Application Brief

Fast Power Fault Detection by Monitoring 24V AC Systems Using TPS37x Voltage Supervisor

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This technical note discusses a novel implementation of combining both wide voltage alternating current (AC) and direct current (DC) monitoring, with programmable sense and reset delay features of the TPS37x, to create a unique approach to voltage monitoring. Designing the TPS37x to detect undervoltage (UV) and overvoltage (OV) system faults into industrial and factory applications provides innovative solutions.

The TPS37x incorporates the sense delay which is the delay time for which the sense voltage needs to be under the voltage threshold in order to assert a reset. On previous TI voltage supervisors this delay was small and fixed, however, on the TPS37x, sense delay time can be programmed from several hundred microseconds up to several seconds via an external capacitor.

There are many applications for which a sense delay would be useful. One application of sense delay is the sensing of the slowing of the operating frequency of a wide voltage AC voltage rail in an industrial setting. By detecting the AC operating frequency of an AC power rail, the speed of fault detection is greatly improved to prevent crucial downstream systems from being damaged. Another application for sense delay is preventing false resets on noisy power voltage rails.

How to Combine AC and DC Sensing to Detect System Faults

In many industrial and factory automation applications, there are multiple alternating current (AC) and direct current (DC) power rails that power various subsystems within the application. Some of these power rails include 24 V_{AC} source with a known operating frequency that requires a full-bridge rectifier and capacitors to convert its signal into a DC voltage. Monitoring the DC rectified voltage ranges, with a voltage supervisor, is vital to maintaining and supporting the power requirement to prolong the health of the system operation. Although the described conversion is well established, it has significant speed detection drawback. While monitoring the DC rectified voltage is an easier way, it may not be fast enough to sense the changes of the AC input. One approach to increase the speed detection is to directly monitor the AC power input.

The Full-Wave Diode Bridge DC Rectifier Approach: Slow but Proven Effective

The full-wave diode bridge DC rectifier circuit, illustrated in Figure 1, has been proven in multiple circuits to effectively convert an AC voltage into a DC voltage. Many systems today continue to implement the rectifier circuit to generate a DC voltage such that a voltage supervisor can be used to indirectly monitor the AC power rail. One drawback of using the full-wave diode bridge rectifier circuit is the response time of the DC voltage when the AC power rail experiences a change of operating frequency or voltage amplitude. Due to the output filter of the full-bridge rectifier, the detection of a change in voltage or operating frequency may require many AC cycles before the voltage supervisor alerts a fault condition.

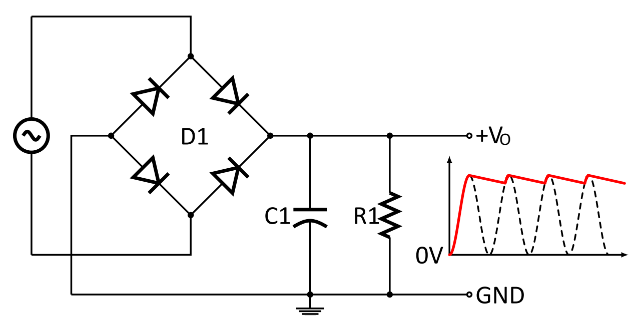

Figure 1. Classic Full-Wave Diode Bridge DC Rectifier

The Half-Wave AC approach for Fast Transient Response

One unique approach to detect a faster fault condition; whether the AC power rail has a change in operating frequency or voltage amplitude, is shown in Figure 2. The circuit allows direct monitoring of an AC source by using a topology called a "resistive-drop" where the passive circuit elements are used to provide a fast-transient fault detection. During the positive phase of the AC voltage, the voltage going into UV SENSE2 is a sinusoidal voltage that is divided down and its voltage value is compared to the factory programmed threshold voltage of the TPS37A. The negative phase is excluded or omitted by R3, C1, and D1 resulting in only positive phase voltage at the UV SENSE2 input. Because the TPS37A is directly monitoring the AC voltage and eliminating the delay inherited with full-bridge rectifier, the fault detection time is substantially shorter.

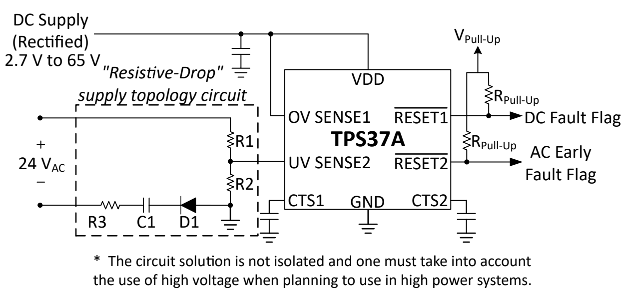

Figure 2. Half-Wave AC Circuit on UV SENSE2 Input

Combining the Best of Both Sensing Schemes: DC + AC Fault Detection Using TPS37A

Figure 2 shows one of many ways in which the TPS37A can be used to monitor an industrial or factory AC power rail. Input OV SENSE1 is setup to sense the DC signal from the rectification of the 24 V_{AC} source and monitors the AC source for overvoltage events due to a change of voltage amplitude. The UV SENSE2 is setup to monitor the AC undervoltage (UV) positive half-wave signal that is generated from the "resistive-drop" supply topology circuit. The resulting outputs from the TPS37A is a DC (OV) fault and a fast-transient AC (UV) fault signal. Combining both monitoring schemes (DC and AC), the TPS37A offers engineers the ability to implement a unique "window operating" voltage sensing solution.

Speed Up Fault Detection by AC Sensing

The "resistive-drop" circuit in Figure 2 resistively divides the AC voltage signal and provides only a periodic positive half-wave signal into UV SENSE2 input. The signal does not go through any output filtering and hence any change to the AC voltage or operating frequency can be rapidly detected. Given the operating frequency of the AC source and converting the frequency to the time domain, a sense time delay is determined to monitor a change in operating frequency. The sense time delay is programmed by placing a capacitor on the CTS pin and its value sets the sense time delay or the detection time. For example, Figure 3 shows a periodic positive half wave cycles with a frequency of 800 Hz or 1.25 ms. Each full cycle is 1.25 ms or 0.625 ms for a half cycle. When the half wave voltage amplitude falls below the SENSE2 threshold voltage, the programmed sense time delay capacitor begins to charge while monitoring the AC source. If the next voltage amplitude positive cycle exceeds the SENSE2 threshold voltage, the SENSE2 programmed time delay capacitor, CTS, will reset and the pin will not indicate a fault. Conversely, if the voltage amplitude of the positive cycle does not reach the SENSE2 threshold voltage within the programmed time delay of t_{CTS}, a fault will occur. In an event where the operating frequency from the AC source decreases (half cycle > 0.625 ms), the AC voltage amplitude may not cross the SENSE2 threshold voltage at the programmed time delay t_{CTS} resulting in a fault condition.

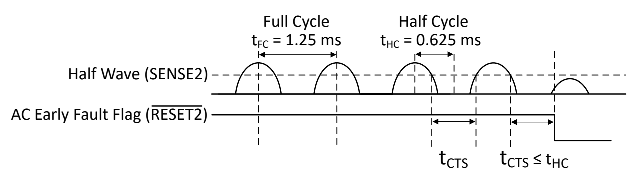

Figure 3. Timing Diagram

Conclusion

The flexibility of wide-voltage range monitoring ensures that critical systems in an industrial and factory settings are operating within the safety limits of the workplace environment. Wide-voltage range supervisors are able to monitor various types of DC and AC voltage power rails with a few passive components, offering engineers many benefits, including an effective and novel way to provide a direct rapid AC sensing method. Monitoring a voltage rail with over and under voltage capability on each SENSE pin provides redundancy to create a highly reliable system without false system resets.

*Note that this design solution is not isolated and one must consider the dangers of high voltage when planning to use in high power systems.

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