

**Features**

- Low Quiescent Operating Currents  
 $2\mu\text{A}/4\mu\text{A}$  in OFF/ON state
- Scalable galvanic isolation from primary to secondary sides of the device
- Single control signal for on/off input (CLK)  
 Operation from 2.7V to 5.5V  
 Compatible with standard microcontrollers
- Switch Characteristics  
 High voltage switch with bi-directional blocking in OFF state  
 60V switch and  $110\text{m}\Omega$   $R_{DS(on)}$   
 Up to 4A operating current
- Transient protection for SW1 and SW2 to:  
**IEC 61000-4-2 (ESD)  $\pm 30\text{kV}$  (air),  $\pm 30\text{kV}$  (contact)**  
**IEC 61000-4-4 (EFT) 40A (5/50ns) level 4**  
**IEC 61000-4-5 (Surge/Lightning) 160V with  $2\Omega$  internal impedance (1.2/50 $\mu\text{s}$ )**

**Specification**

- Junction operating temperature  $-55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$
- Packaged in a 20 pin QFN (4x4)
- Product is lead-free, Halogen Free, RoHS / WEEE compliant

**Description**

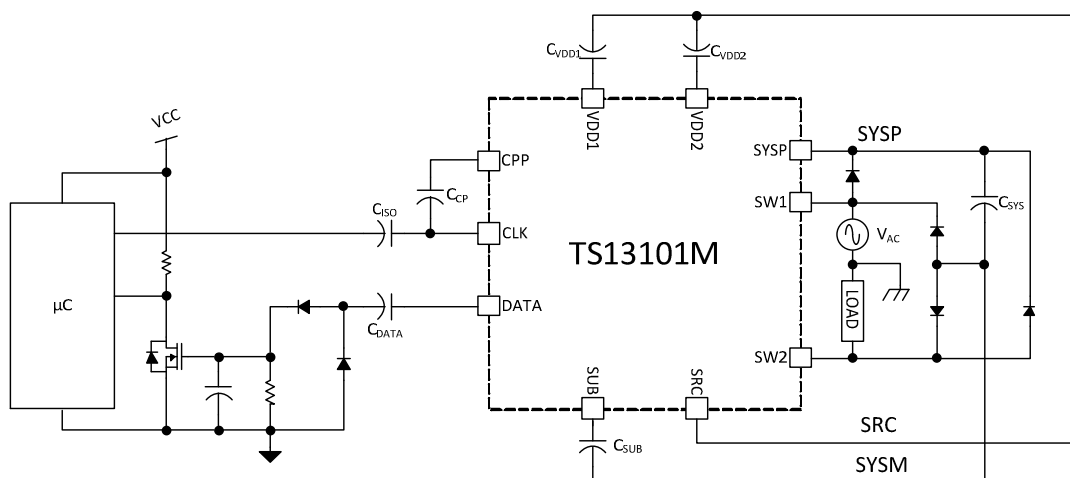
The TS13101M is a galvanically isolated 60V solid state relay with bi-directional blocking. The device includes a single integrated  $110\text{m}\Omega$  high voltage switch allowing high efficiency switching of power loads or other high current applications. The input pin, CLK, controls the turn on/off of the switch. When the correct CLK sequence is provided the switch will latch on and stay on until the turn off sequence is given or a fault is detected.

The TS13101M includes several protection features. Each switch has an integrated over-current shut-down to prevent device damage during short-circuit or other unusually high load conditions. If an over-current event is detected for a time, the FET is latched off until the CLK turn on sequence is given. While the CLK pin is active after an over-current event or in the event of an incorrect turn-on sequence, the DATA pin is toggled at  $\frac{1}{4}$  the CLK frequency.

**Applications**

- Power load/rail switching
- Input supply multiplexing
- Isolated power supplies
- Solid state relays
- HVAC control

**TYPICAL APPLICATION CIRCUIT**



## PIN DESCRIPTION

Pin #	Pin Name	Pin Function	Description
1	SRC	Switch Driver Supply Return	Local common supply return
2	SW2	Switch Output Node 2	
3	SW1	Switch Output Node 1	
4	SW1	Switch Output Node 1	
5	SW2	Switch Output Node 2	
6	SW1	Switch Output Node 1	
7	SW2	Switch Output Node 2	
8	SW2	Switch Output Node 2	
9	DATA	Data Output	AC Coupled Data Output
10	CLK	Clock Input	AC Coupled Clock and Power Input
11	SYSP	Positive System Voltage	
12	CPP	Charge Pump Cap	Additional Cap used for lower voltage Clock drive
13	VDD1	Internal Supply 1	Bypass Capacitor for Internal Supply
14	VDD2	Internal Supply 2	Bypass Capacitor for Internal Supply
15	NC	No Connect	
16	SUB	IC Substrate Bias	Connect C <sub>SUB</sub> Capacitor to SYSM
17	NC	No Connect	
18	SW1	Switch Output Node 1	
19	SW1	Switch Output Node 1	
20	SW2	Switch Output Node 2	
PAD	PAD	Power PAD	Must be floating or connected to SUB

## FUNCTIONAL BLOCK DIAGRAM

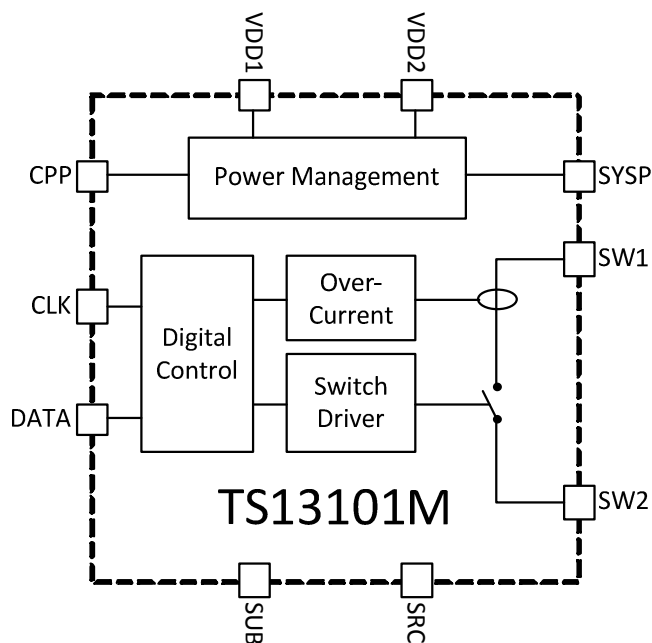


Figure 1: TS13101M Block Diagram

## ABSOLUTE MAXIMUM RATINGS

Over operating free-air temperature range unless otherwise noted. <sup>(1, 2, 3)</sup>

Parameter	Range	Unit
SW1, SW2, SYSP (Peak Voltage, with respect to SUB, SRC)	-0.5 to 60	V
SW1, SW2 (with respect to each other)	-60 to 60	V
CLK, DATA, VDD1, VDD2, CPP (with respect to SUB, SRC)	-0.3 to 5.5	V
SUB	-60 to 0.3	V
Maximum Junction Temperature, $T_{J\text{MAX}}$	150	°C
Storage Temperature Range, $T_{\text{STG}}$	-65 to 150	°C
Electrostatic Discharge – Human Body Model	±2	kV
Electrostatic Discharge – IEC Contact (SW1 and SW2 Pins) <sup>(4)</sup>	±30	kV
Electrostatic Discharge – IEC Air Discharge (SW1 and SW2 Pins) <sup>(4)</sup>	±30	kV
Peak IR Reflow Temperature (10s to 30s)	260	°C

Notes:

- (1) Stresses beyond those listed under “absolute maximum ratings” may cause permanent damage to the device. These are stress ratings only and functional operation of the device at these or any other conditions beyond those indicated under “recommended operating conditions” is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) All voltage values are with respect to SRC terminal.
- (3) ESD testing is performed according to the respective JESD22 JEDEC standard
- (4) IEC ESD testing is performed on Semtech Product Evaluation Board TS13101-EVMX3.

## THERMAL CHARACTERISTICS

Symbol	Parameter	Value	Unit
$\Theta_{JA}$	Thermal Resistance Junction to Air (Note 1)	25	°C/W
$\Theta_{JC}$	Thermal Resistance Junction to Case (Note 1)	2.5	°C/W
$T_J$	Operating Junction Temperature Range	-55 to 125	°C

Note 1: Assumes 20LD 4x4 QFN with hi-K JEDEC board and 13.5 inch<sup>2</sup> of 1 oz. Cu and 4 thermal vias connected to PAD

## RECOMMENDED OPERATING CONDITIONS

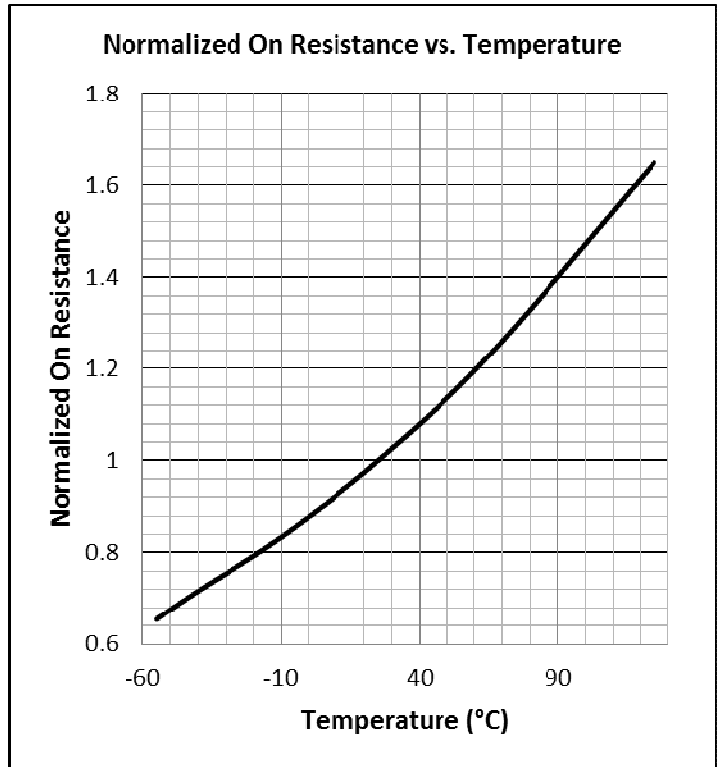
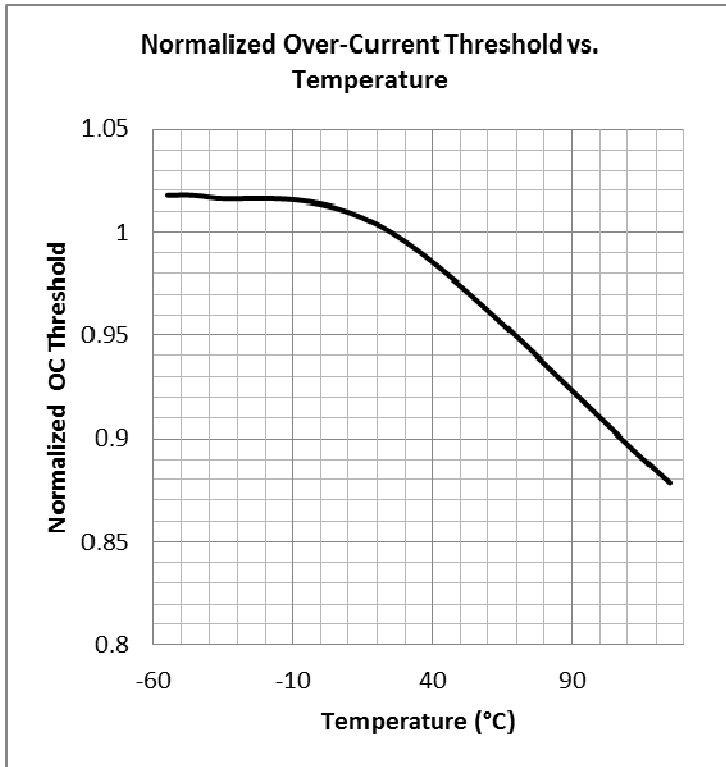
Symbol	Parameter	Min	Typ	Max	Unit
$V_{SW}$	AC Switch Voltage (RMS Voltage)	-36		36	V
$V_{SW}$	DC or AC Peak Switch Voltage	-51		51	V
$C_{DATA}$	Data Isolation Capacitor		100		pF
$C_{ISO}$	Clock Isolation Capacitor		680		pF
$C_{CP}$	Charge Pump Capacitor		100		pF
$C_{VDD1}$	VDD1 Bypass Capacitor		10		nF
$C_{VDD2}$	VDD2 Bypass Capacitor		1		μF
$C_{SUB}$	Sub Capacitor		100		nF
$C_{SYS}$	System Bypass Capacitor		100		nF
<b>CLK Drive</b>					
$V_{CLK}$	Clock Drive Voltage; Amplitude of driven CLK signal, Drive Impedance < 100Ω	2.7		5.5	V
$F_{CLK}$	Clock Frequency to Turn on Switch	500		2000	kHz
$N_{CLKON-INIT}$	Number of CLK pulses to initialize Turn On	3		8	pulses
$T_{LOW-ON}$	CLK Low time during Turn On Sequence	10		20	μs
$N_{CLKON}$	CLK Pulses to Turn on SW After $T_{LOW-ON}$	15			pulses
$T_{CLKOFF-INIT}$	CLK Low time to Initialize Turn-Off	10		20	μs
$N_{CLKOFF}$	CLK Pulses to Enable Turn-Off After $T_{CLKOFF-INIT}$	6		13	pulses
$N_{CLK-OFFDET}$	CLK Pulses to Detect Incorrect Turn-On Sequence	19			pulses
$T_{PRE-CHG}$	Pre-Charge Time for VDD1, VDD2 when $ V_{SW2}-V_{SW1} <5.0V$ $V_{CLK} = 3.0V, F_{CLK} = 1MHz$	50			ms

## ELECTRICAL CHARACTERISTICS

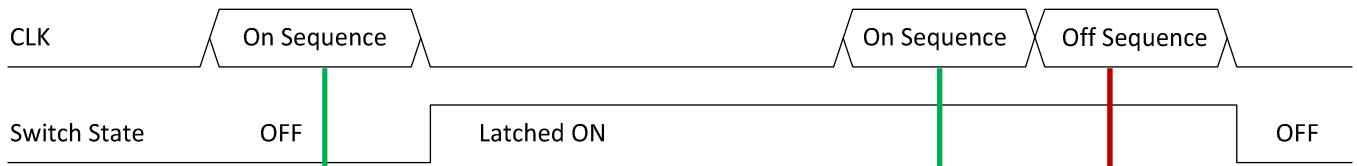
Electrical Characteristics,  $T_J = -55^{\circ}\text{C}$  to  $125^{\circ}\text{C}$  (unless otherwise noted)

Symbol	Parameter	Condition	Min	Typ	Max	Unit
<b>Supply Voltage</b>						
$I_{\text{CLK-NORM}}$	Normal Mode, CLK running	$V_{\text{CLK}} = 5.0\text{V}$ , $F_{\text{CLK}} = 500\text{kHz}$		15		$\mu\text{A}$
$I_{\text{CLK-NORM}}$	Normal Mode, CLK running	$V_{\text{CLK}} = 3.0\text{V}$ , $F_{\text{CLK}} = 1000\text{kHz}$		50		$\mu\text{A}$
$I_{\text{CLK-STBY}}$	Quiescent current	$V_{\text{CLK}} = 0\text{V}$ , $C_{\text{ISO}} = 680\text{pF}$		3		$\mu\text{A}$
$I_{\text{SYSP}}$	Quiescent current	$T_J < 125^{\circ}\text{C}$ , Latch Mode		3	20	$\mu\text{A}$
<b>DATA Output</b>						
$F_{\text{DATA}}$	Data Frequency during Current Shutdown			$F_{\text{CLK}}/4$		kHz
<b>Output Switch</b>						
$R_{\text{DS(on)}}$	On Resistance	$T_J = 25^{\circ}\text{C}$	85	110	135	$\text{m}\Omega$
$I_{\text{OFF}}$	Off State Leakage	$V_{\text{SYS}} = V_{\text{SW}}$ , $T_J < 125^{\circ}\text{C}$		0.1	3	$\mu\text{A}$
$I_{\text{OUTOC}}$	Over Current Shutdown	$T = 25^{\circ}\text{C}$		5.5		A
$\text{OC}_{\text{FILT}}$	Output Over Current Deglitch			25		$\mu\text{s}$
$V_{\text{CLAMP}}$	Differential SW1/2 Clamping Voltage	(SW1-SW2) or (SW2-SW1) $I_{\text{SW}} = 50\text{mA}$	58	63	68	V
$T_{\text{CLKOFF}}$	Time for Turn Off		4		10	$\mu\text{s}$

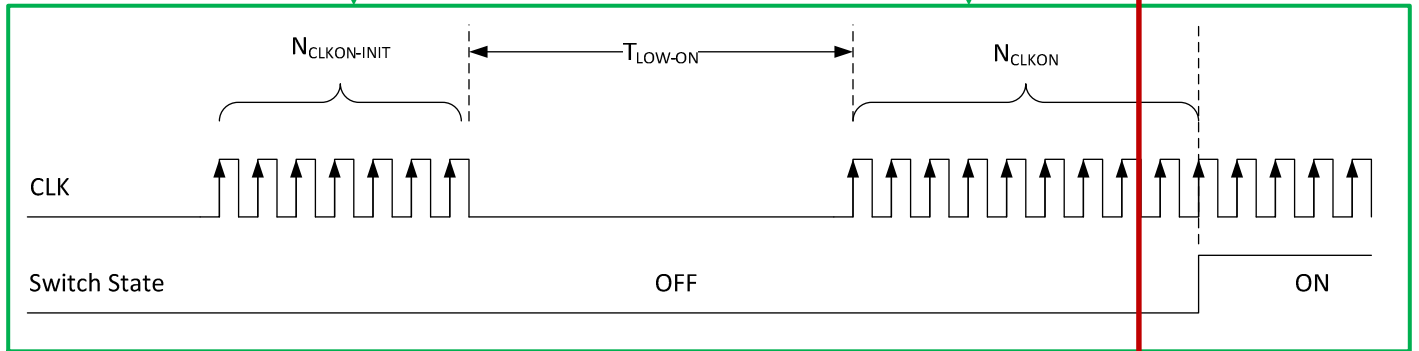
# PRODUCT CHARACTERISTICS



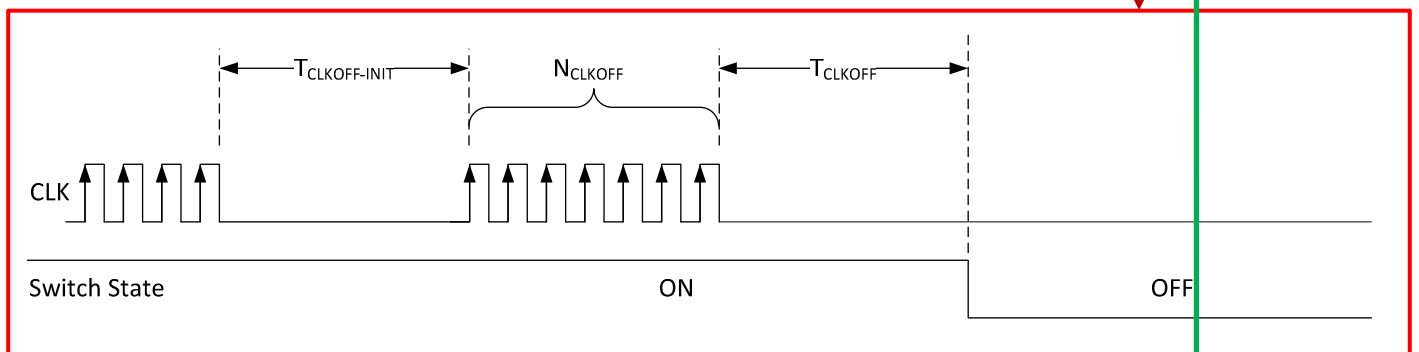
# APPLICATION WAVEFORMS



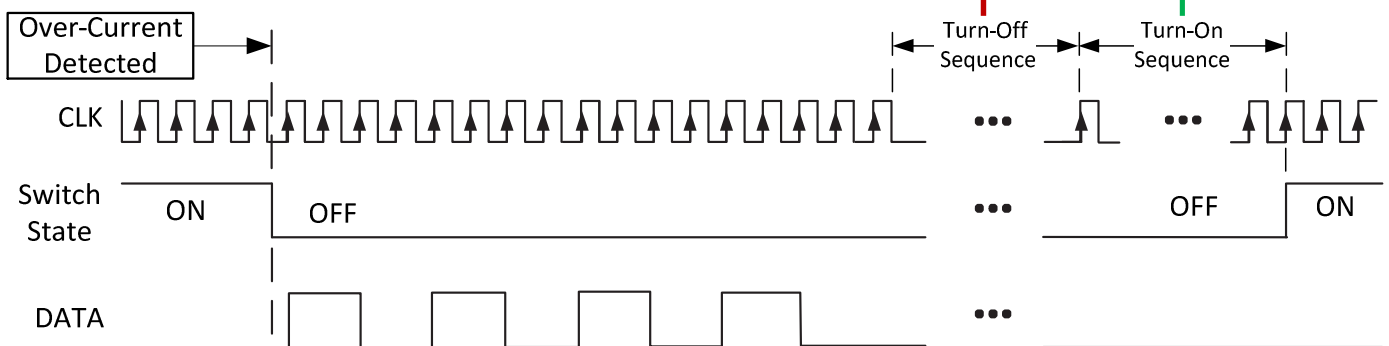
**Figure 2: Latch Mode On / Off Sequence**



**Figure 3: CLK Turn-On Sequence**



**Figure 4: CLK Turn-Off Sequence**



**Figure 5: Over-Current Shut-Down and Restart**

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## SWITCH CONTROL

The TS13101M CLK pin performs a dual function:

1. It provides the command sequences in level and timing that determine the state of the switch.
2. It provides a source of power by which the switch can operate.

The microcontroller provides the CLK signal to the switch by a coupling capacitor,  $C_{ISO}$ , that provides galvanic isolation between the microcontroller supply domain and that of the switch, the latter of which has a different reference voltage with respect to ground dependent on its state. Because of the requirement to source power, it is required that the microcontroller has a maximum source impedance of  $100\Omega$ .

The CLK pin is used as a means to command the state of the switch by the ON and OFF sequences shown in Figure 2 through Figure 5. Figure 2 shows the state of the switch being changed by sending ON and OFF Sequences. On initial power up, the switch state will default to the OFF condition.

It is necessary to send a device ON Sequence to transition the device to the ON state, as shown in Figure 3. First a series of clocks,  $N_{CLKON-INIT}$ , of frequency  $F_{CLK}$  is transmitted, followed by a CLK low time of  $T_{LOW-ON}$ . Then another series of clocks of number  $N_{CLKON}$  is transmitted. On the final CLK edge the switch will be closed. Note that the CLK continues to cycle and the state of the DATA pin continues to be low. This indicates that the device is ON.

When it is desired to transition the device to the OFF state, the OFF Sequence must be transmitted via the microcontroller. This sequence is shown in Figure 4. Here the CLK is stopped for a period of  $T_{CLKOFF-INIT}$ , followed by a series of clocks of number  $N_{CLKOFF}$ . Then the CLK must be asserted low for a period  $T_{CLKOFF}$ , after which the switch will be opened. If the CLK resumes switching, the DATA pin will return a signal  $F_{CLK} / 4$ , indicating that the state of the switch is OFF.

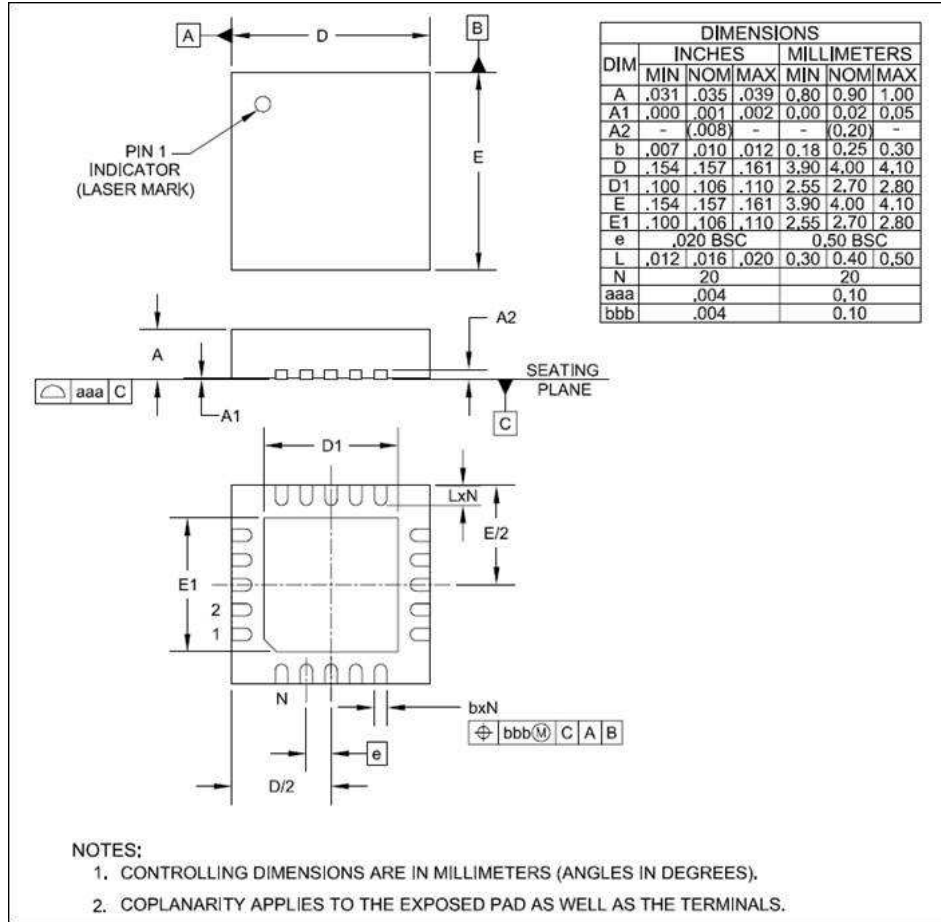
Figure 5 shows the operation when an over-current event is detected, and the device autonomously transitions to the OFF state in order to protect itself and the load in the system. During the ON time, the CLK was being switched and the DATA pin was static, being held by the device in the low state. After the over-current event opens the switch, the DATA pin will start switching at  $F_{CLK} / 4$  to signal the microcontroller that the switch is no longer in the ON state. The microcontroller may infer from this that there has been a fault in the system. If diagnostics (performed elsewhere in the system) determine that the fault condition has been removed, the device may be returned to the ON state through the restart sequence shown. After an over-current event opens the switch, an OFF Sequence must be registered in the part before an ON Sequence can successfully transition the device back to the ON state. The DATA pin will assert low and stay low after the ON Sequence as long as load current remains below  $I_{OUTOC}$ . If the switch transitions to the closed state and an over-current condition is detected, the process of Figure 5 will repeat.

### Failed Communication

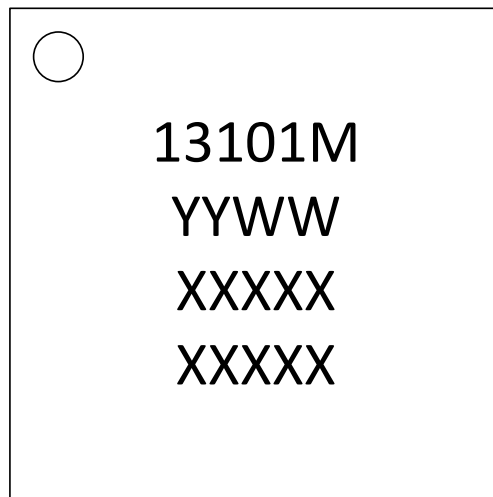
In the event of a failed ON command sequence (due to external interference, system transients, etc.) the DATA pin will begin sending a signal at frequency  $F_{CLK} / 4$ . Thus the microcontroller is alerted to a communication failure. Similarly, when an OFF command sequence has been sent, resuming CLK pulses after the  $T_{CLKOFF}$  time will result in the DATA pin sending a signal of frequency  $F_{CLK} / 4$ . If the DATA pulses do not commence after 23 CLK cycles, the microcontroller can discern that the OFF sequence was not received correctly and the switch is still in the closed state. It is up to the microcontroller to do this fault handling and rectify the situation.



# PACKAGE INFORMATION

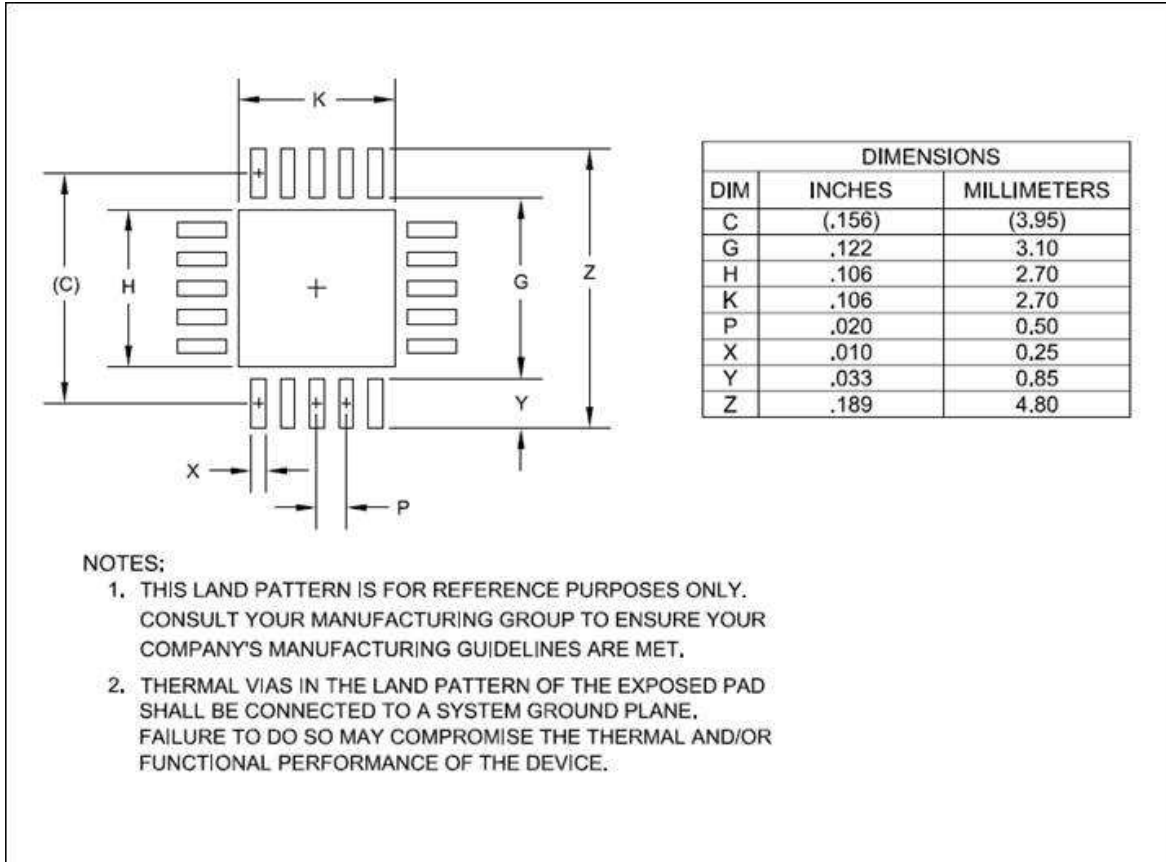


**Figure 6: Package Outline Drawing**



**Figure 7: Device Symbolization**

Notes:  
 YYWW = Year Calendar Week  
 XXXXX = Semtech Lot Number  
 XXXXX = Lot Number (Continued)



**Figure 8: Recommended Board Layout Land Pattern**

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## ORDERING INFORMATION

Part Number	Description	Package
TS13101M-QFNR	Latching Galvanic Isolated Switch	20-pin PQFN Reel (3,300 pcs)



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## CONTACT INFORMATION

Semtech Corporation  
200 Flynn Road, Camarillo, CA 93012  
Phone: (805) 498-2111, Fax: (805) 498-3804  
[www.semtech.com](http://www.semtech.com)

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