Switches

Introduction

Switches are available over a large range of different sizes, packaging styles, and quality levels. They range from miniature pushbuttons to large power conductors. In fact, so many switch styles are available it is often difficult to select the most appropriate.

Like relays, switches contain moving parts. This makes them sensitive to wear-out failure mechanisms. Moving parts also cause switches to have relatively high failure rates, although these high failure rates are often due to misapplication of the part rather than inherent problems with the switch itself. Switch selection often does not receive sufficient attention during the design or parts selection process because switches are not considered high priority items.

This is intended to be a guide to aid the designer in the selection of an appropriate switch for the intended application. More detailed information is available from vendors and MIL-STD-1132, Selection and Use of Switches and Associated Hardware. A further source of information and complete listings of all military specifications are available from DSCC (Defense Supply Center Columbus) 3990 E. Broad St., Columbus, Ohio, 43216-5000.

Packaging

Switches are available in a variety of package styles, especially among the commercial types. Many are unique to particular applications e.g., pushbuttons, momentary tact, thumbwheel, lever types, slide switches, rocker, key (or switchlock), toggle, rotary, DIP switches, among others. In addition, keypads and keyboards are also considered switches. It is beyond the scope of this document to give a detailed description of every switch type; Tables 1 and Figure 1 give an overview of switch types.

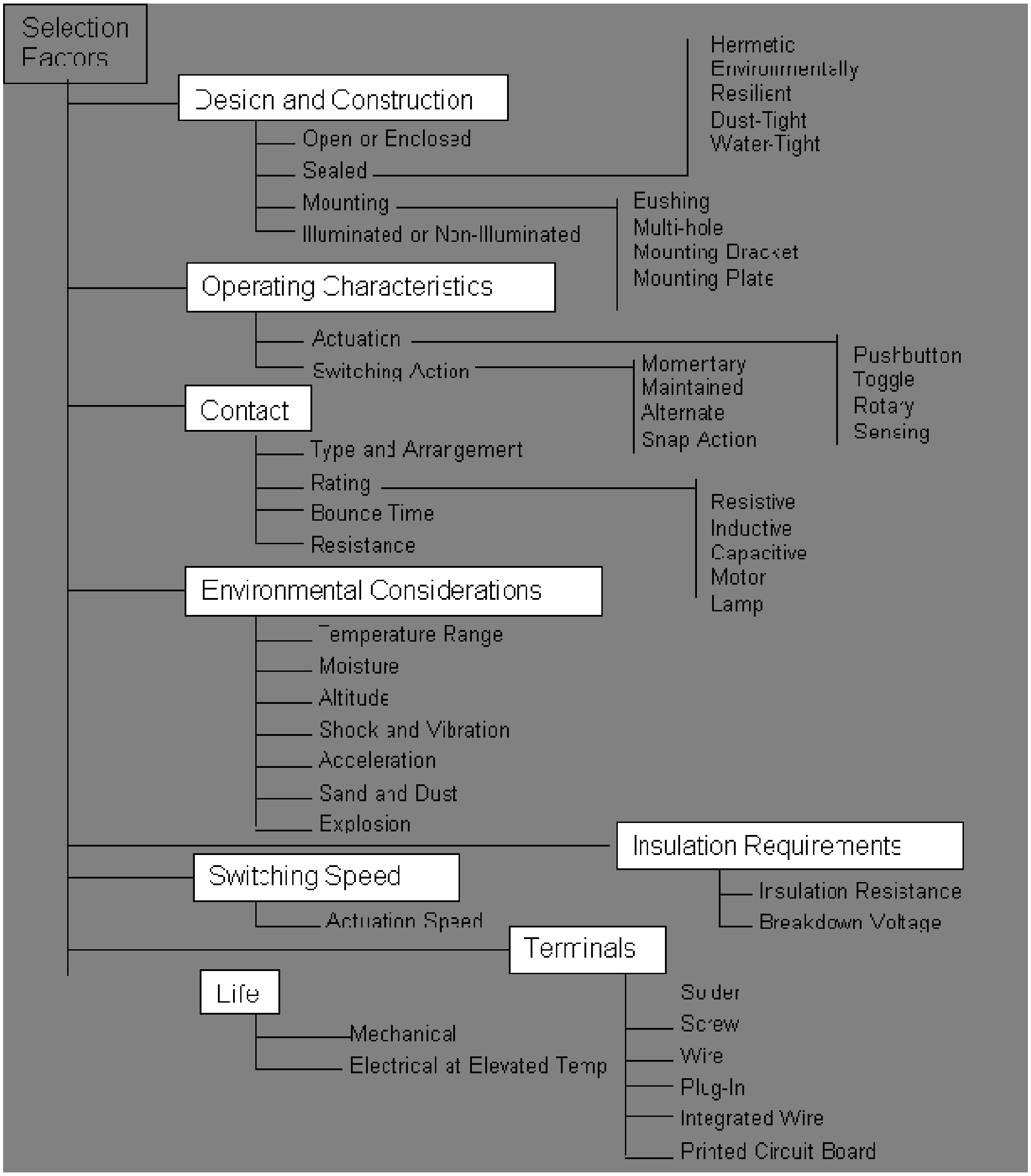

Figure 1. Factors Affecting the Selection of Switches

Table 1. Military Switch Styles and Applications

Switch Type	MIL-SPEC	Intended Application
Switch, Push-Button, Illuminated	MIL-S-22885	Intended for panel displays and switching devices in AC and DC applications. Panel displays include various combinations of colors and legends.
Switches and Switch Assemblies, Sensitive and Push (Snap Action)	MIL-S-8805	Intended for AC and DC applications, where predetermined small and accurately controlled characteristics are required. Various means of actuating by toggle levers, push buttons, cams, and other light pressure devices. These switches have snap-action, which eliminates teasing.
Switches, Multi-Station, push-button (Illuminated and Non-Illuminated	MIL-S-24317	Intended as panel displays and switching devices in AC and DC applications.
Switches, Pressure	MIL-S-9395	Intended primarily to detect changes in pressure, liquid and gas applications.
Switches, Rotary	MIL-S-3786	Intended primarily for low power, AC or DC switching applications (capable of making and breaking a resistive load of <2A). Includes both manually and solenoid actuated switches.
Switches, Rotary Selector Power	MIL-S-6807	Intended for power circuits capable of making, arraying, and breaking electrical loads of <10A.
Switches, Rotary (Printed Circuit), (Thumbwheel, Inline, and push-button)	MIL-S-22710	Intended primarily for low power AC or DC switching applications. Thumbwheel switches provide numerical or other legend readout tied to a particular switch position. Also provided for is logic circuitry for computer operation.
Switches, Thermostatic (Metallic and Bimetallic)	MIL-S-24236	Intended primarily in AC and DC applications where temperature protection or accurate temperature control or an enclosure is required.
Switches, Thermostatic (Volatile Liquid), Hermetically Sealed	MIL-S-28827	Intended primarily in AC and DC applications that require rapid temperature response.
Switches, Toggle Environmentally Sealed	MIL-S-3950	Intended where simple make-and-break actions are required and are suitable for use on AC and DC circuits.
Switches, Toggle, Positive Break	MIL-S-8834	Intended in AC and DC circuits where a positive make-and-break action is required. Positive break actuation causes minimum contact "tease."
Switches, Air and Liquid Flow	MIL-S-28788	Used primarily in equipment to sense velocity and flow of air or liquid.
Switches, Reed	MIL-S-55433	Used in circuits as a separate element where magnetically actuated, hermetically sealed switch contacts are required. Capable of millions of operations and operations were low-level (dry circuit) loads.
Switches, Rotary, Snap Action	MIL-S-15291	Intended for high current circuits capable of making and breaking 10 - 100 A at 120-150 VDC and 125-150 VAC.

Switch enclosure methods can be divided into three types:

a. Open Package: A package in which no effort is made to protect the switch or its parts from atmospheric conditions

b. Environmentally Sealed or Resilient Package: The switch is contained within a completely sealed case where there is a seal of resilient material (e.g., gasket or seal) protecting the switch from the ingression of the outside environment. This type of package offers increased resilience over an enclosed package.

c. Hermetically Sealed Package: The switch is contained within a package sealed by a process that involves fusing or soldering, and does not use gaskets. It provides protection against the ingression of moisture, gasses, and other harmful particulate.

Switch mounting is of four general types: (1) bushing, (2) multi-hole, (3) mounting bracket, and (4) mounting plate. Terminals are of six general types: (1) solder, (2) screw, (3) wire, (4) plug in, (5) integrated wire, and (6) printed circuit board termination. The choice of mounting is dependent on the particular application. Switch packages are also classified by several miscellaneous categories. For example, many types of push button switches are available in illuminated and non-illuminated styles. Furthermore, some packages are classified as "explosion-proof," meaning they are intended for environments where volatile gasses surround the switch where a spark could cause an explosion.

Failure Mechanisms and Anomalies

Failure modes of switches are heavily dependent on the particular design of the switch, although some generalizations can be made. Table 2 divides switches into three general categories and gives particular failure modes of each. However, care should be exercised when using this table because intricacies of a particular design will affect the result. For example, the failure modes of a heavy ruggedized switch differs substantially from the failure modes of a momentary action plastic switch.

Unlike most other electrical parts, switches contain mechanical elements and are therefore subject to failure mechanisms associated with mechanical wear of the switching elements. In addition, many switches contain spring mechanisms (especially in momentary action switches) that will lose resiliency with age. Therefore, switches do not follow a constant hazard (failure) rate or traditional "bathtub curve" profile. Instead, failure rates tend to increase with age.

Early life failures of switches are often caused by contamination. Mechanical contamination creates shorts or physically blocks the movement of mechanical elements. Non-metallic or corrosive gaseous contamination creates open circuits by forming a surface film or oxidation on the contacts to create an insulative barrier. Except for special high voltage and high temperature applications, solid-state switches are inherently more reliable and predictable for long life applications.

Table 2. Normalized Failure Mode Distributions for Switches					
Switch Type	Failure Mode				
	Open	Short	Sticking	Parameter Change	No Control
Pushbutton	60%	7%		33%	
Toggle		65%	16%	19%	
Thermal		27%	2%	63%	8%

Reliability

From a reliability point of view, switches and relays are very similar devices and suffer from many of the same reliability problems. Most of the poor design practices for relays are also applicable for switches.

Switches are considered relatively high failure rate items due to the moving parts and the wear-out mechanisms. Vendors often specify switch reliability by giving a maximum number of switching sequences rather than a rate of failure with time. Reliability is further decreased as temperature rises and adverse chemical reactions from internal materials are accelerated. In addition, the insulation resistance between the switch contacts and ground decreases as the temperature rises. High temperature can also affect the insulation from the standpoint of voltage breakdown, due to a change in dielectric strength. At the opposite extreme, switch reliability can be degraded by low temperatures. Low temperatures can cause material contraction and cracking, allowing foreign material and moisture to enter resulting in short circuits voltage breakdowns, and corona arcing.

Moisture ingression has an adverse affect on reliability as moisture in the dielectric decreases the dielectric strength, life, and insulation resistance of the switch. It can also cause corrosion by increasing the galvanic action between dissimilar metals in the switch. Switches that need to give a long life in high humidity environments should therefore be hermetically sealed. An alternative approach is to use boots, "O" rings, or diaphragms over switch openings to decrease moisture entry.

For airborne applications, flashover becomes a problem at low barometric pressures (see Connectors). This is particularly true of small switches because they have smaller contact spacings. Flashover causes the switch to momentarily engage while in the "off" position, and will decrease life if the flashover occurs continuously. Care must be used when selecting a switch that will operate at low barometric pressures.

Derating

Derating of continuous current depends on load type, as shown in Table 3.

Derating is more severe for inductive loads due to high current demands upon initial startup and increased probability of voltage spikes.

Some switch specifications will contain individual current limitations for capacitive, inductive, motor, and filament loads. For such specifications, limit current to either the current derived from Table 3 or the maximum current rating for the particular load type given in the specification, whichever is less.

Limit maximum power dissipation as shown in Table 3.

Table 3. Derating Requirements for Switches

		% of Max Rated Value of Resistive Load in Environment		
Part Type	Derating Parameter	Category 1 Protected	Category 2 Normal	Category 3 Severe
Switch Non-MMIC	Contact Current (Continuos)	70--Capacitive Load 70 -- Resistive Load 50 -- Inductive Load 30 -- Motor 20 -- Filament (Lamp)	60 -- Capacitive Load 60 -- Resistive Load 40 -- Inductive Load 20 -- Motor 10 -- Filament (Lamp)	50 -- Capacitive Load 50 -- Resistive Load 30 -- Inductive Load 20 -- Motor 10 -- Filament (Lamp)

Where surge current is of concern, limit surge current to 80% of maximum rated. If surge current is of concern and the switch has no a surge current rating, it should not be used without consulting the manufacturer.
For Monolithic Microwave Integrated Circuit (MMIC) switches, derate according to Table 4.

Table 4. Derating Requirements for MMIC Switches

			Maximum Allowable Rating in Environment		
Part Type	Derating Parameter	Rec. Max. Value	Category 1 Protected	Category 2 Normal	Category 3 Severe
Switch MMIC	RF Input Power Control Voltage Operating Temp Storage Temp	Mfr. Rec. max. -8V 125°C -65°C to 150°C	100% 90% 70°C>	95% 80% 85°C	90% 70% 125°C

Design and Material

Controls on the materials and processes used to manufacture switches are reflected in performance parameters. Requirements on specific materials and processes are not generally specified in specifications with the exception of interface requirements such as size, mass, lead plating, etc. To obtain further information on the material and baseline-design controls, contact the vendor, consult MIL-STD-1182, or examine an individual military specification listed in Table 1.

Facility Assessment and Quality

Nearly every type of switch is available in a wide range of quality levels. Numerically, quality can be specified by operating life, which is given as the number of switch cycles before wear-out. Switch cycles normally range from 50,000 to 1 million, which vendors consider the guaranteed minimum number of cycles the switch can withstand under normal operating conditions before failure. Quality is further dependent on the ruggedness of the package and how well the internal switching elements are sealed against influences of the outside environment. Selecting commercial grade switches or switches used on COTS hardware for Military applications is not recommended unless there is assurance the switch will operate for the extended lifetime and typically harsher environmental conditions of Military hardware.

Some vendors will advertise they are ISO 9000 quality certified or have an ISO 9000 quality system in place. This means that the vendor has a disciplined quality system in place, but it does not necessarily mean the switches produced will operate reliably in the harsh conditions of a Military environment. Attention must also be paid to the design of the switch.

Sampling

Sampling plans of switches constructed to Military specifications are specified within the Military specifications listed in Table 1, although the current trend in the military specifications is away from calling out specific sample sizes and towards end item performance requirements. If the user needs to know the quality control sample size used during manufacturing, consult the individual vendor.

Process Controls

The user needs to know the process controls and SPC used during the manufacturing operation; the manufacturer should be consulted. The military specifications for switches, listed in Table 1, contain process control requirements, but each specification is different and the current trend is to move away from process control requirements and towards end item performance requirements.

Part Assessment

No additional testing, qualification, screening, or conditioning is normally required of the manufacturer at the part level.

Handling and Storage Precautions

Switches require only normal handling precautions as they are not considered Electrostatic Discharge (ESD) sensitive.

Switches should never be placed in parallel redundancy for increasing the current handling capability of a circuit. Parallel redundancy should only be used for switches when each switch can sufficiently handle the current carrying requirements of the circuit.

Switches used in digital circuits should be carefully reviewed to assure contact bounce (or chatter) will not be incorrectly interpreted and result in logic errors. Further, the designer should take into account that contact bounce and settling time will increase with age.

High vibration and shock environments of many Military applications, particularly airborne, may cause contact chatter. Such environments may dictate the use of solid state devices, or special mounting methods may be used to minimize vibration and shock amplification.

For high vibration and shock environments, the maximum anticipated vibrational acceleration should remain less than 75% of the maximum rated acceleration the switch is rated to withstand.

DIP switches are mounted directly to printed wiring boards and are used to initialize settings or configurations. DIP switches are discouraged on Military hardware due to propensity of the switch to contain incorrect settings and lack of documentation in fielded conditions.

Some switch devices do not specify a surge current rating. Recommend such devices not be used if surge current is of concern, as, generally, these devices are not designed to handle surge currents.