CPC2501M Doorbell Chime Bypass
Video Doorbell Application

Introduction

With growing concerns for household safety and personal security, video doorbell monitoring devices are becoming a more common trend all over the world. Because installation of video doorbell products is very simple and requires few hand tools, many are installed by the homeowner. To protect their household, verify deliveries, and safely identify visitors at the door along with the ease of installation, many consumers prefer the monitoring video doorbell solution. In addition, integration of these products with internet access provides customers the freedom to remotely monitor their home using a smartphone or other personal computing devices.

Traditionally, implementation of video doorbell chime bypass circuits by means of a discrete solution required designers to use many components such as a voltage regulator, comparators, logic gates, counters, oscillators, power MOSFETs or solid state relays, and other support components just to provide this function. This of course comes with a more expensive BOM and demands for greater printed circuit board (PCB) real estate.

In order to reduce component count, shrink PCB size, simplify circuit design, and improve or enhance the video doorbell product, Littelfuse has developed the CPC2501M Normally Closed, 60V, 1.84 A_{RMS} Solid State Relay (SSR). This self-actuating, voltage controlled SSR was designed specifically to bypass a wide range of electromechanical and electronic chimes for video doorbell applications and ensure proper video and chime operation. Compatible with existing power transformers and wiring, this smart relay includes various features such as peak voltage detection, a programmable time-out for prolonged chime operation and a fast response time to minimize thermal stress.

Offered in a thermally enhanced 6x6 [mm], 16-pin QFN package, the CPC2501M is an ideal solution for designs that require a compact layout with a reduced BOM that can be easily integrated into numerous video doorbell applications with minimal design effort.

Revised: SC.06/24/2025
AN-180_R05

Table of Contents

List of Figures

1. Functional Description

The CPC2501M, with its minimal support components provides the two requisite functions necessary for successful video doorbell operation: chime bypass and chime alerting. Chime bypass occurs while the system is idle and the doorbell chime is silent, whereas chime alerting occurs whenever the doorbell switch is operated and chime bypass is disabled. Although the doorbell switch is typically a simple push button, it could be an electronic motion or proximity sensor. All ongoing references to the doorbell switch will be with regards to the manual push button type.

Chime bypass provides power to the video doorbell unit whenever the doorbell button is not pushed while preventing the video doorbell bias current from activating the chime. This is accomplished by a low impedance path parallel to the chime consisting of inexpensive discrete resistors in series with the CPC2501M's very low impedance normally closed output switch. To prevent the chime from sounding, the low impedance chime bypass circuit forces most of the video doorbell bias current to circumvent the chime, thereby limiting the voltage available to the chime.

Chime alerting is achieved when a visitor pushes the doorbell button, causing the chime to sound. Sensing the pressed doorbell button, the video doorbell unit activates a TRIAC or similar device to divert the supply voltage from the video doorbell unit to the chime and chime bypass circuit. When the supply voltage across the bypass circuit reaches a predetermined threshold, the CPC2501M will open its normally closed bidirectional output switch. Opening the output switch changes the chime bypass impedance from low to high making the voltage supply's power available to the chime.

Chime alerting does not end concurrently with release of the doorbell button. To ensure compatibility with electronic chimes, the CPC2501M utilizes its two internal peak voltage detectors with different time constants and an internal comparator to determine when to re-open the output switch. External capacitors are required to set the time constants.

In the event of an extended or permanent pressed doorbell button, the CPC2501M will cycle chime on and off approximately every 17 seconds typically, cycling on and off at 50 % percent duty cycle, until the button is released. This cycling feature ensures video functionality and protects the IC from excessive thermal stress, in the event the user pushes the ring button for too long, or the button gets jammed.

Revised: SC.06/24/2025
AN-180_R05

2. Design Considerations

Figure 1 and Figure 2 shows Typical Video Doorbell Design using the CPC2501M Chime Bypass Circuit and two conventional current paths.

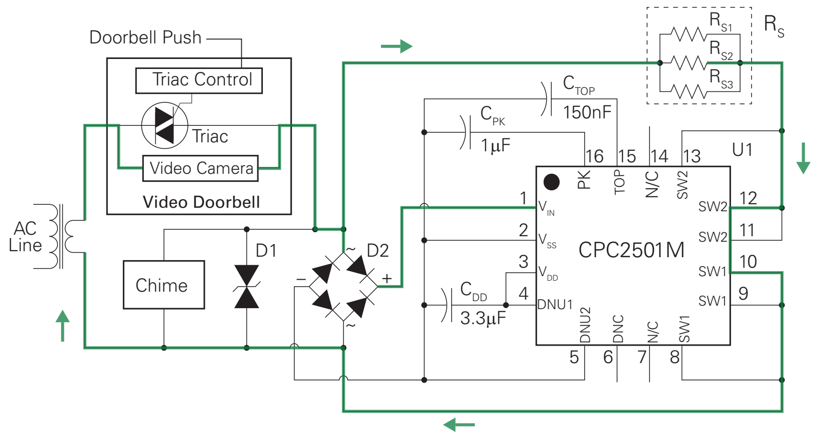

Figure 1. Conventional current path before doorbell button pressed

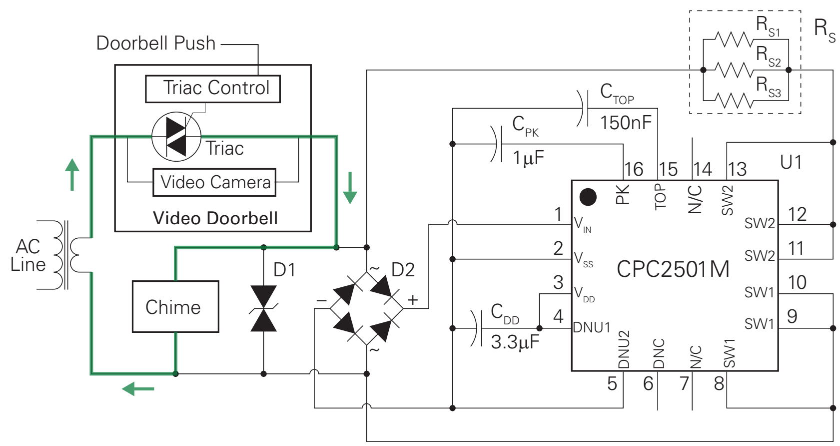

Figure 2. Conventional current path when doorbell button pressed and when CPC2501M's V_{IN} is enabled (chime enabled)

Table 1. Bill of Materials

Component	Description	Manufacture: Part Number	Qty.
R_{S1}, R_{S2}, R_{S3}	10 Ω, 5 %, 2W Resistor	Multiple Vendors: Varies	3
C_{TOP}	150 nF, 5 %, 100V, X7R Capacitor	Multiple Vendors: Varies	1
C_{PK}	1 µF, 5 %, 100V, X7R Capacitor	Multiple Vendors: Varies	1
C_{DD}	3.3 mF, 10 %, 16V, X7R Capacitor	Multiple Vendors: Varies	1
D1	Transient Voltage Suppressor	Littelfuse: SMBJ33CA	1
D2	60V, 2 A Schottky Bridge Rectifier	Taiwan Semiconductor: SBS26	1
U1	Chime Bypass IC	Littelfuse: CPC2501M	1

Revised: SC.06/24/2025
AN-180_R05

2.1. Step-down Transformer and Chime

Step-down transformers are used in residential doorbell systems to reduce the AC line voltage to a much lower potential, in order to safely provide power to the door chimes. To protect the end user from dangerous ground referenced potentials, the transformer's output voltage is electrically isolated from the high voltage power mains applied to the transformer's primary side windings by means of a galvanic safety insulation barrier. This shields the end user from dangerous ground referenced potentials which could be lethal when touched. Worldwide, the step-down transformers typical output voltage ranges from $8V_{AC}$ to $24V_{AC}$. In North America, the most common step-down transformer utilized in wired doorbell applications is rated for a nominal input voltage of $120V_{AC}$ to provide an output voltage of $16V_{AC}$ at 10VA to 30VA. With a power factor of PF = 1, the output current a 30VA transformer can deliver to a load is calculated as follows:

$$I = \frac{30\,VA}{16\,V} \cdot 1 = 1.875\ A_{RMS}$$

This current is sufficient to operate a wide variety of chime and video doorbell combinations.

The CPC2501M works with the installed base of electromechanical and electronic chimes ranging from the basic to the modern feature rich models found in many homes. To ensure compatibility with the many available electronic chimes, the bypass relay is designed to work with impedances up to 850 Ω.

2.2. Transient Voltage Suppressor D1 and Bridge Rectifier D2

Selection of the rectifier diode bridge and voltage suppressor is based on application requirements such as maximum load current and load voltage. A rectifier diode bridge with a working voltage rating of $V_{RRM} = 60V$ and a maximum forward current of $I_F = 2A$ is chosen. Selection of a Schottky rectifier is preferred due to its lower forward voltage drop when compared to standard PN junction rectifier diodes which factors into improved input voltage detection for lower voltage step-down transformers and system power dissipation. From the Typical Forward Characteristics graph provided in the SBS26 data sheet, the approximate per diode voltage drop can be estimated to be $V_F = 0.25V$ at $I_F = 1\,mA$ and $T_{vj} = 25\,°C$. Rectifier power dissipation can be calculated using the simple power formula, $P = 2 \times V_F \times I$. With a current of $I = 1\,mA$, the calculated power dissipation is $P = 0.5\,mW$. This very small power dissipation will have a negligible effect on the local internal ambient temperature when installed in a sealed enclosure. A bi-directional TVS diode is chosen to protect the rectifier bridge and the CPC2501M from over voltage faults. The TVS diode SMBJ33CA with a reverse standoff voltage rating of $V_R = 33V$ and a maximum clamping voltage of $V_C = 53.3V$ at $I_{PP} = 11.3A$ is selected. This maximum clamping voltage provides good margin for the CPC2501M and the diode bridge by limiting voltage transients well below the 60V maximum voltage rating of both devices.

2.3. Voltage Regulator and Bypass Capacitor C_{DD}

The CPC2501M has an internal voltage regulator that takes the full wave rectified voltage of the diode bridge and outputs V_{DD}, which is used by various internal circuit blocks. C_{DD}, the external 3.3 μF, 10 %, 16V, X7R, filtering capacitor should be placed as close as possible to pin 3 to ensure proper filtering and circuit operation.

2.4. External Resistive Load R_S Selection

The CPC2501M has an internal voltage regulator that takes the full wave rectified voltage of the diode bridge and outputs V_{DD}, which is used by various internal circuit blocks. C_{DD}, the external 3.3 µF, 10 %, 16V, X7R, filtering capacitor should be placed as close as possible to pin 3 to ensure proper filtering and circuit operation.

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

Where:

V_F = Forward voltage drop of each diode in the bridge
V_{INP} = Typical input voltage activation threshold from the datasheet
R_{ON} = Typical switch on-resistance from the datasheet

Setting the desired activation current to a nominal I = 850 mA, the voltage drop per bridge diode to V_F = 0.25V and using the equation above we can calculate the nominal value of R_S as shown below.

Setting the desired activation current to a nominal I = 850 mA, the voltage drop per bridge diode to V_F = 0.25V and using the equation above we can calculate the nominal value of R_S as shown below.

$$R_S = \frac{2 \cdot 0.25\,V + 2.96\,V}{0.85\,A} - 0.75\,\Omega = 3.32\,\Omega$$

$$\text{Power} = I^2 \cdot R = 0.7225\,A^2 \cdot 3.32\,\Omega = 2.40\,W$$

The power calculation above is the instantaneous power dissipation across R_S at the activation threshold voltage. Selection of three 10 Ω, 5 %, 2W, 2512 size resistors in parallel will be adequate to handle this power requirement and provide the necessary external resistance calculated above.

Revised: SC.06/24/2025
AN-180_R05

2.5. Peak Detection and selection of C_{PK} and C_{TOP}

The CPC2501M has an internal peak detection block that constantly monitors the input voltage to determine when to close the relay and restore the low impedance shunt, so the video doorbell can get power for proper operation. The C_{PK} capacitor is used to store a voltage which is the peak excursion of the rectified AC waveform while C_{TOP} stores a voltage that is the envelope of the rectified AC waveform. When the incoming rectified AC waveform amplitude starts collapsing, C_{PK} will hold the peak excursion while C_{TOP} allows for a gentle decay of the collapsing waveform (see Figure 3). The CPC2501M monitors the voltage ratio of V_{TOP} to V_{PK} and closes the switch when the V_{TOP} voltage decreases to approximately 75 % of V_{PK} (Deactivation Threshold).

Charge and discharge times of V_{PK} and V_{TOP} are determined by internal resistors and external capacitors C_{PK} and C_{TOP}. Selection of different external capacitors will provide alternative delays from the TRIAC turning off to the actual closing of the power relay switch. The table below shows recommended capacitor values and typical response delay. As seen in the table "C_{DD} (External)" column, C_{PK} = 1 µF and C_{TOP} = 0.15 µF. With these capacitor values the relay will close and begin conducting in about 2.7 cycles of a 60 Hz AC voltage. Select general purpose capacitors with rating of 100V, 5 %, X7R.

Table 2. Recommended External Capacitor Values and Nominal Response Times

	Charge R (Internal) (kΩ)	Discharge R (Internal) (kΩ)	C_{DD} (External) (µF)	Charge τ_{RC} (ms)	Discharge τ_{RC} (ms)	Delay (Cycles)*
V_{PK}	12.5	800	1	12.5	800	—
V_{TOP}	12.5	300	0.15	1.875	45	2.25 / 2.7

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

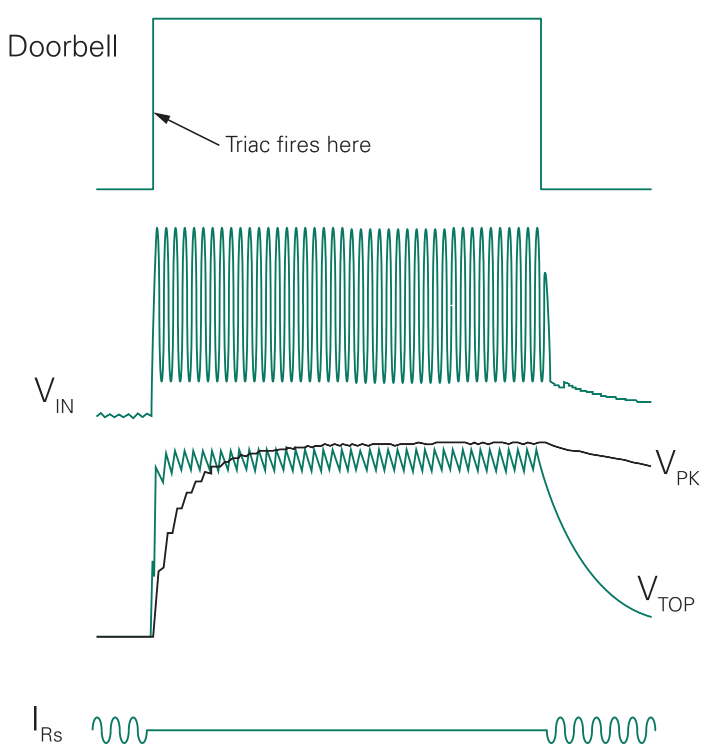

Figure 3. V_{PK} and V_{TOP} response waveforms

2.6. Layout Considerations

In high power applications the printed circuit board (PCB) layout is very critical. The 2 oz, thick-copper traces connecting bridge will allow for relieve of some of the thermal stress. In addition, R_S power resistors should be sized accordingly to handle high current. The CPC2501M datasheet provides additional guidelines and critical notes on CPC2501M thermal management, so that designers can achieve desired thermal values.

Below is a typical PCB layout (see Figure 4) that can provide good thermal management. Designers can also implement thermal vias, connecting the top and bottom side of the PCB on the DR1 and DR2 output pads, further improving the heat dissipation capability. The output pads are located close to two power Depletion-Mode MOSFET (DMOS) switches that will have to handle a large current.

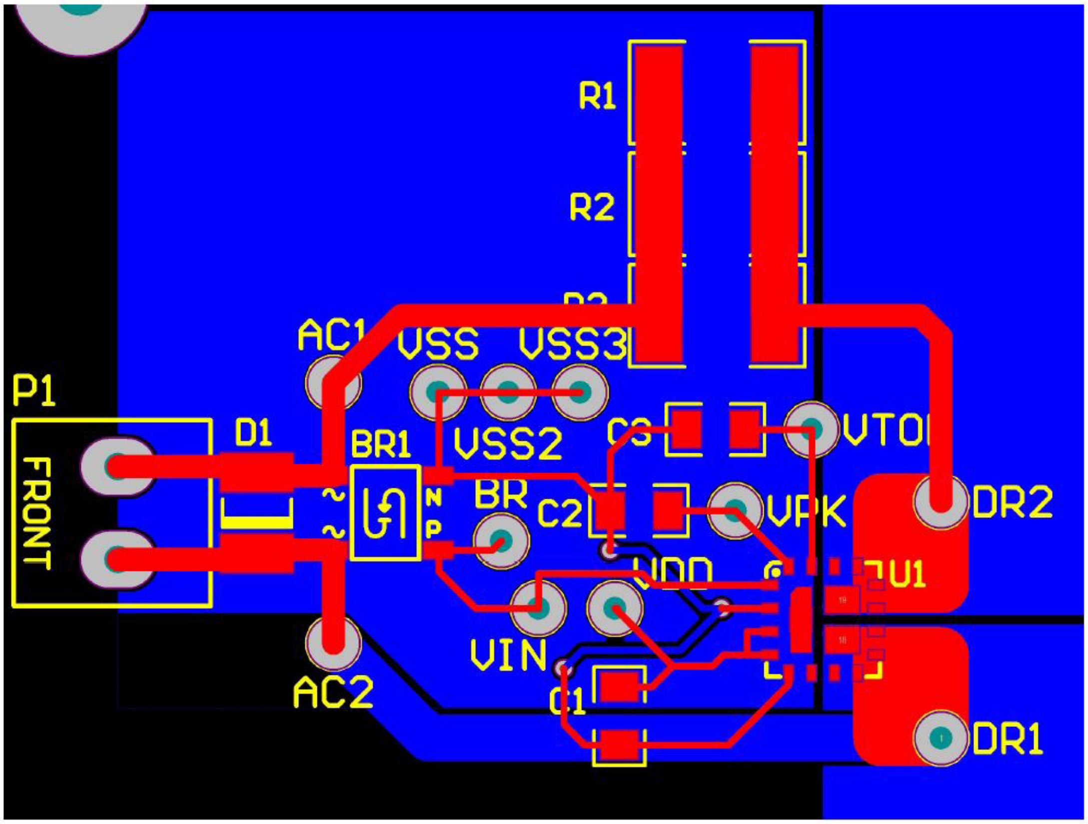

Figure 4. Typical Layout using CPC2501M

Revision History

Date	Revision	Changes
June 2025	05	Style change only with addition of Table of Contents and List of Figures