SDM-SW8A
8 CHANNEL SWITCH CLOSURE MODULE
INSTRUCTION MANUAL

REVISION: 11/92

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SDM-SW8A
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SDM-SW8A SWITCH CLOSURE INPUT MODULE

1. FUNCTION

The 8 channel SDM-SW8A Switch Closure Input Module (see Figure 1) is a CR10 or 21X datalogger peripheral for measuring up to 8 channels of switch closure or voltage pulse inputs. Each channel may be configured to read single-pole double-throw (SPDT) switch closure, single-pole single-throw (SPST) switch closure, or voltage pulse. Output options include counts, duty cycle, and state.

The SW8A is addressed by the datalogger, allowing multiple SW8As to be connected to one datalogger (refer to Theory of Operation, Section 9). Sixteen addresses are available, but for most applications, Campbell Scientific, Inc. recommends no more than 4 SW8As be connected to one datalogger. If more SW8As are required, please consult Campbell Scientific's Marketing Department.

In October, 1988, the SDM-SW8A was introduced for use with the CR10 and 21X dataloggers. Datalogger I/O Instruction 102 is used by both dataloggers for communication with the SW8A. Previous to October, 1988, the SDM-SW8 (no "A") was offered for use only with the CR10, utilizing CR10 I/O Instruction 15. **SDM-SW8As are not compatible with CR10s containing Instruction 15, and SDM-SW8s are not compatible with CR10s containing Instruction 102.** Contact Campbell Scientific's Marketing Department for update options if incompatibilities exist.

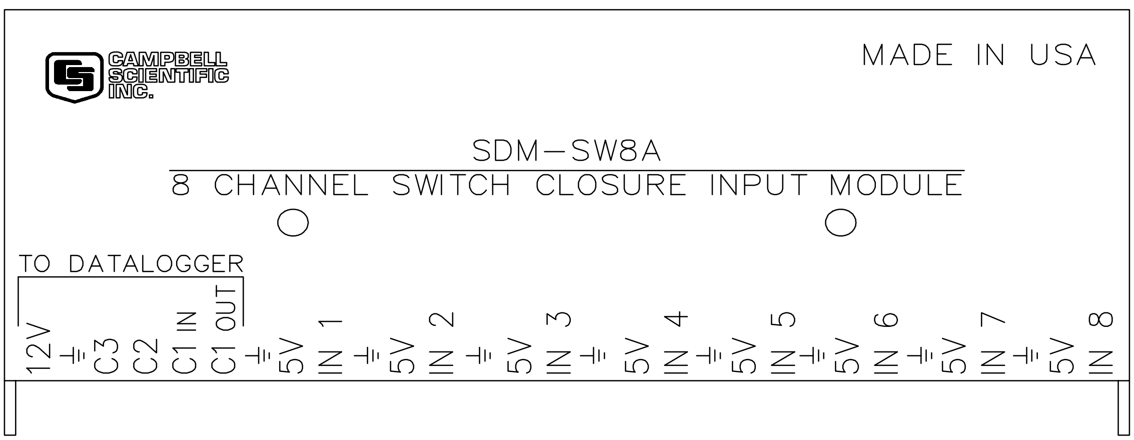

FIGURE 1. SDM-SW8A Front Panel

2. SPECIFICATIONS

Operating voltage	12 VDC nominal (9.6 to 16)
Current drain	3 mA quiescent, 6 mA active (max)
Environmental	-25 to +50^{o}C, 0 to 90% RH, noncondensing
Measurement types	Switch closure (SPDT, SPST) DC voltage pulse
Input voltage threshold	From below 0.9 to above 4.0 VDC,±20 VDC max
Maximum input frequency	100 Hz (50% duty cycle)
Minimum input pulse width	5 ms high, 5 ms low
Maximum bounce time	3 ms open without counting
Output options	State, duty cycle, counts
Max count/port	65535
Internal sampling frequency	500 Hz
Watchdog reset	Yes
Total length of connecting cables	20 feet
Physical	0.9"(H), 6.2"(L), 2.7"(W) 0.5 lb.

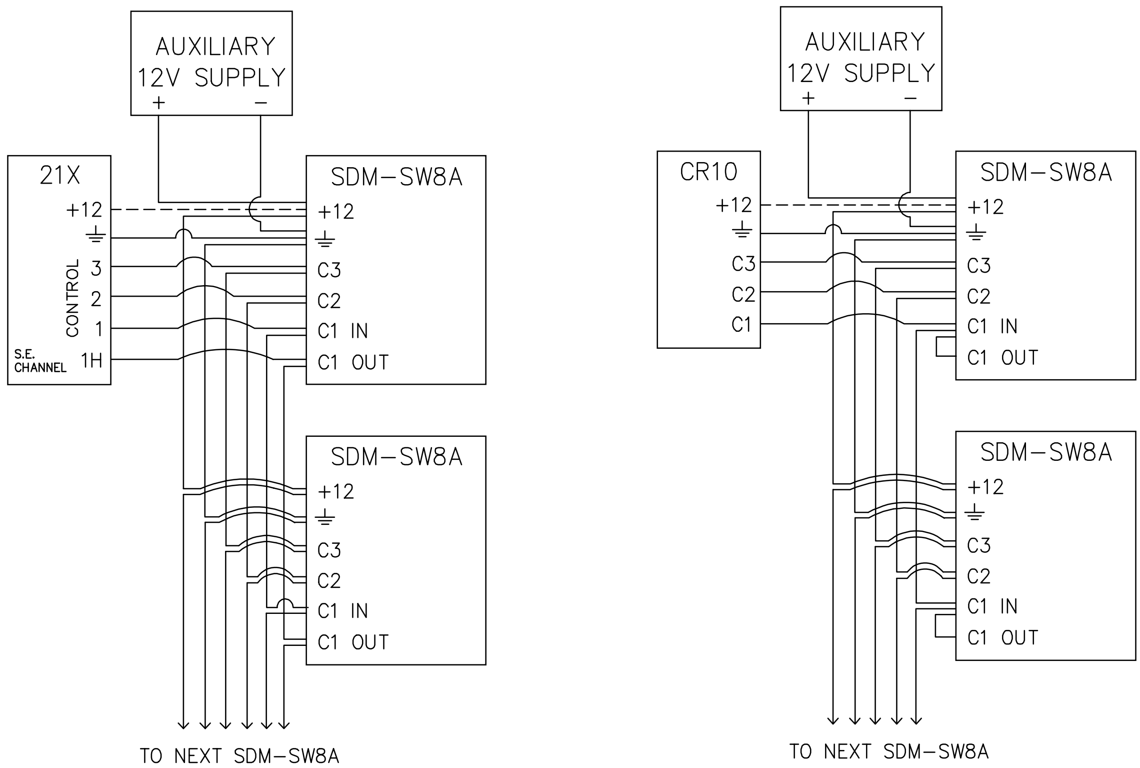

FIGURE 2. SDM-SW8A Connections

3. POWER SUPPLY CONSIDERATIONS

Due to the 3 mA continuous and 6 mA active current drain, an auxiliary 12 VDC power supply is recommended for powering the SW8A in remote, long term applications. Figure 2 shows the connections between an SW8A and an auxiliary power supply.

For some applications it may be convenient to use the datalogger supply to power the SW8A. The connection to a datalogger power supply is shown as a dashed line in Figure 2. For long term applications where AC power is available, or where a solar panel can be used for recharging, the lead acid power supply available with Campbell Scientific, Inc. dataloggers could be used. For short term applications only, the alkaline power supply available with Campbell Scientific, Inc. dataloggers could be used to power the SW8A.

If the 21X power supply is used to power the SW8A, all low level analog measurements (thermocouples, pyranometers, thermopiles, etc.) must be made differentially. This results from slight ground potentials created along the 21X analog terminal strip when the 12 V supply is used to power peripherals. This limitation reduces the number of available analog input channels and may mandate an external supply for the SW8A.

4. CONNECTIONS

All connections to the datalogger, power supply, and other SW8As are made from terminals located under "TO DATALOGGER" on the SW8A (refer to Figure 1). Sensor connections are made at the remaining terminals.

4.1 CONNECTIONS TO DATALOGGERS AND OTHER SW8AS

Connections between an SW8A and the CR10 and 21X dataloggers are shown in Figure 2. Connections to multiple SW8As are also shown. Important differences between CR10 and 21X connections are noted below.

SDM-SW8A to 21X - When using a 21X with the SW8A, connect "C1 OUT" of the SW8A to single ended channel 1 (H1) of the 21X, as shown in Figure 2.

SDM-SW8A to CR10 - For all SW8As used with a CR10, connect "C1 OUT" to "C1 IN" as shown in Figure 2. Connect "C1 IN" from the first SW8A to CR10 Control Port 1 (C1).

> **CAUTION:**
>
> 1. The order in which connections are made is critical. **ALWAYS CONNECT GROUND FIRST, followed by 12 V and then the Control Ports.**
>
> 2. The sum of all the cable lengths connecting SW8As or other SDM devices and a datalogger should not exceed 20 feet. Lengths in excess of 20 feet may prevent communication.

4.2 SENSOR CONNECTIONS

Figure 3 shows the connections between the SW8A and compatible sensor types.

5. INTERNAL JUMPERS

Inside the SW8A, jumpers must be set to configure the Module address and the channel measurement type for each channel. Remove the two panel screws and lift the cover to access the jumpers. Figure 3 shows jumper location.

5.1 ADDRESS JUMPERS

Each module can have 1 of 16 addresses (00 to 33, Base 4). The address is factory set to 00. Figure 3 shows the location of the address jumper block. Table 1 lists the jumper settings for each address.

TABLE 1. Address Jumpers

	Pins			
Address	1-8	2-7	3-6	4-5
00	c	c	c	c
01	c	c	c	nc
02	c	c	nc	c
03	c	c	nc	nc
10	c	nc	c	c
11	c	nc	c	nc
12	c	nc	nc	c
13	c	nc	nc	nc
20	nc	c	c	c
21	nc	c	c	nc
22	nc	c	nc	c
23	nc	c	nc	nc
30	nc	nc	c	c
31	nc	nc	c	nc
32	nc	nc	nc	c
33	nc	nc	nc	nc

c = connected nc = not connected

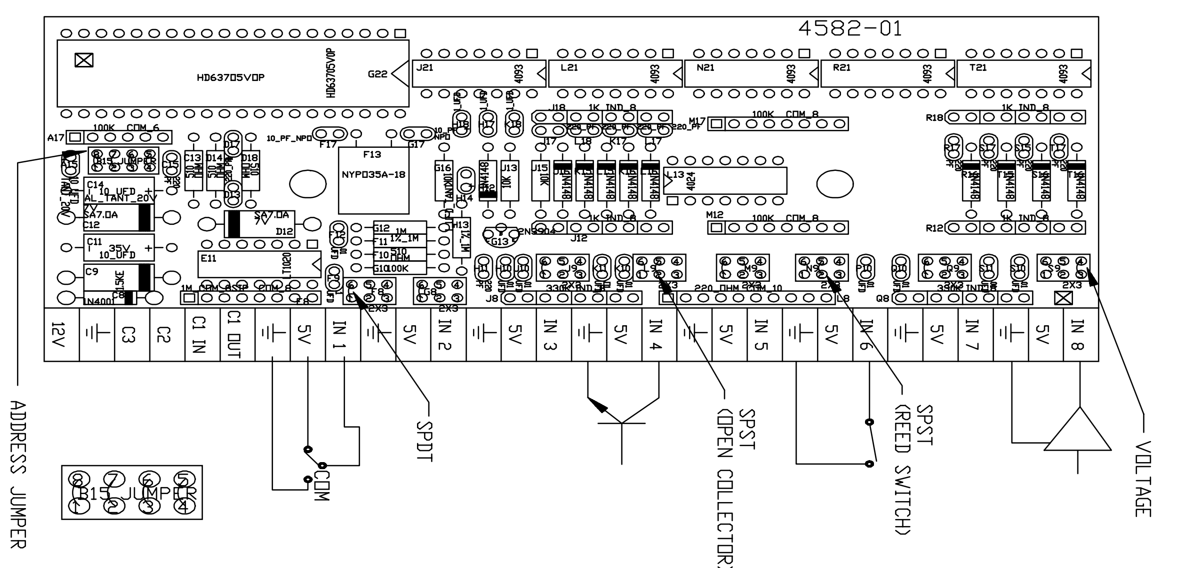

FIGURE 3. SDM-SW8A Address and Port Configuration Jumpers with Sensor Wiring Examples

5.2 MEASUREMENT JUMPERS

Near each input channel is a jumper triplet used to configure the channel for the measurement type. The SDM-SW8A is shipped from the factory with each channel configured for DC Voltage pulse. An example of each configuration is illustrated in Figure 3. Table 2 shows jumper pins and the corresponding measurement type.

TABLE 2. Measurement Jumpers

Measurement Type	Pins Jumpered
SPDT Switch Closure	1 and 6
SPST Switch Cl. or Open Coll.	2 and 5
Voltage Pulse	3 and 4

6. DATALOGGER INSTRUCTION - 102

Instruction 102, Table 3, is used to address and retrieve information from the SW8A. The execution time of the instruction may be estimated from the information in Table 4.

TABLE 3. Instruction 102 - SDM-SW8A

PARAMETER NUMBER	DATA TYPE	DESCRIPTION
01:	2	Repetitions
02:	2	Module Address (00..33)
03:	2	Function Option (0=State, 1=Duty 2=Counts, 3=Signature)
04:	2	SDM-SW8A Starting Channel (1..8)
05:	4	Starting input location for results
06:	FP	Mult
07:	FP	Offset

> **NOTE:** Instruction 102 is not contained in all CR10 or 21X PROMS. To verify that the datalogger contains the Instruction, enter 102 into a datalogger Programming Table. If the Instruction is accepted, the PROM contains the Instruction.

TABLE 4. Instruction 102 Execution Rate

CR10: T = 4 + (F * R)

21X: T = 5 + (F * R)

where: T = Execution time, ms
R = Repetitions
F = Function Execution, ms

	CR10	21X
State	1	1
Cycle	2	2.2
Counts	2	2.2
Sig	0	0

Repetitions (Reps, **Parameter 1**) specifies the number of SW8A channels to read. **Parameter 2** is the address of the first SW8A. If more Reps are requested than exist in one module, the datalogger automatically increments the address and continues to the next SW8A. The address settings for the SW8As must be sequential. For example, assume two SW8As with addresses of 22 and 23 are connected, and 12 Reps are requested. Eight channels from the first SW8A and the first four channels from the next will be read.

Only one Function Option (**Parameter 3**) may be specified per Instruction. If all four functions are desired, four Instructions must be entered in the datalogger program.

Function Option 0 provides the **state** of the signal at the time 102 is executed. A 1 or 0 corresponds to high or low states, respectively.

Function Option 1 provides signal **duty cycle**. The result is the percentage of time the signal is high during the sample interval.

Function Option 2 provides a **count** of the number of positive transitions of the signal.

Function Option 3 provides the **signature** of the SW8A PROM. A positive number (signature) indicates the PROM and RAM are good, a zero (0) indicates bad PROM, and a negative number indicates bad RAM. Function Option 3 is not used but is helpful in "debugging." Only one Rep is required for Option 3.

Parameter 4 specifies the first SW8A channel to be read (1..8). One or more sequential channels are read depending on the Reps. To optimize program efficiency, the sensors should be wired sequentially.

Data are stored in sequential datalogger input locations, starting at the location specified in **Parameter 5**.

The number of input locations consumed is equal to the number of Reps.

The scaling multiplier and offset **(Parameters 6 and 7)** are applied to all readings. Enter 1 for the multiplier if no scaling is desired.

If the SW8A does not respond, -99999 is loaded into input locations. Modules which do not respond when addressed by the datalogger are possibly wired or addressed incorrectly. Verify that the address specified in Parameter 2 corresponds to the jumper setting and that all connections are correct and secure.

An example program for reading state, duty cycle, and counts of all 8 ports in a Module with an address of zero (0) is given in the Appendix.

7. DATALOGGER PROGRAM DETAILS

7.1 DATALOGGER SCAN RATE

The Module samples channel state every 2 ms and accumulates the information for duty cycle and counts. Each channel has one 16 bit accumulator for duty cycle and one for counts. The accumulators are reset when the datalogger requests information from the SW8A and when the count exceeds 65535. The datalogger scan rate must be frequent enough to avoid SW8A accumulator overflow.

Each Duty Cycle accumulator resets every 131 seconds (2 ms * 65536) or roughly 2 minutes. If Duty Cycle is requested, the datalogger scan rate must be less than 131 seconds.

The rate at which Count accumulators are reset is input frequency dependent. For example, at a maximum input frequency of 100 Hz, the datalogger must sample the SW8A at least every 655 seconds (approximately 10 minutes) or the accumulator for that channel resets and starts over again.

7.2 FIRST SCAN

From the time power is applied, the SW8A samples the state of all channels every 2 ms. The first time the datalogger executes Instruction 102 and requests information, the results represent the time period since the SW8A was powered up, not the datalogger scan interval. This problem may be avoided by ignoring the data from the first scan after the datalogger is compiled. The example program (see Appendix) includes a routine which discards first scan data.

7.3 WATCHDOG RESET

Any microprocessor may occasionally fail due to input transients or intermittent component failure (e.g., a bombed condition). The SW8A has a "watchdog" counter which resets the processor under such conditions. When functioning normally, the processor resets the watchdog counter. To transfer data between the datalogger and the SW8A, the datalogger drives the clock line, Control Port 2, high and low (refer to Theory of Operation, Section 9). The watchdog counts clock line transitions, and if the count exceeds 64, the watchdog resets the SW8A processor. Requesting State produces 16 clock transitions. Duty Cycle and Count each produce 24 + 16 clock transitions per channel.

The length of time that the SW8A stays bombed before a watchdog reset occurs is a function of the datalogger scan rate and the amount of information requested from the Module. For example, if the datalogger scan rate is 10 minutes, and 2 channels of counts are requested, the SW8A may stay bombed for 20 minutes. To avoid this undesirable time delay before resetting, a trapping routine may be programmed into the datalogger to detect a bombed condition and immediately force a watchdog reset.

The trapping routine keys on the fact that -99999 is stored in input locations when the Module is bombed (-99999 is also stored if the Module is incorrectly addressed or wired wrong). When -99999 is detected, the routine immediately forces a watchdog reset by addressing the Module and requesting sufficient information to cause a minimum of 65 clock line transitions. Advantages to the trapping routine are:

- The bombed processor is detected before erroneous values (-99999) are included in subsequent processing.
- The processor may be reset sooner.
- The time of processor failure may be logged by the datalogger.
- Number of failures may be logged.

A trapping routine, as described above, is included in the example program in the Appendix.

8. MEASUREMENT APPLICATIONS

8.1 SPDT SWITCH CLOSURE

Single-pole double-throw switches may be found on some flow or volume sensors such as Watt-hour and water meters. The positive throw is connected to the 5 V terminal located next to the input channel, providing a 5 V bias for the SW8A to discriminate between throws. Similarly, the negative throw is connected to a ground terminal (refer to Figure 3, SPDT wiring example). When contact is made to the positive throw, SW8A circuitry holds a high state (5 V). When contact is made with the ground throw, a low state is maintained (0 V). Switch bounce may occur any number of times at a throw, but until contact is made with the opposite throw, a change in state will not occur. The pole must make contact with the throw for 3 ms for a state change to occur. Figure 4 illustrates a raw SPDT signal in relation to the signal conditioned by the SW8A.

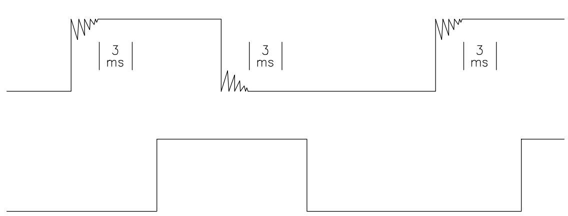

FIGURE 4. SPDT Signal Conditioning by SDM-SW8A

> **NOTE:** The 5V output located next to each of the 8 input channels is for biasing in the SPDT measurement. A 200 Ohm resistor is in series to protect against accidental shorting to ground.

8.2 SPST SWITCH CLOSURE

Single-pole single-throw switches are either open (high state) or connected to ground (low state). Typical SPST switches include contact closure (reed switch) anemometers, tipping bucket rain gauges, and open collectors (semiconductor switches). Many control devices utilize open collectors and provide terminals for monitoring the switch.

For all SW8A measurements, the 100 Hz maximum input frequency and 5 ms pulse width specifications must be taken into consideration. To illustrate, consider the Met-One 014A Cup Anemometer which is an SPST-type sensor. The 014A calibration is:

$$MPH = 1.789 * f + 1$$

where: MPH = miles per hour
f = pulse frequency in Hz

The 100 Hz maximum input frequency to the SW8A equates to 180 MPH. The duty cycle of the 014A as measured by the SW8A is 35%. A 5 ms pulse width becomes a limitation at 70 Hz (0.35/0.005sec), or about 126 MPH. The SW8A's maximum input frequency and 5 ms minimum pulse width specifications are not a limitation given the 014A's maximum calibrated speed of 100 MPH.

8.3 DC VOLTAGE PULSE

Voltage pulse transitions from below 0.9 V to above 4.0V, not exceeding ±20V, with a minimum pulse width of 5ms, are counted accurately at any frequency less than or equal to 100 Hz.

8.4 DUTY CYCLE

Duty cycle is not an exact measurement due to the SW8A input filtering and 2 ms sampling frequency. Signal magnitude also affects duty cycle measurements. Optimum duty cycle measurements result if an integral number of cycles are measured per datalogger scan interval, and the scan interval is at least 1 second.

Input Filtering and Sample Frequency Error - In a "worst case" analysis, input filtering will distort the time that the signal is high by ±2.5 ms. If the input filtering is at worst case, the 2 ms sampling frequency can create an error of

±2 duty cycle samples on any measurable cycle.

Equations given below estimate the "worst case" duty cycle measurement error for a 50% duty cycle and the minimum/maximum measurable duty cycle for a given frequency. The error limits are calculated, assuming a sample interval of a single cycle. The error may be significantly reduced by allowing the SW8A to measure duty cycle over several cycles. As shown by the equations, the error decreases with decreasing frequency.

50% Duty Cycle - The "worst case" duty cycle measurement error for a 50% duty cycle at a given input frequency is

$$\pm ERROR = Hz * 0.4$$

where ERROR = Actual Duty Cycle ±Measured Duty Cycle.

For example, a 50% duty cycle at 10 Hz could be measured as 46% to 54% in the worst case.

Minimum/Maximum - The measurable minimum/maximum duty cycle is defined by the 5 ms pulse width specification of the SW8A. For example, at a 10 Hz frequency, the minimum and maximum duty cycle that can be measured is 5% and 95%, respectively (0.005/0.100 * 100). The "worst case" duty cycle measurement error for the minimum/maximum measurable duty cycle is

$$\pm ERROR = Hz * 0.3$$

For example, the minimum measurable duty cycle for a 1 Hz signal is 0.5%. The duty cycle measurement could range from 0.2% to 0.8%.

Signal Magnitude - The signal magnitude should range from 0 - 0.9 V low, to 4 - 5 V high, or the signal should be centered around 2.5 V with a minimum 8 V peak to peak magnitude. When the magnitude is 0 V to greater than 5 V, the wave form begins to distort, resulting in less accurate duty cycle information.

9. THEORY OF OPERATION

The Switch Closure Input Module uses a 63705 microprocessor to sample the 8 ports and communicate with the datalogger. The processor is in a low power "Wait" mode except when interrupted.

An internal timer interrupts the processor approximately every 2 milliseconds to sample the input ports. At this time, for each port, the duty cycle accumulator is updated, and the transition counter is incremented if the state represents a positive transition from the previous state.

C3, driven high by the datalogger, also interrupts the SW8A. The SW8A prepares to receive an 8 bit byte (consisting of address in the most significant nibble and command in the least significant nibble with the least significant bit always a 1) from the datalogger. The datalogger drives C2 as a clock line and C1 as a serial data out line. The datalogger shifts out each bit (LSB first) on the falling edge of the clock; the Switch Closure Module shifts in each bit on the rising edge of the clock.

When all 8 bits are received by the SW8A, the SW8A is again interrupted by its serial communication interface. If the address part of the byte received equals the jumpered address, the SW8A executes the command part, providing it is valid. For Function Options 1 and 2, the module receives another byte containing Reps and Channel information from the datalogger. For a valid address and command, the SW8A prepares to return a code byte as acknowledgment to the datalogger. The CR10 switches C1 to an input and after 2 milliseconds clocks back the code byte from the SW8A. If the code byte is correct, the CR10 knows the addressed SW8A is present. The 21X works similarly, except the data from the SW8A is input to single ended analog channel 1, not C1.

Depending on the Command, Reps, and Channel information, the module will shift out one or more bytes to the datalogger, again using C2 as a clock driven by the datalogger. The module shifts out each bit on the falling edge of the clock; the datalogger reads each bit on the rising edge of the clock.

Each time an entire byte is transmitted to the datalogger, the SW8A is interrupted and prepares to send the next byte, if any. When all requested bytes have been sent, the SW8A disables its serial communication interface and waits for both C3 and C2 to be driven low by the datalogger. When this happens, the SW8A prepares again to start a new command cycle.

An important feature of the module is its watchdog counter. The counter pulls the processor momentarily into reset if the count gets too high. The counter counts the C2 clock transitions. Under normal operating conditions, the processor resets the counter. If the processor is "bombed," it will not reset the counter. As the datalogger makes requests of the Switch Closure Module, the counter increments to the point where it resets the processor; the module will then start operating correctly again.

APPENDIX A. PROGRAM EXAMPLE

The example program is written for the CR10 or 21X. It is an example only and is not meant to be used verbatim. In application, the concepts illustrated here are likely to be only fragments of a larger program.

The example program reads all 8 ports of an SW8A which is set to address 00. It is read three times per scan, once each for State, Duty Cycle, and Count information. The scan rate is fixed at 1 second, with a 5 minute output of State, average Duty Cycle, and average Count.

To prevent erroneous values from being included in Output Processing routines, the datalogger's Intermediate Processing Disable Flag (Flag 9) is set under the following two conditions.

1. **When the SW8A is not responding** - If the processor is not responding, a value of -99999 is detected in the first Location containing SW8A data, and Flag 9 is set high. The SW8A is accessed a second time to increment the watchdog counter to greater than 64 and force a watchdog reset (refer to Section 7.3). A RESET COUNTER (input location 25, RESET CNT) is incremented and output with time to create a record of when and how many times the SW8A has been reset since the last datalogger compilation.

2. **When the current scan is the first scan after compiling the datalogger program** - If the datalogger program is compiled in the *0 Mode, all Flags are set low following compilation. To detect the first scan after the datalogger is compiled, the state of user Flag 1 is checked. If Flag 1 is low the Intermediate Disable Flag (Flag 9) is set high to prevent the first readings from being included in subsequent Output Processing Instructions. Flag 1 is set high at the end of the first scan.

A flow chart of the example program is presented in Figure A-1.

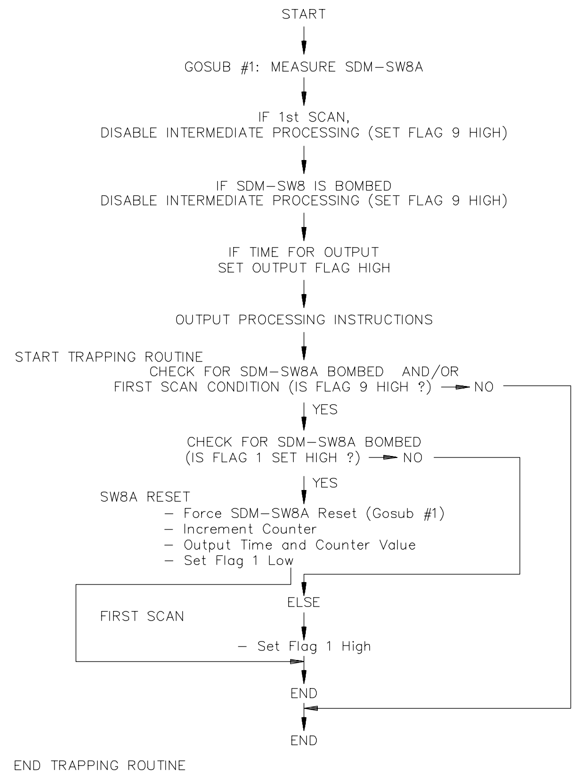

FIGURE A-1. Example Program Flow Chart

PROGRAM EXAMPLE

Input Locations Used:

1:STATE #1	13:DUTY #5
2:STATE #2	14:DUTY #6
3:STATE #3	15:DUTY #7
4:STATE #4	16:DUTY #8
5:STATE #5	17:COUNT#1
6:STATE #6	18:COUNT #2
7:STATE #7	19:COUNT #3
8:STATE #8	20:COUNT #4
9:DUTY #1	21:COUNT #5
10:DUTY #2	22:COUNT #6
11:DUTY #3	23:COUNT #7
12:DUTY #4	24:COUNT #8
	25:RESET CNT

Output Arrays: ID = 105, 27 ELEMENTS
ID = 112, 4 ELEMENTS

105, DAY, HRMN, STATE #1,... STATE #8, DUTY #1, ... DUTY #8, COUNT #1, ... COUNT #8

112, DAY, HRMN, RESET COUNT

```
*         1        Table 1 Programs
  01:     1        Sec. execution interval

01:     P86        Do
  01:     1        Call Subroutine 1
```

If SDM-SW8A was just programmed or its processor is bombed, set intermediate processing disable flag.

```
02:     P91        If Flag/Port
  01:    21        Do if flag 1 is low
  02:    19        Set high Flag 9

03:     P89        If X<=>F
  01:     1        X Loc state #1
  02:     4        <
  03:     0        F
  04:    19        Set high Flag 9
```

OUTPUT STATE AND AVERAGE DUTY CYCLE EVERY 5 MINUTES.

```
04:     P92        If time is
  01:     0        minutes into a
  02:     5        minute interval
  03:    10        Set high Flag 0 (output)

05:     P77        Real Time
  01:   110        Day,Hour-Minute

06:     P70        Sample
  01:     8        Reps
  02:     1        Loc state #1

07:     P71        Average
  01:    16        Reps
  02:     9        Loc duty #1
```

******* START TRAPPING ROUTINES *******

```
08:     P91        If Flag/Port
  01:    19        Do if flag 9 is high
  02:    30        Then Do

09:     P91        If Flag/Port
  01:    11        Do if flag 1 is high
  02:    30        Then Do
```

************* RESET ROUTINE *************

To force a watchdog reset, increment reset counter, output time and number of resets, and set flag 1 low.

```
10:     P86        Do
  01:     1        Call Subroutine 1

11:     P32        Z=Z+1
  01:    25        Z Loc [:RESET CNT]

12:     P86        Do
  01:    10        Set high Flag 0 (output)

13:     P77        Real Time
  01:   110        Day,Hour-Minute

14:     P70        Sample
  01:     1        Reps
  02:    25        Loc RESET CNT

15:     P86        Do
  01:    21        Set low Flag 1
```

********** FIRST SCAN ROUTINE **********

```
16:     P94        Else

17:     P86        Do
  01:    11        Set high Flag 1

18:     P95        End

19:     P95        End

20:       P        End Table 1
```

```
*           3          Table 3 Subroutines

** SUBROUTINE TO MEASURE SDM-SW8A **

01:       P85          Beginning of Subroutine
  01:       1          Subroutine Number

02:      P102          SDM-SW8A
  01:       8          Reps
  02:      00          Address
  03:       0          Channel state(s) function
  04:       1          Chan
  05:       1          Loc [:state #1 ]
  06:       1          Mult
  07:       0          Offset

03:      P102          SDM-SW8A
  01:       8          Reps
  02:      00          Address
  03:       1          Duty cycle function
  04:       1          Chan
  05:       9          Loc [:duty #1  ]
  06:       1          Mult
  07:       0          Offset

04:      P102          SDM-SW8A
  01:       8          Reps
  02:      00          Address
  03:       2          Counts function
  04:       1          Chan
  05:      17          Loc [:counts #1]
  06:       1          Mult
  07:       0          Offset

05:       P95          End

06:         P          End Table 3
```