e., the Field Function Generator), and a variation of the Volt-Sensor, 4-OA.

A signal equal in magnitude, but of opposite phase from the Voltage Reference is summed at the Field Function Generator, and when this signal is greater than 2.7 volts (i.e., 2.7 volts is 1/3 of 8.1 volts), the output of the F.F.G., 5-OA, begins to go negative which begins to weaken the field. The F.F.G. feedback circuit allows close matching of field current -- field flux curvatures. In order to more closely match various motor characteristics, the slope adjust pot, 3P, was incorporated.

The Volt-Sensor, 4-OA, has been modified from the version used on Speed Regulators. It now has a deadband which corresponds to operation below 120% rated armature voltage. Its' only purpose is to limit armature voltage to this value when the field is quickly strengthened, as would be the case if a speed reduction were demanded. For example, when the Volgage (Speed) reference is lowered abruptly, the F.F.G. immediately senses this decrease and immediately a field current increase is initiated, which increases the motor CEMF since speed can not drop rapidly enough. When the voltage exceeds 120% of rated armature voltage, however, the Volt-Sensor output increases by 10% for every 1% increase in voltage over 120% armature rated voltage. This tends to rapidly weaken the field and bring the bus voltage back below 120% of rated. This correction is continuously made until the field has strengthened to full field, at which point the Volt-Sensor goes inactive since operation is now below base motor speed (and voltage). Since the input to the Volt-Sensor is tied to the armature directly, the voltage will not exceed safe limits even under dynamic braking when the motor is disconnected from the T.P.M. It is essential therefore, that the Volt-Sensor be properly connected for safe operation.

SET UP

Adjust pot 6P, on the S600 Controller Board such that exactly -15 volt appears from terminals "-15" to "PSC" on the Field Crossover Board. This adjustment is critical since it adjusts the voltage on the armature at which crossover takes place.

Adjust pot, 2P, on the Field Crossover Board to adjust the field current to rated field.

Adjust the Field Loss Adjust Pot, 1P, to just below the minimum field current value required by the process (i.e., no less than the field current corresponding to 3 to 1 speed range). This can be done by increasing the speed or voltage reference just greater approximately 0.1V to 0.2V. than the maximum value of reference voltage to be expected for maximum process speed, and then reducing the field loss pot, 1P, slowly until the terminal "FL" to "PSC" switches positive. Do not then increase setting to make this voltage swing negative or you may experience false tripouts when running normally.

Turn Slope Adjust Pot, 3P, full CCW.
Start the motor running and slowly run Speed pot on operators station (i.e., speed reference) up until the maximum reference voltage (i.e., corresponding to maximum desired speed) is obtained. Then, with a speed measuring means, adjust 3P clockwise until the desired speed is reached. This is the best setting for 3P.

SPECIFICATIONS

CROSSOVER VOLTAGE	-	240/500 VDC ±5%
MAXIMUM FIELD CURRENT	-	22 Amps DC.
FIELD LOSS ADJUST	-	0 to 100% rated.
AC LINE VOLTAGE	-	230 VDC ±10%, 50/60 Hz.
FIELD RANGE	-	3 to 1 Max.

S600 - QUICK SLOWDOWN

DESCRIPTION, SET-UP, AND SPECIFICATIONS

DESCRIPTION

The Quick Slowdown Board comprises a low voltage comparator, a timer, and an isolated switch, which operates the quick-slowdown contactor connected to terminals SD1 and SD2. AC (115 VAC 50/60 Hz.) control power is connected to terminals AC1 and AC2. Jumper 1J allows timeouts of 1/3 Sec., 1 Sec., and 3 Secs., as 1J is positioned in positions 1, 2, 3 respectively. See Figure 17.

Whenever the input terminal to the comparator "Comp" is positive, the output of 1-OA goes from positive saturation to -0.5 volts allowing the timer (comprised of 2-OA, 4R, 5R, 6R, 22R, 10D) to switch after the prescribed time out period. After the time-out period the output of 2-OA goes to positive saturation, biasing 1TR on and activating the AC switch circuit, which in turn closes the QSD contactor through the dynamic braking resistors. Conversely whenever the "Comp." input goes negative, the output of 1-OA goes to positive saturation. This signal is coupled through diode 9D and resistor 3R to cause output of 2-OA to immediately (100ms.) switch to -0.5 volt, which removes bias to 1TR and causes the A. C. switch to de-energize the QSD contactor.

The A. C. switch incorporates a triac (1SCS), which turns on whenever a negative gate pulse is received at terminal 3 of 1SCS. This occurs whenever transistor 3TR becomes conductive. Two conditions must be met for conduction of 3TR. One is that the transistor portion of the optical coupler 1-OC becomes conductive, thereby necessitating light to shine on the transistor by light emitting diode within the optical coupler 1-OC. This occurs whenever 1TR is biased on. The isolation afforded by the coupler is 1500V. The second condition for triac conduction is that the AC line voltage be about 10 volts before a gate is released. This insures that 1SCS is usign gate power only for turn-on and not during the whole 1/2 cycle, as this gate voltage comes from the zener supply made up of 5D, 4C and 21R, and it must have voltage on it for the gate pulse required for the next 1/2 cycle. As soon as 1SCS becomes conductive the gate pulse is removed due to the fact that base drive on transistor 2TR is removed, allowing its collector to float, which doesn't allow gate current to flow through 1-OC. The 10 volt level is determined by the ratio of 14R to 15R (which determines bias level for 2TR). For the opposite 1/2 cycle the current path is "AC1" through 19R, 17R, 1-OC, 1D and 16R, with 16R and 17R essentially determining the bias level (i.e., when drop on 17R 0.7 volts, 3TR turns on pulling gate current from 1SCS.).

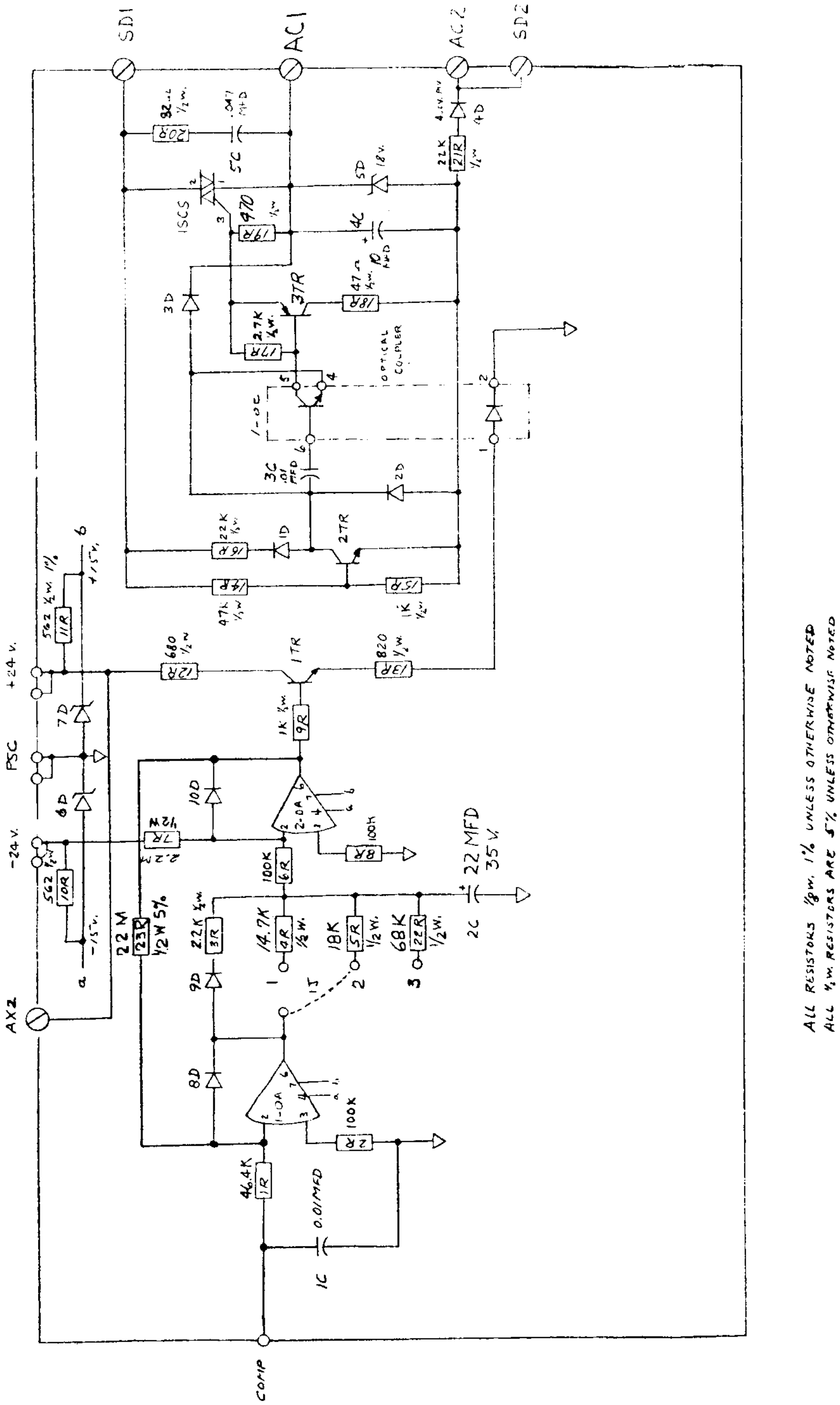

SD1
AC1
AC2
SD2
AX2
COMP
+24 V.
PSC
-24 V.
22 MFD
35 V
ALL RESISTORS 1/8W. 1% UNLESS OTHERWISE NOTED
ALL 1/2W. RESISTORS ARE 5% UNLESS OTHERWISE NOTED

FIG. 17

SET-UP

To ease installation and start-up a minimum of adjustments have been incorporated. The only adjustment, therefore, is for adjusting the time delay on closing of the Quick Slowdown Contactor. This adjustment is made via jumper 1J located on the Quick Slowdown Board, as mentioned in the description above. In choosing the proper position a tradeoff between the number of brakings and accuracy of following the speed reference must be made. Obviously to maximize contactor life, as few brakings as possible is desired. Yet this means setting the jumper 1J for 3 seconds (i.e., position 3), which means that slowdown doesn't occur when desired, but after a delay. Practice has shown that it is desirable to have the contactor cycle no more than 2 or 3 times during the typical slowdown cycle. In some rarer cases more accuracy in following the slowdown signal is desired and more brakings are tolerated, but this operation will accelerate contactor wear and hence shorten life.

SPECIFICATIONS

DC INPUT POWER	-	±24 VDC ± 10%
AC POWER TO AC1 and ACe	-	115 VAC, 50/60 Hz, ± 10%
AC SWITCH ISOLATION	-	1500V
COMPARATOR SWITCHING VOLT	-	± .4 volts or greater
MAXIMUM CONTINUOUS SWITCH CURRENT		1.2 Amps. RMS.

S600 ISOLATOR

DESCRIPTION, SET-UP, AND SPECIFICATIONS

DESCRIPTION OF OPERATION

The Isolation Board is made up of two distinct circuits; one for Voltage Isolation (Volt-Sensor), and one for Current Isolation (Current-Sensor). See Figure 18.

VOLT-SENSOR

This Volt-Sensor circuit senses the Bus Voltage (armature circuit) at terminals "TP" and "TN" and drops the nominal armature voltage rating to 8.15 volts at "$-V_B$". This voltage is fed through resistor (9R) and constitutes the voltage feedback to the S600 controller board. The op-amp (1-OA) derives its power from PSP, PSC, and PSN of the S600 Controller Board. On 240VDC drives, bus connections should be made to terminals TP1 and TN1. On 500VDC drives, connections are made to TP2 and TN2. Capacitors, 1C and 2C, provide high frequency rolloff for both common mode and differential mode signals which are unwanted.

CURRENT SENSOR

The Current Sensor circuit is composed of the Exciter Transformer (4T), Rectifier Bridge (1D through 4D), Burden resistors (1R, 2R, 3R), and Filter Circuit (10R, 3C and 4C). The Current Transductor (located conveniently on the S600 back panel) provides an AC current proportional (by the turns ratio of the transductor) to D. C. Armature Current. The AC current is rectified by the Rectifier Bridge and is sensed by the burden resistors which are chosen to produce 0.5 volts at rated armature current.

SET UP

No set-up is required on the S600 Isolator. A visual check should be made to verify that the armature voltage feedback leads go to the proper terminals on the isolator board (i.e., on 500VDC drives, TP2 and TN2 terminals are used ---on 240VDC drives, terminals TP1 and TN1 are used).

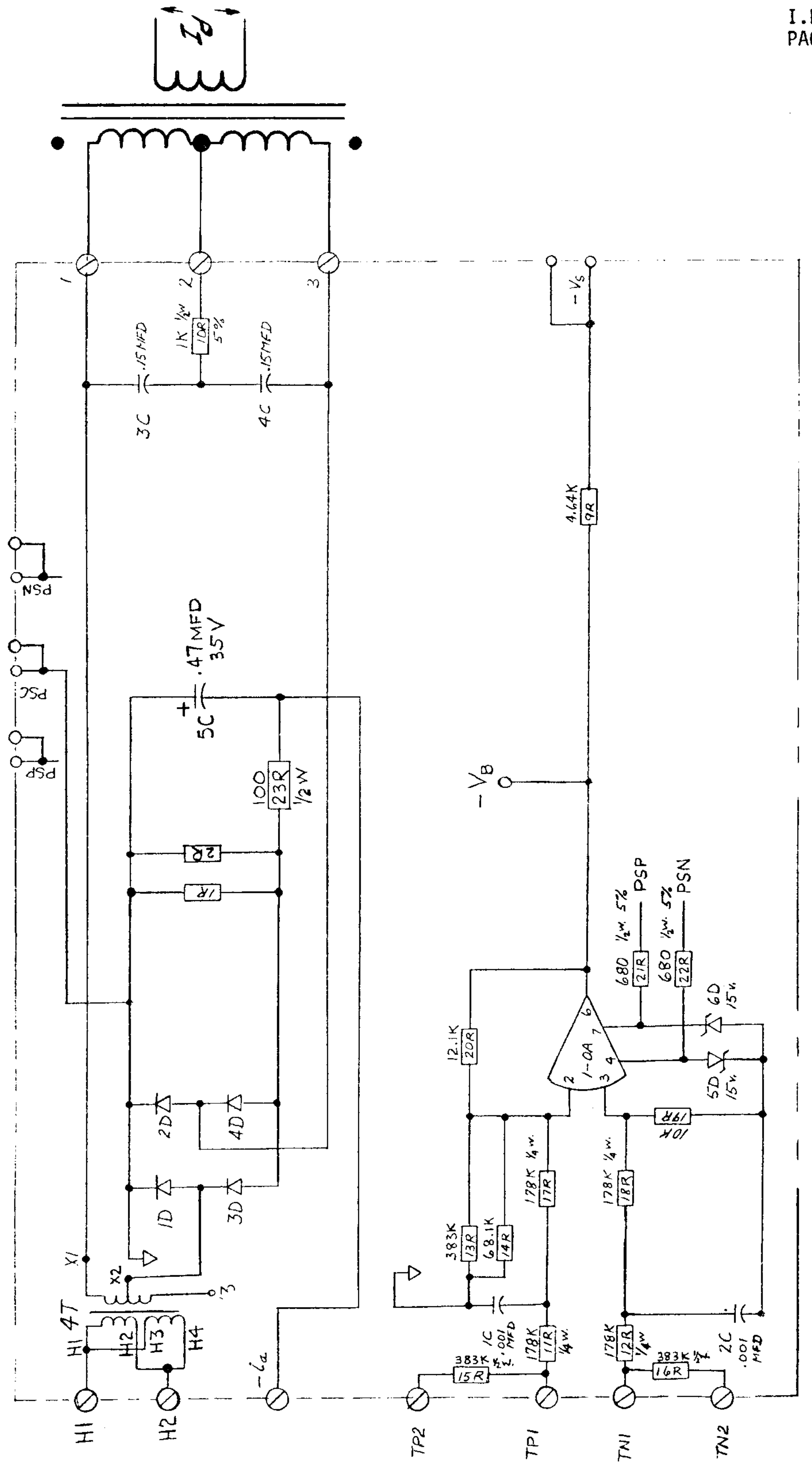

H1
H2
TP2
TP1
TN1
TN2
PSP
PSC
PSN
.47MFD
35V
5C
100
23R
1/2W
4.64K
9R
12.1K
20R
1-OA
10K
19R
680
21R
22R
383K
13R
68.1K
14R
178K
17R
18R
11R
12R
15R
16R
3C
4C
1D
2D
3D
4D
5D
6D
4T
1C
2C

FIG. 18

SPECIFICATIONS

POWER SUPPLY INPUT	± 24VDC ± 10%
VOLT-SENSOR INPUT (NOMINAL)	240VDC ---TP1 - TN1 500VDC --- TP2 - TN2
VOLT-SENSOR INPUT (MAX.)	360V PEAK TP1 & TN1 to PSC. 715V PEAK TP2 & TN2 to PSC.
VOLT-SENSOR OUTPUT (NOMINAL)	8.2 VOLTS FOR NOMINAL INPUT
CURRENT-SENSOR	
Current Feedback voltage	0.5 VDC at rated armature current.
Linearity	a. Flat to 300% rated current b. Less than 10% low at 400% rated current.

S600 PULSE TRANSFORMER BOARDS

Three pulse transformer boards, each comprising a pulse transformer and filter capacitor, provide isolation of the power circuit (via T.P.M.) and control circuits. The turns ratio is unity. A capacitor on the secondary provides immunity from random signal pickup which might inadvertently trigger the thyristors. The clamping diodes and a damping resistor for each transformer are located on the Controller Board.