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A Motor Drive Chassis for the Plutonium Protection System

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A MOTOR DRIVE CHASSIS FOR THE PLUTONIUM PROTECT SYSTEM

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ABSTRACT

A motor drive chassis has been developed for use in the Plutonium Protection System. Rotation of the desired carousel in a secure storage module is controlled by this chassis which supplies the power and drive pulses required by the carousel motor. This work was sponsored by the Department of Energy/Office of Safeguards and Security (DOE/OSS) as part of the overall Sandia Fixed Physical Protection Program.

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A MOTOR DRIVE CHASSIS FOR THE PLUTONIUM PROTECTION SYSTEM

Introduction

The Plutonium Protection System (PPS) is an item protection system that demonstrates advanced storage concepts which integrate detection and delay elements with careful monitoring and control of operational procedures. In addition, the accountability, operations, and security centers are physically separated to reduce vulnerability to insider threats. Organization of the PPS is illustrated in Figure 1. Five components of the PPS which are interconnected with a data communications network are:

- The Storage Vault -- An Item Control Area (ICA) in which advanced detection and delay elements reduce the vulnerability to insider and to forced entry threats. Personnel access is carefully controlled and the three control centers continually interact to assure the proper movement of material.
- The Container Module Packaging (CMP) room -- The point of entry to the PPS, where material is packaged into standardized containers to prepare it for storage. For this demonstration, the CMP room is under the direct control of the Material Operations Center; in actual application, its structure would be similar to that of the vault, with access control and interaction among the three control centers.
- The Material Operations Center (MOC) -- A control center which monitors and controls all operations involving movement of items in the system.
- The Material Accountability Center (MAC) -- A control center which maintains the accountability of all items in the system.
- The Security Operations Center (SOC) -- A control center which monitors and responds to all alarms in the system and controls personnel access to various parts of the system.

Movement of material between the CMP room and the vault is accomplished in a secure fashion by means of a Secure Transport Module (STM) which is essentially a minivault on wheels. The STM must be securely docked at a port in the wall of the ICA before material can be loaded or unloaded. The actual transport of material is carefully timed to minimize the time available for tampering or diversion.

Figure 1. Plutonium Protection System Organization

The focal point of the PPS is the vault, which includes a personnel entry corridor, alarm and assessment components, a protected computer, and a storage room that contains Secure Storage Modules (SSMs). The first three items carefully control access to the storage area, while the SSM provides physical barriers and alarms to detect any attempt to gain unauthorized access to the stored items once entry to the storage area is achieved. Figure 2 illustrates how the PPS has been set up in the Sandia Systems Integration Laboratory.

Figure 2. Plutonium Protection System/Systems Integration Laboratory

The SSM consists of four concrete cubicles, each housing a carousel containing 35 storage locations in 7 layers of 5 positions each. The storage locations are staggered so that the door assembly limits access to one location at a time. The carousel assembly must be rotated to present the desired storage location at the opening of the door so that the container can be removed or inserted. Following insertion or removal, the carousel must be rotated back to its original position which has been chosen so that no containers are fully exposed in the door opening (designated the "null position").

Each carousel is mounted on a worm-gear reduction gearbox drive by a bidirectional stepper motor. The Motor Drive Chassis described provides the power and drive pulses to the stepper motor under direction of the SSM Controller which determines the carousel to be rotated as well as the direction and angle of rotation. The SSM Controller sends a carousel-select code to the Motor Drive Chassis which activates the desired motor. Then the Controller sends a calculated number of pulses on CLOCKWISE or COUNTERCLOCKWISE lines to the chassis which drives the carousel motor the required number of steps in the desired direction.

Summary

The Motor Drive Chassis, located in the electronics enclosure at the top of the SSM, provides the power and pulses to drive the carousel stepper motors. Its primary components are two power supplies, four commercial printed circuit (PC) cards, and one Sandia-designed motor select card. The commercial cards (called Translators) provide the drive pulses to the stepper motors, one card for each motor. The Motor Select Card supplies the -15 V needed to power up the Translator card associated with a selected motor. Problems encountered with the Motor Drive Chassis are most easily corrected by using spare parts or cards.

PPS Motor Drive Chassis

General Description

Viewed from the front, the Motor Drive Chassis is located in the left end of the equipment bay of the SSM. Its primary function is to turn on the power to a given carousel motor and supply the drive pulses to turn the carousel as required.

The primary components of this chassis are a large negative 15-V dc supply (Standard Power Model SPS 120-15), a smaller positive 15-V dc supply (Standard Power Model SPS 30-15), four Superior Electric SLO-SYNTM Translator cards (one model STM 1800 V and three STM 1800), and one Sandia-designed Motor Select Card (Figure 3).

Figure 3. SSM Motor Drive Assembly

The -15 V supply provides power for the carousel motors and the +15 V supply provides power for the electronics circuits on the translator cards and motor select card. The Translator cards receive pulses which toggle the interconnected flip-flops in a given sequence, according to which input line is pulsed. The flip-flop outputs drive power transistors which are connected to the four windings of a motor. The Motor Select Card controls the -15 V power to the Translator cards, enabling their circuitry and output. This card also provides pull-up power for the incoming pulses.

Six Pygmy Triflock (PT) connectors are located on the back of the chassis and one ribbon connector on the side of the card cage, towards the rear. Connectors DJ1 through DJ4 and cards 1 through 4 are associated with carousels 1 through 4, respectively. Connector DJ6 provides incoming ac power which is switched by the AC Controller Chassis. Connector DJ5 brings out power supply voltages for sampling, if desired. Connector DJ7 is the ribbon connector which transmits the motor select signals and low-power drive pulses from the SSM Controller (micro-computer). Card 5 amplifies the motor select signals that select the proper Translator card, and provides pull-up resistors for the motor drive pulses.

Detailed Circuit Description

When the FSM is in the background mode, where only mask monitoring is being performed, no ac power is supplied to the Motor Drive Chassis. When a carousel must be turned, the AC Controller supplies power through connector D16 (see Dwg T4255a, Appendix). The power supplies are now energized, supplying -15 V dc to the carousel motors through their respective resistors. Positive and Negative 15 V dc is also supplied to the PC cards.

The micro computer then selects which carousel to turn. This signal comes in through Connector D17 to card 5 (see Dwg T4187a, Appendix, for card 5 schematic). The base of the selected transistor in Circuit U3 is pulled down to ground, turning on the transistor and the associated transistor (Q1, Q2, Q3, or Q4). The collectors of Q1 through Q4 are connected to the -15 V dc (pin N, Dwg CK-T58701) terminal of Translator cards 1 through 4 respectively, and thus supply -15 V dc to the card associated with the selected carousel.

The flip-flops on the Translator card (Dwg CK-T58701, Appendix) are now active and will forward-bias the bases of two of the power transistors (Q5 through Q8) connected to the motor. These in turn draw current through two motor windings. Anytime a motor is selected, two output transistors conduct current.

Motor drive pulses are supplied by the microcomputer through connector D17. These pulses are generated by open collector circuits pulling down the +15 V provided by the pull-up resistors in Circuit U1 of the Motor Select Card (Dwg T4187a). If the carousel is to be driven toward a lower number position, the drive pulses come into pin R of the Translator card; if to a higher position, they enter through pin S.

The Translator card consists of two flip-flops and four power output transistors (Dwg CK-T58701). Card 1 also contains an oscillator, described later. The trigger circuits are coupled between the two flip-flops in such a way that the flip-flops change states in one sequence when pulses are applied to pin R and a reverse sequence when pulses are applied to pin S.

Each output transistor is connected to an individual winding on the carousel stepper motor. At any time that a given motor is selected, two transistors are conducting and the other two are off. The bases of these transistors are driven either low or high as the associated flip-flops change state, alternately supplying power to their respective windings. A 1.5-ohm resistor located next to the drive motor is in series with the motor to limit the current. Diodes CR15 through CR18 suppress surges to protect the output transistors.

Card 1 is a model STM 1800 V whereas cards 2, 3, and 4 are model STM 1300. The STM 1800 V has an oscillator circuit (which is boxed in on Dwg CK-T58701) that can provide drive pulses to the motor drive circuits. Although this card will operate in positions 2, 3, and 4, only connector D18 is wired to this circuit (Dwg CK-T4255a). Operation of this circuit is described in troubleshooting section.

Connectors DJ1 through 4 transmit motor power to the four carrousels. Pin A transmits the -15 V dc motor excitation, pins B through E connect to the motor windings, and pin F provides a signal ground connection which is presently not used.

Troubleshooting

General -- The Motor Drive Chassis has four major active components which may fail: the +15 V supply (PS1), -15 V supply (PS2), Translator cards (cards 1-4), and the Motor Select Card (card 5) (Figure 3). Fuse F1 is also likely to fail and probably should be the first component checked.

If the carrousels are not turning properly, the trouble can be isolated by disconnecting the AC Controller end of the cable to connector DJ6 and plugging it into the enclosure outlet strip. The power supplies should now have 115 V ac going to their transformer terminals. If not, replace fuse F1.

Check the power supply voltages either at their terminal boards or at Connector DJ5. Pin B of connector DJ5 should be +15 V dc and pin C -15 V dc both with respect to pin A; if not, refer to Specific Problems, below.

Disconnect the ribbon cable from Connector DJ7 and make certain there is a model STM-1800-V Translator card in position 1. String a short cable with dual, 26-pin in-line connectors at both ends to Connector DJ7. A 100 k-ohm potentiometer between pins 25 and 26 controls the frequency of the oscillator on card 1. Pin 24 carries the oscillator output pulses which will be transmitted to one of the pins from 1 to 8, according to which carrousel is to be turned and the direction it must be turned. Shorting pin 24 to pin 1 will cause carrousel 1 to rotate to a lower position number and shorting it to pin 2, to a higher position. The same order applies to carrousels 2 through 4 (Dwg CK-T42558). NOTE: The waist bolt must be lifted either manually or by computer command before the carrousel can move.

Pins 9 through 12 of Connector DJ7 are the lines which select motors 1 through 4 respectively. These lines must be shorted to ground, available on pins 15 and 16, to send power to the desired motor. If the previously described connections have been made, then that carrousel should turn.

If the carrousels rotate properly with this setup, then the problem is in the SSM Controller or the wiring to it (see SAND78-0384 and SAND78-0689). If the problem still exists, see Specific Problems, below.

Specific Problems -- Problems encountered to date have involved the -15 V power supply (PS2), some Translator cards, and the Motor Select Card.

The greatest trouble with PS2 has been caused by transistor Q5, which is in the current-limiting circuit (CK-T58700, Appendix). The first symptom normally observed is erratic movement of the carrousel; the carrousel may move properly in the high speed mode, but may not move in the low speed mode. The voltage from PS2 can be observed on its terminal board, on Connector DJ5 pin C, or Connector DJ12 pin M. This will generally be -15 V when no motors are selected, but may drop to -5 V or -7 V when a motor is selected. This problem often does not appear until PS2 has been on for some time. When it occurs, either replace the whole Motor Drive Chassis, replace PS2, or replace transistor Q5 with a 2N3404 or higher-powered NPN transistor. If none of these options are available, transistor Q5 can be removed, eliminating any current-limiting capability.

The bridge rectifier (CR1) of one power supply has failed, resulting in little or no output voltage and the inability to rotate the carrousel. Remedies include replacing the entire Motor Drive Chassis, the affected power supply, or the bridge CR1.

Problems experienced with the Translator cards have been either a shorted or an open power transistor. In this case, the carrousel does not move, although humming in the motor may be detected when drive pulses are applied. Probably failure of these transistors has been caused by improper functioning of other components, such as PS2 not outputting full voltage or the motor select transistors on card 5 not fully turning on.

The quickest way to check for a Translator card problem is to replace the appropriate card with a spare or one of the first four cards. Card 1 through 4 drive carrousel 1 through 4. Although card 1 can be interchanged with the other cards, local checkout as described in Trouble-shooting, General above cannot be performed without a type STM 1800 V card in the first slot.

Two problems have been encountered with the Motor Select Cards (Dwg T41878). Originally, transistors Q1 through Q4 were placed so close together that two of their cases touched. This caused two motors to be selected when either of these transistors was turned on, exceeding the current limit of PS2, and so reducing its voltage that the carrousel would not turn properly. This may have caused some of the power supply problems mentioned previously. If this problem is suspected, pull card 5 and inspect the positions of Q1 through Q4. Card version A02 should not have this problem.

Another problem with the Motor Select Card apparently has been caused when some transistors used for Q1 through Q4 do not have enough gain, causing the transistors to be unsaturated, creating several problems. One is that the faulty transistor can dissipate more power than it should, eventually failing. This failure generally results in a short from the collector to the emitter effectively leaving that one carrousel motor selected and symptoms similar to the touching-transistor problem will be seen when any other carrousel is selected.

Another problem that can be caused by a weak motor select transistor is faulty flip-flop operation on the Translator card. This may result in intermittent or no carousel rotation. Another possible effect may be that the power transistors on the Translator cards are not driven into saturation. This causes them to dissipate more power until they fail, with the symptoms noted above. Replace the Motor Select Card with a spare if it is suspected; a faulty card of this type may have caused a Translator card or PS2 to fail.

If all PC cards and power supplies appear to be functioning properly, inspect the wire wrap pins on the back of DJ7. These pins have been found bent, shorting each other; sometimes their wires have been broken.

This chassis is easy to disconnect from the system, and we recommend that it be exchanged if a simple PC card replacement does not solve the problem.

APPENDIX
Wiring Diagrams and Schematics

SCHEMATIC

Printed Wiring Board, Motor Select Card (T41878)

NOTES:

▷ THIS CIRCUIT NOT ON STM-1800.

Schematic, Motor Translator Card, STM-1800V (CK-T58701)

Schematic, -15 V Supply, SPS 120-15, SSM Motor Drive (CK-T58700)

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