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#### FINAL REPORT

FOR

SOLID STATE SWITCH PANEL

26 NOVEMBER 1973



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#### ABSTRACT

An intensive study of various forms of transducers was conducted with application towards hermetically sealing the transducer pick off and all electronics. The results of the study indicated that the Hall effect devices and a LED/phototransistor combination were the most practical for this type of application. Therefore, hardware was developed utilizing a magnet/Hall effect transducer for single action switches and LED/phototransistor transducers for rotary multiposition or potentiometer applications. All electronics could be housed in a hermetically sealed compartment. A number of switches were built and models were hermetically sealed to prove the feasibility of this type of fabrication. One of each type of switch was subjected to temperature cycling, vibration, and EMI tests. The results of these tests are indicated in the following report.

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#### RESULTS

The results of this project are:

- 1. An operating switch panel conforming to the requirements of NAS-9-13144.
- 2. Test data taken during environmental tests performed on selected switch and rotary components. The tests performed were comparable to tests run on NASA flight hardware delivered on the skylab project. Satisfactory results were obtained on all tests.
- 3. Reliability data indicating MTBF for selected devices.
- 4. A project report covering the study phase of the project and containing test data, schematics, and outline drawings of the switch devices and the mounting panel.

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### CONCLUSIONS

The results of this project indicate that solid state switches and rotary components capable of meeting the requirements of manned space flight are feasable and well within the current state of the art. The environmental and reliability data indicate that a production unit would have the superior reliability associated with solid state equipment. The large selection of contact closure types will allow switches to be fitted to various requirements. A phase II production type unit would be packaged in a smaller and lighter housing. The feel of each switch and the front panel appearance would be improved in the phase II design.

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#### RECOMMENDATION

The study indicated that the most efficient switch is one designed to switch a specified voltage and current. Using a high current switch to handle a low current is inefficient. Any production switches should be designed for a specific power level.

In production quantities a hybrid package containing all the electronics is recommended as a way to save size and increase reliability of the solid state switch devices.

Reduction of switch size would allow the toggle section of the switch to be brought flush to the panel surface and otherwise improve the appearance of the switches.

It is also recommended that a closer analysis of the front panel removability criteria be made with an effort to reduce the panel area used for fastening.

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#### INTRODUCTION

The purpose of this report is to summarize the results of a study conducted to determine the optimum transducer type and output circuitry for a solid state switch configuration and to demonstrate with hardware, the feasibility of the resulting designs. Two basic types of switches are required, a single action switch (toggle, pushbutton) and a multiposition rotary switch and/ or potentiometer. The switches will be designed to be hermetically sealed and removable as an integral unit from the front of the panel. Selected switches contain a Light Emitting Diode (LED) display indicating the status of the switch position and/or operable or failure mode.

The various types of transducers studied included the following:

- Light
- Capacitive
- Hall effect
- Magneto-resistor

Many factors were considered in selecting the appropriate transducer for the application and the necessary circuitry for the switch output. They were as follows:

- Type of excitation required
- Power required
- Cost
- Size
- Reliability
- Hermetic sealing capability
- Cross talk effects
- Packaging
- Switching characteristics

A matrix indicating these characteristics of the various transducers are shown in Table I.

		INANSDUCER MAINIX		
	LIGHT	CAPACITANCE	HALL EFFECT	MAGNETO RESISTOR
POWER	.150 WATTS	.100 WATT	.050 WATT	.050 WATT
EXCITATION	DC 5-10V	AC 10 KHZ	DC 5-10V	DC 5-10W
COST	MODERATE	HIGH	LOW	MODERATE
CROSS TALK	NONE	PROBLEM AREA	NONE	NONE
HERMETIC SEAL	PROBLEM AREA GLASS TO MET- AL SEAL	PROBLEM AREA GLASS TO MET- AL SEAL	COMPATABLE	COMPATABLE
SIZE	MODERATE	LARGE	SMALL	MODERATE
COMPONENTS	TWO SILICON SEMI-CONDUC- TORS AND GLASS SEAL	TWO SEALED METAL PLATES AND DRIVE CIRCUITRY	ONE INTEGRA- TED CIRCUIT AND MAGNET	ONE SEMI- CONDUCTOR AND DRIVE CIRCUITRY
SWITCHING CHARACTERISTICS	REQUIRES TRIGGER	REQUIRES TRIGGER	TRIGGER PART OF IC	TRIGGER REQUIRED

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TABLE I. TRANSDUCER MATRIX

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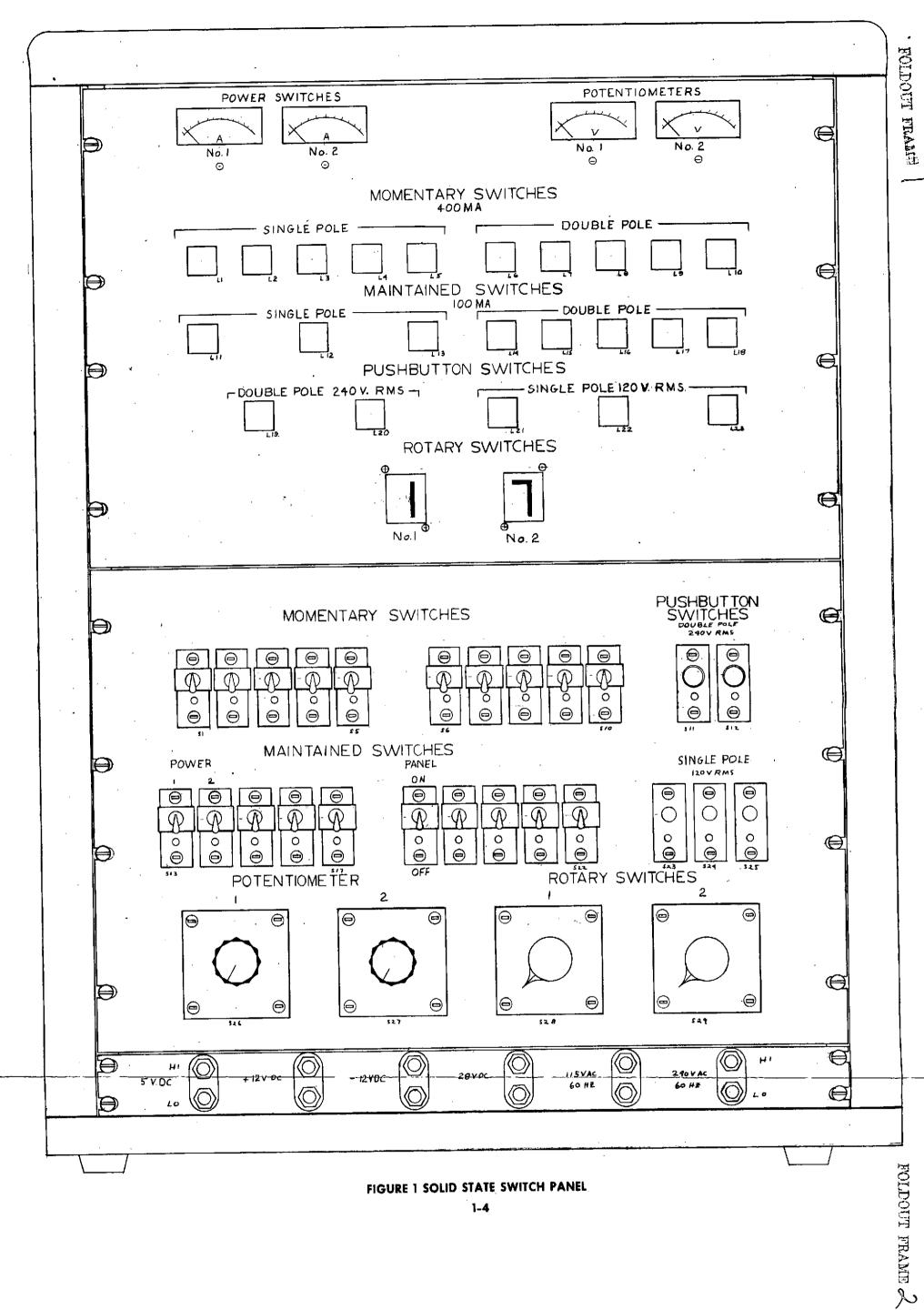
The results of the study indicated that the Hall effect transducer is the most effective for the single action switch and the LED/phototransistor is the optimum device for the multiposition rotary switch and potentiometer.

Dependent upon the function of the switch, four types of output circuits were selected to interface with peripheral equipment. The determining factor in the circuitry was the contact rating of the switch.

•	High current	DC	(10 AMP)
•	Medium current	DC	(400 MA)
٠	Low current	Analog	(50 MA)
٠	Low current	AC	(I AMP)

To insure reliable operation, redundant circuitry has been included wherever size and circuitry dictates practicability. The subject of man-hardware interface has not been discussed because standard mechanical switch actuating devices are used for inputs with normal actuating pressure loads and travel.

Envelope drawings and schematics are included in the appendices (Section 8) indicating the design approach configurations for the Phase I program. Production versions of these modules would require some modification for facility of fabrication and appearance. As a result of the study program, a panel was fabricated including 25 single pole or double pole toggle and pushbutton switches, two rotary 10 position switches and two potentiometers as indicated in Figure 1.



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#### TECHNICAL DESCRIPTION

The following four basic areas were studied in order to produce the required switch/potentiometer configurations for the switch panel:

- Transducers
- Mechanical Packaging
- Output (switch contact) circuitry
- Solid state potentiometer circuit configurations

#### TRANSDUCERS

Many types of transducers were evaluated to determine the optimum switch transfer. For each transducer the source and sensor of the switching medium is discussed along with the various configurations.

#### MAGNETIC CIRCUIT TRANSDUCER

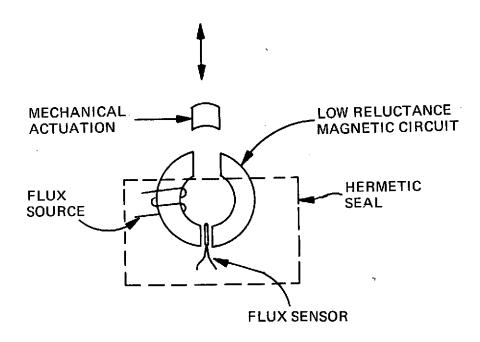
A magnetic circuit transducer depends on changing magnetic flux for switching action. A mechanical switch change occurring external to the hermetic seal changes the reluctance of the magnetic circuit. This flux change is sensed inside the hermetic seal and interfaced with the logic section of the switch. Both alternating and direct flux devices have been reviewed.

#### DC Devices

The flux flows in only one direction in a direct flux circuit and is a function of the following relationship.

$$\Phi = \frac{MMF}{R}$$

A change in the flux is sensed and a typical simple switch is illustrated in Figure 2. With the switch open as in Figure 2 a high reluctance air gap exists in the magnetic circuit. If the missing slug is moved into the gap, the reluctance is diminished. This increases the flux and changes the characteristics of the flux sensing element. Two sources of mmf appear most appropriate for switch applications: permanent magnets or solenoid coils. Permanent magnets require the following characteristics to be effective.



#### FIGURE 2

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• Small size

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- High induction
- High demagnetization force

Of the present commercially available magnetic materials, the following best suit these characteristics:

- Ceramic permanent magnets
- ALNICO SERIES\*
- Gecor\*

The life characteristic of these materials (time of retention of useful magnetic properties) has been estimated at approximately 15 years.

Solenoid coils require electrical power in order to operate. However, these devices utilize materials which are more readily available than magnets and do not require any special handling techniques as is sometimes the case with magnets. Of the flux sensing elements available the following exhibit the most suitable properties for switch application:

- Pick up coil
- Hall effect device
- Magnetic resistor
- <u>Pick Up Coil</u> The simplest of the three devices is a pick up coil which is a coil of wire of many turns wound around the magnetic core. This coil does not require a gap in the magnetic circuit which greatly increases the reluctance and, therefore, reduces the magnetic strength required. Many magnetic materials can be used for this application. The greatest disadvantage of using a pick up coil in a direct flux circuit is the fact that a coil can only sense a change in flux. Therefore, an output voltage would only be available from the coil during switching transition. After the coil has reached a different steady state valve as a result of the new switch position no voltage is present at the coil. The logic necessary to sense these

\*Trade name of a General Electric Co. product

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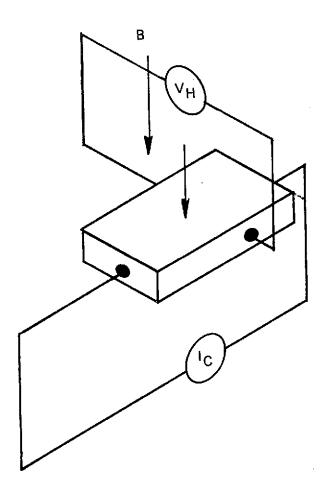
transient pulses is relatively simple, however, the problem exists in the initial start up procedure. The use of this device is limited to momentary switch applications where the switch mode of operation is in the normally off condition.

- <u>Hall Effect Device</u> The Hall effect element is a semiconductor device that generates a voltage as a function of control current and magnetic field. As illustrated in Figure 3 control current is passed through one axis of the semiconductor. The Hall voltage will appear perpendicular to the control current at the edges of the semiconductor chip. This voltage will be a function of the magnetic flux passing through the chip perpendicular to both control current and the output voltage. In the switch application, this voltage is used to control the switch output. The advantages of the Hall effect device are:
  - Small size
  - Detection of steady state flux levels
  - Life and reliability similar to silicon semiconductors

Because the Hall effect device has a relatively low output voltage (in the order of 50mv) an amplification stage is necessary as an interface between the transducer and the switch output circuitry. The control current required for the Hall effect device is approximately  $5 \rightarrow 50$  MA. The Hall effect device is made very thin (.006 inches typical) in order to retain a high flux density across the Hall device in the on condition.

A device available from Honeywell Microswitch incorporates a Hall effect device and an amplifier and trigger circuit in one integrated chip. This device operates on low levels of flux and provides as an output two current sinks. In addition to being small and sensitive this magnetic switch requires very little power to operate (30 mw max. at 5 volts). This power level is equivalent or lower than most flux sensing devices made of discrete parts.

The device has been designed to operate over the standard Military temperature range (-55°C -- +125°C) and is available off the shelf from Micro-Switch. The device is sensitive enough that no specific flux path need be incorporated in the hermetic seal. The switch will sense



V<sub>H</sub> = HALL VOLTAGE I<sub>C</sub> = CONTROL CURRENT B = FLUX

#### FIGURE 3

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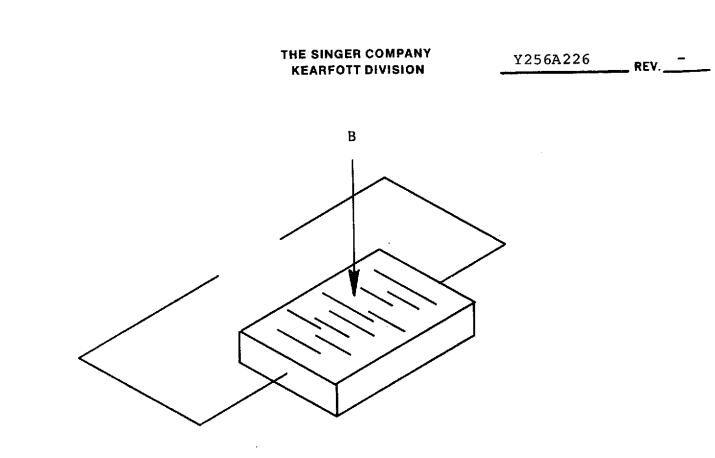
the presence of a small magnet at distance of .090 in. with any non-magnetic material between the magnet and the sensor. This feature will greatly simplify the process of hermetically sealing the final package.

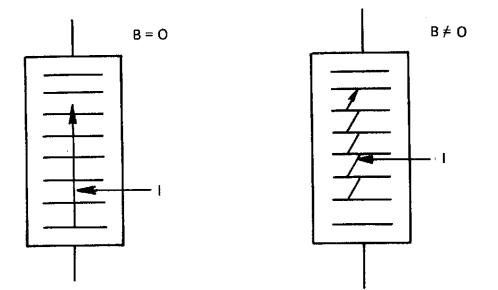
- Magneto Resistor Magneto resistors are solid state passive devices that change their resistance in the presence of a magnetic field. The devices are thin crystals of Indium Antimonide with electrical connections at both ends (Reference Figure 4a). The crystal is a semiconductor with a grid-like conducting material running perpendicular to the direction of the current flow. With no flux passing through the device current flows perpendicular to the conducting bands implanted in the semiconductor. Under these conditions the device exhibits its lowest resistance. If flux is allowed to pass through the device, the current is forced to travel a greater distance between conducting bands (Reference Figure 4b). The longer current path increases the resistance between the ends of the device. Typical ratios between maximum and minimum resistance are on the order of 13 to 18 for sensitive devices. The application of the magneto resistor is similar to the Hall effect devices in that they are mounted in the gap in the magnetic circuit. Magneto resistors have the following advantages:
- Small size
- Low power
- Life and reliability similar to silicon semiconductors

Power consumption of magneto resistors is a function of the input current and resistance and is, therefore, in the order of mw.

#### Alternating Magnetic Flux Devices

Alternating magnetic flux can also be used to convey mechanical switch status through a hermetic seal. Switches of this type operate using transformer coupling. This method would require the use of AC signals inside the hermetic seal. Because AC signals must be generated to produce the alternating flux and later rectified to interface with the logic and switch sections, this method will consume more power and be more complex than direct flux circuits.







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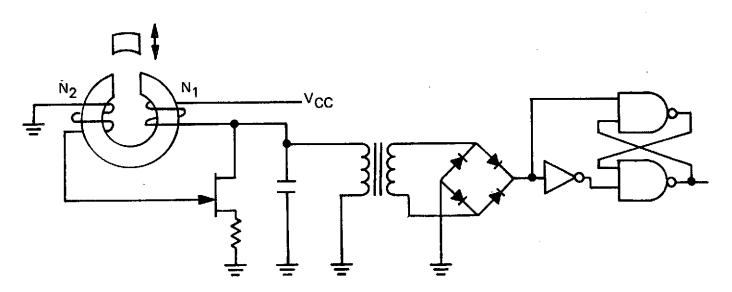
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The only source of alternating flux convenient for use in this application is a coil of wire around the magnetic flux path. The optimum frequency at which the flux should oscillate will be a function of core losses in the magnetic circuit, the size of the oscillator, and the amount of radiated energy acceptable.

The greatest disadvantage to this type of design is the possible energy radiated to other switches and circuitry behind the switch. This radiation can be minimized to some extent by placing a magnetic shielding around the switch and EMI filters on the electrical lines, however, this would complicate both the packaging and the manufacture of the final switch.

All the sensors which sense direct flux also sense alternating flux. Of the three types discussed (pick up coil, Hall effect, magneto resistor), the pick up coil is the most adaptable to alternating flux. A transformer type switch using coils might operate as follows:



In the configuration above, coil  $N_1$  is not strongly coupled with coil  $N_2$ . Coil  $N_2$  is a feedback circuit for the oscillator. With the slug removed from the magnetic path the feedback is insufficient to maintain oscillation. This results is a zero voltage output at the full wave rectifier. If the missing part of the core is placed into the magnetic circuit, coil  $N_1$  is coupled to coil  $N_2$  providing feedback to the circuit. This causes the circuit to break into oscillations and provides a DC voltage at the full wave rectifier switching the latching logic.

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The selection of the material to form the magnetic core, is based on a number of factors.

- Magnetic properties
- Ease of machining
- Compatibility with switch housing material
- Ability to form hermetic seal.

A material of high relative permeability and low magnetic retentivity is most desirable. This would insure the greatest change in flux for a given magnet. Two materials appear best suited to this requirement.

- 1. Cold rolled armco Magnetic input iron.
- 2. Cold rolled electro-magnetic iron.

When properly heat treated these materials are easily machined and can be soldered or brazed in the normal fashion.

One other consideration must be made if alternating flux is to be used. Core losses must be kept to a minimum which will require either a laminated core or a ferrite core. Both of these cores would be difficult to hermetically seal and will complicate the machining and manufacture of the transducer unit.

#### Transducer Evaluation

In the following section each of the sensors and sources are evaluated, thereby, allowing the best possible combination to be determined. A summary at the end of this section compares all the combinations.

Coil Source With Coil Sensor

This approach is not acceptable because of the inability of the coil sensor to detect a steady state flux. A memory device of some type would be required to hold the switch in either the on or off state after a change in the flux level. Such a transducer would be further complicated by the circuitry required to guarantee proper start up. When power is first applied to the switch, circuitry must be provided to set the memory in either the on or off position depending on the position of the moveable core section.

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Another disadvantage of this method is the coil source which dissipates electrical power to provide a steady state flux. Permanent magnets use no power to accomplish the same thing.

Coil Source With Hall Effect Sensor

A transducer of this type is feasible. It has two major disadvantages which make it less acceptable than other methods to be described.

- 1. Power must be supplied to both the coil and the Hall effect device for proper operation. This current would be on the order of 30 ma which is much higher than other types of transducers.
- 2. The Hall effect device puts out a low voltage (40 400 mv) when magnetic flux passes through it. This voltage level would have to be amplified in order to drive logic. The addition of an amplifier would consume more power and space in the final design and is therefore not desirable.

Coil Source With Magneto Resistor Sensor

A transducer of this type offers many advantages. The magneto resistor requires no control current as does the Hall effect device so the total power consumption will be smaller than the Hall effect. With a flux change of 10 kilogauss the magneto resister changes its resistance by a factor of 7 from its 0 kilogauss level. This change is enough to actuate logic without amplification. At worst a single transistor will interface between the transducer and the logic section.

The only drawback to this combination is the coil source which will draw current to generate the flux.

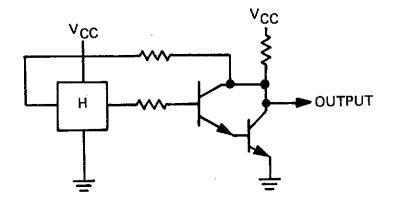
Permanent Magnet With Coil Pick Up

This method is unacceptable for reasons mentioned under coil source coil pick up.

Permanent Magnet With Hall Effect Device

This arrangement has the same drawbacks as the one using Hall effect with coil source. The only advantage is the fact that no current would be required to generate the flux.

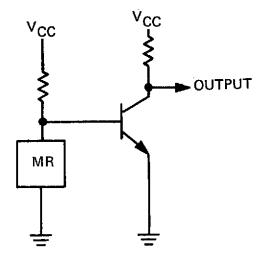
The complete transducer circuit is indicated as follows:



Permanent Magnet With Magneto Resistor

This combination is acceptable because the flux is generated without the use of power and the Magneto resistor requires few additional components and uses little power.

The complete transducer is as follows:



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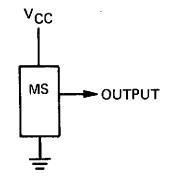
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Permanent Magnet With Micro-Switch Sensor (Hall Effect/Amplifier/ Trigger)

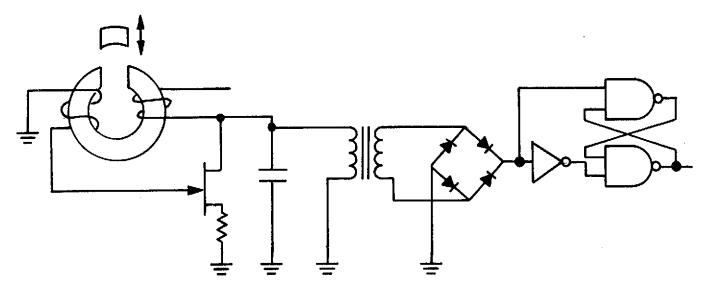
Because this device is very sensitive and comes packaged with a trigger and amplifier on the same chip it appears to be by far the most advantageous transducer. It is sensitive enough that no pole pieces would have to pass through the hermetic seal barrier. This would greatly simplify the sealing process. Furthermore, the device comes in a small package allowing the overall switch size to remain small.

The complete circuit is shown below:



Coil Source With Coil Sensor (ac)

A transducer operating with these components would require the following circuitry:



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The variable inductive coupling between the output and the input controls the feedback to the oscillator. Thus, by changing the feedback, the oscillator can be driven out of oscillation. By rectifying the output and using this signal to control the logic section, switch operation can be made.

The following problems complicate this approach to the transducer problem.

- The oscillation inherent in this type of switch will be difficult to shield from the outside world. Use of large RF filters would be difficult due to the small package size required.
- 2. The difficulty in hermetically sealing a low loss AC type core (laminated or ferrite) would necessitate use of a DC type core. This would force the oscillator to work at a higher power level to offset core losses.
- 3. Part count for this type of transducer would be high making a small package size difficult.

Coil Source With Hall Effect Sensor (ac)

This type of transducer would have all the drawbacks mentioned under coil source and coil sensor plus the following:

The Hall effect device must be placed in the path of magnetic flux requiring a gap in the core of the oscillator decreasing the coupling. The output from a Hall effect device would be a very small voltage (40 - 10 mv).

The Hall effect device requires a control current for operation which is an added power requirement not necessary with a coil pick up. This type of transducer is not acceptable because of the poor AC flux characteristics of the Hall effect device. A coil pickup is far superior in every respect for this application.

Coil Source With Magneto Resistor Pick Up

This transducer is unacceptable for the same reasons mentioned under coil source Hall effect device pick up.

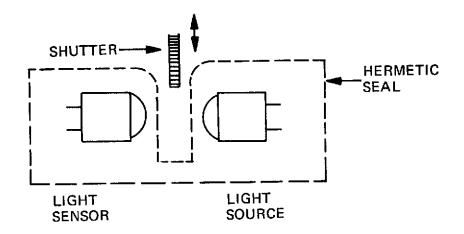
#### Conclusions

Of all the magnetic transducers discussed in this section, the most acceptable is the Honeywell magnetic switch used in combination with a permanent magnet. It is the best selection for the following reasons.

- Low power
- Smallest size of any magnetic transducer
- Lowest component count.

#### LIGHT TRANSDUCERS

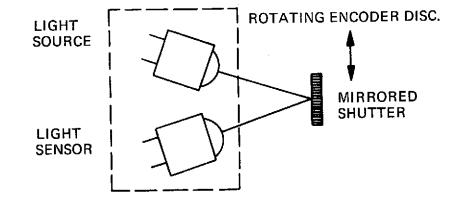
Transducers of this type will direct a beam of light from a light source through a shutter arrangement to a light sensor. Both light sensor and source will be contained inside a hermetic seal. The shutter arrangement will be external to the hermetic seal. By either allowing the light beam to strike the sensor or interrupting the light beam with the shutter, switch control of the light sensor can be obtained.



The shutter type of transducer would require that the hermetic seal wrap around the movable shutter. This means a transparent hermetic seal would have to be made at each side of the shutter. To avoid this complicated seal, an alternate configuration with a reflective surface can be used. In this method light is directed through a transparent hermetic seal towards a reflective surface. Upon striking the surface the light beam is directed back toward the light sensor through the same transparent seal through which it originally passed. In this way only one

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transparent seal is required and both source and sensor can be placed in the same place. Switching is obtained by either reflecting or not reflecting the light beam back to the sensor. No moving parts are required within the hermetic seal.



#### Light Sources

A beam of light can be obtained from the following sources:

- Incandescent lamp
- Light emitting diode
- Electro luminescent lamp

The following characteristics would be desirable in a light source:

- Small size
- High brightness
- Low power
- Long life

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It would also be desirable to have the light eminate from a single point source. As the light must be gathered into a beam to pass to the detector a single point source would simplify this requirement.

- Incandescent lamps A light source of this type satisfies the size and brightness requirements with no difficulty. Light intensities as high as 2,400 foot LAMBERTS can be obtained in package sizes as small as Figure 5. The drawbacks of this source are its power consumption and its limited life. There would be no way to conveniently replace the lamp because of the hermetic seal. This factor alone makes use of incandescent lamps PROHIBITIVE.
- Light emitting diode Light emitting diodes satisfy most of the requirements. They are small, have a very long life time, moderate power consumption with moderate brightness. A further advantage of the LED source is its narrow frequency band of light output.

Many types of photo diodes and photo transistors are optimized for use at a single frequency. This means that the proper combination of LED and photo diode will make more efficient use of the light than a combination of photo transistor and any other light source.

LED's come in a variety of package sizes. The device pictured in Figure 6 would be most suited to the requirements of this application. This device was designed to be used with a particular photo transistor in high speed card and tape readers. The characteristics of this device are listed in Table II.

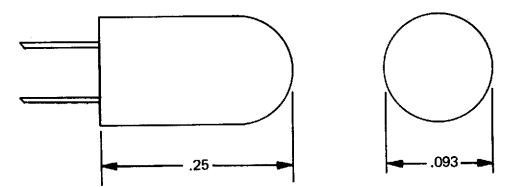
• Electro-Luminescent Lamps - This type of lamp would not be suitable for this application. Electro-luminescent lamps have very low brightness (20 fL) and are better suited to surface illumination.

#### Light Sensors

Light emitting diodes are the best choice for light sources so only sensors which interface with LED's will be considered. The following devices are specifically designed to interface with LED's.

- Photo Diodes
- Photo transistors

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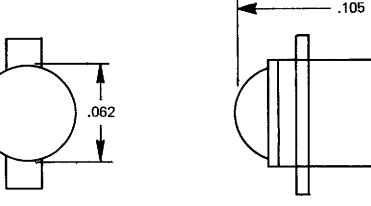


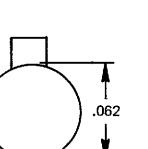


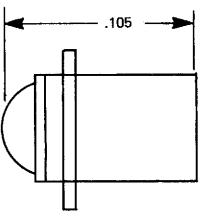
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#### TABLE II. LIGHT EMITTING CHARACTERISTICS

ELECTRICAL CHARACTERISTICS ( $T_A = 25^{\circ}C$  unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Тур	Max	Unit
Reverse Leakage Current ( $V_R = 3.0 V, R_L = 1.0$ Megohm)	-	I <sub>R</sub>	-	50	_	nA
Reverse Breakdown Voltage (I <sub>R</sub> = 100 µA)	-	bv <sub>r</sub>	3.0	_	-	Volts
Forward Voltage (I <sub>F</sub> = 50 mA)	2	∖ V <sub>F</sub>	_	1.2	1.5	Volts
Total Capacitance (V <sub>R</sub> = 0 V, f = 1.0 MHz)	-	с <sub>т</sub>	-	150	-	pF

OPTICAL CHARACTERISTICS ( $T_A = 25^{\circ}C$  unless otherwise noted)

Characteristic	Fig. No.	Symbol	Min	Тур	Max	Unit
Total Power Output (Note 1) (I <sub>F</sub> = 50 mA)	3,4	Po	50	150	-	µ₩
Radiant Intensity (Note 2) (I <sub>F</sub> = 50 mA)		Io	-	0.66	-	m₩/ stera- dian
Peak Emission Wavelength	1	λΡ	_	9000	-	° A
Spectral Line Half Width	1	Δλ	-	400	-	° A

The characteristics desirable for this application are:

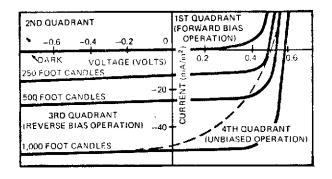
- Small size
- Compatible with LED light sources
- High light sensitivity
- Low power consumption

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 <u>Photo Diodes</u> - Photo diodes are P on N or N on P silicon function devices that generate a photo current in response to a beam of light focused on the sensitive junction.

Being composed of silicon, these devices are small, rugged and reliable. The photo-diode is the basic photo sensitive device in all of the photo transistor varieties, so in one form or another it will be used in any kind of light transducer. The current voltage curves for a typical photo diode are shown below.



The voltage and current levels are sufficient to drive the logic section without further amplification. However, if a photo transistor were used, lower light intensities would be able to drive the same logic section. This would mean lower power consumption in the LED.

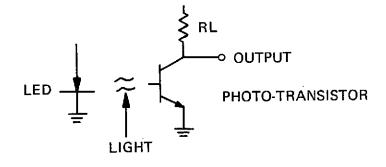
• <u>Photo-transistors</u> - The photo-transistor uses a photo diode to generate base current for a normal transistor. This, in effect, amplifies the current sensitivity of the device by the  $\beta$  of the transistor. There is no difference in package sizes between the photo diode and photo transistor, both can be obtained in packages as small as Figure 6.

Photo FETS take advantage of the photo voltaic effect of photo diodes. This is the change in output voltage as a function of light intensity of an open circuited photo diode. The increase of current gain available using a photo FET is of the same order of magnitude as that of a photo-transistor.

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<u>Configurations</u> - The simplest configuration of a light transducer would look as follows:



In this configuration the light from the LED provides base current for the photo transistor turning it on. The shutter can be placed in the path of the light beam turning off the transistor.

The LED must be provided with from 20 to 50 ma of current depending on the distance between the diode and the transistor, the load RL on the transistor, and any attenuating devices between the diode and the transistor (glass, light pipes, etc.).

The configuration of the reflective type transducer would be identical to that pictured above except for the shutter which would become a mirrored surface.

#### Conclusions

Of the light type transducers the light emitting diode in conjunction with the photo-transducer is the only method which will adequately meet the requirements of this application.

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Table III below lists the characteristics of this type of transducer.

POWER	.150 WATTS
COMPONENT COUNT	3
CROSS TALK	NONE
EXCITATION	DC-5-10V
HERMETIC SEAL	PROBLEM AREA GLASS TO METAL SEAL

TABLE III. LIGHT TRANSDUCER CHARACTERISTICS

#### CAPACITANCE TRANSDUCERS

A transducer of this type would operate by sensing the change of a capacitor and operating a trigger circuit from this change. Because all electrical components must be contained inside a hermetic seal the only portion of a capacitor which could be used to change the capacitance would be the dielectric. The plates of the capacitor being current carrying devices must lie within the hermetic seal and are therefore inaccessable for mechanical change.

This factor makes it very difficult to implement this type of transducer. Both plates must be sealed behind at least .050 thick sheets of glass while the dielectric contained within the environmentally sealed section is moved in or out of the plate gap.

A further complicating factor is the dielectric itself. It would be desirable to have the capacitor make a very large change in capacitance. This would mean using a material with a high dielectric constant. Most materials with this characteristic are unacceptable for use in a space cabin environment.

A variable capacitance transducer is therefore unacceptable for use in this application.

#### CIRCUITRY

#### SINGLE ACTION SWITCH

The basic circuitry of the switch consists of a magnet and Hall effect transducer, amplifier and output solid state relay switch as shown in schematic SW201 (Appendix I). The Hall effect device is an integrated hybrid chip containing the Hall effect pick off, an amplifier and a Schmitt trigger. The output of the Schmitt trigger drives a transistor amplifier which supplies current to the coil of the solid state relay switch. The output of the solid state relay directly supplies the load. The solid state relay coil is in series with the transistor driver and a light emitting diode. The light emitting diode provides an indication that the switch is in the ON condition and that approximately 80 percent of the circuitry is operating normally. The only difference between the single pole and double pole switch is the addition of a solid state relay, the coil of which is in series with the original solid state relay coil, and an increased supply voltage to provide additional drive power.

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#### TEN POSITION ROTARY SWITCH

The circuitry of the ten position rotary switch is shown in Schematic RD001 (Appendix I). Four LED - phototransistor transducers provide the initial BCD triggering to obtain 10 discrete switch position outputs. The output of the phototransistors provides triggers to exclusive or gates which inserts the proper logic format into a BCD to one of ten decoders. The output of the decoder supplies through transistor amplifiers the current to drive the appropriate coil of solid state relay matrix. The output of the solid state relay directly supplies the load.

#### POTENTIOMETER

The input to the potentiometer consists of 7 LED - phototransistor transducers providing a resolution of 128 bits. The output of the phototransistors provides logic states to exclusive or gates, the outputs of which supply the necessary binary data to the digital to analog decoder. The decoder utilizes a ladder network with an operational amplifier output. The output is a 0 to 10 volt analog voltage capable of supplying a 1000 ohm or greater load. A visible LED on both the rotary switch and potentiometer indicate that all internal LEDs are energized.

#### OUTPUT SWITCH CIRCUITRY

The output characteristics of the switches are tabulated in Table IV. Physically all chips are the same size so that any possible combination of switch outputs is available. An important consideration with all types of switches is that the input to output isolation impedance is in excess of 10" ohms.

#### SWITCH CONFIGURATION

The following types of mechanical packages must be produced to comply with the contract.

- Toggle switch (maintained)
- Toggle switch (momentary)
- Push button
- Potentiometer
- Rotary switch

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TABLE IV. SWITCH CHARACTERISTICS

SWITCH	100 MA	140V	28V	400 MA
TYPE	DC	AC	AC	DC
LOAD	+50V MAX	140 VAC	280 VAC	60 VDC
VOLTAGE	Peak	RMS	RMS	

INPUT (CONTROL) SPECIFICATIONS

CONTROL VOLTAGE RANGE	3.8-10 VDC	3.8-10 VDC	3.8-10 VDC	3.8-10 VDC
MAX INPUT CURRENT @ 5V	22 MA DC	15 MA DC	15 MA DC	15 MA DC
TURN OFF VOLTAGE (MAX)	0.4 VDC	0.8 VDC	0.8 VDC	0.4 VDC
DIELECTRIC STRENGTH INPUT TO OUTPUT	1000 VAC (PP)	2500 VAC (RMS)	2500 VAC (RMS)	1500 VAC (PP)
ISOLATION INPUT TO OUTPUT	10" Ω MIN	10" Ω MIN	10" Ω MIN	10" Ω MIN

OUTPUT (LOAD) SPECIFICATIONS

OUTPUT CURRENT RATING	+100 МА РЕАК	1.0 AMP	1.0 AMP	400 MA
OUTPUT VOLTAGE	+50 МАХ РЕАК	140 VAC RMS	280 VAC RMS	60 VDC
OFFSET VOLTAGE	+5.0 MV MAX	_	-	-
CONTACT "ON" RESISTANCE (OHMS	)5.0 MAX		-	-
CONTACT "OFF" RESISTANCE (OHMS	)10 <sup>9</sup> MIN	2 x 10 <sup>5</sup> MIN	$2 \times 10^5$ MIN	7 10 MIN
MAX DRIVE FREQUENCY (Hz)	100K	500	500	30к
MAX SURGE RATING	0.1 JOULE	10 AMP	10 AMP	-
CONTACT VOLTAGE DROP AT RATED CURRENT (MAX)	250 MV	1.5V RMS	1.5V RMS	1.5VDC

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Each type must have the electronics hermetically sealed. The packages for each type therefore have two sections, a hermetically sealed section and an environmentally sealed section. The hermetically sealed section contains the drive electronics. The mechanical actuation is contained in the environmentally sealed section.

There are two basic types of package. One contains all the single action switch configuration and the other houses the rotary switch and potentiometer.

SINGLE ACTION SWITCH

The single action switch is packaged in a rectangular case of the same approximate dimensions as the present hermetically sealed single pole double throw mechanical switch made by Texas Instruments for the LEM and Apollo missions.

Of all approaches tried, Hall effect devices and magneto resistors were the most acceptable. The Hall effect device, because of the higher sensitivity of the Micro-switch device, results in no pole pieces extending through the hermetic seal and, therefore, is the optimum selection.

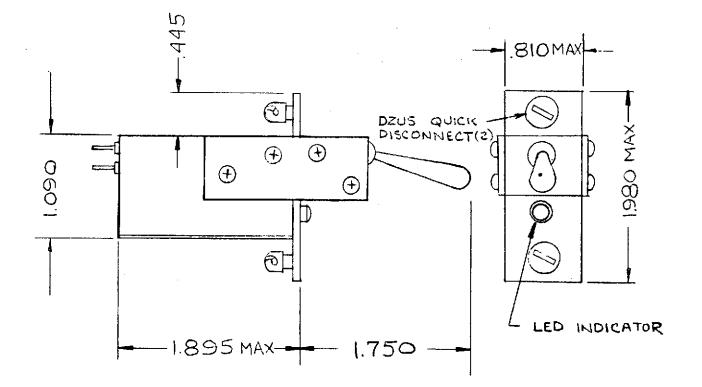
Figure 7 depicts the layout of the single action switch using this Hall effect device.

POTENTIOMETER AND ROTARY SWITCH

A potentiometer with a resolution of 3.6 degrees is provided. The potentiometer is not a variable resistor but a variable voltage supply which should serve all the functions normally performed by a potentiometer. Rotation of the pot shaft varys the digital input to a D to A converter (DAC) producing a variable voltage. The pot is, in effect, a 7 bit encoder connected to a DAC.

The encoder portion of the potentiometer is a mirrored disk outside of the hermetic seal. Inside the hermetic seal a series of photo diodes and light emitting diodes operating through a transparent seal senses the position of the mirrored disk. This digital information is connected to a DAC to provide the output.

The rotary switch is of the same configuration as the potentiometer. An encoder disk is mirrored into 10 sections. A series of photo diodes and light emitting diodes senses the position of the encoder disk and operates 10 individual switches. Any of the switch outputs shown in Table IV can be provided in the rotary switch. THE SINGER COMPANY KEARFOTT DIVISION <u>Y256A226</u> REV. \_\_\_\_



# FIGURE 7. SOLID STATE TOGGLE SWITCH OUTLINE DRAWING (Sheet 1 of 2)

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FIGURE 7. SOLID STATE TOGGLE SWITCH OUTLINE DRAWING (Sheet 2 of 2)

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The potentiometer and rotary switch are both packaged in a cylindrical housing approximately 2.5 inches in diameter and 1.5 inches in depth. Figure 8 depicts the layout for the solid state pot and rotary switch. A glass seal separates the hermetic section from the encoder wheel. The encoder wheel is environmentally sealed at the shaft with an 0- ring. Light from the LEDs passes through the glass seal, is reflected by the silvered encoder disk and after again passing through the glass seal turns on the phototransistor. Seven LED phototransistors are arranged to align with a Gray code disc providing seven bits of non-redundant binary information. This information is converted into a variable voltage in the D to A section located on the two PC boards in the sealed area.

# HERMETIC SEAL

A sample of each package style is hermetically sealed. The hermetically sealed portions of these packages constructed as gas tight enclosures completely sealed by fusion of glass to metal or bonding of metal to metal. Special sapphire glass discs already hermetically sealed to a metal ring are brazed into the brass casing to provide the chamber hermetic seal. After the electronics are inserted into the chamber and leads attached to the soldered glass/metal interconnect the back cover is soldered into place. Prior to sealing, the enclosure is cleaned and The enclosure is purged of all air and backfilled with dried. one atmosphere of gas consisting of 95 percent nitrogen/5 percent helium. A primary consideration in the selection of enclosure materials is the ease of welding, brazing or soldering the bonding methods typically employed for metal to metal hermetic seals. Final material selection provides for brass casings for ease of brazing and soldering.

#### Environmental Seals

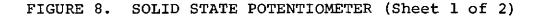
Environmental sealing is accomplished primarily by gasketing. Silicone 0-rings and gaskets are utilized at closure points to prevent dirt or moisture infiltration and other contaminants.

#### PANEL CONFIGURATION

The sold state switch panel contains the following types and quantities of switches.

Toggle	maintained	SPST	5
Toggle	maintained	DPST	5

THE SINGER COMPANY Y256A226 , REV. \_\_\_\_ **KEARFOTT DIVISION** DZUS QUICK DISCONNECT (4)LED INDICATOR 1.460 ъ 2.760 MAX 2.325 01A  ${}^{\odot}$ ନ L. 2.760 MAX -OUTPUT TERMINAL



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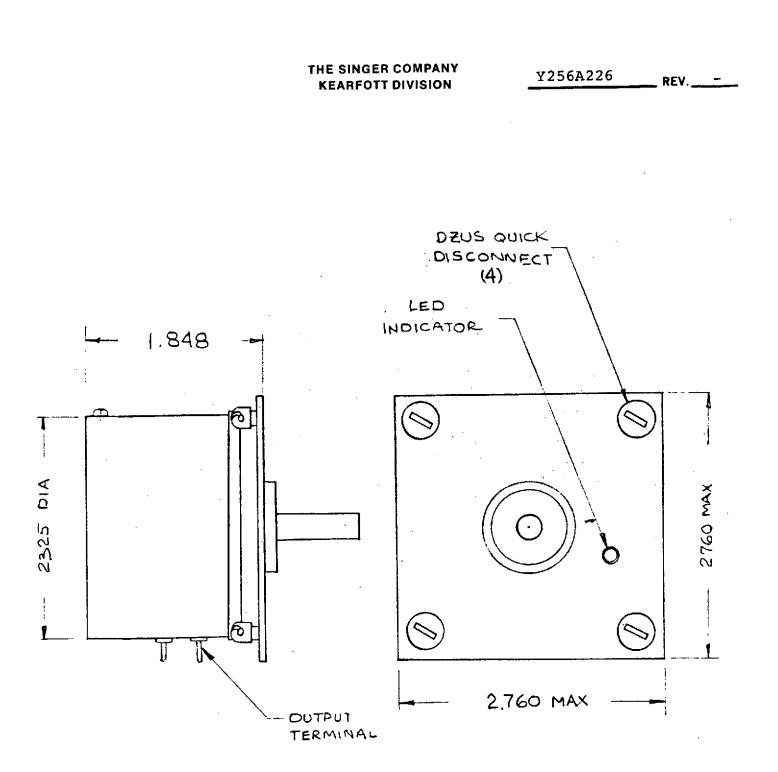


FIGURE 8. SOLID STATE 10 POSITION SWITCH (Sheet 2 of 2)

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Toggle momentary	SPST	5
Toggle momentary	DPST	5
Pushbutton	SPST	3
Pushbutton	DPST	2
Rotary	10 position	2
Potentiometer		2

These switches are mounted on a 19-inch wide rack. Two of these switches control high powered 10 amp switches mounted directly on the test panel. The test panel also contains the rated loads for all the switches and potentiometers and provides an indication as to which switches are being operated. The switches are grouped relative to contact rating and identified accordingly on the test panel.

# SUMMARY

For the small number of switches produced, several techniques were utilized which would not necessarily remain in the production unit. The same housing was used for both pushbutton and toggle switches which necessitated the use of an add-on toggle assembly. In production units, the toggle assembly would become an integral part of the switch body thereby enhancing the usual outline of the toggle switch.

In production quantities, all switch and rotary components would be hybridized to miniaturize the electronics. This would diminish the package size and simplify hermetic sealing.

#### POWER CONSUMPTION

Excluding the switch contact ratings, the following power is required in the quiescent (non-operating) state and the operating mode for each type of switch.

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	Volta (volt		Power Quiescent (mw)	Power	Operating (mw)
Pushbutton/toggle SPST	5 &	12	20	320	mw
Pushbutton/toggle DPST	5&	28	20	720	mw
10 Position Rotary	5&	12	500 mw	50 <b>0</b>	mw
Potentiometer	5 &	<u>+</u> 12	450 mw	450	mw

total panel power quiescent 2.4 watts

Operating 14.7 watts

#### PANEL OPERATION

## POWER APPLICATION

Place all switches in the off (down) position. Apply the power to the proper pins on the input jack panel located at the bottom of the switch panel. The positive side of the -12 volt input connects to the black input jack and the negative connects to the red jack. The 28 power supply shall be capable of suppling 25 amps in order to test the power switches.

The AC voltages (120 VAC, 240 VAC) are only used to provide contact voltage ratings on the 5 pushbutton AC switches. The AC need not be connected for proper check out of all DC switches and rotary components.

## OPERATION

The switch labeled panel controls power to the entire panel. Power is connected to this switch whenever power is present on the jack panel. When it is switched to the ON position, power is applied to all other switches.

With power connected to the panel and the panel switch on, all switches will operate. Switching any toggle momentary or maintained to the ON (up) position or operating any pushbutton will cause the appropriate load light to illuminate. For the two power switches there are no load lights. Closure indication for these switches is given by two current meters located at the top of the panels.

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The rotary devices are also actuated by the panel switch. The outputs of the potentiometers are indicated by two volt meters located at the top of the panel. The rotary switches are connected to decimal displays which indicate the position of the switch.

# LOAD CONNECTOR PIN OUT.

PIN	LOAD	PIN	LOAD
1 2 3 4 5 6 7 8 9 10 11	S10 S9 S8 S7 S6 S5 S4 S3 S2 S1 S22	35 36 37 38 39 40 41 42 43 44 45	
12 13 14 15 16 17 18 19	S21 S20 S19 S18 S17 S16 S15 S23	46 47 48 50 51 52 53	POWER SWITCH 2 S14 POWER SWITCH 1 S13 ROTARY SWITCH 2 0 9
20 21 22 23 24 25 26	S22 S21 S20 S19 POTENTIOMETER # 1 POTENTIOMETER # 2 ROTARY SWITCH 1 POSITION 1	54 55 56 57 58 59 60	8 7 6 5 4 3 2 1
27 28 29 30 31 32 33	ROTARY SWITCH 1 POSITION 2 ROTARY SWITCH 1 POSITION 3 ROTARY SWITCH 1 POSITION 4 ROTARY SWITCH 1 POSITION 5 ROTARY SWITCH 1 POSITION 6 ROTARY SWITCH 1 POSITION 7	61 62 63 64	11ROTARY SWITCH 1 POSITION0ROTARY SWITCH 1 POSITION9ROTARY SWITCH 1 POSITION8

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#### TESTS

#### FUNCTIONAL TESTS

All switches were tested at standard ambient conditions to insure proper operation at rated voltage and 10 percent under and over voltages. Power at nonoperating (quiesent) and operation conditions were measured for the entire panel with the following results:

Panel	Quiesent I	Power	2.4	Watts
Panel	Operating	Power	14.7	Watts

The panel operated satisfactorily when submitted to the various functional tests.

#### ENVIRONMENTAL TESTS

One type of each switch: toggle, pushbutton, rotary and potentiometer were submitted to the following environmental tests.

# TEMPERATURE

2 Hour Soak at 0°C Functionally tested

2-Hour Soak at 70°C

Functionally tested

# RESULTS

SPST, DPST, and Rotary Switch operated satisfactorily. Potentiometer intermittent at high temperature as a result of low current through LED's. Increasing current through LED's provides stability over temperature range, however, higher power dissipation results.

#### RANDOM VIBRATION

#### Procedure

A random vibration equal to the total G level utilized on the LEM and Skylab was impressed on the switches. Period of application is 2 minutes.

1150-2000 Hz 20-2000 Hz .02 gr/Hz

Switches Tested

Pushbutton

Toggle

Rotary Switch

## RESULTS

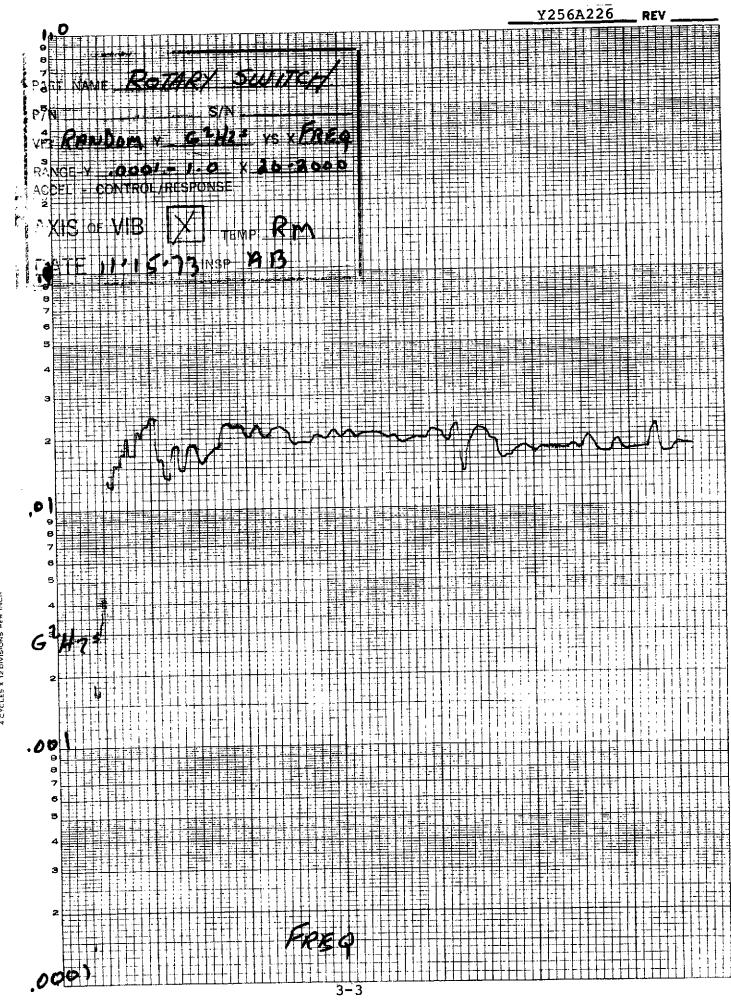
All switches functioned throughout the random vibration. The pushbutton normally open remained in the normally open state, the toggle maintained in a closed switch position remained in that state without interruption and the rotary switch set at position 5 remained closed in that position with all other positions normally open. The graphs on the following pages visually depict the vibration levels applied in the during the test.

## EMI TESTS

EMI tests were conducted on the double pole, single pole and the potentiometer in accordance with MIL-STD-461. The tests performed were CE01, CE03 and CS06. CE01 and CE03 were preformed on every lead of the device under test. CS06 was preformed on all power leads with the spike equal to 50% of the nominal line voltage.

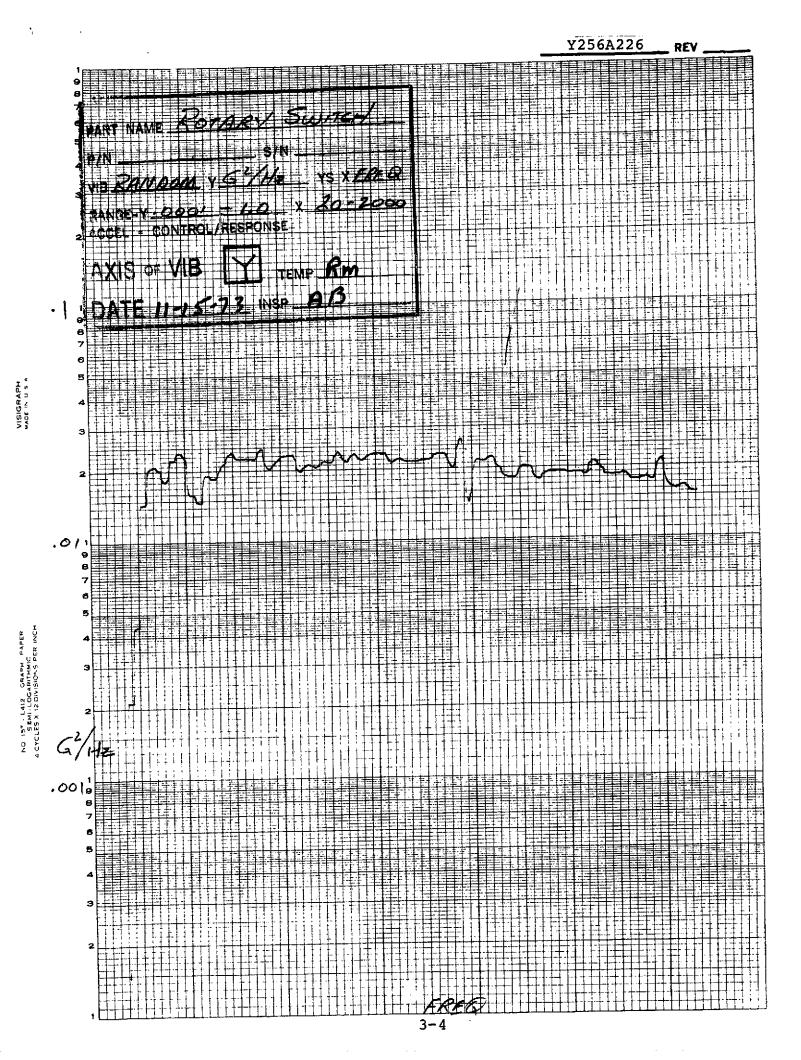
#### RESULTS

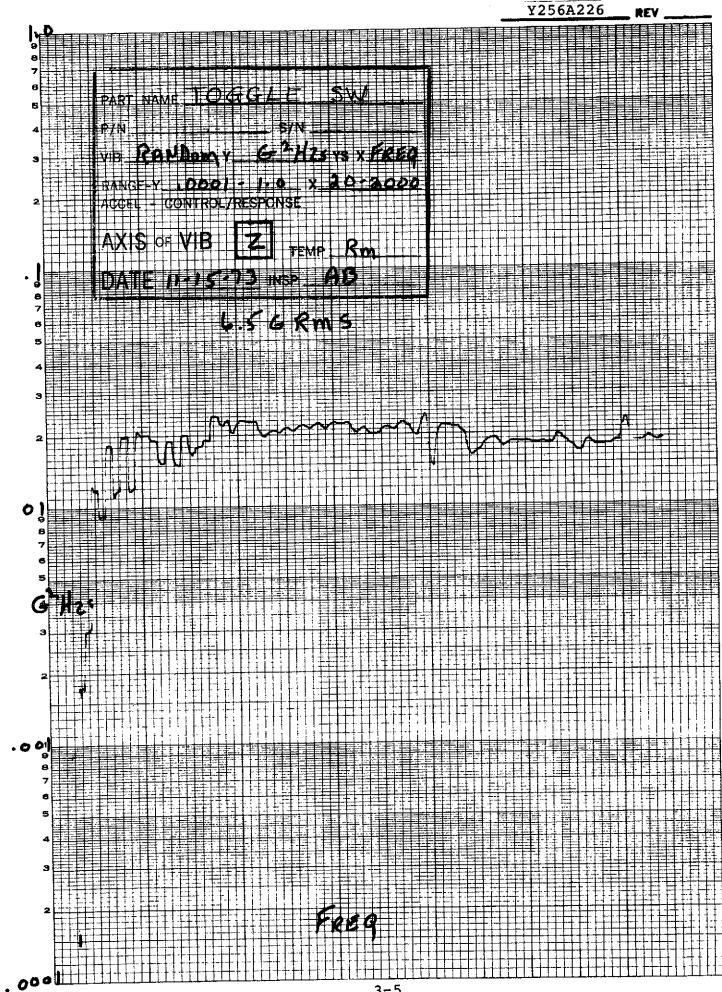
The results of the CEO1 & CEO3 tests are contained in the attached data. Emissions for all devices were within the max specification limit. All devices operated successfully during the CSO6 tests.



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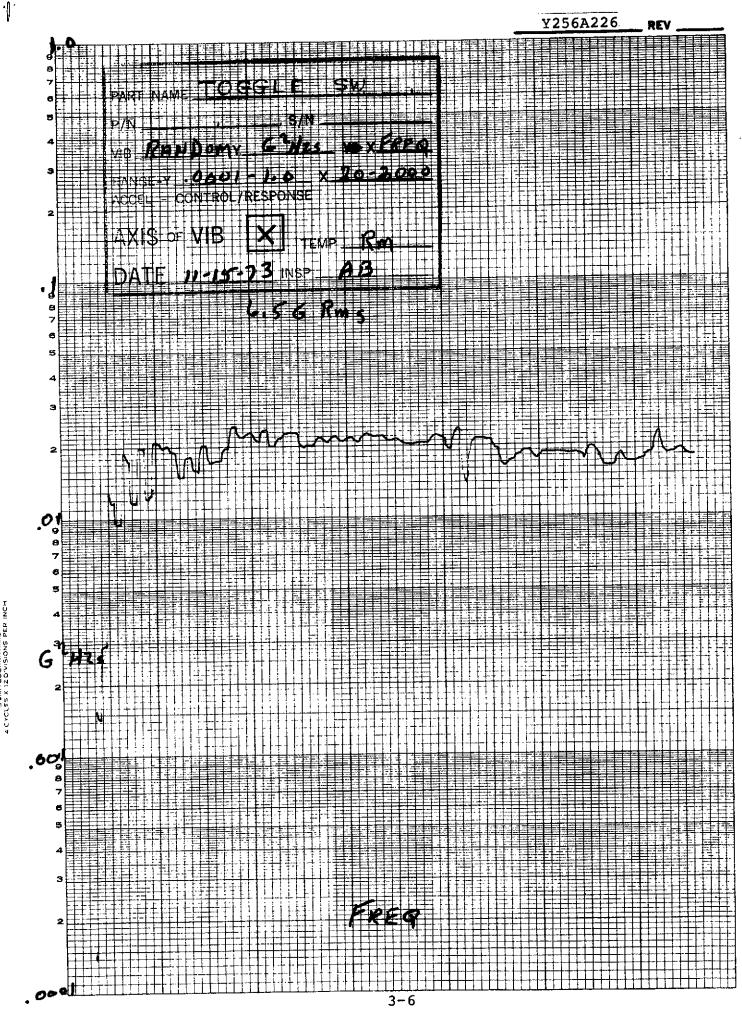




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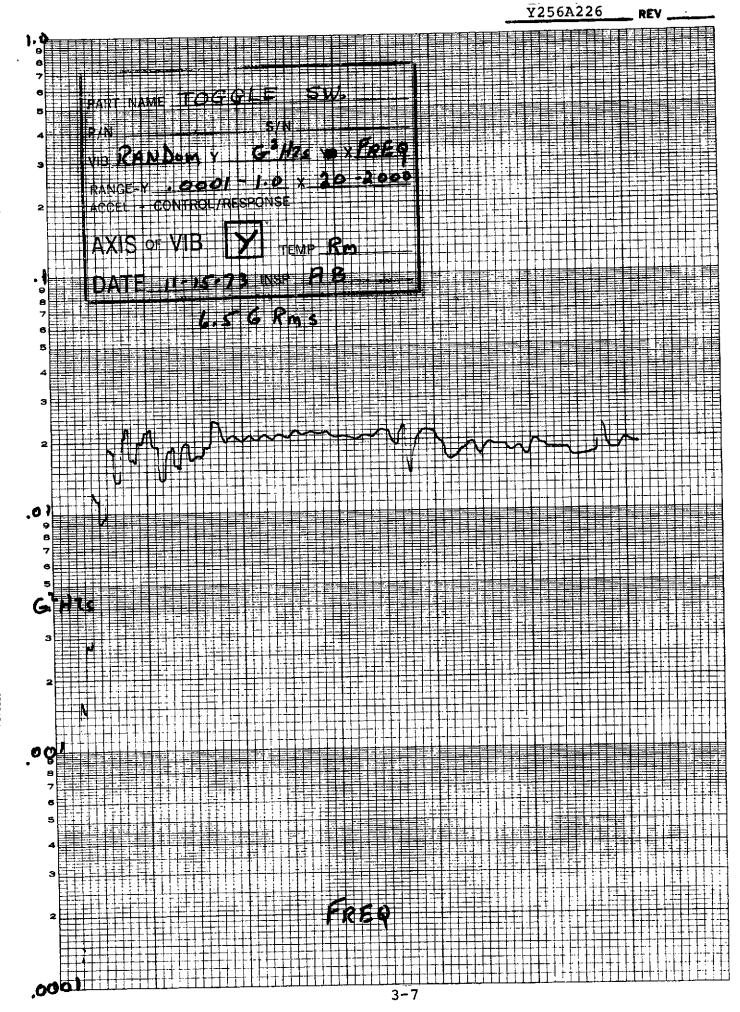
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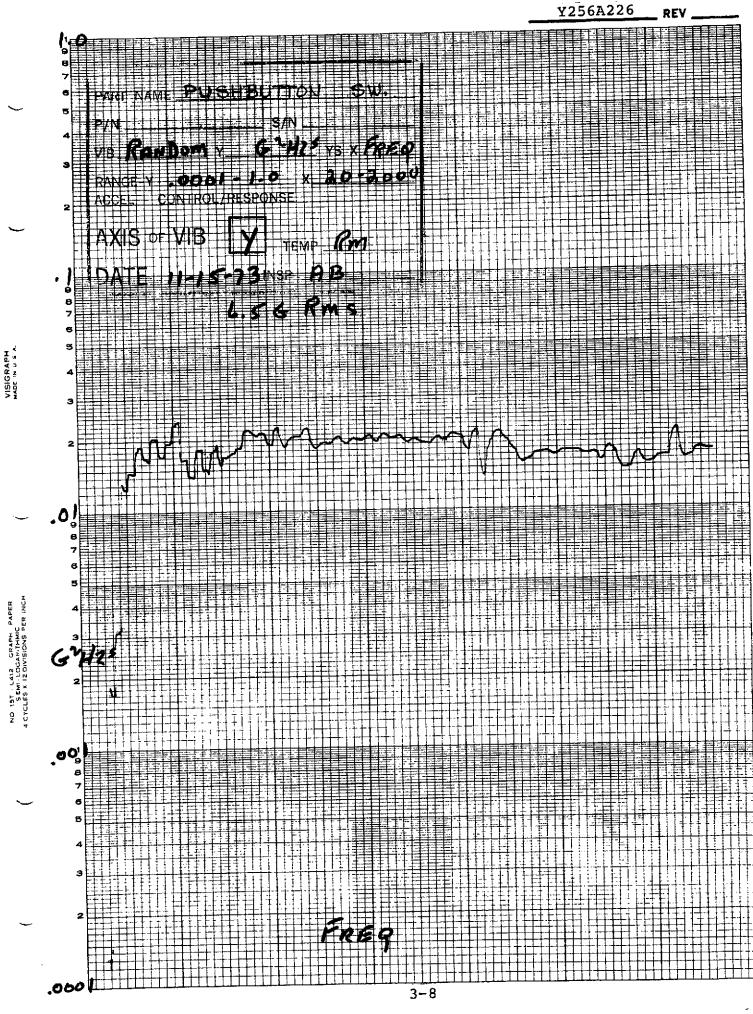
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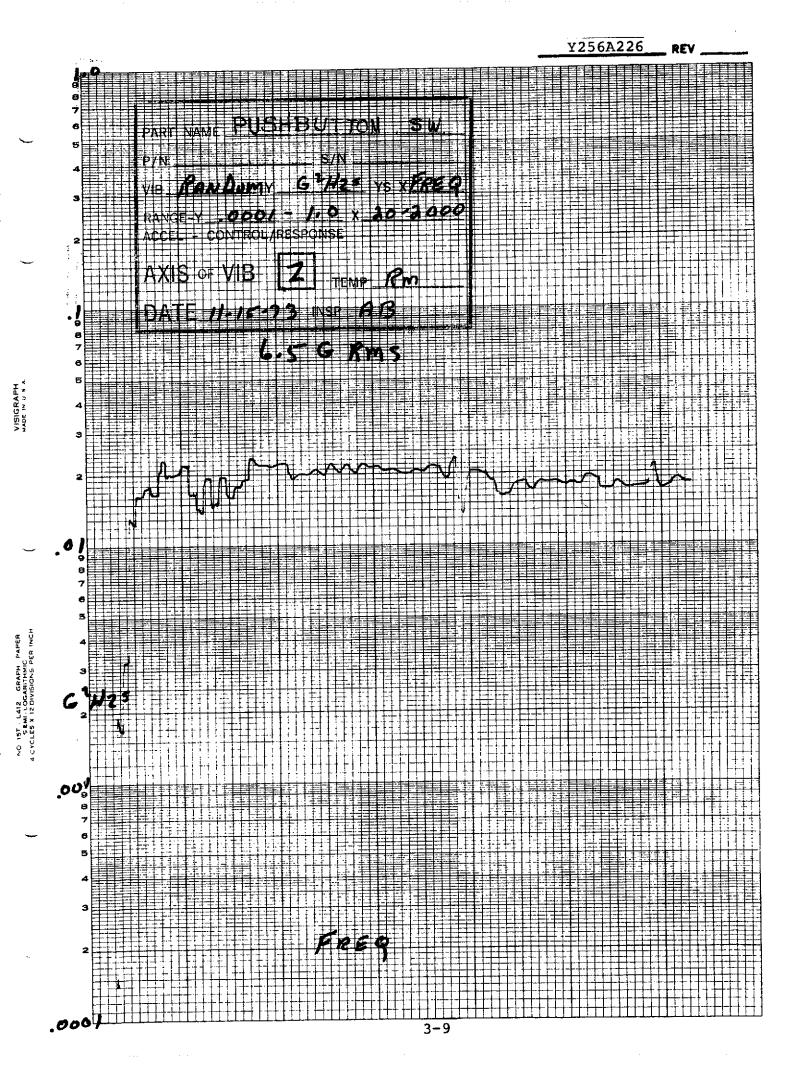
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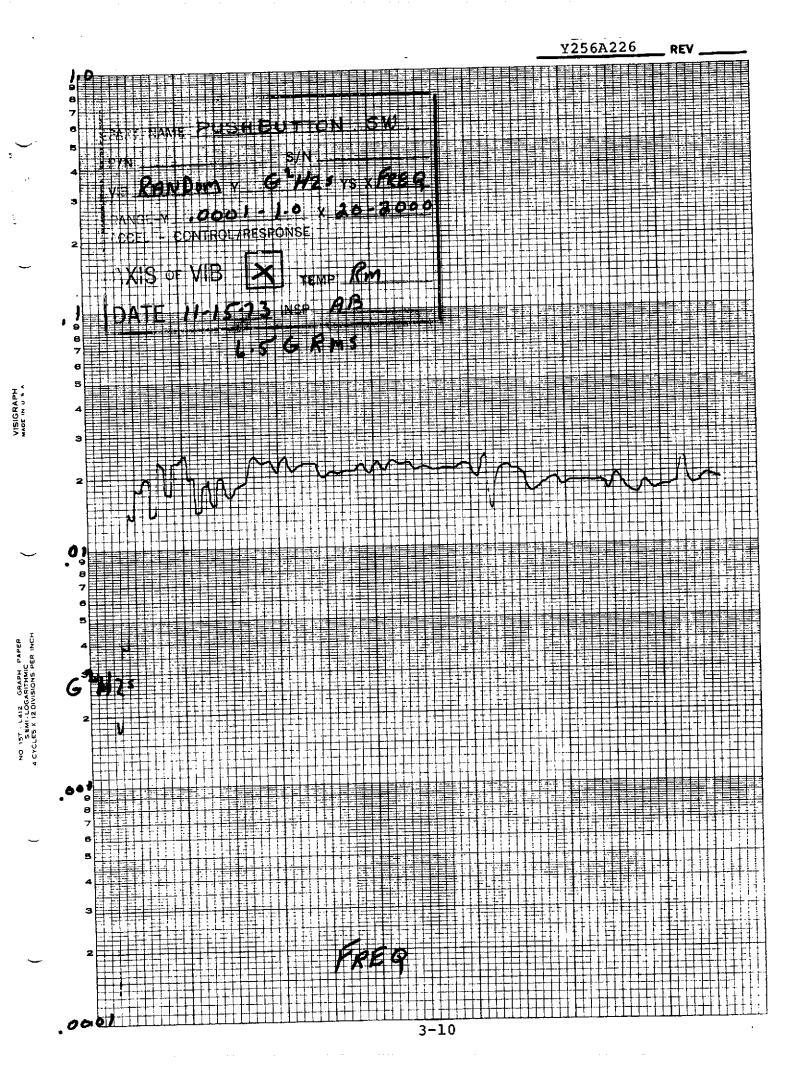


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PARAGRAPH       TEST //2 //3       CHECKED BY //2 //3       CHECKED BY //2 //3       CHECKED BY //2 //3       CHECKED BY //2 //3       DATE //3 <th c<="" th=""><th>ECIFICATION PNDUCTED BY TEST FREQ DB: 0 2 0 10 2 5 0 3 5 0 4 5 0 6 5 0 8 5 10 5</th><th><math display="block">A \cdot G \cdot</math> <math display="block">\frac{A \cdot G \cdot}{B \cdot C \cdot}</math> <math display="block">\frac{A \cdot G \cdot}{B \cdot C \cdot}</math> <math display="block">\frac{A \cdot G \cdot}{B \cdot C \cdot}</math> <math display="block">\frac{A \cdot G \cdot}{C \cdot}</math> <math display="block">\frac{A \cdot G \cdot}</math> <math display="block">A</math></th><th>CORRECTION FACTOR C : /<sup>3</sup>. // / 7 5</th><th>/73 CHE READING 123/2000 1133/2000 123/2000 113442 79 73 67 55 47 47 47 47 47 47 47 47 47 30 30 30 35 70</th><th>BY       BJ.         SPECIFICATION       LIMIT         DB/MII       1/1/14         120       1/16         1/2       1/17         1/2       1/16         1/2       1/17         1/2       1/16         1/17       1/17         1/16       1/17         1/17       1/17         1/17       1/17         1/17       1/17         1/17       1/17</th><th>INTER. TYPE (SEE HOTE B) / / / / / / / / / / / / / / / / /</th><th>DATE 11-20-73 REMARKS Presed</th></th>	<th>ECIFICATION PNDUCTED BY TEST FREQ DB: 0 2 0 10 2 5 0 3 5 0 4 5 0 6 5 0 8 5 10 5</th> <th><math display="block">A \cdot G \cdot</math> <math display="block">\frac{A \cdot G \cdot}{B \cdot C \cdot}</math> <math display="block">\frac{A \cdot G \cdot}{B \cdot C \cdot}</math> <math display="block">\frac{A \cdot G \cdot}{B \cdot C \cdot}</math> <math display="block">\frac{A \cdot G \cdot}{C \cdot}</math> <math display="block">\frac{A \cdot G \cdot}</math> <math display="block">A</math></th> <th>CORRECTION FACTOR C : /<sup>3</sup>. // / 7 5</th> <th>/73 CHE READING 123/2000 1133/2000 123/2000 113442 79 73 67 55 47 47 47 47 47 47 47 47 47 30 30 30 35 70</th> <th>BY       BJ.         SPECIFICATION       LIMIT         DB/MII       1/1/14         120       1/16         1/2       1/17         1/2       1/16         1/2       1/17         1/2       1/16         1/17       1/17         1/16       1/17         1/17       1/17         1/17       1/17         1/17       1/17         1/17       1/17</th> <th>INTER. TYPE (SEE HOTE B) / / / / / / / / / / / / / / / / /</th> <th>DATE 11-20-73 REMARKS Presed</th>	ECIFICATION PNDUCTED BY TEST FREQ DB: 0 2 0 10 2 5 0 3 5 0 4 5 0 6 5 0 8 5 10 5	$A \cdot G \cdot$ $\frac{A \cdot G \cdot}{B \cdot C \cdot}$ $\frac{A \cdot G \cdot}{B \cdot C \cdot}$ $\frac{A \cdot G \cdot}{B \cdot C \cdot}$ $\frac{A \cdot G \cdot}{C \cdot}$ $\frac{A \cdot G \cdot}$ $A$	CORRECTION FACTOR C : / <sup>3</sup> . // / 7 5	/73 CHE READING 123/2000 1133/2000 123/2000 113442 79 73 67 55 47 47 47 47 47 47 47 47 47 30 30 30 35 70	BY       BJ.         SPECIFICATION       LIMIT         DB/MII       1/1/14         120       1/16         1/2       1/17         1/2       1/16         1/2       1/17         1/2       1/16         1/17       1/17         1/16       1/17         1/17       1/17         1/17       1/17         1/17       1/17         1/17       1/17	INTER. TYPE (SEE HOTE B) / / / / / / / / / / / / / / / / /	DATE 11-20-73 REMARKS Presed
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 (2) Broadband, Transients
 (3) Narrowband (CW) A - All trequencies nor B - Interference Type: NO

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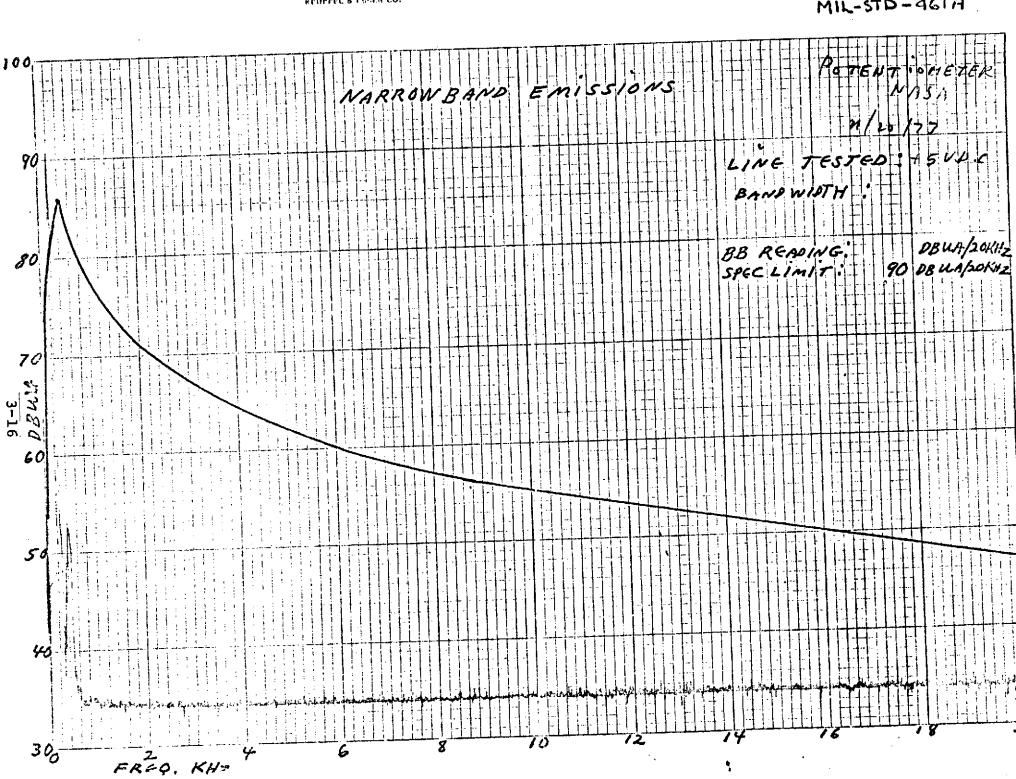
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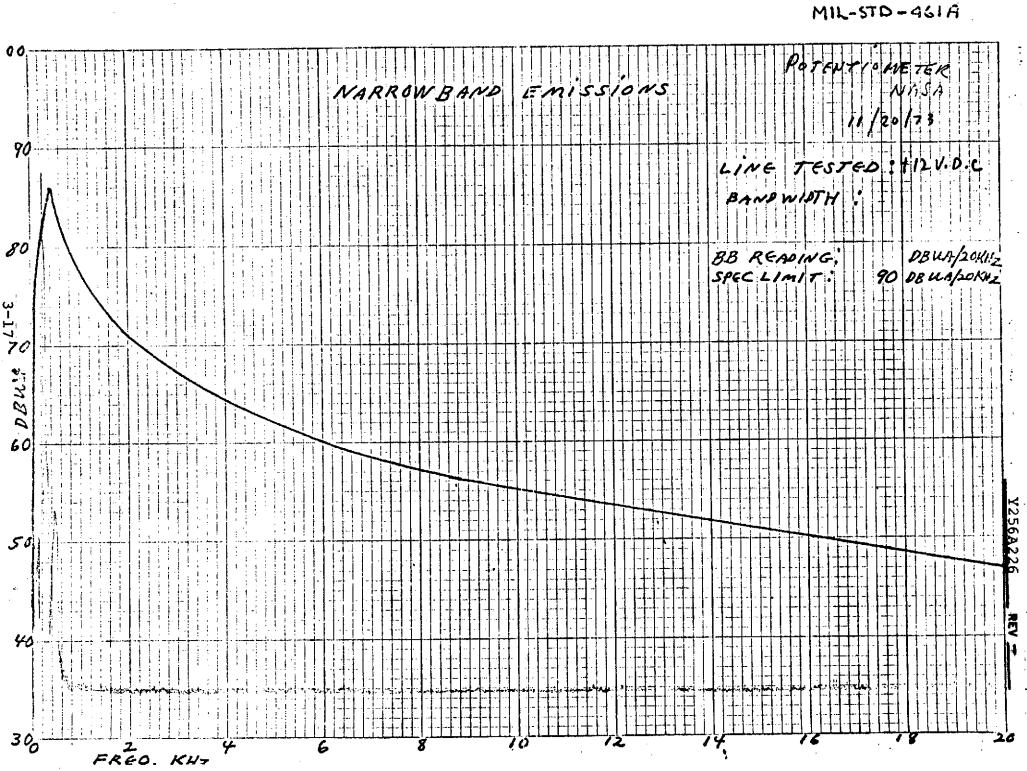
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NOTE: A - All frequencies not B - Interference Type:

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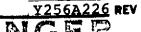
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.045	34	. 5	39	112		
. 665	32	4	36	106		
· 6 2 0 · 0 2 5 · 0 4 5 · 0 5 · 0 5 · 1 0 0 · 1 2 0 · 1 5 0	30	3	33			
.100	3 •	2	32	98		
120	30	/	31	96		
. 15 0	30	)	31	92 87		
,200	30	0	30			
300	30	0				
,400	30		3 u	76		4
.500	55		55	- 72		
1800	30		30	64	· · · ·	
	30		30	60		
1.5	35		3	60 5 5 5 5 0		
2.0	30		30	<u> </u>		1
3,0	30					1
4, 0	30		30	2		-
5.0	55	· · · · · · · · · · · · · · · · · · ·			···	
6,0	37		37			
9.2	38		38			- <b>1</b>
12.0	30		30			<u>.</u>
15.0	30		30			· · · · · · · · · · · · · · · · · · ·
20.0	30	-	30			
36,0	30-		30			
40.0	37	<u> </u>	37	en al la ser de la ser en en el ser de la		
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NOTE: A - All frequencies not listed are scanned for maximum interference. B - Interference Type: (1) Broadband, Steady-State (2) Broadband, Transients (3) Narrowband (CW)

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SINGER KEARFOTT DIVISION

# Electromagnetic Compatibility Test Data Sheet

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NAS		····				•
	2 514-			· · · · · · · · · · · · · · · · · · ·		
ECIFICATION	·	<u></u>	PARAGRA	PH	TEST DU	7 PO7 # 2
ONDUCTED BY A		DATE 17-73	CHEC	RED BY		DATE 11-17-73
			FINAL READING		INTER. TYPE	REMARKS
ppla	s/. 2 C.P			Delvala 2		0.0.00
.620 4	15	1)	5 1 5 2 48	124	<u> </u>	PROFIL
127	12	13	<u>52</u>	160		
1075	-1		48	112		
.645	77	<u> </u>	46 47	106		
	3	<del>_7</del>	45	102		
	12	2	<del>73</del> 44	94		
1100	16	- <del>}</del> +	43	4.6		
.120	35		36	32	1	
	3	2	36 33	<u><u> </u></u>	!	
	33	0	33	80 54	Y	V
,300	32	0	32	54.	<u> </u>	¥
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NOTE: A - All frequen B - Interferenc	s [voe: (i) C≮00	1900ug, steady—stat	n Interference e	•		
P 1115114161	(2) Brod	dband, Transients				
	(3) Marr	owband (CW)				

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# Y256A226 REV -

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	netic Comp					KEARFOTT DIVISION	
TEST SPECIMEN	NASA		MODEL N	0-1-2		R NO.	
TEST MODE	<u> </u>	<u>ר</u>	<u>l</u>	<u>-</u>			
	POWER	0,0 .					
SPECIFICATION		,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,	PARAGR	\РH	TE	OUTPUTNO ONE	
CONDUCTED BY	A.G.	DATE	CHE	CKED BY B-		DATE 11-17-73	
TEST FREQ	MÉTER READING	CORRECTION FACTOR	FINAL READING	SPECIFICATION	INTER. TYP (SEE NOTE B	E REMARKS	
	1. 1. 1. 1. 1. 1. 2.	C.P.		DB/MA / MIZ			
.020	¥ 5	11	57	124	1	PRORE	
.015	4.7	10	51	120			
1035	34	7	41	116	•		
. 645	34	5	34	112		i	
.065	32	4	36	106			
, 383	31	3	34	102			
,100	30	2	32	98	!		
120	<u></u> >	/	31	-7'2			
, 150	20	1	31	G2 87	,		
,200	30	6	30		j		
1300	30	·	30	<u> </u>			
<u>، ۲۹۵۶</u> دنکې			30	76	· · · · · · · · · · · · · · · · · · ·		
.803	30		30	64	. <u></u>		
110			30	60	:		
1.5	30		30	54			
7.0	<i>7</i> ,3		30	50			
3,0	30		30				
4.0	فسر کا		30		:	l	
5.5	30		30		1	•	
6.0	30		30				
4.2	30		30				
/2,0	30	4	76				
15.0	30		30				
2010	?0	-	30				
23.2	ې <u>ې</u>		30				
30.0	32		32	{			
40.0	43		30 43				
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NOTE: A - All frequencies not listed are scanned for maximum interference. B - Interference Type: (1) Broadband, Steady-State (2) Broadband, Transients (3) Narrowband (CW)

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S	N	G		R	)	
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# Electromagnetic Compatibility Test Data Sheet

TEST SPECIMEN	NACA		MODEL	0-1-7	SER NO	5.
TEST MODE	NASA		L		L	·
Da	WER ON	)		,		•
SPECIFICATION		<u> </u>	PARAGI	RAPH	TEST OU	TPUT # 1
CONDUCTED BY	AG-	DATE	7-73 **	ECKED BY BJ		DATE 11-17-73
TEST			· · · · · · · · · · · · · · · · · · ·	SPECIFICATION	INTER. TYPE	REMARKS
TEST FREQ	METER READING		FINAL READING	LINT.	(SEE NOTE B)	
.620	51	11	62	124	2	P FU / J E
1025	43	10	56	/20		
,035		<u> </u>	49	1/16	1	
1045	ر نوسه	2	46	112	l l	
1065	5	4	47	106		
,080	43	3 ·	46	102		
100	42	<u> </u>	44	96		
120°	24		35			
.200	34	0	34	87		
,305	33		33	80		
.400	33		37	76		
1500	3.2		32	ウン		
1800	32		32	64	1	
1.0	32		32	60		
115	33		33	54		
7.0	35 .		35-	50	¥	¥
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NOTE: A - All fre	quencies not listed	are scanned for max	imum interference		L	L

 Broadband, Steady-State
 Broadband, Transients
 Narrowband (CW) B - Interference Type:

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KEARFOTT DIVISION

SER NO.

0-1-2

## Electromagnetic Compatibility Test Data Sheet MODEL NO

TEST	SPECIMEN

TEST MODE

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J OU SPECIFICATION	NER JN		PARAGR	APH	TEST 5	V, D.C
ONDUCTED BY	A.C	0ATE 1)-1	7-73 CHE	B.J.		DATE 11-17-73
TEST FREQ	METER READING	CORRECTION	FINAL READING	SPECIFICATION LIMIT	INTER. TYPE (SEE HOTE B)	REMARKS
	DBARA/11-2	C.P	Delapting	DR/up/1042	SUITCH TO CFA	
,070	4 2	11	5-1	124	2	PROBLE
.0 2 5	43	10	53	120		1
1035	30	7	45	116		
.045	38	5	43	112		
.065	4 }	4	4.5	106		
680	42	3	45	102		
,106	41	2	45	98		<u> </u>
1/20	40	1	41	96		·····
150	34	1	37	92 87	└ <u>──</u>	<b> </b>
,200	37	0	37	2	<u> </u>	
1300	37		37	50		
,400	34		37	72		l
540	33		the second s	64		
,800	31		31	60		
1.0	35		32	54		
	37		21	50		
2,0	32		32	1 50	- 1.	
610	56		56	50	V	V V
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Broadband, Steady-State
 Broadband, Transients
 Narrowband (CW)

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EST SPECIME	NA	57 - 18 - 57 - 184	MODEL N	0-1-2	SER NO	
EST MODE						•
PECIFICATION	CR ON		PARAGR	APH	TEST.	
			•		5	V.D.C
ONDUCTED B	* AG-	DATE	7/73 CHE	CKED BY B J		DATE 1/17/7
TEST FPEQ	METER READING	CORRECTION	FINAL READING	SPECIFICATION	INTER. TYPE	REMARKS
	DRW MAR	C.P.	DB/CA/MH2			
1020	42		53	124		PRUBE
,025		10	45	120	1	1 11 0 - 54
.035		-7	46	116	i	· · · · · · · · · · · · · · · · · · ·
10 45	32	. 5	37	106	!	······
,0 65	32	4	36	112		· · · ·
082	30	3	33	93		·
1/00	30	2	37	96		
1120	2.5		31	92		i
1200	30	0	30	80		1
1300	30	,	30	75		<u> </u>
1400	30	<u> </u>	30	76		i
,500	30	<u> </u>	30	64		<u> </u>
1800	30		30	60	<u> </u>	
1.0	30		30 30	54		_ <u></u>
2,0	30		30			
3,0	30		30			
4.0	. 30		30		i	
5.0	31		-31		l l	
6.6	50	<u> </u>	50			
9.2	<u>54</u> 30		54			
12.0	30	<u> </u>	30			
0.00	30		30			
25.0	36	····	36	<u>├</u> ──┤		
20.0	30		30			
16.0	33		33		·····	
0.0	32	Y .	32	<b>₩</b>		<u> </u>
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2 SER	NO.
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TES	28.0.12.0.
3J	DATE 11-17-73
TION INTER. TYPE	REMARKS
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#### Y256A226 REV -SINGER Electromagnetic Compatibility Test Bata Sheet KEARFOTT DIVISION TEST SPECIMEN MODEL NO SER NO. 0-1-1 NASA TEST MODE POWER ON SPECIFICATION TEST PARAGRAPH OUTPUT #2 DATE /1-17-73 CONDUCTED BY DATE CHECKED BY B.J. 11-17-73 AC INTER, TYPE TEST FREQ SPECIFICATION METER CORRECTION FACTOR REMARKS FINAL ISEE NOTE B) LHHI NBMA lagz BRIDA Jun Z. - 2 C , 220 53 124 1 PKJME ÷. ٠ 15 2.2.5 1 45 120 ł 7 42 . : 37 116 35 54 , 0 4 5 ŗ. 5 112 i .065 32 Ý 36 106 ,080 2.5 23 1 3 102 98 კა .100 į 27 r ÷ .120 30 1 31 96 i .150 30 1 31 92 ÷ 36 87 30 ,200 0 . 300 30' 30 80 ţ . 400 30 30 74 ÷ 30 って 1500 30 1 i 30 64 850 ł 30 66 1.0 30 30 5 54 1.5 30 30 30 50 210 30 2.2 30 30 7 3 30 30 1 , 30 č. ) 30 1 6.0 30 30 Ţ . 9.2 30 30 i 30 12.0 30 ł 15-5 35 30 ÷ 30 20.0 30 Ì 25.0 : > 30 L 25 30.0 30 40.0 3) 20 ł. 50,0 30 30 7 . NOTE: A - All frequencies not listed are scanned for maximum interference. B = Interference Type: '(1) Broadband, Steady-State (2) Broadband, Transients (3) Narrowband (CW)

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## Electromagnetic Compatibility Test Data Sheet

EST SPECIMEN . NASA			мо	MODEL NO O-1-1 SER NO.				
EST MODE		. <u></u>			· · ·		· ·	
POWER PECIFICATION			P/	RAGRA	РН	TEST 5	V.D.C.LINE	
CONDUCTED BY A G. DATE/17			/73	CHE	CKED BY B.J		DATE /17/73	
TEST FREQ	METER READING	CORRECTION	FIN/ READ		SPECIFICATION LIMIT	INTER, TYPE	REMARKS	
	67: 01 Land	с.Р	DE/OF /	10,4 Z	DE/UA/MHZ			
,020	43	1/	54		124		PROPE	
. 625	45	70	50		120			
,035	33		40		116	· · · · · · · · · · · · · · · · · · ·		
1045	34	5	34		112	!	. <b> </b>	
.065	30		34		106			
. 080	30	3	33		102	<u>}</u>	1	
.100	30	2,	32		98	•	1	
,120	<u> </u>	/	31		96			
. 150	30 30		31   30		92 87		· · · · · · · · · · · · · · · · · · ·	
,200	30	C	30		80			
.300	3 - 1		301		76	· · · · · · · · · · · · · · · · · · ·		
. 500	32		30		72			
\$ 50	30		30		64			
.1.0	30		301		60			
1.5	3.5		30 1		54	;	1	
2,0	30	i i	30 1		50	· · · · · · · · · · · · · · · · · · ·		
3.10	34 90		30			algen i		
e, 0	- 32	;	30			3		
5,0	261		30.			{ \$		
6.0	70 :		30			<u> </u>		
9.2	79		30 .	<u></u>		!		
12.0	30		30 1			<u> </u>	<u> </u>	
15.0	30 :		30					
20,0	3)		30 -		[ ]			
25.0	20		30				<u> </u>	
30.0	30					<u>.</u>		
	301	4	30		Y I	¥	<u> </u>	
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	equencies not listed		1		I	<u> </u>		

V(1) Broadband, Steady-State
 (2) Broadband, Transients
 (3) Narrowband (CW)

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PAGE 3-32 ÷

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SINGER

Electromagnetic Compatibility Test Data Sheet KEARFOTT DIVISION TEST SPECIMEN MODEL NO SER NO. NASA 0-1-1 TEST MODE FOWER ON TESTOUTPUT # 2\_ SPECIFICATION PARAGRAPH DATE 11-17-73 CHECKED BY CONDUCTED BY DATE 11-17-73 AIC BIJ INTER, TYPE SPECIFICATION CORRECTION TEST FREQ EINAL READING METER REMARKS ISEE NOTE BI LIMIT 03-0-11-2 De el prop BBAA MAZ C.P PROCE 124 53 -070 2- <u>3</u> 11 ,025 4-1 51 120 10 .033 36 43 116 7 39 112 .045 34 5 38 34 4 106 .065 35 102 080 2 36 98 2 32 100 30 96 1 31 110 30 31 92 150 33 1 ,200 30 20 0 87 3.0 ,300 30 83 24 30 30 ,400 3 2 72 ,500 30 64 30 30 . 860 35 60 30 1.0 1.5 C4 35 30 (n t 2. 1 25 32 3.0 33 30 į 3.2 3, 410 ÷ 7 د 5.0 23 : 6.0  $\gamma$ 30 ł 9,2 61 61 12.0 30 30 ×. 30 15.0 3 > , 30 • ķ . 20.0 ł 25.0 30  $: \mathbf{i}$ i i 27 30 30.0 70 30 40.0 F 3 Ŷ 30 V 50.0 35 ¥ V

NOTE: A - All frequencies not listed are scanned for maximum interference.

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B - Interference Type: (1) Broadband, Steady-State (2) Broadband, Transients

(3) Narrowband (CW)

PAGE 1 3-33



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TEST SPECIMEN			MODI	0-1-1	354	SER NO.			
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	R ON					· ·			
PECIFICATION			PAR	AGRAPH	TES	12 U.D.C. LIN			
ONDUCTED BY	AG	DATE 11-17	-73	CHECKED BY	J,	DATE/ 11/17/73			
TEST FREQ	METER READING	CORRECTION	FINAL READIN		(SEE NOTE B)	REMARKS			
MHZ	ON OFF	د ک	2.10 S 010 ( 417 F 2.3 L1	N DEJUH /MHZ					
.07.3		1	55	124	1	PASRE			
. 0 2 5	421	10	50	120		· · · · · · · · · · · · · · · · · · ·			
.035	33	7	40	114					
1045	34	5	34	112		2			
,063	37	. 4	41	106		;			
.080	38	?	41	102					
,100	38 .	2	43	98	1	· 1			
.120	30	1	31	96	ļ				
.150	30 . 46	1		16 42		<u> </u>			
100	301 43	<u> </u>		43 87					
<i>,320)</i>	3, 40			44 80					
.439	30 44			<del>49</del> 76 47772	· · · · · · · · · · · · · · · · · · ·	· · · · · · · · · · · · · · · · · · ·			
· 500				51 64	1 1				
.800	30 51	1		54 60					
1.0	22 56	1		57 54					
2.0	3, 54			54 50	1				
3:0	35 49		김 이 아이들 것 같아.	49 1 1					
4.0	33 40			15					
57	48 41	1		48					
6.0	35 55	1		50					
9.2	38 73	,	the second second second second second second second second second second second second second second second s	73					
/2.0	30 42	i	1	12					
15.1	33 35	<u>{</u>		35					
20,2	30 26	1	30 3	36					
250	3> 30		30	30					
30.0	70 30		1	30					
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(2) Broadband, Transients
 (3) Nerrowband (CW)

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PAGE

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EST SPECIME		<u> </u>		DEL NO	)	SET	R NO.	
	· NASA	-			0-1-1			
EST MODE								
PECIFICATION	WFR ON			ARAGRA		1 75		·····
- Letrick Hor	•				<b>FN</b>			U. A.C
ONDUCTED BY A.G. DATE 1/18/73		8/73	CHEC	KED BY BJ	<u></u>	DATE	1/18/73	
TEST METER CORRECTION FREQ PETENG FACTOR		REAT	AL DING	SPECIFICATION	INTER, TYP (SEE NOTE B)	ε	REMARKS	
	Del 4ª							C.N.
5.1	60	0	6	<u>ر</u>	20	3		PRISE
.10.0	45	0	4	4.	20	з		11
26.0	26	Ø	2		2.0	3		1/
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Broadband, Steady-State
 Broadband, Steady-State
 Broadband, Transients
 Narrowband (CW)

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T SPECIMEN	MACA	· · · · · · · · · · · · · · · · · · ·	MODEL	0-1-	/ SER NO	<b>.</b>
ST MODE	NASA		l			<u> </u>
POU	IER ON		PARAGI		TEST	
GUIFICATION						+ 5.0 U. D.C
NDUCTED BY	A. C-	DATE	СН	ECKED BY		DATE 11-18-73
TEST		CORRECTION	FINAL READING	SPECIFICATION	INTER. TYPE	REMARKS
FREQ	METER PEADING	the second second second second second second second second second second second second second second second s	READING	LIMIT		c.w,
	DEJUI			DR/UK 16+4 20	3	PROJE
5.1	30	D	30	20	3	11
10.0	27	0	26	20	3	<i>n</i>
19.8	26	<u> </u>	20			
		<u> </u>			·····	
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DIVISION

# Electromagnetic Compatibility Test Data Sheet

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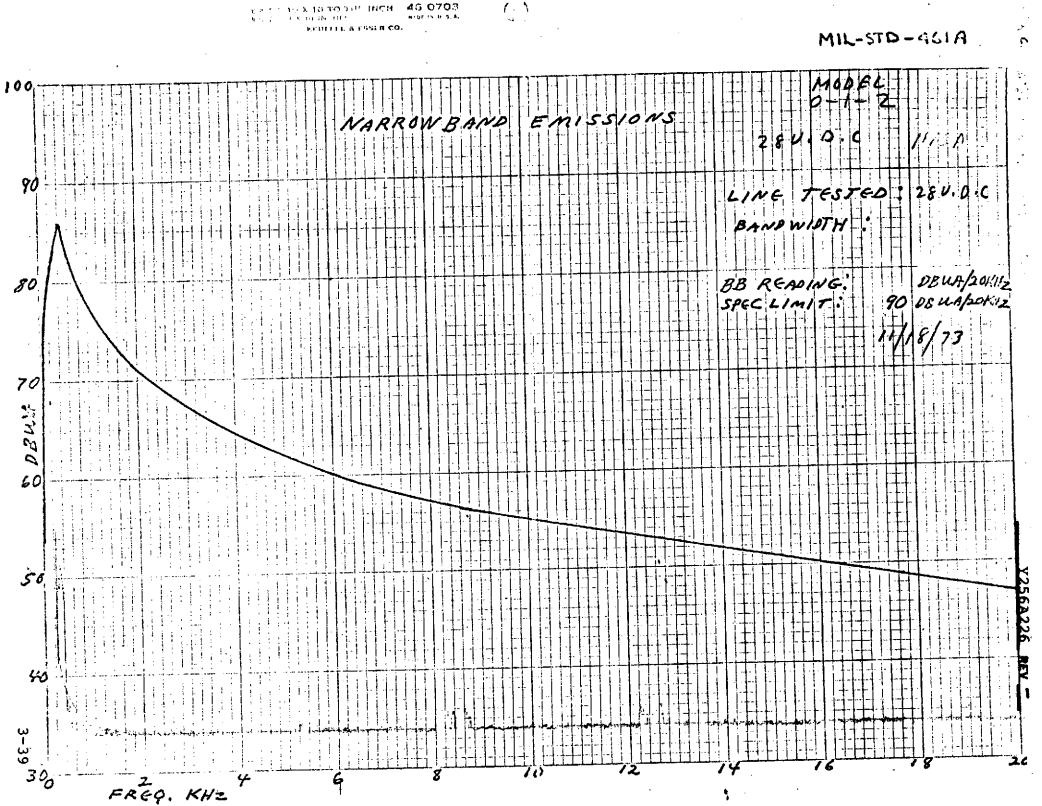
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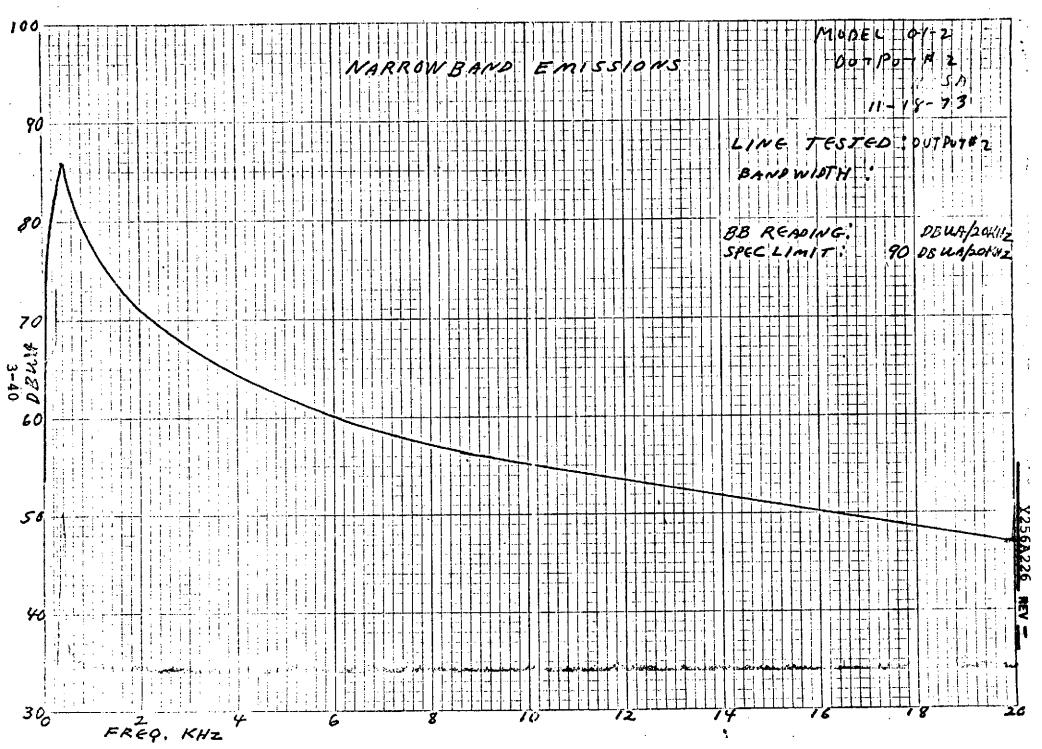
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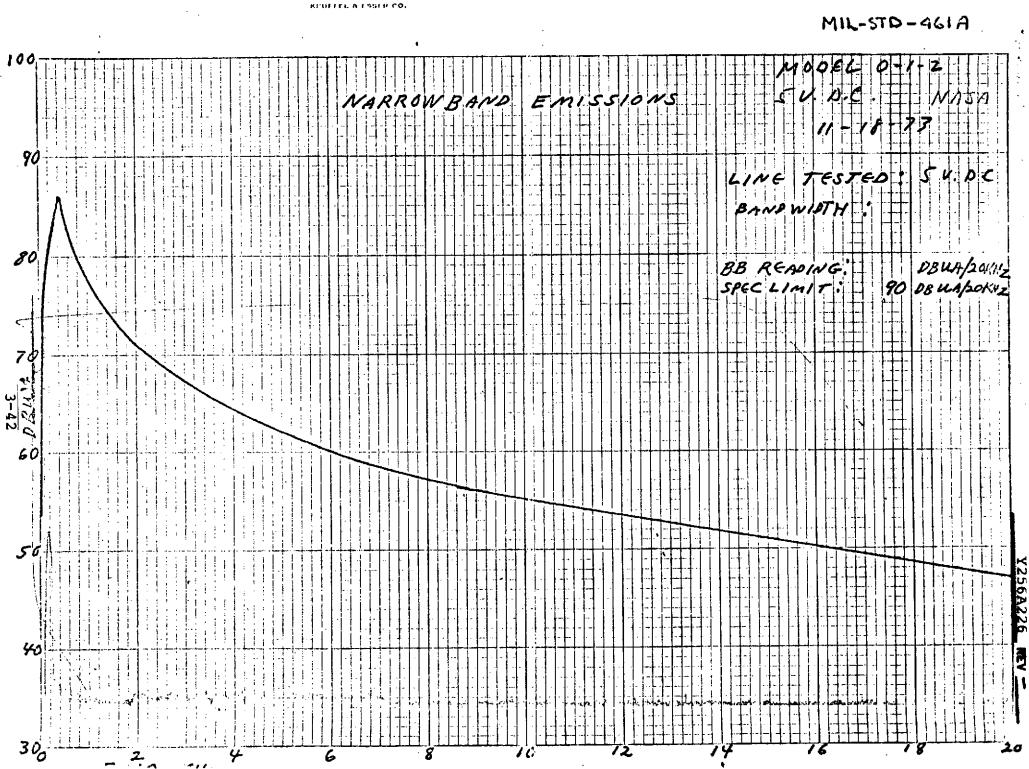




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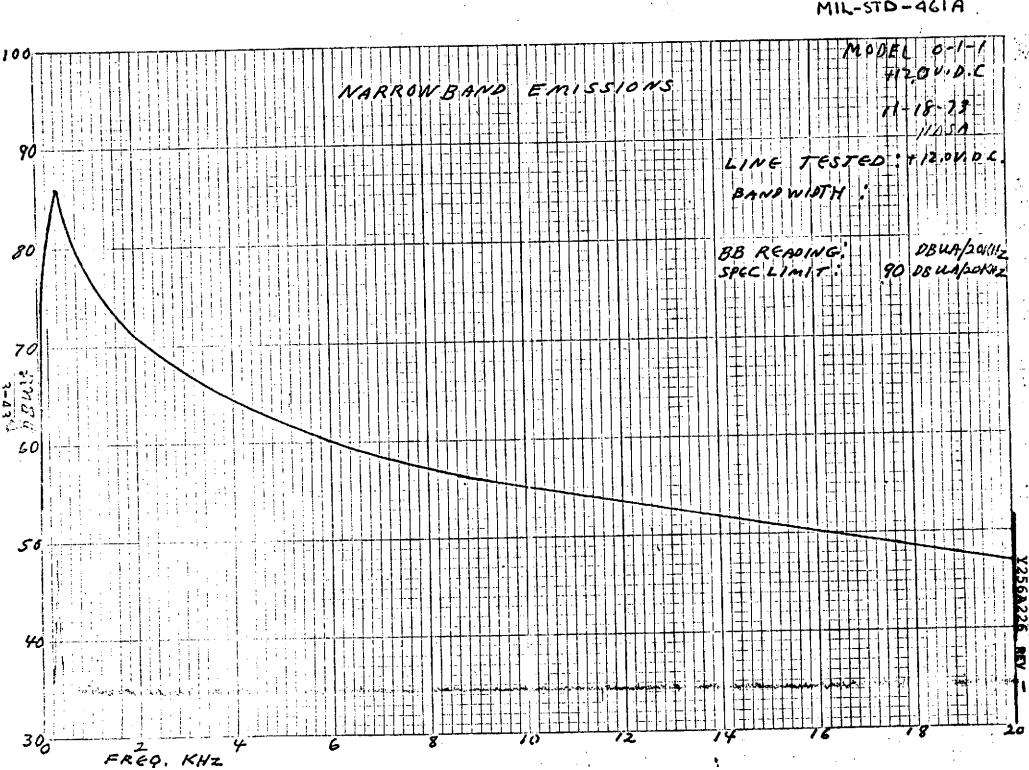
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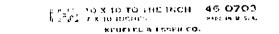
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		NARROWBAN	DEMISSIONS	
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90				LINE TESTED COUTPUT #1
				BANDWIDTH . MISA
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80				BB READING: DBUA/201412 SPECLIMIT: 90 DBUA/201412
				SPEC LIMIT: 90 DB UA/20KHz
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#### THE SINGER COMPANY KEARFOTT DIVISION

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<u>Y256A226</u> REV. -

#### RELIABILITY

A reliability prediction was preformed to establish the failure rate of each of the solid state switch devices. This data is summarized on the attached computer data sheets. Also included in this section is a reliability failure mode and effects analysis. This analysis was made on the 10 position rotary, potentiometer, and the double pole switch.

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#### FIXED GROUND ENVIRONMENT

#### NOV. 8,1973

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SUBASSEMBLY -- CIRCUIT BUARD =1

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	AMBIEr	T TEMPERA	TURE =	4	0C	
	PART TYPE Diude Zener	QUANTITY. 1.0		FR 1.0700		STRESS 50
	RES CUMP RC	2.Û .	6.0000	0.0035	0.0420	25
:	RES COMP RC	4.0	6.0000	0.0035	0.0840	10
4-2	SOLID STATE RELAY	10.0	1.0000	0+0045	0.0450	10
•	TRANSISTOR NPN	4.0	1.5000	ù.1975	1,1850	10
	CIRCUIT BOARD	1.0	1.0000	0.0630	0.0630	10
	SUBASSEMBLY TO	TAL			2.489	
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SUBASSEMBLY CIRCU	1I T	BUARD	=2 '
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	AMBIEN	T TEMPERA	TUR⊾ ≖	4	٥ç		
	PART TYPE Circuit büaru	QUANTITY 1.0	K(ENV) 1.0000	FR 0.0630	Q.F.K 0.0630	STRESS 10	· · · · · · · · · · · · · · · · · · ·
	DIUDE	4.0	1.5000	0.2600	1.5000	20	
	LED TRANSISTOR NPN	4.0	1.5000	0.1975	1.1850	10	
	PHOTOTKANSISTOR TRANSISTOR NPN	7.0	1.5000	0+1975	2.0737	10	
	RES COMP RC	11.0	6.0000	0.0035	0.2310	10	· · · · · · · · · · · · · · · · · · ·
	RES CUMP RC	1.0	6.0000	0.0035	0.0210	25	
HI-R	INTEGRATED CIRCUIT	1.0	1.2000	0.0300	0.0360	10	
HI-R	INTEGRATED CKT.MSI	1.0	1.2000	0.0600	0.0720	. 10	
	SUBASSEMBLY TOT	AL		<b>.</b> .	5+242		
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	AMBIENT TEMPERAT	ſURċ =	4	oc	
PART TYPE Shaft	GUANTITY 1.0		FR 0.3500		STRE SS
BEARING	3.0	1.0000	0.5000	1.5000	10
DIODE LED	1.0		0.4175	0.6262	40

SUBASSEMBLY -- SWITCH ASSY

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	CIRCUIT BOARD =2	1.0 1.0	000 5.2417	5.2417	10 ,	
ſ	SWITCH ASSY	1.0 1.0	000 2.4762	2.4762	2 10	
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		DIODE ZENER	.1.0	1.0000	1.0700	1.0700	50			. · · · · ·			-	· ·		-
		TRANSISTOR NPN	1.0	1.5000	0.1975	0.2962	10									
		RES COMP RC	5.0	6.0000	0.0035	0.1050	10		•						• . • • • • • • •	-
		CAPACITOR CER CK.	2.0	1.0000.	0.0020.	0.0041_	15	· ·	· _	<del></del>						
	HI-R	INTEGRATED CIRCUIT	2.0	1.2000	0.0300	0.0720	10									
	HI-R	INTEGRATED CKT MSI	1.0	1.2000	0.0600	0.0720	10	<b>-</b>			. <u> </u>			· ••• · ···· •• ·		
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· · ·	AMBIE	NT TEMPEKATURE =	40 (	2								 ·
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	D.100E	7.01.5000	0.2600	.7300 .	20				<b>.</b>		·	 ·
	TRANSISTOR NPN PHOTOTRANSISTOR	7.0 1.5000			10	• .		. <u></u>		· :		 
	RES COMP RC	7+0 6+000u	0.0035 (	3.1470	10							
	SUBASSEMBLY TO	TAL	` !	5.014	<b>.</b>		•			<u> </u>		 
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ANDIENT THEMPERATURE -         40C           FART TIPE         CLANLITY KIENU FR UCERN STRESS           DEARLMS         3.q           DIGOE         1.0           DIGOE         1.0           SUBASSEROLT TUTAL         2.4T6	יי <i>י</i> ז		FD	KED GROUND ENVIRONMENT	NOV. 8,	1973		
PART TYPE         COANTTY KLENT         CFR         CLASS STRESS           BEARTING         3.4         1.0060         6.5000         1.0000	* ~~ *	SUBASSEMBLY PUT ASS	5¥					
3       Singrift       1.0       1.0000       0.3500       10         Singrift       1.0000       0.3500       1.0000       10       10         Dioos       1.0       1.5000       0.4000       10       10         Supassendury TuTAL       2-470       10       10       10         1       1       2-470       10       10       10         1       1       10       10       10       10       10         1       1       2-470       10       10       10       10         1       1       10       10       10       10       10       10         1       1       10       10       10       10       10       10       10         1       1       10 <td>1</td> <td>AMBI</td> <td>LENT TEMPERATURE ≖</td> <td>400</td> <td>••••••••••••••••</td> <td>. <u></u></td> <td></td> <td></td>	1	AMBI	LENT TEMPERATURE ≖	400	••••••••••••••••	. <u></u>		
DIDDE 1.c 1.5000 0.4175 0.6202 40 SUBASSERULY TUTAL 2.475 2.475	, n				- ·	۰ <u>۰</u>		
DIDDE LED SUBASSERIELY TUTAL 2-476		BEARING	3.0 1.0000	0.5000 1.5000 10	and a second second	· · · · · · · · · · · · · · · · · · ·		
			1.0 1.5000	0.4175 0.6262 40				
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		SUBASSEMBLY	TUTAL	2.476		·		
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FIXED	GRUUND	ENVIRONMENT	NUV.	8,1973
FIXE0	GRUUND	ENVIRUNMENT	NU V =	0,17

ANDIENT THATEMONIE         400           PART TYPE         QUANTITY KIEWI         FF         QUANTITY KIEWI           PL BUARD =2         1.0         1.0020         1.0233         100           PUT SST         1.0         1.0020         5.0137         9.017         10.           PUT SST         1.0         1.0020         6.0172         10.         9.0172         10.           SUBASSLEBUY TOTAL         9.172         9.172         9.172         9.172         9.172	SUBASSEMBLY - SULID	STATE POT									
PC BDARD =2 1.0 1.0000 1.0023 1.0023 10 PC BDARD =2 1.0 1.0000 5.0137 5.0137 10 DV TASS 1.0 1.0000 1.0752 (2.072 10 SUGASSLABLY TOTAL 9.172	AML	IENT TEMPERA	TURE =	4	00						
PUT ASSY 1.0 1.0000 1.4762 2.4762 10 SupASSEBELY TUTAL 9.172			K(ENV) 1.0000	FR 1.6823	W.F.K 1.6823				······	· · · · · ·	
SUGASSERBLY TOTAL 9.172	PC BUARD =2	1.0	1.0000	5.0137	5.0137	10		-		-	
SUGASSEMBLY TUTAL 9.172		1.0	1.0000	2.4762	2.4762	10					
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FIXED GROUND ENVIRONMENT

NUV. 8,1973

SUBA:	SEMBLY TOGGLE SWITCH	H SP				
C.	AMBIENT TE	EMPERATURE =	. 41	0C		
		ANTITY_K(ENV) 1.0 1.5000	FR 0.4175		STRESS	5
	CIRCUIT_BUARD		0.0630		10	
	TRANSISTUR NPN	1.0 1.5000	0+5100	0.7650	50	· · · · · · · · · · · · · · · · · · ·
	SOLID STATE RELAY		<b>0</b> ₊0045		10	
HITR	INTEGRATED CIRCUIT				÷	
(	SWITCH TOGGLE	•	0.2500		10	
-	MAGNET	1.0 1.0000	0.5500	<b>U.</b> 5500	10.	
- * -	SUBASSEMBLY TOTAL			2.295	· · · · · · · · · · · · ·	
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1				Fli	CED GROU	NU ENVIR	UNMEN 1			NOV.	8,1973			• •	. *	
<u>_</u>	SUBAS	SEMBLY TUGGLE SW	ITCH UP										•		۰ <i>۱</i> ,	
			T TEMPERA	TURE =	4	06										
• •		PART TYPE DIODE	QUANTITY 1.0	K (ENV)	FR 0.4175	Q.F.K 0.6262	STRESS 40		.= .			· -	•			. <u> </u>
		LED CIRCUIT BUARD	1.0	1.0000	u.ú630	0.0630	10	•					• •		· · <u></u>	
		TRANSISTOR NPN	1.0	1.5000	0.5100	0.7650	. 50								· · · · · · · · · · · · · · · · · · ·	
		SOLID STATE RELAY	2.0	1.0000	6.0045	0.0090	10	-								
	HI-R	INTEGRATED CIRCUIT	1.0	1.2000	0:0300	0.0360	10									
<b>،</b> ،		SWITCH TOGGLE	1.0	1.0000	0.2500	0.2500	10									
		MAGNET	1+0	1.0000	0.5500	0.5500	10									
		SUBASSEMBLY TO	TAL			2.299	<b></b>				· · · · · · · · · · · · · · · · · · ·					
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#### FIXED GROUND ENVIRONMENT

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EQUIPMENT	SOLID STATE	KE Y BOARD
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#### AMBIENT TEMPERATURE =

PART TYPE Rotary SW 10 POS	QUANTITY 2.		FR 10.2070		STRESS 10
SOLID STATE PUT	2.	1.0000	9.1723	18.3447	10
TOGGLE SWITCH SP	10.	1.0000	2.2947	22+9475	10
TUGGLE SWITCH DP	15.	1.0000	2 <b>.2992</b>	34.4887	10
TOTALS				96.195	

TEMPERATURE/TIME PROFILE

PERCENT OF TIME AT TEMPERATURE 1.0000

EQUIVALENT PROFILE FAILURE KATE = 96.1948

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PROFILE MTBF = 10395.57 HOURS

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EQUIPMENT -- SULID STATE KEYBLARD

AMBIENT TEMPERATURE 400

FIXED GROUND ENVIRONMENT

-		PREDI	CTION BY PART TYPE		
-	PART TYPE CIRCUIT HUARD =1 CIRCUIT BUARD =2 Switch ASSY PC BUARD =1	UANTITY 2. 2. 2. 2.	TUTAL F.R. 4.978 10.453 4.952 - 3.365	SUURCE OF DATA PREDICTED SUBASSEMBLY PREDICTED SUBASSEMBLY PREDICTED SUBASSEMBLY PREDICTED SUBASSEMBLY	-
	PC_BOARÚ=2. POT ASSY DIODÉ	2 2 25	10.027 4.952 15.656	PREDICTED SUBASSEMBLY PREDICTED SUBASSEMBLY MIL-HDBK-217A FIGURE 7.4.38 (MIL-S-19500)	•
-	CIRCUIT BUARD TRANSISTOR NPN SOLID STATE RELAY	25. 25. 40.	1.575 19.125 0.180	NINTH SYMPOSIUM (EARLES/EDDINS) MIL-HOBK-217A FIGURE 7.4.48 (MIL-S-19500) KEARFOTT SECUNDARY DATA	,ì
HI-R	SWITCH TOGGLE Magnet Integrated circuit	25. 25. 25.	6.250 13.750 0.900	MIL-HDBK-217A FIGURE 7.10.2 (TYPE A) KEARFOTT SECONDARY DATA KEARFUTT EXPERIENCE	

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202. TUTAL PARTS

TOTAL FAILURE RATE = 96.19

MTBF = 10395.57 HOURS

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EQUIPMENT SOLID	STATE KEYBUARD						
400 AMBIENT TEMPER	RATURE				 <u></u> .		
FIXED GROUND ENVIRON	NMENT	• . سبه		-			
SUBASSEMBLY.	FAILURE HATE						
ROTARY SW 10 PUS	20.41				 Manut das 1977-111		
SOLID STATE PUT	18.34	· ·					
TOGGLE SWITCH SP	22.95						
TUGGLE SWITCH DP	34.49				 	.,	
TOTAL FAILURE RATE =	96.19	A	<u></u>				

MTBF = 10395.57 HOURS .... . . -----. . . . . .... -------

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## RELIABILITY FAILURE MODE & EFFECTS ANALYSIS

REARPOTT OLYMPION GINGEP-GENERAL PRECISION, INC. LITTLE FALLS, REW JERGET

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10 POSITION SOLID STATE ROTARY SWITCH

-						1.0.0	76				C CRIT	CALITY	
4	DESCRIPTION		PUNCTION	FAILURE MODES	FEACEN?	LURE RA		CAUSE OF FAILURE	FUNCTIONAL PAILURE EPPECT	EQUIPMENT FAILURE EFFECT		-	
t	LIGHT EMITTING DIODE PN MLED 910 MOTOROLA	CR1 THRU CR4	TRANSDUCER LIGHT SOURCE	OPEN	100			· · · · · · · · · ·	IMPROPER DUTAUT				
	PHOTO TRANSISTOR	91		OPEN SNORT	75 25				IMPROFER OUTPUT				
	DUAL MPUT GUAD EXCLUSIVE "OR" GATE PN CD4030AK RCA	U2	DECODER LOGK CONTROL	OPEN SHORT TO +51 SHORT TO OV	90 10 10				IMPROPER OUTPUT IMPROPER OUTPUT IMPROPER OUTPUT				
ł	BCP TO I OUT OF ID DECODER PN CD4028AK RCA		TRANSDUCER MAUT TO OJTPUT SWITCH DECODER	NO OUTPUT IMPROPER OUTPUT	20 80				NO OUTPUT IMPROPER OUTPUT	. 7 <sup>.</sup>			
	PAR REDGE IDAK	R 1 THEU R4	GRTE INPUT GRW	OPEN	100			1	MARSAGE NOISE SUSCEPTIBILITY	د. د			•
	RESISTOR PN RC03GF102K	RO	TRANSISTOR BASE BIAS	OPEN	100				INCREASED NOISE SUSCEPTIBILITY		-		, <b>f</b>
	TRAISS TOR PN 2N5845	96 THA Q15	RELAY COLL DRIVER	OPEN SMORT	75				IMPROPER ONTANT				ŕ
1	SOLID STATE RELAY PN 640-1 TELEOYUE	N-1 THRU N-10	OUTPUT SWITCH COMFACT	OPEN OUTPUT SMORTED OUTPUT OPEN COLL SHORTED COLL	60 15 15				IMPROPER OUTPUT IMPROPER OUTPUT IMPROPER OUTPUT IMPROVER OUTPUT				
	LIGHT ENITTING PIODE PN 5082-4420	CRS	SWITCH FAIL INDICATOR	OVEN	100				NO FAIL INDICATION	<b>I</b> .			
	RE 31-570R PN	R5	LED CURRENT LIMITER	OPEN .	100				INCREASED BRANT- NESS FAIL IND		•	ця, т	
	TRANSISTOR PRI 2N 2222A		LED DRIVER	OPEN SNORT	15 25				NO FINE MUNCATION CONTRACTORS FRANC		-		
	ZENER DIODE PN MZ 4626		LED YOLTAGE	OPEN SHORT	20				DECREASED FAIL MOD BES	7	-	ľ	•
	RESISTOF PNRCOSGF202K		TRANSISTOR BASE DIAS	OPEN	100				CONTINUOUS FAIL MU				۲ ۲
	RE51570R PN RC05	AF6	DIODE CURRENT LIMITER	SALA	100			and the second	NO FAIL DIDIGATION				:
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# RELIABILITY FAILURE MODE & EFFECTS ANALYSIS

KEARFOTT DIVIBIEN Di**der-Ge**rgeral Presióndia, INC. Little Falle, New Jerset

POUBLE POLE TOGGLE / PUSHBUTTON SWITCH (SOLID STATE)

-					FA	LURE RAT	. 1		PUNCTIONAL FAILURE	******	EQUIPMENT PAILURE EFFECT		CALITY	
	DESCRIPTION	BYMBOL	FUNCTION	FAILURE MODES			weel	CAUSE OF FAILURE				PUNCTION	CQUI PMEST	<b>I</b> .
	HALL EFFECT DEVICE PN 2551 MICROSWITCH	Ai	TRANSDUCER SWITCH	OPEN SHORT					SWITCH OUTPUT SWITCH OUTPUT	SHORT		ł		
	TRANSISTOR	QI	RELAY COLL DRIVER	OPEN SHORT	75 25				SWITCH OUTPUT SWITCH OUTPUT	SHORT	•			
	RESISTOR PN RCOSGF271K	RI	MALL EFFECT CURRENT	OPEN	100				SWITCH OUTPUT	OPEN				
	RESISTOR PN RC05GF272K	Rz	TRANSISTOR BASE BIAS	OPEN	100				IMPROPER OUT	PUT				
	SOLID STATE RELAY PN 640-1 TELEDYNE	К1/ К2	OUTPUT SWITCH CONTACT	OPEN OUTPUT SHARTED OUTPUT OPEN COIL SMORTED COIL	3440				SWITCH OUTPUT SWITCH OUTPUT SWITCH OUTPUT SWITCH OUTPUT	OPEN	,			
	MAGNET PN 102 SSIZ MICROSWITCH		TRANSDUCER ACTUATOR						SMITCH EDITOR	,e.,			- - -	
	LIGHT EMITTING DIODE PN 5082-4420-HP	CR1	SWITCH FAIL	OPEN	100				SWITCH OUTPU	T OPEN				
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REARFOTT DIVIALON \$1009B-RENERAL PRECISION, ING. Little Falle, Dew Jenset

# RELIABILITY FAILURE MODE & EFFECTS ANALYSIS

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ŀ	DESCRIPTION	SYMBOL	FUNCTION	FALLURE MODES	PERCENT	LUAE RA	CAUSE OF FAILURE	PUNCTIONAL PAILURE EFFECT	EQUIPMENT PAILURE EFFECT	FURETION	-
	LIGHT EMITTING DIODE PN MLED910 MOTOROLA	CR1 THRU CR7	TRANSDUCER LIGHT SOURCE	OPEN	100		/ / / / _ / _ /	IMPROPER WITPUT			
	PHOTOTRANSISTOR PN MRD604 MOTOROLA	φ1 74RU Φ7	TRANSDUCER SWITCH OUTPUT	OPEN SHO <b>RT</b>	15 25		·	IMPROPER OUTPUT IMPROPER OUTPUT			
	RESISTOR PN RC03GF104J	R1 74RU R1	GATE INPUT GAN ADJUST	OPEN	100			INCREASED NOISE SUSCEPTIBILITI			
1	DUAL INPUT QUAD EXCLUSIVE OR GATE PM CD4030AK RCA	U1/ UZ	CONVERTER LOGK CONTROL	OPEN SHORT TO ISI SHORT TO OI	80 10 10			IMPROPER OUTPUT IMPROPER OUTPUT IMPROPER OUTPUT	÷		
	DIGITAL TO ANALOG CONVERTER PN DAC OZACUL PREC MON	<i>U</i> 3	DIGITAL IN PUT TO CONTINUOUS MIALOG VOLTAGE OUTPUT	NO OUTPUT IMPRCIER OUTPUT	20 80			NO OUTPUT IMPROPER OUTPUT			
	CAPACITOR PN CKOGBX104K	61/ Cz	POWER JUPPLY FILTERING	OPEN SHORT	90 10			INCREASED NOBE SUS IMPROPER OUTPUT			
	TRANSISTOR PN 2N2222A	98	LED DRIVER	OPEN SHORT	75 25			NO FAIL INDICATION CONTINUOUS FAIL IND			
	ZENER DIODE PN MZ4619 HOTOROLA	CR9	TRANSISTOK BASE VOLTAGE REF	OPEN SHORT	<b>80</b> 20			DECREASED FAIL IND BER NO FAIL INDICATION			1
	LIGHT EMITTING BODE PN 5082-4420 HP	CR8	NOTENTIONER FAIL	OPEN	100			NO FAIL INDICATION	1		
	RESISTOR PN RCOSGF 272K	RB	TRANSISTOR BASE BIHS	OPEN	100			CONTINUOUS FAIL IND		ч	
	RESISTOR PN RCOSGES60K	RIO	LED VOLTNGE LIMITER	OPEN	100			NO FAIL INDICATION			
	RESISTOR PN RC05GF15DK	Rg		OPEN	100			INCREASED FAIL NO BRIGHTNESS			
	RESISTOR PN RCOS	R11	ANALOG SCALE ADJUST	OPEN	100			MACCURATE OUTPOT			
	RESISTOR PN REOS	R12	ANRLOG SCALE ADJUST	OPEN	100			WARLIRATE OUTPUT			ŀ
			.*								

#### THE SINGER COMPANY KEARFOTT DIVISION

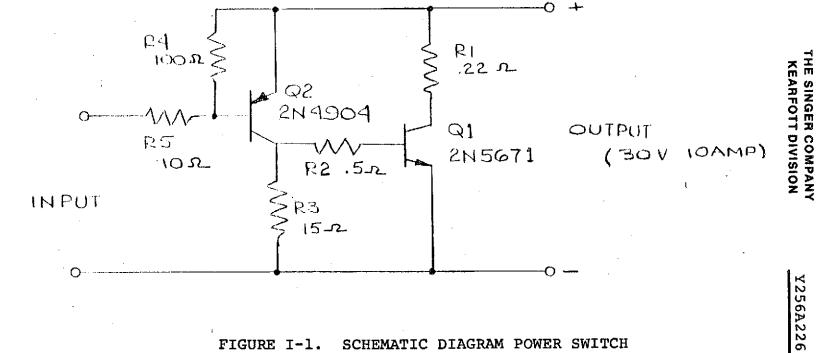
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#### APPENDIX I

### SCHEMATIC DIAGRAMS





SCHEMATIC DIAGRAM POWER SWITCH FIGURE I-1.

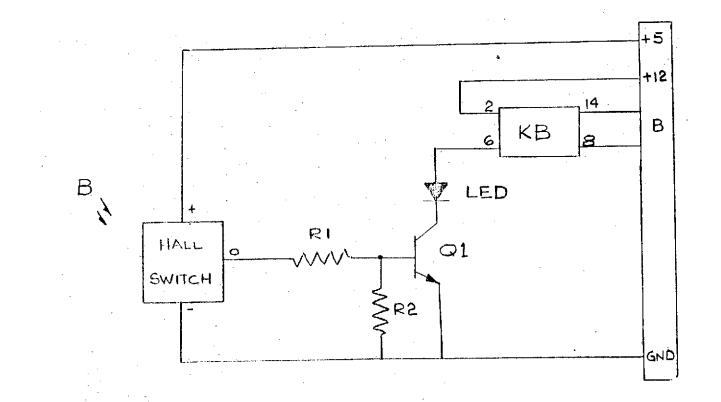
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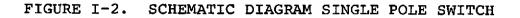
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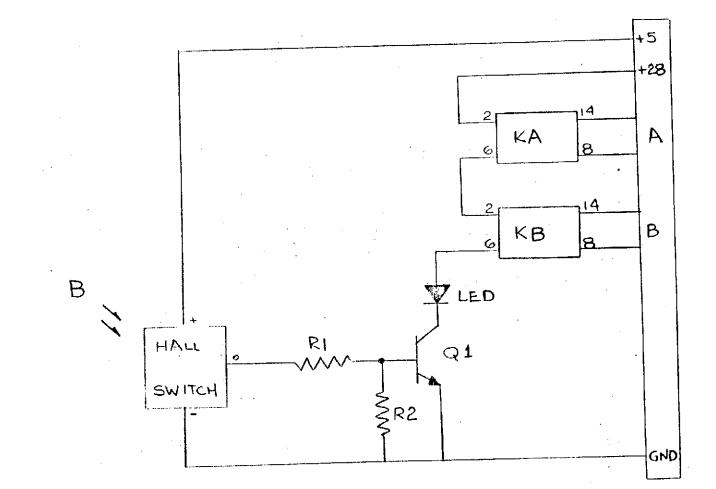
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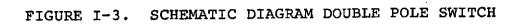
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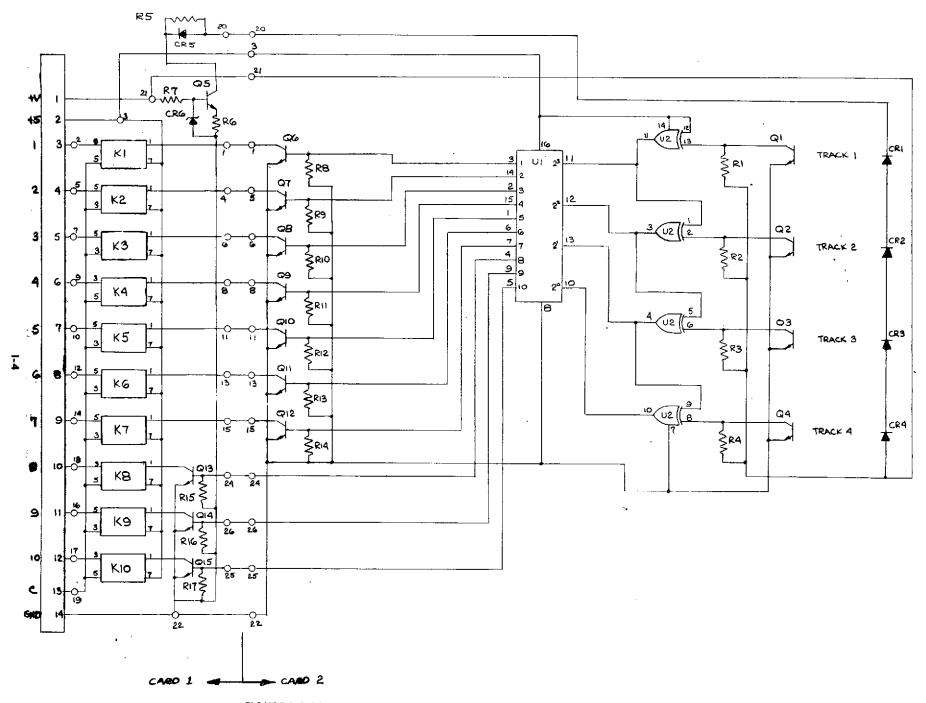


FIGURE I-4 SCHEMATIC DIAGRAM 10 POSITION SOLID STATE ROTARY SWITCH

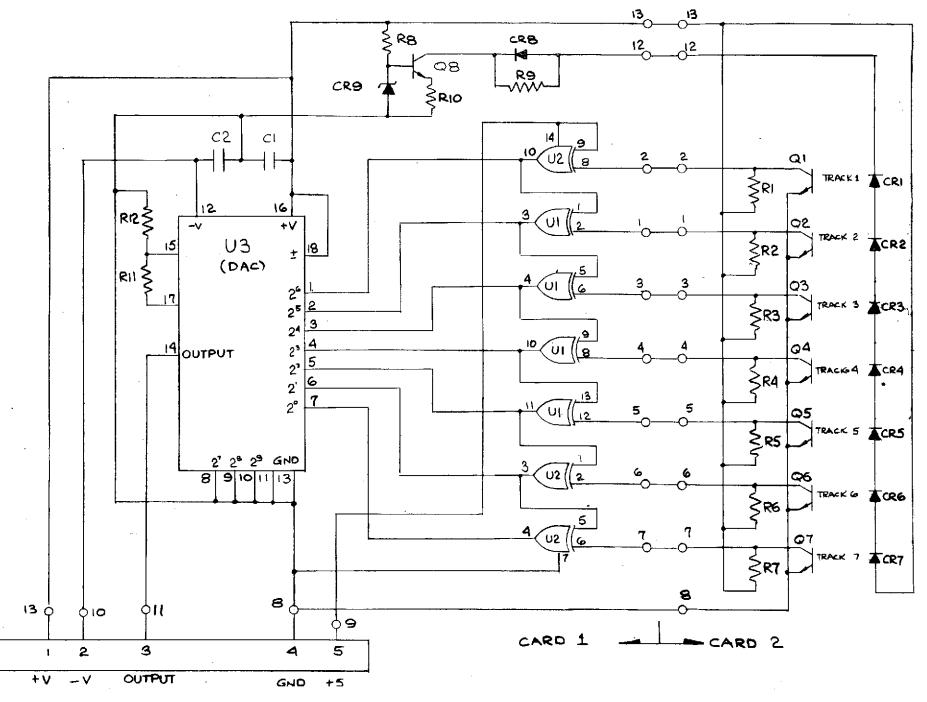


FIGURE I-5 SCHEMATIC DIAGRAM POTENTIOMETER

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