

ACPL-K378

Adjustable AC/DC Threshold Detection for Industrial Control Systems

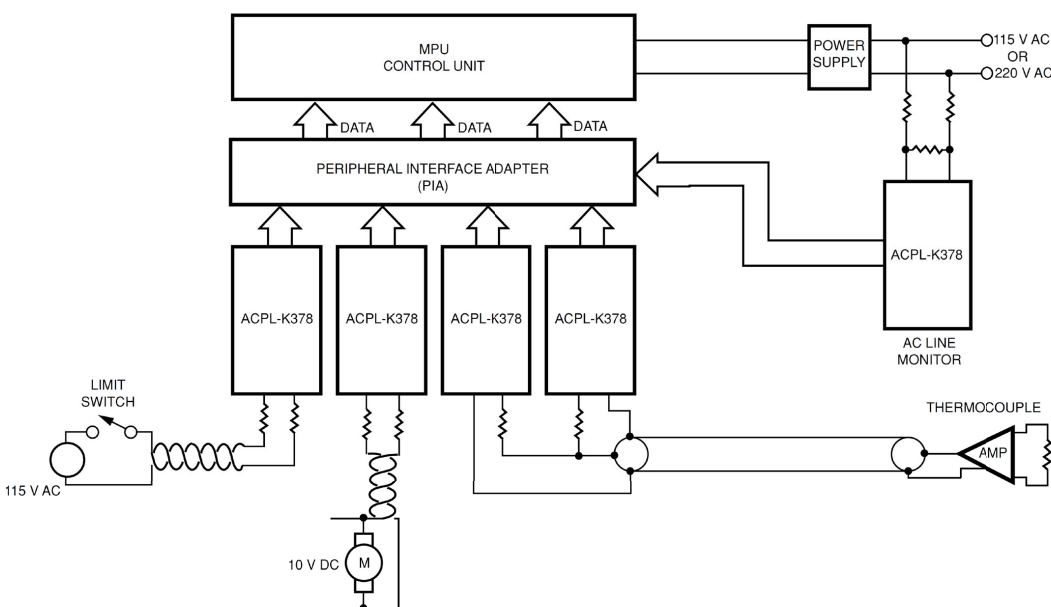
Introduction

AC mains detection is a fundamental function in industrial electronics. Detecting the presence of AC mains allows a system to shut down safely or prevent operation if the mains power is absent or unstable. Many systems have multiple power domains (AC and DC circuits). Knowing when AC mains is available allows proper sequencing; for example, turning on the DC-DC converters only when the AC is stable. AC detection is used to monitor utility power and to trigger alarms or notifications when the voltage drops or when surges or interruptions occur.

In addition to detecting mains power, industrial systems also rely on AC/DC input sensing within I/O modules and programmable logic controllers (PLCs) to interpret signals from field devices. These inputs detect whether external field devices—such as switches, sensors, or actuators—are energized, allowing the system controller to make logical decisions and coordinate industrial processes.

To achieve safe and accurate detection of these AC/DC signals, designers commonly use optocouplers to provide galvanic isolation between high-voltage field wiring and low-voltage logic circuits. The ACPL-K378 offers an adjustable threshold input, allowing engineers to fine-tune the detection level for different AC or DC voltages. It supports both signal types with high noise immunity and reinforced insulation, making it an ideal solution for AC mains detection, I/O modules, PLC input cards, and industrial control systems operating in harsh environments.

Figure 1: ACPL-K378 Applications for Interfacing AC and DC Voltages to a Microprocessor



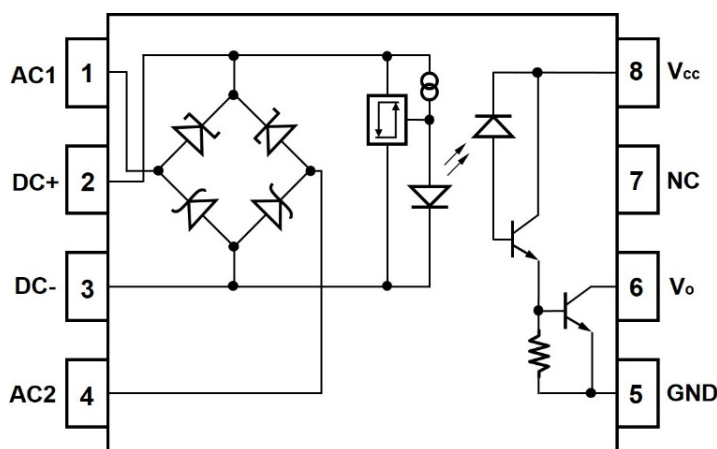
ACPL-K378 for Isolated AC/DC Threshold Detection

As shown in the following block diagram, the ACPL-K378 consists of a full-wave bridge rectifier and threshold-detection integrated circuit, an LED, and an optically coupled detector integrated circuit. The detector circuit is a combination of a photodiode and a high-current gain, split Darlington amplifier.

The input circuit operates from an AC or DC source and provides a guaranteed, temperature-compensated threshold level with hysteresis. The device can be programmed for higher switching thresholds through the use of a single external resistor.

In addition to allowing AC or DC input signals, the Zener diodes of the bridge circuit also provide input voltage clamping to protect the threshold circuitry and LED from overvoltage/overcurrent stress conditions. The LED current is provided by a switched current source.

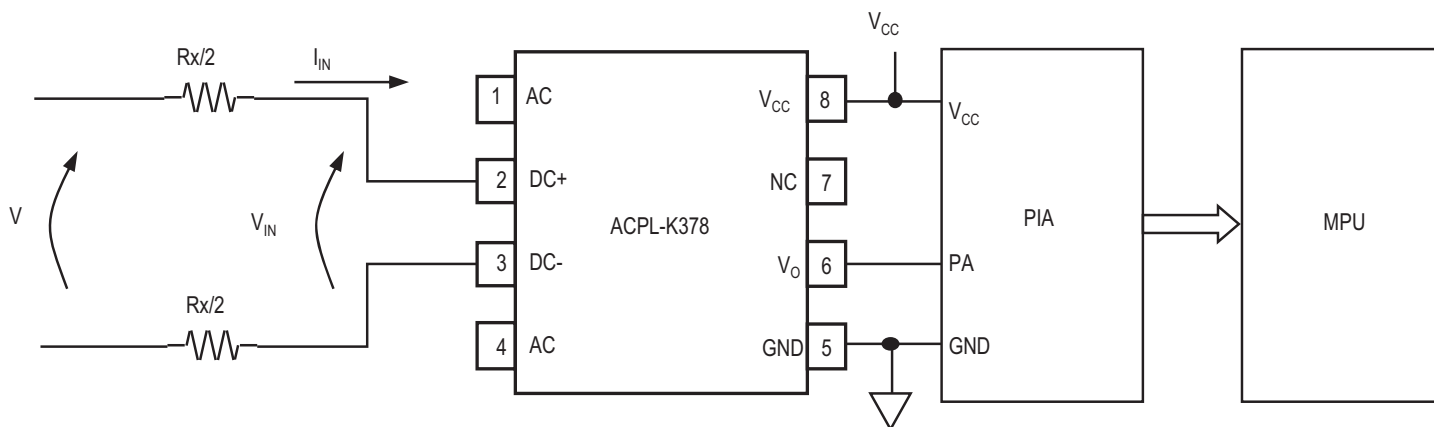
Figure 2: Block Diagram of the ACPL-K378



Overvoltage (Undervoltage) Detection

The ACPL-K378 has preprogrammed upper and lower voltage and current threshold levels: V_{TH+} , V_{TH-} , I_{TH+} , and I_{TH-} . To achieve a higher external threshold detection level (V_+ or V_-), a resistor, R_X , can be connected in series externally, and the resistor can be split in half to reduce power dissipation. R_X is used to determine the threshold levels, either V_{TH+}/I_{TH+} or V_{TH-}/I_{TH-} . The following figure shows a connection diagram with the ACPL-K378.

Figure 3: Overvoltage (V_+) Detection Using the ACPL-K378



Equation 1:

$$\text{Series Resistor, } R_X = \frac{V_+ - V_{TH+}}{I_{TH+}}$$

Equation 2:

$$\text{Resulting Lower Threshold, } V_- = I_{TH-} \cdot R_X + V_{TH-}$$

Where:

V_+ = Targeted Upper Threshold

For DC Input, $V_{TH+} = 3.8V$

For DC Input, $V_{TH-} = 2.6V$

$I_{TH+} = 1.32 \text{ mA}$

$I_{TH-} = 0.68 \text{ mA}$

For example, a DC voltage applied to the motor is monitored as an indication of proper speed or load condition. If the applied voltage is greater than 5V, it is assumed that the desired speed has been obtained. The maximum applied voltage in the system is 10V.

Targeted Upper Threshold (V_+)

$$V_+ = 5V \text{ (50\% of 10V)}$$

Then:

$$R_X = \frac{5V - 3.8V}{1.32 \text{ mA}} = 910\Omega$$

$$V_- = (0.68 \text{ mA} \cdot 910\Omega) + 2.6V = 3.2V$$

In this case, the ACPL-K378 output enters a low-impedance state (logic '0') when the motor voltage exceeds 5V and then switches to a high-impedance state (logic '1') when the motor voltage falls below 3.2V.

To reduce power dissipation across the series resistor, R_X can be split into multiple resistors. For example, R_X can be divided in half to 455 Ω . Because 455 Ω is not a standard resistor value, a standard 470 Ω resistor is chosen instead.

For $R_X/2 = 470\Omega$, the final threshold voltages are as follows:

$$V_+ = [1.32 \text{ mA} \cdot (470\Omega \times 2)] + 3.8V = 5.04V$$

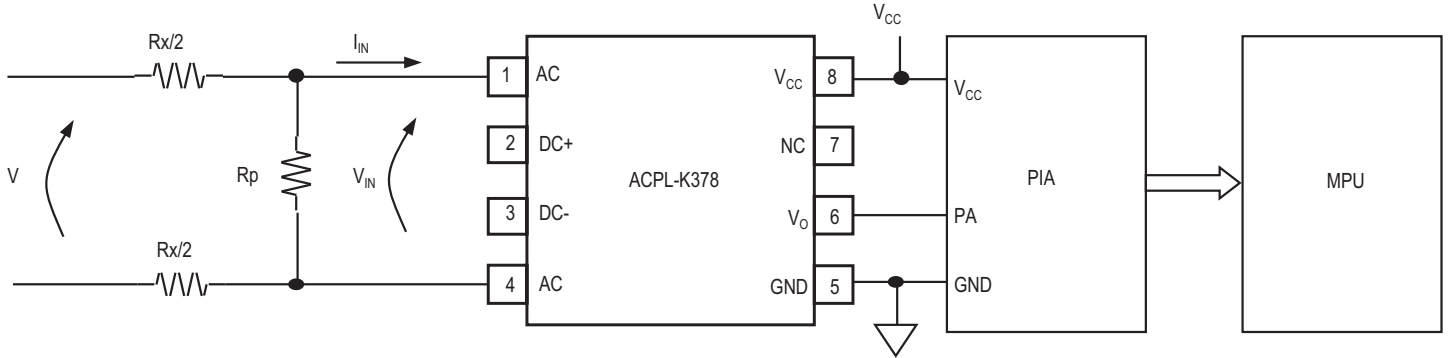
$$V_- = [0.68 \text{ mA} \cdot (470\Omega \times 2)] + 2.6V = 3.24V$$

As seen from the preceding calculations, the final threshold voltages do not deviate significantly from the original target values, because the use of standard resistor values introduces only a minor variation.

Window (Dual-Threshold) Detection

In the earlier example, a single external series resistor (R_X) was used to determine one of the threshold levels. The other threshold was set by the device's internal hysteresis and was not user adjustable. To provide designers with greater control over both the upper and lower threshold voltages, a combination of series resistance (R_X) and parallel resistance (R_P) can be employed, as illustrated in the following figure.

Figure 4: Window Detection Using the ACPL-K378



Equation 3a:

$$V_+ = R_X \left(I_{TH+} + \frac{V_{TH+}}{R_P} \right) + V_{TH+}$$

Equation 3b:

$$V_- = R_X \left(I_{TH-} + \frac{V_{TH-}}{R_P} \right) + V_{TH-}$$

Equation 4a:

$$R_X = \frac{V_{TH-}(V_+) - V_{TH+}(V_-)}{I_{TH+}(V_{TH-}) - I_{TH-}(V_{TH+})}$$

Equation 4b:

$$R_P = \frac{V_{TH-}(V_+) - V_{TH+}(V_-)}{I_{TH+}(V_- - V_{TH-}) + I_{TH-}(V_{TH+} - V_+)}$$

Where:

For AC Input, $V_{TH+} = 4.9V$

For AC Input, $V_{TH-} = 3.7V$

$I_{TH+} = 1.32 \text{ mA}$

$I_{TH-} = 0.68 \text{ mA}$

Consider an example where a 115V AC 60-Hz line ($163V_{PEAK}$) must be monitored for a 50% drop condition and a 75% line-presence condition.

Targeted Turn-On Threshold (V_+)

$$V_+ = 122.5V \text{ (75\% of } 163V_{PEAK})$$

Targeted Turn-Off Threshold (V_-)

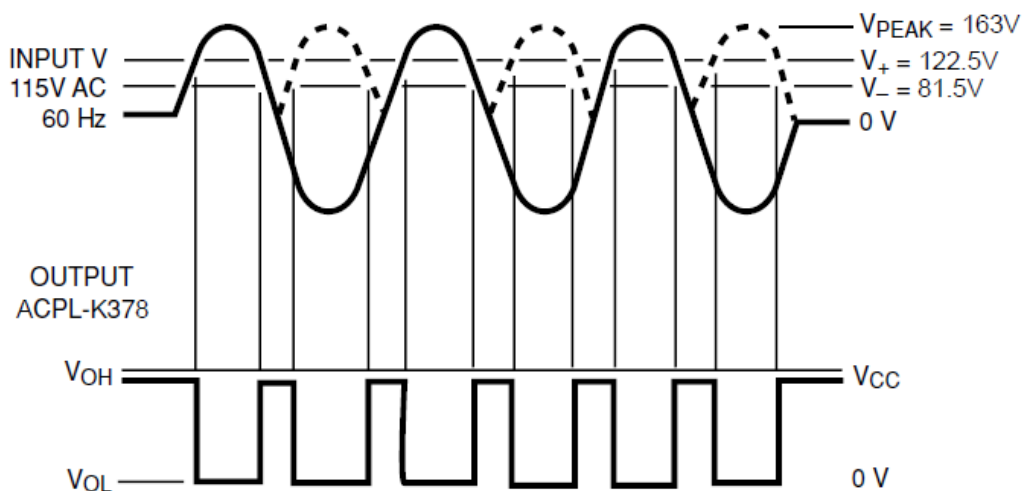
$$V_- = 81.5V \text{ (50\% of } 163V_{PEAK})$$

Solving Equation 4a and 4b yields:

$$R_X = 34.7 \text{ k}\Omega \quad R_P = 2.4 \text{ k}\Omega$$

The following figure illustrates the expected output waveform of the ACPL-K378. Because the output is unfiltered, it directly reflects the sensed AC signal. In this configuration, the microcontroller can periodically sample the optocoupler output to determine whether AC is present or absent at the input. This approach eliminates the need for analog filtering—and the associated signal delay—but requires a more sophisticated software algorithm within the microcontroller to correctly interpret the waveform.

Figure 5: Output Waveform of the ACPL-K378 with No Filtering Applied



Input Filtering for AC Operation

A convenient way to maintain a continuous output low state in the presence of an AC signal is to filter the input DC terminals (pins 2-3) with a capacitor, while the AC signal is applied to the AC input (pins 1-4) of the full-wave rectifier bridge. Figure 6 illustrates this. The minimum capacitor value is determined by the optocoupler parameters: at low AC voltage, the capacitor must charge to at least V_{TH+} to turn on and must not discharge below V_{TH-} during the cycle. A conservative estimate for the minimum value of C is given by the following equations.

Equation 5:

$$V_{TH+} - V_{TH-} = V_{TH+} e^{-t/\tau}$$

Where:

$$\tau = R_{IN} C_{MIN}$$

Equation 5a:

$$C_{MIN} = \frac{t}{R_{IN} \cdot \ln\left(\frac{V_{TH+}}{V_{TH+} - V_{TH-}}\right)}$$

Where:

$$R_{IN} = 2.6 \text{ k}\Omega$$

$$V_{TH+} = 3.8\text{V}$$

$$V_{TH-} = 2.6\text{V}$$

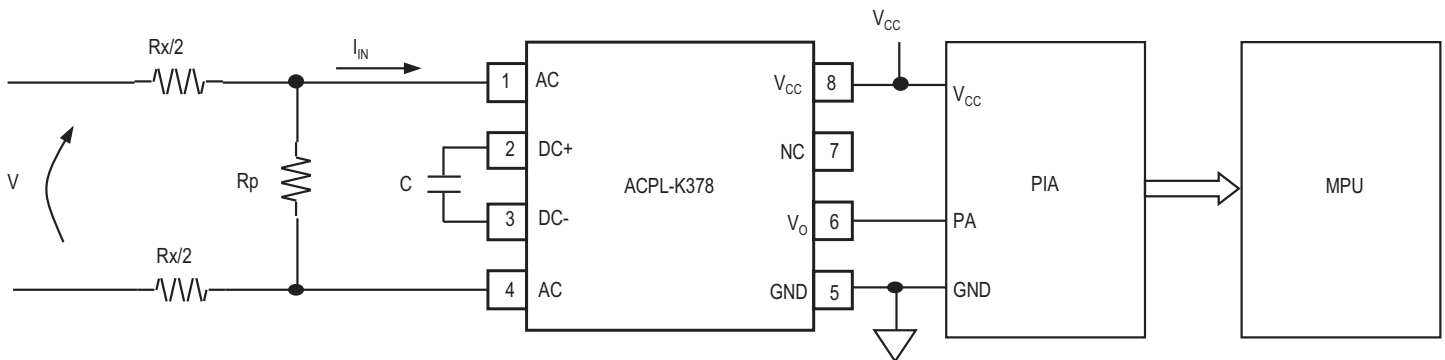
$$t = 10 \text{ ms for 50 Hz or } 8.33 \text{ ms for 60 Hz}$$

Finally:

$$C_{MIN} = 3.3 \text{ }\mu\text{F for 60 Hz or } 2.8 \text{ }\mu\text{F for 60 Hz}$$

To ensure proper filtering, the capacitor value should be selected such that, even with tolerance variations, it remains greater than C_{MIN} . At the same time, C should be kept as small as possible to minimize the inherent delay times associated with this filtering technique.

Figure 6: Input Filtering with the ACPL-K378



Excel-Based Resistor Selection Tool

An Excel calculation tool is available to help users determine the appropriate external resistor values, R_X and R_P , when configuring the ACPL-K378 for overvoltage, undervoltage, or window detection of AC or DC input signals.

Users simply enter the desired upper (V_+) and/or lower (V_-) threshold voltage levels based on their detection requirements, and the tool automatically computes the recommended resistor values.

This Excel tool is available upon request.

Revision History

ACPL-K378-AN100; November 19, 2025

Initial release.

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