SAE Aerospace
An SAE International Group

AEROSPACE INFORMATION REPORT

SAE AIR4272 REV. A

Issued 1991-09
Cancelled 2006-05

Superseding AIR4272

Power Controllers: Signal Interface Applications and Considerations

CANCELLATION NOTICE

This document has been declared "CANCELLED" as of May 2006. By this action, this document will remain listed in the Numerical Section of the Aerospace Standards Index.

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: CustomerService@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

FOREWORD

Various control interface concepts for solid state power controllers (SSPC) and electromechanical power controllers (EMPC) are presented. Examples are cited of actual implementations of these concepts.

The intent of this AIR is to inform the user/designer of some existing options available for interfacing to SSPCs, EMPCs (remote control circuit breakers with an electronic control compatible interface), and hybrid power controllers. It is not intended to specify an interface. To aid in this process, examples are given of existing applications. The type of interface used depends on the application of the power controller. Power controllers used in an electrical load management center (ELMC) have different design concerns than power controllers located remote from the control unit. The interface examples given show the variety of electrical interfaces available and the types of information which can be extracted from the modern power controller.

1. SCOPE:

This AIR is applicable to SSPCs, EMPCs, and hybrid power controllers. It covers the control, status, BIT, etc., interfaces, other than electrical power. For the purpose of this document, a power controller shall have, as a minimum, the following characteristics:

a. Power switching function
b. Control input
c. Overload protection
d. Status feedback

To accomplish the goals set forth in the Foreword, the interfaces are first categorized by function. Next, examples of actual implementations are given.

2. REFERENCES:

2.1 Applicable Documents:

MIL-STD-1553B	Aircraft Internal Time Division Command/Response Multiplex Data Bus
MIL-P-81653	Solid State Power Controllers
MIL-C-83383	Remote Control Circuit Breaker
ARP4258	Application of Low Speed Avionics System Discrete Signal Interfaces

3. POWER CONTROLLER INTERFACES:

The power controller interface can be divided into three parts, the mechanical/thermal interface, the power interface, and the control interface (includes status and information feedback). This report focuses on the control interfaces. This interface covers the on/off control of the device and information feedback, such as status, trip, current, BIT, etc. There are many things to consider in defining the interface, such as EMI/EMP, noise immunity, complexity of the interface, cost, and reliability, to name a few.

In applications where SSPCs are housed in an ELMC, the SSPC density is usually high, but wire runs are short and techniques such as printed circuit boards can be used to minimize interface wiring.

When devices are controlled from a remote location, such as an EMPC would likely be, simple interfaces with minimum wiring are desirable.

The physical aspects of the interface must always be traded off against the type of information feedback desired. SSPCs, inherently, are capable of feeding back much information to the control system; however, this must be weighed against the physical interfacing problems associated with transmitting this information.

One method of moving large amounts of data over a simple physical interface is by multiplexing. Several of the examples employ this technique. The disadvantage to this is the complexity of the multiplexing circuitry.

The basic input/output signals as categorized in the solid state power controller specification, MIL-P-81653, are;

a. On/off control
b. Status (on/off)
c. Over current trip indication

Additional signals (either inputs or outputs) which may be provided include:

a. Current
b. BIT
c. Disable/enable
d. Temperature
e. Programmable parameters: rating, location, power quality, etc.

3. (Continued):

f. Trip override
g. Nuclear interrupt

These same signals may be implemented in EMPCs and hybrid power controllers.

Examples of power controller interfaces are described in the following sections.

3.1 Serial/Discrete Interface-Leach SSPC:

The SSPCs used in the Air Force's Fault Tolerant Electrical Power System (FTEPS) program were contained in an ELMC as shown in Figure 1. Communications to the SSPCs were accomplished through a MIL-STD-1750A processor in the ELMC. Both SSPCs and ELMCs were built by Leach. The signal interface to the SSPCs was a combination of discrete signal lines (TTL signal levels) and a serial data line. The signal interface to the power controller is shown in Figure 2. This is for the 28 V DC power controller. The 115 V AC power controller has a slightly different interface (but also uses both discrete and serial signals). A discrete signal control line is used to turn the SSPC on and off. The SSPC provides a discrete status signal and a serial status word (over a serial data line) to the ELMC processor. The use of a serial data line allows a significant amount of data to be transmitted from the SSPC while minimizing the signal wiring. The data transmitted over the serial data line is shown in Table 1. The SSPCs can be controlled without the serial data line.

A major concern in the FTEPS application was the large number of SSPCs in each ELMC, approximately 100. This necessitated particular attention be paid to thermal dissipation and space required for control wiring. By employing the combination of low level discrete and serial interfaces, a considerable amount of information was transmitted between the ELMC processor and the SSPCs using relatively little space and while minimizing power dissipation.

The packaging concept used in the ELMC protected the low level control lines from EMI.

3.2 Discrete Interface-Eaton EMPC:

The EMPCs used in the FTEPS program were developed by Eaton. These devices were controlled by remote terminals and used to control power to the loads powered from the main power buses. Figure 3 shows a block diagram of the EMPC. The EMPC interface is described in Table 2. As shown in Figure 3, the status and trip feedback are provided through mechanical contacts, thus, the user has the option to select his own voltage and current levels for the status and trip feedback circuits. Power for the contact coil is provided from the input power line.

3.3 Five V DC Logic Interface-Texas Instruments SSPC:

TIs' SSPC use a simple 5 V DC control interface, as shown in Figure 4. This interface incorporates a discrete on/off control input, a discrete status output, and discrete trip output. By using a combination of the input and output signals, BIT information can be obtained from the device. The I/O truth table is shown in Table 3. The user interface is isolated from the power line through the use of opto-isolators. Two mA are required to drive the command (on/off) input and the open collector outputs have a maximum sink capability of 1 mA. This interface has not yet been incorporated into a production device by TI.

3.4 Five V DC Logic Interface-Mechanical Products SSPC:

Mechanical Products' SSPC uses nominal 5 V control input signals. The SSPC interface is shown in Figure 5. The addition of a pull up resistor allows these input signals to be compatible with 54/74LSxx series logic (i.e., TTL). The SSPC interface is shown in Figure 5. The status output signals are designed as open drain outputs. The addition of the appropriate pull up resistor allows compatibility with any standard logic family. The control input and the status output signals are described below;

3.4.1 Control Input Signals:

a. On/Off: This is an optional signal intended to open circuit the output.

b. Reset: This is a signal that resets a tripped SSPC. If the user prefers not to use the separate on/off control signal it functions as the combined on/off and reset signal.

c. Range Switch: This is a signal that allows the user to dynamically reconfigure the system remotely. For example, a 10 A SSPC could be reconfigured as a lower ampere rated device.

3.4.2 Status Output Signals:

a. Trip: This signal provides an indication of a tripped SSPC.

b. Load Voltage: This signal provides an indication of load voltage present.

c. Line Voltage: This signal provides an indication of line voltage present.

3.4.2 (Continued):

d. Over Temperature: This signal provides an indication of excessive internal SSPC temperature.

All of these signals, with the exception of the over temperature output, are available as positive or negative true logic. This interface has not yet been incorporated into a production device by mechanical products.

3.5 Discrete Interface-Kilovac 270 V DC Power Controller:

The kilovac 270 V DC power controller utilizes a discrete control interface. The 270 V DC is switched by a vacuum contactor. The control interface is shown in Figure 6. The control and status signals are described below;

a. Control: This signal turns the power controller on.

b. Trip Indicator: This signal indicates whether the contactor should be open, due to either the removal of the external control signal or an internally sensed overload.

c. Contact Indicator: This signal indicates the position of the load contacts, if load voltage is applied.

The control signal may be TTL, CMOS, transistor, or a mechanical switch input. The trip and contact indicators are TTL and CMOS compatible outputs. The truth table for the control and status signals are shown in Table 4.

3.6 Five V DC Logic Interface-Teledyne SSPC:

Teledyne's SSPC uses a TTL/CMOS compatible control and status interface, as shown in Figure 7. This interface includes an on/off control input which also provides reset capability and two status outputs, flow and trip. The truth table shown in Table 5 shows how the status signals can be used to provide system status and diagnostics. The control and status circuitry is optically isolated from the output and does not share a common ground or return, thus, the output can be used to sink or source power to the load. The overload/short-circuit protection characteristics are constant over temperature and have been configured to provide rapid response to overloads while allowing in-rush currents to pass without nuisance tripping. These features are incorporated into production SSPCs for both 28 V DC and 270 V DC load management systems.

3.7 Serial Interface-Eaton:

A two wire control interface was implemented by EATON for their power controllers. The interface allows for three control states and four status states to be transmitted on the two wire interface as shown in Figure 8. The power controllers are intended to be controlled by a remote terminal. The interface specification is shown in Table 6 and the truth table in Table 7. All voltages are at the input terminals of the power controller.

3.7.1 Controller Operation: With power available, the power controller will assume a closed state when a +10 V DC level (close command) is applied. When a -10 V DC level (open command) is applied, the power controller assumes an open state. When the control voltage level is returned to zero (from positive or negative), the controller remains in the state it was in prior to the level of change. When the controller opens due to an overload or a fault, it will not reclose until it receives an open control signal followed by a close control signal.

3.7.2 Controller Status Feedback: The controller is intended for use within electrical power management systems. Commands to change state are received by the power controller from an input/output device (the remote terminal as shown in Figure 8.) Device status feedback is provided by the power controller when a +20 V DC, 180 μs inquiry pulse is applied by the remote terminal. The power controller's response is an encoded signal defining its status. In addition to responding with open or closed contact state and open due to an overload trip state, a fourth ("problem") state is provided. The "problem" state denotes any of the following: low voltage at the device, an open control line, the control line shorted to ground, or a failure within the device.

3.7.3 Control And Status Feedback Voltages: The controller will respond to the appropriate voltage levels specified in Table 6. All voltages are at the input terminals of the power controller. In addition to the three command inputs, the controller will recognize the inquiry pulse and will establish a reference voltage for logic zero, followed by the transmission of two logic levels (S1 and S2) which uniquely define its status. The three logic intervals (the S0 reference plus two status) occur within the specified period of the inquiry pulse (180 μs) and conform to the truth table of Table 7.

3.8 Switched Impedance Interface-Navy:

The Navy sponsored the development of a two wire interface using the switched impedance technique. Westinghouse developed SSPCs using this interface. These devices use a two wire 20 mA control line which also provides status feedback. A block diagram showing the control circuitry in the power controller is shown in Figure 9. A constant 10 mA signal will turn the power controller on. Removing the 10 mA signal turns the device off. Status of the power controller is reflected in the input impedance of the device, as shown in Table 8. A voltage level sensing circuit is required to interpret this status signal. To interrogate the status when the device is off, a 10 mA pulse of less than 50 μs is sent to the power controller and the resulting voltage read. A fault signal is provided when the following conditions exists:

a. An ON command signal is present and no load current is present.

b. An OFF command signal is present.

3.8 (Continued):

c. An OFF command signal is present and load current is supplied to the load.

This interface has high noise immunity and is ideally suited for applications where control lines are long.

4. RECOMMENDATIONS:

It is recommended that the interfaces described in this report be considered for application in any new development of power controllers.

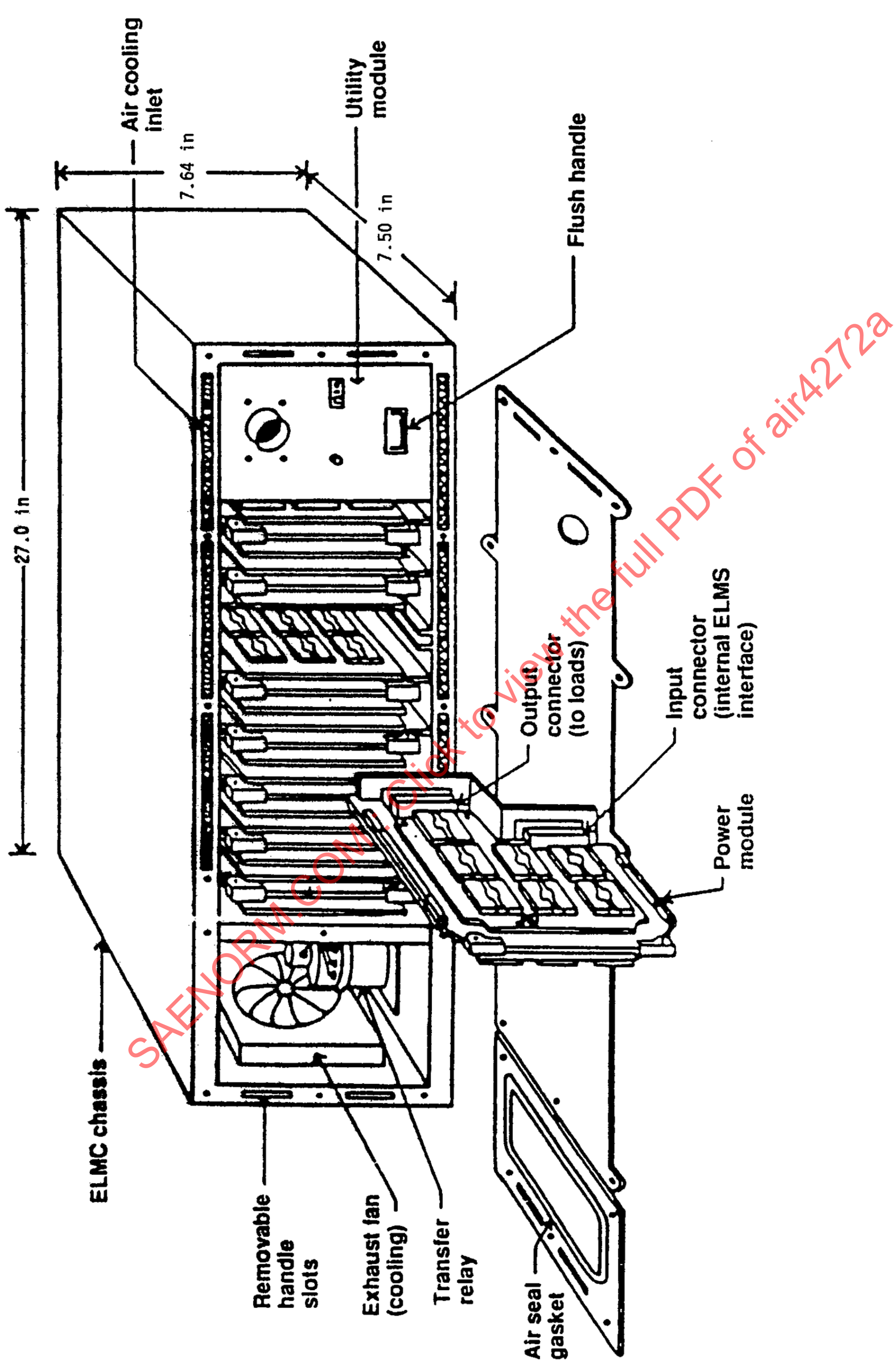


FIGURE 1 - FTEPS ELMC Configuration

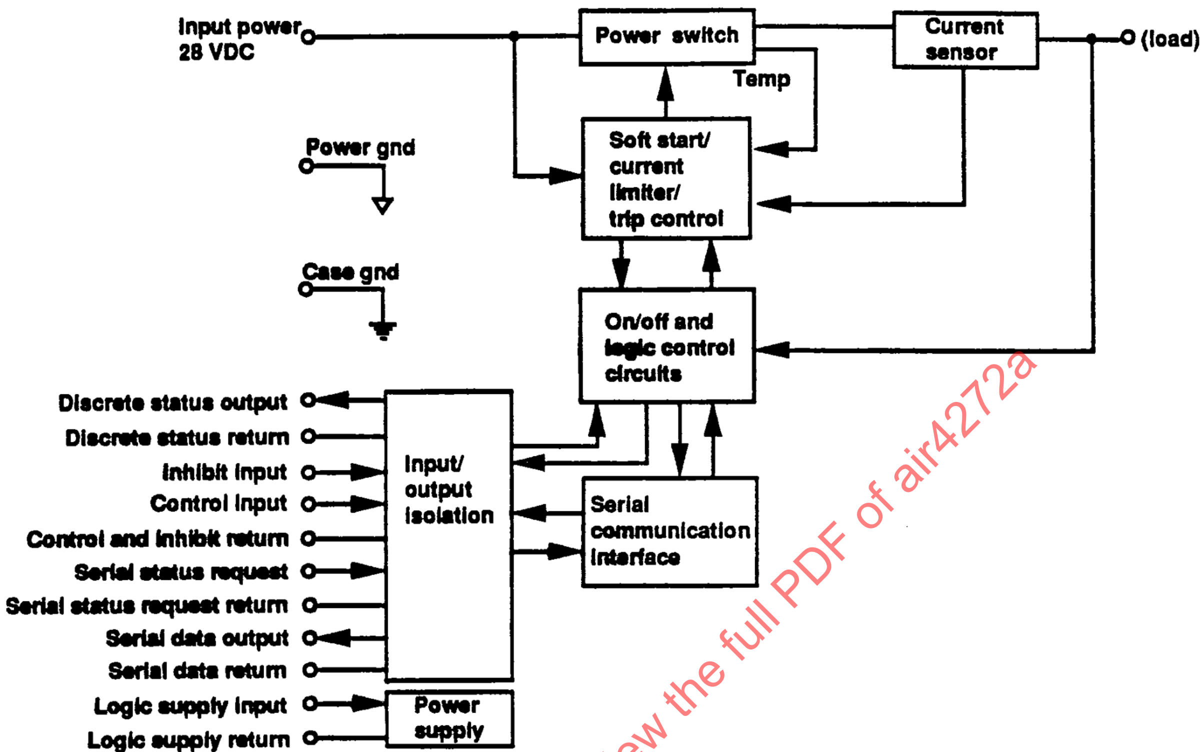


FIGURE 2 - Leach DC SSPC Interfaces

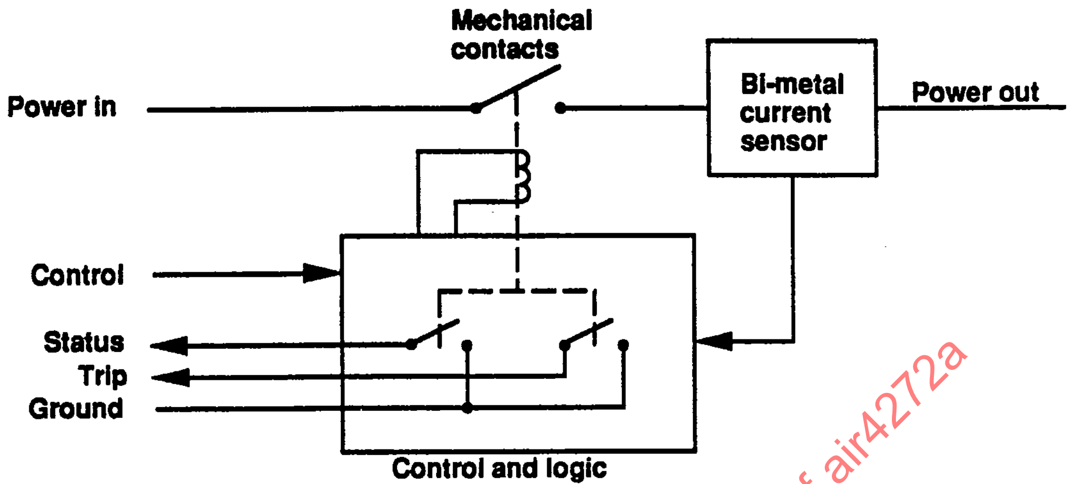
TABLE 1 - DC SSPC Serial Status Word Format

Bit No.	Bit description with SSPC "on"	Bit description with SSPC "off (tripped)
0	Start "0"	Start "0"
1	LSB; current value	Over temperature tripped
2	NLSB; current value	Tripped/overvoltage
3	Current value	Over temperature,present
4	NMSB; current value	Future use
5	MSB; current value	Future use
6	Current greater than 110%	Tripped/overcurrent
7	Bite	Bite
8	Status "1"	Status "0"
9	Stop "1"	Stop "1"

Serial request Command: "1" (TTL level) enable data transmission - Minimum pulse width = 1/baud rate

NOTES: Unless otherwise specified

1. Transmitting format within each word; start-bit, LSB of data...MSB of data, stop bit.
2. Transmission speed: 4800 baud, 9700 baud and 19.2 kbaud; selectable by hard wire
3. Least significant bit (LSB)
4. Next least significant bit (NLSB)
5. Next most significant bit (NMSB)
6. Most significant bit (MSB)



EMPC features:
- Mechanical contacts
- Status and trip feedback
- Trip curve tailored like thermal circuit breaker
- Performs switching and wire protection in one unit
- Ratings 12A - 100A

FIGURE 3 - Eaton EMPC Interface

TABLE 2 - EMPC State Indication

Control	Status	Trip	Condition
1	1	1	Fail
1	0	1	On
1	1	0	Fail
1	0	0	Trip
0	1	1	Off
0	0	1	Fail
0	1	0	Fail
0	0	0	Fail

Positive logic:

1 = 15 V DC nominal, 7 V DC minimum
0 = 0 V DC nominal, 3 V DC maximum

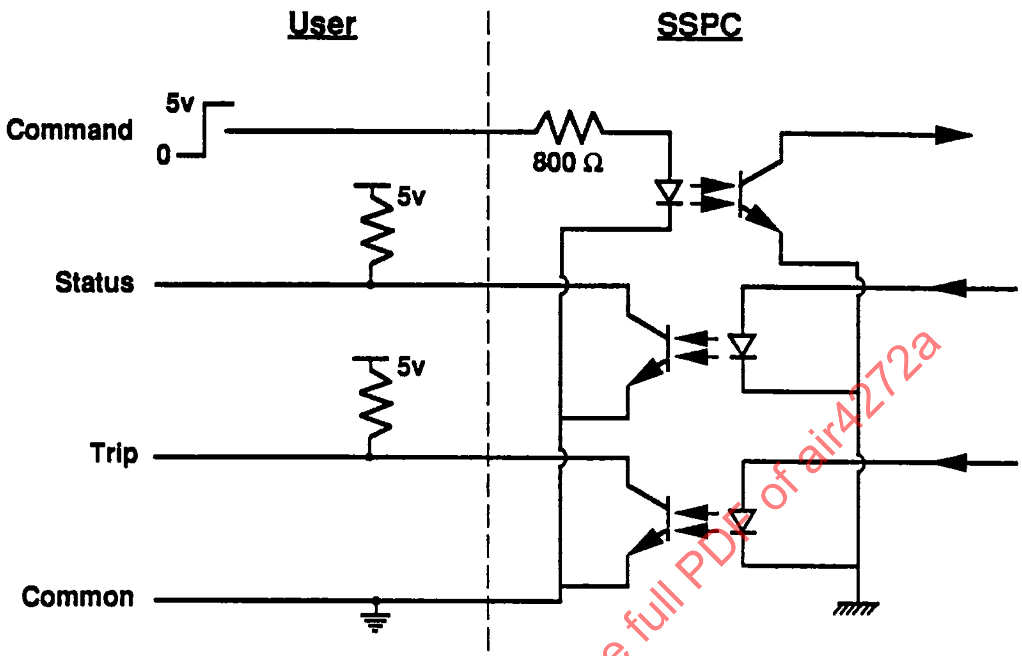


FIGURE 4 - TI SSPC Interface

TABLE 3 - TI I/O Truth Table

Control	Status	Trip	Condition
0	0	0	Off
1	1	0	On
1	0	1	Trip
0/1	1	1	Bit fault[1]

The status output can be configured to represent:

1. Drive voltage at the power switch
2. Load current
3. Load voltage

[1] The bit circuit monitors the power switch to detect shorts or opens. The bit function can be disabled if desired.

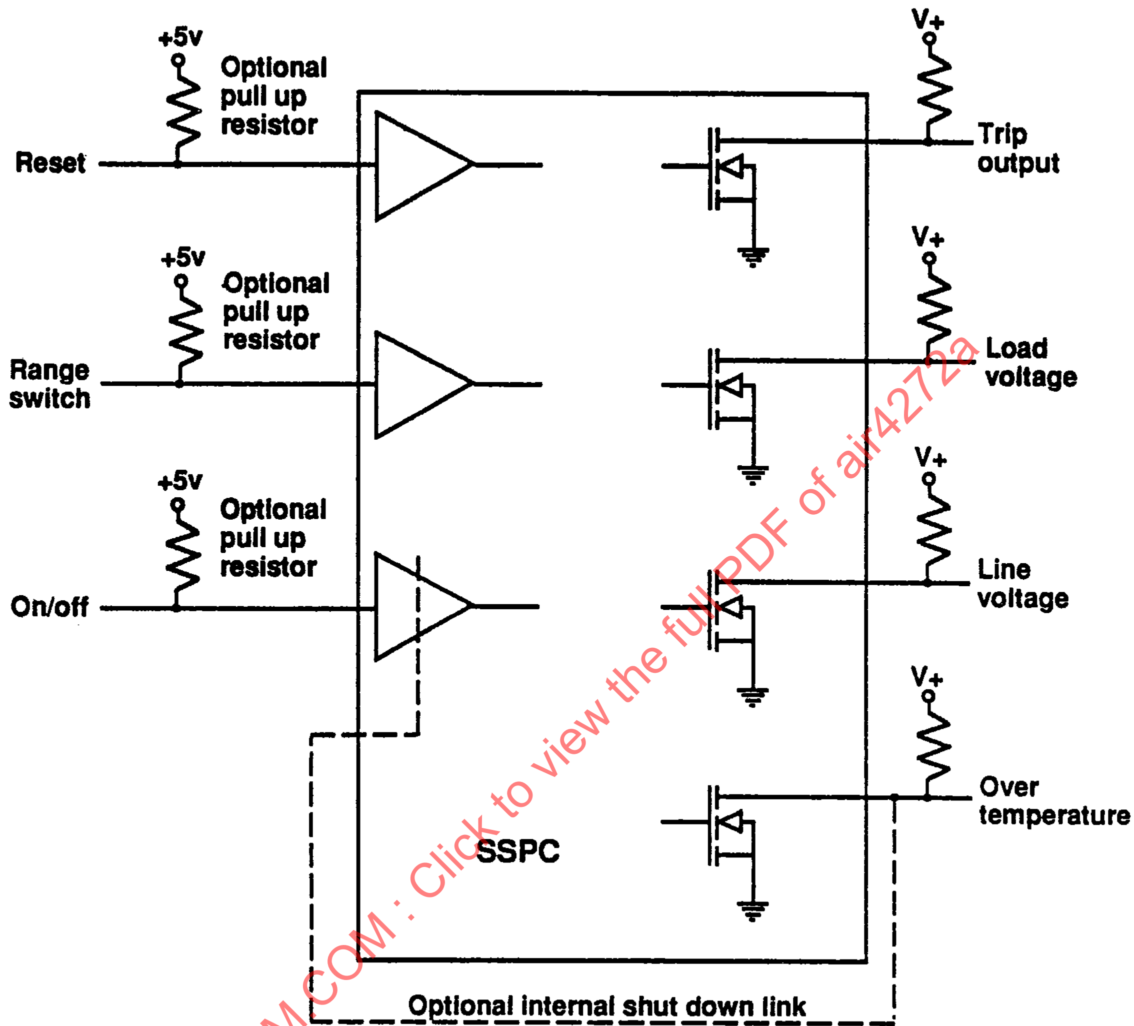


FIGURE 5 - Mechanical Products SSPC Interface