Pressurized Water Reactor
B&W Technology
Crosstraining Course Manual

Chapter 6.3

Rod Position Indication

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6.3 CONTROL ROD POSITION INDICATION

Learning Objectives:

1. State the purposes of the control rod position indication systems.

2. Explain the two methods used to determine control rod position.

3. Explain how the two rod position indication systems are used in the following:

   a. Asymmetric rod determination
   b. In, out limits
   c. Regulating group sequence enabling
   d. Inhibit circuits
   e. Sequence monitoring

6.3.1 Introduction

Two methods of position indication are used to monitor control rod position. The first method, absolute position indication (API), monitors the actual position of the control rod leadscrew in the motor tube. The second method, relative position indication (RPI), uses circuitry that monitors the input pulses to the control rod drive motor. Relative position indication is a demanded position indication.

6.3.2 Absolute Position Indication

6.3.2.1 System Description

There are 72 equally spaced (2 in. apart) reed switches mounted in a fiberglass housing that is strapped to the outside of the motor tube. The reed switches are closed by a magnet attached to the torque taker. As the leadscrew moves up and down, this magnet passes by the reed switches. A reed switch will be held closed whenever the magnet passes by. These reed switches are connected to a voltage divider network. As the reed switches open and close (because of the proximity of the magnet on the leadscrew), the resistance of the network changes. This varying resistance results in a variable current output from the network, which is then translated into the position indication.

6.3.2.2 Reed Switches

The current API design uses high differential reed switches. These switches (Figure 6.3-1(a)) are completely encased in glass, and the contact points are constructed of rhodium. Previous designs used a low differential reed switch with a gold plating on top of

the rhodium plating (Figure 6.3-1(b)). The change in design was due to the failure rate and sometimes erratic operation of the reed switches. The low differential switches had a tendency to build up a surface film on the contacts, which, combined with a small closing force resulting from the low differential gap, led to reed switch failures. In addition, the switches were prone to fluttering in stray magnetic fields.

The high differential switches give a more positive contact because of the higher closing force, thus reducing surface film buildup. The more positive actuation also minimizes the possibility of fluttering. A small penalty is paid in accuracy with this change; however, total system accuracy remains well within specifications.

6.3.2.3 Position Indicating Circuit

Previously designed indicating circuits used a two-channel averaging circuit as shown in Figure 6.3-2. As the leadscrew traveled up and down with the control rod motion, the reed switches would close in a 2-1-2-1 sequence. A failed-open reed switch, when the system was in the one-switch-closed configuration, would give an erroneous indication of a dropped rod and would initiate an automatic runback to 60% power resulting from an asymmetric fault condition (paragraph 9.3.5.1).

This system was designed with 48 reed switches evenly spaced along the motor tube. If a switch failure occurred, the entire assembly had to be replaced; no means existed for bypassing the failed switch.

The new design (Figure 6.3-3) uses 72 reed switches evenly distributed along the motor tube. The reed switches are located on two separate printed circuit boards of 36 switches each. The switches are divided into four separate isolable channels. The output from the four channels is averaged to obtain an output for the amplifier. The amplifier output is a 0- to 5-V signal, which produces a 0% to 100% indication on the position indication (PI) panel (Figure 6.3-5).

Up and down travel of the leadscrew closes the reed switches in a 3-2-3-2 sequence. This sequence enables the system to withstand a failed-open switch without incurring an asymmetric rod fault condition and to incur only a slight loss of accuracy in the immediate area of the failed switch. Two adjacent switches failing open would be required to give the asymmetric rod fault condition.

Production tests have shown that the worst-case error for normal system operation is 1.89% (2.62 in.). During a reed switch failed-open condition, the worst-case error is 2.56% (3.56 in.).

A switch failed-closed condition causes an asymmetric alarm, but not one of sufficient magnitude to cause a runback. Once the alarm condition is noted, maintenance personnel can locate, through troubleshooting procedures, the failed switch. The channel in which the

failed switch is located may be bypassed, allowing three-channel operation. The worst-case error in three-channel operation is 2.65% (3.69 in.).

6.3.2.4 Reference Switches

In addition to continuously monitoring rod position from 0% to 100%, three other groups of reed switches monitor the position of the control rods:

1. In limit and 0% zone reference switches: The In limit switch is actuated between 0.12 and 1.00 in. above the tripped position. The 0% zone reference switch is located 1.5 in. above the In limit switch. Each switch is adjustable (at the drive) over the first 2 in. of travel.

2. Out limit and 100% zone reference switches: The Out limit switch is actuated between 139.75 and 140.25 in. above the tripped position. The 100% zone reference switch is mounted 1.5 in. below the Out limit switch. Each of these is also adjustable within the last 2 in. of travel.

3. Three zone reference switches at 25%, 50%, and 75%: These switches are actuated at 34.75, 69.50, and 104.25 in. above the tripped position. (No visual indication of the three zone reference switches on simulator.)

Two switches are used near the full-out and full-in positions (1 and 2 above): one indicates that a particular control rod is nearing its full-out or in position, and the other stops further travel. The first rod in any group to reach the second switch stops further travel of all rods in that group.

6.3.3 Relative Position Indication

A pulse stepping motor is connected in parallel to the A, C, and BB phases supplying each mechanism (Figure 6.3-4). As the phases are energized to cause rod motion, the stepping motor turns. The motor drives a potentiometer, which produces a variable output corresponding to rod position. The system is extremely accurate, but it only reflects rod position as a function of field rotation. Thus, it will not show the correct position if a rod is tripped or dropped, or if it is stuck or binding mechanically. In such cases it will be necessary to adjust the RPI to agree with actual conditions. This is done with the reset pulser. An individual rod or rod group is selected with the group and single select switches, and the raise/lower switch on the PI panel is then used to adjust the indication. This is done by driving the pulse stepping motor(s) for the selected rod or group of rods with a pulsed 24-Vdc signal in place of the normal three- phase input.

6.3.4 Position Indication Panel

The position indication panel (Figure 6.3-5) is located on the control room wall in view of the operator near the Diamond control station. The panel provides: (1) a visual display for each of the 76 control rod drive mechanisms in scale percentage (0% to 100%) of withdrawal, (2) provisions for selecting an absolute position or a relative position signal for panel display, (3) a toggle switch for resetting the RPIs and, (4) display lights for the IN LIMIT, XFR CONFIRM (transfer confirm), OUT LIMIT, and ASYM ALARM (asymmetric alarm) signals for each rod.

6.3.4.1 Position Indication Meters

The position indication meters are used to indicate either the absolute or relative position of the control rods according to the position of the POSITION INDICATION SELECT switch.

The absolute position is an analog output of the PI tube assembly corresponding to the leadscrew position over the full travel of the control rod. The output is a 0- to 5-v analog signal, which is sent to the PI SELECT switch, where it may be selected for display on the PI meter for that rod.

The relative position is the analog output of a motor-driven potentiometer, which is buffered and amplified to supply a 0- to 5-v analog output directly proportional to the control rod position. The output is sent to the PI SELECT switch, where it may be selected for display on the PI meter for that rod.

The 0- to 5-v analog signal from the PI SELECT switch is indicated on the PI meter as control rod position in terms of percent withdrawn. A mechanical 0 adjustment is located on the side of each PI meter. The full-scale adjustment is made when a 100% withdrawn signal is present. The bezel is removed to gain access to the external full-scale adjustment potentiometer mounted at the bottom and front of each PI meter.

6.3.4.2 Position Indication Select Switch

When the POSITION INDICATION SELECT switch is in the ABSOL (API) position, the absolute positions of the control rods are sent to the PI panel and plant computer.

When the POSITION INDICATION SELECT switch is in the REL (RPI) position, the relative positions of the control rods are sent to the PI panel and the plant computer. Also, in the REL (RPI) position an RPI select signal is sent to the plant computer.

The 0- to 5-v analog API/RPI outputs to the plant computer are reduced to 0- to 100-mv outputs.

6.3.4.3 Relative Position Indication Reset Switch

The RPI RESET switch is installed to allow the resetting of the relative position indication after dropped rod or reactor trip events. Rod motion, in these cases, was not caused by an electrical signal; therefore, it was not sensed by the relative position indication.

When the RPI RESET switch is in the RAISE position, the RPI reset pulser pulses at slow speed in the withdraw direction. When the RPI RESET switch is in the LOWER position, the RPI reset pulser reverses and pulses at fast speed in the insert direction.

When the RPI RESET switch is in the RAISE or LOWER position, a group is selected by the GROUP SELECT switch on the control panel, and a rod or all rods are selected by the SINGLE SELECT switch on the control panel. There is an RPI reset enable signal for each group and each rod in the group selected.

When an RPI reset relay is energized, the output of the RPI reset pulser is coupled to the selected RPI amplifier and drives the potentiometer motor in the direction and speed selected by the RPI RESET switch.

The RPI amplifier relative position output is sent to the PI meter and used to align the RPI potentiometer to the actual control rod position.

6.3.4.4 Transfer Confirm Indicators

When one or more rods in groups 1 through 8 are transferred to the auxiliary SCR power supply, the XFR CONFIRM indicator for each rod is illuminated to confirm the transfer.

6.3.4.5 OUT LIMIT Indicators

An OUT LIMIT indicator is illuminated to indicate that the control rod has been withdrawn far enough to actuate the 100% withdrawn zone reference switch in the PI tube. The operator is alerted that the control rod is approaching the out limit switch.

6.3.4.6 IN LIMIT Indicators

An IN LIMIT indicator is illuminated to indicate that the control rod has inserted far enough to actuate the 0% withdrawn zone reference switch in the PI tube. The operator is alerted that the control rod is approaching the in limit switch.

6.3.4.7 Asymmetric Alarm Indicators

An ASYM ALARM indicator is illuminated to indicate that a control rod's absolute position is out of alignment with the group absolute position average by at least the amount of the asymmetric alarm setpoint.

6.3.5 Group Average Meters

The group average meters (Figure 6.3-6) are located near the Diamond control station. They provide a visual display for four group absolute average positions. The indicators display either the safety group (1-4) positions or the regulating group (5-8) positions; the selector switch for determining either average is located on the Diamond control station.

When the GROUP METER switch on the diamond control panel is selected to the S position, the safety-regulating relay in the PI select rack is energized to send the API group averages for safety groups 1-4 to group meters 1-4, respectively.

When the GROUP METER switch on the control panel is selected to the R position, the safety-regulating relay in the PI select rack is de-energized to send the API group averages for regulating groups 5-8 to group meters 1-4, respectively.

6.3.6 System Operations

6.3.6.1 Applications of Absolute Position Indication

Absolute position indication is applied in the following cases:

1. Asymmetric Rod

   Each rod in a group is compared with the group average. If a rod deviates by more than 7 in. (5%) from the group average, the ASYM ALARM light for that rod lights on the PI panel. A rod that is 9 in. (6.5%) from its group's average lights the asymmetry fault light on the Diamond panel and initiates a runback to 60% power.

   It is important to remember that the faulted rod is included in the group average calculation. For example, for a group that contains eight rods that are all initially 100% withdrawn, the group average is calculated as follows:

$$\text{Group average} = \frac{8(100\%)}{8} = 100\%$$

If one rod in the group is dropped, the group average calculation becomes:

$$\text{Group average} = \frac{7(100\%) + 0}{8} = 87.5\%$$

Because the group average has dropped to 87.5%, all the ASYM ALARM (7-in. fault) lights for the group will come on. The rod on the bottom is 87.5% from the group average, and the rods that are still fully withdrawn are 12.5% from the group average.

2. Group In and Out Limits (Figures 6.3-7 & 6.3-9)

   The first rod in a group to reach its out limit causes the group OUT LIMIT light on the Diamond panel to light. The group out limit prevents any additional out commands from reaching the programmer. The first rod in a group to reach its in limit causes the group IN LIMIT light on the Diamond panel to light. The group in limit prevents any additional in commands from reaching the programmer. This function may be bypassed for groups 1-7 with the IN LIMIT BYPASS pushbutton on the Diamond panel and is automatically blocked by a runback fault to ensure that the ICS can properly respond to an asymmetric fault. For group 8, no in motion is permitted when the IN LIMIT BYPASS pushbutton is depressed.

3. Sequence Enable (Figure 6.3-8)

   Regulating rod groups are normally operated with 25% overlap to provide uniform reactivity insertion rates. This overlap is accomplished through the use of the sequence enable circuits.

   a. Group 5 sequence enable: group 5 is permitted to withdraw if:

      (1) safety rods are out
      (2) group 6 is less than 25% withdrawn
      (3) group 7 is at its in limit

   b. Group 6 sequence enable: group 6 is permitted to withdraw if:

      (1) safety rods are out
      (2) group 5 is more than 75% withdrawn
      (3) group 7 is less than 25% withdrawn

c. Group 7 sequence enable: group 7 is permitted to withdraw if:

(1) safety rods are out
(2) group 6 is more than 75% withdrawn
(3) group 5 is at its out limit

4. Auto Inhibit Circuit

In addition to supplying the sequence enable logic, the out limits for groups 1-4 have an input to the auto inhibit circuit. All safety rods must be completely withdrawn before automatic rod control is permitted. (See Figure 6.2-6.)

5. Feed and Bleed Permits

The following rod position requirements must be met to satisfy the plant's feed and bleed permits:

(a) safety rods out (group 1-4 out limits)
(b) regulating group position - this requirement varies. The regulating group input to the feed and bleed permits may be bypassed with a key lock. The safety rod input cannot be bypassed.

6.3.6.2 Applications of Relative Position Indication

The relative position indications for groups 5, 6, and 7 are inputs to the sequence monitor (Figure 6.3-10). The sequence monitor checks the overlap between regulating groups. It only checks for too much overlap (i.e., one group moving in or out too soon in relation to the other groups) and is based on maintaining an even %ΔK/K insertion rate. It does not consider too little overlap.

The sequence monitor checks for greater than 25% overlap at discrete intervals. The following conditions result in a sequence fault:

1. Group 5 less than 80% and Group 6 more than 5%
2. Group 5 less than 95% and Group 6 more than 20%
3. Group 6 less than 80% and Group 7 more than 5%
4. Group 6 less than 95% and Group 7 more than 20%
5. Group 5 less than 95% and Group 7 more than 5%

In the event of an asymmetric fault, the first priority of the system is to automatically reduce power to less than 60%. To ensure this capability, RPI is used to monitor sequence faults. In the original design of the system, API was used to monitor sequence faults. As a result, a dropped rod could have resulted in a sequence fault that would have prevented the asymmetric fault runback by resetting rod control to manual. To avoid such an

occurrence, RPI is used as the input to the sequence monitor because it does not respond to a dropped rod.

6.3.7 Summary

Two types of control rod position indication are used in the current Babcock & Wilcox design. The first type, absolute position indication (API), has reed switches located outside the motor tube, which are actuated by a magnet attached to the torque taker on the leadscrew. Closure of the reed switches, which are connected to a voltage divider network, establishes a varying system resistance that is converted to a 0- to 5-v analog signal for meter indication. The second type of indication, relative position indication (RPI), uses pulses from the rod control system, which in turn drive a motor-driven potentiometer to produce a 0- to 5-V signal for position indication.

RPI or API can be selected for viewing on the PI panel, as determined by the position indication select switch. In addition, the PI panel contains for each rod indicating lights for rod out limit, in limit, asymmetric fault, and transfer confirm. The RPI reset switch is also located on the PI panel.

Group meters, located on the main control board, display the average positions of groups 1 through 4 or groups 5 through 8, as selected on the Diamond panel. RPI and API, in addition to providing 0% -100% control rod position indication, provide other control and interlock functions.

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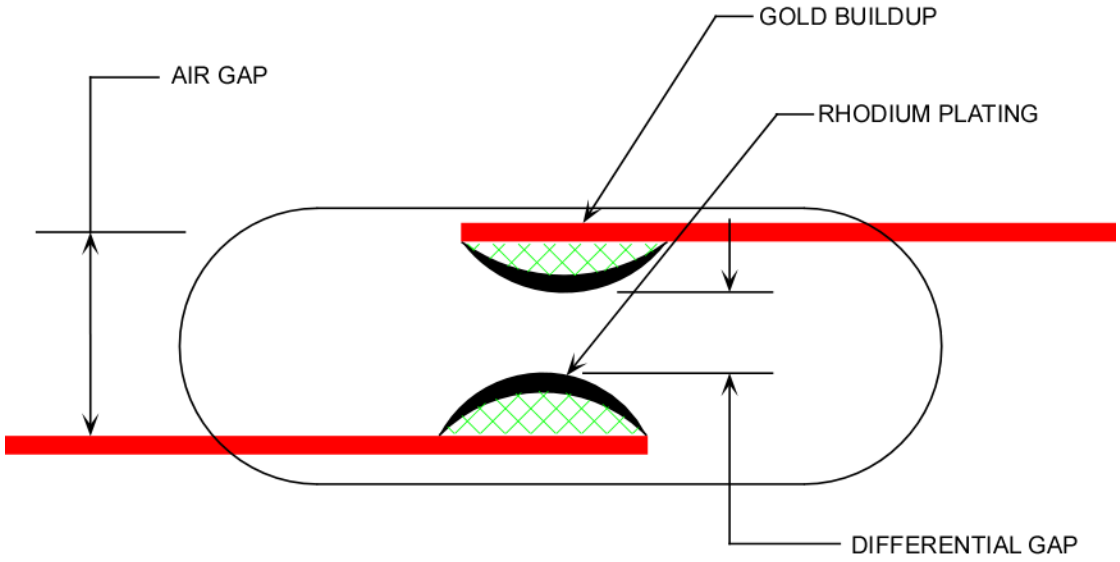
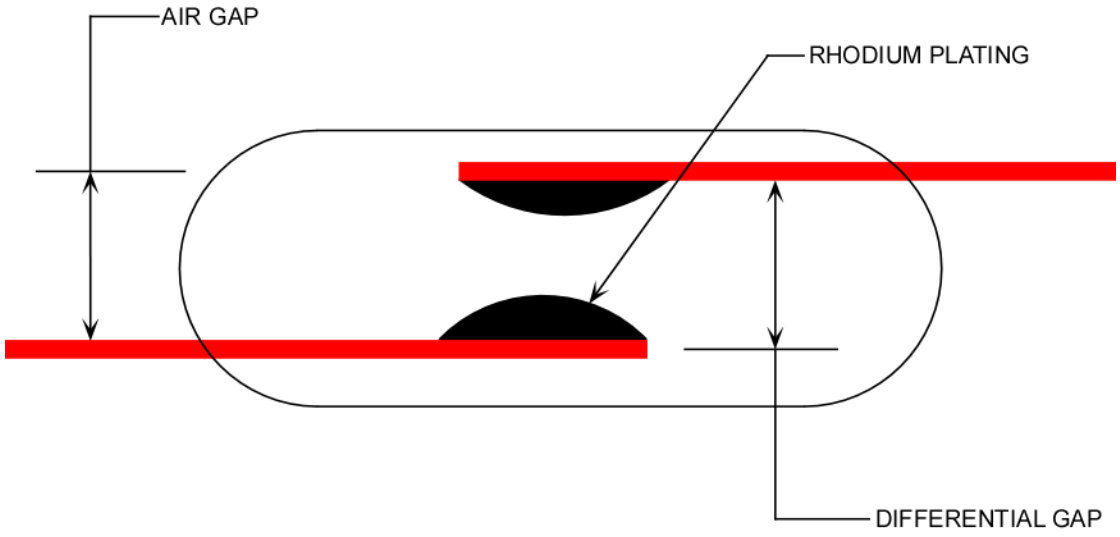


(b) **LOW DIFFERENTIAL SWITCH**



(a) **HIGH DIFFERENTIAL SWITCH**

Figure 6.3-1 Reed Switches

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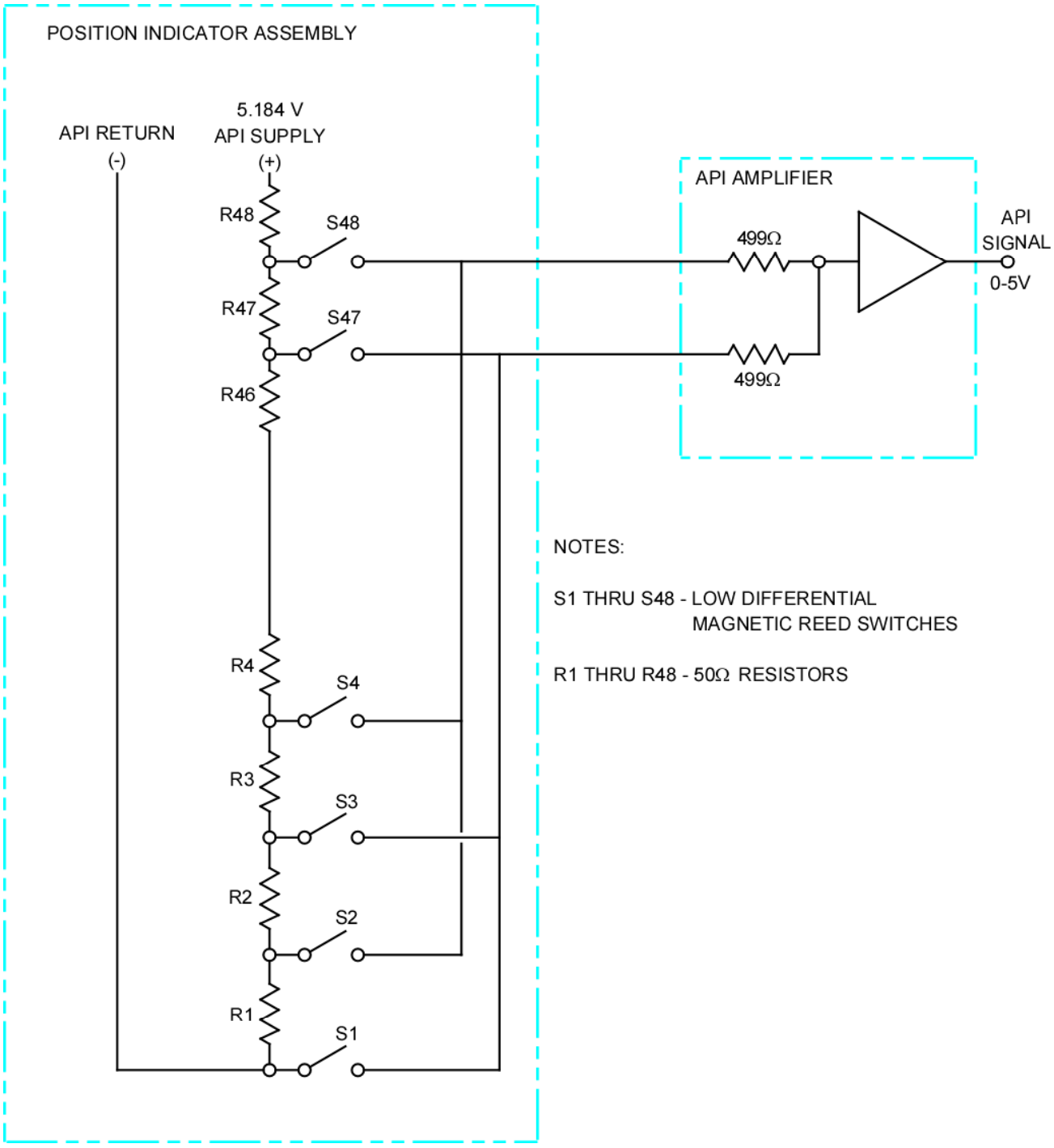

Figure 6.3-2 Absolute Position Indication (API) – Two-Channel Averaging

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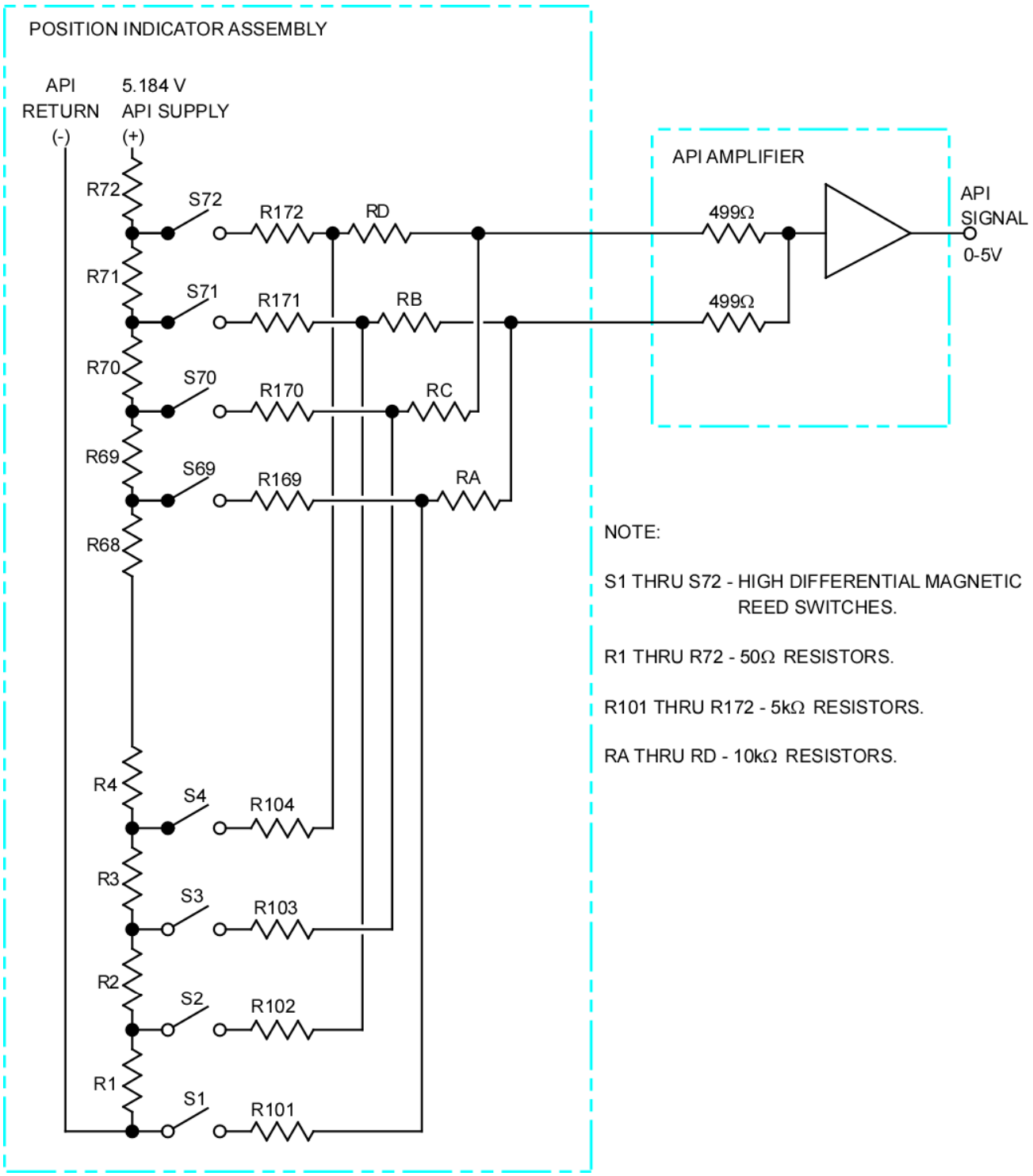

Figure 6.3-3 Absolute Position Indication (API) – Four-Channel Averaging

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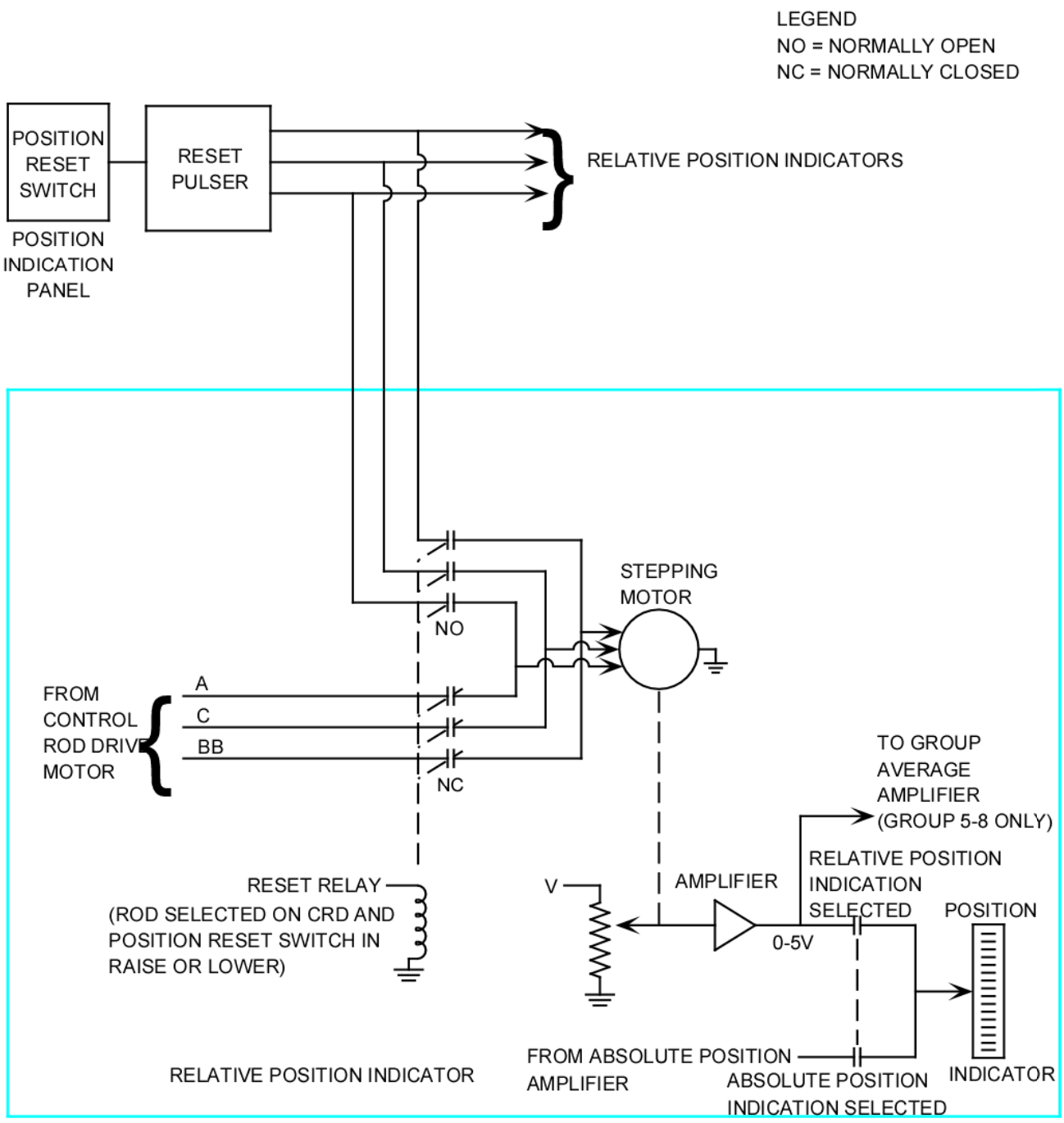

Figure 6.3-4 Relative Position Indicator

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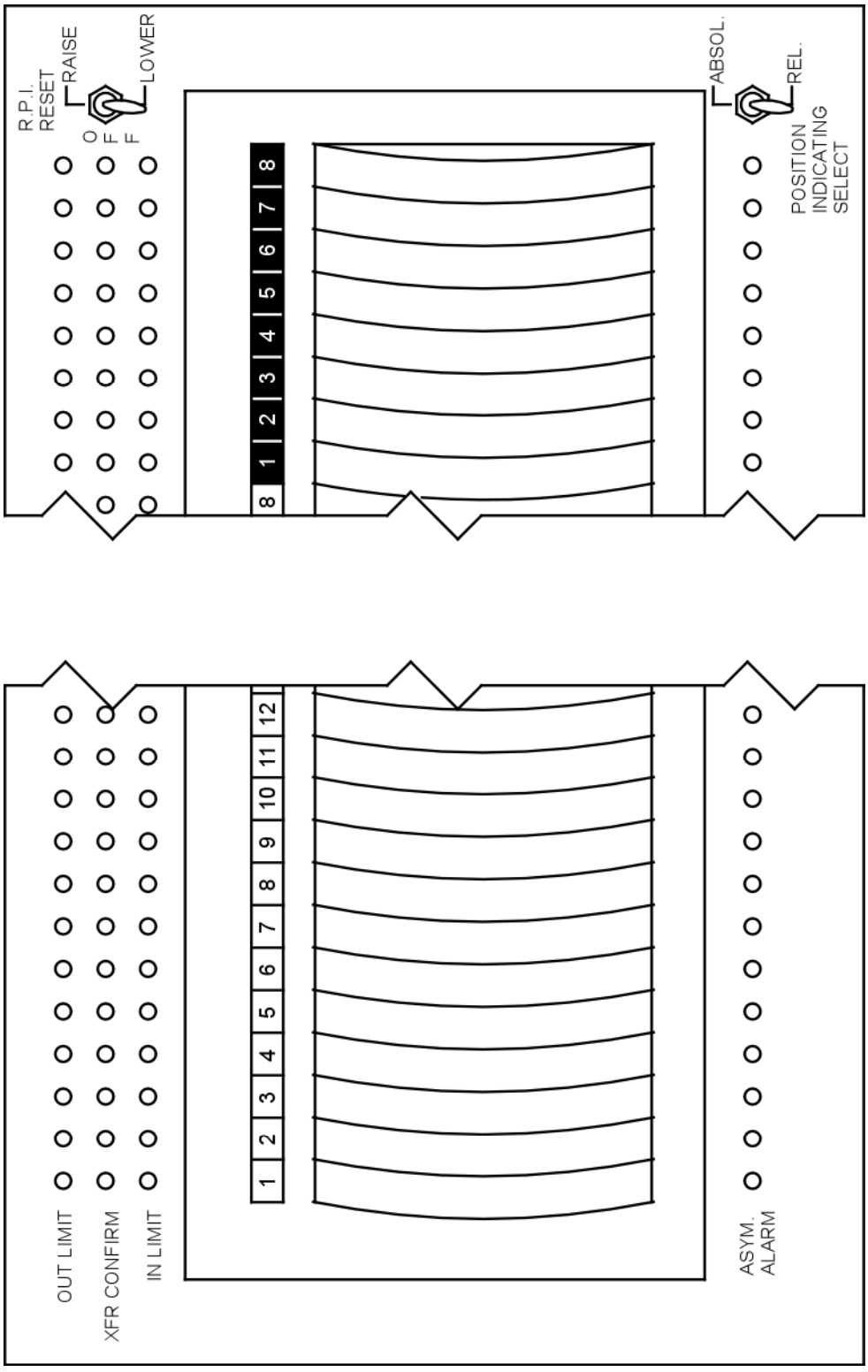

Figure 6.3-5 Position Indication Panel

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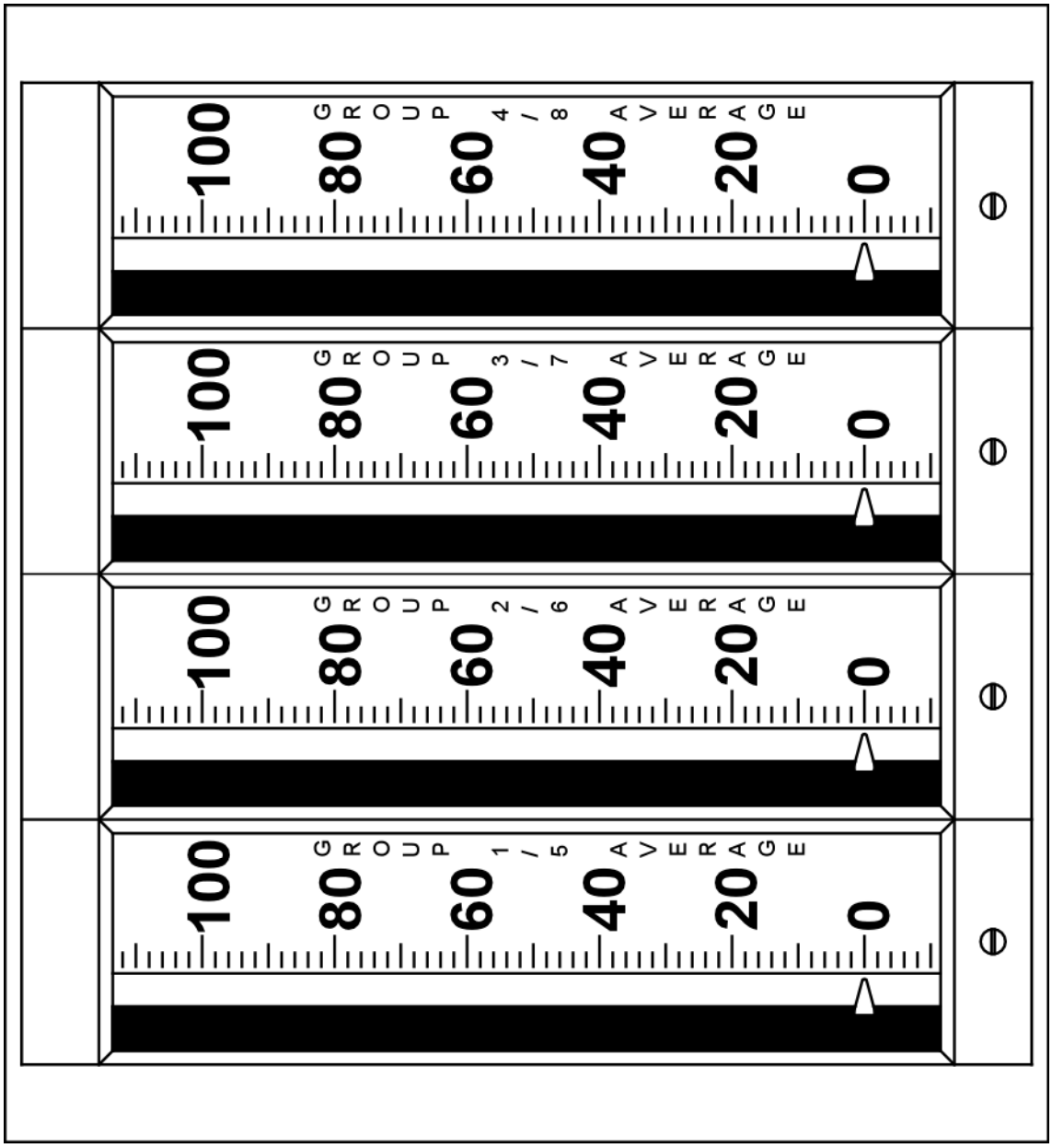

Figure 6.3-6 Typical group Average Meters

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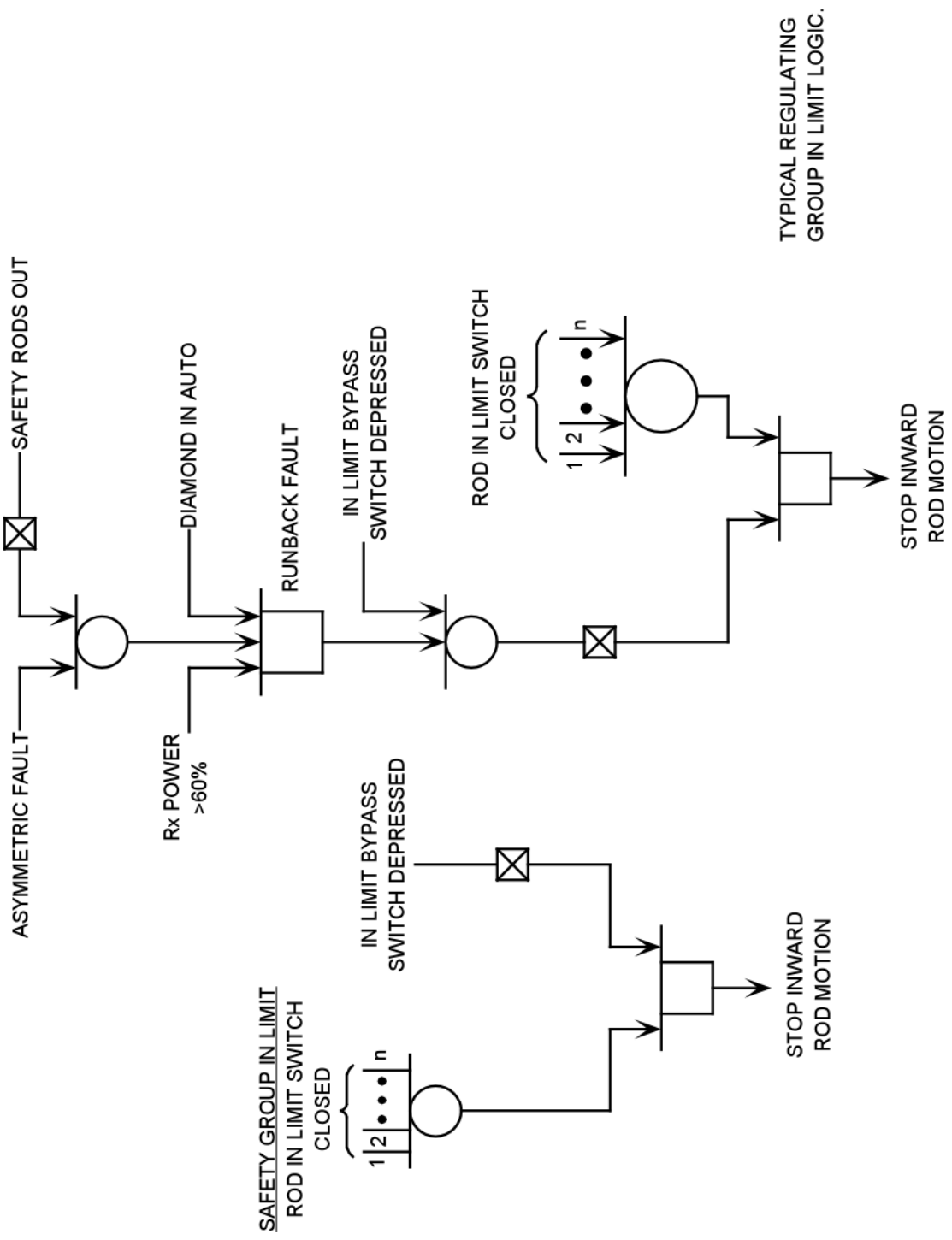

Figure 6.3-7 Inhibit Logic

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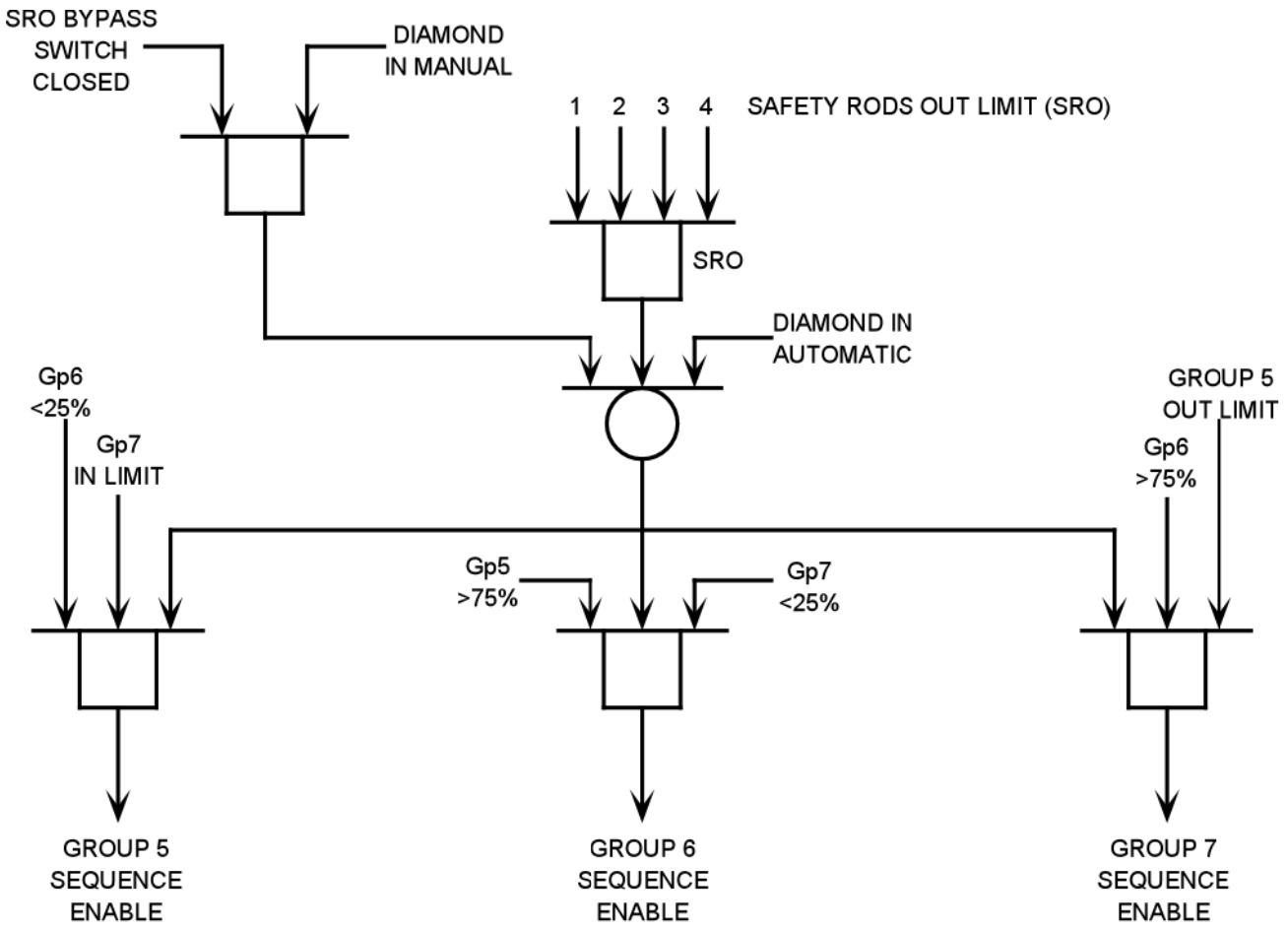

ALL POSITION SIGNALS ARE SUPPLIED BY THE ABSOLUTE ROD POSITION SYSTEM.

Figure 6.3-8 Sequence Enable Logic

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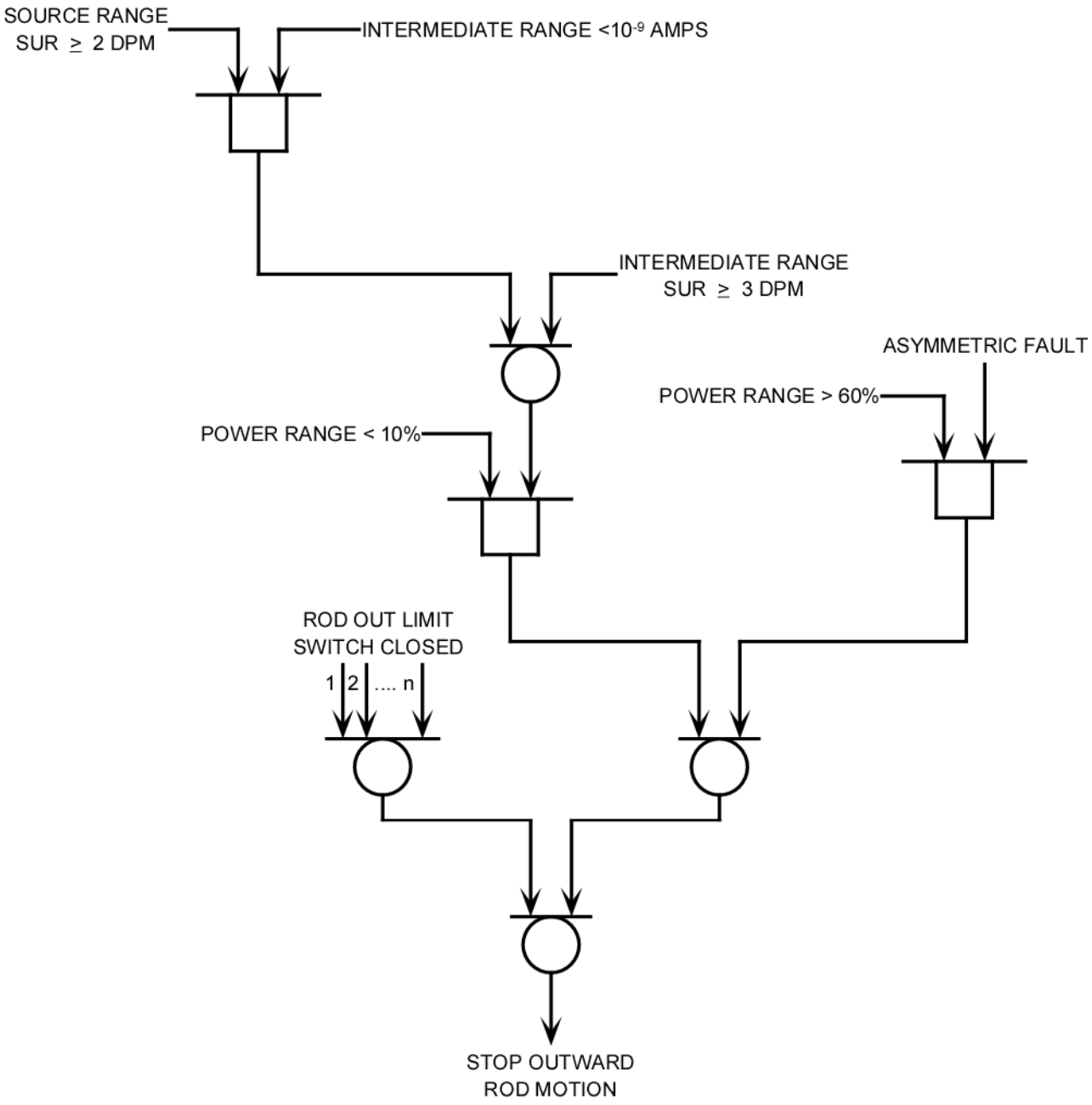

Figure 6.3-9 Out Inhibit Logic

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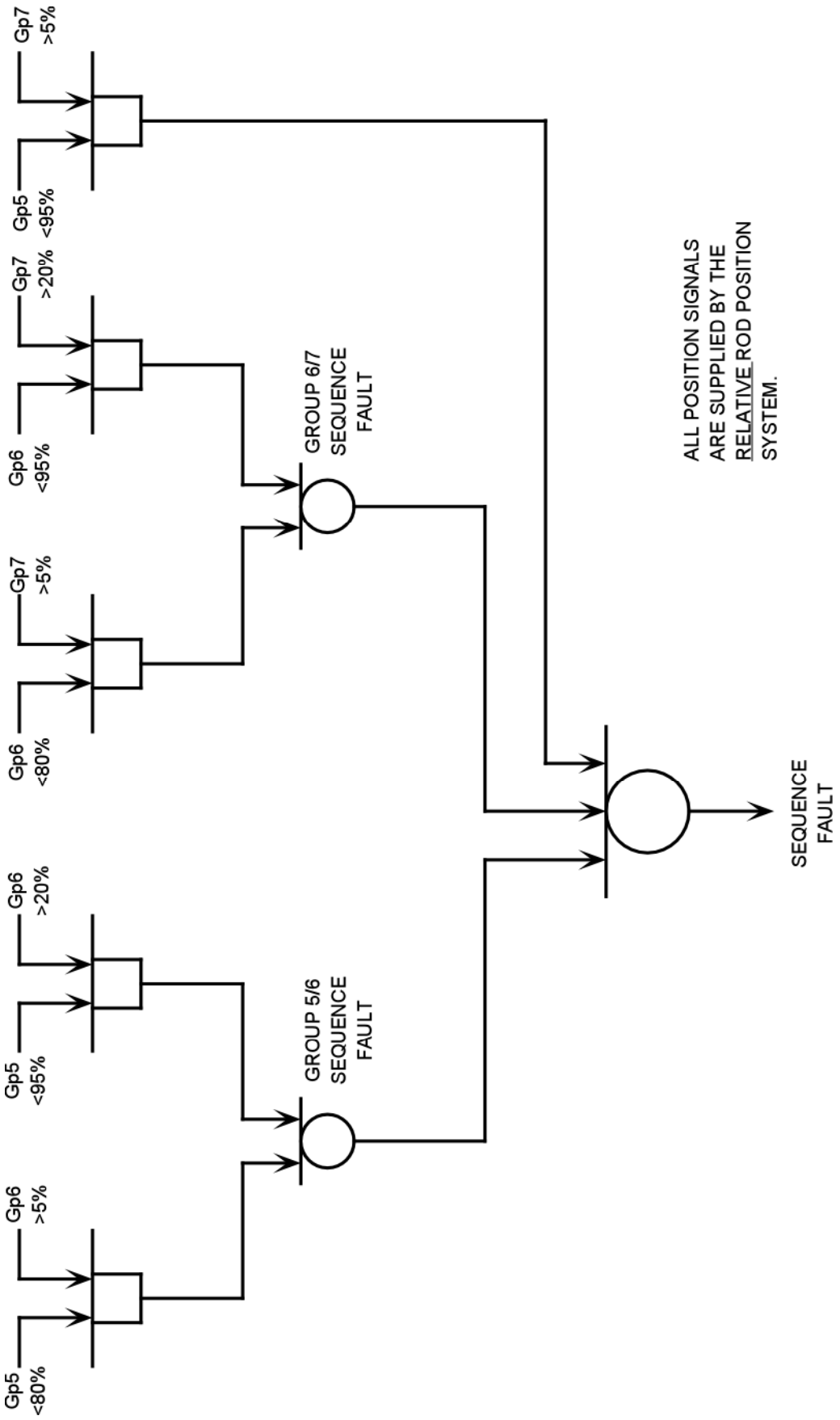

Figure 6.3-10 Sequence Fault Logic

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