# DIGITAL RATIO CONTROL

## GENERAL DESCRIPTION

The 3S7506NA300 series Multi-Channel Digital Speed Ratio Control develops a digital controlled "Reference Frequency" used to accurately and independently control the speed of several adjustable frequency ST-100* static AC motor controls.

The Speed Ratio Control utilizes a pulse rate multiplier and ratio adjuster for each channel, in conjunction with a high accuracy frequency reference. This signal becomes the input or reference frequency to the ST-100 discriminator circuit.

## ENCLOSURE

The Multi-Channel Speed Ratio Control is housed in an enclosure which is approximately 28" wide, 22" deep and 46" minimum high (see outline for exact dimensions). The entire top front of the enclosure is an operator's control station and the number of operator's devices required will determine the height of the enclosure for a specific application. As shown in the outlines, the front door which swings out 90°, is located below the operator's control station and may be locked by key.

A door at the rear of the enclosure allows access to the printed circuit modules.

## VENTILATION

Three fan assemblies are mounted under the logic stack, across the bottom area of the enclosure. The fans draw air into the control through a replaceable filter which is located behind a ventilating grille on the bottom portion of the rear door. The air is forced upward through the logic stack and expelled through another filter at the top of the rear doors. The operating temperature of the control is monitored by a thermostat mounted on the top of the logic stack. The thermostat automatically switches off the control power if the stack temperature reaches 124°F ± 5°F.

## ELECTRICAL CONNECTIONS

Control connections are brought into the control through removable plates on the bottom left and right sides of the enclosure. Input power should enter through the removable plate on the top left side of the enclosure.

## CONDITIONS FOR OPERATION OF CONTROL

The control operates with:

A power input of either 115 volts or 230 volts (not both), 60 Hz, single phase, 0.8 KVA. Check nameplate to determine proper input voltage.

Ambient temperature from 50°F to 110°F (control overtemperature cutoff is provided).

## SOLID-STATE LOGIC

Logic circuit boards using transistors and diodes are built on plug-in circuit boards which slide into slots in metal racks. Each rack contains twenty-four slots. Each board has an identifying symbol which also appears below the particular slot where it belongs. Thus, a board which has been removed may be easily returned to its proper location in the rack.

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## LOGIC WIRING

Where possible, the racks are wired with #22 solid wire. The wire is wrapped around the socket pins of the logic board. If stranded wire must be used, as in the case of shielded cables, a miniature fast-on terminal is soldered to the socket pins.

The color code of the logic wiring used is as follows:

| Color of Logic Wire | Where Used |
|---|---|
| Black | Master Reference Frequency (Clock) |
| Blue | -18V Logic Supply Voltage |
| Brown | +6V Logic Supply Voltage |
| Red | +12V Logic Supply Voltage |
| Yellow | Logic wiring leading from logic stack |
| Green | Logic wiring between sockets in the same rack |
| Violet | Logic wiring between the pins on the same socket |
| Gray | Logic wiring between the racks in the logic stack |
| White | Logic ground (OV) |

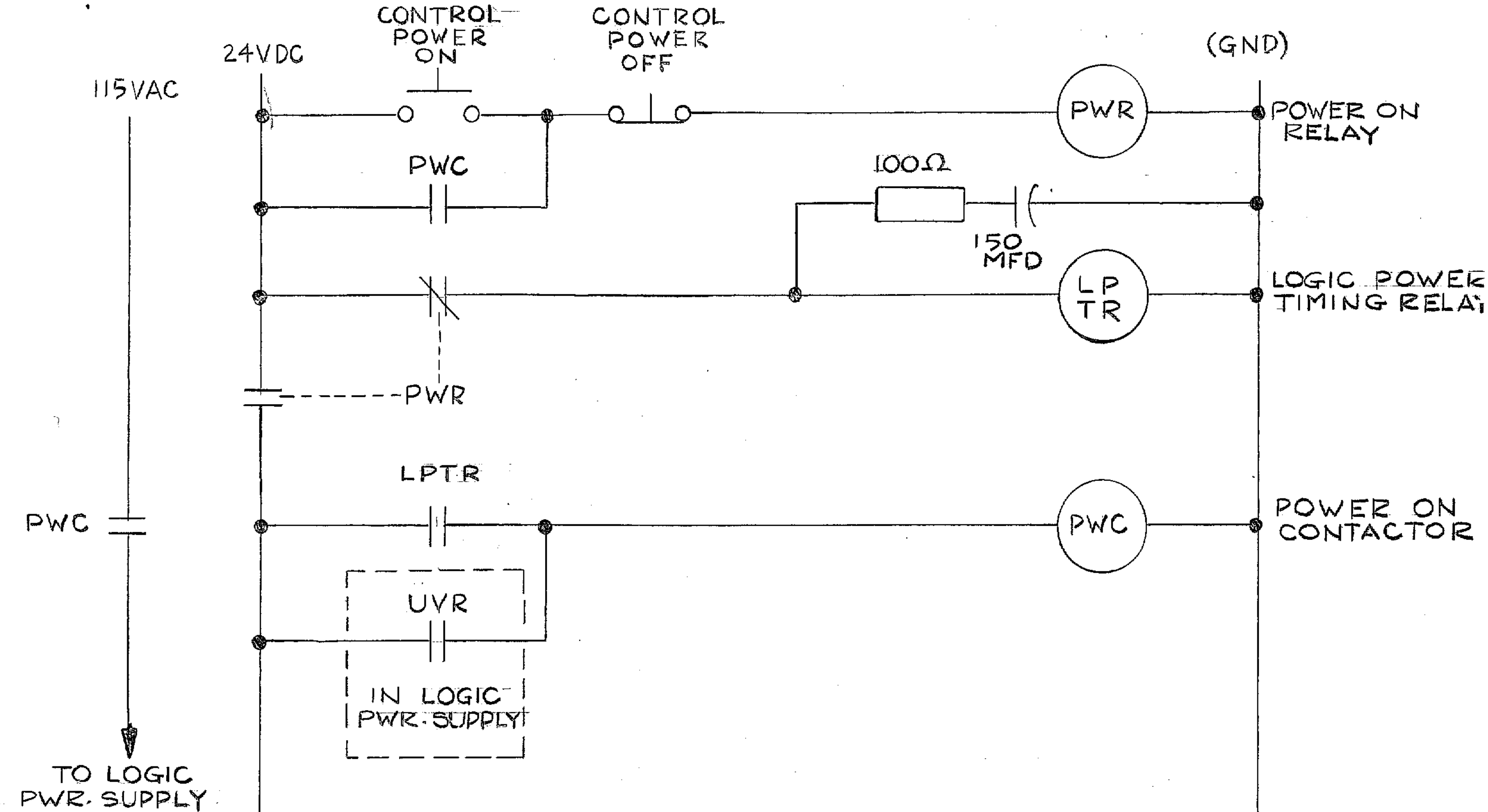
Logic power is carried by bus conductors for each logic voltage and ground. The conductors, which are sandwiched together between insulators, run vertically along the side of the logic stack. Other connecting conductors fan out horizontally across the power connections of the logic boards.

There are four pins on each logic board which are reserved for power supply voltages as indicated on the following page. Those through which the same voltage is supplied bear the same pin numbers.

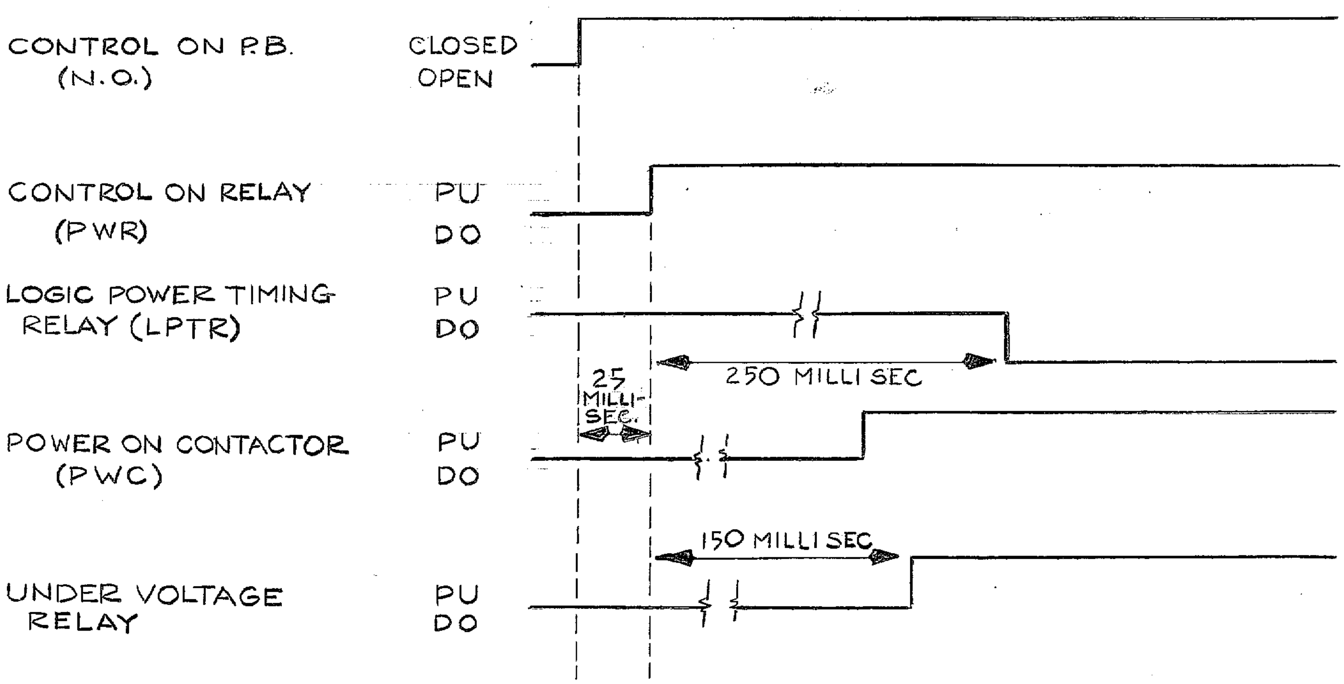
| Pin Number | Power Supply Voltages |
|---|---|
| 1 | -18V |
| 3 | Ground (OV) |
| 5 | +12V |
| 7 | +6V |

## GROUND CIRCUITS

All ground circuits in the control are brought together at the grounding stud (also called the "enclosure ground"). The grounding stud is located on the left wall of the enclosure below the line filters.




NOTE: THIS DIAGRAM IS SIMPLIFIED. IT PERTAINS ONLY TO ASPECTS ASSOCIATED WITH THE INITIAL APPLICATION OF POWER.




NOTE: ALL FIGURES REFERRING TO TIME ARE APPROXIMATE.

FIG 1

— SEQUENCE FOR APPLYING POWER TO CONTROL —

## MAGNETICS FOR THE CONTROL POWER SUPPLY

The magnetic components used in the initial application of power to the control are shown in Figure 1.

The dropout of the Logic Power Timing Relay (LPTR) is delayed long enough to permit the voltages of the logic power supply to come to their proper values. This permits the undervoltage relay to energize; consequently, PWC will stay energized after LPTR has dropped out.

## LOGIC POWER SUPPLIES

The power supplies used for the various logic circuits are filtered +12, +6 and -18VDC.

Regulated power for the logic power supply is furnished by a constant voltage transformer located on the floor of the control. The logic power supply is mounted above the logic stack.

The +12, +6, -18 and 0 volt (ground) power buses in the control are actually large conductor sandwiched together with separating insulators and located vertically on the side of the logic stack. Connecting strips fanning out from these main buses make connections to smaller horizontal buses located across each rack section. These horizontal buses are connected to all logic board sockets. The maximum variation in DC voltage, including peak to peak ripple voltage, is not greater than ±4% for a change in line voltage of ±10% and for a change in load of 20%.

An undervoltage relay UVR, is included in the power supply to interrupt the AC voltage coming from the constant voltage transformer when an undervoltage condition exists in any of the +12, +6, or -18 volt buses. The undervoltage relay is connected to a relay-puller output from an undervoltage detection circuit which is located on a special undervoltage (UV) logic board.

## UNDERVOLTAGE CIRCUIT 1UV1

The 1UV1 board contains the undervoltage detection circuit for the +6, +12 and -18 volt power supply. 13 CN (control network) elements are also included on the 1UV1 board.

The undervoltage circuit on the 1UV1 board energizes the undervoltage relay (UVR) in the logic power supply when the +12, +6, and -18 volt buses are all greater than the minimum bus voltages shown below.

| BUS # | MINIMUM BUS VOLTAGE |
|---|---|
| +12 | 10.7 |
| +6 | 4.6 |
| -18 | 16.3 |

The drop-out time for UVR is approximately 65 milliseconds. Tests have shown that a short circuit on any bus will drop the undervoltage relay before the power supply fuses blow.

## INSTALLATION

The Multi-Channel Digital Speed Ratio Control should be installed in accordance with the following directions:

1. Locate the control in an environment which does not contain corrosive gases or liquids as these could adversely affect the components.
2. Leave enough space around the control to permit all doors to be opened, with sufficient additional space to permit walking around it when the doors are open. This insures easy access to the various parts of the control.
3. Install the control near the power units in a dry location where the ambient temperature does not exceed the limits (50°F to 110°F).
4. Be sure not to expose the control to coolant or other kinds of liquid or spray, flying chips, dust or any other foreign matter. Give particular attention to the operator's panel, since all devices are not 100% oiltight.
5. Whenever possible, avoid exposing the control to an atmosphere having a high foreign matter content, otherwise, the ventilating air filters will have to be changed more frequently than would normally be required.
6. Whenever possible, mount the control in a location which is not subject to vibration, otherwise, the unit will have to be suitable shock mounted.

## INTERCONNECTIONS

For information concerning wires going from the console to the power units and from the control to customer's devices or power source, refer to the elementary diagrams and interconnection diagrams supplied with the equipment. Be sure to observe the following directions when making interconnections:

1. Keep the wiring between the logic console and remote locations as short as practical.
2. Run motor leads and wires from AC power circuits in separate conduits from the conduits containing the signal leads which are in separate shielded cables as shown on interconnection diagrams.
3. Power wiring must be kept separated from all control wiring.

## LINE VOLTAGE

Whatever equipment is required to provide proper line voltage must be supplied by the customer. The power required for the control will be in the order of 0.8 KVA. Sudden changes in line voltages, such as could occur when a welder or large motor load is applied, may adversely affect the operation of the control and must be avoided.

# OPERATION OF MULTI-CHANNEL DIGITAL SPEED RATIO CONTROL

The function of the Digital Speed Ratio Control is to accurately set, using a stable reference frequency, the signal ratio between several ST-100 Static AC motor control units. In essence, this unit is an electronic gear.

Referring to Sheet 2 of the elementary diagram, we see a functional block diagram showing the major blocks in the system. This diagram will help you understand the system as a whole as we proceed to our detailed discussion of the various parts of the Digital Speed Ratio Control system.

## MASTER REFERENCE FREQUENCY

The master reference frequency is generally developed by use of a low frequency temperature controlled oscillator (primary osc.) and a secondary oscillator which steps up the frequency by use of a voltage controlled oscillator and discriminator circuit. A timed acceleration and deceleration circuit is used in conjunction with the oscillator and discriminator circuits to control the rate of change in frequency of the secondary oscillator. This is necessary so that the St-100 static AC motor controllers will stay in synchronism with the master reference (output of secondary oscillator).

Other reference frequency sources may also be used, such as crystal oscillator, non-temperature controlled oscillator or digital pulse tachometer.

Only the temperature controlled oscillator approach will be covered in this section. See auxiliary section for all others.

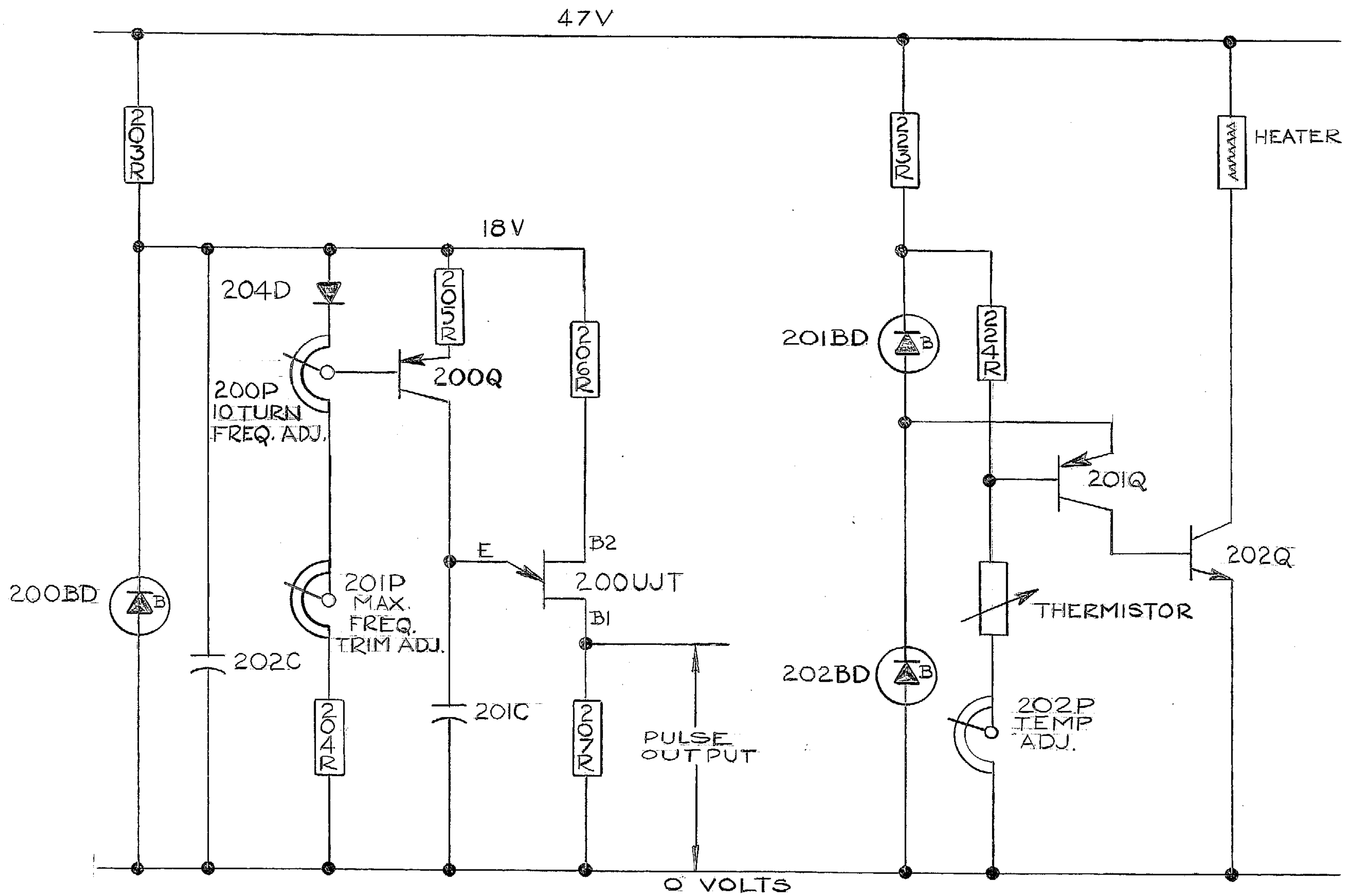
## TEMPERATURE CONTROLLED OSCILLATOR

The oscillator with a 10 turn potentiometer is a completely encapsulated unit and is enclosed in a small insulated box. Temperature deviations inside of the box is held to a minimum by a proportional type temperature regulator and associated heater. Drift accuracy will be plus or minus .05% of set frequency.

The oscillator and temperature regulator circuits will operate as follows, refer to Figure 2. Voltage set at the slider of 200P will determine the magnitude of current supplied through 200Q and 205R to capacitor 201C. When the voltage across capacitor 201C increases to approximately 9 volts, the emitter to base 1 junction of 200UJT will change from a high impedance to a very low impedance discharging 201C through 207R. The emitter to base 1 junction of 200UJT will then change back to a high impedance allowing the voltage across 201C to start increasing again. The charging rate of 201C and the frequency of the voltage pulses across 207R will be determined by the magnitude of current supplied through transistor 200Q. The voltage across 200P and the resulting maximum frequency range can be adjusted by rheostat 201P. The 18 volt supply is held constant by zener diode 200BD and capacitor 202C.

The temperature inside of the enclosure is controlled by a proportional type regulator using a thermistor to sense temperature changes. Transistor 201Q supplies current to the base of power transistor 202Q which in turn controls the heater current.

Zener diodes 201BD and 202BD hold the voltage constant across the divider consisting of 224R, 202P and the thermistor. The supply voltage for transistor 201Q is also held constant by zener 202BD. Voltage at the base of 201Q will be determined by the resistance of rheostat 202P plus the resistance of the thermistor. Rheostat 202P is used to set the temperature regulating point.




TEMPERATURE CONTROLLED OSC.

FIG 2

The thermistor resistance change for .5°C temperature change will be sufficient to turn transistor 202Q from off to full on. As the temperature increases, the thermistor resistance will increase, which is in the direction to reduce the current flowing in 202Q and the heater. A decrease in temperature will have the opposite effect.

DISCRIMINATOR CIRCUIT

The discriminator circuit shown on elementary diagram 44C300888 is used to lock the high frequency voltage controlled oscillator thru a divide by 200 circuit, consisting of a hundred counter and one flip-flop, to an external reference (temperature controlled oscillator). The voltage controlled oscillator will increase in frequency at a controlled rate determined by the timed acceleration circuit (upper left hand side) until the output of the divide by 200 circuit reaches the frequency set by the temperature controlled oscillator. At this point, the voltage controlled oscillator will lock on to this frequency and thereafter will oscillate at a frequency 200 times the temperature controlled frequency.

The circuit can be divided into the following parts:

1. Power supply buses and filters which includes the following components: 24R, 25R, 26R, 27R, 3BD, 13C and 14C. The DC voltage bus is supplied by a full wave bridge rectifier consisting of 7, 8, 9 and 10D which in turn draws its power from the 230 VAC line thru a step down transformer. The DC voltage out of the bridge is approximately 48 volts. The bus voltage of the discriminator circuit is filtered and zener regulated at 24 VDC ± 10%.
2. Basic digital discriminator consisting of transistors 8 - 13Q, diodes 12 - 17D, capacitors 6-11C and resistor blocks 1 - 6RB.
3. Feedback pulse amplifier circuit consisting of transistor 7Q and resistor 18 - 20R. The purpose of this circuit is to develop a negative going pulse of known amplitude at 6, 8 and 10C for each positive pulse generated at the output of the divide by 200 circuit.
4. Reference pulse amplifier circuit consisting of transistor 14Q and resistors 21 - 23R. This circuit will develop a negative going pulse at 7, 9 and 11C for each positive pulse supplied by the temperature controlled oscillator.

OPERATION OF DIGITAL DISCRIMINATOR

This circuit consists of three flip-flops which are interconnected by steering lines and which as a group, receive reference pulses at 7, 9 and 11C and feedback pulses at 6, 8 and 10C. Outputs are fed back into the voltage controlled oscillator in a way which affects the pulse rate supplied to transistor 7Q and thus 6, 8 and 10C. Each collector of the center flip-flop also supplies a base signal to an auxiliary transistor in whose collector circuit a lamp can be connected in order to indicate the state of that particular collector. For example, 15Q is the auxiliary transistor associated with collector of transistor 11Q in the center flip-flop. When 11Q is non-conducting, 15Q will be conducting and the associated lamp will be turned on. Transistors 15Q and 16Q thus can provide a visual indication of the states of the transistors in the center flip-flop.

The logic states at the collectors of 8 - 13Q will be defined as follows: when a transistor is non-conducting and as a result, its collector is positive, we will say that the collector is at a logic "one". Also, when a transistor is turned on and as a result, its collector is almost at ground potential, we will say that the collector is at logic "zero".

First, let us assume that the collectors of 8-13Q are in the initial order 1, 0, 1, 0, 1, 0. Let us assume for the time being that there are pulses on (7, 9 and 11C) but not on 6, 8 and 10C. The steering between flip-flops is arranged such that on successive pulses, the collector states will change as shown in Table 1.

Table 1. (Ref. Pulse Input)

| | 8Q | 9Q | 10Q | 11Q | 12Q | 13Q |
|---|---|---|---|---|---|---|
| Initial Condition | 1 | 0 | 1 | 0 | 1 | 0 |
| After First Pulse | 1 | 0 | 1 | 0 | 0 | 1 |
| After Second Pulse | 1 | 0 | 0 | 1 | 0 | 1 |
| After Third Pulse | 0 | 1 | 0 | 1 | 0 | 1 |
| After Fourth Pulse | 0 | 1 | 0 | 1 | 0 | 1 |
| After nth Pulse | 0 | 1 | 0 | 1 | 0 | 1 |

To summarize the above; if pulses come only into 7, 9 and 11C, the collectors of the flip-flops will go to, and stay in the states shown in the last entry in Table 1.

If we now assume that pulses stop coming into 7, 9 and 11C and appear only at 6, 8 and 10C, the collector states will change as shown in Table 2.

Table 2. (Feedback Pulse Input)

| | 8Q | 9Q | 10Q | 11Q | 12Q | 13Q |
|---|---|---|---|---|---|---|
| Initial Condition | 0 | 1 | 0 | 1 | 0 | 1 |
| After First Pulse | 1 | 0 | 0 | 1 | 0 | 1 |
| After Second Pulse | 1 | 0 | 1 | 0 | 0 | 1 |
| After Third Pulse | 1 | 0 | 1 | 0 | 1 | 0 |
| After Fourth Pulse | 1 | 0 | 1 | 0 | 1 | 0 |
| After nth pulse | 1 | 0 | 1 | 0 | 1 | 0 |

Table 2. indicates that if pulses come only into 6, 8 and 10C, the collector will go to and stay in the states shown in the last entry of Table 2.

For the condition where there are pulses on both the reference pulse line (7, 9 and 11C) and on the feedback line (6, 8 and 10C) but with the feedback pulse rate being lower than the master pulse rate, it will be seen that the two right hand flip-flops will stay in the logic states where collectors of 10Q and 12Q are zeros and 11Q and 13Q are ones. The left hand flip-flop will alternate, however, from one state to another as pulses arrive on the two input pulse lines.

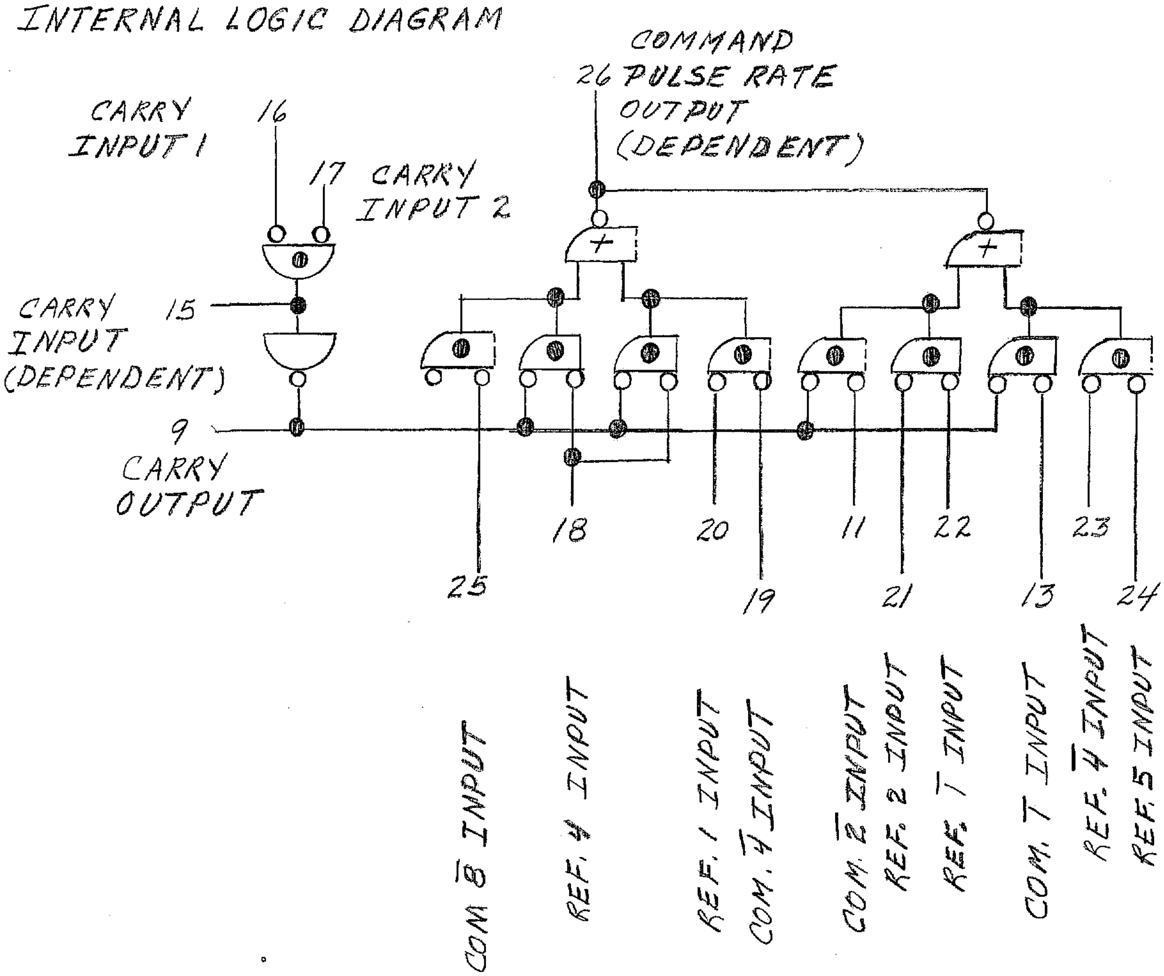
The output of the center flip-flop is supplied to the base of transistor 1Q. Since this output is very nearly zero for the operating conditions assumed above, transistor 1Q is non-Conducting and voltage will be applied to the timed acceleration circuit. As a result, the pulse rate generated in the frequency control circuit will increase. These pulses not only determine the master reference frequency, but also constitute the feedback to the digital discriminator thru the divide by 200 circuit. As long as the feedback rate is lower than the reference pulse rate, the above conditions will prevail and the feedback pulse rate will increase at a rate set by the acceleration circuit.

GENERAL ELECTRIC

| REV NO. | TITLE | CONT ON SHEET SH NO. |
|---|---|---|
| CONT ON SHEET SH NO. | SECTION #1 GATES 2MG1 BD. FIRST MADE FOR | |

REVISIONS

INTERNAL LOGIC DIAGRAM




OUTPUT PULSE PATTERN

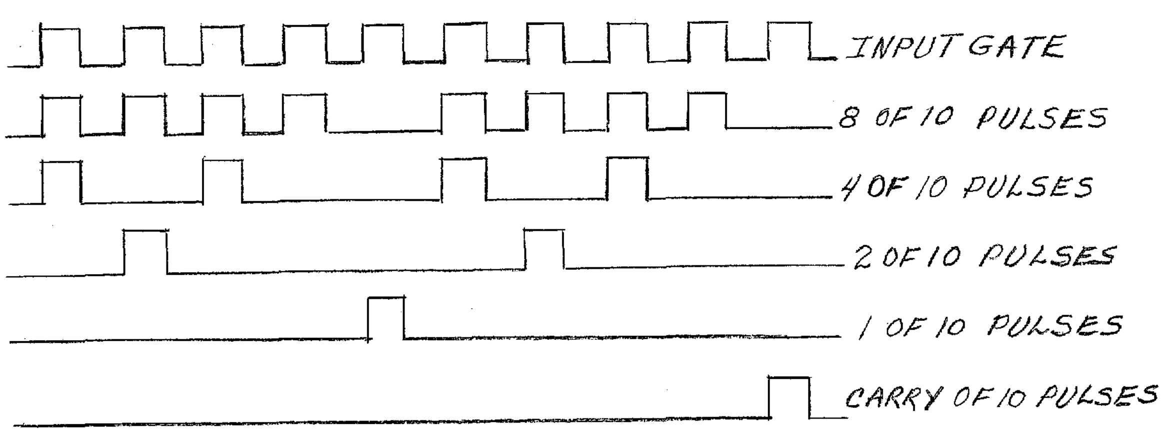



FIG. 4

PRINTS TO

| MADE BY | APPROVALS | DIV OR DEPT. | |
|---|---|---|---|
| ISSUED | | LOCATION | CONT ON SHEET SH NO. |

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PRINTED IN U.S.A.

CODE IDENT NO.

GATES 11G4, 11G5, 11G6

Logic gates are used to amplify a logic signal, to the required level for a given load and/or to perform a logic function. These gates are used in the circuit as required.

Each of the gate boards listed above contains eleven separate gates. These are two input "Fast Gates". Fast gates are identified with the letters GF in the elementary diagrams. The fast gate circuit has two transistors (one for each input) which have a common collector resistor. Each gate can be used as a "Not And" gate or as an "Or Not" gate.

The only difference between the 11G4, 11G5, and 11G6 boards is the difference in the number of independent gates versus dependent gates on each board. The same pin numbers are used for correspondingly numbered elements on each of the three boards. In other words, gate element number 1 on each of the three boards uses pins 10 and 11 as inputs and pin 9 as the output; gate element #2 on each of the three boards uses pins 12 and 13 as inputs and pin 20 as the output, etc. The pin numbers assigned to each element are shown on Sheet 1A of the elementary diagram as well as the combination of independent gates versus dependent gates on each of the three boards.

MULTIPLIER GATE (2MG1)

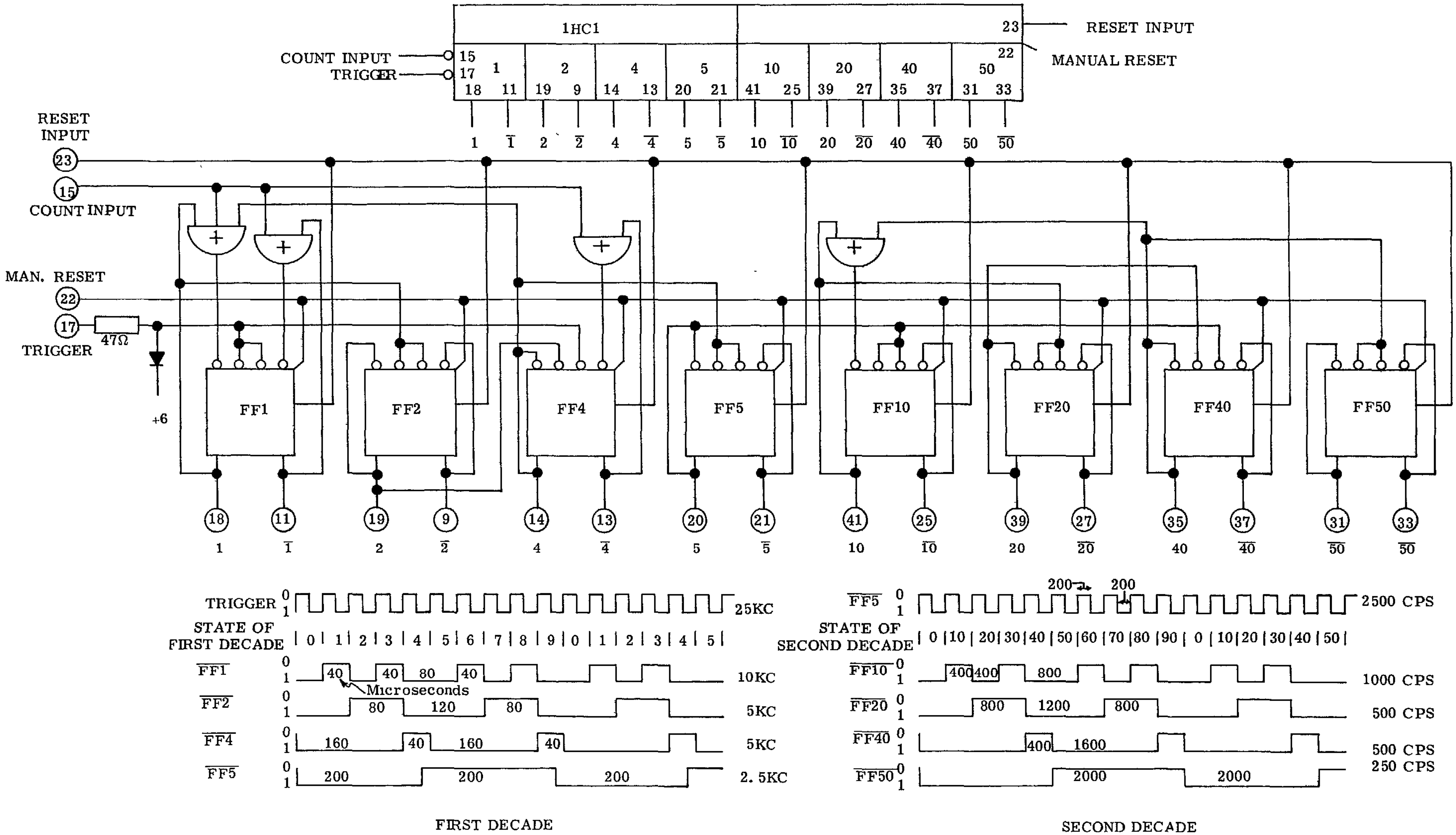
The 2MG1 board contains two groups of 12 gates, arranged to gate non-concurrent pulses at a reference rate. Each gate series will gate 1 pulse per 10, 2 pulses per 10, 4 pulses per 10, or 8 pulses per 10. The pulse total cannot exceed 9 pulses per 10.

Using the 2MG1, with the 1HC1 as a reference counter to distribute the gate input in proper sequence, the pulse rate control will gate these "gate input pulses" at a rate commanded by the setting of the ratio switches. The pulse rate commanded may vary from 0 out of 10 to 9 out of 10 pulses per decade.

The purpose of the multiplier gate or "pulse rate multiplier" is to act as an adjustable digital frequency reducer. The adjustment, typically, is made by use of a thumbwheel switch. The pulse rate multiplier, also known as a "fractional multiplier" produces at its output, a train of pulses whose repetition rate is equal to the input pulse rate from the high frequency oscillator multiplied by the decimal fraction represented by the thumbwheel switch setting. The decimal point is to the left of the first thumbwheel digit. Internal gating in the pulse rate multiplier is arranged to produce a relatively uniformly spaced output pulse train for any thumbwheel setting.

For any given thumbwheel setting, the relationship between the reference frequency and multiplier gate output frequency is absolute when considered over the averaging period of the multiplier. This period would be .05 seconds using a 200K Hz reference frequency and four-digit thumbwheel switch. Even within this short period, the perturbations around the set ratio would be very small. While the high frequency input signal could be considered the frequency reference, the output of the pulse rate mulitplier is the actual reference that is supplied to the digital discriminator of the ST-100 power unit through a divide-by circuit. It is this secondary reference to which the power unit is locked.

As you can see, if each power unit is required to run at any frequency independent of the speeds of the other units, a separate pulse rate multiplier must be used for each.




HUNDRED COUNTER, 1HC1
Figure 3

they are amplified and inverted for use in driving the required logic gates. This signal is used as the master reference frequency or clock for the Multi-Channel Speed Ratio Control and in turn through a ratio and divider circuit, the ST-100 static AC motor controllers. The amplitude of the pulses at the collector of 6Q are limited to a logic level of 6 volts by 6D and 1BD. 2BD and 4C regulate and filter the 12 volt supply bus.

## HIGH FREQUENCY OSCILLATOR FEEDBACK CIRCUIT (DIVIDE BY N)

Typically, the feedback circuit consists of a hundred counter and a flip-flop which divides the signal by 200. This signal which is fed back to discriminator circuit will cause the high frequency oscillator to operate at a frequency 200 times the frequency of the temperature controlled oscillator. This divider may vary depending on the application.

## HUNDRED COUNTER 1HC1

The hundred counter consists of eight flip-flops and necessary gates to form a two-decade counter. In each decade, the flip-flops are weighted 1, 2, 4 and 5. The outputs of both decades (ie, the outputs of FF5 and FF50) form a train of pulses which are evenly spaced.

The hundred counter has a reset input and a manual reset connection. It counts when logic 0 is applied to its count input (pin 15) and subsequent pulses are supplied to its trigger input (Pin 17).

## FLIP-FLOP 4F1

The 4F1 flip-flop board contains four separate flip-flops, one of which is used in the feedback circuit, while the remaining units may or may not be used for other functions depending on the application. The manual reset connection to the board is common for all four flip-flops.

A flip-flop goes to the set state when:

1. A logic 1 is applied to its set input.
2. A logic 0 is applied to the set steering and a subsequent positive-going trigger pulse is applied to the set trigger. (The set steering must go to logic 0 at least two microseconds before the set trigger goes to logic 0).

A flip-flop goes to the reset state when:

1. A logic 1 is applied to reset input.
2. A logic 0 is applied to the reset steering and a subsequent positive-going trigger pulse is applied to the reset trigger. (The reset steering must go to logic 0 at least two microseconds before the reset trigger goes to logic 0).

## FREQUENCY COUNT DOWN

The frequency count down circuit consists of two hundred counter boards (described earlier) and shown on block diagram as four decade counters. These counters are used to distribute in proper sequence the gating to the Multiplier gate boards (2MG1).

## ACCURACY AND SETTABILITY

Two types of accuracy are involved. One is the drift accuracy of the master reference frequency ± .05% of set frequency for temperature controlled oscillator. The other is the fineness of adjustment steps or the "settability". Settability is related to the number of digits. If it is 4, the output frequency can be set in steps of approximately .01% if a setting of 9999 represents top frequency.

Frequency adjustment - The means of adjusting the frequency out of the pulse rate multiplier is the ratio switch. It is desirable to give a specific meaning to the number setting of this switch; for example, it may be desirable for it to read feet per minute, percent of output frequency, output frequency in hertz or whatever quantity happens to be of special significance in a particular application. In order to implement this desire with circuitry, it is necessary only to add a divide by block (divide-by N) at the output of the pulse rate multiplier.

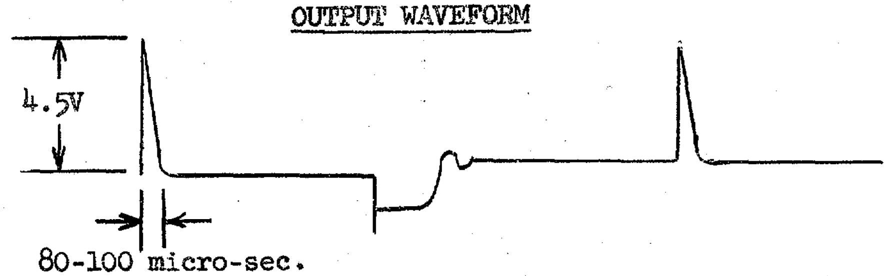
## DIVIDE BY (N)

The purpose of this block as stated earlier, is to smooth out the perturbations of the pulse rate multiplier and to give specific meaning to the reading of the ratio switches. In terms of the hardware required, it is one decade of a hundred counter board (operation described earlier) and N quantity of flip-flops depending on the specific application.

## OUTPUT ISOLATION

To isolate the logic circuitry from the power units and also to transform the square wave output of the logic into a pulse, a pulse transformer is used. The pulse out of this transformer is approximately 4 volts in amplitude and 80 to 100 microseconds in width measured at the base of the signal.

OUTPUT WAVEFORM




This isolating transformer is mounted on a general purpose plug-in board which has four such transformers and associated components and is referred to as the "output" board.

## OPTIONAL FEATURES

See auxiliary section for operating description of all optional features.

Excessive vibrations and shock (e. g. during transportation) may shake one or more printed circuit boards partially out of their sockets. The boards may have been incompletely inserted during troubleshooting by substitution of boards.

Note that an incompletely inserted board which may be partially energized may cause an intermittent malfunction.

C. Wires and Sockets

Wires and sockets may be broken due to mishandling of the control. Usually a broken wire or connector is fairly obvious after a few minutes inspection (with power switched off).

D. Power line transients

A malfunction which starts or coincides with the operation of any machinery or apparatus connected to the same AC power line as the control may be caused by excessive line transients.

ISOLATING THE TROUBLE AREA

The following list contains some of the typical questions that should be answered when the performance of a malfunctioning system is being observed.

1. Is the trouble area in the ratio control, power units, or associated magnetics?
2. Does the control repeat the malfunction consistently every time, or is the malfunction intermittent?
3. Does the malfunction occur in one or all of the channels?

Since the above list is not complete, further examination of the control may be necessary. The waveforms and voltage level in the suspected trouble area should be observed and compared with the expected behavior of the control as described in the elementary diagrams and in this Instruction Book. Further troubleshooting will then entail the available evidence and the formulation of a set of possible causes for the malfunction. Each possible cause should be proved or disproved by further observation and measurements.

FAULTY LOGIC ELEMENTS

A malfunctioning logic element does not necessarily represent a faulty element at the point of observation. The trouble may be due to one of three reasons:

1. All or some of the input signals to the element have failed to arrive. This may be due to a faulty logic element in the input signal path or may be caused by broken wires or bent pins due to mishandling of the control.
2. A logic element under observation may be prevented from assuming the correct state because its output is connected to a faulty logic element or to a wrong point in the circuit due to bent pins or broken wires.
3. The logic element under observation is faulty. This occurs most often due to the failure of a transistor or diode. Replacing the board containing the faulty element will cure the malfunction, except in cases where the

## PREVENTIVE MAINTENANCE

Because the Ratio control uses solid-state logic and hermetically sealed relays, very little control maintenance is required. The air filters are the only units in the control which require a maintenance program. The Ratio control enclosure should be opened only when necessary for service or inspection, then only by qualified personnel.

### AIR FILTERS

Air filters, located in the rear door of the enclosure must be removed and cleaned periodically. The degree of cleanliness of the surrounding air has a direct bearing on the frequency of cleaning required. Unclean air will cause the filters to become clogged so that the air passage into the control becomes restricted. Reduction in ventilating efficiency may cause the control to overheat. In dusty or dirty locations, therefore, the filters should be checked daily.

Clean air filters with hot water and a detergent or similar type of solvent and then wiring them as dry as possible. Do not oil the filters. Replacement filters (No. 44A235705-008) may be ordered from the Communication and Control Devices Department., General Electric Company, Waynesboro, Virginia.

circuit fault which caused the original failure will damage the replacement element (e. g., output of a gate or flip-flop connected to ground).

Items 1, 2 and 3 should be kept firmly in mind whenever a decision is made to substitute an apparently faulty board.

If a defective logic element is suspected and it appears easy to prove this fact by lifting a wire from that element, it should be remembered that if an input to a NOR element is disconnected, that input will assume 6 volts and its operation will be the same as if 6 volts were connected to it. This may give the same symptoms as before or it may change some other circuit operation depending upon whether the open terminal is an input or an output. Since this may confuse the facts, a further study of the circuit should be made before any wires are removed.

CHECKS ON HUNDRED COUNTER BOARDS (1HC1 BDS)

To check the 1HC1 Boards, observe each decade output waveforms on the oscilloscope and compare these with expected waveforms in Figure 3. Although this figure depicts the waveforms for a particular frequency, the time base will be the only change for any other frequency.

Once the reference frequency counters have been checked, the output of the driver gates distributing this reference to each digital ratio channel should be checked for proper frequency and waveshape.

RATIO SWITCHES

The ratio switches are BCD (Binary Coded Decimal) type with a weight of 8-4-2-1 and are used to command a pulse output from the multiplier gates. This command may vary from 0 out of 10 to 9 out of 10 pulses per decade.

These switches may be checked by using a multimeter for continuity checks from the common terminal to each of the BCD outputs.

CHECKS ON MULTIPLIER GATES (2MG1 BOARDS)

To check the multiplier gates set the ratio switch controlling the channel in question to zero. With the top trace of an oscilloscope on the input to the first decade of reference counter, obtain 10 pulses of this frequency. With the bottom trace on the summation point of the multiplier gates (pin 26 or 41), turn the most significant digit on the switch from 0 thru 9. Observe waveforms and compare these with expected waveforms in Figure 4. Return the thumbwheel to zero and move the top trace of the scope to the input of the second decade (pin 20) on the hundred counter board. With the bottom trace still on the summation point, again observe the expected waveforms as shown in Figure 4 by turning the second most significant digit on the thumbwheel. Repeat the above for each decade. Note that the switch section for all other decades other than the one under test must be on zero to obtain correct waveforms and that the pulse width at summation point is always the same as the input to the first decade counter.

CHECKS ON DIVIDE BY (N) CIRCUIT

The Divide By N Circuit utilizes one decade of a hundreds counter board and the

STATIC EQUIPMENT

If vibration is present, all screw type connections should be checked regularly. Normally, the static components should require no further attention.

OTHER EQUIPMENT

All contactors and relays should be regularly inspected and maintained in accordance with applicable instructions. The automatic and manual regulator voltage adjuster contact brushes should be inspected annually and the brushes should be reset by working them back and forth across the total winding surface many times. If arcing is present, or if brush becomes worn, a complete brush assembly should be installed. Since it is made of special material, it should be obtained from the rheostat manufacturer. In addition, where discoloration is present, clean the contact surface with crocus cloth.

Silicon diodes are used in the power circuit of the static exciter. These diodes are not at this time known to age; therefore, they are either good or should be replaced. Individual diodes can be checked as shown in Figure 12. With switch in position 1, the ammeter should read approximately 12 amperes. With switch in position 2, the ammeter should read zero. The DC source should be a battery, rather than a rotating exciter, since the latter may have voltage spikes that may damage the diode.

If the diode is open, the ammeter will read zero in both switch positions. If the diode is shorted, it will read approximately 12 amps in both switch positions.

Bad diodes can be found with the equipment in service with a voltmeter and a clamp-on ammeter.

The shorted diode can be found by measuring the inverse voltage across the diodes, since the shorted diode will have no inverse voltage drop, and the other diode in the leg will have all the inverse voltage drop.

The leg containing an open diode can be found by clamping a clamp-on ammeter around one diode pigtail in each leg. Upon ascertaining that an open diode exists in a leg the faulty diode can be found by shorting each individual diode in that leg. When current flows, the open diode has been shorted.

An oscilloscope may also be used to check for an open diode.

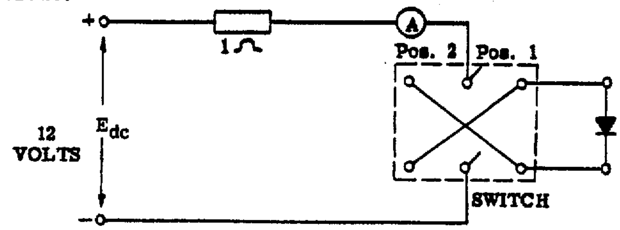



Figure 12. Diode Test Circuit

If it becomes necessary to replace a faulty diode, use the following procedure:

1. Shut down the equipment.

2. Discharge all capacitors in the AC machine field circuit.

3. Disconnect Ground Detecting relay.

4. Remove diode.

5. Screw in new diode after first applying a small amount of Wakefield type 120 thermal compound to approximately the first three threads. Also apply a little to the rectifier base. Refer to the manufacturers specifications for the required mounting torque.

## RENEWAL PARTS

When ordering renewal parts, the following information should be given.

1. Catalog number, stamped on the part, with a complete description, including use and location.

2. Complete nameplate data appearing on the assembly of which the part is a component.

3. If possible, data on original order on which equipment was first supplied including all numerical references.

# TROUBLESHOOTING

| SYMPTOM | POSSIBLE CAUSE | POSSIBLE CURE |
|---|---|---|
| Voltage fails to build up after flashing (Regulator on Manual.) | Insufficient Flashing Current | Short C3R |
| | Shorted Power Diode | Replace Diode |
| | Insufficient Resistance in off-line control | Increase C6R and/or 90R5 |
| | Loose Connections | Tighten ALL Power Circuit Connections |
| Generator Armature Voltage goes to ceiling after flashing (Regulator on Manual.) | Excessive resistance in 90R5, C6R, SCT circuit. | Decrease C6R or 90R5 |
| | Incorrect PPT Secondary voltage | Check to see that PPT is on the correct tap. |
| | SCT control windings not in the circuit | Look for wiring error involving SCT control windings. Check contacts of 83SR** |
| | Insufficient Reactance in $X'_L S$ | Change Taps |
| Generator Armature Voltage goes to zero after transfer to auto. | Incorrect Sensing Voltage | Adjust A3P and A4P |
| | Incorrect Zener Voltage | Check Zener and replace if necessary. |
| | Open Potentiometer A5P | Check and replace if faulty. |
| | Open diode A11D | Check and replace if faulty. |
| Generator Armature Voltage goes to ceiling (or higher than desired) after transfer to Auto. | Incorrect sensing voltage | Adjust A3P and A4P |
| | Incorrect Operation of 83SR | Check and adjust or replace |
| | Incorrect Zener Voltage | Check and replace if necessary |
| | Insufficient supply Voltage to SCR's | Check A1T |
| | Faulty SCR | Check output of regulator with Oscilloscope and replace the SCR if faulty. |
| Generator unstable at No-Load | Incorrect Stabilization | Adjust A2P, A5R and/or A2C |
| | Feedback circuit connected with wrong polarity | Swap leads to A15 and A16 |
| | Excessive Gain | Increase A1P and/or A4R |
| Generator unstable at Load but stable at No-Load | Change in Gain caused by Excessive Ambient | Decrease Gain or Ambient Temperature |
| | Change in Gain caused by Phasing Error between SCT and PPT | Check control current as load is changed. If approaches zero or maximum, then check phasing of PPT and SCT. |

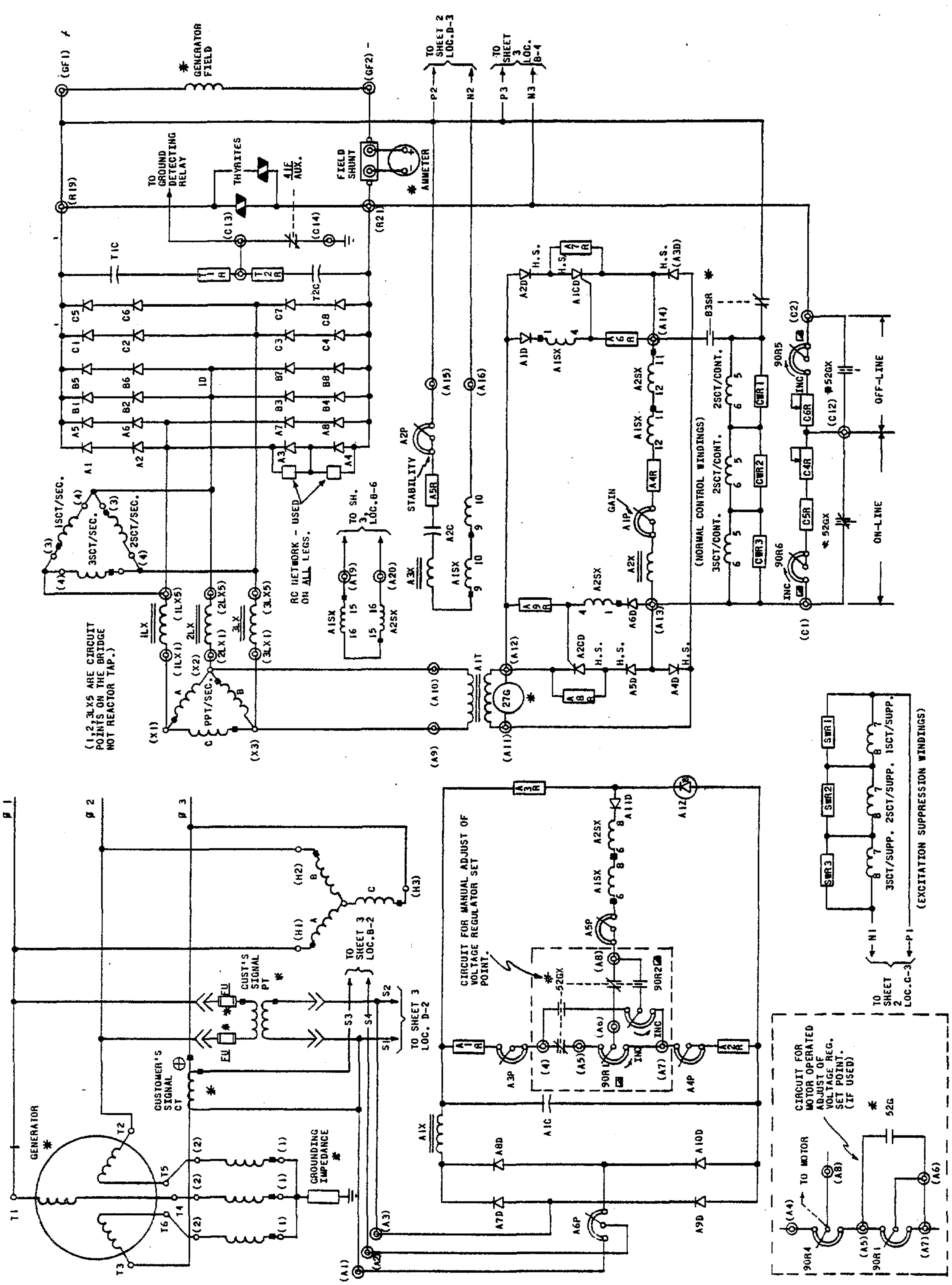



Figure 13 - Typical Elementary Diagrams of 3S7501FS141 Static Exciter Regulator Equipment (Sheet 1 of 4)

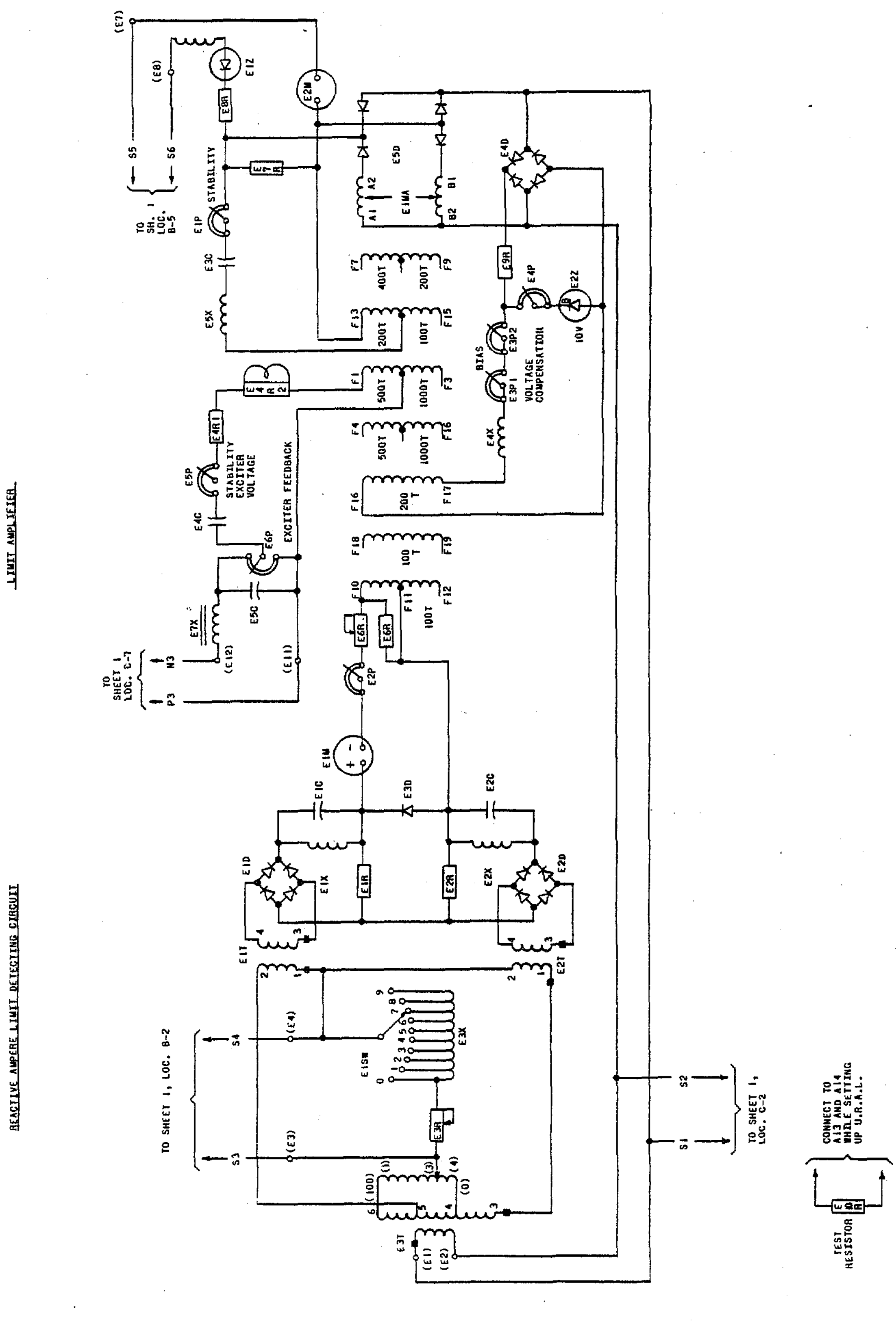



Figure 13 - Typical Elementary Diagrams of 3S7501FS141
Static Exciter Regulator Equipment
(Sheet 3 of 4)

NOTES

THE FOLLOWING ITEMS ARE FURNISHED ON THE RECTIFIER ASSEMBLY 3S7501FS141A1

| | |
|---|---|
| SHUNT | FIELD SHUNT, 100MV., 600 AMP |
| PBA | POTTED BLOCK ASSEMBLY, 44B314558-G01 |
| RECTIFIERS | POWER RECTIFIERS, 1N3741 AND 1N3741R |
| T1C,T2C | CAPACITORS, 25MFD., 600WVDC |
| T1R,T2R | RESISTORS, 560HM, 435 WATT |
| THYRITE | THYRITE RESISTOR, 9RV6A230 |
| ELEM-CONN | 44C303257 |
| OUTLINE | 44C303201 |

THE FOLLOWING ITEMS ARE FURNISHED ON THE REGULATOR PANEL 3S7931SA224A1 (PANEL A):

| | |
|---|---|
| A1Z | ZENER DIODE, 36 VOLT, 125 MA, 44B212755-006 |
| A1T | TRANSFORMER, 240 VOLT PRI., 160 VOLT SEC., 44B314075-001 |
| A1CD,A2CD | RECTIFIERS, 44B212741-009, C35E |
| A2SX,A2SX | SATURABLE REACTORS, 44B219907-001 |
| A2X | REACTOR, 3958584P1, 20 H., 25 MA DC |
| A3X | REACTOR, 44B210645-001, 0.8 H., 375 MA DC |
| 90R | RHEOSTAT, 75 OHM, 75 WATT |
| A6R,A9R | RESISTOR, 100 OHM, 10 WATT |
| A4RA | RESISTOR, 4700 OHM, 10 WATT |
| A4RB,A5RA<br>A5RB,A5RC | RESISTOR, 10,000 OHM, 10 WATT |
| A7R,A8R | RESISTOR, 22,000 OHM, 10 WATT |
| A4RC | RESISTOR, 1,000 OHM, 10 WATT |
| A1R | RESISTOR, 600 OHM, 20 WATT |
| A2R | RESISTOR, 200 OHM, 20 WATT |
| A3R | RESISTOR, 1,200 OHM, 20 WATT |
| A1P | POTENTIOMETER, 5000 OHM, 50 WATT |
| A2P | POTENTIOMETER, 10,000 OHM, 50 WATT |
| A3P | POTENTIOMETER, 250 OHM, 25 WATT |
| A4P | POTENTIOMETER, 250 OHM, 25 WATT |
| A5P | POTENTIOMETER, 75 OHM, 25 WATT |
| A6P | POTENTIOMETER, 2 OHM, 75 WATT |
| A1C | CAPACITOR, 50 MFD., 600 WVDC |
| A2CA,A2CB,A2CC | CAPACITOR, 10 MFD., 600 WVDC |
| A2CD,A2CE | CAPACITOR, 20 MFD., 600 WVDC |
| A1D,A6D-A11D | RECTIFIER, 1N1697 |
| A2D-A5D | RECTIFIER, 1N1206A |
| A1X | REACTOR, 44B219991-001, 1.5 H., 200 MA DC |
| 43SR | PUSHBUTTON, CR104A8102 |
| ELEM-CONN | 44D209431 |
| OUTLINE | 44B204757 |

THE FOLLOWING ITEMS ARE FURNISHED ON THE CONTROL PANEL 3S7932CD141B1 (PANEL C):

| | |
|---|---|
| ELEM-CONN | 44C303223 |
| 41S | CONTACTOR, 44A315565-001 |
| 41F | CONTACTOR, 44A315565-001 |
| C1D | RECTIFIER, 20 AMP., 400 P.I.V., 4JA3512DH1AD1 |
| C1R,C2R,C1RA,C2RA | RESISTOR, 5.4 OHM, 710 WATT |
| C3R | RESISTOR, 3.5 OHM, 710 WATT, TAPPED |
| C4R | RESISTOR, 33 OHM, 755 WATT, ADJ. |
| C5R | RESISTOR, 42 OHM, 755 WATT |
| C6R | RESISTOR, 26 OHM, 755 WATT, ADJ. |
| 90R5 | RHEOSTAT, 15 OHM, 300 WATT |
| 90R6 | RHEOSTAT, 25 OHM, 500 WATT |
| OUTLINE | 44A302630 |
| CWR1 - CWR3<br>SWR1 - SWR3 | RESISTOR ASM. 44A316002-G02 |
| OUTLINE DIAGRAM | 44C303201 |

THE FOLLOWING ITEMS ARE FURNISHED ON THE UNDEREXCITED REACTIVE AMPERE LIMIT PANEL, 3S7932KA118G2:

| | |
|---|---|
| E10R | TEST RESISTOR, 200 OHMS, 130 WATTS |

U.R.A.L. PANEL 3S7932KA118G1 ON WHICH IS MOUNTED:

| | |
|---|---|
| E1SW | 10 POSITION TAP SWITCH |
| E1R,E2R | RESISTOR, 200 OHMS, 130 WATTS |
| E3R | RESISTOR, 8.6 OHMS |
| E4R1 | RESISTOR, 10,000 OHMS, 85 WATTS |
| E4R2 | RESISTOR, 20,000 OHMS, 85 WATTS |
| E5R | RESISTOR, 240 OHMS, 85 WATTS |
| E6R | RESISTOR, 47 OHMS, 20 WATTS |
| E7R | RESISTOR, 510 OHMS, 85 WATTS |
| E8R | RESISTOR, 390 OHMS, 85 WATTS |
| E9R | RESISTOR, 1000 OHMS, 85 WATTS |
| E1C,E2C | CAPACITOR, 0.5 MFD, 2000 WVDC |
| E3C1-E3C9 | CAPACITOR, 500 MFD, 250 WVDC |
| E4C1 | CAPACITOR, 30 MFD, 600 WVDC |
| E4C2,E4C3 | CAPACITOR, 10 MFD, 600 WVDC |
| E1P,E2P | POTENTIOMETER, 500 OHMS, 50 WATTS, WIRE WOUND |
| E3P1 | POTENTIOMETER, 2500 OHMS, 50 WATTS, WIRE WOUND |
| E3P2 | POTENTIOMETER, 300 OHMS, 50 WATTS, WIRE WOUND |
| E4P | POTENTIOMETER, 150 OHMS, 50 WATTS, WIRE WOUND |
| E5P | POTENTIOMETER, 10K OHMS, 50 WATTS, WIRE WOUND |
| E1D,E2D | RECTIFIER, 378V, PIV, 1.25 AMPS DC, 6RS25PD6ACF |
| E3D | RECTIFIER, 37V, PIV, 1.25 AMPS DC, 6RS25PD1ADF1 |
| E4D | RECTIFIER, 490V, PIV, 3 AMPS DC, 4JA411EB1AD1 |

U.R.A.L. PANEL 3S7932KA118G1 (CONT):

| | |
|---|---|
| E5D | RECTIFIER, 490V, PIV, 3 AMPS DC, 4JA411EM1AD1 |
| E1VT | TRANSFORMER, VARIABLE, 115V, INPUT, 0-140V. OUTPUT, 50/60 CYCLE |
| E1T,E2T | TRANSFORMER, 115V, PRI., 115V. SEC., 075 KVA, 50/60 CYCLE |
| E5C1 | CAPACITOR, 1 MFD, 600 WVDC |
| E5C2 | CAPACITOR, 2 MFD, 600 WVDC |
| E6P | POTENTIOMETER, 5000 OHMS, 50 WATTS |
| E1M | METER, 30-0-30 MADC |
| E2M | METER, 250 VADC |
| E3T | TRANSFORMER, 130V. PRI., 102/68/34 SEC., 100KAV 50/60 CYCLE |
| E1X,E2X,E7X | REACTOR, 2.5 HENRIES, L8206585 |
| E3X | REACTOR, L-8206504 |
| E4X,E5X,E6X | REACTOR, 10 HENRIES |
| E1MA | MANGETIC AMPLIFIER, .090 KVA, 60 CYCLES |
| E1Z | ZENER DIODE, SV910,9-12 VOLT, 10 WATTS |
| E2Z | ZENER DIODE, SV912, 10-14 VOLT, 10 WATT |

CUSTOMER RELAY FUNCTIONS

| | |
|---|---|
| 1Y | - MASTER CONTROL RELAY-TIME DELAY |
| 2E | - EXCITER VOLTAGE TIMER |
| 2EX | - AUX. RELAY TO 2E |
| 4 | - MASTER CONTROL RELAY |
| 14HAX | - PICKUP AT 50% SPEED, DROPOUT AT 25% SPEED |
| 14HMX | - PICKUP AT 20% SPEED, DROPOUT AT 2% SPEED |
| 14HSX | - PICKUP AT 95% SPEED, NORMAL TRIP AT 75% SPEED & CUTS OFF FUEL. IMMEDIATE DROPOUT ON EMERGENCY TRIP. |
| 14HSY | - PICKUP AT 95% SPEED, DROPOUT AT 90% SPEED |
| 27G | - GENERATOR UNDERVOLTAGE RELAY |
| 52GX | - GENERATOR BREAKER AUXILIARY RELAY |
| 59E | - OVERVOLTAGE RELAY |
| 86G | - GENERATOR DIFFERENTIAL RELAY |
| 86T | - TRANSFORMER DIFFERENTIAL RELAY |
| 94 | - PICKUP ON NORMAL SHUTDOWN |
| 83SR | - VOLTAGE REGULATOR CONTROL - TRANSFER RELAY |

KEY

| | |
|---|---|
| + | - IF USED |
| ⊕ | - INSTRUMENT TRANSFORMERS ARE SHOWN CONNECTED FOR PHASE SEQUENCE 1-2-3. IF GENERATOR HAS OPPOSITE PHASE SEQUENCE, REVERSE CT SECONDARY LEADS. |
| * | - NOT FURNISHED BY G.E. CO., WAYNESBORO |
| H.S. | - INDICATES STUD END OF RECTIFIER CONNECTED TO HEAT SINK. |
| ◎ | - INDICATES CUSTOMER'S TERMINAL BOARD CONNECTION |

Figure 13 - Typical Elementary Diagrams of 3S7501FS141
Static Exciter Regulator Equipment
(Sheet 4 of 4)

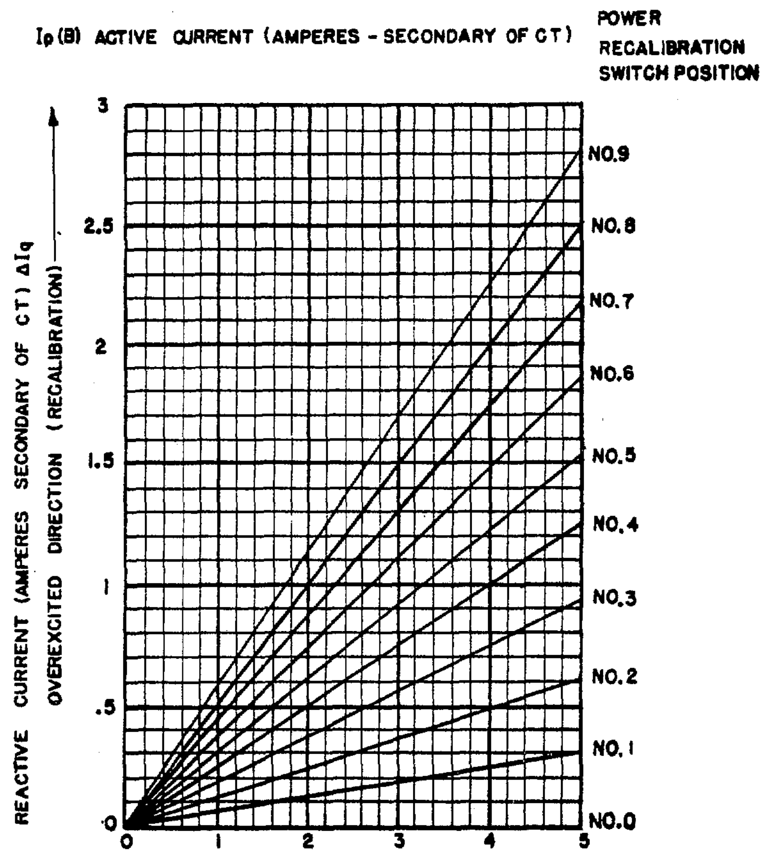



Figure 11. Calibration of Reactive-Ampere Power Recalibration Limit Circuit

## NORMAL OPERATION

### General

The complete voltage-regulator equipment should be placed in normal service with the AC machine only after the control circuits, regulators, and the reactive current compensator have been properly tested in general conformance with the previous described instructions. Final adjustment of these units may, of course, be delayed until operating experience has been obtained, but circuits which have not been thoroughly tested must not be employed with the automatic regulator in service if the possibilities of damage to the equipment and disturbance of the system are to be avoided.

With the automatic regulator in control of the AC machine excitation, the manual regulator voltage adjuster 90R6 is ineffective. However, additional excitation system reliability may be secured by proper adjustment of 90R6 when the automatic regulator is in control of a AC machine excitation.

For this purpose, it is recommended that a predetermined position be such that the AC machine excitation will be sufficient under all normal loads, give stable operation and avoid serious operating disturbances if the excitation system should be suddenly returned to manual control resulting in loss of the automatic regulator. It is suggested that this voltage adjuster position be selected so that when the excitation system is under manual control, it will produce rated AC machine current. It is essential that under any sustained load condition, 90R6 must be set to maintain sufficient excitation in the event of a sudden return to manual control.

The automatic regulator may be removed from service and the AC machine excitation returned to manual control under any load condition.

The proper adjustment of 90R5 is equally important when transferring from "on-line" to "off-line" condition and vice versa to prevent excessive generator armature voltages.

# MAINTENANCE

### PPT's and SCT's

These devices normally require little or no maintenance. It is suggested, however, that the air passages be inspected during shut down periods. Exposed connections should be inspected for corrosion and tightness.

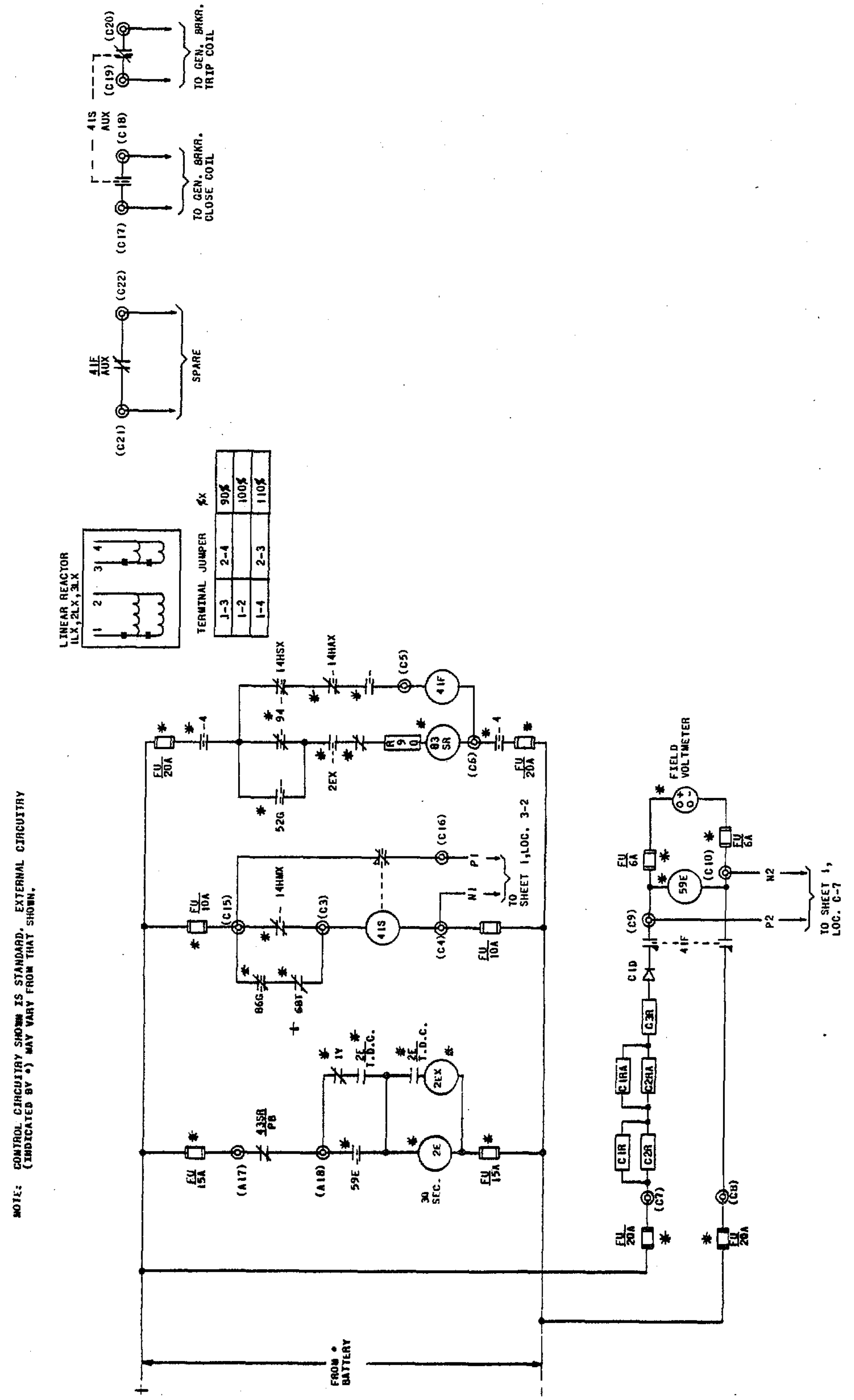



Figure 13 - Typical Elementary Diagrams of 3S7501FS141 Static Exciter Regulator Equipment (Sheet 2 of 4)

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