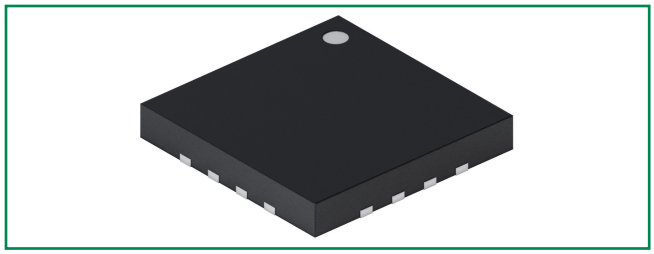
CPC2501M

Voltage Controlled, Normally Closed, 60 V, 1.84 A Solid State Relay



Features

- 1-Form-B (Normally closed) relay
- Internal control circuitry
  - Self-actuating
  - Fault protection timer
- 600 mΩ Maximum On-resistance at 25 °C
- 60V peak AC or DC load voltage
- Load Current
  - 1.84 A_{RMS} Continuous
  - 5A Peak
- Fast Turn-on: 170 µs maximum
- Small 6×6 [mm] thermally enhanced QFN package

Applications

- Door chime bypass
  - Derives power from standard 2-wire chime supply
  - System BOM savings and reduced PCB demands
- Building Automation
- Internet of Things (IoT)
- Security
- Voltage controlled relay

Description

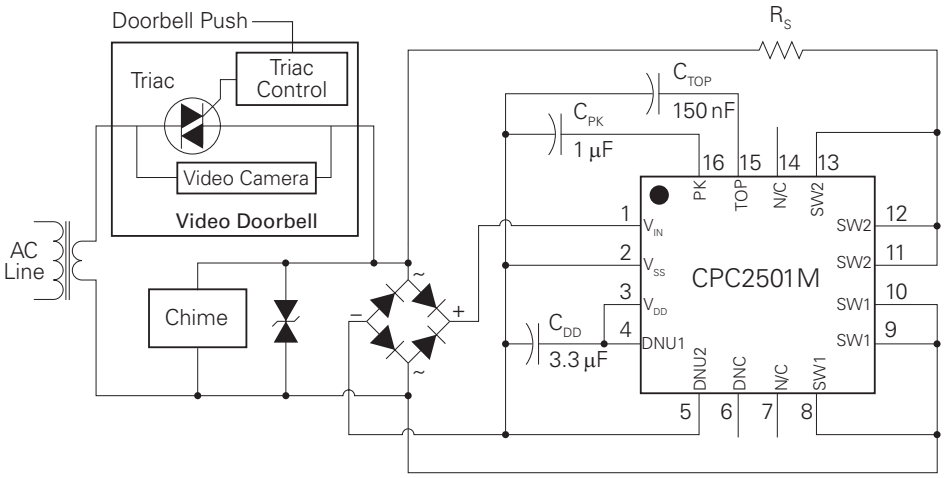
The CPC2501M incorporates a normally closed (1-Form-B) solid state relay switch with an integrated circuit specifically designed to control and manage the relay state based upon the applied voltage.

When configured for video doorbell applications, the CPC2501M becomes a self-actuating, non-isolated solid state relay that provides the ringing chime bypass function necessary to ensure proper video and chime operation. In addition to superior performance over video doorbells implemented with discrete devices, it offers superior power handling of 2.5W, a fast response time of 170 µs, fault protection circuitry, and the industry's highest load current of 1.84 A. The CPC2501M provides reduced BOM costs and printed circuit board real estate demands through integration.

Ordering information

Part Number	Description
CPC2501MTR	QFN-16 with exposed pads in Tape and Reel (3000 pcs/reel)

Figure 1. CPC2501M Typical Video Doorbell Application Circuit

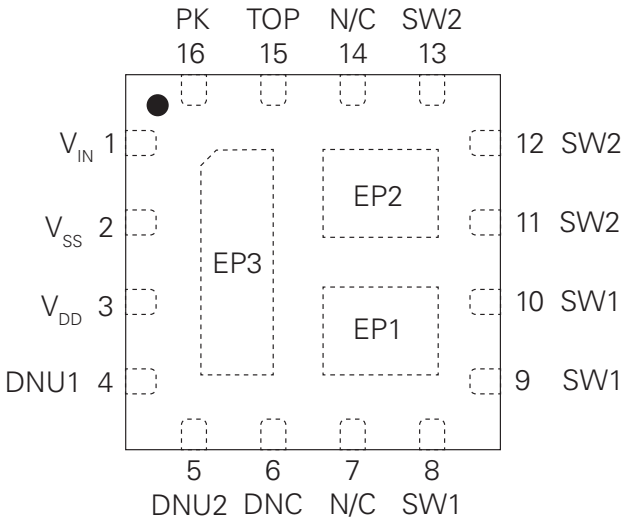


Revised: SC 7/10/2025
CPC2501M_R05

Revised: SC 7/10/2025
CPC2501M_R05

1. Specifications

1.1 Pinout



1.2 Pin Descriptions

Pin	Name	Type	Description
1	V_{IN}	Power	Supply voltage. Positive full wave rectified voltage from diode bridge
2	V_{SS}	Power	Supply voltage return. Negative voltage from diode bridge
3	V_{DD}	Output	Regulated supply voltage for internal circuitry. Connect capacitor from V_{DD} to V_{SS}.[1]
4	DNU1	—	Do Not Use: Connect to V_{DD}
5	DNU2	—	Do Not Use: Connect to V_{SS}
6	DNC	—	Do Not Connect: Do not connect this pin.
7	N/C	—	No Connection: Not internally connected.
8, 9, 10	SW1	I/O	Switch terminal 1
11, 12, 13	SW2	I/O	Switch terminal 2
14	N/C	—	No Connection: Not internally connected.
15	TOP	Output	Envelope tracking voltage of V_{IN}. Connect capacitor from TOP to V_{SS}.[1]
16	PK	Output	Peak voltage of V_{IN}. Connect capacitor from PK to V_{SS}.[1]
EP1	SW1	Thermal	Thermal pad for SW1 power MOSFET. Connect to SW1, pins 8, 9 and 10. [2]
EP2	SW2	Thermal	Thermal pad for SW2 power MOSFET. Connect to SW2, pins 11, 12 and 13. [2]
EP3	DNC	Thermal	Thermal pad for the Control IC. Do not connect to this pad. [2]

[1] See text regarding capacitor selection.

[2] Package bottom side exposed pads EP1, EP2 and EP3 must be soldered to printed circuit board lands. See instructions in Section 1.5 Thermal Characteristics on page 4.

1.3 Absolute Maximum Ratings

Unless otherwise noted all voltages are with respect to V_{SS} and all electrical ratings are at $T_A = 25\,°C$.

Parameter	Rating	Unit
V_{IN}, V_{PK}, V_{TOP}	–0.3 to +60	V
SW1 to SW2	–60 to +60	V
V_{DD}, DNU1, DNU2	–0.3 to +5.5	V
Switch Peak Load Current (I_L) (for t < 16 ms)	5	A
Total Power Dissipation [1]	2.5	W
ESD Rating, Human Body Model	±2	kV
Ambient Temperature (T_A)	–40 to +85	°C
Virtual Junction Temperature (T_{vj})	+125	°C
Storage Temperature (T_{stg})	–40 to +150	°C

[1] *Derate linearly 25 mW/°C for $T_A > 25\,°C$*

Absolute Maximum Ratings are stress ratings. Stresses in excess of these ratings can cause permanent damage to the device. Functional operation of the device at conditions beyond those indicated in the operational sections of this data sheet is not implied.

1.4 Recommended Operating Conditions

Parameter	Symbol	Value		Units
		Min	Max	
V_{IN} to V_{SS}	V_{IN}	—	44	V
Switch Load Current	I_L	—	1.84	A_{RMS}

1.5 Thermal Characteristics

Parameter	Symbol	Rating	Units
Thermal Impedance, Junction to Air	θ_{JA}	40	K/W
Thermal Impedance, Junction to Case	θ_{JC}	3	K/W

Note: *The thermal impedance values listed above and the total power dissipation rating stated in the Absolute Maximum Ratings table are based on measurements done on a 1.57 mm thick FR4 printed circuit board with the QFN bottom side exposed pads soldered to copper lands on the PCB. Each of the component side EP1 and EP2 PCB lands for SW1 and SW2 are thermally and electrically connected to a 70 µm thick (2 ounce) copper heat spreading shape of 0.75 square inches on the non-component side of the PCB by two 0.3 mm copper filled vias. It may be necessary to enlarge the SW1 and SW2 thermal lands shown in* *Section 4.5.2 CPC2501M Recommended Land Pattern on page 13* *to accommodate the thermal vias and to reduce the trace length connection to their pins.*

It is not necessary to thermally connect EP3 to a heat spreading shape on the non-component side of the board.

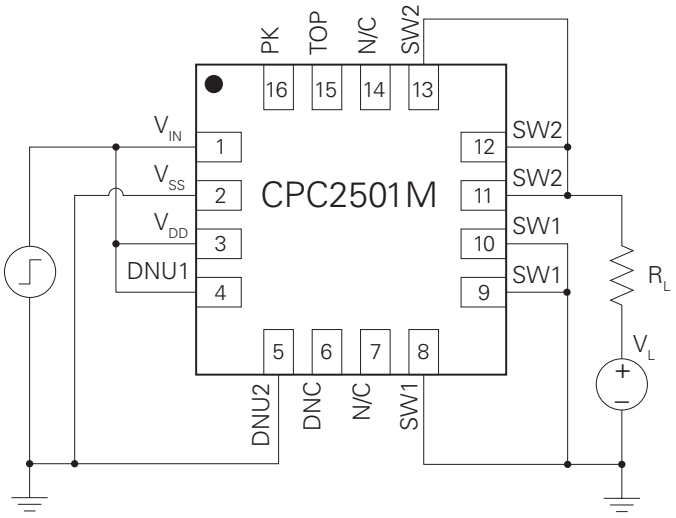
1.6 Electrical Characteristics

Unless otherwise noted, the Electrical Characteristics ratings are over the operational ambient temperature range of –40 °C to +85 °C.

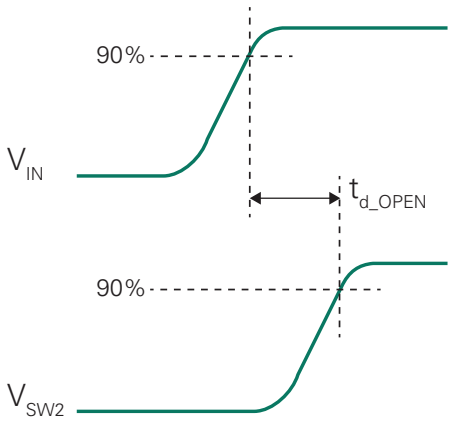
Typical values are characteristic of the device at T_A = +25 °C, and are the result of engineering evaluations. They are provided for information purposes only, and are not part of the manufacturing test requirements.

Parameter	Conditions	Symbol	Value			Units
			Minimum	Typical	Maximum	
Input Characteristics						
Input Current	V_{IN} = 7V, C_{DD} = 3.3 µF	V_{IN}	210	407	950	µA
	V_{IN} = 3.3V, C_{DD} = 3.3 µF		130	245	545	
Input Voltage Activation Threshold	C_{DD} = 3.3 µF	V_{INP}	2.5	2.96	3.4	V
Activation to Switch Open Delay	Pulse V_{IN} from 0V to 4.5V, V_L = 10V, R_L = 1 kΩ	t_{d_OPEN}	—	81	170	µs
Regulator						
Output Voltage	V_{IN} = 7V, C_{DD} = 3.3 µF	V_{DD}	4	4.6	5.2	V
	V_{IN} = 3.3V, C_{DD} = 3.3 µF		3.2	3.297	3.3	
Peak Detection To Deactivate						
PK Discharge Resistance	—	R_{PK}	415	800	1325	kΩ
TOP Discharge Resistance	—	R_{TOP}	155	300	500	
V_{TOP_PK} DC Ratio to Close Switch (Deactivation Threshold)	C_{DD} = 3.3 µF	V_{TOP}/V_{PK}	0.7	0.75	0.79	—
Time-Out Protection						
Switch Open Duration (Time-out)	V_{IN} = 7V, C_{DD} = 3.3 µF	t_{d_CLOSE}	10	17	25	s
Switch Characteristics						
On-Resistance (Switch Closed)	V_{IN} = 0V, I_L = 100 mA, C_{DD} = 3.3 µF	R_{ON}	—	0.388	0.75	Ω
Leakage Current (Switch Open)	V_{IN} = 7V, V_L = 60V, C_{DD} = 3.3 µF	I_{LEAK}	—	—	1	µA

1.7 Activation Delay Test Configuration and Timing Diagram



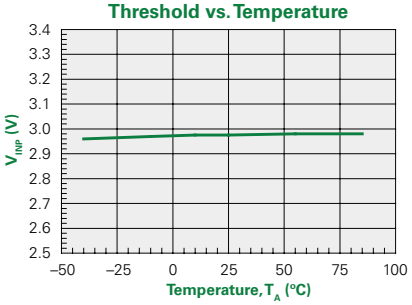
Test Configuration



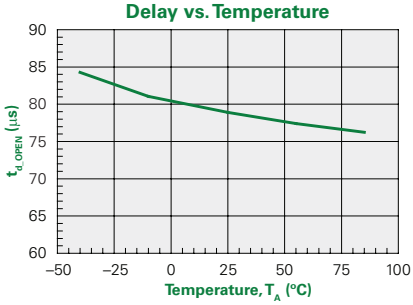
Timing Diagram

2. Performance Data

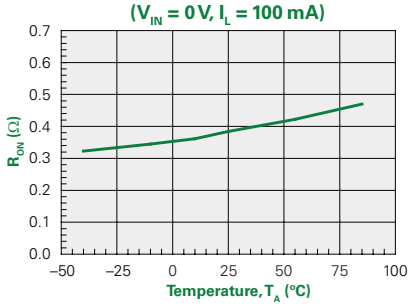
Input Voltage Activation Threshold vs. Temperature



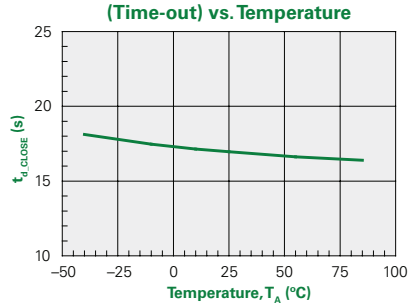
Activation to Switch Open Delay vs. Temperature



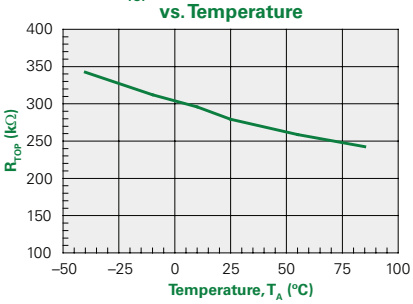
On-Resistance vs. Temperature (V_{IN} = 0 V, I_L = 100 mA)



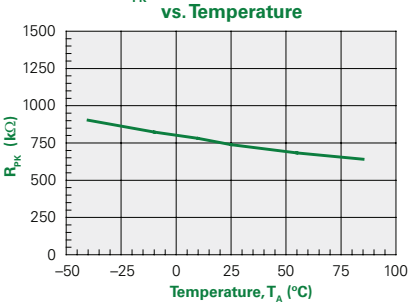
Switch Open Duration (Time-out) vs. Temperature



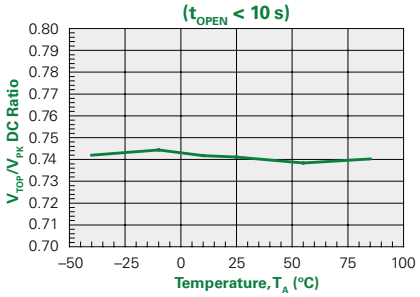
R_{TOP} Discharge Resistance vs. Temperature



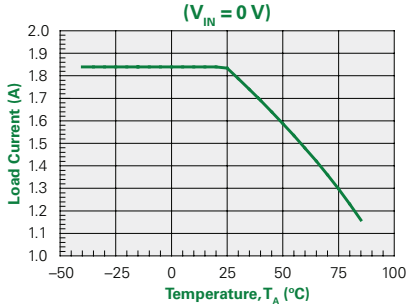
R_{PK} Discharge Resistance vs. Temperature



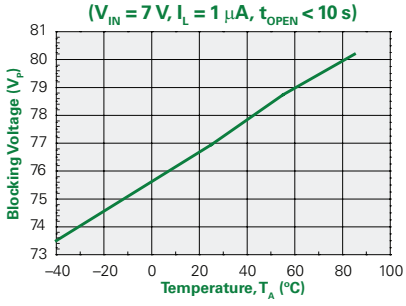
V_{TOP}/V_{PK} DC Ratio to Close Switch vs. Temperature (t_{OPEN} < 10 s)



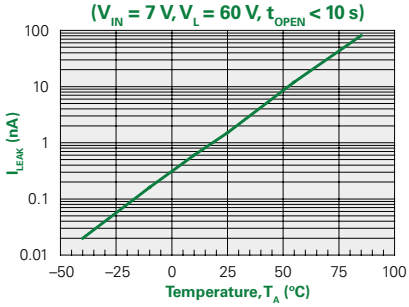
Maximum Load Current vs. Temperature (V_{IN} = 0 V)



Blocking Voltage vs. Temperature (V_{IN} = 7 V, I_L = 1 µA, t_{OPEN} < 10 s)



Leakage Current vs. Temperature (V_{IN} = 7 V, V_L = 60 V, t_{OPEN} < 10 s)



Unless otherwise noted, the data presented in these graphs is typical and T_A = 25 °C

3. Functional Description

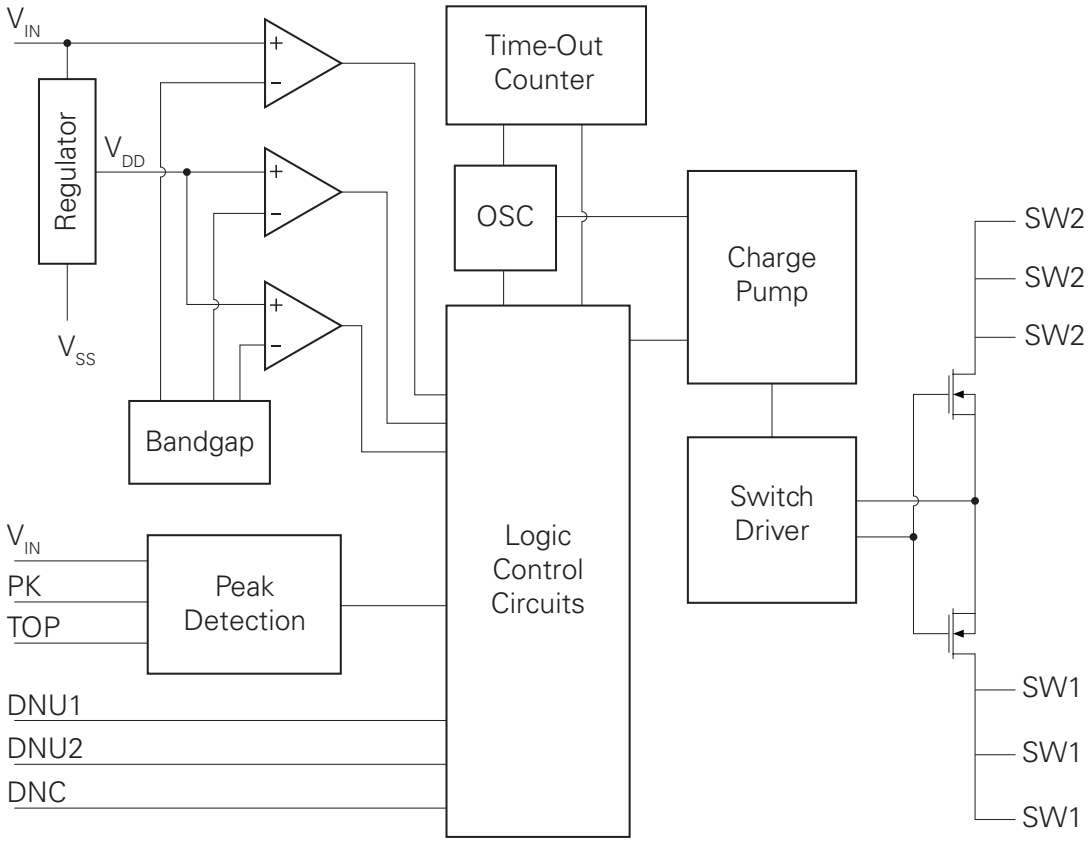


Figure 2. CPC2501M Functional Block Diagram

3.1 Description of Functional Blocks

Regulator: The regulator takes the full-wave rectified output of the diode bridge and outputs V_{DD}, a regulated DC voltage used to power the internal functional blocks.

Comparators: Inputs to the comparators are the Bandgap reference voltages: V_{DD} and V_{IN}. The comparators monitor these voltages to ensure the CPC2501M switch activates at the correct voltage levels.

Bandgap: Provides a voltage reference to the internal circuits.

Peak Detection: This block is used to detect the presence, or absence of a valid doorbell push event.

Oscillator: The oscillator is enabled whenever a doorbell push is detected and validated by the Comparators and Logic Control Circuits. The oscillator AC output is used by the Charge Pump and Time-Out Counter.

Charge Pump: The charge pump is enabled upon detection of a doorbell push event. It converts the oscillator AC voltage into a DC voltage for the switch driver.

Switch Driver: This block uses the charge pump DC output to drive the Depletion-Mode MOSFET solid state switches.

Output Switch: Two 60V Depletion-Mode MOSFETs are set up in a common source series formation to block AC or DC voltages when open and to pass AC, or DC current when closed.

Time-Out Counter: When the CPC2501M normally closed switch is opened to allow the chime to operate. A timer is initiated to limit the active chime duration to a nominal 17 seconds. Following the time-out, circuitry in the Logic Control Circuits block will return the switch to its normally closed state thereby disabling the chime.

3.2 Typical Video Doorbell Implementation

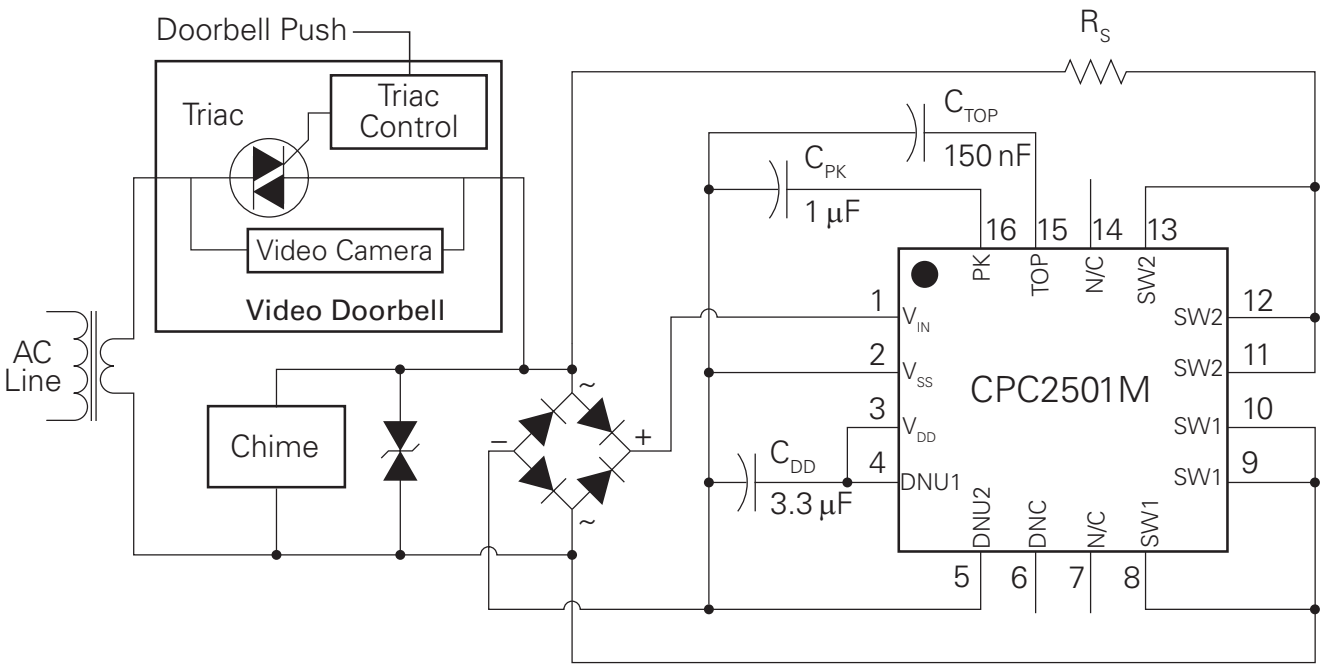


Figure 3. CPC2501M Typical Video Doorbell Application Circuit

A typical CPC2501M video doorbell application consists of four major elements: the power feed circuit, the chime, the video doorbell, and the CPC2501M chime bypass circuit. In the application circuit shown in Figure 3, the video doorbell, the chime, and the CPC2501M get their operating power from a power feed circuit consisting of a doorbell transformer and the two-wire cabling.

This design does not require any modifications to the ubiquitous two-wire feed circuit found in most homes and is compatible with a wide range of transformer voltages.

The chime bypass circuit consists of the CPC2501M, a rectifier diode bridge, three capacitors and a power resistor in series with the CPC2501M solid state switch. The CPC2501M derives its operating power from the voltage developed across R_S and R_{ON} (the resistance of the solid state switch) whenever the triac is activated.

In the idle state, the CPC2501M provides a low impedance shunt path across the chime thus enabling the video doorbell unit to draw operational power from the transformer. Whenever the doorbell is pushed, the Video Doorbell unit activates its triac, causing the current through the R_S and R_{ON} resistive load located in the chime bypass circuit, to increase substantially. The AC voltage developed across the resistive load by the increased current, is full wave rectified by the diode bridge and applied to the V_{IN} and V_{SS} power input pins. The positive output of the diode bridge is connected to V_{IN} while the diode bridge negative output is connected to V_{SS}.

When R_S is sized properly, the resulting AC voltage generated by the increased current will activate CPC2501M. Activation occurs when the voltage applied to V_{IN} exceeds V_{INP}; the Input Voltage Activation Threshold. When activated, the internal normally closed (Form-B) switch opens, which removes the low impedance chime bypass, making it possible for the chime to operate.

When the doorbell is released, the triac is deactivated causing the input voltage applied to V_{IN} to decrease. Reduction of the input voltage applied to CPC2501M causes the voltages V_{TOP} and V_{PK} at pins TOP and PK to decay at a rate determined by their internal discharge resistors (R_{TOP} and R_{PK}) and their external capacitors (C_{TOP} and C_{PK}). When the ratio of V_{TOP} to V_{PK} reaches an internally set threshold the switch is return to its normally closed state, thereby reestablishing the low impedance shunt across the chime. Power to the video doorbell is now restored and the chime is deactivated, as it now lacks sufficient power to operate.

3.3 Resistive Load

Control circuitry within the CPC2501M opens and closes the switch by detecting the video doorbell press and release. A doorbell push is detected and qualified by the magnitude of the voltage applied to V_{IN}. Because the applied voltage is sourced from the voltage developed across the R_S and R_{ON} resistive load when the doorbell triac is activated, the input voltage (V_{IN}) to open the switch is a function of the current through the resistive load.

Selection of R_S is based on a current level that represents the available current when the doorbell is pushed. Based on this current, the nominal value of R_S where the CPC2501M will activate and open the switch can be determined by the following equation:

$$R_S = \frac{2V_f + V_{INP}}{I} - R_{ON}$$

Where:

- $2V_f$ = Voltage drop of the diode bridge.
- V_{INP} = Typical V_{IN} Threshold from Electrical Specifications table.
- R_{ON} = Typical Switch On-Resistance from Electrical Specification table.
- I = Desired activation current.

3.4 Voltage Regulator

As shown in Figure 3, the input voltage is sourced from the positive output of the external diode bridge. The regulator takes the full wave rectified input voltage applied to V_{IN}, reduces it to level compatible with the internal low voltage circuitry and outputs it at the V_{DD} pin. Filtering of the reduced voltage is accomplished by C_{DD}, a 3.3 µF external capacitor. This filtered regulated voltage (V_{DD}) provides the power required by the internal circuitry.

3.5 Solid State Switch

In the idle state the normally closed solid state switch integrated into the CPC2501M is conducting, providing a low resistance shunt to bypass the chime. Consequently a very low input voltage is presented to the CPC2501M. Once the doorbell is pushed and V_{IN} exceeds the threshold voltage, the switch opens and stops conducting. Now all the current flows through the chime allowing sufficient power for the chime to operate.

3.6 Peak Detection

When the video doorbell is released, CPC2501M uses a peak detection method to determine when to close the solid state switch and restore the low impedance chime bypass shunt, allowing the video doorbell to regain operating power. Referring to Figure 3, capacitor C_{PK} stores a voltage that corresponds to the peak excursion of the rectified AC waveform, while C_{TOP} stores a voltage that corresponds to the envelope of the rectified AC waveform. When the video doorbell button transitions from pressed to released, (triac stops conducting) the incoming rectified AC waveform exhibits a collapse in amplitude. Capacitor C_{PK} is needed to hold the peak excursion as long as possible while C_{TOP} allows a "gentle" decay to track the waveform collapse. The CPC2501M monitors the voltage ratio of V_{TOP} to V_{PK} and closes the switch once V_{TOP} decreases to approximately 75 % of V_{PK} (Deactivation Threshold). This makes the CPC2501M compatible with digital chimes with up to 850 Ω impedance under typical conditions. Figure 4 shows the typical response waveforms of V_{PK} and V_{TOP} during doorbell press and release.

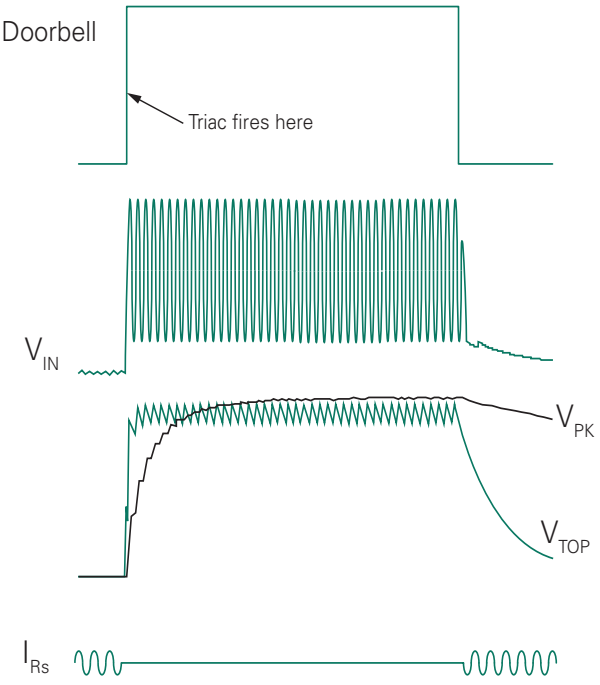


Figure 4. V_{PK} and V_{TOP} Response Waveforms

Charge and discharge times of V_{PK} and V_{TOP} are determined by on-chip charge and discharge resistors and their external capacitors C_{PK} and C_{TOP}. Note that the selection of C_{TOP} and C_{PK} will manifest itself as response delay from the triac, turning off to the actual closing of the switch. The following table shows the recommended values of the external capacitors and the estimated response delay. The solid state switch will close and begin conducting in less than three cycles after the video doorbell release, using the recommended C_{PK} and C_{TOP} values.

	Internal Charging Resistor (kΩ)	Internal Discharging Resistor (kΩ)	External Capacitor (μF)	Charging RC Time Constant (ms)	Discharging RC Time Constant (ms)	Switch Closure Delay (Cycles)*
V_{PK}	12.5	800	1	12.5	800	—
V_{TOP}	12.5	300	0.15	1.875	45	2.7 (2.25)

***** *Delay cycles are calculated based on 60 Hz (50 Hz) AC signals.*

3.7 Time-Out Protection

Once activated the CPC2501M will open its normally closed switch and enable the Time-Out Counter. The Time-Out Counter will cause the switch to transition from open to closed if the CPC2501M determines the chime has been continuously enabled for approximately 17 s. If the amplitude of V_{IN} does not decrease sufficiently for V_{TOP} to decay below approximately 0.75 V_{PK} within 17 s, the switch will re-open for another 17 s time-out. The CPC2501M will continue to open and close the switch every 17 s until V_{IN} decreases and the ratio of V_{TOP} to V_{PK} (V_{TOP}/V_{PK}) falls below the deactivation threshold.

3.8 Power Considerations

Note that maximum power dissipation of the resistive load, R_S and R_{ON}, will occur while the triac is conducting and the CPC2501M switch is closed such as when a Time-Out event has occurred. Attention to proper power management must be taken into account during component selection and printed circuit board layout with respect to end product environmental operating conditions.

3.9 Reference Design and BOM

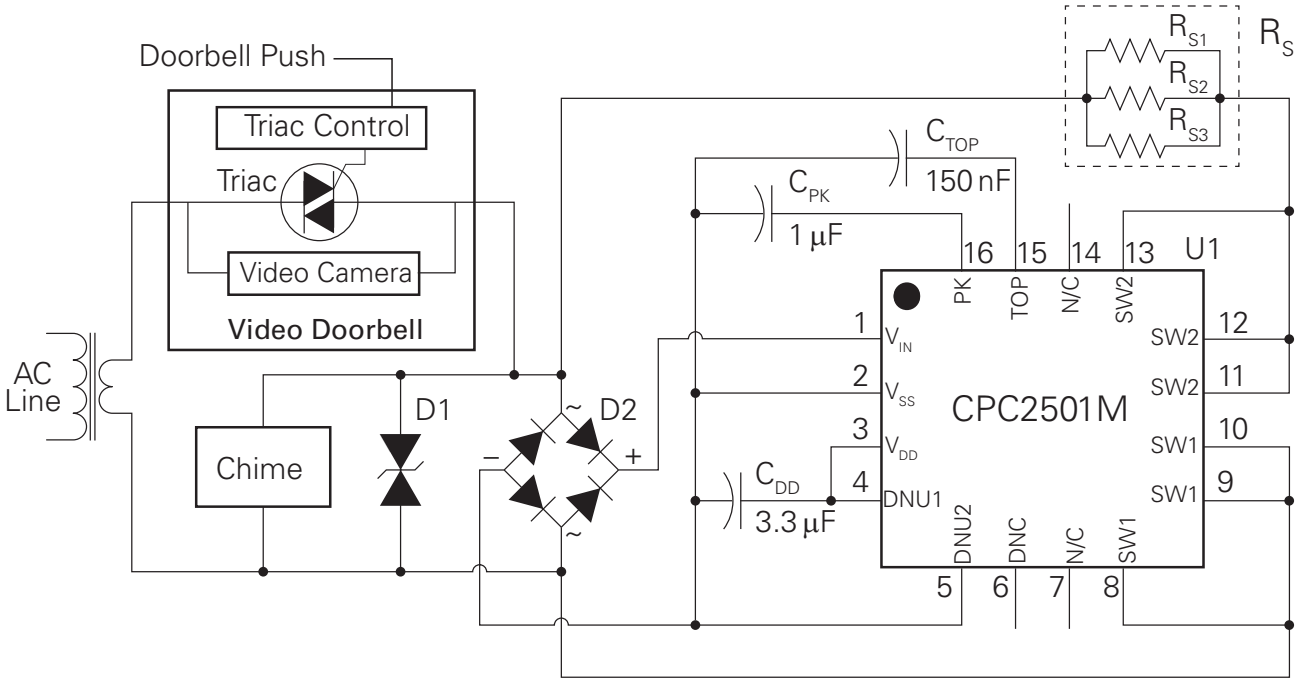


Figure 5. Reference Design

Component	Description	Manufacturer: Part Number	Qty.
R_{S1}, R_{S2}, R_{S3}	10 Ω, 5 %, 2W	Generic Thick Film Chip Resistor	3
C_{TOP}	150 nF, 5 %, 100V, X7R	General Purpose Ceramic Capacitor	1
C_{PK}	1 µF, 5 %, 100V, X7R	General Purpose Ceramic Capacitor	1
C_{DD}	33 µF, 10 %, 16V, X7R	General Purpose Ceramic Capacitor	1
D1	Transient Voltage Suppressor Diode	Littelfuse: SMBJ33CA	1
D2	60V, 2 A Bridge Rectifier	Taiwan Semiconductor: SBS26 or equivalent	1
U1	Chime Bypass IC	Littelfuse: CPC2501M	1

The reference design shown above is set to activate with an approximate peak current of 1 A.

4. Manufacturing Information

4.1 Moisture Sensitivity

All plastic encapsulated semiconductor packages are susceptible to moisture ingression. Littelfuse classifies its plastic encapsulated devices for moisture sensitivity according to the latest version of the joint industry standard, **IPC/JEDEC J-STD-020**, in force at the time of product evaluation. We test all of our products to the maximum conditions set forth in the standard, and guarantee proper operation of our devices when handled according to the limitations and information in that standard, as well as to any limitations set forth in the information, or standards referenced below.

Failure to adhere to the warnings or limitations as established by the listed specifications could result in reduced product performance, reduction of operable life, and/or reduction of overall reliability.

This product carries a Moisture Sensitivity Level (MSL) classification as shown below, and should be handled according to the requirements of the latest version of the joint industry standard **IPC/JEDEC J-STD-033**.

Device	Moisture Sensitivity Level (MSL) Classification
CPC2501M	MSL1

4.2 ESD Sensitivity

This product is **ESD Sensitive**, and should be handled according to the industry standard **JESD-625**.

4.3 Soldering Profile

Provided in the table below is the **IPC/JEDEC J-STD-020** Classification Temperature (T_C) and the maximum dwell time (T_C – 5 °C). The Classification Temperature sets the Maximum Body Temperature allowed for these devices during reflow soldering processes.

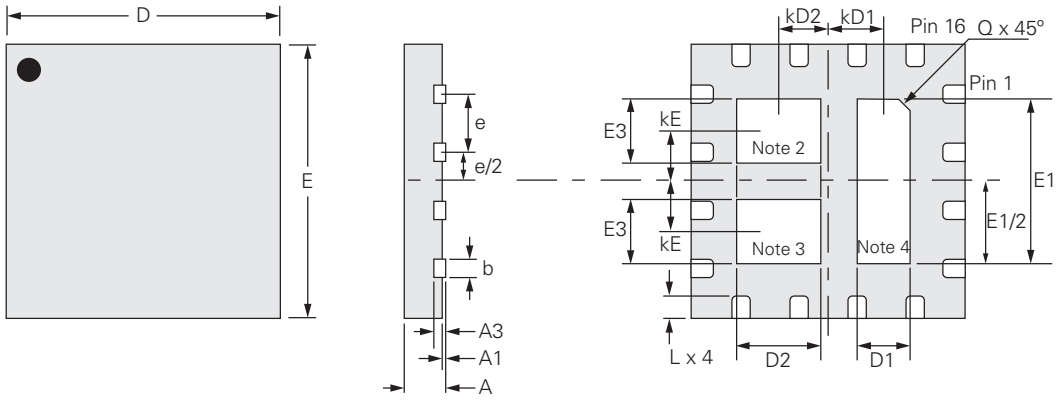
Device	Classification Temperature (T_C)	Dwell Time (t_p)	Max Reflow Cycles
CPC2501M	260 °C	30 seconds	3

4.4 Board Wash

Littelfuse recommends the use of no-clean flux formulations. Board washing to reduce, or remove flux residue following the solder reflow process is acceptable, provided proper precautions are taken to prevent damage to the device. These precautions include, but are not limited to: Using a low pressure wash and providing a follow-up bake cycle sufficient to remove any moisture trapped within the device, due to the washing process. Due to the variability of the wash parameters used to clean the board, determination of the bake temperature and duration necessary to remove the moisture trapped within the package is the responsibility of the user (assembler). Cleaning, or drying methods that employ ultrasonic energy may damage the device and should not be used. Additionally, the device must not be exposed to halide flux or solvents.

4.5 Mechanical Dimensions

4.5.1 CPC2501M 16-Pin QFN Package

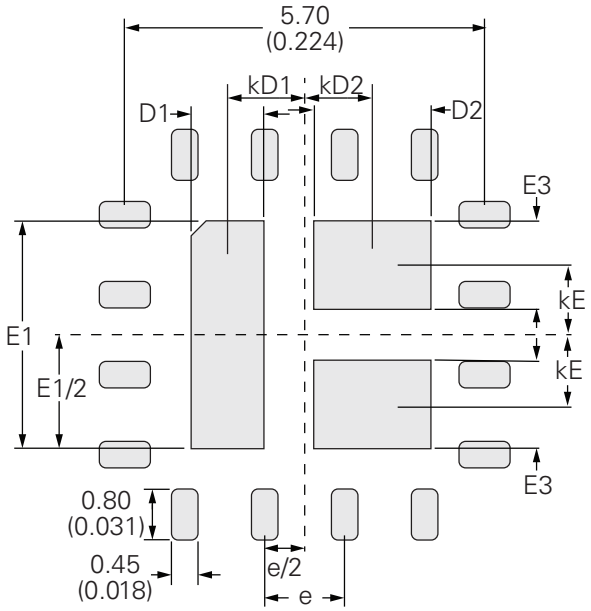


SYMBOL	MILLIMETER		
	MIN.	TYP.	MAX.
A	0.80	0.85	0.90
A1	0.00	0.02	0.05
A3	0.20 REF.		
b	0.35	0.40	0.45
D	6.00 BSC		
D1	1.10	1.15	1.20
D2	1.80	1.85	1.90
E	6.00 BSC		
E1	3.60 BSC		
E3	1.35	1.40	1.45
e	1.27 BSC		
kD1	1.22 BSC		
kD2	1.08 BSC		
kE	1.10 BSC		
L	0.45	0.50	0.55
Q	0.30	0.35	0.40

SYMBOL	INCHES		
	MIN.	TYP.	MAX.
A	0.031	0.033	0.035
A1	0.000	0.001	0.002
A3	0.008 REF.		
b	0.014	0.016	0.018
D	0.236 BSC		
D1	0.043	0.045	0.047
D2	0.071	0.073	0.075
E	0.236 BSC		
E1	0.142 BSC		
E3	0.053	0.055	0.057
e	0.050 BSC		
kD1	0.048 BSC		
kD2	0.043 BSC		
kE	0.043 BSC		
L	0.018	0.020	0.022
Q	0.012	0.014	0.016

NOTES:
1. Controlling dimension: millimeters.
2. Exposed pad: EP2, connect to SW2 pins.
3. Exposed pad: EP1, connect to SW1 pins.
4. Exposed pad: EP3, no connection.
5. All exposed pads must be soldered to their PCB lands.

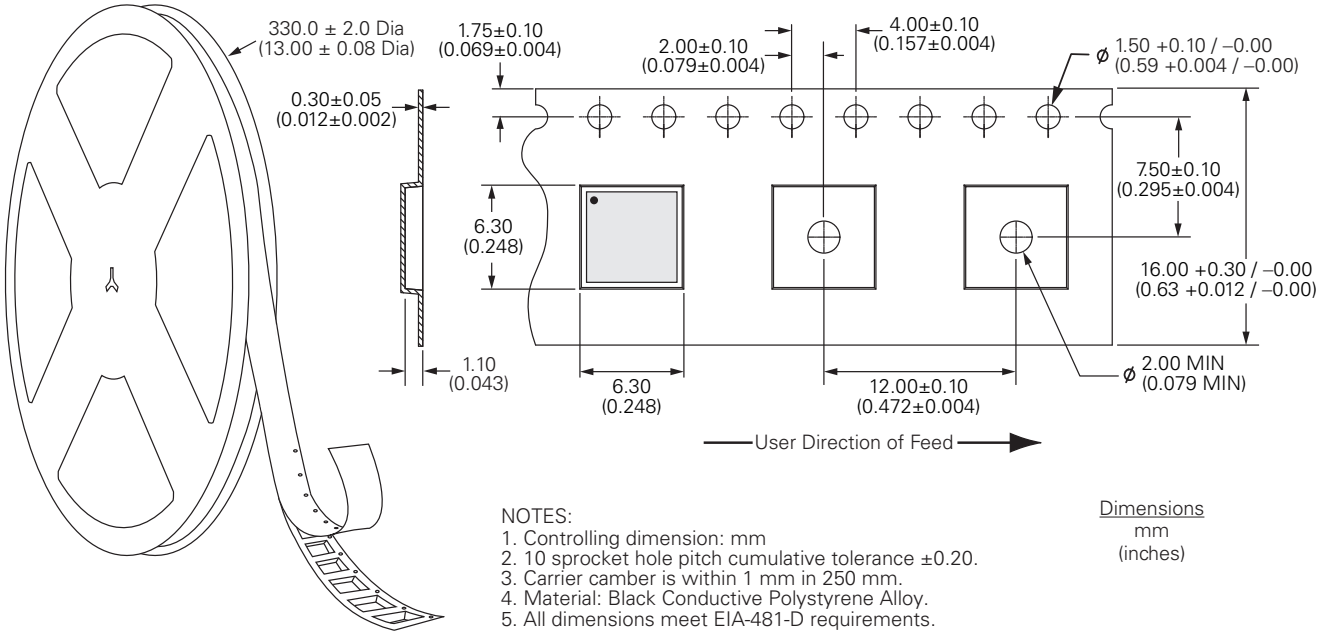
4.5.2 CPC2501M Recommended Land Pattern



SYMBOL	mm	inch
D1	1.15	0.045
D2	1.85	0.073
E1	3.60	0.142
E3	1.40	0.055
e	1.27	0.050
kD1	1.22	0.048
kD2	1.08	0.043
kE	1.10	0.043

NOTE: It may be necessary to enlarge the EP1 and EP2 thermal lands shown above to accommodate the thermal vias and to reduce the trace length connection to their pins.

4.5.3 Tape and Reel Dimensions



NOTES:
1. Controlling dimension: mm
2. 10 sprocket hole pitch cumulative tolerance ±0.20.
3. Carrier camber is within 1 mm in 250 mm.
4. Material: Black Conductive Polystyrene Alloy.
5. All dimensions meet EIA-481-D requirements.

Dimensions
mm
(inches)